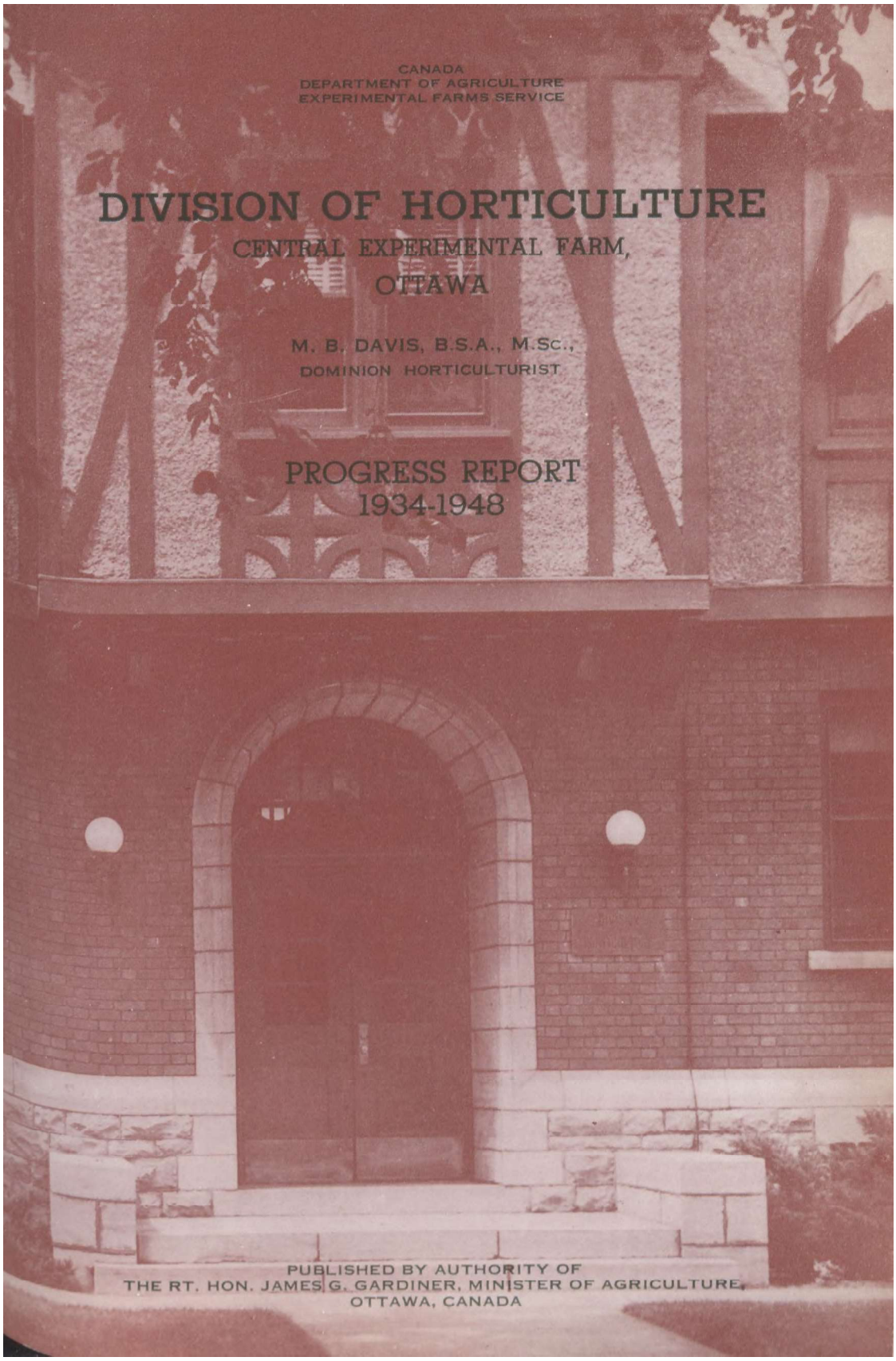

CANADA
DEPARTMENT OF AGRICULTURE
EXPERIMENTAL FARMS SERVICE

DIVISION OF HORTICULTURE

CENTRAL EXPERIMENTAL FARM,
OTTAWA

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DOMINION HORTICULTURIST

PROGRESS REPORT
1934-1948

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DIVISION OF HORTICULTURE

EXPERIMENTAL FARMS SERVICE

Progress Report—1934-1948

INTRODUCTION

The last report published by this Division appeared in 1936 and covered the work for the years 1931 to 1933 inclusive. This present report presents a brief summary of the work from 1934 to 1948 inclusive. During this period press articles, bulletins, and scientific and technical papers have been released, so that in these pages it is not necessary to do more than summarize much of the work and refer to the more complete articles or bulletins where such have been published. However, this report presents more complete details on certain projects where the data are of more recent date.

The Division of Horticulture is one of the original Divisions of the Experimental Farms System but over the long period of years since its establishment it has undergone certain contractions and expansions. Originally the Division concerned itself with the arboretum which, in 1911, was transferred to the Division of Botany, now a part of Science Service. In the earlier days of the Division the work consisted mainly of variety testing and plant breeding. In more recent years the work has been expanded to include fruit products, low temperature research, certain phases of plant nutrition, histology, plant physiology, and work with greenhouse crops. A statement on the present organization of the Division will be found at the end of this report.

POMOLOGY

Winter Injury

M. B. Davis, D. S. Blair, H. B. Cannon.

The period covered by this report (1934-48) began with one of the most severe and unusual winters in the history of the Division, viz., the winter of 1933-34. During this winter much damage was done to fruit trees in this and surrounding districts, while during the following season, 1934-35, a great deal more injury became apparent as a result of the weakened condition of the trees.

In the provinces of Ontario and Quebec served directly by this Division, apple production was reduced by 60 and 70 per cent respectively over the previous five-year average. The injuries were of three main types:

1. Injury to fruit and leaf buds;
2. Injury of the woody tissues above the main trunk and scaffold branches, and
3. Injury to main crotches, lower regions of scaffold branches and trunk.

The most serious of these was type 3, where splitting and lifting of the bark was so serious that many trees died or were so impaired in usefulness that repair

Fig. 1—Badly injured trunk of tree.

Fig. 2—Hardy trunk, top-worked.

work was almost impossible. However, some trees were saved by planting vigorous seedlings at the base for later successful inarching and others by bridge grafting. A survey of the Central Experimental Farm and growers' orchards revealed that where a variety like McIntosh had been top-worked on very hardy material such as Hibernal, trunk and main crotch injury was limited.

Hardy Frameworking

Since injury confined to the top of a tree well beyond the main crotches is not a major disaster, double-working, wherein a hardy stem builder or framework is employed, would appear to be a correct avenue of approach to the winter injury problem. As a result of the experience of 1933-34, growers were urged to work a goodly percentage of new plantings on Antonovka, which at Ottawa had proved to be about the hardiest variety on which sufficient information was available concerning its compatibility with the commercial varieties. This recommendation has resulted in a good many thousand trees being double-worked, but the majority have been worked on Hibernal, partly because of the greater ease in getting propagating material and partly because it makes a more vigorous tree in the nursery.

In 1935, a comprehensive tree building program was started at Ottawa to study the performance of a wide range of stem builders and their compatibility with the more popular commercial varieties of this area. Some sixty varieties have been employed as stem builders in this test and the most promising ones to date are evaluated below:

Hibernal.—A very hardy variety of Russian origin, making vigorous growth when young and producing strong right-angled crotches. While probably hardy enough, this variety is susceptible to sun scald to some extent and is not resistant to fire blight, undesirable features in any stem builder. It has proved compatible with all the standard sorts at Ottawa and has been the easiest of all the varieties under test to train and top-work.

Antonovka.—Although not so vigorous as Hibernal when young, this variety produces a good strong tree with reasonably strong crotches. To date it has proved compatible with all the commercial sorts of Central Canada. Hardier than Hibernal, resistant to collar rot, quite resistant to sun scald, and while not immune to fire blight it is much more resistant than Hibernal. Of the better known older varieties this is probably the best recommendation for a stem builder from the hardiness standpoint.

M. robusta No. 5.—A clone originated at Ottawa in connection with rootstock studies. It appears to be perfectly winter hardy, very vigorous when young, almost immune to fire blight at Ottawa, makes very strong crotches, is not subject to sun scald and to date has proved compatible with the main varieties. On account of its resistance to fire blight this variety is now being used for Sandow.

Virginia Crab.—One of the most vigorous frame-builders under test. Produces very strong crotches, but is incompatible with Sandow at Ottawa. Since other workers have found it to be selective as to its partners, Virginia Crab is not being recommended as a frame-builder until more information is available.

Osman and Columbia.—Extremely hardy and compact and so appear very promising. Some trouble has been experienced with fire blight cankers on the trunks of the Osman trees and although losses have not been great, this may prove the limiting factor with this variety. No similar fire blight infection was noted on the Columbia trees.

Methods of Hardy Tree Building

Considerable attention has been given to the technique of hardy tree building. The best method is to force the newly planted trees into vigorous growth in order to have an ample number of shoots for framework selection. Trees handled in this manner are ready for top-working two or three years after planting. Experience has shown that a period of two to three years for working the trees over is more satisfactory than completing the operation in one year. The low branches are worked over in the first year and the upper branches in the subsequent years.

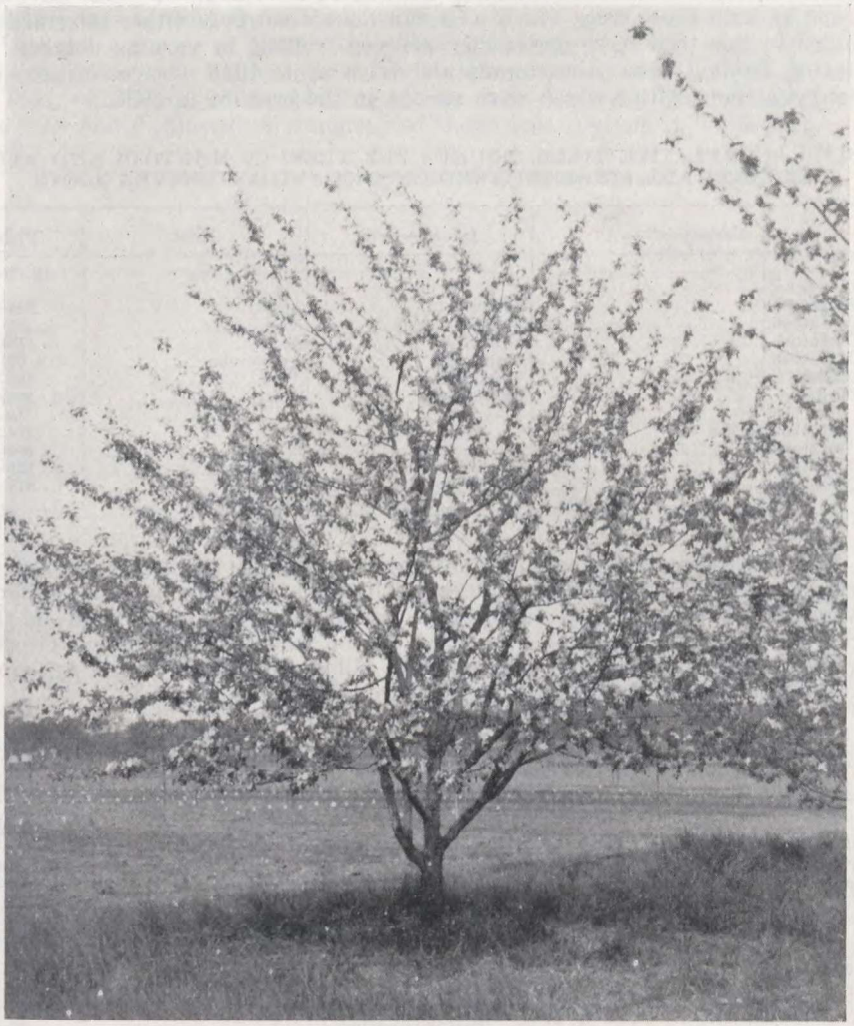

Fig. 3—McIntosh in full bloom. McIntosh top-worked on hardy crab.

Budding is the most economical method of top-working trees. This method surpasses grafting since it is not only quicker but also does not require the storing of scions. The buds are inserted on the side or underside of the

scaffold limbs approximately ten to twelve inches from the trunk. When the buds are placed eighteen to twenty-four inches from the trunk, the branches of the hardy frame builder tend to twist and split longitudinally. Cutting back the scaffold limbs to the inserted bud causes many shoots to form behind the bud. Only those shoots which are interfering with the growth of the bud should be removed. In the hardy tree building investigations at Ottawa it has been observed that the complete removal of these shoots appreciably retards tree development.

In considering double-working, the question of delayed fruiting naturally arises. Results up to the present time with McIntosh and Melba varieties indicate that where Hibernal has been used as an intermediate, yields have been as good as with those trees which were not double-worked. Other intermediates included in this trial have apparently delayed fruiting in varying degrees. The following Table 1 shows the cumulative yields up to 1948 of trees on Anis and Antonovka roots, all of which were set out in the orchard in 1936.

TABLE 1.—CUMULATIVE YIELD (POUNDS PER TREE) OF McINTOSH AND MELBA, DOUBLE- AND SINGLE-WORKED ON ANIS AND ANTONOVKA ROOTS

Variety	Intermediate	Root	Yield
			lb./tree
Double-worked—			
McIntosh	Hibernal	Anis	288·9
McIntosh	*M. baccata*	Anis	185·2
McIntosh	Antonovka	Anis	154·3
McIntosh	Antonovka	Antonovka	99·7
Melba	Antonovka	Anis	183·9
Melba	Charlamoff	Anis	229·7
Single-worked, budded—			
McIntosh		Anis	258·8
McIntosh		Antonovka	235·3
Melba		Anis	318·5

In a further trial set out in 1937 for the purpose of comparing different intermediates or stem builders, differences in varietal yields are now apparent. A summary of these yields in Table 2 again shows a higher yield in those varieties where Hibernal has been used as the intermediate. Patten Greening has given approximately the same yields as Hibernal while Anis and Antonovka have to date apparently delayed fruiting somewhat.

TABLE 2.—CUMULATIVE YIELD UP TO 1948 OF VARIETIES ON ANIS ROOTS WITH DIFFERENT INTERMEDIATES, PLANTED IN 1937

Variety	Intermediate	Yield
		lb./tree
McIntosh	Anis	62·7
	Antonovka	135·9
	Hibernal	177·8
	Patten Greening	180·2
Lawfam	Anis	18·4
	Antonovka	43·8
	Hibernal	114·9
	Patten Greening	95·2
Sandow	Anis	21·3
	Antonovka	10·7
	Hibernal	43·6
	Patten Greening	35·6

Apple Rootstock Studies

Practically all the commercial orchards in Canada have been propagated on seedling rootstocks.

In Central Canada winter hardiness of rootstock may frequently be an important factor and as the only clonal rootstocks that have been available are of European origin they have not been generally recommended for adoption until such time as a hardiness reading could be obtained.

In 1938 a collection of the Malling stocks together with a few clonal rootstocks originated at Ottawa were planted in an area where snow coverage could be removed. After each snowfall the area was swept clean and this procedure was continued for three years.

By the summer of 1940 (two years after planting) the roots of all the English stocks were badly injured and in many cases were completely killed. By 1941, two-thirds of the Malling stocks were dead and the remaining third were very badly injured. A summary of these data is given in Table 3.

TABLE 3.—VEGETATIVE ROOTSTOCK WINTER HARDINESS TEST, 1941

Rootstock	Trees Completely Killed (a)	Injury
		Per cent
Anis 46	0	10
Anis 322	0	10
Anis 376	0	10
M. robusta No. 5	0	0
M.A. 452	2	40
M.A. 462	1	20
M.A. 466	5	90
M.A. 472	0	10
M.A. 478	1	30
E.M. I	4	90
E.M. II	4	90
E.M. IX	5	90
E.M. XII	2	80
E.M. Crab C	4	80

(a) Six trees of each rootstock.

Of the Ottawa originations one, namely, *M. robusta* No. 5, was completely free of injury. On three others, Anis 46, 322 and 376, a trace of sun scald was the only sign of injury.

On the basis of these results, the Division has hesitated to recommend Malling stocks where root hardiness is essential. *M. robusta* No. 5, the outstandingly hardy stock of the series, has also proved highly resistant to fire blight and collar rot. This stock roots very freely in the stool bed, grows vigorously in the nursery, and to date has proved compatible with the main commercial varieties. The stock is inclined to be a bit rough but if desired for framework this roughness may be largely eliminated by budding *M. robusta* No. 5 stock from the stool bed with *M. robusta* No. 5 buds.

Comparison of Vegetative and Seedling Rootstocks of Apples

Apple rootstock investigations have been carried on at Ottawa since 1937. Results of the earlier investigations appear in "Present Status of the Apple Rootstock and Double-Working Trials in Eastern Canada" by D. S. Blair. Sci. Agr. 20: 150-154. Oct., 1939. The present report presents some of the later

results of the trials in which varieties such as McIntosh and Fameuse on various rootstocks, including the Malling stocks and seedling stocks of Russian origin, are compared.

Table 4 shows the average size of McIntosh trees on three seedling rootstocks and four Malling vegetative stocks, together with a comparison of Fameuse on Anis and E.M. I. As an index of tree size and vigour, the cross-sectional area of the trunk has been used as the best single expression of these factors.

TABLE 4.—AVERAGE CROSS-SECTION AREA OF McINTOSH AND FAMEUSE TREES AT FIVE AND THIRTEEN YEARS OF AGE

Variety	Rootstock	Cross-Section Area	
		5 Years	13 Years
		Sq. in.	Sq. in.
McIntosh	Anis	25·9	116·4
	Antonovka	24·4	110·1
	M. baccata	23·5	138·8
	E.M. I	18·0	80·4
	E.M. II	14·5	86·6
	E.M. IX	6·3	21·7
	E.M. XII	25·0	168·8
Fameuse	Anis	27·6	147·5
	E.M. I	15·8	107·4

Table 4 shows that in tree size or vigour the McIntosh trees fall into four general groups. The differences, although relatively small at five years of age, are much more apparent at thirteen years of age. The most vigorous trees at age thirteen are those on E.M. XII. In the semi-vigorous group, the three seedling rootstocks, Anis, Antonovka and *M. baccata,* have shown similar effects upon tree growth. Trees on Antonovka, however, are slightly smaller in size than those on Anis or *M. baccata.* Little difference is evident between E.M. I and E.M. II in their effect upon the growth of the scion variety and both may be classed in the semi-dwarfing group. The dwarfing habit of trees on E.M. IX is very pronounced when these are compared with trees of the same variety growing on other stocks. With Fameuse, the results are similar; the trees on Anis seedlings being considerably larger than those on E.M. I.

Yields were recorded, and the cumulative yields are given in Table 5.

TABLE 5.—TOTAL YIELD PER TREE OF McINTOSH AND FAMEUSE TREES AT FIVE AND THIRTEEN YEARS OF AGE

Variety	Rootstock	Total Yield per Tree	
		5 Years	13 Years
		Number of Fruits	Pounds
McIntosh	Anis	19	258·8
	Antonovka	19	235·3
	M. baccata	28	194·9
	E.M. I	27	151·9
	E.M. II	36	192·9
	E.M. IX	41	78·5
	E.M. XII	3	246·8
Fameuse	Anis	8	201·3
	E.M. I	20	144·0

Rootstock effects upon the yielding ability of McIntosh and Fameuse trees in early life are illustrated in Table 5. In the first five years, trees on E.M. IX were much more precocious than trees on either the other vegetative or the seedling rootstocks. Some tendency towards early bearing was exhibited by trees on E.M. II, and, to a lesser extent, on *M. baccata* and E.M. I. Trees on Anis, Antonovka and E.M. XII were somewhat later in coming into bearing, particularly those on E.M. XII. In general, there seems to be a fairly consistent negative relationship between tree vigour and precocity or early bearing. In other words, the more vigorous the rootstock, the later the scion variety is in coming into bearing.

At the age of thirteen years, the picture with regard to yield has completely changed. The trees which were later coming into bearing have now produced a greater crop than those which were more precocious. This is particularly evident when the yield over the first thirteen years of trees on E.M. IX is compared with yields produced by trees on Antonovka, Anis and E.M. XII. At the present time there appears to be a positive relationship between the yield of McIntosh and Fameuse on these rootstocks and the vigour of the tree induced by the rootstock (see Table 5).

Hardy Vegetative Rootstocks

It is felt that the only permanent solution to a satisfactory rootstock for the commercial apple orchards in Canada, particularly those located in the colder sections, is hardy clonal stocks. Selection work within the hardy seedling rootstocks of Russian origin, in an endeavour to find a hardy stock that will stool readily, has been under way in the Division for some twenty-five years, but by nature is slow in progress. It is necessary to find out first of all if the rootstock is hardy; second, if it can be readily propagated vegetatively, and third, if it is compatible with the commercial varieties budded upon it. In addition, the resistance of the rootstock to certain diseases, such as collar rot, must be established.

TABLE 6.—CROSS-SECTION AREA OF APPLE TREES ON OTTAWA VEGETATIVE ROOTSTOCK SELECTIONS. TREES TEN YEARS OF AGE

Rootstock	Cross-Section Area		
	McIntosh (*a*)	Lawfam (*a*)	Melba (*b*)
	Sq. in.	Sq. in.	Sq. in.
Anis 46	49·4	65·1	52·4
Anis 322	39·4	41·5	62·7
Anis 376	56·9	58·8	60·5
M. robusta No. 5	85·8	98·6	92·4
M.A. 452	62·2	58·8	68·8
M.A. 462	77·8	77·8	81·5
M.A. 466	92·1	71·3	98·2
M.A. 472	86·9	84·2	75·4
M.A. 478	82·3	73·5	72·8

(*a*) 8 trees of each combination.
(*b*) 6 trees of each combination.

The hardiness of some Ottawa vegetative rootstocks as measured by the field test was given in Table 3. One measure of compatibility between scion and vegetative rootstock is the appearance of the growing tree; a second is growth or vigour, an index of which is the cross-section area. This measure of growth in three varieties of ten-year-old trees on Ottawa vegetative rootstocks is given in Table 6.

Table 6 indicates a fairly wide range of vigour between trees growing on the various Ottawa clonal selections. The rootstock effects illustrated here are not

consistent with all three scion varieties. The Anis selections appear to have a dwarfing effect upon all three varieties when compared with *M. robusta* No. 5 and the mixed apple selections. The most vigorous growing trees appear to be the three varieties on *M. robusta* No. 5 and M.A. 466 while those on Anis 322 and Anis 46 are the least vigorous of these selections. *M. robusta* No. 5 is outstandingly hardy (Table 3). The Anis selections are also very hardy and although they have a dwarfing effect on the strains of the three varieties employed in Table 6, the appearance of these trees indicates compatibility.

In 1947, some five thousand Antonovka and Beautiful Arcade seedlings were stooled. From these, twenty-eight Antonovka and thirty-seven Beautiful Arcade clones were selected on the basis of their ability to stool readily. These clones are being further processed for compatibility, hardiness and resistance to disease. It should be stated that these and the foregoing experiments are necessarily long range. Table 5 indicates how the yield picture changes, and there is always the possibility that compatibility may change suddenly with time.

FRUIT BREEDING

Apples

M. B. Davis and D. S. Blair

Apple breeding has been an important effort in this Division since its inception.

The eastern part of Ontario and the fruit regions of Quebec have in the past been rather limited in their choice of varieties that were hardy enough to withstand the severe winters of these regions. During the last twenty-five years the recommended fruit list of these areas has, with the exception of McIntosh, undergone a complete change. The new varieties that have been added include Melba, Joyce, Hume, Atlas, Lobo and Cortland. The first five are Ottawa originations and Cortland is a product of Geneva, N.Y.

There is still a need for a few more varieties. An apple earlier than Melba, but of similar quality, would be desirable, and winter apples of acceptable quality and hardiness are almost a *must*. The present breeding program is therefore being largely concentrated on winter sorts.

Some New Early Varieties Under Trial

Apples earlier than Melba are now being distributed for trial. These are all crosses between Melba and Crimson Beauty and three outstanding ones are O-272, O-274 and O-277. They all resemble Melba in appearance and quality, but are a little earlier than that variety, O-277 being the earliest.

O-244.—McIntosh × Duchess, an improved Duchess type, fully as hardy as Duchess, with much superior quality. While this apple does not size well enough to consider it for commercial planting, it may prove of real value for home use when hardiness is the limiting factor. Ready for picking in early September.

O-294.—McIntosh × Fameuse, ripens a few days earlier than McIntosh and has the crisp texture and full flavour of the latter. It is an attractive apple of commercial size and since it appears to be more hardy than McIntosh and is of similar season to Lobo, it may be a useful substitute for that variety where more quality is desired.

Varieties Later than McIntosh

The search for a variety later than McIntosh has faced many difficulties. The combination of late maturity, good quality and hardiness is apparently rare. At the present time with over sixty per cent of all planting in this area consisting of McIntosh, the grower is faced with a difficult picking problem and also a marketing problem.

Several late varieties have been introduced for trial but none has shown up sufficiently as yet to be recommended for widespread commercial planting. The more important of these are evaluated below:

Lawfam.—Ready for picking a week to ten days after McIntosh, which is a valuable feature. The tree appears to be as hardy as McIntosh, is a good strong grower with good form and strong crotches. The fruit is very highly coloured, very uniform, good quality and keeps somewhat longer than McIntosh.

Under some conditions it has proved a disappointment. In the first place it is very susceptible to magnesium deficiency, but this is easily controlled by

adoption of recommended practices. In addition, however, it is a heavy feeder, requiring considerably more feeding than McIntosh to enable it to carry a crop. Under low nutrition conditions it is a shy bearer while under a high level of nutrition it tends to overbear and does not size up too well. This latter point can apparently be controlled by the use of the various thinning sprays. Still recommended for trial or for commercial planting in orchards where it has proved suitable.

Linda.—Ripens with McIntosh so does not improve the picking problem. The fruit is of good size, very highly coloured and if used after January 1 is of excellent, aromatic, sprightly quality. An excellent keeper. The tree is vigorous, comes into bearing at an early age, but is not fully hardy at Ottawa and should be top-worked on a hardy frame builder. Recommended for further trial.

Edgar.—One of the newer Ottawa hybrids that follows McIntosh in picking season. The fruit is of good commercial size, highly coloured and of very good texture and quality. Its chief merit is that it has a longer season than McIntosh. Trees are equal to McIntosh in hardiness but are slower to come into bearing.

Sandow.—Undoubtedly one of the highest quality winter apples on the market. The fruit is of good size and highly coloured. It may be picked two to three weeks after McIntosh. The tree is susceptible to fire blight. While more winter hardy than Spy, it is not fully hardy at Ottawa so should be top-worked on a hardy blight resistant framework. Like its parent, Spy, it is susceptible to bitter pit in the early years or on trees bearing a light crop. At present it is recommended for western and southern Ontario and for extended trial when double-worked in eastern Ontario and Quebec.

Bancroft.—To date this variety has proved to be almost the ideal variety. The tree is a strong grower of good form, bearing at a young age, and appears to be fully as hardy as McIntosh. The fruit sizes well, is highly coloured and is an excellent keeper in cold storage holding first class condition until April 1. Its quality, however, while moderately good is far below that of Sandow, Spy or McIntosh. But for this one point, it would be recommended as the winter apple for eastern Ontario and Quebec. Despite this lack of very high quality it may be the variety that will have to be accepted for some years to come. Recommended for further trial.

Newtosh.—A high quality winter apple. Fruit is highly coloured with firm flesh. Harvesting date about mid-October and keeps well until April. The tree resembles McIntosh in habit and hardiness. If this apple will size up well under various conditions it should prove of distinct value. Worthy of very extended trial.

O-2016.—The most recent addition to the late winter apples under trial. The fruit is of good size and very attractive. It has superior keeping qualities but is only medium in quality. The tree is outstanding in growth and habit and it fruits at an early age. It cannot be overlooked as a possibility where hardiness is a requisite. Recommended for trial only.

Melba Sports.—Several sports of Melba are under test at Ottawa. They are superior to Melba in appearance, firmness of flesh, and keeping qualities, but ripen a few days later. Probably the significant feature of these sports is that they show bruises less readily than Melba.

Pears

A. W. S. Hunter

The development of improved hardy pear varieties in Canada is lagging behind that of the apple by about fifty years. The well-known standard varieties may be grown only in the milder parts of the country and most pears hardy enough to be grown elsewhere are of little commercial value.

Five hardy varieties, named respectively Enie, Menie, Miney, Moe and Phileson, have already been introduced by this Division. They are the result of crosses made in 1916 between the hardy Russian sorts, Kurskaya and Zuckerbirn, and the standard varieties, Clapp Favorite and Flemish Beauty. These varieties have found a limited acceptance in eastern Ontario and Quebec, but there is still room for improvement.

Breeding is being continued at Ottawa with the object of producing high quality pears that are fully hardy, suitable for both canning and dessert purposes, good keepers, and resistant to fire blight. Crosses are being made between the better standard pears, the five Ottawa varieties mentioned above, and a number of hardy but otherwise less desirable varieties, seedlings and species.

Fire blight, a bacterial disease caused by *Bacillus amylovorus* (Burr.) Trev. is very destructive in some years and on some varieties. Therefore, in order to avoid the introduction of non-resistant sorts, the susceptible seedlings are being eliminated by artificial inoculation in the seedling stage. This is accomplished by sprinkling the seedlings with a suspension of the organism under conditions of high atmospheric temperature and humidity.

STONE FRUITS

A. W. S. Hunter

Cherries

Cherries, both sweet and sour, are not a commercial crop outside of the milder parts of Canada. At Ottawa the sweet cherries cannot be grown at all, and the best sour cherry varieties, although reasonably hardy in the wood, have their flower buds killed in most winters (Davis, 1). Some of the hardy sour cherries from northern Europe succeed quite well but their small fruit size and acid flavour render them commercially unacceptable.

Numerous attempts have been made at Ottawa to produce improved hardy cherries. In the sour cherry group, crosses have been mostly between the hardier small-fruited varieties, and the resultant seedlings have lacked size and quality. However, a few seedlings from recent crosses between Montmorency and 0-241, a selection of the hardy Russian variety Vladimir, give promise of considerable improvement and suggest that it may be possible to produce hardy sour cherries that are equal in size and quality to Montmorency.

The situation with respect to the sweet cherry is less promising. There is no closely related source of particular hardiness. Many unsuccessful attempts have been made to cross the sweet cherry with the extremely hardy pin cherry, *P. pennsylvanica* L., and the equally hardy chokecherry, *P. virginiana* L. Crosses have also been attempted with the Nanking or Chinese cherry, *P. tomentosa* Thunb., and with the sandcherry, *P. Besseyi* Bailey.

The cross, sour cherry × sweet cherry, may be made with ease, and a high proportion of the seeds obtained are viable. Since the sour cherry is a tetraploid (32 chromosomes) and the sweet cherry a diploid (16 chromosomes) the seedlings from such a cross are triploids (24 chromosomes) and are highly sterile. The

triploids produced at Ottawa have had a hardy variety as the sour cherry parent and many of them are hardy in both wood and flower bud. These triploids produce an occasional fruit from which it can be seen that some tend towards the sweet cherry and others towards the sour cherry type. Attempts to double the chromosome number of these cherry triploids are described in another section of this report.

The seed of these triploids has been saved. Plump kernels were found in about 30 per cent of this seed and 107 seedlings were grown. The chromosome counts so far obtained on these plants run from $2x = 24$ to $2x = 40$, the majority being aneuploids with intermediate numbers. None of these seedlings has yet fruited.

P.fruticosa Pall.—Selection within this species has given some seedlings with fruit up to three-quarters of an inch in diameter. This hardy bush cherry is useful where the benefit of snow coverage is desired. However, the fruit is very acid, and it is being crossed with Montmorency and other good quality sour cherries in an attempt to improve the flavour and to increase fruit size but retain the bush habit.

P. tomentosa Thunb.—The Nanking or Chinese cherry is an attractive ornamental plant. The fresh fruit is highly palatable and makes a fine jelly. Large numbers of open-pollinated seedlings have been grown. The best are fully hardy at Ottawa and bear fruit up to two-thirds of an inch in diameter. *P. tomentosa* will cross with *P. Besseyi*, but the hybrids have been less desirable ornamentally and less productive than *P. tomentosa*. The fruit resembles *P. tomentosa* in shape, but it is almost black in colour, little if any larger, and sometimes flat and unpalatable in flavour.

New Varieties

The Ottawa cherry selections have not been widely tested, but they are being propagated for trial and will be sent out as rapidly as possible. The most outstanding appears to be 0-391 from the cross, Montmorency × 0-241. The fruit is above medium in size and equal to Montmorency in flavour. The tree is still young but it has been completely hardy at Ottawa. A seedling of Vladimir, 0-241, is of interest because of its hardiness. This medium-sized sour cherry rarely fails to produce a good crop at Ottawa. Three promising selections of *P. tomentosa* are 0-311, 0-312 and 0-383, the first because of its very early maturity and apparent great hardiness and the other two because of their large fruit size. The *P. fruticosa* selections 0-381 and 0-382 are the best of this species seen so far. 0-381 is a very heavy yielder of medium sized fruits. 0-382 is less productive, but its fruit is larger.

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Plums

This Division has engaged in the development of improved hardy varieties of plums since 1890. The early work was confined largely to the growing of open-pollinated seedlings of *Prunus americana* Marsh and *P. nigra* Ait. varieties. Twenty-six of the better seedlings of this type are described in the Annual Reports of the Dominion Horticulturist from 1901 to 1921. A few open-pollinated seedlings of European varieties were also grown from which two promising varieties, Carleton and Nepean, were obtained.

Since 1913, the plum improvement program has been based almost entirely on controlled crossing. Records have been taken on 593 seedlings of known

parentage, representing a wide range of intra- and interspecific combinations. Twenty-six seedlings were selected for further testing. The following five have been particularly promising:

Algoma, formerly 0-302, is a fair sized, very hardy cherry-plum from the cross *P. Besseyi* × Burbank. Grenville (Burbank × *P. nigra*) is a large, red fruited, early maturing, dessert variety. Three Wickson hybrids, at present known by the numbers 0-306 (*P. bokhariensis* × Wickson), 0-308 (*P. bokhariensis* × Wickson) and 0-3010 (Burbank × Wickson) are not quite hardy enough for Ottawa, but are being distributed for trial in milder regions because of their desirable fruit characteristics.

Fig. 4—Algoma (*P. Besseyi* × Burbank) is a hardy, good quality cherry-plum.

It is apparent from the results obtained that crosses between the Japanese varieties and varieties derived from *P. americana* and *P. nigra* offer excellent opportunities for the production of hardy, large fruited, high quality plums. However, all varieties are not equally valuable as parents. Burbank was the best of the Japanese varieties used, and an unnamed seedling of *P. nigra*, which unfortunately was lost, was the best of the hardy plums. A wider range of varieties is being used in present crosses to obtain more information on this point.

The Japanese-native hybrids themselves have been disappointing as parents. Selfed progeny was produced with difficulty and the few seedlings that were grown were not impressive. Backcrossing to the native parent resulted in seedlings that resembled the wild plum too closely. Many of the seedlings from backcrossing to Japanese varieties lack hardiness.

The current plum breeding program is being centered mainly on Japanese-native crosses, but attention is also being given to other types of combinations. Crosses between the Japanese-native hybrids and the Simon group of plums, represented by Kaga, Superior and Toka, may be readily effected. The combining of the two groups may give interesting results. The so-called "cherry-plums", hybrids between the sand cherry (*P. Besseyi* Bailey) and Japanese

varieties, are extremely hardy and intermediate in habit between the two parental types. The "cherry-plums" will cross with Japanese sorts and also with the Simon plums, and they would appear to offer unusual opportunities for improvement. An attempt is also being made to produce better hardy European-type plums by making use of some of the hardy *domestica* material that is available.

Filberts

The European varieties of filbert are not hardy in eastern Ontario and Quebec. The male flowers are killed in most winters and the plant frequently dies back to the snow line. However, the two native species, the American hazel (*Corylus americana* Marsh.) and the beaked hazel (*C. cornuta* Marsh.), are fully hardy in Eastern Canada. Selection within these two species has been conducted at Ottawa since 1922. The fourth generation, consisting of approximately 750 seedlings, fruited in 1942. There was considerable variation in the size of the nuts, thickness of shell, freedom from a scurfy pellicle, yield, plant vigour, etc. Four of the best *C. americana* seedlings selected for further trial had relatively large nuts with thin shells, clean kernels and a good flavour. Propagation by layering has been attempted, but progress is slow. There was little variation within *C. cornuta*, all the seedlings having rather small nuts.

Successful crosses have recently been made with some of the larger fruited better quality European-type varieties, using the *C. americana* selections as the female parent. It is hoped in this way to develop hardy, good quality, large sized filberts.

SMALL FRUITS

A. W. S. Hunter

Strawberries

The primary objectives in the strawberry breeding program have been increased yield, firmer fruit and more attractive appearance. It is upon these that the commercial suitability of a variety depends. However, improved flavour has not been ignored. Better early and late maturing varieties have also been sought, and recently considerable attention has been given to the testing of seedlings for resistance to the more troublesome strawberry diseases.

New Varieties

In the period 1933 to 1948, 92 new selections were distributed to experimental stations and private growers for trial. Three of these, Tupper, Louise and Elgin, have assumed some importance because of their late maturity. King and Mackenzie, two early midseason varieties, are being grown to a limited extent in some localities. Two recent introductions, 0-371 and 0-374, are promising, but have not yet been properly evaluated. A number of newer selections are undergoing preliminary tests at Ottawa.

The parentage of the above introductions is as follows:

Elgin	Ettersburg 214 × Wm. Belt
King	(Delecto × Cassandra) Selfed
Louise	Ettersburg 80 Selfed
Mackenzie	Excelsior × Premier
Tupper	Ettersburg 214 × Cassandra
0-371	Fairfax × King
0-374	(Easy Picker × Ettersburg 80) × Fairfax.

The Value of Varieties as Parents

The determination of the usefulness of a variety as a parent and the value of different parental combinations is an important part of the breeding program.

In the past fifteen years, approximately 14,000 seedlings from 87 different combinations have been examined. A number of Ottawa varieties and selections as well as varieties originated elsewhere have been used in these crosses. Some of the outstanding features are presented herewith:

Claribel, (Ettersburg 121 × Cassandra), is a very firm fleshed, late maturing variety of rather poor quality. In combination with Fairfax it produced a high proportion of late, good quality, firm, attractive seedlings. On the basis of the good performance of this combination a number of other crosses have been made that will fruit in the next year or two.

Dresden, in combination with Fairfax and 0-371, was outstanding for large fruit size, attractiveness and good plant vigour, but the flavour of most of its progeny was rather insipid.

Fairfax has been an outstanding parent. It transmits to a high proportion of its seedlings the *chiloensis* type of foliage, and glossy, well shaped, attractive, good quality fruits. Many of the seedlings are a little dark in colour.

Geneva 7225 gives a good proportion of early maturing and high yielding seedlings, but almost all are very soft-fleshed and many are susceptible to mildew.

Louise transmits lateness but also deeply sunken seeds and soft flesh. In combination with Elgin, extremely late seedlings ripening as much as three weeks later than Elgin were obtained.

Premier produces seedlings whose general level is quite high, although many have soft flesh and are susceptible to mildew. This variety is being used extensively as a parent.

Valentine appears to be a good source of earliness. However, it is dark in colour and produced mostly dark coloured seedlings when crossed with Fairfax and Premier.

0-371 is not so good a parent as Fairfax. Many of its seedlings bruise easily on the surface and are susceptible to mildew.

Disease Resistance

The development of resistant varieties by breeding is recognized as the most efficient method of controlling plant diseases. Several foliage diseases of the strawberry are frequently economically important in Canada. Of these diseases, mildew (*Sphaerotheca humuli* (DC.) Burr.) is not a great problem from the breeding standpoint since it is usually sufficiently prevalent to permit the ready identification of susceptible seedlings in the field in their first fruiting year. Leaf spot (*Mycosphaerella fragariae* (Schw.) Lind.) rarely becomes epidemic in the seedling plantation. Artificial inoculation at the small seedling stage by a method developed by the Division of Botany and Plant Pathology is used for the elimination of susceptible seedlings. Two other important diseases are leaf scorch (*Diplocarpon earliana* (Ell. & Ev.) Wolf.) and leaf blight (*Dendrophoma obscurans* (Ell. & Ev.) H. W. And.) but no attempt at artificial inoculation has yet been made with them.

It is becoming increasingly evident that many stocks of strawberries in Canada are infected with virus and that this is responsible for the frequently observed "running out" of varieties. The recognition of this fact has been delayed by the failure of the commonly grown varieties to show readily identifiable symptoms. The effect of virus infection in these varieties is a varying amount of dwarfing of the plants and suppression of runner formation, the end result of which is reduction in yields. The recognition of the presence of such viruses is important in a breeding program because steps must be taken to prevent the infection of seedling material. This is being done at Ottawa by isolation, screening, and protective insecticidal dusting.

Leaf Hopper Injury

The feeding of leaf hoppers on strawberry plants produces characteristic chlorotic areas at the edges of the leaves which are buckled and, in severe cases, rolled downwards. Leaf hopper injury is ordinarily not a serious matter at Ottawa, although the importance of leaf hoppers as a vector of virus diseases, negative evidence notwithstanding, cannot be altogether disregarded.

In 1941, a very severe infestation of leaf hoppers at Ottawa provided an opportunity to collect information on the relative susceptibility of a large collection of varieties and species in the plantings of the Division. The majority were slightly to moderately affected, but some showed severe leaf rolling and chlorosis and others were completely free or showed only a trace of attack.

The better known among the most severely attacked were:

Catskill	Northstar
Crimson Glow	Shelton
Lupton	Vanrouge

Among the varieties that were not attacked, or on which only a trace of symptoms was found, were the following:

Aberdeen	Louise
Chesapeake	Nancy Lee
Culver	Redwing
Daybreak	U.S.D.A. 665
Eleanor Roosevelt	*F. chiloensis*
Elgin	*F. moschata*
Fairfax	*F. vesca*
Fairmore	*F. virginiana*

Many of these varieties have the *chiloensis*-type foliage; dark green, thick, leathery and hairy leaves and petioles. Only two varieties with this type of foliage were rated higher than a trace and they were only slightly affected. However, that this thick, tough, hairy leaf is not entirely responsible for lack of leaf hopper attack is shown by the complete freedom of *F. vesca* and *F. virginiana*, both of which have a soft, thin type of leaf.

Inbred Strawberries

A program of inbreeding strawberries was initiated in 1919 using such varieties as Parson's Beauty, Magoon, Bederwood and Valeria. Many of the lines showed rapid deterioration in vigour and fertility following selfing. Others maintained good vigour, fruit size and fertility, even after six generations. The purpose of this work was twofold: (*a*) to produce inbreds that might on crossing together exhibit hybrid vigour, and (*b*) to produce strawberries homozygous for certain desirable characteristics that could be used in breeding, the expectation being that the number of good seedlings would be considerably increased by the use of such inbreds as parents. Virtual homozygosity for several characters such as external and flesh colour, seed placement, firmness of flesh and plant vigour was secured in some F_5 lines.

Recombinations at the F_2, F_4 and F_5 levels failed to show any appreciable improvement over the parental inbreds. This is probably not surprising in view of the fact that hybrid vigour is less prevalent where self-pollination or a combination of self- and cross-pollination is the rule than where cross-pollination is obligatory. Also, in plants such as the strawberry, selection for such characteristics as high vigour and high yield, which are largely the result of hybrid vigour, has been perpetuated by asexual propagation. Jones and Singleton (4) did obtain some promising selections from combinations of two inbred strawberries, and also from combinations of inbreds and named varieties, but they

were unable to state that better results were secured than might have been obtained from the crossing of ordinary varieties.

The use of homozygous inbreds as parents in combination with ordinary varieties has met with some success at Ottawa, suggesting the possible value of this type of breeding. A number of inbreds have been crossed with Fairfax, a variety that is known to be a good parent. The results from most of these "top-crosses" were indifferent, but one fourth generation inbred derived from the variety Magoon produced a population that was uniformly very high in plant vigour and freedom from mildew. It was also very uniform for medium fruit size and medium yield. The carrying by inbreds of undesirable dominant characters in addition to their desirable ones is a drawback that may complicate their use in this manner, but that may be overcome by backcrossing. This is being investigated.

The inbreeding of strawberries is being continued with modern varieties. The previous work was with inbreds derived from varieties most of which are not now grown. It is possible that better results from top-crossing might follow the use of inbreds from better varieties. In addition, if the solution of the virus problem becomes too difficult by other means, it may be useful to have reasonably homozygous strawberries that can be grown from seed for commercial use.

Interspecific Crosses

Crosses have been made between *Fragaria* species with different chromosome numbers. In 1935 several octoploid varieties (2x = 56) were pollinated with a variety of *F. vesca* (2x = 14). Approximately 700 flowers were pollinated and 163 fruits containing 2,788 seeds were harvested. Only 44 plants grew from these seeds. Chromosome counts were obtained from root tips of 39 of these, with the following results:

Diploids (2x = 14)	4
Pentaploids (2x = 35)	26
Octoploids (2x = 56)	9

The pentaploids are true hybrids and are highly sterile. They resemble their octoploid parent, as would be expected, because of the preponderance of chromosomes from that parent. The presence of diploids and octoploids in this population cannot be explained with certainty. The octoploids are probably the result of self-pollination and the possibility cannot be ruled out that the diploids are mechanical mixtures.

Pentaploid strawberries, although highly sterile, occasionally form a few viable seeds following cross-pollination. Yarnell (5) has reported 63, 70 and 90 chromosome offspring from such plants. In 1939 several pentaploids were selfed, and some were crossed with *F. chiloensis* and *F. virginiana*. The selfings were entirely barren, but seedlings were produced from most of the crosses. The progeny of a cross with *F. chiloensis* and another with *F. virginiana*, a total of ten plants, was examined cytologically. Six seedlings were 9-ploids and had 63 chromosomes. One was an octoploid with 56 chromosomes and three had approximately 45 chromosomes. The 9-ploids are apparently the result of the union of an unreduced egg cell of the pentaploid with a normal pollen grain of the octoploid. The 9-ploids are much like the pentaploids in appearance but they are more vigorous and show a trace of the foliage colour and texture of *F. chiloensis* and *F. virginiana* respectively. All but two are fully fertile. The 45 chromosome plants were all from the cross with *F. virginiana* and undoubtedly have arisen from a reduced egg cell of the pentaploid. They are all highly sterile and exhibit a marked resemblance to their male parent. The octoploid is fully fertile and shows a close resemblance to the 9-ploids in fruit and plant characteristics so that it is highly probable that it is of the parentage claimed. It could have resulted from

the functioning of an egg cell with 28 chromosomes. The pentaploid parent has not been studied cytologically, but meiosis in similar pentaploids reported by Ichijima (3), Yarnell (5) and Dogadkina (1) shows variation in association at first metaphase from seven bivalents and 21 univalents, through almost complete pairing (17 bivalents and one univalent) to the formation of varying proportions of quadrivalents, trivalents, bivalents and univalents. Therefore, the production of a 28-chromosome gamete in such a plant would appear to be quite possible.

Several crosses have also been attempted between octoploids and the hexaploid (2x = 42) species *F. moschata*. Only one seedling has been obtained. It has 49 chromosomes and is absolutely sterile. Unlike the hybrids reported above, this seedling does not resemble the parent contributing the majority of its chromosomes. As observed by others in similar crosses, it shows a marked resemblance to *F. moschata*.

Parthenocarpic Strawberries

Parthenocarpic fruit production was induced in the pistillate varieties, Louise, Portia and Simcoe, by spraying the blossoms with 1·0, 0·5 and 0·25 per cent concentrations of indolebutyric acid, naphthaleneacetic acid and colchicine. Some stimulation was also produced by dusting the pistils with powdered acenaphthene. The majority of the fruits produced were in every way typical for the variety except that the achenes were small and non-viable. Parthenocarpic development was also stimulated in some untreated blossoms by applications to other blossoms on the same plant. This work has been reported by Hunter (2).

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Raspberries

The raspberry improvement work at Ottawa has been directed toward the development of varieties that are winter hardy and that are productive and bear reasonably large, firm, attractive fruits with good flavour and freedom from disease. Five seedlings from crosses made in 1926 and 1927 were named in 1943 following wide spread tests in Canada. Two others, still under introduction number, have attracted some attention. These varieties, together with their introduction numbers and their parentages, are as follows:

Gatineau (0-276)	Lloyd George × Newman 23
Madawaska (0-272)	Lloyd George × Newman 23
Ottawa (0-275)	Viking × (Loganberry × St. Regis)
Rideau (0-262)	Lloyd George × Newman 23
Trent (0-264)	Newman 23 × Lloyd George
0-201	Newman 23 × Herbert
0-263	Newman 23 × Lloyd George

The Lloyd George—Newman 23 varieties resemble Lloyd George in having purple thorns on the new canes and in having thick-walled, conic-shaped berries. Ottawa shows its Viking parentage especially in cane vigour and the appearance of the fruit, but it is hardier than Viking. Gatineau, Madawaska, Trent and 0-263 are early maturing. Ottawa, Rideau and 0-201 are midseason varieties.

Madawaska, 0-201 and 0-263 are particularly hardy. All are satisfactory for freezing, and Madawaska is outstanding for jam purposes.

A limited amount of information on the relative value of different parental combinations has been obtained. Most of the earlier breeding work of the Division, largely intervarietal crosses between such varieties as Brighton, Count, Cuthbert, Herbert, Latham, Newman 23, St. Regis and Sunbeam, resulted in little of value. However, a marked improvement began with the use of Lloyd George as a parent. The first crosses were made in 1926 and the combination Lloyd George—Newman 23 was particularly outstanding. Lloyd George was also crossed with several other varieties but with the exception of Lloyd George —Latham, the numbers of seedlings grown were small. It is interesting to note that of the 110 Lloyd George—Latham seedlings first selected only 1·8 per cent survived beyond the second test and none was introduced for trial, but that in the Lloyd George—Newman 23 combination, 26·7 per cent of the 202 first selections survived the second test. Nine were introduced for trial and four were later named.

Small populations grown from crosses made in 1935 suggest the value of combinations between Ottawa and the Lloyd George—Newman 23 varieties. Three of these are at present being multiplied for testing. Similar crosses were made on a large scale in 1948.

Mention should be made of the parentage of Ottawa. According to the records, this variety is a seedling of Viking from pollination with 21-19-06, a seedling from the cross Loganberry × St. Regis. The latter is one of a group of Loganberry—raspberry hybrids, all of which failed to set fruit under field conditions. Several of these hybrids were crossed reciprocally with Latham, Newman 23 and Viking. When used as the female parent, some fruit was formed but no seedlings were obtained. When used as the male parent, small populations of seedlings were secured in every case, but sterility was high except where 21-19-06 was used in which case 87·3 per cent of the seedlings were fertile. Unfortunately this plant is not now in existence, and no cytological examination was made at the time. Two similar hybrids, one Loganberry × Fillbasket and the other Loganberry × Washington, are both tetraploids. This corresponds with the findings of Thomas (1) who suggested that such seedlings contain two homologous sets of seven raspberry chromosomes and two non-homologous sets of seven blackberry chromosomes. The variety Ottawa is a diploid; it is fully fertile, and it shows no trace of Loganberry characteristics. If it is of the parentage recorded, and there seems to be no reason to doubt this, it must have arisen through the functioning of a pollen grain of 21-19-06 containing seven raspberry chromosomes. In the absence of cytological evidence, the mechanism of the formation of such a pollen grain can be only a subject of speculation.

Disease Resistance

As a preliminary step in the breeding of raspberries for resistance to disease, a survey was conducted in 1943, 1944 and 1945, in co-operation with the Division of Botany and Plant Pathology, of the varieties growing in the plantation of the Division of Horticulture. The main part of this plantation was a randomized and replicated trial of the 13 varieties, Chief, Gatineau, Indian Summer, Latham, Madawaska, Marcy, Monroe, Newburgh, Newman 23, Ottawa, Rideau, Taylor and Viking. This was surrounded by guard rows containing a number of other varieties and seedlings. The following diseases were considered:

mosaic—virus
leaf curl—virus
late yellow rust—*Pucciniastrum americanum* (Farl.) Arth.
leaf spot—*Septoria rubi* West
powdery mildew—*Sphaerotheca humuli* (DC.) Burr.
anthracnose—*Elsinoe veneta* (Burkh.) Jenkins
spur blight—*Didymella applanata* (Niessl.) Sace.

The severity of the fungous diseases varied from year to year. In general, infection was heaviest in 1943, followed by 1945 and 1944 in that order. This plantation was not sprayed with a fungicide.

Mosaic.—Chief, Cuthbert, Latham and Ottawa were the most severely affected and the disease spread quite rapidly in these varieties. Many other varieties had one or two affected plants, but the disease did not become widespread. Herbert, Indian Summer, Madawaska, Marcy, Milton, Tahoma, Trent and Washington showed no mosaic symptoms in this plantation.

Leaf Curl.—Only one case of leaf curl—in the variety Marcy—was found in the whole plantation. In this plot, the disease spread at the rate of one plant a year.

Late Yellow Rust.—This disease was most severe on Ottawa, some plants being almost completely defoliated in 1943. Viking, a parent of Ottawa, is moderately susceptible, and five out of ten seedlings with Viking ancestry exhibit some degree of susceptibility. Chief, Latham, Newburgh and Newman 23 showed a trace to slight infection in most years. All other varieties were completely free.

Leaf Spot.—This was not a particularly important disease, most varieties showing a trace to slight infection. Gatineau, Rideau, Taylor, Trent and Washington were moderately susceptible.

Powdery Mildew.—Ottawa is quite susceptible to this disease, infection varying from a trace to very severe depending upon location and season. Latham is slightly susceptible, and a trace was sometimes found on Viking. Powdery mildew was not found on any other variety.

Anthracnose.—All the Lloyd George—Newman 23 hybrids were moderately to highly susceptible to anthracnose. These included Gatineau, Madawaska, Marcy, Rideau, Taylor and Trent. However, the most susceptible variety was Washington. Tahoma was also moderately affected. No variety was completely free from anthracnose, but Chief, Latham, Monroe, Newburgh, Newman 23, Ottawa and Viking showed only slight infection.

Spur Blight.—The most susceptible varieties, Madawaska, Rideau and Taylor, have Lloyd George—Newman 23 parentage. Other varieties of similar parentage such as Gatineau and Marcy were only slightly to moderately susceptible. Spur blight was found to some extent on all varieties.

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Black Currants

One of the most pressing needs in currant improvement has been resistance to white pine blister rust (*Cronartium ribicola* A. Fisch.). This disease is important because of its effect on currants, and also because of the menace of diseased currant plants to white pines. A search was begun in 1935 in the plantings of the Division of Horticulture for a source of resistance to rust. This was found in a seedling of the black currant species *Ribes ussuriense* Jancz. from Siberia, and in the red currant variety Viking, both of which are completely free from rust at Ottawa. The F_1 from the crosses between *R. ussuriense* and the susceptible varieties Boskoop Giant and Kerry was completely resistant to rust with the exception of a few seedlings from accidental self-pollinations that occurred where the female parent was a susceptible variety. These results have been reported by Hunter and Davis (4).

Ten F_1 seedlings were selected for trial on the basis of resistance to rust, yield, size of berry, length of fruit cluster and evenness of ripening. Two of

these selections, 0-381 and 0-393, both from the cross *R. ussuriense* × Kerry, were widely distributed in Canada in 1945, and in the years following, to Dominion Experimental Farms and Stations, provincial horticultural stations, agricultural colleges and schools, and to numerous private growers. Plants were also sent to England, Ireland and Scandinavia, and to several state and federal institutions in the United States. Reports have been received from the majority of these co-operators and in no case has rust been found on either variety, although the disease was usually abundant on plants of standard varieties growing nearby.

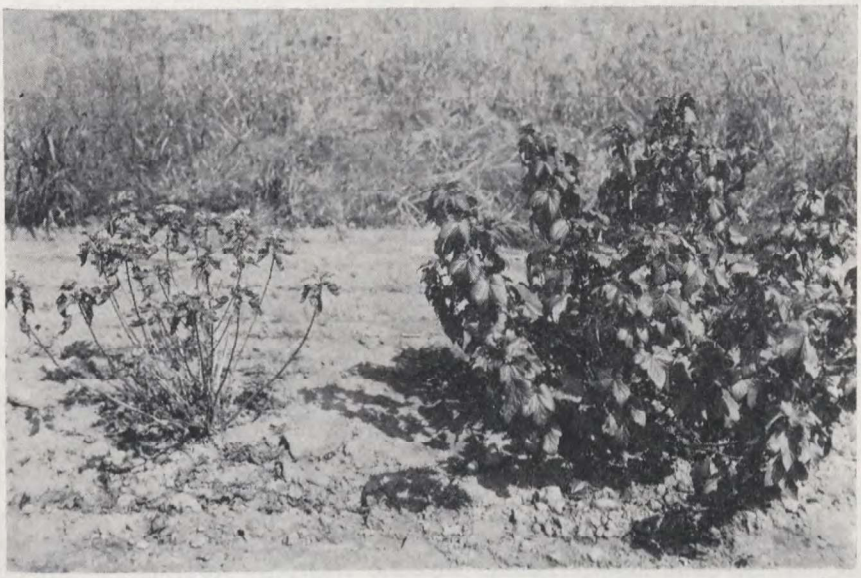

Fig. 5—(Left) Variety susceptible to white pine blister rust. (Right) Resistant variety.

Continued and careful observation at Ottawa over the period from 1941 to 1948 has failed to show any sign of rust, notwithstanding the fact that these plants have not been sprayed with a fungicide during that period. Hahn (2) reported inoculation experiments on 0-381 and 0-393 and stated that under the conditions of the test both varieties "appear to be truly immune from blister rust in the nice sense of that term, i.e., completely free or exempt from rust". In view of the reported freedom from rust throughout the wide range over which these varieties have been tested, it appears likely that they are resistant to all strains of blister rust, if such strains exist, (see also Hahn (3)).

Ottawa Yield Trial on Rustless Currants

In 1945 a yield trial was laid down at Ottawa consisting of the ten rustless selections, 0-381, 0-382 and 0-391 to 0-398 inclusive, and the standard varieties Climax, Kerry, Magnus and Saunders. On the basis of the first full crop harvested in 1948, 0-381 and 0-393 are two of the highest yielding rustless varieties and they are equal in yield to Climax and Magnus, but slightly less productive than Kerry and Saunders. These relative positions may be altered by further crop yields.

Jam and Jelly Tests

All ten rustless selections and the standard variety Champion, were made into jam and jelly by the Fruit and Vegetable Products Laboratory in 1948. The rustless varieties made jams that were slightly stronger in flavour than Champion, but that were in every way acceptable products. Jellies from the rustless

varieties were practically indistinguishable from jelly made from Champion. There was very little difference between jams and jellies from the several rustless varieties.

Vitamin C Content

Strictly comparable data on the vitamin C content of rustless and standard black currant varieties are not available, but the range for rustless varieties appears to be from about 130 to 180 mg. per 100 gm. The standard varieties vary between 150 and 280 mg. per 100 gm. Of the rustless varieties, 0-381 and 0-393 were first and third in vitamin C content. It should not be difficult to increase the amount of vitamin C in rustless currants by crossing them with high-vitamin standard varieties.

Rustless Varieties Named

The rustless varieties 0-381 and 0-393 were named on December 9, 1948, on the basis of the favourable results from the yield and processing tests at Ottawa, the generally favourable comments of growers in all parts of the country, and the complete resistance of these varieties to rust wherever they have been grown. The names given were:

0-381	Crusader
0-393	Coronet

Crusader.—(*R. ussuriense* × Kerry). Bush vigorous, upright; canes long, medium stout. Foliage immune from rust (*Cronartium ribicola*), slightly susceptible to mildew (*Sphaerotheca mors-uvae*). Flower cluster long, loose, with eight to twelve flowers. Fruit large, black; skin medium thick, slightly bitter; fresh fruit flavour sub-acid, quality good; fruit firm, clings well to cluster, ripens fairly evenly, late midseason in maturity. This variety makes excellent jam and jelly.

Coronet.—(R. *ussuriense* × Kerry). Bush vigorous, slightly spreading; canes long, medium stout. Foliage immune from rust (*Cronartium ribicola*), slightly susceptible to mildew *(Sphaerotheca mors-uvae)*. Flower cluster medium long, loose, with seven to twelve, usually eight flowers. Fruit large, black; skin medium thick; fresh fruit flavour sub-acid, quality good; fruit firm, clings well to cluster, ripens fairly evenly, late midseason in maturity. This variety makes excellent jam and jelly.

Inheritance of Resistance to Rust

It is evident from the F_1 of crosses between *R. ussuriense* and susceptible varieties that resistance to rust is dominant to susceptibility. In order to study the inheritance of resistance to rust, F_1 plants were selfed, and backcrossed to the recessive parent. The number of plants obtained was small and the data from six backcross families have been combined in Table 7. The selfed seedlings are the progeny of one plant.

TABLE 7.—F_2 SEGREGATIONS FOR SUSCEPTIBILITY TO RUST

—	Number Seedlings Grown	Number Seedlings Resistant	Number Seedlings Susceptible
F_1 *Selfed*—			
Observed	11	8	3
Expected (3 : 1)		8·25	2·75
F_1 *Backcrossed* (to Boskoop Giant or Kerry)—			
Observed	115	62	53
Expected (1 : 1)		57·5	57·5

Both selfed and backcrossed progenies gave segregations very closely approaching the 3:1 and 1:1 ratios, respectively, that would be expected on the basis of a single factor difference for resistance and susceptibility. Larger F_2 populations are being grown to place this interpretation on a firmer foundation.

Ribes aureum and R. odoratum Seedlings

It was reported earlier, Hunter and Davis (4), that Kerry × *R. aureum* gave seven resistant and five susceptible seedlings, and that Boskoop Giant × *R. odoratum* gave no resistant and twenty susceptible seedlings. It was taken for granted that the above seedlings were indeed of the parentage indicated, although there was no indication of any characteristics of the paternal parent in any of the F_1 seedlings. One of the susceptible F_1 seedlings from the cross Kerry × *R. aureum* has since been selfed, and one resistant F_1 seedling has been backcrossed to Kerry. Only five F_2 plants from selfing and thirty-four from backcrossing have been grown, but there has been no trace whatever of *R. aureum* in any of these seedlings. The paternity of the original hybrids would appear to be in considerable doubt.

Red Currants

Rust is not as troublesome a disease of red as it is of black currants. The report of Hahn (1) that the variety Viking is immune, and that resistance is dominant to susceptibility has been borne out by observations at Ottawa. In an attempt to produce rust-resistant red currants of better horticultural value than Viking, crosses were made between that variety and Cascade, Red Lake and Stephens No. 9. Only a few seedlings have fruited to date, but all have been resistant to rust. Their general excellence suggests that it should be easy to develop superior rust resistant varieties.

Resistance to attack by aphids is probably more important than resistance to rust in red currants. Even a reasonable amount of resistance to this insect would be a decided advantage. The variety Viking is not so heavily attacked by aphids as are most varieties. Therefore it is interesting to note that in a small population from the cross Viking × Stephens No. 9, although several of the seedlings were just as susceptible as Stephens No. 9 to aphid attack, some were much less susceptible and one was highly resistant. This particular plant is not immune but it is not attacked so early in the season and aphids do not multiply on it to the same extent as on most varieties.

The wild species *Ribes diacantha* Pall., a native of northern Asia, also appears to be resistant to aphids. Seedlings have been obtained from crosses made in 1947 with Red Lake, Stephens No. 9 and Viking. However, the small fruit size of *R. diacantha* may make it less useful than Viking as a parent.

References

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2. Hahn, G. G. Immunity of Canadian black currant selections from blister rust. Phytopath. 38:453-456. 1948.
3. Hahn, G. G. Further evidence that immune Ribes do not indicate physiologic races of *Cronartium ribicola* in North America. Plant Disease Reporter 33:291-292. 1949.
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Gooseberries

The sole objective in the breeding of gooseberries at Ottawa has been the development of thornless varieties. This work began about 1918 with the crossing of the English variety Victoria with a thornless plant of *Ribes oxyacan-*

thoides L. No record was kept of whether the F_1 was thornless or not, but some F_2 plants from selfing were without thorns and had slightly larger fruit than the wild species. One of the thornless F_2's crossed with the American variety Mabel gave the almost completely thornless variety Spinefree (Davis, 1), which has fruit of nearly commercial size. Spinefree crossed with Clark, a large-fruited, thorny variety of the English type, gave 64 thorny and 37 almost thornless seedlings. Six of the latter had fruit equal in size to the best American sorts. They are vigorous and productive at Ottawa and are being multiplied for extensive testing.

Although not entirely thornless, the thorns on these six are so short that they do not interfere with fruit picking. The selection with the fewest thorns is 0-272, which is completely unarmed except at the base of shoots arising close to the bottom of the plant. The general effect in 0-261, 0-271, 0-274 and 0-275 is thornlessness, although a single short thorn is borne at some nodes on some shoots. The thorniest of this group is 0-273 which has from one to three short thorns at every node. However, these thorns are not so long nor so troublesome as those of any of the standard varieties. With the exception of 0-275, these varieties have fruit that is red at maturity. The fruit of 0-275 is green at all stages.

No precise information has been obtained on the inheritance of thorns in the gooseberry, but it is evident that thornlessness is recessive to the thorny condition. It is also evident, from the different degrees of thorniness encountered, that several pairs of genes are involved.

Reference

1. Davis, M. B. Gooseberry breeding. Rept. Dom. Hort. 1925: 11. 1926.

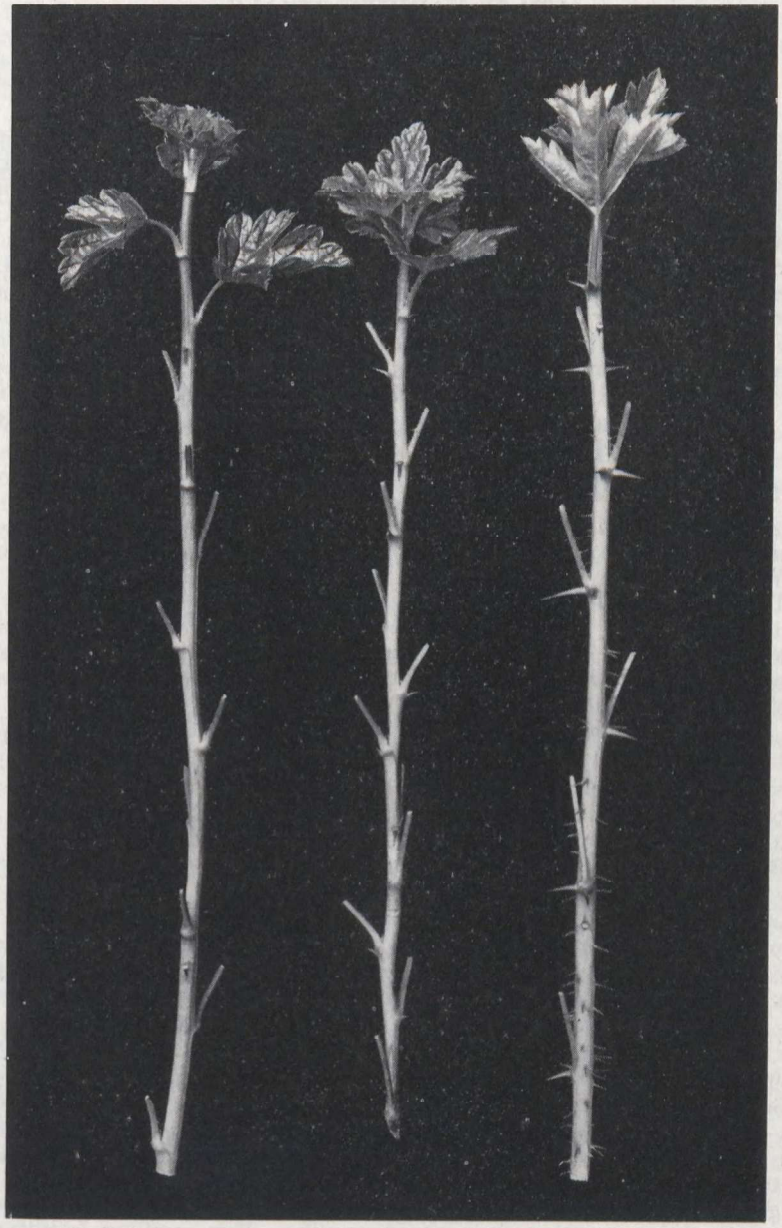

Fig. 6—The difference in thorniness of gooseberry plants is shown by branches of 0-272 (left), 0-273 (centre) and Poorman (right).

FRUIT VARIETY TRIALS

D. S. Blair

Pears

Dessert pears may now be grown with a fair measure of success in eastern Ontario and Quebec. Although perfection has not by any means been reached, the hybridizing of the hardy Chinese and Russian pears with the hardier commercial varieties by the plant breeders at the Division of Horticulture, Central Experimental Farm, Ottawa, and the Minnesota Fruit Breeding Station, St. Paul, Minnesota, has gone a long way in developing hardy, fire-blight-resistant varieties of sufficient quality for home use and local markets. There is no good reason now why every farmer in eastern Ontario and Quebec should not grow enough pears to meet his home requirements.

Among the sixty-odd hardy varieties fruiting at Ottawa, five Ottawa originations, Enie, Menie, Miney, Moe and Phileson, along with five introductions, mostly from the United States, Mendel, No Blight, Patten, Patten 1200 and Parker, are recommended for limited trial.

Ottawa Pear Varieties Recommended for Trial

Enie.—A Zuckerbirn by Clapp Favorite cross; ripens a week to tend days later than Moe. The trees are very vigorous, and come into bearing earlier than those of Menie, Moe and Phileson. No winter injury has been observed on the trees at Ottawa but some fire blight has been experienced. The fruits are of medium size (2¼ in.); attractive yellow, with blush on cheek; white, buttery, juicy flesh with flavour like Clapp Favorite; good quality. It is recommended for planting in eastern Ontario and Quebec, where the commercial varieties such as Bartlett are not hardy enough.

Menie.—A cross between Kurskaya and Flemish Beauty. It comes in shortly after Enie and is ready for picking early in September. Season extends to early October. The trees are quite hardy, vigorous, but slow to come into bearing. Slight fire blight infection has been observed in this variety. The fruits are large (2½ in.), nearly as large as Flemish Beauty; yellow; white, juicy flesh with pleasing flavour; good quality. This seedling is well worth a trial in eastern Ontario and Quebec.

Miney.—A Zuckerbirn by Clapp Favorite cross, of about the same season as Menie, being ready for harvesting early in September. The trees are fairly vigorous and so far have proved resistant to fire blight and winter injury. The fruits are large (2½ in.) and resemble Clapp Favorite in shape and skin colour. Flesh is white, juicy, buttery, of pleasing flavour and good quality. It has probably the best textured flesh of any of the hardy pears fruiting at Ottawa, and is worthy of extended trial in eastern Ontario and Quebec.

Moe.—A Zuckerbirn by Clapp Favorite cross, and the earliest of the Ottawa introductions. The fruits usually ripen at Ottawa around mid-August and the season extends to late August. The trees are apparently very hardy as no winter injury has been observed to date. They are also quite resistant to fire blight. The fruits are of medium size (2 in.), yellow, with faint orange blush; white, juicy, melting flesh; good quality. This seedling is not so full flavoured as Enie, but because of its earliness should be given extended trial in the colder regions where the commercial varieties will not thrive.

Phileson.—The same parentage as Menie but matures later and is ready for harvesting the middle of September. It is a good keeper and will hold up

in storage a month or more. The trees appear resistant to winter injury and are vigorous, but slight fire blight injury has been noted. The fruits are large (2¾ in.); attractive, yellow with slight red blush; white, buttery, juicy flesh with full flavour; good quality. This pear because of size, texture, quality and keeping quality is highly recommended for planting in eastern Ontario and Quebec.

Other Varieties Recommended for Trial

Mendel.—Originated at New Ulm, Minnesota. The trees have withstood the rigours of the Ottawa climate for eight years without winter injury or fire blight. The fruit is above medium size, yellowish-green overlaid with russett, shape of Bartlett; flesh juicy, flavour sweet and quality good. A late maturing pear, ready for picking mid to late September and keeps well in storage.

No Blight.—Sent in for trial by David Tait, Carterton, Ontario, in 1937. Trees appear hardy and resistant to fire blight. The fruits are medium in size, globular, yellowish-green with attractive orange blush; flesh juicy but a bit coarse; flavour sweet and quality good. Because of its hardiness, freedom from fire blight and pleasant flavour should be watched carefully.

Patten.—Originated at Iowa Fruit Breeding Station, Ames, Iowa. Trees are hardy and appear resistant to fire blight. Fruits large, yellowish with a distinct reddish-brown blush; flesh juicy, quite free of stone cells; flavour sweet and quality good. Ripens mid to late September.

Patten 1200.—Also originated at the Iowa Fruit Breeding Station. Trees are hardy and appear resistant to fire blight. Fruits are medium to below, globular, yellowish-green with reddish-orange blush; flesh buttery, juicy; flavour sweet and quality good. Ready for harvesting mid to late September.

Parker.—Originated at the Minnesota Fruit Breeding Station, St. Paul, Minnesota. Of value because of its hardiness and fruit size. Tree hardy and quite resistant to fire blight. Fruit above medium, yellowish-green with slight reddish blush, resembles Bartlett in shape; flesh juicy, buttery, slightly coarse-grained; sweet flavour and quality good. Matures mid to late September.

Plums

The production of large, luscious plums in eastern Ontario and Quebec, comparable with the imported plums from California so often seen in the fruit stores, is no longer a vision. As a result of years of hybridization and careful selection work the plant breeders at the Horticultural Division, Central Experimental Farm, Ottawa, and the Minnesota Fruit Breeding Station, St. Paul, Minn., have developed varieties that will withstand the climate in the cooler regions and which produce fruits of excellent quality up to two inches in diameter.

There is a splendid opportunity for progressive growers to develop small plantations of these large-fruited plums to meet local fruit store requirements. A good market can be developed for this type of plum provided the proper care is exercised in packing and marketing the fruit. Large plums of this type should be packed in layers in shallow boxes similar to those used by the California growers to meet fancy trade requirements.

A large collection of these super-red plums has been under test for some little time in the Ottawa plantations and very complete notes on their performance are now available. Grenville, Underwood and Fiebing are outstanding among the early ripening varieties; Pipestone, Redcoat, Superior and Kahinta are the best of the mid-season sorts; with Elliot and Ember the pick of the late maturing varieties.

Among the blue varieties or *domestica* group, Mount Royal is the most outstanding for the Ottawa region because of its tree hardiness. Carleton, Chercuts of Kharkoff and Nepean are other promising hardy *domestica* sorts.

Promising Hardy Plum Varieties

Grenville.—Originated at Ottawa, the result of a cross between Burbank and the native wild plum. Tree, very hardy, somewhat like Burbank in habit, heavy yielder and a biennial bearer. Fruits are very large, round; bright, attractive red; juicy, sweet and very good quality.

Underwood.—A Minnesota Fruit Breeding Station introduction. Ripens very early, usually mid-August at Ottawa. Tree hardy, fairly vigorous and productive. Fruit large, attractive, juicy, and of excellent quality.

Fiebing.—Another Minnesota introduction. Tree very vigorous and hardy. Fruit very large, round, bright red; juicy, sweet and of good quality. It appears to be quite susceptible to the brown rot fungus.

Pipestone.—A recent Minnesota introduction, thought to be a backcross involving *P. salicina* and *P. americana.* Trees develop a strong framework, vigorous, spreading, hardy and productive. Fruit very large, round conic, handsome, solid deep red; skin thin but tough; flesh bright yellow, juicy, sweet, pleasant; excellent dessert quality, and a good canner.

Redcoat.—The result of a cross between Burbank and Wolf made at the Minnesota Fruit Breeding Station. Trees hardy, vigorous, inclined to be spreading in habit, productive. Fruits freestone, large, prune-shaped, pointed, dark attractive red with heavy bloom; skin thin and quite tender; flesh bright yellow, firm, sweet to mild sub-acid, pleasant, and good quality.

Superior.—Of Minnesota origin. An excellent shipper. Trees vigorous and apparently hardy. Fruits very large, somewhat pointed, washed with lively attractive red; flesh golden, juicy, sweet and of excellent quality.

Kahinta.—The best of Dr. Hansen's South Dakota introductions under Ottawa conditions. Tree very vigorous, fully hardy. Fruits very large, pointed, bright red; juicy, sweet and of good quality.

Elliot.—Of Minnesota origin. A very handsome late variety. Tree vigorous, hardy and a heavy bearer. Fruits large (when thinned), rather thick skin, deep red; juicy and of fairly good quality.

Ember.—Another recent Minnesota origination. The largest and best in quality of the late varieties under test. Trees strong, hardy, free growers. Fruits very large, slightly pointed, lively red; very juicy, sweet and of excellent quality.

Mount Royal.—A chance seedling found near Montreal, and an excellent canning plum. Trees of medium vigour, hardy, very productive. Fruits medium size, blue; juicy, mild, sub-acid, and of good quality.

Carleton.—Originated by the Division of Horticulture, Ottawa. A large freestone prune type of plum. Ripens in late September. Fruits very large, egg-shaped, reddish purple; flesh pale yellowish green, medium juicy and meaty; flavour sweet, and quality medium to good. This plum has attracted some very favourable comment in the St. John River valley in New Brunswick.

Chercuts of Kharkoff.—Sent in for trial by P. C. Crath, Peterborough, Ontario, who imported it from Asia. Promising because of its high quality and apparent tree hardiness. Fruit medium size, round, blue; yellowish green, meaty flesh and sweet flavour. Ripens in mid-September.

Nepean.—Another recent Ottawa origination. A little larger and a few days later than Mount Royal, ripening in late September. Fruits round, blue; flesh yellow, juicy, meaty; flavour sweet, pleasant, and quality good. Tree is of medium vigour and hardiness.

Apricots

Apricots do not crop well at Ottawa. In most winters the varieties tested to date break their dormancy during the winter months and the fruit buds are killed. Because of this apricots are not at present recommended for planting in the Ottawa region.

Strawberries

New varieties are being introduced at a rapid rate by experiment stations in the United States and Canada. Most of these varieties are not widely adapted, having been originated under special local conditions. However, all must be tested to establish their merit in a particular region. Brief descriptions and performance of the newer varieties under test are given.

Valentine.—A product of the Ontario Horticultural Experiment Station, Vineland, Ontario. It is the most promising of the early ripening sorts. It starts ripening several days before Premier. The berries are firm, conic, with dark glossy appearance and hold their size well. The plants are vigorous, healthy and runner well.

Maytime.—Originated by the United States Department of Agriculture and is the earliest high quality variety in Maryland. At Ottawa, it comes in a few days later than Premier and is not quite so productive. Berries are very attractive, uniform, conic, firm and of very good quality.

Mackenzie.—Introduced by the Division of Horticulture, Central Experimental Farm, Ottawa. It resembles Premier closely in appearance and season, but under Ottawa conditions it is usually more productive and holds up better in size. Plants are vigorous, healthy and runner freely.

Redwing.—A New Jersey origination. A mid-season variety of considerable promise. The berries are large, firm and very attractive, with high quality. The plants are vigorous, healthy, and the berries hold their size well.

Crimson Glow.—Another New Jersey variety that is well worth trying. It is a high quality berry, of real value for the home garden.

Fairpeake (U.S.D.A.).—A mid-season variety; produces large, glossy red fruit of medium firm texture and good quality. The plants are very vigorous and produce heavy crops.

Suwanee (U.S.D.A.).—Because of its productiveness and high quality it is highly recommended for the home garden.

Sparkle.—A new Jersey origination. Another mid-season variety of considerable promise. The berries are fairly large, attractive, firm and of good quality. However, there is a tendency for the berries to be medium in size and rather dark under certain conditions. The plants withstand drought well.

Tupper.—Originated by the Division of Horticulture, C.E.F., Ottawa. A very attractive and highly productive mid to late season variety. The berries are not firm enough for shipping to distant markets but are of real value for local market and home use. The plants are vigorous and good runner makers.

Louise.—A Division of Horticulture, C.E.F., Ottawa, origination. The highest quality late ripening strawberry fruiting at Ottawa. The berries are large, bright glossy red, very attractive, and very firm and meaty in texture. It is a good shipping and freezing variety. Highly recommended to growers seeking high quality late berries to extend the marketing season. Plant subject to leaf spot which is its major fault.

Elgin.—Another Division of Horticulture origination. The latest variety ever grown at Ottawa, ripening three to four days after Louise. The berries are

not so attractive nor of so good quality as Louise but are larger in size. The plants are more resistant to leaf spot than Louise. Since Louise is imperfect, Elgin should be used as a pollinator. Because of their extreme lateness both Louise and Elgin are worthy of extended trial by all growers interested in late ripening varieties.

Midland, Massey and *Northstar.*—Products of the U.S.D.A. strawberry breeding project. Inclined to be too dark and unproductive at Ottawa and do not appear worthy of further trial.

Raspberries

In 1940 a raspberry trial was set out at Ottawa to evaluate the earliness and yield of several promising raspberry hybrids originated by the Division of Horticulture in comparison with the standard varieties. The performance of these varieties over the five-year cropping period, 1943-1947, is clearly presented in Table 8.

TABLE 8.—YIELD OF RASPBERRY VARIETIES DURING THE FIVE-YEAR CROPPING PERIOD, 1943-1947. PLANTATION SET OUT, FALL, 1940

Variety	Average Yield per Year	Average Yield in First Week	Average Date of First Pick	Average Date of Largest Pick
	lb./ac.	lb./ac.	July	July
Trent	3,934	1,420	10	17
0-263	3,682	1,995	10	15
0-201	2,884	479	12	24
Madawaska	2,368	538	10	20
Latham	2,310	62	14	25
Newman 23	2,300	229	12	23
Newburgh	2,291	199	12	23
Ottawa	2,205	269	11	22
Monroe	2,134	511	10	24
Rideau	2,098	331	12	23
Marcy	2,045	118	14	27
Viking	1,862	108	12	23
Chief	1,757	258	11	21
Taylor	1,407	24	16	27
Indian Summer	1,358	331	10	18
Gatineau	1,315	742	10	18

It will be seen that 0-263 is the outstanding early variety, yielding in the first week of the picking season nearly 2,000 lb./ac. It is also a very heavy cropper outyielding such standard varieties as Latham and Newburgh. Trent, besides being outstandingly early, is the highest yielding variety at Ottawa producing some 4,000 lb./ac. yearly. Both Trent and 0-263 are extremely promising as early, high yielding varieties. Gatineau and Madawaska also are impressive as early ripening varieties. 0-201 and Madawaska are two other high yielding Ottawa varieties and have outyielded the leading commercial varieties, Latham, Viking and Newburgh.

These Ottawa introductions are increasing in popularity.

Trent.—The best of the early varieties under test at Ottawa. Besides ripening early it is a very heavy yielder of bright, very attractive berries which are firm enough to ship. It appears to be quite free of virus trouble.

Madawaska.—A variety of many merits. It is very hardy, outyields Latham, ripens early, and is excellent for canning and freezing. Extensive trials indicate that it is well adapted to most of the raspberry growing districts in Canada.

The berries, however, are not firm enough for distant shipment but are satisfactory for local markets. Plants are quite free of virus but are susceptible to anthracnose and spur blight.

Ottawa.—Outstanding as a shipping raspberry and should be given extended trial by all growers who ship to distant markets. Resembles Viking in appearance and quality. Plants are resistant to anthracnose and spur blight but susceptible to powdery mildew and may take mosaic. It appears to withstand drought better than most varieties.

Rideau.—Resembles Taylor closely and is of the same parentage. It is a heavy feeder and where fertility is high produces an abundance of firm, bright, attractive berries that are enthusiastically received by the fresh fruit trade. Susceptible to anthracnose, spur blight and alkaline soils.

Gatineau.—Mainly of interest as an early variety. However, where earliness is not of primary importance, its dark colour and the fact that it is not too firm rather militate against it.

0-263.—Because of its extreme earliness, productivity and hardiness it should be widely tested. Unfortunately the berries are not so large nor so attractive as Viking and Latham and are inclined to be a bit soft.

0-201.—The hardiest raspberry fruiting at Ottawa and is apparently standing up very well to the winters on the prairies. It is a large, rather attractive berry but is inclined to be somewhat crumbly. Because of its extreme hardiness this hybrid should be widely tested in the colder regions of Canada.

Only one, Durham, of the recent introductions from the United States would appear to offer any commercial possibilities in eastern Ontario and Quebec.

Durham (Taylor Sdlg.).—Originated by the New Hampshire Agricultural Experiment Station, Durham, N.H. It is an ever-bearing variety which has been particularly impressive at Ottawa because of its fall crop. It is worthy of test as a fall-bearing variety.

Washington (Cuthbert × Lloyd George) and *Tahoma* (Latham × Lloyd George).—Washington State introductions. Too tender in the cane to withstand the winter at Ottawa. They kill back badly and are unproductive. Both produce berries of high quality and are worthy of trial in the milder regions.

Milton (Lloyd George × Newburgh).—Originated at the New York State Agricultural Experiment Station. It shows no improvement in fruit characteristics over the standard varieties but the canes appear highly resistant to mosaic and for this reason should prove a valuable breeding parent.

Sunrise (Ranere × Latham).—A New Jersey Agricultural Experiment Station origination. It resembles Latham in berry characteristics but ripens five days earlier; about the same season as Monroe and Gatineau and a pick or two ahead of Chief. The berries are dark red when ripe, compact and good quality. Many fruits were below commercial size in the 1948 season. Sunrise is inferior to Trent, Gatineau and Monroe at Ottawa.

September (Marcy × Ranere).—Originated at the New York Agricultural Experiment Station, Geneva, N.Y. Another ever-bearer but has not been outstanding. Its fall crop ripens too late and there is a tendency for the berries to cling, making them difficult to pick.

Grapes

Great strides have been made by the New York State Agricultural Experiment Station in recent years in improving the quality of the native grapes by crossing with the European grape (*Vitis vinifera*). A large number of these new

introductions have been added to the varietal collection at Ottawa and several are very promising, so much so that they are likely to replace all the old varieties now grown in eastern Ontario and Quebec. Besides improved quality, many of these new varieties mature earlier than the varieties grown heretofore, and for this reason are better suited to regions where the growing season is short. Among these New York State originations, Fredonia and Seneca, are rapidly becoming standard varieties. Brocton, Buffalo, Eden, Erie and Van Buren are all worthy of extended trial, while Geneva No. 17102 should be given limited trial. Dunkirk, Keuka, Westfield and Yates have shown little promise at Ottawa and do not appear to warrant further testing. Violante Early, plants of which were obtained from Joe Violante, St. Catharines, Ontario, should be widely tested as a very early maturing dessert grape.

Brief descriptions of the more promising new varieties are given below:

Fredonia.—Undoubtedly the best early black grape fruiting at Ottawa and particularly suited to the home garden. The vines are vigorous, somewhat susceptible to mildew but very productive. Clusters are medium, compact and cylindrical; berries are large, round, rather tough skin; juicy flesh and very good quality.

Seneca.—A high quality green dessert grape that ripens with Ontario. Vines are vigorous and productive, yielding heavier than Ontario in the Ottawa vineyard. Clusters are medium, compact and tapering. Berries are medium, oval; tender flesh; sweet, aromatic flavour and very high quality. An excellent dessert grape.

Brocton.—Another high quality green grape that ripens later than Ontario. The vines although none too vigorous have produced well at Ottawa. Bunches are large, very compact and tapering. Berries medium, oval, sweet and richly flavoured.

Buffalo.—An early ripening black variety. Clusters are medium to above, slightly tapering and medium compact; berries medium, roundish oval; juicy flesh, sweet, pleasing flavour and good quality.

Eden.—Very promising as a high quality, early maturing black grape. Vines are vigorous and productive. Bunches are medium to large, cylindrical, and quite compact. Berries medium, roundish oval; tender, juicy flesh, sweet flavour, and very good quality.

Erie.—Another high quality, early ripening black variety. Clusters are small to medium but compact. Berries are medium, roundish; tender, juicy flesh, sweet flavour, and good quality.

Van Buren.—Especially promising as a very early black dessert grape, ripening ahead of Fredonia and Eden. Bunches medium to above, slightly tapering and compact. Berries are medium, roundish; juicy flesh, sweet flavour and good quality.

Geneva No. 17102.—The best early ripening red grape that has fruited to date at Ottawa and should be widely tested. Clusters are medium to above and fairly compact. Berries, medium to above, oval; tender meaty flesh, sweet flavour and excellent quality. A very promising dessert grape vastly superior to the commercial red varieties now grown in this region.

Gooseberries

Although the demand for gooseberries is limited in eastern Ontario and Quebec, there is a market for varieties producing berries of large size and high quality that are resistant to powdery mildew. Furthermore, a few bushes in the home garden are desirable. Of the thirty-one varieties at present under observation, only four are of outstanding merit: Poorman, Silvia, Ross and

Fredonia. Poorman and Silvia are in commercial use while Ross and Fredonia are relatively new varieties. Brief descriptions of these recent introductions are given below:

Ross.—Originated by the Forest Nursery Station, Indian Head, Saskatchewan. It produces berries almost as large as Clark. The bushes are very hardy, vigorous and productive. The fruits are very large and of pale green colour. Because of its hardiness, productivity and berry size, it is worthy of extended trial.

Fredonia.—A New York Agricultural Experiment Station origination; a very large, late, dark red gooseberry of the English type. The bushes are vigorous and spreading in habit which facilitates picking, and are productive but inclined to lack hardiness at Ottawa. The berries are attractive, firm and of good quality.

Red Currants

Great strides have been made by the plant breeders in recent years in developing improved red currants. Two new varieties, Stephens No. 9 and Red Lake, are so superior to the varieties in use commercially that they should in the future completely replace the standard sorts. Two open-pollinated seedlings of Diploma, Cascade and Minn. 69, developed at the Minnesota Fruit Breeding Station have shown real promise at Ottawa during the past four years and should be given extended trial in Canada.

Brief descriptions of these new red currant introductions are presented:

Stephens No. 9.—Originated by C. L. Stephens, Orillia, Ontario, and distributed by the Central Experimental Farm, Ottawa. Bushes are vigorous, somewhat spreading and productive. Clusters medium length, not so long as Red Lake, but compact. Berries are very large, bright attractive red, sub-acid, of excellent quality, and can be used for dessert purposes.

Red Lake.—Originated at Minnesota Fruit Breeding Station, and parentage unknown. Bushes are vigorous, upright in habit and produce heavy crops. Clusters are long and compact, which facilitates harvesting. Berries are very large, light glossy red, of sub-acid flavour, good in quality and may be eaten out of hand.

Cascade (Minn. 70)—Bushes are medium in vigour, medium erect and productive. Clusters are above medium in size, compact with medium long stems. Berries are very large, attractive dark red, of pleasant sub-acid flavour and very good quality. The fruit of Cascade ripens about a week earlier than Red Lake and berries are larger but clusters not as long.

Minn. 69.—Bushes are large, vigorous, erect and moderately productive. Clusters are medium, compact with long stems. Berries are very large, glossy red, attractive, of pleasant sub-acid flavour and good quality. Ripens at least a week in advance of Red Lake. It is the largest red current under trial at Ottawa.

INDUCED POLYPLOIDY IN HORTICULTURAL CROPS

A. W. S. Hunter and Berta Danielsson

Induced polyploidy has been investigated in connection with the breeding of some horticultural crops. Interest in this field has centered around (*a*) the direct effect of a doubled number of chromosomes on the size and other characteristics of certain plant parts, particularly flowers and fruits; (*b*) the conferring of fertility on sterile interspecific hybrids and (*c*) the use of tetraploids in breeding, either for crossing with diploids to produce triploids, or for crossing with other tetraploids.

Apple

Tetraploid apples are desired for three reasons:

1. To determine the effect on fruit size of a doubled chromosome number in certain varieties that bear small but otherwise desirable fruits.

2. To provide tetraploids that may be crossed with diploid varieties to make triploids. Many of the present triploid apples are good keepers and all have arisen as chance seedlings. If tetraploids were available, it would be possible to obtain at will triploids of known parentage. This might be a useful method of producing late keeping varieties.

3. To repeat with tetraploid material certain crosses between very small-fruited hardy species and commercial apples. With tetraploids it may be possible to secure fruit size in the first generation, which with diploids would require a backcross to a commercial variety to attain.

Methods of Treatment

Colchicine treatments were begun in 1947 on seeds and seedlings, and on named varieties. Two different methods were used on seeds. One is a combination of Thomas' (10) method of soaking peeled unafterripened seeds in a weak (0·05 per cent) aqueous colchicine solution, and the embryo culture method devised by Tukey (11) for stone fruits. Open-pollinated seeds of McIntosh, Northern Spy and *Malus baccata* were used Losses from contamination of the cultures by moulds and bacteria, and following transplanting to soil, were frequently high in this method. However, of the seedlings that survived, a high proportion were tetraploids. The figures to date are 522 seeds treated and 362 seedlings transplanted to soil. Ninety-five plants survived, of which 66 or 69·5 per cent appear to be tetraploids. This figure represents 12·6 per cent of the number of seeds treated and includes preliminary experiments in which mortality from contamination and at transplanting were very high. Improved methods of handling have reduced these losses materially.

A simpler method is the germination of afterripened seeds on filter paper soaked with colchicine solution. As soon as the seeds germinate they are planted in soil in flats or small pots. Only seeds of *Malus baccata* were treated in this manner. The concentrations of colchicine used and the results obtained are given in Table 9.

The number of tetraploids in this experiment represents only 12·0 per cent of the seedlings and 2·2 per cent of the seeds treated, but in a later experiment in which approximately 1,000 seeds of *Malus baccata* were germinated on filter paper soaked with 1·0 per cent colchicine, 52 seedlings were obtained of which 27 or 51·9 per cent were tetraploids. Where seed is plentiful, this is considered to be the most suitable method for apple.

One difficulty was encountered in germinating afterripened seeds. Seeds dusted prior to the afterripening process with Ceresan or Semesan for the control of moulds completely failed to germinate when treated with colchicine. Comparable lots of the same seed that were not colchicine-treated germinated freely. The *Malus baccata* seed used in the previous experiment was not dusted with a fungicide before afterripening but was disinfected with a two per cent calcium hypochlorite solution before treatment with colchicine. The germination of the seed so treated did not appear to be affected by the colchicine. Apparently a substance that inhibits germination is produced by the combination of colchicine and the fungicide.

TABLE 9.—A COMPARISON OF RESULTS OF TWO METHODS OF COLCHICINE TREATMENT OF APPLE SEEDS

Treatment	Colchicine Concentration	Number Seeds Treated	Number Seedlings Obtained	Tetraploids		
				Number	Per cent of Seedlings	Per cent of Seeds Treated
	%					
Germinated on soaked paper[1]	0·05	200	56	8	14·3	4·0
Germinated on soaked paper[1]	0·2	200	30	2	6·7	1·0
Germinated on soaked paper[1]	1·0	200	22	3	15·8	1·5
Total	.....	600	108	13	12·0	2·2
Culture bottle[2]	0·05	522	95	66	69·5	12·6

[1] Afterripened seed.
[2] Unafterripened seed.

In developing a technique for the treatment of named varieties of apples, experiments were conducted on young seedlings and on one-year whips of named varieties. From the results obtained, it appears that if the application is long enough and strong enough there is no advantage in multiple over single applications of colchicine. The continuous immersion of the terminal buds of young seedlings of McIntosh and Northern Spy, when the buds were just beginning to grow, in a 2·0 per cent aqueous colchicine solution for 24 or 48 hours resulted in eleven tetraploids from 40 plants treated, or 27·5 per cent. In comparison, the best result from multiple treatments was 26 tetraploids from 291 seedlings treated, or 15·4 per cent. This was produced by the application of a warmed solution of 2·0 per cent colchicine in 0·5 per cent agar to the terminal buds of freshly germinated seedlings of McIntosh and Northern Spy on 45 approximately consecutive days.

The application of 1·0 per cent colchicine in 20·0 per cent glycerine solution to the terminal bud of a growing shoot as recommended for pears by Dermen (1) resulted in the death of most of the treated buds. The omission of the glycerine appeared to give satisfactory results. Similarly, 1·0 per cent colchicine in 0·65 per cent agar in gelatin capsules slipped over the terminal bud from which as many as possible of the young leaves had been removed appeared to be effective.

An attempt to induce chromosome doubling in the buds of scions by immersing the scions in 2·0 per cent aqueous colchicine solution for 24 hours resulted in no evidence of tetraploidy. The scions were top-worked into a tree of a hardy variety immediately after treatment.

Tetraploids from Open-Pollinated Seeds of Triploid Varieties

The majority of the open-pollinated seedlings of triploid apples have chromosome numbers that fall somewhere between 34 and 51. However, the

occasional tetraploid with 68 chromosomes is found, as reported by Johansson (4), Nilson-Ehle (7), Einset (2, 3) and others. These tetraploids are apparently the result of the union of an egg cell of the triploid with an unreduced chromosome number of 51, and a normal pollen grain of a diploid variety with 17 chromosomes.

Open-pollinated seed of the triploid varieties, Baldwin, Gravenstein, King, Stark and Staymared, was obtained from the Dominion Experimental Station, Kentville, N.S., and seed of Rhode Island Greening from Northumberland and Durham counties in Ontario. A count of the chromosome number has been made in some of this material. One tetraploid was found in 53 seedlings of Rhode Island Greening and none in 144 seedlings of Baldwin.

Cherry

The work with cherries was begun in 1939 and has been largely confined to interspecific hybrids from crosses between the tetraploid sour cherry *(Prunus cerasus)* and the diploid sweet cherry *(P. avium)*. The seedlings resulting from this cross are triploids and are highly sterile. Many are completely hardy at Ottawa in both flower-bud and wood and if they were fertile, some might be useful varieties.

In an effort to determine if doubling the chromosome number of the triploids might result in fertility, plants and seeds have been treated with colchicine. The treatment of buds on young trees or seedlings has not been successful, but it should be possible to apply the methods developed for apples to this fruit.

The treatment of actual triploid seed from the cross sour cherry × sweet cherry, although it makes possible the handling of large numbers of individuals, does not permit any preliminary selection for hardiness or other characteristics. The most useful technique appears to be the seed peeling—culture bottle method described for apples. This method has been used on triploid cherry seed with the same difficulties of contamination and loss following transplanting. Out of a total of 400 seeds treated, only 22 seedlings survived, of which two are hexaploids and have 48 chromosomes. These seedlings are only two years old and have not flowered yet.

Snapdragon

Tetraploids

Attempts to induce tetraploidy in the greenhouse snapdragon (*Antirrhinum majus* L.) were begun in January, 1940. The first treatments were with 0·2 and 0·4 per cent colchicine dissolved in an agar solution and contained in waterproofed gelatin capsules. The capsules were placed over decapitated stems that had been cut just above a node in such a way that the axillary buds were covered by the capsule. Fourteen tetraploid shoots in four varieties were produced from 369 nodes treated in this manner.

The stems of the tetraploids were stouter and the leaves thicker, broader and slightly shorter than those of diploids. The flowers were very large and the petal margins were wavy and frequently papillionated, but on most plants the flowers did not open completely. These tetraploids were late in maturity and did not have an attractive spike form. The flowers were closely arranged on the stem and the tip of the spike had an abrupt instead of a gradual more graceful taper.

In 1945 seed of good parental material was secured from two commercial breeders of snapdragons. Tetraploids were obtained by soaking this seed in 0·2 or 0·4 per cent aqueous colchicine solution for 24 or 48 hours. Selfed progenies were grown from most of these tetraploids, and a number of intervarietal crosses were made. It was apparent from the performance of some of the seedlings that this material was superior to the earlier tetraploids for greenhouse purposes. Many of the selfed progenies were not at all outstanding but

a few were quite promising. The best results were obtained from some of the ivory-pink and ivory-bronze intervarietal combinations. These tetraploid F_1 hybrids were in general reasonably early, tall growing, very strong stemmed, large flowered, pale pink in colour, with well opened flowers and with a spike that was very graceful in form but that was not so long in proportion to its diameter as the hybrid diploids. The individual tetraploid plants varied considerably in their combining ability, some combinations being much better than others in uniformity of maturity and plant height, and in shape of spike and openness of flowers. The flower colour of the above tetraploid hybrids is approximately the same as that of some of the diploid hybrids such as Christmas Cheer and Mary Ellen, but the tetraploids have much larger flowers and, with their wavy petal margins, they are much less formal in appearance than the diploids.

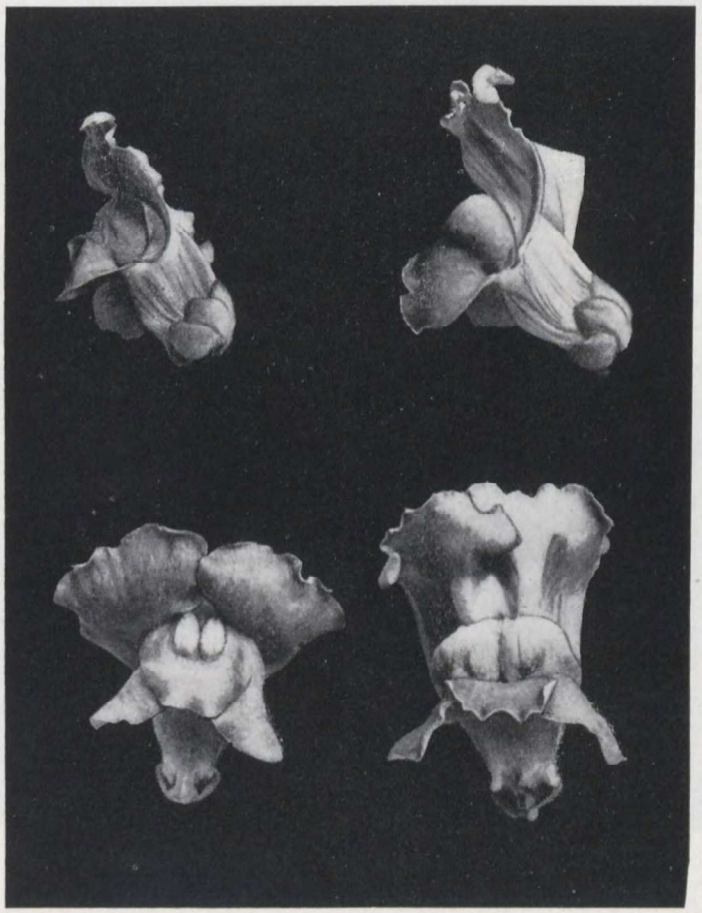

Fig. 7—Comparative size of diploid (left) and tetraploid (right) snapdragon flowers.

Triploids

Crosses were also made between tetraploids and diploids to produce triploids. Seed set and seed viability were poor in such crosses, but most of the few triploids produced were very desirable. The flower size of the triploids was intermediate between that of diploids and tetraploids. The spike form resembled

that of the better hybrid diploids in being very long and tapering, but because of the larger flower size, the triploid spikes appeared to be better filled. Several of the better triploids are being vegetatively propagated for a comparative trial with diploids and tetraploids.

Inheritance of Flower Colour

It has not been possible to make a detailed study of the inheritance of flower colour in tetraploid snapdragons because of the limitations of greenhouse space. Only one large F_2 family has been grown. This consisted of 295 plants, the selfed progeny of three F_1 plants from a cross between a tetraploid Velvet Beauty (dark red) and a tetraploid Rose Queen (pink). The F_1 plants were all dark red. The combined F_2 gave 282 dark red-flowered plants and 13 pink-flowered plants. The expected ratio on the basis of a single factor difference, complete dominance of dark red and random assortment of the four chromosomes, would be 35:1 or 286·8 red to 8·2 pink.

The only other information that has been obtained on the inheritance of flower colour is that dark red is dominant to pink, which is dominant to bronze. Both pink and bronze are dominant to ivory, but only partly so, the F_1 from a cross between pink or bronze and ivory being pale pink. The pink $\times$ ivory F_1 when selfed, segregates into five quite clearly defined colours. These results are in agreement with tetraploid inheritance and with the inheritance of flower colour in *Antirrhinum majus* as described by Scott-Moncrieff (8).

Fertility

Seed set in tetraploid snapdragons growing in the greenhouse varies with the season of the year. Under conditions of short days and low night temperatures, it is usually much lower than later in the season when days are longer and temperatures higher. However, even under good environmental conditions, there is considerable variation in fruitfulness. Some plants set seed quite readily with their own pollen and others do not. The same variation is found in cross-pollinations, some combinations being fruitful and others not. This is in marked contrast to tetraploid intervarietal F_1 hybrids, all those so far studied being highly self- and cross-fruitful.

No detailed study of the causes of this variation has been attempted, but observations of meiosis in a number of sterile and fertile plants did not indicate an association between meiotic irregularity and sterility. This is in agreement with Sparrow, Ruttle and Nebel (9) who failed to find any satisfactory correlation between cytological irregularities and the marked difference in fertility as measured by seed set that they observed between intravarietal and intervarietal tetraploid snapdragons. They were led to the belief that high fertility might be associated with heterozygosity. This does not explain the marked variation in fertility found in intravarietal tetraploids at Ottawa. It is not improbable that incompatibility and other genetic processes may be operative.

Asparagus

Asparagus tetraploids might be expected to have stouter spikes, which would be advantageous. Seedlings of the variety Eden were soaked in colchicine solution and seven tetraploids were obtained. The tetraploids appear to have stems stouter than most diploid plants, but since they have been grown in pots in the greenhouse, their true performance is not known. The tetraploids have been quite fertile and a small crop of seed was obtained in 1948. Plants from this seed will be grown in the field for comparison with the parental diploid.

Fig. 8—Representative spikes of diploid (left), triploid (centre) and tetraploid (right) snapdragons. The triploid is from the cross pink tetraploid × ivory diploid. The tetraploid is from a cross between a pink and an ivory tetraploid.

Radish

Radish tetraploids were produced in 1946 and 1947 by germinating seeds of the variety Scarlet Globe on filter paper soaked with colchicine solution. Radish seed appears to be very sensitive to colchicine, and good results were secured with 0·05, 0·1 and 0·2 per cent for 24 hours and with 1·0 per cent for one hour.

Selfed seed was obtained from most of the tetraploids, although their fertility varied considerably. This seed was sown in the greenhouse in November, 1947, and the seedlings checked by size of stomata and pollen grains. Some chromosome counts were also made. The tetraploid seedlings from each original tetraploid were interpollinated. A good supply of seed was obtained from several lines which will be planted in comparative varietal trials at Ottawa in 1949.

Tomato

The currant tomato, *Lycopersicon pimpinellifolium* Mill., has been used in the breeding of early ripening varieties particularly for the prairie regions, but a drawback has been the small fruit size attainable. Lindstrom and Humphrey (6) found that tetraploid *L. esculentum* × *pimpinellifolium* F_1 hybrids are highly fertile and that they are sturdier and larger in all respects than the diploid F_1, even in the matter of fruit size, although the difference here was slight. To investigate the effect of chromosome doubling on later generations from hybrids between these two species, seed of second and third generation selections was germinated for four days on filter paper soaked with 0·4 per cent aqueous colchicine. From this seed 160 seedlings were grown, 11 of which were tetraploid either wholly or in part, judged on the basis of pollen grain size. Seed was obtained from nine tetraploids. The seed was noticeably larger than that from comparable diploids. However, the fruit of tetraploids was smaller than that of comparable diploids. This was particularly noticeable on plants which bore both tetraploid and diploid fruits. The tetraploid tomatoes contained fewer seeds than the diploids, so that the reduction in fruit size may be due to lowered fertility. Plants from tetraploid seed will be grown in 1949 for comparison with diploids.

Acenaphthene as a Polyploidizing Agent

Colchicine is the most effective polyploidizing agent known, but it is expensive. Kostoff (5) reported the use of acenaphthene, a very inexpensive product, for the induction of chromosome doubling. This substance has the disadvantage of being only slightly soluble in water, but Kostoff produced the desired results by germinating seeds in water containing acenaphthene crystals and in the presence of sublimating crystals of acenaphthene.

To obtain more information on the value and use of acenaphthene for the induction of polyploidy, seeds of Scarlet Globe radish, a plant that is very sensitive to colchicine treatment, were germinated for six days in covered petri dishes in (1) direct contact with wet acenaphthene crystals, (2) separated from the crystals by moist filter paper, and (3) in petri dishes coated on the inside with a layer of acenaphthene crystals which had been deposited by evaporation from an ether solution. The seeds germinated readily and the seedlings grew strongly, but only one partly tetraploid plant was found among the 270 plants grown from this seed. In apple, no tetraploids were obtained from 120 seedlings of *Malus baccata* grown from afterripened seed germinated in contact with wet crystals of acenaphthene for eight to eighteen days. These results suggest that acenaphthene is probably of very limited value for the induction of polyploidy.

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NATIVE FRUITS

E. L. Eaton

One of the newer assignments of the Division is the adaptation of the native fruits, blueberries, cranberries and elderberries, to cultivation in the Maritimes.

Blueberries

Lowbush Blueberries

In the three Maritime Provinces the lowbush blueberry is an important source of revenue. The 1948 crop estimate at an average value of 10 cents per pound was 4 million pounds for New Brunswick, 12 million pounds for Nova Scotia, and for Prince Edward Island somewhat less than for Nova Scotia.

The lowbush blueberry occupies a temporary place in natural plant succession. On light soils and soils of low fertility, it forms a sparse ground cover in forest shade; it grows in open uncultivated areas and gradually occupies abandoned pastures and hayfields. In all such areas other heath plants, alders, goldenrod and wild roses, compete with the blueberry.

The standard plan of management is late fall or early spring burning every second or third year. In certain regions competing plants are checked by mowing, usually before the fall burning. In experiments on the best time to mow, early mowing was best at one location, but in two other areas there were no differences in plots mowed the first week in July, August or September. Mowing was particularly effective in destroying the sweet fern stand.

Fertilizer Tests.—Duplicate plots of an almost pure stand of blueberries on an abandoned farm were treated with nitrogen, phosphorus and potash (ammonium sulphate, 20 per cent superphosphate and muriate of potash) alone and in combination at the rate of 500 pounds per acre of 9-5-7 in October and November of 1941 and 1942. The area had been burned over the spring before first application. No consistent differences in crop yield could be observed either in 1942 or 1943. A more extensive test on the effect of fertilizers and limestone with and without sawdust is being conducted at three locations in New Brunswick.

Propagation.—It is very probable that the hard bony seeds lie dormant for many years, which accounts for the sparse emergence in any one year and for the lack of success by sowing cull berries. At Kentville, fresh seeds of highbush seedlings are sown in flats of sand and peat over-layering fertile soil. The flats are kept thoroughly damp and are held at 75° to 90°F. Good germination results but such conditions are artificial.

Seedlings of the lowbush berry grown at Kentville from fruit of desirable clones collected in New Brunswick were set out in a nursery bed. In 1947 and 1948 transplantations were made to permanent rows about a foot apart. Cultivation about the roots prevented their normal underground spread so that early growth was slow. When roots and underground stems of attractive clones were divided and set firmly in damp soil most rooted freely.

Another method under test is the rooting of hardwood cuttings in granulated peat for later transplantation.

Highbush Blueberries

In the Maritimes, highbush blueberries are native to the three western counties only. The original planting at Kentville was set out in 1926. Plantings were made at four other localities. Again, when propagation was started at

Kentville, rooted cuttings were widely distributed. The four early plantings and those from the later distributions all suffered from neglect. Since then locations on a variety of soil types have been chosen for a trial of selected native seedlings with named varieties imported from United States as checks.

Results have shown that highbush blueberries are exacting in soil and cultural requirements. They are killed out by shade, heaved by frost, grow feebly in saturated ground, and if conditions force delay in cultivation, they may become choked by grass. Nevertheless, on fertile, well-drained soil where mill sawdust was worked into the soil and where a high nitrogen fertilizer (frequently 9-5-7) was used, the plants have been thrifty and productive.

Cranberries

The Maritimes have a history of bog plantings of selected wild cranberry vines but, as the early bogs were not protected against frost, losses occurred and most have reverted to the wild.

Between the two wars the remaining productive bogs were definitely profitable and much interest was aroused in the crop. Cranberry investigation with headquarters at Kentville, Nova Scotia, has been mainly on varieties, bog management, insecticides and weed control.

Nova Scotia.—At Aylesford, N.S., native selections and the varieties, Early Black and Howe, imported from Massachusetts, are being tested on a black muck soil with an impervious hard-pan subsoil. The clones are set four feet apart each way in the prepared bog. This is the usual method of planting, but in another Maritime area, vines run through a straw-cutter, scattered over the prepared ground and disked in, have done quite as well as those planted by hand, and at a fraction of the cost.

The effects of dates of planting were tested. Small lots were planted in July, August and September, on well-drained black muck covered with four inches of sand. All rooted freely, but initially the earliest planted made the strongest growth. After several years, there were no observable differences.

The Early Blacks were given the preference at the Aylesford and other test locations. Although more difficult to hand pick, because they are small and dark, they are high yielders of early maturity, good in colour and flavour.

New Brunswick.—Quite successful cranberry bogs have been established on damp upland soil and on dark mucky soil with an impervious brick-clay subsoil at a depth of two feet. Attempts to establish a bog on deep raw sphagnum were entirely unsuccessful.

In bog preparation the turf is removed altogether or burned over, cut and inverted; then sand is spread over the area before planting the following spring. Ideally, drainage ditches are dug; a dam constructed to hold winter flood waters and to provide water for flooding for both frost and insect protection. Installation of a pump ensures facilities for summer flooding for the latter.

Prince Edward Island.—In the island province cranberries grow naturally near the coast line on varied soil types, among sand dunes where proximity to the sea protects them from fall frosts, in old pastures and hayfields and along swamps and intervales. Although the fruits are variable in size and colour, they can be graded to make a fairly attractive pack.

In co-operation with the Illustration Stations Division, two bogs were set up at East Point, both on dryland but one on well-drained red soil, the second on a poorly-drained grey soil. A comparison of yields, salt applications, summerfallow with and without sanding, sanding alone, turfing and planting, and turfing, sanding and planting were tested with the following results:

1. Yields from the poorly-drained grey soil, treated and untreated, were negligible.

2. Salt application gave immediate benefit where the vines were established; e.g., 1600 lb. checked grass and moss and so lessened competition, but with heavier annual applications salt injury accumulates.

3. Summerfallow, with and without sanding, encouraged weeds and grass.

4. Sand alone failed to suppress the grass, but stimulated more growth.

5. Turfing and planting established a good plot with few weeds.

6. Turfing, sanding and planting gave the best stand of plants.

Insecticides.—The cranberry fruit worm usually destroys up to one-third of the crop in the wild areas. Summer flooding which is possible on certain established bogs reduces the loss. Of the many spray and dust mixtures, cryolite gave only moderate control and Pyradee, a trade mixture of pyrethrum and D.D.T., gave substantial control.

Weed Control.—Most of the chemical weed killers are fatal to cranberries but weed killers have their place as a substitute for turfing. Esteron 44, an ester form of 2,4-D, carefully applied at the rate of one quart per 100 gallons of water resulted in moderate to severe injury to an overgrowth of heath shrubs, wire bush, speckled alder and willow. Water white kerosene as a spray at 200 to 400 gallons per acre gives a large measure of control of rushes and grasses if the work is done in the early spring.

Elderberries

The common elder, *Sambucus canadensis,* is found on rich soils throughout Eastern Canada. This fruit has been used for blending with apple products in the home. Since disposal of cull apples is an annual problem, a co-operative project is under way to use the elderberry for commercial blending with apple jellies and juice.

The more desirable seedlings are being bred at the Kentville Station and plots of five acres at each of six locations representing varied soil types have been set out. This project is in its infancy, but it has already been found that elderberries are easily propagated and grow quickly on well-drained tillable land. The crop responds readily to cultivation and fertilizing and can be produced more cheaply than the other common small fruits.

USE OF CHEMICALS IN APPLE PRODUCTION

Thinning Apples with Chemicals

D. S. Blair

In commercial apple growing, thinning is of utmost importance in the production of a high quality, uniform, marketable product. It is a necessary practice with such varieties as Wealthy which usually produce a large crop with a high percentage of fruits below marketable size. Until recently hand thinning, a labourious and costly operation, was the only method used. In 1935, Auchter and Roberts (1) reported the first chemical prevention of fruit set. They used cresylic acid and tar-oil distillate, both of which were effective in reducing fruit set, but cresylic acid caused severe injury to the tree. Since then extensive research has been conducted on various chemicals as a means of blossom-thinning. Recently plant hormones have proved effective.

Chemicals Used

At the present time the most extensively used materials are the dinitro compounds and the hormones, naphthaleneacetic acid and the sodium salt of naphthaleneacetic acid. Other chemicals which have been used include Dowax T.T.S., 82 and 222; Goodrite p.e.p.s. (polyethylene polysulphide) combined with Fruit Thinner (Zimate-cyclohexylamine) and Goodrite p.e.p.s. combined with Goodrite Z.A.C. (zinc dimethyl dithiocarbamate-cyclohexylamine complex).

Application

Blossom-thinning chemicals are applied in spray form using the power sprayers operating at sufficiently high pressures to give good coverage. Time of application is undoubtedly the most important factor to be considered in the spray method of blossom-thinning. Good judgment on the part of the grower is a necessity, a lapse of twelve to twenty-four hours may make the difference between success and failure. The dinitro sprays should be applied when seventy-five per cent of the bloom is out, while the hormone sprays are best applied at the calyx stage immediately following petal fall.

Effect on Trees

The dinitro materials are caustic in effect. As soon as contact is effected they destroy the pollen that has been liberated from the dehisced as well as that still in the indehisced anthers. The effect of the plant hormone sprays is different in that it causes abscission of young fruits which would normally adhere. Dowax does not kill the blossom but forms a wax coating over the stigmatic surfaces and so prevents pollen germination. In the absence of pollen germination, the young fruit drops. The caustic dinitro sprays applied in concentrations sufficient to effect thinning cause severe injury to the young leaves and to such floral parts as the petals and tips of the styles. However, the trees quickly recover and at harvest time appear normal. The hormone sprays do not burn the foliage but wilting has been observed immediately after application. Later, some dwarfing of the foliage and crinkling along the midrib of the leaf may occur in some varieties.

The use of blossom-thinning sprays to control biennial bearing is of prime interest. Such notorious biennial bearers as Wealthy, Golden Delicious and Yellow Transparent, when heavily thinned with blossom sprays in the "on" year produce a commercial crop in the "off" year. With these sprays the

crop may be completely eliminated thus changing the tree from the "on" to the "off" year. Such a practice permits the grower to change half the trees of a given variety to the "off" year and by so doing he can regulate annual production. Therefore, chemical blossom-thinning offers a means of modifying the biennial bearing habit.

Varietal Differences

Varieties do not react alike to bloom-killing sprays. With certain varieties a given concentration will completely remove the crop, with others the thinning is quite effective and with still others the crop removal is insufficient. For example, for effective commercial thinning Wealthy requires a higher concentration of spray than Melba.

Variation in Results

Seasonal conditions have an effect on the degree of thinning. Concentrations that give satisfactory thinning one season do not necessarily give effective thinning the next. Weather and condition of the tree influence the degree of thinning achieved. Variations in degree of thinning at different locations, even when the same concentration is used, may be caused by differences in the thoroughness of application and gallonage applied to the tree. It is now thought that the gallonage per tree may be as important as the concentration; in other words, it is the amount of active ingredient applied to the tree that is the governing factor.

Trials on Thinning at the Central Experimental Farm, Ottawa, and Rideau Fruit Farm, Manotick, Ontario

Preliminary experiments with Elgetol, a dinitro spray, on potted trees in the greenhouse at the Central Experimental Farm were begun in 1943. In the 1943 field trials effective thinning without injury to the foliage was obtained with a strength of one quart of Elgetol to one hundred gallons of water, but in the repeat experiments of 1944, an exact duplicate of the 1943 field trials, the blossoms on most varieties were completely killed. This is evidence of a concentration being satisfactory one year, but unsatisfactory the next.

From 1946-48, extensive trials were made at the Rideau Fruit Farm and at Ottawa. Varieties used in these trials included Atlas, Elmer, Fameuse, Lawfam, Lobo, Duchess, Joyce, Melba, Wealthy, Yellow Transparent and McIntosh. The materials used were: Elgetol; D.N. Nos. 1, 2 and III; Dowax T.T.S., 82 and 222; Parmone; App-L-Set; Goodrite p.e.p.s. combined with Goodrite Fruit Thinner; and Goodrite p.e.p.s. combined with Goodrite Z.A.C. All the data cannot be included in a report of this nature. Data for the 1947 experiment on the Rideau Fruit Farm are presented in Table 10.

Table 10 shows that Elgetol used at the rate of two pints on Melba was effective in thinning. With Yellow Transparent effective thinning was accomplished with App-L-Set (6 oz.), Elgetol (1½ pt.) and D.N. No. 2 (1 lb.). From the data it appears that the Goodrite p.e.p.s. plus Goodrite Fruit Thinner on Melba and Yellow Transparent and Dowax on Melba increased rather than decreased the set of fruit. On Wealthy, App-L-Set (8 oz.) resulted in too heavy thinning while Elgetol (3 pt.) and Goodrite p.e.p.s. plus Goodrite Fruit Thinner were effective.

Table 11 gives the summarized data on the 1947 experiments at the Central Experimental Farm.

Table 11 shows that in general the dinitros and App-L-Set gave reasonably good thinning on the varieties McIntosh, Lawfam and Melba. Some thinning was effected with Dowax and Goodrite p.e.p.s. plus Goodrite Fruit Thinner.

TABLE 10.—BLOSSOM-THINNING EXPERIMENT. RIDEAU FRUIT FARM, MANOTICK, 1947

Spray	Concentration	Melba			Yellow Transparent			Wealthy		
		Average Mean Temperature	Stage of Bloom	Per Cent Set	Average Mean Temperature	Stage of Bloom	Per Cent Set	Average Mean Temperature	Stage of Bloom	Per Cent Set
App-L-Set	6 oz. : 100 gal.	68° F.	F.B. + 2	4·58	63° F.	Calyx	3·00	63° F.	Calyx	4·43
App-L-Set	6 oz. : 100 gal.	64	Calyx + 6	4·50				63	Calyx	0·09
App-L-Set	8 oz. : 100 gal.	64	Calyx + 6	4·62				64	Calyx + 5	0·70
Goodrite p.e.p.s. + F.T.	2 lb., 8 oz. : 100 gal.	63	Calyx	10·13	63	Calyx	12·80	63	Calyx	1·68
Goodrite p.e.p.s. + F.T.	2 lb., 4 oz. : 100 gal.	63	Calyx	6·61						
Dowax 222	1 gal. : 100 gal.	68	F.B. + 1	6·02						
Elgetol	1½ pt. : 100 gal.	70	F.B. + 1	3·97	73	F.B.	4·88			
Elgetol	2 pt. : 100 gal.	74	F.B. + 1	2·25	72	F.B.	4·08			
Elgetol	3 pt. : 100 gal.							64° F.	F.B. + 1	1·75
D.N. No. 1	1 lb. : 100 gal.	74° F.	F.B. + 1	4·44						
D.N. No. 2	1 lb. : 100 gal.	74	F.B. + 1	3·24	74	F.B.	3·82	64° F.	F.B. + 1	4·82
(*a*) Elgetol	2 pt. : 100 gal.								F.B. − 2	
(*b*) D.N. No. 1	1 lb. : 100 gal.							72° F.	F.B.	3·43
Check				5·22			12·61			5·56

F.B. + 2 = 2 days after full bloom.
F.T. = Fruit thinner.
Calyx + 6 = 6 days after calyx stage.

(*a*) First Spray.
(*b*) Second Spray.

TABLE 11.—BLOSSOM-THINNING EXPERIMENT. CENTRAL EXPERIMENTAL FARM, OTTAWA, 1947

Spray	Concentration	McIntosh			Lawfam			Melba		
		Average Mean Temperature	Stage of Bloom	Per Cent Set	Average Mean Temperature	Stage of Bloom	Per Cent Set	Average Mean Temperature	Stage of Bloom	Per Cent Set
Elgetol	1 pt. : 100 gal	70° F.	F.B.	7·43	70° F.	F.B.	3·98			
Elgetol	1½ pt. : 100 gal	70	F.B.	7·66	70	F.B.	2·76			
D.N. No. 1	½ lb. : 100 gal	64	F.B. + 1	13·99	70	F.B.	7·60	72° F.	F.B.	9·60
D.N. No. 1	¾ lb. : 100 gal	66	F.B. + 1	7·67	66	F.B.	6·61			
D.N. No. 2	½ lb. : 100 gal	68	F.B. + 1	6·02	68	F.B.	3·85			
D.N. No. 2	¾ lb. : 100 gal	70	F.B. + 1	7·51	70	F.B.	3·10			
D.N. III	½ lb. : 100 gal	72	F.B. + 1	5·59	72	F.B.	6·83			
App-L-Set	4 oz. : 100 gal	68	Calyx	4·44	68	Calyx	5·41			
App-L-Set	8 oz. : 100 gal	63	Calyx	6·17	63	Calyx	3·46	63° F.	Calyx	4·83
Dowax 222	1 gal. : 100 gal	70	F.B. + 1	7·28	70	F.B.	9·74			
Goodrite p.e.p.s. + F.T.	2 lb., 4 oz. : 100 gal	60	Calyx	9·28	60	Calyx	7·52			
Goodrite p.e.p.s. + F.T.	2 lb., 8 oz. : 100 gal	63	Calyx	8·23	63	Calyx	6·29	63° F.	Calyx	7·15
Check				15·82			16·00			15·25

F.B. = Full bloom.
F.B. + 1 = One day after full bloom.

In the 1947 trials it was found that Dowax had no commercial thinning effect on the varieties Melba (*see* Tables 10 and 11) and Duchess. This material does not appear to emulsify readily. Considerable thinning was accomplished with naphthaleneacetic acid on Melba, Yellow Transparent and Duchess. This material did not cause burning of the foliage although some stunting of the primary leaves resulted. Very effective thinning was accomplished with one and one-half pints of Elgetol on McIntosh and Lobo and with two pints on Melba, Yellow Transparent, Duchess and Wealthy. These concentrations caused considerable foliage injury but the trees recovered quickly and outwardly performed in a normal manner.

In the 1948 trials a new material, Goodrite Z.A.C., was combined with Goodrite p.e.p.s. instead of the Fruit Thinner used in 1947. Goodrite p.e.p.s. (2½ lb.) combined with Goodrite Z.A.C. (⅓ lb.) gave effective thinning on McIntosh, partial thinning on Lawfam and had little effect on Melba. The other chemicals showed the same trend as in 1947, although the thinning was not so heavy. However, even this lighter thinning greatly reduced the cost of later hand work.

Experimental Results on Thinning at Smithfield Substation

The Dominion Horticultural Substation, Smithfield, Ontario, carried out thinning trials in the Lake Ontario region in 1948. The data obtained for one orchard are presented in Table 12. Thinning was not so marked as in the trials at Ottawa, but the chemicals performed in a similar manner. App-L-Set (10 oz.) gave partial thinning on Wealthy and Fameuse, but overthinned McIntosh). Goodrite p.e.p.s. (2½ lb.) combined with Goodrite Z.A.C. (⅓ lb.) was ineffective on Wealthy, appeared to increase the set on McIntosh and gave partial thinning on Fameuse.

TABLE 12.—THINNING APPLES WITH CHEMICALS. W. A. FRASER'S ORCHARD, R.R. No. 4, TRENTON, ONTARIO, 1948

Spray	Concentration	Variety	Stage of Bloom	Average Set
				Per cent
App-L-Set	10 oz. : 100 gal.	Wealthy	Calyx + 5 days	10·6
Goodrite p.e.p.s. + Goodrite Z.A.C.	2½ lb., ⅓ lb. : 100 gal.	"	" "	21·0
Check		"		19·3
App-L-Set	10 oz. : 100 gal.	McIntosh	" "	1·3
Goodrite p.e.p.s. + Goodrite Z.A.C.	2½ lb., ⅓ lb. : 100 gal.	"	" "	18·9
Check		"		12·7
App-L-Set	10 oz. : 100 gal.	Fameuse	" "	12·4
Goodrite p.e.p.s. + Goodrite Z.A.C.	2½ lb., ⅓ lb. : 100 gal.	"	" "	14 1
Check		"		24·0

Recommendations

Since seasonal conditions have an effect on the degree of thinning it is not possible as yet to give definite rates of application. This is further complicated by the fact that varieties do not react alike. Until definite recommendations are available the grower without previous experience should use these chemicals cautiously. For trial purposes, the dinitros should be used at the rate of one and one-third pints or three-quarters of a pound per 100 Imperial gallons, while the hormone compounds are applied at the rate of five ounces per 100 gallons. The safest policy is to slightly under-thin with the chemicals and finish off with the hand thinning.

Harvest Sprays

The pre-harvest dropping of apples is a problem which annually confronts the commercial grower and in many years the resulting losses amount to thousands of dollars. It was not until 1939 that Gardner, Marth and Batjer (2) first reported the control of pre-harvest drop by the use of hormone sprays. This discovery stimulated widespread interest among fruit research workers and in subsequent years extensive trials were conducted. From these investigations it was pretty well established that chemicals could be successfully employed as pre-harvest sprays. Several manufacturers responded to the demand for drop control chemicals, and commercial preparations in both liquid and dry form were developed. In 1941 and 1942 harvest sprays were used commercially by hundreds of growers in every apple growing region in the United States and by a number of growers in Canada. The aeroplane was used for this type of spraying; first in the state of Washington in 1944 when over a thousand acres of apples and pears were treated. The following year the acreage covered by plane spraying increased fifteen to twenty times. At the present time harvest sprays, not necessarily applied by aeroplane, are a standard practice in the control of harvest drop in all apple growing areas of both the United States and Canada.

Chemicals Used

Most commercial preparations contain either naphthaleneacetic acid, the sodium salt of naphthaleneacetic acid or naphthaleneacetamide as the active agent with carriers to facilitate their use in spraying or dusting operations. 2,4-dichlorophenoxyacetic acid (2,4-D) has been used as a harvest spray, but it is specific to the Winesap varieties. More recently, 2-methyl-4 chlorophenoxyacetic acid, which differs from 2,4-D in that a methyl group replaces the two-position chlorine atom, has proved superior to the sodium salt of naphthaleneacetic acid on McIntosh.

Application

As in all spraying operations, the effectiveness of the material used is dependent upon good coverage. The rate of application varies according to spraying conditions, amount of foliage and fruit on the tree. Best results are obtained when enough spray is applied to "wet" the entire tree. Time of application is a very vital factor in the effectiveness of the spray. Under average conditions the spray becomes effective within two days after being applied, and reaches its peak in four to five days. The interval between application and effect is longer during cool weather. A spray applied too early, especially on McIntosh, may lose its retarding effect before the crop is harvested. Best results are obtained, especially with McIntosh, by waiting until a few good sized apples, free of insect injuries, have dropped to the ground.

Effect on Trees

No bad effect of the spray on the tree, fruit, or foliage, has been recorded. Some may wonder if the spray causes the leaves to hang on longer, thus increasing the risk of winter injury. Apparently the effect on the leaves is temporary and leaf fall takes place at the normal time. The effect on the fruit is merely that of delaying its dropping by slowing down the processes taking place in the abscission layer, thereby allowing for better colour development. This improved colour and longer picking season is perhaps an even more important feature of the spray than preventing fruit drop, since the demand for extra fancy grades is increasing. The grower must exercise extreme care in using this spray to attain fruits of better colour. It is a mistake to allow the fruit to remain on the tree too long, for such fruits are too mature for long storage. Hormone sprays

hasten the maturity of summer apples but apparently have little or no effect on the fall and winter apples. This is of commercial importance since it results in a considerable saving in the picking of the summer varieties.

Fig. 9—Fruits sprayed with naphthaleneacetic acid. Note that fruits have cracked and are still clinging to the tree.

Varietal Differences

Varieties do not react alike. Harvest sprays, generally, are more effective on the summer than on the fall varieties. The relatively high temperatures prevailing when the summer apples reach maturity are considered to be the main contributing factor in this effectiveness. Melba and Yellow Transparent, for example, respond well to these sprays while McIntosh is inconsistent.

Variation in Results

The successful use of harvest sprays depends on the condition of the tree. Trees suffering from disturbances such as leaf scorch and winter injury do not respond to these sprays. Rainfall is also a factor, and in relatively dry years the sprays are less effective.

Harvest Spraying Experiments at Two Ontario Locations

Investigations with harvest sprays were initiated on pot trees of the Crimson Beauty and U.S.D.A. No. 49 varieties in the greenhouse at the Central Experimental Farm, Ottawa. The results of these preliminary tests were so significant that large-scale orchard trials were conducted in 1940. Two commercial preparations, Parmone (napthaleneacetic acid) and Fruitone (naphthaleneacetic acid plus naphthaleneacetamide) were used. Data from the 1940 and 1941 experiments are presented in Table 13. The two preparations gave essentially the same

control, and both were effective in reducing the pre-harvest drop of all varieties included in these experiments. The sprays were more effective on summer than on fall and winter varieties. The period of effectiveness varied with varieties. With McIntosh the period was approximately one week; with Crimson Beauty, Melba and Yellow Transparent two weeks. The addition of russian oil to the harvest sprays, one-fourth of one per cent in an emulsifying agent (Bordeaux 3-6-40), did not increase the efficiency of the spray enough to justify its use.

TABLE 13.—HARVEST SPRAY EXPERIMENTS, 1940, 1941

Variety	1940 Percentage Drop			1941 Percentage Drop		
	Fruitone	Parmone	Check	Fruitone	Parmone	Check
Crimson Beauty	4·9	9·3	30 0	.....	.....	.....
Yellow Transparent	2 6	.....	14·8	.....	.....	.....
Melba	1·0	0·7	10·2	14·75	14·25	32·00
McIntosh	13·8	18·0	24·4	6·50	5·75	9 25
Wealthy	27·9	22·5	47·8	11·00	12·75	31·50
Joyce	0·5	.....	2·9	7·25	6·50	17·25
Honora	1·0	.....	6 6	7·50	7·25	13·75
Brisco	.....	5·7	12·1	19·25	.....	53·75
Lobo	1·9	2 9	6·2	.....	5·25	6·25
Stonecrop	.....	.....	.....	11·00	.....	50·00
Atlas	.....	.....	.....	6·50	6·50	8·50
Dudley	.....	.....	.....	7·75	5·03	19·75
Gilda	.....	.....	.....	.....	21·00	23·75

In 1948, the 2-methyl-4 chlorophenoxyacetic acid, also known under the trade names of "Toloxy" and "A-814", was tried on McIntosh at Ottawa. It was quite effective when applied at a five-ounce concentration. The sodium salt of naphthaleneacetic acid (5 oz.) moderately reduced the percentage drop, showing better results than the four-ounce concentration of 2-methyl-4 chlorophenoxyacetic acid. Trials in the Lake Ontario region under the supervision of the Dominion Horticultural Substation, Smithfield, Ontario, showed that both the four- and five-ounce concentrations of A-814 were much better than the sodium salt of naphthaleneacetic acid. To date this new compound appears to have promise as a "Harvest Spray" for McIntosh.

Recommendations

The standard recommendation for controlling pre-harvest drop of apples is either naphthaleneacetic acid, the sodium salt of naphthaleneacetic acid or napthaleneacetamide, all at five oz. per 100 Imperial gallons. On the basis of one year's results 2-methyl-4 chlorophenoxyacetic acid appears to be promising as a "Harvest Spray" for McIntosh when applied at the rate of five oz. per 100 Imperial gallons.

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VEGETABLE CROPS

W. Ferguson, L. H. Lyall, J. J. Jasmin
Statistical Analyses—H. B. Cannon

In presenting this section of the report attention is drawn to the fact that much of the work was carried on in earlier years by T. F. Ritchie, now retired.

The vegetable crop work in the Division of Horticulture is planned for application to various phases of the vegetable industry. This industry has become one of the major fields of agriculture in Canada and includes vegetable production, vegetable seed growing and canning crop production.

The major lines of investigation include plant breeding with a number of vegetable crops, various types of trials, foundation seed production, methods of culture and weed control.

VEGETABLE BREEDING

One of the major lines of work in the field of vegetable crops is plant breeding. Although the production of better vegetable varieties is the main object, a number of special aims are followed. These aims include earliness of maturity, increased yield, quality and flavour, better appearance, adaptability to canning and freezing and resistance to drought, wind, disease and insects.

With this in view a number of vegetable varieties were originated in this Division in past years. Some served their purpose until displaced later by improved varieties, others hold a prominent place in Canadian horticulture and are widely grown. Recently developed varieties are now entering the vegetable industry and new originations are being tested and evaluated to determine their merit or usefulness. The progress made in plant breeding with various vegetable crops is set forth on the following pages.

Asparagus

A selection was made from a plantation of the variety Elmira, at the Central Experimental Farm. This showed excellent colour and freedom from asparagus rust. It was propagated vegetatively and the progeny tested for seed production. The plants produced from seed remain true to the original type. This selection, named Eden, is described as follows:

Eden

Origin.—Selected from a plantation of Elmira; named in 1945. *Plant characters.*—Vigorous. Long, compact, brittle spears, pale green with purplish tips. Lateral branch buds and leaf scales remain compact for quite a long period making it possible to pack a large percentage of extra long first grade spears. *Season.*—Early. *Adaptation.*—A wide range, making it suitable for most localities. Resistant to asparagus rust.

Beans

Breeding work with beans has certain aims. Earliness has naturally been a prime point. An acceptable variety producing pods in less than sixty days is a benefit in those regions with a very short frost-free period and for early production in longer season localities. Stringlessness in the pods and quality are desirable features. There is little advantage in earliness alone without these

features. Naturally, yield must not be neglected in the breeding program. The type of seed produced is also kept in mind, for it is considered that an improved variety would have an added advantage if the dry seed is suitable in size, appearance and quality for use as baking beans.

In carrying on the breeding work for the development of improved types a considerable number of varieties were used as parent material. Numerous combinations were made and many selections tested. At present this work has resulted in four suitable varieties, three of which have been named and one is still under number.

Ace

Origin.—Selection from the cross Round Pod Kidney Wax × Princess of Artois from which the variety Pacer also originated; named in 1942. *Seed Characters.*—Seed coat white, smooth, glossy with fine almost indistinct veining and a narrow black line from end to end on the hilum side and encircling the eye. This black mark also extends on either side of the eye from the radicle end, either solid black or as fine dots or smudging. Kidney shaped with depressed eye and bulging radicle; occasional seeds truncated on one or both ends, roundly flattened in cross-section; about 60 per cent of the seeds bent slightly sideways; measurements, 1·51 x 0·71 x 0·48 cm.; 94 seeds per ounce. *Plant Characters.*—Dwarf, bushy, erect growing, compact; leaves medium to small, medium to pale green. Flowers white, small, in pairs in centre of plant. *Fruiting Habit.*—Pods in medium sized clusters hidden by foliage, occasionally showing above, rarely touching ground. Waxy yellow, with slight greenish tinge in the early stage. Straight, occasionally slightly curved back, roundly flat in cross-section, full between seeds, stringless when young. Average length five inches. Brittle, tender when young, developing strings toward maturity. Ripe pods thresh easily and contain four to five seeds. *Season.*—Early, 54 days from planting until ready for use. Ripe seed in 82 days. *Adaptation.*—Home or market garden for early production and in short season areas where later maturing varieties are not adapted.

Pacer

Origin.—Selection from the cross Round Pod Kidney Wax × Princess of Artois. Named and introduced in 1941. *Seed Characters.*—Seed coat white, smooth, glossy with fine almost indistinct veining. Kidney shaped with depressed eye and bulging radicle; occasional seeds slightly truncated, roundly flattened in cross-section, occasional seeds bent sideways; measurements, 1·35 × 0·71 × 0·48 cm.; 98 seeds per ounce. *Plant Characters.*—Dwarf, bushy, average height 11 in., erect, compact, medium green. Flowers white, small, in pairs in medium sized clusters showing above the leaves usually in centre of plant. *Fruiting Habit.*—Pods in medium sized clusters, hidden by foliage, occasionally showing above, rarely touching the ground. Waxy yellow with slight greenish tinge in early stage; straight, occasionally slightly curved back, roundly flat in cross-section, full between seeds, stringless when young. Average length 5 inches. Brittle, tender when young, developing strings toward maturity. Ripe pods split fairly easily and contain an average of five white seeds. *Season.*—Early, 54 days from planting to ready for use as green snap beans. Ripe in 82 days. *Adaptation.*—Home or market garden for early production and in short-season areas where later maturing varieties are not adapted. Dry seeds excellent for baking.

Strider

Origin.—Selection from the cross Stringless Refugee Wax × Princess of Artois. Named in 1945. *Seed Characters.*—Seed coat white, smooth, glossy with fine almost indistinct veining. Hilum protruding, surrounded by a sunken yellowish halo. Kidney shaped, occasional seeds truncated on one or both ends,

roundly flattened in cross-section, occasional seeds bent sideways. About 102 seeds per ounce; dimensions 1·30 × 0·75 × 0·65 cm. *Plant Characters.*—Dwarf to medium height, bushy, erect, compact; leaves medium size, slightly tapered, prominently veined; foliage medium dark green. Flowers white, carried well above foliage. *Fruiting Habit.*—Pods creamy yellow (almost white); flat to oval in cross-section, slightly curved, stringless and tender. *Adaptation.*—Home or market garden and possibly canning. Dry beans excellent for baking.

Ottawa BA-2

Origin.—Numbered selection from the cross Red Kidney × Unrivalled Wax. *Seed Characters.*—Seed coat pale brown to brownish yellow; hilum white, pronounced, surrounded by a dark brown ring. Kidney shaped, roundly flattened and averaging 95 seeds per ounce; dimensions, 1·45 × 0·55 × 0·65 cm. *Plant Characters.*—Large, bushy, vigorous, tall, dark green with large leaves. Pods long, slender, curved, flat to oval; pale green, stringless, tender with good quality and flavour. Flowers pink to pale purple. *Season.*—Early, averaging 58 days from sowing to ready for use. *Adaptation.*—Home and market garden; some resistance to *Anthracnose.*

Soybean

In addition to the bush beans, selection work has been carried on since 1934 to obtain a satisfactory type of vegetable soybean. Such a type is one which would mature early enough to produce a seed crop during the normal growing season. Large pods and seed are considered important for ease of picking, handling and appearance. A mild flavour is also essential for use as an edible green bean.

Seeds were obtained from numerous sources but the most promising was from Raymond Kabolkin, Harbin, Manchuria. This was first tested at Ottawa in 1934 and produced a number of types of plants ranging from dwarf to tall. By continued individual plant selection, a desirable type was obtained which would mature seed in 104 days at Ottawa and had large pods containing large edible green beans for fresh use. The attractive dry seed has a black hilum from which the variety takes its name Blackeye. It is a good yielder averaging 1,200 pounds and more of dry seed per acre. In fact this variety on a ⅕ acre plot at Ottawa, yielded at the rate of 2,300 pounds per acre in 1948.

Further, the dried beans contain almost 40 per cent protein and over 19 per cent oil as shown by the following analysis on a moisture-free basis, by the Division of Chemistry, Science Service.

Protein (N × 6·25)	39·86%
Ether extract	19·36%
Ash	6·4%
Crude Fibre	4·38%
Nitrogen-free extract	30·36%

In addition, tests at Ottawa have demonstrated that the green beans make an excellent, tasty and nutritious frozen vegetable.

Blackeye

Origin.—Selection made in 1934 at the Division of Horticulture from soybeans introduced through the co-operation of Mr. R. Kabolkin, Harbin, Manchuria. *Seed Characters.*—Seed coat smooth, semi-glossy; medium to pale green, occasional seeds with very slight smudge of dark colour at hilum side; round to roundly oblong, full to slightly protruding at the black hilum; dimensions average 0·95 × 0·87 × 0·71 cm.; 85 seeds per ounce. *Plant Characters.*—Strong, upright, height about 18 in., slightly branching, stems hairy. Leaflets medium large, abundant, hairy, rough, medium green. Flowers small, inconspicuous in clusters on main stem and branches, pale mauve; well hidden in the foliage. *Fruiting Habit.*—Pods set freely on main stem and branches. Pedicel

very short and pods borne close to stem and branches, singly or in clusters of two or more; measuring 6·35 to 6·51 × 1·27 × 0·87 cm.; curved back, flatly rounded to oval in cross-section; pale green, hairy, tawny to light brown when ready for use, turning to leather brown when ripe. Seeds, when ready for use large, oblong, oval to round, oval in cross-section; attractive green, tender, mild. When ripe, seeds reduce in size; moderately easy to shell. Harvesting should be done when the plants are moist with dew. *Season.*—Early, 104-110 days from sowing to maturity. *Adaptation.*—Home garden and field production for shelled green beans. Excellent for freezing.

Breeding Beans for Resistance to Disease

Recently the work with beans has been extended to include breeding for resistance to the diseases, halo blight and common blight, caused by the bacterial organisms, *Pseudomonas medicaginis* var. *phaseolicola* and *Xanthomonas phaseoli* respectively. These diseases cause extensive damage to bean crops throughout Canada.

This work in co-operation with the Division of Botany and Plant Pathology was started in 1948 and therefore only a progress report is made here.

Some 91 varieties and strains of beans were grown in preliminary test plots during 1948 to eliminate those which showed infection. Although no attempt was made to inoculate these plants, every fifth row was a variety known to be infected with the common blight organism. Most of the 91 showed symptoms of common or halo blight indicating that the disease had been present in the seed or had spread to the plant. However, the stocks which remained free of these diseases during the season were:

Bountiful
Brittle Wax
Coco Bicolor du Pape
Fordhook Favorite
French Horticultural
Giant Stringless Green Pod
Idaho Refugee
Improved Kidney Wax
Logan
Noir de l'Hermitage Amélioré
Pencil Pod Black Wax
Refugee
Round Pod Kidney Wax
Rustproof Golden Wax
Sensation Refugee 1066
Sensation Refugee 1071
Stringless Black Valentine
Surecrop

The foregoing list is probably larger than it would be if the season were more favourable for the development of the disease.

In subsequent tests these blight-free stocks will be subjected to epidemic conditions under which bacterial water suspensions will be sprayed upon the plants. Any resistant material will be propagated and efforts will be made to incorporate this resistance into suitable varieties. During 1947 and 1948, thirty seed stocks were subjected to inoculation in this manner in test plots in the Division of Botany and Plant Pathology. None showed complete resistance but three showed only slight infection. Seed from these plants is being increased for further testing and breeding.

Beets

Since 1934, individual plant selections have been made with a view toward developing a particularly good type of Detroit Dark Red beet that would be prized for table quality and for processing. The features desired are uniformity, appearance and rich internal colour. Continued selection and improvement have resulted in the following strain:

Detroit Dark Red No. 16

Origin.—Developed by individual plant selection and identified as Detroit Dark Red No. 16 in 1944. *Plant Characters.*—Upright, with a clear, well defined crown of medium size. Top medium size; leaves upright, medium size, uniform

reddish green with slight crinkling of younger leaves. As plants mature leaves show more red or bronzing. *Root.*—Globular to almost round, ½ to ⅔ above ground when mature, full with considerable russeting. Tap root medium to short, fleshy; clean and well defined, joining almost abruptly to base of beet which is free from root hairs, smooth, dark to almost blood red. Flesh dark red with a little lighter zoning. This strain is usually darker red than the average Detroit Dark Red. *Season.*—Second early or midseason but suitable for early bunching, about 65 days from seeding to ready for use. *Adaptation.*—Widely adapted. Home, market garden, shipping or canning.

Carrots

Improvement work with Chantenay carrot has been under way for several years with a view to developing a strain which would meet with favour among Canadian vegetable growers. Such a carrot should be uniform, refined, with a pleasing smooth appearance and a rich internal colour, suitable for bunching and with mature roots suitable for storage or processing.

The strain developed for this purpose and now known as No. 27 has proved popular for its appearance, colour, flavour and storage qualities. Recent tests at several agricultural institutions rate this strain high for colour.

Chantenay No. 27

Origin.—Developed by individual plant selection and identified as Chantenay No. 27 in 1945. *Plant Characters.*—Growth medium to strong. Leaves moderately fine, light green. Neck medium small, short. *Root.*—Broad-shouldered, tapering slightly to a bluntly rounded stump end, deep in ground with only rim of crown showing. Length 4¾ to 5½ in.; diameter at crown 2 to 2½ in., at the base where root rounds off, 1 to 1½ in. Single rat-tailed tap root extends from base. Crown slightly hollowed with well rounded shoulder. Appearance smooth; lenticels shallow, small. Outer flesh good orange-red, shading to lighter colour toward medium large, well defined, deep red core. Texture moderately fine, cri tender and sweet. *Adaptation.*—Home, market garden, field crop, shipping a canning.

Corn

In the past years this Division originated and introduced several varieties sweet corn. Such varieties as Banting, Dorinny and Pickaninny have be widely grown. Dorinny is still in popular demand particularly among ho e gardeners who desire an early, sweet, high quality corn. It is also popular as a choice variety for freezing. These varieties have been described in earlier reports from this Division.

Open-Pollinated Varieties

The preceding are all open-pollinated and until comparatively recently n of the breeding work was devoted to the origination of improved open-pollinated varieties. Selection work was carried out on the progenies of the many crosses in an attempt to combine and fix the desirable features of original parents in the offspring. This is a long slow process which must be carried through numerous generations until segregation is complete, and there is the ever present possibility of losing desirable characteristics by segregation.

Numerous crosses were made with a wide variety of parent material. A number of very promising selections have been obtained from this work including the two following open-pollinated varieties:

Goldban

Origin.—By selection from the cross Golden Bantam ×Banting, and named in 1938. *Seed Characters.*—Amber yellow or golden, finely wrinkled. *Plant*

Characters.—Stalk medium to strong, upright, 57 inches high. Averages two weak tillers per plant. Leaf medium to broad, medium long, slightly coarse. Tassel strong, spreading, producing pollen freely. *Ear Characters.*—Average length 6 in., husks numerous, extending well over ear tip, silks pale green; ear slightly tapering at tip and usually well filled. Eight-rowed; occasional ten- and twelve-rowed. Kernels golden yellow, broad, thick, deep, tender and easily separated from cob. *Season.*—Early to midseason, ready for use in 71 to 78 days. *Adaptation.*—Home, market garden and whole ear canning.

Dorick

Origin.—By selection from the cross Dorinny × Pickaninny and named in 1936. *Seed Characters.*—Yellow, wrinkled. *Plant Characters.*—Stalk 55 to 60 in. high, erect, strong, a few weak tillers. Leaf coarse, short to medium, length 22 to 25 in., width 3 to 3½ in. Tassel open, many branches, 8 in. from node to lower branch, 11 in. from lower branch to tip; pollen abundant, vitality strong. *Ear Characters.*—Average length 7 in., silks green; usually two ears per stalk borne 15 to 18 in. from ground at fourth node; diameter with kernels 1⅞ in., without kernels, 1¼ in. Pedicel short, 12 rows, compact, tip blunt to pointed. Kernels yellow, medium deep, broad, thick, rounded at tip; pericarp medium tender. *Season.*—Early, 73 days from sowing till ready for use. *Adaptation.*—Home garden; good quality for canning and freezing.

Hybrid Sweet Corn

In more recent years emphasis has been placed on the development of inbred lines for producing first generation hybrids. The greater vigour and larger yields which can be obtained from hybrid sweet corn have given added impetus to this work.

In the past few years hybrid sweet corn varieties have largely, if not entirely, replaced open-pollinated varieties in the canning districts of Canada, and the same changes are taking place among the market growers. Improvements in earliness, size of ear, yield and quality for fresh use, canning or freezing are needed in hybrid sweet corn.

Hybrid sweet corn seed is the seed produced from crossing two or more parent lines. On a commercial scale this is done by growing the two parents in rows side by side in the same field. Usually one row of pollen or male parent plants is grown for every four or six rows of seed or female parent. The tassels are removed from the rows of seed parent plants before they start to shed pollen. Thus the silks on these plants are ensured pollination with the pollen from the male or pollen plants. The hybrid seed produced in this fashion is used to grow only one crop of corn. New hybrid seed must be produced for each generation.

To produce these hybrid sweet corn varieties, pure parent or inbred lines are necessary. For this purpose some thirty-five inbred lines are at present maintained in this Division. The following show excellent promise for the production of improved hybrids:

Inbred Line	Days to Silking	Days to Tasseling	Rows of Kernels	Inbred Line	Days to Silking	Days to Tasseling	Rows of Kernels
CO–11	49	48	8	CO–100	56	55	10
CO–13	51	50	8	CO–102	56	54	8
CO–17 (C-3)	50	49	16	CO–104	56	55	12
CO–20	56	54	12	CO–106	57	56	8
CO–29	61	61	12	CO–108	61	57	12
CO–35	56	54	8	CO–110	68	66	10
CO–37	55	54	12				

A number of these lines originated as selections from varietal crosses and others from named varieties. The inbred CO-17 (C-3) was originally obtained from the Connecticut Agricultural Experiment Station.

A desirable early hybrid has been produced and designated under the number Ottawa CH-1. It follows Dorinny closely in season, has excellent quality and larger ears. It proved very well adapted to freezing and superior to many other varieties in tests at Summerland, British Columbia, and at Ottawa, Ontario. This variety should prove popular in many parts of Canada for fresh use and for processing.

Ottawa CH-1

Origin.—A single cross hybrid produced by crossing the Ottawa inbreds, CO-29 and CO-13. *Seed Characters.*—Golden yellow, well wrinkled, averaging 137 seeds per ounce. *Plant Characters.*—Usually 64 to 68 in. tall, dark green; green silks, two or three tillers. Ears well covered with a thick husk, borne close to the stalk on the third or fourth node about 16 in. from the ground. Ten-rowed, length 6·5 to 7 in., diameter with the husks removed 1·6 in. Kernels golden yellow when ready to use, excellent in quality. *Season.*—Early, 77 days from sowing until ready for use. *Adaptation.*—Home or market garden and especially good for freezing.

In addition to CH-1 there are other promising hybrids still under test. These are all single cross hybrids. All are still under number and are described briefly as follows:

Ottawa CH-2

A hybrid produced from the inbreds CO-29 × CO-11. A good yielder, early, with ears averaging 7·3 inches long by 1·5 inches in diameter and 8 to 12 rows of large kernels. Quality good but not quite equal to CH-1. Because of its earliness, good ear size and good yield, this hybrid may have a place as a home garden, market or canning type.

Ottawa CH-3

A hybrid produced from the Ottawa inbreds CO-13 × CO-102. The plant averages 58 inches in height, slightly earlier than CH-1 and ready for processing in 74 days. It yields an average of 1·3 marketable ears per plant. Tillers vigorous, often producing ears suitable for table use but not for processing. Ears usually 8-rowed, 5·8 inches long and 1·4 inches in diameter. Kernels deep, golden, tender and sweet. It rated high in freezing tests, is remarkable for its prolific character and high quality, and may be of value for market and freezing. The small size ear is its chief disadvantage.

Ottawa CH-4

Produced from CO-100 × CO-14. A medium late type requiring 84 days until ready for processing. This has rated very highly in freezing tests. Plants vigorous, erect, averaging 63 inches. Ears average 7·1 inches in length, 1·6 inches in diameter with 8 or 10 rows of kernels which are golden, wide, deep and thick. This hybrid appears promising as a freezer or a canner.

Ottawa CH-5

Obtained from CO-101 × CO-110. It averages 85 inches in height; is late, requiring 85-90 days until ready for use; productive, with ears averaging 7·4 inches in length and 1·9 inches in diameter, with 10 to 14 rows of kernels. Kernels are golden, wide, thick and very deep. This hybrid produces a fine appearing good quality corn of canning type.

Ottawa CH-6

Produced from CO-108 × CO-20. A medium late type requiring 83 days until ready for use. Average height 80 inches with 1·6 marketable ears per plant. Mostly 12-rowed, with small proportions of 10- and 14-rowed ears. It has good quality, is heavy yielding and may be well adapted for canning.

Ottawa CH-7

A hybrid involving the cross CO-110 × CO-18. Late, ready for use in 85 days, a heavy yielder. Ears average 6·5 inches in length and 1·7 inches in diameter; the majority are 12-rowed with some 10-rowed. Kernels golden, deep, with a tender pericarp and good flavour. This may be of value for canning.

In the production of these single cross hybrids one of the principal objectives has been to combine high yield and large ear size with the top quality of some of the older inbred and open-pollinated lines. The hybrids described in the foregoing are notable for their good quality and are superior in this respect to many of the standard hybrids tested at Ottawa up to this time.

Onions

The onion breeding program before 1934 was aimed at developing a high quality, early maturing, long keeping onion. Several crosses were made, but selection work has been slow since each generation requires two years to produce seed. The process has been hastened to some extent by growing seed crops in the greenhouse during winter but this has been very limited. Each of the seed-producing bulbs must be isolated with a cage or bag, at least in the earlier segregating generations. The flowers must then be pollinated by hand, or by the introduction of bees or flies into the cage.

In addition to this earlier work, a series of crosses was made in 1936-37. With a view toward producing a good keeping, mild and white skinned variety some of the mild white onions were included. The progenies of these latter crosses are still showing some segregation, but include some promising material.

From the older crosses a number of promising lines have been isolated. Two of these have been placed under number and are as follows:

Ottawa ON-1

A selection from the cross Flat Red × Yellow Globe Danvers. Skin yellow and texture fine as in Yellow Globe Danvers. Of medium size, definitely flattened with an approximate shape index (equatorial diameter divided by polar diameter) of 1·6. Exceptionally early maturing and an excellent keeping onion.

Ottawa ON-2

A selection from the cross Bermuda × Ebenezer. Skin tan-yellow, and the outer skin tends to be rather thick in the dry state. Bulbs round to very slightly flattened with an approximate shape index of 1·1. It is not quite so early as ON-1 and is an excellent storage onion.

Peas

Breeding work for the improvement of garden and canning peas has been carried on at the Division of Horticulture for a number of years with definite progress. The variety Tiny has already been introduced to the canners and has met with some favour as a high quality, very small seeded canner. It is described as follows:

Tiny

Origin.—Selection from the cross Winged Sweet × Pois de Roston, made in 1925 and named in 1932. *Dry Seed.*—Small (380 per ounce), wrinkled, squared; medium green, shading to cream. *Plant.*—Medium to tall, approximately 38 in. Internodes medium length; some branching. Leaflets medium green. A prolific cropper. *Flowers.*—White, medium size, borne singly and in pairs. *Pods.*—Small, average length 2 in., depth (dorsal to ventral side) $\frac{3}{8}$ in., breadth $\frac{1}{4}$ in. Slightly curved backward, ends blunt; medium green. *Green Peas.*—Small, average diameter $\frac{9}{32}$ in., free in the pods in the early stages, becoming crowded

at maturity; six peas per pod; medium to pale green; medium quality. *Season.*—Midseason, requiring 65 days from sowing to ready for use. *Adaptation.*—Canning as a very small pea.

Field Selections for Resistnce to Root-Rots

From 1934 to 1936, the emphasis in breeding and selection work was upon the improvement of canning and garden peas by combining earliness of maturity, heavy yield and good quality. It became apparent also that selection work could be carried on in the field for disease resistance. Root-rots (especially *Fusarium* sp.) had become quite prevalent and it was possible to note definite varietal differences. In 1935 and 1936, a number of selections from the numerous crosses made in previous years showed real promise. Two of these selections have been developed into named varieties which have a wide range of adaptability and are suitable for prairie conditions. They are:

Engress

Origin.—Selection from the cross English Wonder × Laxton Progress made in 1922 and named in 1935. *Dry seed.*—Large (89 per ounce), very wrinkled, flattened to very slightly squared. Cream to pale green. *Plant.*—Height approximately 22 in., stem branching, internodes relatively short; leaves medium size, dark green. *Flowers.*—White, borne singly, occasionally in pairs. *Pods.*—Large, length 3½ in., depth $\frac{13}{16}$ in., breadth ½ in. *Green Peas.*—Large, round-oval, averaging 6 per pod; attractive green, very tender and sweet and retaining these qualities over a long period. *Season.*—Second early, requiring about 64 days until ready for use. *Adaptation.*—Home and market garden. Considerable tolerance to heat and drought conditions.

Laxall

Origin.—A selection from the cross Laxton Progress × Earliest of All. Named in 1936. *Dry Seed.*—Very wrinkled, squared, cream to olive-green (175 per ounce). *Plant.*—Small, sturdy, with a single, erect, zig-zag stem. Height averages 14 to 18 in.; foliage dark green. *Flowers.*—White, borne singly or in pairs. *Pods.*—Straight, semi-blunt, well filled, average length 2½ to 3 in., dark green. *Green Peas.*—Medium to small, dark green, high quality, average 6 per pod. *Season.*—Drought resistant home garden type well suited for Western Canada; some resistance to Fusarium root-rot.

The increasing prevalence of the soil borne Fusarium root-rot disease has brought about the initiation of breeding work designed to produce disease resistant, horticulturally desirable types. Some of the smooth-seeded field pea varieties possessed apparent tolerance to this disease. They included the varieties Sterling, English Marrowfat, Brown Eyed Susan, Alaska, White Elephant, Small Round and Green Scotch. The good quality wrinkled seeded varieties which were used included Lincoln, Thos. Laxton, Giant Stride, Prince of Wales, V.C., American Wonder, Onward, Quite Content, Laxall and Laxton Progress. A number of combinations were made with these varieties, and by 1937 when most of the selections were in the fifth generation there was some evidence that superior types would be obtained. In this work no artificial inoculations were made, but the various segregations from the crosses were grown on disease infested soil. Certain of the crosses made in this series have produced selections which, although not highly disease resistant, do possess other valuable characteristics. Noteworthy among these are the varieties Smallton and Alton which are described as follows:

Smallton

Origin.—Selection from the cross Small Round × Thos. Laxton made in 1929 and named in 1937. *Dry Seed.*—Medium size (143 per ounce), almost round

to slightly flattened, finely wrinkled; pale green to cream. *Plant.*—Tall, average height 45 to 55 in., strong, vigorous; leaves medium large, medium green. *Flowers.*—White, borne singly and in pairs. *Pods.*—Borne well up from the ground, length 3¼ to 3½ in., slightly curved, blunt and borne singly or in pairs. *Green Peas.*—Good quality, firm texture, medium to dark green. *Season.*—Midseason, about 43 days to flowering and from 60 to 70 days until ready for use. *Adaptation.*—Moderately susceptible to Fusarium root-rot, but especially well suited for freezing because of the good colour and firm texture of the green peas.

Alton

Origin.—Selection from the cross Alaska × Thos. Laxton made in 1929 and named in 1938. *Dry Seed.*—Medium size (113 per ounce); square to semi-flat, wrinkled; green and cream to grey-green. *Plant.*—Medium height, averaging 36 in., stem nearly straight with one or two branches, erect habit of growth; leaves pale to medium green; prolific. *Flowers.*—White, borne singly. *Pods.*—Borne well up from the ground. Average length 2¾ in., straight, blunt; medium to dark green. Deeper than Alaska and round in cross-section. Usually 3 to 4 pods ready for canning at one time. *Green Peas.*—Average 6 per pod, medium to large; medium to dark green; flavour sweet; pericarp medium tough and does not break down in processing. *Season.*—55 to 60 days until ready for use. *Adaptation.*—A high quality, early variety for canning and freezing and well adapted to field production. Also useful as a home and market garden variety.

Field Selections for Tolerance to Ascochyta Blight

In 1938 work was begun on selection of pea strains for their tolerance to Ascochyta blight. The disease had become prevalent in the Gaspé area of Quebec and in some Ontario localities. A number of the more advanced segregations from Ottawa crosses were sent to Gaspé for trials. Results were not too promising and it was decided to begin a systematic search for resistance to Ascochyta blight. This experiment is still in progress and is discussed in more detail under the section on "Breeding and selection of peas for resistance to Ascochyta blight".

From 1939 to 1948, emphasis has been on disease resistance and the only new crosses made have involved some of the strains of peas showing partial resistance to *Ascochyta pisi*. However, since a large number of crosses had been made from 1929 to 1939, there were still a great many segregates available for testing and selection in the field. Several of these appear very promising for tolerance to root-rots or as processing types. Two such strains are as follows:

Ottawa PE-1

Origin.—Selection from the cross Dwarf Telephone × Forty Days. *Dry Seed.*—Medium size (140 per ounce), somewhat rounded drum shape, well wrinkled; green with a small percentage of greenish cream seeds. *Plant.*—Medium to tall, averaging 42 in., straight stems and upright habit. Foliage dark green, medium to small leaflets. A prolific cropper. *Flowers.*—White, majority borne in pairs, some singly. *Pods.*—Borne well up from the ground; small, average length 2½ to 2¾ in.; roundly blunt, straight, slender, dark green. *Green Peas.*—Small, averaging 6 to 7 peas per pod, firmly packed. Good green colour and good quality. *Season.*—Midseason, requiring about 64 days until ready for use. *Adaptation.*—Some resistance to Fusarium root-rot and to some strains of *Ascochyta pisi*. Suitable for home and market garden and as a heavy yielding mid-season canner with possibilities for freezing.

Ottawa PE-2

Origin.—Selection from the cross Dwarf Telephone × Moscow White. *Dry Seed.*—Large (86 seeds per ounce); deep-flat, well wrinkled; cream and green.

Plant.—Medium height, averaging 30 in.; stem stout, moderately zig-zag; leaflets large, medium green. *Flowers.*—White, mostly single but occasionally in pairs. *Pods.*—Large, average length 3½ in.; borne singly, medium slender, straight and blunt, somewhat similar to Dwarf Telephone pods. *Green Peas.*—Good dark green, 5 to 7 peas per pod; medium sweet with medium tough skin. *Season.*—Midseason to late, requiring about 40 days from sowing to bloom and 62 to 70 days until ready for use. *Adaptation.*—Home and market garden; produces over a fairly long period. Its good colour and firmness make it suitable for freezing. Stands up well to Fusarium root-rot and moderately well to *Ascochyta pisi.*

Further testing is being carried out with the almost homozygous selections from many of the crosses made before 1939. At present 34 of these strains are under test. These include several which appear to have a useful place as canning, freezing or market types. In this selection work the ability of a selection to resist disease infection in the field has been one of the principal factors on which selections are based. This has resulted in the isolation of several horticulturally desirable strains which possess a high degree of tolerance to disease in the field.

Breeding and Selection for Resistance to Ascochyta Blight

In recent years, with the intensified production of peas for canning, freezing and market, certain pea diseases have assumed considerable importance in Ontario and Quebec. The diseases caused by *Ascochyta* species of fungus have become widespread. These diseases are caused by one or all of the three organisms: *Ascochyta pisi, Ascochyta (*or *Mycosphaerella) pinodes* and *Ascochyta pinodella.* Of these *A. pisi* is the most widespread in Eastern Canada, while *A. pinodes* if present, causes the most serious injury. *A. pisi* is a leaf, stem and pod spot which, if serious, will prevent the pods from reaching the canning stage or cause severe damage in the form of leaf, stem and pod lesions. In addition to leaf, stem and pod lesions, *A. pinodes* also causes a severe foot-rot. *A. pinodella* is a foot-rot organism.

In 1939 a project was initiated at the Division of Horticulture in an attempt to find resistance to both *A. pisi* and *A. pinodes.* The first tests were made with both these organisms, but in later tests it was decided to concentrate on the search for resistance to *A. pisi.* The experiments have been carried out in the greenhouses of the Division of Horticulture, while the disease isolates have been maintained and inoculum supplied by the Division of Botany and Plant Pathology, Science Service. Over 100 strains, varieties and species of peas have been subjected to inoculation with either one or both of the disease organisms, *A. pisi* and *A. pinodes.* In some cases single plant selections were made on the basis of disease resistance and progeny tests were carried out. The test sample of each pea strain consists of 50 plants grown in greenhouse flats. Inoculations are carried out in a large glass moisture chamber capable of holding 500 plants. Infection counts are made and the plants within each pea strain are grouped into "Reaction Classes" giving an indication of the resistance of the strain of peas and of its degree of homozygosity for resistance.

Discussion of Results

The first few tests involved a number of standard varieties of peas, but consisted mainly of established selections from crosses made by the Division of Horticulture. Certain of the Ottawa selections showed a high degree of resistance to *A. pisi.* These strains were propagated, tested and reselected until they appeared to have reached homozygosity for resistance or partial resistance. The most promising selections were A-100 and A-101. The former is a selection of V.C. × American Wonder and the latter a selection from the Ottawa variety Swonder (Green Sweet × English Wonder). No useful resistance was found to

A. pinodes, although it was noted that many of the pea strains differed significantly in their reactions to the disease. No relationship was apparent between reaction to *A. pisi* and reaction to *A. pinodes.*

As the process of variety and strain testing progressed, it became apparent that different physiological races of the disease organism were present. This was evident when new disease isolates used as inoculum produced results which differed from those obtained in previous tests on the same strains of peas. In Test 9 (1945-46) a number of pea strains, which had been selected because of their high degree of resistance to *A. pisi* in previous tests, were subjected to inoculation with an isolate of *A. pisi* not previously used.

The selections from the cross Green Admiral × Horal, previously considered highly resistant, proved very susceptible to the new disease isolate while selections of other crosses were still highly resistant. In these tests it was evident that pea selections which were homozygous for horticultural characteristics might still be heterozygous in their reactions to inoculation with *A. pisi.* However, in Test 10, as a result of further selection, a number of selections from the cross V.C. × American Wonder appeared to be practically homozygous for complete immunity and showed no significant differences in their reactions to the disease. In this same test the check varieties were highly susceptible, and moderately resistant strains were heterozygous in their reaction.

In Test 11 study was made of the effect of 20 different disease isolates, collected from as many sources in Canada and England, on the "resistant" pea selection, A-100, and on the "susceptible" variety, Thos. Laxton. Twenty-five plants of each of the two pea strains were inoculated with each of the 20 isolates.

The results showed that A-100, although highly resistant to the majority of the isolates, was definitely susceptible to others, while the "susceptible" variety, Thos Laxton, actually showed greater resistance to four of the isolates than did the variety with greater general resistance. To three other isolates both varieties showed resistance with no appreciable differences between their mean reactions. This suggested a high degree of resistance even for the "susceptible" variety to certain disease isolates. It is possible also that this might indicate a general lack of virulence on the part of certain races of the pathogen.

It was apparent from these tests that various combinations of resistance and susceptibility to different races of *A. pisi* may exist in pea varieties.

In 1947 and 1948 samples of a number of pea strains were tested in field plots. Results of the 1948 test indicated that an Ottawa selection of the pea sub-species, *Pisum sativum elatius,* might possess considerable resistance to *A. pisi.* In a further greenhouse inoculation test, two selections from this same seed stock have shown almost complete immunity to a highly virulent strain of *A. pisi.*

Single plant selections have been made from these disease resistant strains and will be propagated for further breeding and testing.

Breeding work is now under way in an attempt to transmit the partial resistance of the pea strains, A-100, A-101, A-107 (an Austrian Winter selection) and *Pisum elatius* to more desirable horticultural varieties.

A knowledge of the different races of the disease organism and their effect on different pea varieties will be important in carrying on further breeding work for resistance to *A. pisi.*

Spinach

The four types or groups of plants commonly found in most varieties of spinach are extreme males, vegetative males, females and hermaphrodites. The first two do not produce seed. The extreme males are undesirable; they are

early bolting, have small leaves and the pollen will transmit these characters to seed bearing plants. The vegetative males produce good type plants but since such plants produce male flowers only they shed pollen but do not bear seed. The hermaphroditic plants which bear male and female flowers produce seed as do the female plants.

The presence of extreme males in seed fields presents a serious problem to the seed grower. In addition, the Canadian Seed Growers' Association will not grant "Registered Status" to seed crops of the Bloomsdale group, which have more than 12 per cent extreme males or to seed crops of other varieties with more than 8 per cent.

Work was started in 1942 to overcome this situation and to provide Canadian seed growers with a suitable source of seed. Seed from individual plant selections was sown in the greenhouse during winter months. From the progeny, selected monoecious or hermaphroditic plants were isolated. The seed from these plants was planted for further selection. After several generations a number of selected lines were obtained all of which were hermaphroditic and uniform. These were recombined and have produced two generations of seed which are entirely hermaphroditic in tests at Ottawa. However, co-operators at other institutions across Canada have not always reported complete hermaphroditism. Trials were conducted in 1947 and 1948 at Saanichton, B.C.; Vancouver, B.C.; Edmonton, Alta.; Winnipeg, Man.; Ottawa, Ont., and Macdonald College, Que.

In 1947 a total of 400 plants were grown at these localities and in 1948 the progeny of this stock, totalling 413 plants, was tested. The reports showed the following results:

	1947	1948
Hermaphrodites	72%	89%
Females	23%	6·3%
Vegetative Males	4%	4·4%
Extreme Males	1%	0·3%

In 1947 two localities, Vancouver and Ottawa, reported 100 per cent hermaphrodites. In 1948 Winnipeg and Ottawa reported all plants hermaphrodites.

The progress made at present shows this stock to be very well suited for both production and seed growing. It is expected that further improvement may result in a good strain of Long Standing Bloomsdale which will be completely hermaphroditic in all parts of Canada.

Tomatoes

Tomato breeding in the earlier years at the Division of Horticulture had as its main objectives earliness, quality and productivity. By 1934, two of the earlier originations, Abel and Bestal, were being grown as standard varieties. Abel especially had proved valuable for its exceptional earliness combined with moderately good quality and yield. Breeding work was continued along these lines for several years. A great many controlled crosses were made within the *Lycopersicon esculentum* species, and the most promising selections from these were tested at Ottawa and other stations across Canada. One of these, Globonnie, performed well in various parts of Canada as a medium early, high quality type for garden and canning.

Globonnie

Origin.—Selection from the cross Livingstone Globe × Bonny Best; named in 1935. *Plant.*—Indeterminate, vigorous growing, strong, spreading to moderately upright, leaves large and plentiful. *Fruit.*—Medium size, averaging 4·6 ounces; round, smooth, ripening evenly to the calyx. Skin strong, thick, deep

red. Internal structure firm; cell walls thick and meaty. Flavour mild to almost sweet. Texture firm and good. *Season.*—Midseason, requiring about 75 days from setting out until ready for use. *Adaptation.*—Staking or growing as an unstaked variety. Suitable for canning, home or market garden.

From 1935-39, the crosses made were principally between various standard varieties in an effort to obtain earliness combined with quality and other desirable characteristics. A great many progenies were grown and evaluated for their possibilities as canning, market or home garden types. Results were not too promising with this material, although one cross Abel × Marglobe made in 1935, showed some useful appearing segregations.

In 1939-40 a new series of crosses was made. The parents were varieties or selections which in trials at Ottawa had shown earliness, high yielding ability or in some cases apparent disease tolerance (to Septoria and Alternaria leaf blight).

Crosses with *L. pimpinellifolium* did not result in any outstanding selections since in all cases the earliness of *L. pimpinellifolium* was associated with very small fruit size. Backcrossing resulted in increased fruit size, but loss of the extreme earliness. No selection from the *L. pimpinellifolium* crosses had more than a moderate tolerance to early blight *(Alternaria solani)*. Certain of the crosses with the North Dakota State College introductions did produce some promising selections. One of the best of these was a selection of the cross N.D. 303 × Ventura, an indeterminate type, the fruit of which showed the uniform colour gene (pale green skin) of the N.D. 303 parent.

Among the cosses made in 1938-39 was one, Rutgers × Allred. Rutgers is a high quality, vigorous late variety with some tolerance to Alternaria and Septoria, while Allred is a very early North Dakota variety, dwarf determinate in habit, with good red coloured fruit of medium size. Selections from this cross showed some value in 1940 because of their compact plant habit and good red fruit colour.

By 1942, selections of the crosses Abel × Marglobe, N.D. 303 × Ventura and Rutgers × Allred were showing up very well, especially the Abel × Marglobe selections. In 1942 one of these latter selections was the highest yielding and earliest strain in a test of 21 varieties. Many of the aforementioned crosses were made in the early years of the war and it was found impossible to continue adequate selection work during the war period. However, by 1946 this work was resumed on a wider scale.

The best of the Abel × Marglobe selections was placed under number as Ottawa TO-3. This variety has met with approval at several stations because of its exceptional earliness, good yielding ability and good quality. A brief description follows:

Ottawa TO-3

Origin.—Selection from the cross Abel × Marglobe made in 1935. *Plant.*—Indeterminate, vigorous. Larger than Abel but less vigorous than Marglobe. Moderately spreading habit. Foliage medium green with medium size leaflets. *Fruit.*—Medium size, occasionally small; average equatorial diameter 2½ in., polar diameter 1¼ in.; weight 3·5 oz. Smooth, free from ribbing or roughness. Immature fruit, dark green on shoulders but bright red when ripe. Tendency to rather pale core. Locules occasionally greenish but green tinge lost when fruit is fully ripe. *Season.*—Early, about 65-70 days from setting out to ripe fruit, about one week earlier than Abel. *Adaptation.*—Principally an early home or market type, but may be used as a heavy yielding canner.

Two other very promising selections were placed under number at the same time. These are TO-4 (Rutgers × Allred) and TO-10 (N.D. 303 × Ventura). TO-4 shows particular promise as a canning type. These selections are described as follows:

Ottawa TO-4

Origin.—Selection from the cross Rutgers × Allred made in 1939. *Plant.*—Determinate, but not extremely so, compact; foliage dense, dark green; leaflets medium size giving fairly good coverage to the fruit. *Fruit.*—Medium size averaging 4·6 oz.; slightly flattened to globe, smooth at both blossom and stem ends. Exterior colour deep red, flesh dark to medium red, core tends to be rather light. Texture and flavour good. *Season.*—Midseason, ripe in 75 days from setting out. *Adaptation.*—A desirable canning variety also suitable for market where a non-staking type is desired. Fairly tolerant to early blight *(Alternaria solani)*.

Ottawa TO-10

Origin.—Selection from the cross N.D. 303 × Ventura made in 1940. *Plant.*—Indeterminate, vigorous, staking type. Leaflets medium size, dark green, giving good foliage cover. *Fruit.*—Medium to small, carried in large trusses, average fruit weight 2·7 to 3·0 oz. Very smooth, practically no stem or blossom end cavities. Immature fruit pale green (uniform colour gene). When ripe, exterior colour bright red; flesh medium red occasionally tending to pale red. Core small, texture medium good, walls thick. Resistant to skin cracking. *Season.*—Midseason, 75-78 days from setting out. *Adaptation.*—Good yielding home or market garden type; well suited to staking. Especially useful for its comparative freedom from cracking and splitting.

As mentioned before breeding work was curtailed during the war but was renewed in 1946. In all there were 76 second and third generation progenies grown in addition to 14 selections in more advanced stages. From the F_2 and F_3 strains 52 selections were made. The principal objectives in making these selections were earliness, good fruit colour, desirable plant habit, disease resistance and general suitability for canning or market purposes. Early blight *(Alternaria solani)* was quite prevalent in the plots, although late blight *(Phytophthora infestans)* was not present. This selection work was continued in 1947 when there was a severe infection of early blight. All selections were rated for degree of freedom from early blight and it was apparent that there was a great deal of variation between and occasionally within the strains. Among the many parents used in these crosses, certain ones appeared to transmit at least moderate early blight resistance to their progeny. The better parent strains were *Lycopersicon pimpinellifolium*, Early Rutgers, Devon Surprise, Golden Perfection, Danmark and Ottawa TO-8.

In 1948 selection work was continued with these strains. Several appeared promising as canning types and those which had reached a reasonable degree of uniformity in plant and fruit types were placed under number as follows:

Ottawa TO-14

Selection from the cross Schtambuvy × Bounty made in 1941. Plant moderately determinate, somewhat open, fruit medium size. Interior and exterior good red colour with uniform skin colour and very little cracking. Season early. A possible canning variety.

Ottawa TO-15

Selection from the cross Rutgers × Redskin made in 1941. Determinate, compact with fair leaf coverage. May have some resistance to early blight. Fruit rather small, very little cracking, good red skin and flesh colour, uniform skin colour. Very prolific; early.

Ottawa TO-16

Selection from the cross N.D. 38 × Early Rutgers made in 1941. Indeterminate but compact. Appears to have some tolerance to early blight. Fruit

medium to large, good red skin and flesh colour, uniform skin colour. Early, very smooth and firm and a good possibility for canning.

Ottawa TO-17

Selection from the cross Bounty × Early Rutgers made in 1941. Determinate. Fruit uniform colour, good red skin and flesh colour when ripe; large, meaty and smooth. Midseason, slightly later than Bounty but more vigorous and gives better cover. Shows promise as a canner or a market type.

Ottawa TO-18

Selection from the cross (Jan-ru × Farthest North) × Bounty made in 1941. Determinate, rather open foliage habit. Fruit medium size, firm, very smooth, globe shaped. Fruit uniform colour; when ripe, skin a good red; texture quite strong. Flesh medium good colour, very firm and mild in flavour. Very early and may be useful for its earliness or as a canner.

Further breeding work was carried on in 1948. Several of the well established Ottawa varieties were used in combination with other varieties or species in an attempt to give them better size, colour, disease resistance, increased vitamin C content, etc.

In using the Andean species *L. peruvianum* and *L. hirsutum* some difficulties were encountered. The *hirsutum* species failed entirely to set fruit when either self- or cross-pollinated. *L. peruvianum* at first behaved in the same manner, but later in the season one plant set fruit from self-pollinated flowers. Cuttings from this plant later set fruit freely in the field. However, successful crosses were obtained by using *peruvianum* and *hirsutum* as pollen parents on *esculentum* flowers.

The first generations from all these crosses were grown either in the field or in the greenhouse. The crosses with *L. peruvianum* proved fertile and set fruit and seed readily. Plant and fruit characters were intermediate between the parental types. The crosses with *L. hirsutum* failed to set fruit and in one cross, San Rais × *L. hirsutum*, the F_1 plants showed a progressive necrosis of the leaves, only the upper growing tip remaining green. Scions of this type were grafted to normal *esculentum* plants of the Abel variety, but the necrosis continued on the scion portion. Apparently this is a genetic factor and in fact it is evident in a much milder form on the *L. hirsutum* parent of these crosses. This hybrid is being maintained vegetatively in the hope of obtaining flowers and backcrossing it to the *esculentum* parent. The F_1 of another cross, Sparx × *L. hirsutum*, showed the same type of necrosis plus a small percentage of non-necrotic, extremely vigorous plants very similar to the *hirsutum* parent. After a lengthy growing period these finally set fruit which contained undeveloped seed.

This work is being continued and integrated with the work on resistance to late blight. Thus where certain varieties or species are known to possess some degree of resistance to late blight, then the segregating F_2 progenies of crosses of these strains are subjected to inoculation with the late blight organism.

Breeding for Resistance to Late Blight (*Phytophthora infestans*)

Late blight on tomatoes is caused by the fungus organism *Phytophthora infestans* (Mont.) de Bary, the same organism which causes late blight of potatoes. Because of economic losses caused by this disease, a co-operative experiment has recently been undertaken by the Division of Horticulture and the Division of Botany and Plant Pathology, Science Service, for the purpose of breeding or selecting horticulturally desirable strains of tomatoes resistant to the late blight organism.

The preliminary tests for resistance are made by means of greenhouse inoculations. These tests are carried on in the greenhouses of the Division of Horticulture, where the plant material is assembled and grown. Disease material is provided and examinations are made by the co-operating officer of the Plant Pathology Division. The disease inoculum consists of a spore suspension in distilled water, which is sprayed on the plants when they are about four to five inches high. The plants are grown in wire-bottomed greenhouse flats, fifty plants to a flat. Two flats of each of ten strains are placed at random in a moisture chamber at the time of inoculation. The humidity of the moisture chamber is kept high and the temperature relatively low (50° to 60°F.). After inoculation the plants remain in the chamber two to four days, by which time disease injury is normally quite apparent.

In April, 1948, the first preliminary test was made, mainly in order to ascertain the virulence of the late blight inoculum available at that time. Four varieties of tomatoes, two of them known to be highly susceptible, were inoculated. Individual plants were classified according to their reaction to the disease and a mean reaction value was thus obtained for each tomato variety. The variety, Stokesdale, because of its very definite susceptibility, was selected for use as a check variety in future tests.

The technique was used in one full regular test in the fall of 1948. This test involved two standard varieties and eight second generation progenies of Ottawa crosses. These crosses had been made primarily with a view to obtaining some resistance to *Alternaria solani* (early blight) but it was thought advisable to obtain their reaction to late blight.

In neither the preliminary nor the first regular test was any indication of resistance found, although the varieties, San Rais and San Marzano, appeared to be somewhat less susceptible than the other strains tested. This work is being continued and will involve the testing of a large number of varieties and species now available for this purpose. If resistance is found, attempts will be made to incorporate this into desirable horticultural varieties.

Seed Production and Verification Trials

Seed Production

Seed production of a number of varieties has been an important phase of the vegetable work during the past fifteen years. Continued and careful selection have improved the quality and purity of varieties originated in this Division and others grown as foundation seed. The foundation seed work is carried on in close co-operation with the Canadian Seed Growers' Association and the seed is used as the basis for much of the registered and certified vegetable seed produced in Canada.

The production and importance of foundation seed have increased greatly during the past seven years. At present there are 268 assignments of vegetable varieties for foundation seed production. Certain Provincial and other sources are responsible for 94; the Dominion Experimental Farms Service carry 174 of which 49 are assigned to this Division as follows:

Bean.—Masterpiece, Pacer, Pencil Pod Black Wax, Round Pod Kidney Wax, Stringless Green Pod and Tendergreen.

Beet.—Detroit Dark Red No. 16.

Cabbage.—Chieftain Savoy, Danish Ballhead and Golden Acre.

Carrot.—Chantenay No. 27 and Imperator.

Citron.—Red Seeded.

Corn.—Banting, Dorick, Dorinny, Goldban, Pickaninny and Dorking.

Cucumber.—Delcrow and Mincu.

Eggplant.—Blackie.

Leek.—Giant Carentan.

Lettuce.—Grand Rapids.

Onion.—Red Wethersfield and Yellow Globe Danvers No. 11.

Parsnip.—Hollow Crown.

Pea.—Alton, Director, Engress, Kootenay, Laxall, Laxton Progress, Laxtonian, Onward, Prince of Wales, Thos. Laxton and Tiny.

Radish.—Comet and Saxa.

Soybean.—Blackeye.

Spinach.—Bloomsdale.

Squash.—Golden Hubbard and Kitchenette.

Swiss Chard.—Lucullus.

Tomato.—Abel, Bestal and Globonnie.

Turnip.—White Top Milan.

The distribution of all foundation seed produced at the Dominion and some Provincial institutions to the growers of registered seed is handled through this Division. A seed list of available foundation stocks is prepared and circulated each year to those interested in registered seed production. The increasing value and usefulness of these stocks are shown by the distribution of various quantities in the last three years to different seed producers; 29 varieties in 1946, 34 varieties in 1947 and 51 in 1948.

Commercial seed growers can produce four generations of registered seed of close-pollinated varieties from foundation seed and two generations from open-pollinated varieties of foundation seed. In each case the last generation of registered seed can be used to produce one generation of certified seed.

Verification Trials

Verification Trials are conducted in co-operation with the Canadian Seed Growers' Association at various Dominion and Provincial agricultural institutions including the Division of Horticulture. The seed samples, prior to 1944, were taken from seed crops produced for registration. After successfully meeting the requirements for purity and trueness to type in the Verification Trials, the stocks were granted registration by the Canadian Seed Growers' Association. Since 1944 the trials have been confined to verifying seed stocks grown for foundation status. This reduces the number of verifications and permits the use of much larger populations in the trials. The Canadian Seed Growers' Association grants foundation status to the seed stocks based on the combined reports of the Verification Trials at several testing stations subject, of course, to pathologists' reports on the health condition of the seed stock.

The number of stocks tested in this Division varies each year from 50 to 100 samples depending upon the material to be tested. For example, a verification on a radish sample can be made on a 60 ft. row which would not require more than 90 square feet but a verification on a tomato sample requires 1,000 square feet and a sample of squash or pumpkin requires 2,400 square feet. Therefore, a much larger number of verifications of the smaller type of vegetable can be accommodated in a given area. The reports vary with the different kinds of vegetables but in general they include all pertinent dates, plant formation, maturity, colour, measurements for size and shape, quality and other details. As stated above this information may be compared or combined with that from several testing stations.

Vegetable Varieties Showing Promise in Merit Trials

The purpose of these trials is to test new varieties for merit or value in different parts of Canada. The trials are organized from this Division. Seed samples are obtained from plant breeders and experimental institutions in Canada and other countries and from various seed companies.

This material is then grown in trial grounds at the Division of Horticulture at Ottawa and by co-operators in trial grounds at other institutions across Canada. These co-operators are:

Professor A. F. Barss, University of British Columbia, Vancouver, B.C.

Dr. R. C. Palmer, Dominion Experimental Station, Summerland, B.C.

Professor R. J. Hilton, University of Alberta, Edmonton, Alta.

Professor E. T. Andersen, University of Manitoba, Winnipeg, Man.

Dr. E. F. Palmer, Horticultural Experiment Station, Vineland Station, Ontario.

Professor H. R. Murray, Macdonald College, Que.

W. G. Sallans, Plant Products Laboratory, Sackville, N.B.

The information obtained from these trials is used to indicate the usefulness and superiority of a variety. This may show up in several ways as: Regional suitability, home, market garden or special adaptation for canning and freezing, season, yield, type of growth, appearance, flavour, colour, quality, resistance to disease or insect pests and particular qualities which might be of value in plant breeding.

Several hundred varieties of vegetables have been tested. Naturally some varieties did not show any particular value; in other instances material showed merit in some localities and not in others, which indicated regional suitability. Occasionally samples were included in the trials which were not exactly new to the seed trade or to the growers but their value in different parts of the country was not known.

A comparison of the results from the different trial grounds indicates that the following varieties are worthy of mention as having merit or value:

Beans

Ace.—Seed was obtained from the Dominion Experimental Station, Kentville, N.S., where selection has been maintained. The variety originated at the Division of Horticulture at Ottawa and is described on page 60. It had some merit at the University of Alberta, Edmonton, as a very early wax podded variety of medium quality. It matures in about the same season as the flat podded varieties Pacer and Princess of Artois.

Cherokee Wax.—Seed was obtained from the Harris Seed Company, Rochester, New York. The variety itself was developed by the South Carolina Truck Experiment Station at Charleston, S.C. It was developed as a "sport" which appeared in a stock of Black Valentine. At Winnipeg and Sackville it was a heavy yielding bean, considered as having high quality and good possibilities for processing. It was highly regarded at Ottawa but was badly affected with bacterial blight. Cherokee Wax is a large, vigorous bush type with oval to flat, yellow, stringless, and almost straight, pods. Quality is not quite so good as the variety Logan.

Logan.—Seed was obtained from Vaughan's Seed Company, Chicago, U.S.A. The Logan variety is an origination of the United States Department of Agriculture, resulting from the cross United States No. 5 Refugee × Stringless Black Valentine. It was popular in the trials at Vancouver, Edmonton, Winnipeg, Vineland, Ottawa and Sackville for its earliness, quality and good yield. Logan

is a bush bean with pods which are green, round, stringless and tender. It is suitable for market gardening and processing. This variety may prove generally popular. It shows some freedom from disease but is not completely resistant to halo or bacterial blight.

Merton Selection No. 22X.—Seed was obtained from John Innes Horticultural Institution, Merton, England. It showed possible merit at Ottawa and Vineland in 1947. A bush shell bean; seeds white, medium size, short, plump, "navy" type. Pods pale green, short, stringy and straight. This was a very early and productive variety. At Ottawa pods were ripening in 82 days, which may be early enough to escape serious infection by bacterial blight. However, it was not immune.

Ottawa BA-2.—A numbered variety developed at the Division of Horticulture and described on p. 61. It showed merit at Ottawa and Vineland, Ontario, and at the University of British Columbia as an early to midseason bush variety with an abundance of attractive pale green pods. The season at Ottawa is 56 to 58 days; at Vineland it is rated as late, while at the University of British Columbia it is ready for use in 71 days (early). Moderate tolerance to bacterial blight was observed at Ottawa and Vancouver.

Pacer.—The result of selection from an original cross made at the Division of Horticulture, Central Experimental Farm, and described on p. 60. It is principally valuable as a dry-shelled type which yields heavily under a great variety of climatic conditions. In the very young stages it is stringless and can be used as a yellow-podded snap bean before other varieties are ready. The dry seed is white and has good baking quality. This variety has proved satisfactory on the prairies, in British Columbia, Nova Scotia, Northern Ontario and at Fort Vermilion in northern Alberta.

Strider.—Also introduced from the Division of Horticulture. The description may be found on p. 60. It showed merit at Ottawa and at the University of British Columbia. An early to midseason bush variety, 75 days at the University of British Columbia and 60 to 64 days at Ottawa. The pale yellow flat pods and white seed are its chief attractions. At Vancouver it is considered a good canning type with easily harvested pods.

Lima Beans

Early Market.—Seed obtained from the Harris Seed Company. The variety was originated by the United States Department of Agriculture. It was sufficiently early for the growing season at Winnipeg where it was considered to have good yield and quality and was of value for home and market use. At Vineland, Ottawa and Macdonald College it showed merit as a heavy yielder of good quality beans although at Macdonald College it was not so early as Henderson Bush. Usually, however, it is an early, good yielding variety producing large, broad, green beans of excellent quality. It is well adapted for freezing and fresh use.

Henderson Bush.—Seed of this variety was obtained from Kenneth McDonald & Sons Seed Company, Ottawa. Although not a new variety it was included for comparison with Early Market. It is an early, dwarf bush type producing small seed. At Vineland it is recommended as a good freezing variety and at Macdonald College it showed earliness, good yield and no disease.

Soybean

Blackeye.—Another development from the Division of Horticulture, and described on p. 61. As a vegetable soybean, this has proved popular and has considerable merit. It is best suited for regions with a medium to long summer since it requires 105 to 110 days to grow from seed to full maturity. The dry soybeans have a protein content of 39·86 and an oil content of 19·36 per cent. It makes a very good green vegetable when shelled and cooked like peas. The green beans also make a very satisfactory frozen product.

Beet

Detroit Dark Red No. 16.—A distinctive strain of Detroit Dark Red, selected at the Division of Horticulture, Central Experimental Farm. It is an exceptionally high quality strain with a uniformly deep red flesh colour; excellent for table, market or canning.

Cabbage

Rossebo.—Seed received from Jens Roll-Hansen of Norway. This variety showed possible merit at Ottawa in 1947. Although showing great variation, the strain offers some possibilities as a late fall cabbage. In general it appeared to be a round headed type with medium length stems. Heads were compact and of high quality. At Ottawa it was free from black rot, which was prevalent in Danish Ballhead and other varieties in adjacent rows.

Stavanger Torg.—Seed from Jens Roll-Hansen, Norway. It was thought to have some utility at Vineland, University of British Columbia and Ottawa. Although listed as an autumn type this appears to be more of a midseason variety. It shows considerable variation. Leaf colour medium to dark green; stems short; head shape variable but the majority round topped with rounded to tapered base. Size small to medium, but very firm, compact and of good quality. It would be worth further trial as a midseason cabbage of high quality.

Carrot

Amsterdam.—Seed of this variety came from the originator, Masereuw's Zaadteelt en Zaadhandel, Enkhuizen, Netherlands. All the testing stations recommended it highly. It was considered excellent in quality and colour, suitable for home and market garden and possibly for canning. Its chief merit appears to lie in the high quality of the root. It was considered as having some possibilities as a bunching carrot. The roots are slender, well shaped, parallel sided, stump rooted, with slightly rounded crown. The core is very small and the interior colour is deep orange. The tops, however, are small, which may be a disadvantage in a bunching carrot. At Ottawa this variety was not considered superior to the present registered strain of Amsterdam carrot. Although the Canadian registered strain is a somewhat heavier root, it also has fine quality and a larger top more suitable for bunching.

Chantenay No. 27.—A strain selected at the Division of Horticulture, Central Experimental Farm. It is a medium short type of Chantenay notable for its uniformity, smoothness, good yield and quality. It has done well in most parts of Canada where the Chantenay type of carrot is grown. It is suitable for bunching and especially good for storage.

Corn

Golden Bounty.—Seed obtained from Dupuy & Ferguson Seed Company, Montreal, and favourably regarded in the trials at several localities. It was considered a good late variety, suitable for canning at Vancouver, Summerland, Vineland, Ottawa and Macdonald College. In general, this hybrid is a vigorous but late maturing variety with the upper ear approximately 27 inches from the ground. Ears are attractive, long and thick, and average 12 rows.

Lethsun Hybrid.—A sweet corn hybrid developed at the Dominion Experimental Station, Lethbridge, Alberta. It showed possible merit as a very early variety three or four days later than Dorinny at Ottawa. Ears are 6 to 7 inches long and average 12 rows. This had some promise at the University of British Columbia as an early, good producer, but tended towards flintiness at Ottawa.

Ottawa CH-1—An origination from the Division of Horticulture, Central Experimental Farm at Ottawa and still under number. This hybrid is described

on p. 65. At Summerland it was recommended as a good, early, uniform variety with very sweet tender kernels. Similarly, at Vineland, Ottawa and Sackville it showed merit for earliness, uniformity and high quality. In addition, both Summerland and Ottawa rated it a high quality freezing variety.

Sugar Prince.—Seed obtained from the Dominion Experimental Station at Morden, Manitoba, where the hybrid was originated. It was introduced in 1946. At Vancouver it showed promise as a good, sweet, second early variety and is recommended for that region. At Winnipeg, Vineland, Ottawa and Macdonald College it was regarded as a good, early or second early variety, useful for home and market gardens and with good possibilities for canning in certain regions. The ears are large, average 7 to 7½ inches in length and 12 rows of kernels. The upper ear is carried about 14 inches from the ground.

Vinegold.—Originated at, and seed obtained from, the Horticultural Experiment Station at Vineland, Ontario. At Vineland, Ottawa, and Macdonald College it was recommended as a good, late maturing variety, high yielding, with good quality and uniformity. It also indicated merit as a desirable canning type as well as being useful for the home and market garden. It is a strong growing variety. The plants average a height of about 7 feet and the upper ears are carried well above the ground. It is highly productive with ears averaging 7 to 8 inches in length and 12 rows of kernels.

Cucumber

Delcrow.—An origination of the Division of Horticulture, Central Experimental Farm. It is not a new variety but is worthy of mention here because of its outstanding qualities. It is an excellent greenhouse cucumber and is now grown extensively by a number of greenhouse growers. Delcrow is also a popular garden variety in many districts and is grown as far south as Texas. In addition to these uses, it has the merits of high quality, a small seed cavity and a smooth uniform appearance.

Ohio No. 31.—Seed received from the Ohio Agricultural Experiment Station, Wooster, Ohio. It is a selection from the cross Tokyo Long Green × National Pickling. In 1946, this did well at Vineland, yielding well and producing good quality fruits somewhat larger than other pickling varieties. A midseason type; it was considered rather late and with no special merit at other stations although it is claimed to be resistant to mosaic.

Muskmelon

Farnorth 151.—The Dominion Experimental Station at Morden, Manitoba, is responsible for introducing the strain. At Winnipeg, Vineland, Ottawa and Macdonald College it was highly regarded as a desirable early maturing melon suitable for the home garden and local market. It yielded heavily and the melons showed good quality. In addition, this variety has also shown up well in New Brunswick under the short season conditions prevailing there. Although not completely pure, it has good merit as a very early ripening, small size melon.

Watermelon

Early Canada.—Although not a new variety, seed of this was obtained from Scott-Bathgate Seed Company, Winnipeg, to test its usefulness in various parts of Canada. This variety appears to have some merit and matured ripe fruit at Macdonald College, Ottawa, and the University of Manitoba. The fruit has a pale green skin, is oblong to ovoid in shape, and has pale to medium red flesh. It is a medium size melon, slightly larger than Northern Sweet.

Northern Sweet.—Another established variety. The seed was also obtained from Scott-Bathgate Seed Company for trial in various parts of the country. In trials at Ottawa, Macdonald College, University of Manitoba and University of

Alberta, the red flesh colour and the quality were superior to Early Canada but the fruit was not quite so large. Fruit ovoid to oblong, skin dark green.

White Mountain.—Although the seed was received from the Dominion Experimental Station at Morden, Manitoba, the variety was originated by Dr. A. F. Yeager of the New Hampshire Agricultural Experiment Station. This watermelon met with favour at Winnipeg, Vineland, Ottawa and Macdonald College. Its chief merit lies in its earliness and its small size, which makes it an ideal home garden type. It may be termed an 'ice box' type of watermelon. It is about 4 to 5 inches in diameter and 5 to 8 inches long. The flesh is deep red and extends almost to the outer rind. It has good flavour and texture but a slight tendency to split when ripe.

Onion

Kenearly Yellow.—Developed from an off-type plant which appeared in a plot of Early Flat Red, at the Dominion Experimental Station, Kentville, N.S. It showed merit in 1945 and 1947 at the University of Alberta, Edmonton, and University of British Columbia, Vancouver, and was particularly valuable for its earliness at Edmonton. At Ottawa this is 10 days earlier maturing than Ebenezer or Yellow Globe Danvers No. 11, but it shows rather poor storage qualities. Bulbs are yellow, very flat, small to medium in size, and somewhat like Ebenezer.

Yellow Globe Danvers No. 11.—Strain selected from the variety Yellow Globe Danvers at the Division of Horticulture. This onion has proved popular in all short season districts in Canada. It has a useful place on the prairies, in the regions around Port Arthur and Fort William, in the Maritimes and other short-summer districts. It also has shown very good possibilities as a marsh or muck soil onion. Its chief merit lies in its early maturity, excellent storage qualities and good appearance.

Peas

Alton.—Developed at the Division of Horticulture, and described on p. 68 Alton is a promising early type well suited to canning. In season it is two or three days later than Alaska and about the same season as Thos. Laxton and Wisconsin Early Sweet. Ready for canning in 55 to 58 days. The merit of this variety lies in its earliness, upright habit, high yield, and excellent quality and colour for canning and freezing.

Chief.—Seed obtained from Stokely-Van Camp Canning Company, Trenton, Ontario. The variety was developed by Rogers Bros. Seed Company, Chicago, U.S.A. In the 1946 trials this variety did very well at Ottawa, Sackville, Vineland and the University of Alberta. At Sackville it stood up well to drought conditions. It is a medium to tall variety, height varying from 30 inches at the University of Alberta to 50 inches at Vineland. Season is early to midseason, being from one to two weeks later than Alaska. Quality much superior to Alaska. It is suitable for canning and freezing although rather light in colour when canned. Pods are straight, blunt; average length 2·6 in. with 5 to 7 peas per pod. Sieve size 4 to 6.

Engress.—Another origination from the Division of Horticulture and described on p. 67. It is a high quality variety suited to home or market gardens and possibly processing. This variety has proved quite adaptable to varying climatic conditions. It does very well at Ottawa and is one of the top yielders in the prairie trials, showing considerable tolerance to dry weather conditions. At Ottawa it has consistently shown moderate tolerance to Fusarium root-rot under field conditions.

Fenland Wonder.—Grown at the Dominion Experimental Station at Kentville, N.S., as a selection from Witham Wonder. It is not a new variety but has

not been widely known. It was very highly regarded at Vancouver, Winnipeg, Vineland and Sackville. These institutions were impressed with its earliness, which is the same season as Alaska, its high quality and good yield. It was also regarded as a very suitable variety for early canning. The plants are about 20 to 24 inches tall, with pods 2½ to 3½ inches long, pointed and straight to slightly curved. There are 5 to 8 tender medium green peas per pod.

Laxall.—This variety originated at the Division of Horticulture. It is described on p. 67. It is a dwarf variety (14 to 18 in.) which shows considerable promise as a home garden type. Has been particularly successful under prairie conditions, where it stands up well to drought and wind. For several years it has had a high degree of resistance to Fusarium root-rots under field conditions at Ottawa. It is an early, high yielding variety with good quality.

Ottawa PE-1.—Developed at the Division of Horticulture, Central Experimental Farm, Ottawa, and still under number. It is described on p. 68. At Edmonton it ranked as an exceptionally heavy yielder and one of the best of 48 midseason and late varieties grown there and was considered suitable for home garden, market garden and canning. In addition, Summerland, Winnipeg, Vineland and Ottawa, all rated this variety very highly for its yield, quality and suitability for both garden and canning.

Smallton.—An origination from the Division of Horticulture, Central Experimental Farm, and described on p. 67. This variety did well at several stations: Sackville—vigorous plants, heavy producer; Ottawa—midseason, very good quality for freezing; Vineland—tall, midseason, good quality; and the University of Alberta—tall, stocky and well adapted for canning and home use.

In general this appears to be a useful midseason variety for processing, especially for freezing.

Pepper

T-612.—This pepper variety, although still under number, is a development from the Dominion Experimental Station at Morden, Manitoba. At Edmonton, Winnipeg, Vineland, Ottawa and Macdonald College it showed up very well as a heavy yielding, early type of pepper with a fine sweet flavour, somewhat similar in shape to California Wonder. Although the stock is not perfectly pure it should prove a good, early, desirable type for many areas in Canada.

Vineland 511.—Originated at the Horticultural Experiment Station at Vineland Station, Ontario, from a double cross using Harris Earliest, Sunnybrook and Oskosh varieties. In 1947 this showed merit at several stations. It is a medium size, early, tapered variety of the Windsor A type. At Macdonald College it was rated earlier than Windsor A, productive; at Ottawa, free from disease, early to midseason, productive, sweet; at the University of British Columbia, much earlier than Calwonder, firm, good for stuffing and for shipping, free of insects and disease, productive; and at Vineland, a good early, productive strain, which may require further selection.

Squash

Buttercup.—Although given the name Buttercup this apparently is a selection from that variety developed at the Department of Horticulture, University of Saskatchewan, Saskatoon. From its appearance in the trials at the various testing stations, this stock appears to have been selected with a view to reducing or doing away with the turban or button at the blossom end of the fruit. As a result, this strain has almost ceased to be a turban type. At Edmonton, Winnipeg, Ottawa, and Macdonald College it was considered a good desirable type of squash with excellent quality and should be satisfactory for home and market gardens.

Tomato

Danmark Hybrid.—Seed received from Mr. T. Bacher, Horticultural Experiment Station, Virium, Lyngby, Denmark. An indeterminate variety which yielded well at Ottawa and Macdonald College. Because of its small fruit size this variety is unsuitable for field culture in Canada, but may be a good possibility for greenhouse forcing especially since it is claimed to have resistance to Cladosporium leaf mould.

Early Alberta.—Although seed was obtained from the University of Alberta, the variety was originated by Mr. A. Fruno of Edmonton by crossing Bison with an unnamed yellow variety. It is a very small, determinate type plant, with small, red, early ripening fruit. Considered to have some merit at the University of Alberta because of its ability to ripen a good crop in that area. It did not appear to have a place at other stations because of its small fruit size and susceptibility to Alternaria blight.

Longred.—Produced at the New York Agricultural Experiment Station, Geneva, N.Y. In the 1947 trials at Macdonald College, Ottawa and Vineland, this variety showed considerable promise as a canning type. It is indeterminate, vigorous, with good foliage cover of finely divided leaves. The fruit, globe to slightly elongated, has good red skin and flesh colour.

Morden.—A new yellow variety produced at the Dominion Experimental Station at Morden, Manitoba, from an original cross, Bristol × Round Smooth. It is a vigorous, determinate, yellow fruited variety with medium to large fruits of good quality. In the 1946 trials at Ottawa and Vineland, Ont.; University of Manitoba, Winnipeg, Man. and University of Alberta, Edmonton, Alta., this was a very satisfactory yellow fruited type, well suited to home and market garden.

Ottawa TO-3.—This tomato still under number was developed at the Division of Horticulture, Central Experimental Farm, Ottawa. It is described on p. 72. It appears to have regional suitability; was two weeks earlier than Quebec No. 5 at Edmonton, and at Winnipeg and Ottawa was rated as one of the earliest and best yielding varieties on trial. In addition to these merit trials, it has also shown up as an early, high yielding type in Prince Edward Island and in the canning areas of eastern Ontario where, in replicated trials, it produced 18½ tons of graded canning quality tomatoes per acre, of which 14 tons graded as Canada Grade No. 1. It would appear to have merit as an early home and market garden staking variety and may have good possibilities as a canner.

Ottawa TO-4.—Another numbered strain originated at the Division of Horticulture, Central Experimental Farm, Ottawa, and described on p. 73. Its chief merit lies in its possibility as a canning crop variety for the longer season regions of Ontario. At Vineland, Ottawa, and Macdonald College it rated highly as a commercial variety for the canning industry. Its determinate or bush habit will permit closer planting than the standard varieties already in use in canning regions of Ontario. The plants are uniform and heavy yielding, and the fruit colour is an exceptionally good red. In the canning region of eastern Ontario it performed well in replicated field trials and would permit considerably closer planting than the 6 by 3 feet planting distance used. Nevertheless, it yielded 17½ tons of canning grade tomatoes of which 14 tons were classed as Canada Grade No. 1.

Quebec No. 5.—Seed was obtained from the W. H. Perron Seed Company, Limited, Montreal. The variety was originated at Laval University, Quebec. At Edmonton this variety was 17 days earlier maturing than Earliana. At Vancouver, Vineland and Ottawa it showed merit as an early, good yielding, well coloured variety for both home and market garden. It is apparently more vigorous than Earliana and has smoother fruit. It is indeterminate in habit

so that it is suitable for staking but can also be grown unstaked since it does not cover a large area.

Signet.—The seed was obtained from the Dominion Experimental Station at Summerland, B.C., where the variety was developed. At Vineland, Ottawa, and Macdonald College it appeared promising as an early, good yielding, uniform type. From its habit of growth and the relatively small uniform fruit this variety might have promise as a greenhouse or forcing type. It is vigorous and lends itself to staking.

Vineland 85-11.—An origination from the Horticultural Experiment Station at Vineland Station, Ontario, developed from the cross Italian × Marglobe. It is a large, vigorous, indeterminate plant; midseason in type with a good yield of globe-shaped, good red-fleshed fruit, averaging 5 ounces in weight. Its good size, colour and productivity make it a possibility for canning. Marketable yield was less than that of TO-3 but greater than Bounty.

Variety Trials and Recommendations

Variety trials have been carried on at the Central Experimental Farm for many years. At present these consist of 300 to 400 varieties involving 20 to 30 different crops. This variety testing is distinct from such trials as the Verification Trials and Merit Trials and serves several very useful purposes.

It provides a means of assessing the value of many of the introductions catalogued by the seed trade each year and allows a comparison between them and older standard varieties.

It provides standards of comparison which are essential to the evaluation of selections produced by breeding work.

It serves a useful purpose in providing demonstrations of the different varieties.

As a result of these tests it is possible to draw up an annual list of the varieties which are best adapted to conditions in the Ottawa area. The varieties recommended are:

Asparagus .....Mary Washington.

Beans .....*Bush type*
Green Podded—Stringless Green Pod, Supergreen, Logan, Tendergreen.
Wax Podded—Pacer, Strider, Round Pod Kidney Wax, Cherokee Wax, Puregold.
Pole type
Green Podded—Kentucky Wonder Wax, Stringless Blue Lake, Decatur.
Wax Podded—Kentucky Wonder Wax.

Beet .....Detroit Dark Red, Crosby's Egyptian.

Broccoli .....De Cicco.

Cabbage .....*Early:* Golden Acre, Viking.
Midseason: Copenhagen Market, Jersey Wakefield, Glory of Enkhuizen, Marion Market.
Late or Winter: Danish Ballhead (or Hollander), Penn State Ballhead, Chieftain (Savoy).
Red for Pickling: Red Rock or Red Acre.
Chinese: Chihli.

Carrot .....*Bunching:* Amsterdam, Nantes, Imperator.
Storage: Chantenay, Imperator, Danvers Half Long.

Cauliflower .....Snowball, Erfurt.

Celery .....*Green:* Utah, Summer Pascal.
Golden: Cornell No. 19, Golden Plume.

Citron .....Red Seeded, Green Seeded.

Corn	*Home use:* Early—Dorinny, Pickaninny, Seneca 60. Midseason—Golden Bantam, Marcross. Late—Golden Cross Bantam. *Market garden:* Early—Seneca 60, Priscilla. Midseason—Marcross, North Star. Late—Vinegold, Seneca Chief, Golden Cross Bantam.
Cucumber	*Slicing:* Marketer, Delcrow, Cubit, Straight Eight, Early Fortune. *Pickling:* Mincu, National or Snow Pickling.
Eggplant	New Hampshire Hybrid, Blackie, Black Beauty.
Leek	Giant Carentan.
Lettuce	*Leaf type:* Grand Rapids, Black Seeded Simpson. *Crisp head:* Great Lakes, Imperial 456, Imperial 847, New York 515, New York 12, Cosberg. *Butter head:* Big Boston, Wayahead, Mayking.
Muskmelon	Farnorth, Honey Gold, Golden Champlain, Delicious, Bender's Surprise.
Onion	Early Yellow Globe, Yellow Globe Danvers No. 11, Ebenezer, Red Wethersfield. *For transplanting:* Sweet Spanish, Yellow Globe Danvers No. 44. *For pickling:* White Portugal or Silverskin.
Parsley	Moss Curled.
Parsnip	Hollow Crown or Guernsey.
Pea	*Early:* Wisconsin Early Sweet, Alton, Thos. Laxton. *Midseason:* Laxton Progress, Engress, Little Marvel. *Late:* Onward, Stratagem, Prince of Wales, Perfection, Director.
Pepper	*Sweet:* Harris Earliest, Windsor A, King of the North, Pennwonder. *Hot:* Hamilton Market, Hungarian Yellow Wax.
Pumpkin	Sugar, Connecticut Field.
Radish	Scarlet Globe, Saxa, French Breakfast, Sparkler or Scarlet Turnip White Tip, Icicle.
Rhubarb	Macdonald, Ruby, Valentine, Early Sunrise, Canada Red.
Spinach	Bloomsdale, King of Denmark, Northland (Viking or Heavy Pack).
Squash	Golden Hubbard, Green Hubbard, Kitchenette, Butternut, Table Queen (Des Moines or Acorn), Buttercup.
Swiss Chard	Lucullus.
Tomato	*Bush type:* Early Chatham, Bounty, Red Cloud. *Staking type:* Abel, Quebec No. 5, Geneva John Baer, Stokesdale No. 4, Valiant.
Turnip	*Summer:* White Top Milan, Purple Top Milan. *Swede or Rutabaga:* Laurentian, Acadia.
Vegetable Marrow	Long White Bush, Long White Trailing.

Tomatoes

As part of the variety testing program, replicated plot trials are conducted with different tomato varieties. Varieties showing promise in the smaller preliminary trials are placed in these trials for comparison with older standard varieties. Nine varieties are tested each year with six replications of each variety. The tomatoes are grown unstaked and yields are recorded. Table 14, arranged in order of earliness of varieties, gives results of the 1948 trials.

In this test Red Cloud and Ottawa TO-3 gave the heaviest early yields with no significant difference between them. Abel and Ottawa TO-5 were not significantly lower than Ottawa TO-3.

In total marketable yield for the season there were no significant differences between Bounty, Red Cloud, Ottawa TO-5 and Clark's Early. Red Cloud (the second heaviest yielder) was not significantly higher than Ottawa TO-3.

Ottawa TO-5 although well up in both early and total marketable yield is a rather small fruited type, being smaller than Red Cloud and Ottawa TO-3.

Lima Beans

In 1948, seven varieties of lima beans were obtained from the Division of Fruit and Vegetable Crops of the United States Department of Agriculture. These were: Henderson, Clark's Bush, Early Thorogreen, Peerless, U.S. 343 (Triumph), U.S. 245 and U.S. 147. Trials were conducted at the Central Experimental Farm and several other co-operating institutions to determine whether they could be grown and yield satisfactorily in different parts of Canada. The plots were 30-foot rows with four replications.

The variety Henderson was the highest yielding at the Central Experimental Farm with an estimated 5,082 pounds of shelled beans per acre. This was closely followed by U.S. 343. (Triumph) with an estimated 4,247 pounds. Peerless did not germinate.

TABLE 14.—MARKETABLE YIELD (TONS PER ACRE) OF NINE VARIETIES OF TOMATOES

Variety	Yield First Two Weeks (To August 25)	Yield for Season (To September 15)
	tons/ac.	tons/ac.
Red Cloud	3·55	19·21
Ottawa TO-3	3·21	17·14
Abel	3·06	11·05
Ottawa TO-5	2·93	18·05
Early Chatham	2·21	11·34
Bounty	1·68	20·23
Clark's Early	1.40	17·90
Bonny Best	1·18	17·04
Geneva John Baer	0·96	16·81
Differences required for significance:		
First two weeks		0·49
Season		2 66

At the Dominion Experimental Station, L'Assomption, Quebec, U.S. 343 (Triumph) produced the greatest weight of shelled beans with 2,700 pounds per acre. Peerless was next with 2,372 pounds. This latter variety had the greatest pod weight.

At the Dominion Horticultural Substation at Smithfield, Ontario, Peerless led in pod weight and in weight of shelled beans, the latter being 2,976 pounds per acre. U.S. 343 (Triumph) was next with 2,178 pounds of shelled beans.

In the trials at the Horticultural Experiment Station, Vineland, Ontario, Henderson was the highest yielding variety in shelled beans with 3,533 pounds per acre. Early Thorogreen was next with 3,114 pounds per acre. Peerless had the greatest pod weight but the yield of shelled beans was lower than the two varieties mentioned.

At the Dominion Experimental Station, Harrow, Ontario, the yields were appreciably lower than at the other stations. The highest yielding variety was U.S. 343 (Triumph) with 1,210 pounds of shelled beans per acre, followed by Henderson with 992 pounds.

Good yields from all varieties were obtained at the Dominion Experimental Station at Summerland, B.C. The greatest weight of shelled beans was obtained from U.S. 343 (Triumph) with 6,470 pounds per acre. This was followed by U.S. 147 with 5,658 pounds per acre

On the basis of these trials, there appear to be excellent possibilities for producing lima beans in several parts of Canada. This crop is well adapted to

canning and freezing and could be grown in some of the canning crop districts. The trials also indicate that, in general, the best yielding variety was U.S. 343 (Triumph).

A Comparison of the Sweet Spanish Onion Strains, Riverside, Utah and Valencia

There is some doubt whether sufficient differences exist between the Riverside, Utah and Valencia strains of Sweet Spanish onions to merit classification as separate strains. In "Descriptions of Types of Principal American Varieties of Onions." U.S.D.A. Misc. Publ. 435. 1941. Magruder *et al,* devote a section to the Sweet Spanish onion. This section and the description are based on the Utah strain. The Utah strain was developed by the Utah Agricultural Experiment Station from the Riverside which had been introduced previously as an improvement over the Spanish introduction, Sweet Spanish Valencia. No differences between the several strains are mentioned; in fact, Utah, Riverside and Valencia are classed as synonyms.

At Ottawa, comparisons were made between stocks of these three strains for earliness of maturity, shape index and size of mature bulbs.

Maturity tests, as indicated by the tops falling over, were made on plants grown from seed from several sources. The three stocks of Riverside started to mature a week apart, namely August 1, 8 and 15. Following this they showed a fairly uniform rate of maturity with each one showing 50 per cent of the plants matured within 4 days of each other, September 1 to 4.

Four stocks of the Utah strain were tested. One lot started to mature on August 1, the other three did not start until August 15. There was an appreciable difference in the rate of maturity. Two stocks showed 50 per cent of the plants matured on September 4 and 6 whereas the other two did not reach this stage of maturity until September 15 and 16. This is a considerable maturity difference in samples labelled as Utah strain. If the four samples are considered as one group, 50 per cent of the plants matured in the week of September 5 to 12.

The two samples of the Valencia strain started to mature within two days of each other, August 6 to 8 and reached 50 per cent maturity within two days of each other, September 8 to 10.

These tests indicate that Utah and Valencia strains may be about one week later than Riverside in maturing 50 per cent of their plants. However, when the last readings were taken on September 26, not one stock had reached 100 per cent maturity.

In addition to the above stocks, a selected stock of Riverside, 46-2715, and two of the Utah, 46-2716 and 46-2723, were obtained from the Canadian Seed Growers' Association. When grown at the Central Experimental Farm, Ottawa, Ontario, the results were:

		Started to Mature	50% of Plants Matured
Riverside	46-2715	July 29	Sept. 9
Utah	46-2716	Aug. 5	Sept. 16
Utah	46-2723	Aug. 12	Sept. 15

These same stocks were also tested at the Dominion Experimental Station, Summerland, British Columbia, with the following results:

		Started to Mature	50% of Plants Matured
Riverside	46-2715	Aug. 20	Sept. 8
Utah	46-2716	Aug. 13	Sept. 18
Utah	46-2723	Aug. 26	Sept. 12

At the Horticultural Experiment Station, Vineland, Ontario, the same Riverside stock was tested with a stock of Valencia, 44-2213, also obtained from the Canadian Seed Growers' Association. The results were clear cut.

	Started to Mature	50% of Plants Matured
Riverside 46-2715	Aug. 26	Aug. 30
Vallencia 44-2213	Sept. 3	Sept. 6

In general, these tests support the foregoing observation that Riverside is probably several days to a week earlier than the Utah or Valencia strains in maturing 50 per cent of its plants.

Shape index, that is, the rotundity of the mature onion bulb, is indicated by a figure obtained by dividing the equatorial diameter by the polar diameter. According to the range of indices at present set up as standards by the Canadian Seed Growers' Association, Utah Sweet Spanish should have an index range of ·80 to 1·20 and Riverside should have a range of ·90 to 1·30. However, in U.S.D.A. Misc. Publ. 435 the index range is given as ·90 to 1·30 for Sweet Spanish for the western states and ·80 to 1·20 for the northeastern states.

With an index range of ·90 to 1·30 Riverside should produce a majority of bulbs with an index of rotundity about midway between these two points or from 1·05 to 1·15 but when the Riverside stock 46-2715 was grown at the three institutions mentioned the majority of the bulbs were grouped as follows:

	Proportion of bulbs	Majority Index Range
Ottawa	63%	·85 to 1·05
Summerland	61%	1·00 to 1·10
Vineland	59%	·90 to 1·05

These figures indicate, particularly at Ottawa and Vineland, that this stock has a tendency to be deep.

The Utah strain should have an index range of ·80 to 1·20 according to the C.S.G.A. or ·90 to 1·30 according to U.S.D.A. Misc. Publ. 435. Therefore, the majority of the bulbs should be in the vicinity of ·95 to 1·05 according to the first standard or 1·05 to 1·15 according to the second. The two stocks of this strain showed the majority of bulbs grouped as follows:

		Proportion of bulbs	Majority Index Range
Ottawa	46-2716	64%	·90 to 1·10
	46-2723	59%	1·05 to 1·25
Summerland	46-2716	69%	·90 to 1·10
	46-2723	63%	1·00 to 1·10
Vineland	46-2716	73%	·85 to 1·05

The general similarity in shape index indicates that the Riverside and Utah strains could be classed as synonyms as is done in U.S.D.A. Misc. Publ. 435 and that they would be placed in the same index range.

The Valencia strain, 44-2213, was grown at Summerland and 80 per cent of the bulbs were grouped between 1·00 and 1·25 . This may indicate either that the stock is a little too flat for the strain or that Valencia may be a little flatter than the other strains.

In size of bulb comparisons the Riverside strain was on the average smaller than the others. The majority of the bulbs were 1·7 to 3·0 inches in equatorial diameter, whereas the Utah and Valencia stocks produced bulbs 2·5 to 4·0 inches in diameter.

In general, there appears to be relatively little difference in maturity between Utah and Valencia strains although both may be about a week later in maturing than Riverside. There was no clear difference in shape index range between Riverside and Utah in the stocks tested. However, the Valencia stock

tested might be classed as having a shape index range of ·95 to 1·35 which would be slightly flatter than the range for the other two strains. The Riverside stock under test produced slightly smaller bulbs than either the Utah or Valencia stocks.

A Comparison Between Pelleted and Unpelleted Vegetable Seed

During 1948, comparisons were made on plants grown from pelleted and unpelleted vegetable seed. The seed was either registered or certified and consisted of the following varieties: Beet, Detroit Dark Red; carrot, Red Cored Chantenay; cucumber, Straight Eight; lettuce, New York 515; radish, Scarlet Globe; spinach, King of Denmark and swede turnip, Laurentian. These trials were conducted at the Central Experimental Farm and at the Dominion Experimental Stations at Charlottetown, P.E.I.; Kentville, N.S.; Fredericton, N.B.; Ste. Anne de la Pocatiere, Que.; L'Assomption, Que.; Morden, Man.; Lethbridge, Alta.; Lacombe, Alta.; Saanichton, B.C. and Fort Simpson, N.W.T.

In most cases the unpelleted seed germinated faster, more evenly and with a better stand. In forty-two instances, unpelleted seed gave better germination; in twenty-six there was no difference and in eight, pelleted seed was superior. Observations on the performance of the plants as shown by growth and yield continued to show a general difference in favour of the unpelleted seed. This was indicated by thirty-four instances where plants from unpelleted seed were superior, nineteen cases where there was no difference and twenty-three where plants from pelleted seed were better.

A quantity of pelleted swede turnip seed was analysed by the Division of Chemistry, Science Service, Central Experimental Farm. The report was as follows:

> "100 grams of pelleted seed consisted of
> 4·9 grams of seed, and
> 95·1 grams of pelleting material.
>
> This material contained 0·0017 per cent soluble nitrogen, 0·00005 per cent soluble phosphorus and 0·025 per cent soluble potassium based upon 100 grams of pelleted seed. The pelleting material appears to be diatomaceous earth or a similar substance with some form of binder."

The chief advantage in using pelleted seed is the ease of sowing and spacing. On the other hand unpelleted seed generally gave better germination and performance. In dry soil, pelleting may be a decided disadvantage if the soil moisture is insufficient to penetrate the layer surrounding the seed and so stimulate germination. In addition, the pelleting process and the increased weight and volume of pelleted seed all increase seed costs.

Chemical Weed Control

The development of a number of substances more powerful and effective than the earlier materials has given great impetus to the use of chemicals for weed control. Experiments at the Central Experimental Farm have shown some of these materials to be useful for the control of weeds in certain vegetable crops.

Asparagus

Since asparagus is a perennial, weeds can be a serious pest and their destruction by chemicals is a great benefit to growers. Several materials were used on this crop. The three most effective were calcium cyanamide dust, dry cleaning fluid and the amine salt of 2,4-D. Application and results were as

follows: Calcium cyanamide dust at 150 pounds per acre and the dry cleaning fluid, Stoddard solvent, sprayed at the rate of 50 gallons per acre killed or severely injured all weeds including grasses. The amine salt of 2,4-D (70 per cent) sprayed at the rate of one-half gallon in 50 gallons of water per acre killed or severely injured all weeds except grasses. The calcium cyanamide caused no injury to the asparagus. The other materials injured those asparagus spears which were above the ground at time of treatment but the spears appearing after treatment showed no injury and had no off-flavour.

Pre-Emergence Treatments

Pre-emergence sprays with cleaning fluid at 80 gallons per acre gave good control of all weeds for a period of three weeks. One spray was applied five days after seeding or just before the seedlings emerged. There was no harmful effect on the resulting crop plants of beets, carrots, onions or turnips.

Two other materials were tested as pre-emergence treatments for beets. A two per cent potassium cyanate solution applied at 80 gallons per acre gave very good weed control without harmful effect to the crop plants. Granular calcium cyanamide applied broadcast at 200 pounds and 400 pounds per acre was less effective.

At the Horticultural Substation at Smithfield, Ontario, applications of calcium cyanamide dust were made on plots of canning peas. These pre-emergence treatments were at 200 and 400 pounds per acre applied immediately after seeding and six days after seeding. The 400-pound application immediately after seeding and both applications six days after seeding were equally effective in giving good weed control.

Post-Emergence Treatments

Post-emergence treatments with cleaning fluid have proved a satisfactory method of controlling weeds in carrots. The rate of application depends upon the extent of weed growth. If sprayed when the weeds are small, satisfactory control can be obtained with 60 gallons per acre. Larger growth will require heavier applications up to 100 gallons or more per acre. The fluid has little or no harmful effect upon the carrot plants and can also be used safely to control weeds in parsnips.

POTATO INVESTIGATIONS

Potato Breeding

N. M. Parks

Potato breeding is one of the major projects conducted by the Division of Horticulture at the Dominion Experimental Station, Fredericton, New Brunswick. Since the inception of the breeding program in 1933, the hybridization phase of the breeding work necessarily has received the most attention. With the development of a large number of hybrid varieties showing high resistance to such diseases as late blight, common scab and some of the viruses, consideration had to be given to the next important phases in potato breeding work, testing and selection.

To meet this requirement, a comprehensive system for testing seedlings and new named varieties of potatoes throughout the whole of Canada was organized by the Division of Horticulture in 1946 and put into effect in 1947. This system was planned as a co-operative project between the Experimental Farms and Science Services of the Dominion Department of Agriculture, provincial institutions, agricultural colleges, universities and growers.

Through this system a uniform method of testing laid out in accordance with recognized experimental methods is used in all trials. In this way adaptability, horticultural characteristics, disease resistance, maturity, yielding ability and quality of a seedling or variety can be more accurately appraised under varying environmental conditions. The results of previously conducted preliminary trials had clearly indicated that a hybrid or variety of potatoes may show high resistance to late blight or common scab in one area and extreme susceptibility in another. It is now recognized that there are physiological races of both late blight and common scab organisms. Therefore, for a full appraisal of the value and disease resistance of a particular seedling or variety, it is necessary to test it over a wide area.

In the two years the National Potato Seedling and Variety Trials have been in operation, forty-seven hundred potato seedlings and new named varieties have been included in tests in the various provinces. Forty-five hundred of these seedlings were originated at the Dominion potato breeding station, Fredericton, N.B. The remaining two hundred seedlings and varieties came from potato breeding stations in the United States, Scotland and from private individuals doing potato breeding in Canada.

The trials have not run for a sufficient length of time for a full evaluation of the horticultural characteristics and disease resistance of all seedlings and varieties which have been included in the trials. A number of hybrids have shown such promise from the standpoint of desirable horticultural characters, yielding ability, late blight and scab resistance, that it has been decided to name and release two of the most promising. However, before a new variety name may be used and the variety certified and offered for sale for seed purposes, that variety must be licensed under the Seeds Act. Information on the characteristics, performance and disease resistance of varieties when grown under different environments, as obtained through the National Tests, will be the basis for recommending varieties for licence for sale in Canada.

Inhibition of Sprouting of Potato Tubers

N. M. Parks, W. R. Phillips, L. H. Lyall

Inhibition of Sprouting by Abnormal Atmospheres

Shrinkage of potatoes in storage is a source of heavy loss to both growers and those who handle them in trade. One of the chief sources of shrinkage is the sprouting of the tubers in storage.

During 1936-37 studies were made on the effect on sprouting of atmospheres containing higher amounts of carbon dioxide and lower amounts of oxygen than are found under normal storage conditions. In these studies Green Mountain potatoes were held for six months at the two temperatures, 32° and 39° F., with CO_2 concentrations ranging from 5 to 11 per cent and O_2 concentrations from 2·5 to 16 per cent.

When the samples of tubers were examined at the end of the six month period the following results were observed:

At 32° F.—All tubers stored in gas mixtures at this temperature, except those in the five per cent CO_2 plus 2·5 per cent O_2 concentration were badly damaged.

At 39° F.—The control sample of tubers was in excellent condition with slight signs of sprouting. The tubers in concentrations of 5 per cent CO_2 plus 16 per cent O_2 showed slight sprouting. Those in concentrations of 10 per cent CO_2 plus 2·5 per cent O_2 were all badly rotted. Concentrations of 11 per cent CO_2 plus 10 per cent O_2 completely destroyed all germination of the tubers. The maximum delay of sprouting without completely killing the sprouts was obtained at this temperature in concentrations of 10 per cent CO_2 plus five per cent O_2.

It was quite evident that all gas mixtures had some effect in delaying sprouting of potato tubers; the degree was in direct proportion to the concentration of CO_2 in the storage. The concentration of O_2 appeared to have little effect in the delay of sprouting.

This experiment was not continued beyond the one year as it was felt the storage of potatoes in gas atmospheres would have no practical application.

Chemical Inhibition of Sprouting

Investigational work in the United States indicated that the methyl ester of alpha naphthaleneacetic acid was very effective in inhibiting the sprouting of potato tubers. In 1946-1948, studies were undertaken at Ottawa to determine the effect of certain chemicals on the sprouting and on the germination of treated potato tubers when planted in the field.

The initial experiment of April, 1946, consisted of treating three varieties of potatoes, Irish Cobbler, Green Mountain and Sebago, with the methyl ester of alpha naphthaleneacetic acid in dust form. The concentration used was one c.c. diluted in 30 c.c. of 95 per cent ethyl alcohol. This solution was then atomized into french talc at the concentration of one c.c. of the active ester to one-half pound of talc; when dry, one-half pound of the treated talc was dusted on each bushel of tubers. All samples comprised ten pounds of potatoes. Controls and treated samples of each variety were stored at temperatures of 36°, 39°, 50° and 70° F.

When treated on April 17, the dormancy of the Irish Cobbler and Sebago showed signs of having broken. The Green Mountain appeared completely dormant.

The samples were examined at definite intervals throughout the storage period. On June 25, sixty-nine days after treatment, all samples were removed from storage for a final examination. The results showed that sprouting was inhibited slightly in the treated samples held at all temperatures but the inhibition was not sufficient to be of any commercial value. These potatoes were

treated in the latter part of their storage season, and it was felt that had the treatment been applied earlier and before dormancy of the tubers had broken, the treatment would have shown greater effect.

Therefore, in December, 1946, an experiment was set up to study the effect of the same sprout inhibitor when applied early in the storage period. This was compared with the dust and liquid forms of commercial brands. The active ingredient of the dust prepared in the laboratory and of the commercial material was in each case the methyl ester of alpha naphthaleneacetic acid. Samples were also treated with 2,4-D.

Two varieties of potatoes, Irish Cobbler and Green Mountain, were treated on December 14 as follows:

1. Commercial product, spray form, applied at the rate of 10 c.c. per bushel of tubers.

2. Commercial product, dust form, applied at the rate of 0·15 lb. per bushel.

3. Dust made in laboratory at a concentration of one c.c. active ester to one-half lb. of talc and applied at rate of one-half lb. talc per bushel.

Storage was at 39°F. immediately after treatment.

Five months after storage, one series of controls and treated tubers of each variety was removed to 55°F. storage; a second, to 68°F. while a third was left at 39°F. The tubers remained at these temperatures for three weeks. Recorded observations at the end of the three-week period were as follows:

1. The methyl ester of alpha naphthaleneacetic acid was more effective as a dust than as a spray in inhibiting the sprouting of potatoes.

2. The methyl ester of alpha naphthaleneacetic acid had very little inhibiting effect on the sprouting of potato tubers when stored at 68°F.

3. Storage temperatures of 39°F. were more effective in delaying sprouting than sprout inhibitors. Even a reduction in storage temperature from 68° to 55° F. was more effective in inhibiting sprouting than was the hormone treatment on potatoes stored at 68°F.

In addition to treatments with the commercial and laboratory forms of the methyl ester of alpha naphthaleneacetic acid, samples of Green Mountain and Katahdin were treated on March 27 with 2,4-D at a concentration of 2·5 gm. of 2,4-D mixed with one-half lb. of talc and applied as dust to five bushels of potatoes.

The effects of the several treatments with a storage temperature of 39°F. on the germination and stand of potatoes when planted in the field were investigated. Sufficient tubers to plant 21 hills each of treated and untreated samples in each of three randomized blocks were removed from storage on May 12, 1947, and planted on May 15. Varieties, treatment and stand of plants are recorded in Table 15.

Although there was no reduction in the stand of these potatoes treated with the laboratory-prepared dust and stored at 39°F., it is obvious from Table 15 that potatoes intended for seed purposes should not be treated with sprout inhibitors.

The Effect of the Growth Hormone "Phytergine" on Potatoes

N. M. Parks

The study was undertaken at the request of the Société Agrotechnique of Paris, France, manufacturers of plant growth hormones, to determine the effect of "Phytergine", a growth hormone, on potatoes under Canadian conditions.

Because of the climatic differences across Canada, arrangements were made to have a test conducted at ten different locations in the various provinces. Six of these tests were completed; the remaining four were discarded for various reasons.

The hormone was applied to the seed tubers previous to cutting them into sets and the sets were planted in accordance with the manufacturer's recommendations. The location where the tests were conducted and the results of each test are recorded in Table 16.

TABLE 15.—THE EFFECT OF SPROUT INHIBITORS ON GERMINATION AND STAND OF FIELD-PLANTED POTATOES

Variety	Treatment	Storage Temperature	Per Cent Stand - Av. 3 Replications
Irish Cobbler	Control	39°F.	100·0
	Commercial dust	39	69·8
	Commercial spray	39	60·1
	Laboratory-prepared dust	39	100·0
Green Mountain	Control	39	100·0
	Commercial dust	39	46·0
	Commercial spray	39	50·8
	Laboratory-prepared dust	39	100·0
	2, 4-D	39	95·4
Katahdin	Control	39	96·8
	Commercial dust	39	9·5
	2, 4-D	39	90·4

TABLE 16.—EFFECT OF "PHYTERGINE" ON YIELD OF POTATOES IN CANADA

Location	Variety	Yield	
		Treated	Untreated
		bu./ac.	bu./ac.
C.E.F., Ottawa	Green Mountain	272·0	275·8
D.E.S., Scott, Sask	Irish Cobbler	335·6	326·2
D.E.S., Morden, Man	Irish Cobbler	345·6	431·8
D.E.S., Morden, Man	Warba	460·1	517·8
O.A.C., Guelph, Ont	Katahdin	288·0	294·0
D.E.S., Ste. Clothilde, P.Q	Green Mountain	526·0	600·3
D.E.S., Charlottetown, P.E.I	Green Mountain	399·3	404·1
D.E.S., Charlottetown, P.E.I	Irish Cobbler	442·8	435·6

C.E.F.—Central Experimental Farm.
D.E.S.—Dominion Experimental Station.
O.A.C.—Ontario Agricultural College.

The reports submitted by the various stations co-operating in this work coupled with the yields obtained from both the treated and untreated seed, would suggest that the hormone "Phytergine" had a depressing effect on both growth and yield of potatoes.

The Effect of Missing Hills on Yield of Adjacent Hills of Potatoes

H. B. Cannon and N. M. Parks

To determine the effect of missing hills on the yield of adjacent hills of potatoes three small trials with the Green Mountain variety were conducted in 1948. In all three trials the rows were planted 36 in. apart and the hills 12 in. apart in the row. The first trial involved the effect of a single missing hill upon the yield of the adjacent hills. For this purpose there were 66 comparisons

available which resulted in an average increase in yield of 19 per cent for the hills next to a miss over normal hills in the row.

In the second trial where two consecutive hills were missing, there was an average increase in yield of 24·7 per cent for the hills next to the double misses over normal hills in the row. Fifty-five comparisons were made in this trial.

The third trial consisted of determining the increase in yield of a single hill with a missing hill on either side. The results of this trial were based on forty-five comparisons. The average increase of the isolated hill over a normal hill in the row amounted to 50·9 per cent.

The Competition Effect of Early, Intermediate and Late Maturing Varieties of Potatoes

H. B. Cannon and N. M. Parks

In potato variety trials the question of a possible competition effect arises when a late maturing variety is grown next to an early maturing variety.

To investigate this, six randomized blocks were planted. These included all possible combinations of early, intermediate and late maturing varieties. Distances between rows were 36 in. and between plants, 12 in. The varieties used were: early, Irish Cobbler; intermediate, Canus; late, Green Mountain. They were planted on May 14 and 15, and harvested on September 24, 1948.

The results of this work indicated that, under the conditions of this trial, there was no evidence of any competition effect whatever of one variety upon the yield of another. In fact, in the "Analysis of Variance", the treatment variance was slightly less than expectation. The results of this trial suggest that in laying out variety trials it is not necessary to segregate varieties of varying maturities.

NUTRITION AND SOIL MANAGEMENT STUDIES

H. Hill

Apples

From 1925 to 1934 studies on soil management and nutrition were directed along two main phases. Management and orchard fertilizer experiments were conducted in sod orchards of three of the principal producing areas of the province of Quebec, and fundamental aspects of apple nutrition were studied at Ottawa by means of pot sand nutrient solutions.

As a result of these studies the practical management of permanent sod orchards was established on a basis of scientific information and actual performance, and the principles so established are today the accepted tenets of management. The nutrient solution studies provided information on the actual tree requirements of nitrogen, phosphorus and potassium, and the effect of interactions and ratio concentrations between each of these and other nutrient elements. As a result of this information and that obtained from the field fertilizer plots, the 9-5-7 fertilizer was adopted for general use in apple orchards in Quebec, the Maritimes and eastern Ontario.

Some of the fundamental principles enunciated as a result of these studies were:

(1) Continuous application of nitrogen only could result in a potassium or even a general mineral deficiency.

(2) Continuous application of phosphorus only could result in a deficiency of potassium.

(3) Continuous application of lime in the form of a carbonate could induce a deficiency of iron, or if in the form of a sulphate might cause interference with the intake of potassium.

(4) Continuous high applications of potassium might induce a deficiency of magnesium.

In addition, intimate knowledge was obtained on general growth characteristics and on specific growth and foliage symptoms brought about by a deficiency or excess of one particular element or by a lack of balance between elements. It may be said that many nutritional troubles in growers' orchards have been quickly diagnosed by such symptomatic knowledge. Permanent records of such symptoms were made by water colour paintings by A. Kellett, and many of these were reproduced for the benefit of growers in Publication 714, Technical Bulletin No. 32, 1941, entitled "Apple Nutrition". The bulletin also dealt with the specific function of the different nutrient elements and the principles of maintaining nutrient balance. It was considered that this bulletin gave the necessary information to the grower to enable him to fertilize individual orchards and even individual trees according to their specific requirements, rather than to adhere rigidly to general fertilizer recommendations which were nevertheless given.

Concurrent with the occurrence of severe cork disorders in 1936-37 in the counties of Northumberland and Durham, Ontario, a general soil survey of the orchard growing areas was conducted in co-operation with the Soils Department of the Ontario Agricultural College. In addition, detailed information on soil types, tree root characters and distribution, and cultural and fertilizer practices, was obtained in one hundred and eighty-four orchards. Individual soil reports were prepared and made available to the growers. Incorporated in these reports were the main soil charateristics, suggestions for suitable cultural practices, and fertilizer recommendations.

The soils of the orchard areas were characterized by a number of types occurring within comparatively short distances and varying greatly in physical and chemical nature. Shallow soils underlain by limestone bedrock, outwash sands with heavier material at 3 to 10 feet, moraine soils underlain by calcareous stony till and lacustrine soils were found in the area.

Fifty-eight per cent of the orchards studied were maintained under clean cultivation, and a high percentage of such orchards were located on the lighter textured soils of low natural fertility. The topography of many of these orchards ranged from rolling land to fairly steep slopes. The majority of the growers using clean cultivation did not plant a cover crop but depended on a volunteer crop of weeds to maintain the organic layer. There was a definite erosion problem on the hilly morainic soil types. From eighty-one orchards surveyed in detail, thirty-nine showed the effects of erosion. Out of fifty orchards in clean cultivation, thirty-five showed some degree of erosion, and in a few orchards located on steep slopes the till was exposed at the top of the slope with an accumulation of twenty-four inches or more surface soil at the foot of the slope.

These studies indicated that changes in management practices were advisable. In cultivated orchards more attention should be paid to the maintenance of organic matter by the annual use of cover crops, and on the hilly sites the sod mulch or modified sod systems of management should be followed.

Management and fertilizer plots were set up in grower-owned orchards in Northumberland and Prince Edward counties for demonstration purposes and to obtain further experimental evidence.

In Northumberland county, twenty-five-year-old trees of the Stark variety were employed with the following systems of management:

(1) *Clean cultivation* from early in the spring until the first of July, when a cover crop of crown millet was sown. A short time before harvest the crop was cut and left on the ground. Early in the spring the equivalent of a 9-5-7 fertilizer was applied at the rate of eleven pounds per tree.

(2) *Sod mulch*—The area was seeded down to a mixture of timothy, orchard grass and Kentucky blue. The grass was cut when necessary throughout the season and allowed to lie where cut. Straw or old hay mulch was applied around the trees in November at the rate of 75 to 100 pounds per tree. A 9-5-7 fertilizer was applied early in the spring at the rate of eleven pounds per tree.

(3) *Check*—Clean cultivation from early in the spring until the first of July, then a volunteer crop of weeds or grass allowed to grow. No manure or chemical fertilizers were applied.

The effect of the several systems of management on the growth and the average yield for a four-year period is indicated in Table 17.

TABLE 17.—FOUR-YEAR GROWTH AND AVERAGE YIELD OF STARK UNDER DIFFERENT SYSTEMS OF MANAGEMENT

Plot	Treatment	Tree Girth Increase	Av. Yield	Av. Yield
		in.	bu./tree	bu./ac.
1	Clean cultivation, cover, 9–5–7	7·57	8·74	306
2	Sod mulch, 9–5–7	8·45	13 03	456
3	Check—clean cultivation, volunteer crop	7·29	8·38	293

These results bore out the theory that the sod mulch system of management is capable of keeping trees in high vigour and in as high production as clean cultivation.

In Prince Edward county, the experiments were conducted with the McIntosh variety located on Newcastle loam soil. The methods of management employed were:

(1) Sod of orchard grass, timothy and blue grass, with the grass cut when necessary throughout the season and allowed to lie where cut. A mulch of straw was applied each year at the rate of seventy-five pounds per tree or one and one-third tons per acre. A 9-5-7 fertilizer was applied each spring at the rate of five hundred pounds per acre.

(2) Clean cultivation from early in the spring until the middle of June, when a cover crop of crown millet was sown. A short time before harvest the cover crop was cut and left on the ground. Fifteen tons of barnyard manure and six hundred pounds of a 4-8-10 fertilizer per acre were applied in the spring.

(3) Clean cultivation from early spring until the middle of June, when a cover crop of crown millet was sown, which was cut before harvest and left on the ground. No manure or fertilizer was used, but the ground was heavily mulched each year with pea cannery refuse.

The effect of the three systems of management on the average growth and yield over a six-year period is given in Table 18.

TABLE 18.—SIX-YEAR GROWTH AND AVERAGE YIELD OF McINTOSH UNDER DIFFERENT SYSTEMS OF MANAGEMENT

Plot	Treatment	Tree Girth Increase	Av. Yield	Av. Yield
		in.	bu./tree	bu./ac.
1	Sod mulch	1·387	21·97	758
2	Clean cultivation, cover crop, manure	1·219	21·69	748
3	Cultivation, cover crop, pea refuse	1·281	20·01	690

The six-year average yield is satisfactory with all treatments. However, it is worthy of note that the sod mulch treatment was slightly more productive.

Although tree vigour and yield records are useful indices of treatment effects they should not be solely relied upon, since some management practices may give high yields initially but may eventually impair the productive capacity of the soil. For this reason studies were conducted at Ottawa with the special purpose of investigating the effect of management treatments upon the soil itself. The three systems of management and their effects on the amount of organic matter in the soil are:

	1938 Organic Matter	1945 Organic Matter	Decrease or Increase
	%	%	%
I. Clean cultivation, cover crop, 9–5–7 fertilizer	3·63	3·09	−0·54
II. Grass sod mulch, 9–5–7 fertilizer	3·54	3·98	+0·44
III. Clean cultivation, cover crop, barnyard manure, 4–8–10 fertilizer	4·61	4·72	+0·09

The clean cultivation cover crop plot actually lost 0·54 per cent of the original organic matter, while the sod mulch plot gained 0·44 per cent and the clean cultivation, cover crop and manure treatment just about held its own.

The data on total nitrogen and available minerals in the soil are presented in Table 19.

TABLE 19.—THE EFFECT OF ORCHARD TREATMENT ON TOTAL NITROGEN AND AVAILABLE MINERALS IN THE SOIL

	Treatment I			Treatment II			Treatment III		
	1938	1945	Diff.	1938	1945	Diff.	1938	1945	Diff.
Total nitrogen.....	0·144	0·016	−·037	0·138	0·150	+·012	0·184	0·200	+·016
Exchangeable calcium....	0·161	0·074	−·087	0·190	0·188	−·002	0·272	0·236	−·036
Exchangeable magnesium	0·013	0·003	−·008	0·012	0·013	+·001	0·014	0·019	+·003
Exchangeable potassium.	0·012	0·019	+·007	0·013	0·033	+·019	0·012	0·019	+·007
Soluble phosphoric acid*.	340	195	−144	216	431	+214	506	531	+24
Total phosphoric acid..	0·250	0·240	−·010	0·240	0·286	+·046	0·266	0·326	+·060

* Values in p.p.m.; all others, %.

The clean cultivation, cover crop treatment (Treatment I) decreased the total nitrogen, exchangeable calcium, magnesium, total and soluble phosphorus. When additional organic matter was supplied in the form of manure (Treatment III), total nitrogen, magnesium and phosphorus were increased. In the grass sod mulch plot (Treatment II), total nitrogen increased, calcium and magnesium were maintained and substantial increases occurred in soluble and total phosphorus. Potassium was increased in all plots, with the greatest increase occurring in the sod mulch plots.

Subsequent to these studies the aforementioned bulletin on Apple Nutrition was revised and enlarged to include a section on orchard soil management. This bulletin, Publication 802, Technical Bulletin 65, 1948, was issued under the title "Orchard Soil Management and Apple Nutrition (In Eastern Canada)".

With the acquisition of the Substation at Smithfield in the county of Northumberland, Ontario, a wider range of management plots, including modifications of the standard clean cultivation and sod mulch systems of management, were set up. The results of these studies should apply particularly to the surrounding district since the experiment is located on land ranging from rolling to fairly steep slopes.

In addition to records of growth and yield and soil productivity over an extended period of time, cost records were set up to evaluate the economy of the different systems of management. The orchard for these studies was planted in 1947 and the following treatments laid out:

(1) Clean cultivation across the slope until the middle of June, followed by a cover crop of crown millet.

(2) As the trees reach an adult age plots will not be in sod or cultivated, but the entire surface of the plot will be mulched with straw or hay.

(3) Strip cultivation.—Clean cultivation in the rows for the first three or four years with the middles seeded down. After this period the strip in the row will be seeded down and the middles cultivated.

(4) Alternate sod strips.—Alternate areas between the rows seeded down to timothy and red clover for a season, the grass mowed and left. The remaining alternate areas given ordinary cultivation and then seeded down and the cover crop grown throughout the following season. The strips in cover crop one season are cultivated the next.

(5) Sod mulch.—Area seeded down with grass sod mixture of timothy, red clover, orchard grass and Kentucky blue; grass mowed whenever necessary and left; surface over tree root area mulched with old hay or straw.

(6) Handled the same as treatment five with the exception that every three years the sod is to be checked by roughly disking or harrowing.

(7) Trees planted on the contour, sod strip in tree rows, middles cultivated.

Deficiencies of Potassium and Magnesium in Commercial Orchards

Several instances of marked deficiency of potassium in commercial orchards were diagnosed and corrected in the St. Lawrence Valley, the Hemmingford district in the province of Quebec, and in the county of Northumberland, Ontario. Rapid diagnosis of this deficiency was possible through recognition of foliage symptoms similar to those produced in nutrient solution cultures.

In 1938 a request was made by Provincial fieldmen for a diagnosis of a severe foliage disorder in the Frelighsburg district of Quebec. Comparison of orchard foliage symptoms with those produced in nutrient solution cultures showed a striking similarity to symptoms of magnesium deficiency. Confirmation of diagnosis was obtained by analysis of affected foliage as follows:

	Ash Constituents as per cent Ash			
	K_2O	CaO	MgO	P_2O_5
Orchard 1	31·4	28·4	2·50	5·54
2	43·8	18·2	1·76	7·73
3	35·6	25·2	1·19	6·27
4	31·2	29·2	1·39	6·19
5	32·3	28·1	2·49	6·79
Normal foliage	25–30	20–25	5–7	6·80

Wallace (2) in England had reported the occurrence of magnesium deficiency in apple orchards at three centres, but this was the first instance of magnesium deficiency being positively identified by specific foliage symptoms in commercial orchards on this continent. During the next three to four years, magnesium deficiency was identified and reported in individual orchards in Nova Scotia and Ontario.

Field plot experiments were immediately set up to determine the best methods of correcting this deficiency.

In 1940, magnesium deficiency symptoms of apple trees in sand culture and in commercial orchards were described in detail by Hill and Johnston (1).

As a result of laboratory studies and orchard plot experiments conducted from 1939 to 1947, the following corrective measures for magnesium deficiency were recommended:

In many instances magnesium deficiency is only of an incipient nature, not causing any serious defoliation; in others almost complete defoliation may occur by late August, especially in wet years. A dry season may almost completely remove the trouble for that year. Leaf analysis has shown that leaves containing less than 0·4 per cent MgO in dry weight are liable to suffer from magnesium deficiency. Generally, it is much more prevalent on strongly acid low-lime soils, and under these conditions it is difficult to correct by soil applications.

When the deficiency occurs on acid soils the first step should be the application of dolomitic limestone up to a rate of two tons per acre. Experience has shown that this is not a quick remedy; from three to five years may elapse before marked recovery can be noted. If the orchard is in sod and cannot be ploughed, response may be very slow unless a heavy mulch is maintained. For immediate control, magnesium sulphate in the cover sprays has given satisfactory results. The recommendation for this purpose is the addition of twenty pounds of magnesium sulphate to every one hundred gallons of the regular sprays, starting with the calyx spray and continuing for two or three more applications.

On soils that are not decidedly acid, soil applications of magnesium sulphate at the rate of twelve pounds per tree may give early response. If this does not produce an effect in the year of application, the spray method may be employed.

If magnesium deficiency occurs on soils high in potash, it is advisable to omit potash in the fertilizer until the trouble has been corrected.

Fertility Status of Commercial Orchards by Means of Foliage Analyses and Correlations between Levels of Various Elements so Determined and Fruit Quality when Held in Cold Storage

Although the general principles of management and fertilizer use have been made available to the growers by the studies reported, it was realized that certain orchards might require more individual treatment. It was considered that correlations between levels of different nutrient elements in the foliage and fruit production and quality might be established and so serve as a basis of fertilizer recommendations for individual orchards. Since 1946, foliage samples from the McIntosh and Spy varieties were collected each mid-July from over thirty orchards in the counties of Northumberland and Durham for analyses by the Chemistry Division, Science Service, and samples of fruit from the same trees were harvested, cold stored at 32°F. and examined later.

As a result of these studies, individual management and fertilizer recommendations were made. The minimum level of potassium was set tentatively at 17,000 p.p.m. Seven orchards had levels in the foliage well below this figure, and the fruit in storage was characterized by mealiness in the McIntosh variety and a dull unattractive green finish in the Spy. An attempt to establish a nitrogen figure associated with high yield and good quality was complicated by the marked effect of seasonal conditions. In 1946, an average to somewhat dry season, the average nitrogen of the foliage was 1·94 per cent, whereas in 1947, a season of above average rainfall, the nitrogen content of the foliage from the same orchards receiving approximately the same fertilizer applications was 2·33 per cent. Nitrogen fertilizer treatments which provided an adequate but not excessive level in a season like 1946 might cause an excessive level in another season.

In 1946, the incidence of core flush was employed as the main indicator of storage quality, but in 1947 and 1948 a score sheet for quality involving such characteristics as fruit flavour, texture, colour and firmness was adopted. In these two years certain samples showed a high percentage of core flush, but they received a fairly high rating for quality, and from a commercial standpoint it was considered that the quality factor was of greater importance. There were indications that poor quality was associated with high levels of nitrogen in the foliage. Data from the 1948 studies with McIntosh brought out relationships between levels of different elements in the foliage and fruit quality more clearly, and these will be considered in detail.

The relationship between fruit quality and the percentage of nitrogen in the foliage is shown in Fig. 10. The positions of loci one and two in Fig. 10 are explainable. Locus one represents a very closely planted orchard which has been lightly pruned so that the quality score, especially the fruit colour, was low. Therefore, it is because of orchard conditions and practices rather than the levels of nutrition that the quality of this sample was not higher. Locus two represents an orchard which had a particularly low level of potassium in the foliage. It is considered that potassium was the main factor influencing quality. Fig. 10 also shows that there is a definite trend between a reduction in fruit quality and high nitrogen in the foliage. This is not a simple relationship but is modified by the N/K ratio (Fig. 11). A level of about 2·1 per cent of nitrogen in the foliage may be the maximum for good quality (Fig. 10) but such a standard may not hold if the N/K ratio is above 1·25 to 1·5 (Fig. 11). There is also a definite trend between an increase in quality

and levels of potassium up to 17,000 p.p.m. This is also modified by the influence of the N/K ratio. There does not appear to be any correlation between the occurrence of core flush in storage and the percentage of nitrogen or potassium in the foliage or between core flush and fruit quality. There is no apparent correlation between levels of phosphorus in the foliage and either fruit quality or the occurrence of core flush.

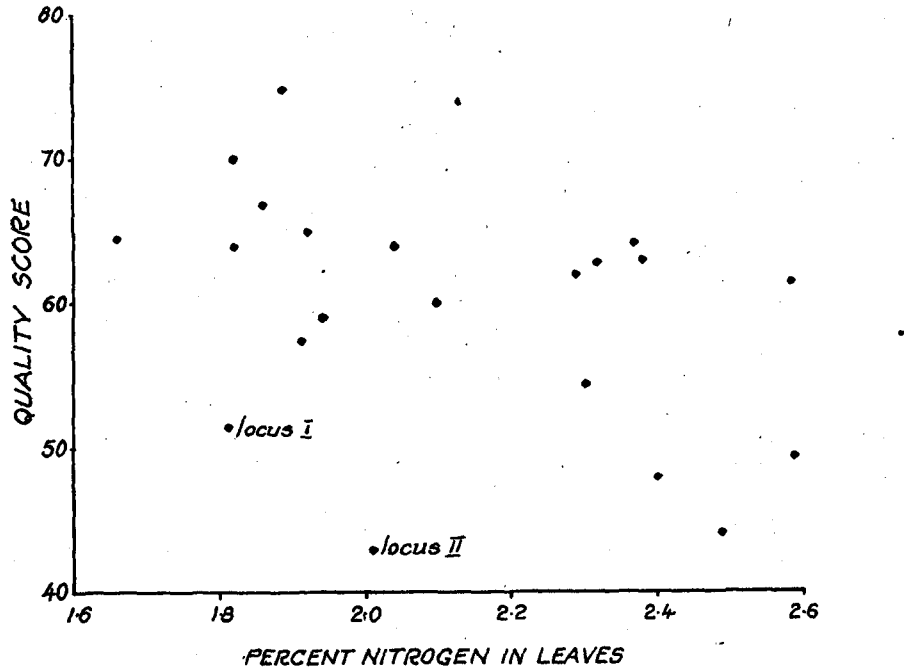

Fig. 10—Relation between nitrogen content of leaves and storage quality of McIntosh apples.

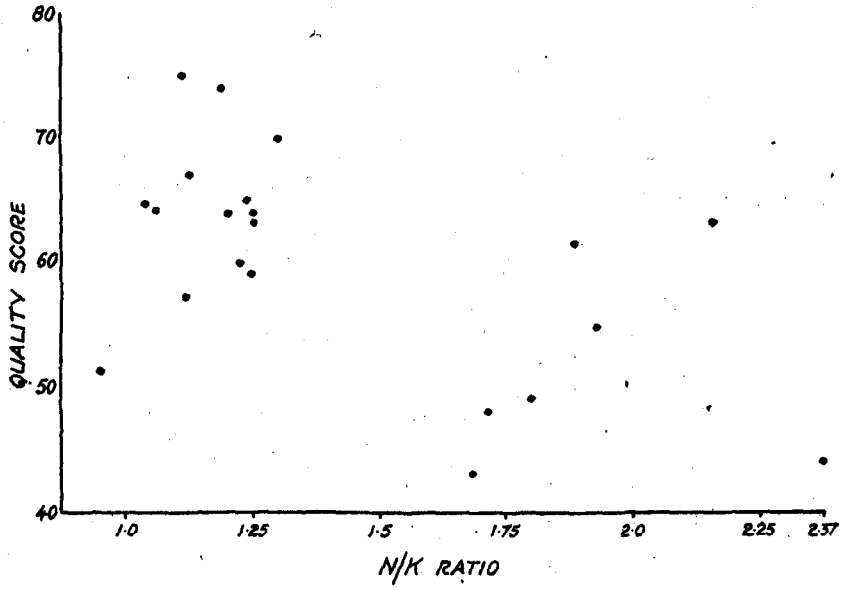

Fig. 11—Relation between N/K ratio in leaves and storage quality of McIntosh apples.

The Relation Between Nitrogen and Phosphorus Fertilizer Application, Tissue Analyses and the Keeping Quality of McIntosh and Spy Apples

Earlier studies of an exploratory nature had indicated a relationship between the N/P ratio and the storage quality of apples. The following fertilizer applications were made to a number of selected trees of the McIntosh and Spy varieties in a uniform orchard block to study this factor.

Application Ratio	Application per Tree		
	Ammonium Sulphate	Superphosphate	Muriate of Potash
	lb.	lb.	lb.
N_1P_1	5	2·5	1·5
P_2	5	5·0	1·5
P_3	5	7·5	1·5
P_4	5	10·0	1·5
N_2P_1	10	2·5	1·5
P_2	10	5·0	1·5
P_3	10	7·5	1·5
P_4	10	10·0	1·5
N_3P_1	15	2·5	1·5
P_2	15	5·0	1·5
P_3	15	7·5	1·5
P_4	15	10·0	1·5
N_4P_1	20	2·5	1·5
P_2	20	5·0	1·5
P_3	20	7·5	1·5
P_4	20	10·0	1·5
P_5	20	20·0	1·5

The effect of fertilizer applications on the contents in the foliage is shown in Table 20.

TABLE 20.—EFFECT OF FERTILIZER APPLICATION ON THE N, P, K AND Mg CONTENT OF McINTOSH AND SPY FOLIAGE

McIntosh

Treatment	1947				1948			
	Per cent Nitrogen	Phosphorus p.p.m.	Potassium p.p.m.	Magnesium p.p.m.	Per cent Nitrogen	Phosphorus p.p.m.	Potassium p.p.m.	Magnesium p.p.m.
N_1	2·21	2,687	18,462	2,350	2·21	2,521	18,285	2,285
N_2	2·46	2,200	16,062	2,418	2·53	2,193	15,750	2,431
N_3	2·59	2,131	14,860	2,431	2·62	2,137	14,412	2,475
N_4	2·64	2,162	15,000	2,493	2·54	2,050	14,312	2,481
P_1	2·50	2,350	16,350	2,300	2·49	2,193	16,000	2,231
P_2	2·43	2,268	16,000	2,412	2·45	2,185	14,928	2,492
P_3	2·48	2,262	15,812	2,387	2·54	2,200	15,850	2,356
P_4	2·48	2,275	16,225	2,593	2·45	2,281	15,625	2,581

Spy

N_1	2·41	3,981	19,012	2,325	2·24	2,994	18,600	2,250
N_2	2·83	3,300	17,400	2,268	2·55	2,333	16,083	2,316
N_3	2·96	2,937	16,937	2,493	2·71	2,212	16,350	2,387
N_4	3·07	2,856	15,362	2,556	2·81	2,194	15,125	2,437
P_1	2·73	3,450	16,975	2,362	2·46	2,569	16,662	2,262
P_2	2·88	3,081	17,152	2,418	2·60	2,243	16,214	2,485
P_3	2·81	3,275	17,500	2,418	2·64	2,400	16,725	2,287
P_4	2·85	3,263	17,087	2,443	2·62	2,536	16,643	2,385

There was a fairly steady increase of total nitrogen in the foliage with increasing increment applications of ammonium sulphate. This increase in nitrogen content was accompanied by a considerable decrease in phosphorus and potassium. In the McIntosh variety the greatest decrease in phosphorus occurred between applications of five and ten pounds of ammonium sulphate per tree, but in the Spy variety the decrease was progressive with each added increment of nitrogen. The magnesium content of the foliage also increased with increased applications of ammonium sulphate. Applications of superphosphate do not appear to have had any consistent effect upon either the phosphorus or the nitrogen content of the foliage. It would appear that the Spy variety was better able to utilize the applied fertilizers, since levels of nitrogen, phosphorus and potassium were consistently higher in this variety than in the McIntosh.

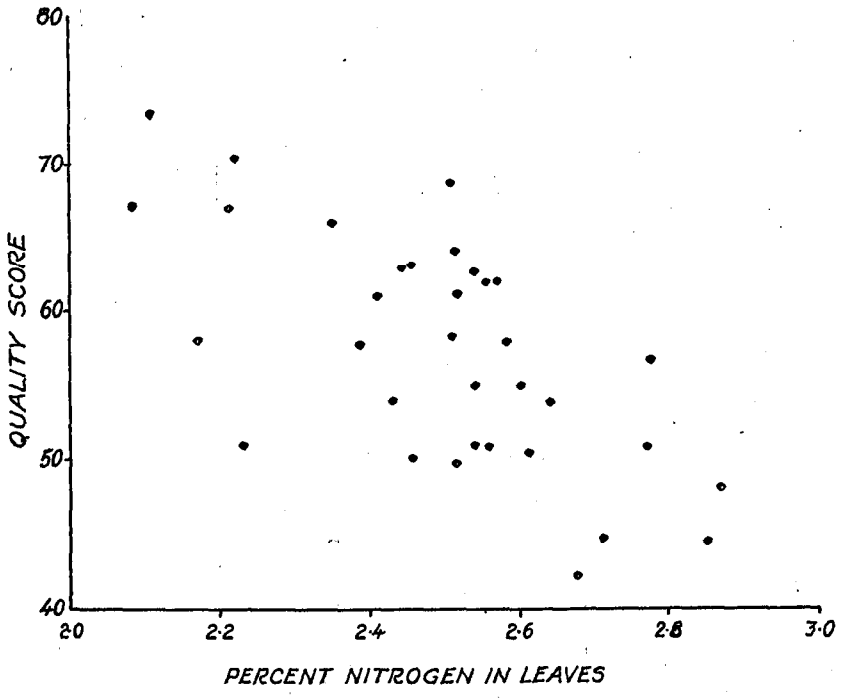

Fig. 12—Relation of quality score of fruit to per cent nitrogen in leaves of apples.

Fig. 12 (McIntosh variety) shows that storage quality increased with a decrease of the total nitrogen content of the leaves. There were also apparent correlations between higher quality and increases of potassium or phosphorus in the tissue. Since increases of nitrogen in the foliage were also associated with decreases of phosphorus and potassium, the single effect of each element must be arrived at by means of partial correlations. There was no apparent relationship between the incidence of core flush in the McIntosh and the level of total nitrogen in the foliage or between core flush and general quality.

These studies establish a relationship between levels of nitrogen in the foliage and quality of the fruit produced. This relationship is modified to some extent by the level of potassium or the N/K ratio and possibly by the N/P ratio. Further studies should clarify their relative effects.

References

1. Hill, H. and F. B. Johnston. Magnesium deficiency of apple trees in sand culture and in commercial orchards. Sci. Agr. 20: 516-525. May, 1940.

2. Wallace, T. Magnesium deficiency of fruit trees. Jour. Pomol. and Hort. Sci. 17: 150-166. 1939.

Tissue Tests of Vegetable Crops as a Means of Determining Fertility Levels and Fertilizer Requirements

Visual symptoms have proved of great value in diagnosing malnutrition in plants but total reliance upon their use is open to the criticism that a deficiency is not anticipated. In some instances the deficiency may bring about a considerable decline in yield but not be so acute as to create visual deficiency symptoms. Tissue tests may be used as a further aid in diagnosis and in determining fertility levels. It may be possible to establish critical concentrations for each nutrient for individual crops at specific growth stages by making many observations in which yields are compared with analytical values. While "quick tissue tests", suitable for use in the field have been employed in diagnosing an acute deficiency, it was considered that more accurate laboratory procedures were necessary to obtain correlations between levels and maximum yields. Quantitative methods were established, employing a colorimeter for reading colour reaction intensities.

Tissue Tests of Vegetables Grown in Nutrient Sand Cultures

Carrots and garden peas were grown in nutrients and cultures under each of the following p.p.m. concentrations of nutrient solutions:

Nitrogen	Phosphorus	Potassium	Magnesium
336	51	257	10
168	25	128	9
84	12	64	5
42	0	32	0

Carrot.—The reduction of nitrogen in the nutrient solution to 84 p.p.m. was reflected in a drop of soluble nitrogen in the tissue from 800 to 600 p.p.m. This concentration still allowed for ample or luxury absorption by the plant since yields were not reduced. When the nitrogen in the solution was only 42 p.p.m. the nitrogen in the tissues was reduced to 55 p.p.m., and this level was associated with definite symptoms of deficiency and a considerable reduction in yield.

There was a consistent reduction in yield and in the soluble phosphorus in the plant tissues as the concentrations of phosphorus in the nutrient solutions were reduced. Slight symptoms of phosphorus deficiency occurred when the concentration of the solution was reduced to 25 p.p.m. and the level in the tissue was 125 p.p.m. Although the vigour was not greatly reduced, the foliage was generally dull dark green in colour with one or two of the older leaves tinged with a dull purple. Very marked deficiency symptoms developed when the concentration in the solution was reduced to 12 p.p.m. or when no phosphorus was supplied and when the level in the tissues was 22 and 15 p.p.m. respectively. It is suggested that reduction in yield is liable to occur if the soluble phosphorus is not above 125 p.p.m. during the active growth period.

When no potassium was supplied the plant tissue contained 656 p.p.m. and showed very severe symptoms of deficiency. Nutrient solutions containing 32 or 64 p.p.m. produced plants showing incipient potassium symptoms. No symptoms were recorded when the solution contained 120 p.p.m. and the tissue 5,900 p.p.m. but higher yield was obtained when the tissue analysis was 7,800 p.p.m. A decrease of potassium in the plant was accompanied by an increase in magnesium.

Pea.—The reduction of nitrogen in the nutrient solution resulted in a marked reduction of soluble nitrogen in the plant. Since yields were not appreciably reduced nor symptoms of nitrogen starvation evident, it is probable that about 70 p.p.m. in the tissue is satisfactory.

The reduction or omission of phosphorus in the nutrient solution resulted in a marked progressive decline in yield. Reduction in yield and the occurrence of deficiency symptoms were associated with levels of 46 p.p.m. and under in the plant tissue.

The reduction or omission of potassium in the nutrient solution resulted in a corresponding reduction of this element in the plant tissue. Yields were materially reduced, and deficiency symptoms appeared with levels of 2,600, 3,200 and up to 4,500 p.p.m. in the tissue. It is probable that the level in the tissue should be from 5,000 to 7,000 p.p.m. to produce maximum yields.

Tissue Tests of Vegetables Grown on Fertilized Plots in Muck Soils

Tissue tests were also conducted with potato, carrot, spinach and onion growing on a wide range of fertilizer plots on a muck soil.

Potato.—Samples were taken from field plots on a muck soil involving the application of three levels of nitrogen, phosphoric acid and potash arranged as a factorial experiment. By the methods of analyses used, the application of fertilizers was reflected in the analyses of the lower petioles of the plant. Analyses indicated that if the plant contains less than 3,500 to 4,000 p.p.m. of potassium some six weeks after planting, yield will be reduced. From the lowest level of phosphorus found up to 70 p.p.m. there was no relationship with yield, but with levels above this figure there was a negative relationship. This negative relationship held only if the potassium level was below 3,000 p.p.m. With nitrogen up to 200 p.p.m. there was probably a positive relationship with yield, while with nitrogen from 200 to 1,000 p.p.m. there was a negative relationship with yield.

There was a significant negative relationship between the combined nitrogen and phosporus unit on potassium levels, and the effects of the higher categories of nitrogen or phosphorus levels on yield are largely conditioned by the potassium level.

A negative relationship existed between levels of potassium and magnesium and between potassium and calcium. Low potassium in the tissue was associated with an accumulation of magnesium and calcium.

Carrot.—The application of potassium was reflected in increased levels of potassium in the tissues and increased yields. A positive correlation was found between yields and levels of potassium in the tissue up to 6,000 p.p.m. above which level no further increase in yields was obtained. Levels in the tissue up to 3,000 p.p.m. were associated with dwarfing of the plant. Levels of phosphorus of 56 and 68 p.p.m. were associated with abnormally dull green foliage and dwarfed habit of growth.

Spinach.—The application of potassium was reflected in higher potassium in the tissues, increased yields and a reduction in the phosphorus concentration. Definite scorching due to low potassium was associated with a level as high as 3,900 p.p.m. of potassium in the plant tissue. Dwarfing and reduction in vigour without definite scorching was associated with levels as high as 5,900

p.p.m. Higher yields were obtained when the level was 7,800 p.p.m. or more. The lowest level of phosphorus found in the tissues was 200 p.p.m., and this level was not associated with any reduction in yield. An increase in plant vigour was associated with an increase of soluble nitrogen in the tissues from 500 to 800 p.p.m.

Onion.—The application of phosphorus was reflected in increased yields, increased levels of phosphorus in the tissues and a reduced K/P ratio. The application of potassium alone, or a high ratio of potassium to phosphorus, reduced the level of phosphorus in the tissue and reduced the yield.

Higher yields were obtained when the phosphorus level in the tissues was not lower than 50 to 75 p.p.m. Poor vigour and yield resulted when levels were 30 p.p.m. or lower. A partial deficiency of phosphorus had more effect on vigour and yield than a relatively low level of potassium.

Symptomatic Diagnosis and Mineral Nutrition Studies of Horticultural Plants by Means of Nutrient Sand Cultures

The most direct method of determining what a given soil requires for normal plant growth is to observe the growing plant as an index of the fertility level. A deficiency of any one of the several essential elements produces distinctive growth manifestations and foliage symptoms. A deficiency of one element is often associated with an excess of another so it is also important to have an understanding of the fundamental relationships between different elements in establishing balanced nutrition.

Nutrient sand culture studies have been conducted with a number of horticultural plants to acquire familiarity with the deficiencies, to obtain permanent records of symptoms, and to obtain information on the fundamental concepts of balanced nutrition.

Boron Deficiency

From 1928 on, brown-heart or water core of turnips was the direct cause of very considerable losses to growers in eastern Canada. Symptoms of boron deficiency as exhibited by turnips growing in nutrient sand cultures were identical with symptoms of brown-heart occurring in commercial production. Symptoms of boron deficiency as affecting the foliage and roots were described and illustrated by Hill and Grant (5). Additional studies by Davis and Ferguson (1) showed that brown-heart could be prevented by applications of boron even if the plants were a month old. It was also established that good control could be obtained by applications of boron as a foliage spray.

Ferguson and Wright (2) produced and described boron deficiency symptoms of celery, cauliflower, cabbage and corn when grown in sand culture, and by the same method Hill (3 and 4) described boron deficiency in table beet, tomato, spinach, carrot and garden pea. Splitting of carrots has been a problem in commercial production. A type of splitting as well as a distinctive pinkish to reddish coloration of the foliage was associated with boron deficiency. Typical scratching and splitting of celery stalks and canker of beets, both prevalent in commercial production, were associated with boron deficiency.

Other Deficiencies

Studies were also made of growth characteristics associated with deficiencies and excesses of nitrogen, phosphorus, potassium, calcium, magnesium and manganese, and in most cases permanent symptom records were secured in the following plants:

Vegetables:—tomato, turnip, carrot, pea, potato, beet, spinach, onion, celery, bean and lettuce.

Ornamentals:—chrysanthemum, carnation, calendula, cyclamen, sweet pea and stocks.

Deficiencies in the Tomato

Especial attention was paid to the nutrition of the tomato. It was shown that excess nitrogen symptoms are similar to those of deficient potassium in the early stages. A very close relationship exists between the feeding of nitrogen and the element potassium. The latter acts as the counterpart of nitrogen; that is, where nitrogen promotes soft, sappy growth, potassium hardens growth. Instances of potassium deficiency are sometimes associated with a medium potash level and a very high nitrogen or high N/K ratio.

It was also shown that excess feeding of phosphorus may induce potassium deficiency in the plant. Phosphorus deficiency was indicated by a marked dwarfing, small sized leaves, at first dull green in colour, later turning to a bluish purple.

A definite correlation was found between the occurrence of blossom-end rot and extreme vigour of the plant. Since this type of growth depended upon a high supply of nitrogen, it is considered that heavy applications of manure or commercial nitrogen are contributory to this trouble.

Specific Symptoms of Deficiencies in Vegetables

Following are descriptive notes of deficiency symptoms of a number of vegetable plants:

Deficient Phosphorus

Potato.—Plants are stunted, leaves dull dark green to bluish green; petioles arise at sharp angles and almost parallel with the stem; many of the tubers are affected with a black rot at the stem end.

Turnip.—Plants are depressed in vigour, leaves small, dull dark green with green fading and becoming a dull bronze.

Celery.—Stunted growth, foliage dull dark green with older foliage turning yellow.

Pea.—Poor vigour, spindly upright stem, leaves reduced in size.

Carrot.—Foliage dull dark green with older leaves dull purple and the leaf petioles affected with the same pigmentation.

Beet.—Plants dwarfed, leaves reduced in size, dull deep purple, petioles shortened.

Deficient Potassium

Potato.—Plants are compact with shortened internodes. The foliage is at first dark green; the margins of the leaves become yellow, followed by a brownish yellow bronzing which is intensified in the veins.

Turnip.—Pin point greyish to white necrotic areas appear around the margins of older leaves, followed by a general greyish scorching. In extreme deficiency the root is merely a thickened continuation of the stem.

Celery.—Plants are very dwarfed and have a marked wilted appearance; petioles are very short; leaves are small and lie flat.

Pea.—Plants are decidedly dwarfed, leaves much reduced in size with the tips and margins first yellow, then white and paper thin.

Carrot.—Plants are markedly dwarfed. The foliage is a dull dark green with the tips of leaflets becoming brown and scorched.

Beet.—Plants are dwarfed. The foliage is dull with a whitish grey mottling frequently toward the outer edge of the leaf but not following a distinct pattern.

Other Deficiency Symptoms in Vegetables

The general symptom of magnesium deficiency is a yellowing of leaf tissue between the veins followed by browning and death of the affected tissue, and either marginal browning or browned patches near the centre of the leaf. Symptoms first appear on older basal leaves, progressing upwards.

A study with the nutrition of head lettuce in the greenhouse suggested that tip burn and scald were intensified by a high supply of available phosphorus, especially when the nitrogen supply was also high.

Deficiency Symptoms in Ornamentals

Chrysanthemums

Rather extensive studies have been conducted with chrysanthemum nutrition. Definite foliage injuries were associated with a high nitrogen-potassium ratio in the nutrient solution. The chrysanthemum is a high potassium feeder and a nitrogen-potassium ratio of 1 to 2 in the nutrient solution produced normal growth. High phosphorus feeding in the presence of a high nitrogen-potassium ratio increased the severity of foliage injury. Lack of phosphorus was characterized by spindly growth, stunting and reddish-purpling of the leaves. Lack of potassium caused poor vigour, fading and yellow-browning of the foliage together with burning and dying of the foliage from the base of the plant upward. Fertilizer treatment had a marked effect upon the production of depth of colour in the bloom. Development of colour was increased by an adequate potassium supply, not only in total amount but also in relation to the amount of nitrogen or phosphorus available.

Stocks

Deficient nitrogen.—Stems are thin and spindly, leaves small, with upright habit of growth. The leaves are at first pale green succeeded by orange coloured chlorosis commencing at the leaf tips and gradually extending down the whole leaf.

Deficient potassium.—The first symptom on the leaves is a yellowish mottling followed by tip or marginal scorching. The scorched tissue is light in colour, almost a dirty white.

Deficient boron.—Abnormal curling back of the upper leaves and the appearance of a greyish cast over the leaf surfaces. In advanced stages there is a marked browning on the midrib and cracking of this tissue. The growing point of the plant becomes compressed and flower buds fail to develop.

Sweet Pea

Deficient phosphorus.—Leaves are very small, standing upright. The internodes, leaf petioles, tendrils and flower stems are noticeably short. Purpling occurs on the under surface of older leaves and on the tendrils.

Deficient potassium.—A marginal yellowing occurs on the lower leaves followed by a light brown straw colour scorching which gradually involves the entire leaf. Flower stems are short.

Deficient boron.—The first symptom is a marked curling or rippling along the margins of the petals. This is followed by a yellowing and death of young flower buds. A typical distortion of the growing part occurs.

Calendula

Deficient nitrogen.—Plants are poorly branched, spindly with thin stalks. The foliage is at first light green to yellow-green followed by a straw-coloured scorching of the older leaves.

Deficient boron.—Irregular, slightly greyish mottled areas occur on the leaves. These areas gradually spread producing a decidedly greyish cast over the entire leaf. A browning and cracking develops on the edge of the stems.

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Physiological Disorders of Apples

Cork Disorders

In 1931, a request was made for diagnosis of and control measures for a disorder present in rather severe form in an orchard at Oka, Quebec. Examination of the fruit showed the disorder to be similar to that described by Mix (6) and to which he had given the name, "cork".

In the varieties Fameuse and McIntosh two different expressions of the disorder of the fruit were recognized. In neither the Fameuse nor the McIntosh variety was there any external evidence of the disorder when the affected fruit was half grown. Internally, in Fameuse light brown spots of dead cork-like tissue occurred in the region of the core or scattered indiscriminately throughout the flesh. Later, the affected Fameuse sometimes became severely deformed by discontinuous elevations and depressions, producing a marked knobby appearance. To this expression of the disorder the name "internal cork" was applied. In the McIntosh variety the internal affected tissue was generally confined to the core area, either as light brown individual spots or as a continuous band or circle around the core, and to this manifestation of the disorder, the name "corky-core" was applied.

At this time no direct control measure for the disorder was known. Mix (6) concluded that "lack of soil moisture was one predisposing factor but since the disorder may appear, to a limited extent, in a rainy season, lack of soil moisture cannot be considered the sole cause. Other factors, yet unknown, may be operative". Based on the evidence, the only control method Mix suggested was conservation of soil moisture, and an even distribution of the moisture supply throughout the season.

From the beginning of these studies at the Division of Horticulture it was considered that some nutritional condition might be a contributory factor in the occurrence of this disorder. In the search for the nutritional factor, roots from affected trees at Oka were analysed in 1931. The analyses showed very heavy accumulation of iron and a low potassium content. Other workers had reported a correlation between iron accumulation and a deficiency of potassium in corn. For this reason affected trees at Oka were treated in the spring of 1932 with drilled soil applications of muriate of potash and a foliage spray of potassium sulphate. Although both methods increased the potassium concentration in the foliage, they had no effect in reducing the severity of cork disorders.

By this time cork disorders were causing considerable concern in individual orchards in all the main apple growing districts in the province.

In 1933, it was decided to conduct a survey of soil conditions and tree root growth of healthy and affected trees in the principal producing areas. Observation trenches five to six feet in depth were dug in some twenty-two different orchards. Soil analyses were made and soil moistures determined. These studies did not establish any direct cause of the disorder, but they did associate certain conditions with increased severity as follows:

(1) High lime soils.

(2) High percentage of nitrogen and organic matter especially where compact subsoils caused shallow rooting of trees.

(3) Soil moisture excesses and deficiencies in association with high nitrogen and organic matter.

These correlations are basically nutritional. They strengthened the original premise that some nutritional condition was a factor in cork disorders. However, the soil and root distribution studies provided information of a much wider character than their possible relationship with this particular disorder. They provided a knowledge of the soil types in the different areas and of the physical characteristics of the soil associated with extensive or restricted tree root systems. These studies have been reported in detail (3).

During the winter 1933-34 such severe winter injury occurred in the Quebec orchards under survey that sufficient tree units were not available for extensive experiments. However, in 1934, dry salts of phosphorus, potassium, nitrogen, calcium, magnesium, manganese and boron were injected directly into limbs of trees for a study of the effect of nutrition on the incidence of cork. Broadcast soil applications of one-quarter pound of boric acid were also made to two trees. All the trees in the experiment set such a small crop that it was impossible to evaluate the effect of treatment. In the small number of apples available for examination cork was absent in some of the untreated as well as in some of the treated limbs.

A fairly definite lead was secured from the pot sand culture experiments on apple nutrition at Ottawa. Up to 1934, boron had not been included in the nutrient solutions used, and with the beginning of fruiting in 1932 a large percentage of the fruit was affected with cork. In 1934, the trees were divided into two groups, one of which had one part per million of boron included in the nutrient solution. A considerable proportion of the experimental trees did not bear fruit in that year, but those fruiting trees which received boron were free of cork. For instance, one tree which had had every fruit affected in 1932 and 1933 bore forty-four fruits in 1934, all of which were free of cork. This effect of boron in controlling cork was confirmed in 1935 when the potted trees were fruiting more normally.

In the Waite orchard, a block of McIntosh, near Brighton, Ontario, practically every tree bearing fruit had been affected with corky-core in 1934. Therefore, in 1935, direct limb injections were made of powdered salts of phosphorus, potassium, nitrogen, calcium, copper, manganese and boron. Before harvest an examination was made of twenty cut apples from each treatment with the following results:

Salt Employed	Injections in Grams per Limb	% Cork Core
Potassium chloride	14	100
Sodium hydrogen phosphate	16	92
Ammonium nitrate	15	97
Calcium acetate	14	97
Copper sulphate	1	97
Manganese sulphate	1	95
Boric acid	1	60
Check		94

These results are the average of several unit limb injections for each salt. In one tree having an average of ninety-seven per cent affected fruit in all other limbs, the limb injected with boric acid had only 45 per cent of the fruit affected and such fruit showed only slight symptoms. Even though injected in such a small amount, boron apparently effected a partial control.

In June, 1936, a request was received from the Agricultural Representative of Northumberland county, Ontario, to diagnose a condition which had arisen in the Hendricks orchard near Trenton. This orchard consisted of about eighteen acres planted to the varieties, McIntosh, Fameuse, Northern Spy, Wealthy, Stark, Ben Davis and Salome. A tree to tree examination revealed that some of the fruits on at least 90 per cent of the trees were affected with an expression of the cork disorders to which Mix had applied the name "drought-spot".

The type of cork designated as drought-spot may appear early in the life of the fruit. It first appears as irregular small to large light brown russeted patches on the skin. These areas later become rugose, darker brown in colour and as they grow, become roughened and cracked. The lesions may not extend deeply into the flesh although in severe cases deep cracks or splits may be formed. This expression of the disorder was found either alone or associated with internal cork or corky-core.

Just before harvest actual examinations were made on fifty apples from each tree in the Hendricks orchard and the percentage of the crop affected with some type of cork disorder was as follows:

McIntosh	85	Stark	39
Fameuse	72	Ben Davis	91
Wealthy	75	Salome	61
Northern Spy	51		

From observations made during the season it was estimated that at least four thousand trees in the Brighton-Trenton district were bearing fruit affected with some form of the cork disorders.

Because injections of boron effected a partial control of internal cork in the Waite orchard in 1935, further treatments were made in the spring of 1936:

1. Direct injection of boric acid into the trunks of trees by boring holes with a $\frac{7}{16}$-inch bit to a depth of two inches then filling these holes with boric acid. The holes were spaced five inches apart around the trunk. Direct injections of three grams of boric acid were also made into individual limbs.

2. Boric acid at the rate of one-quarter pound per tree broadcast on the soil.

In June, when the high incidence of drought-spot was found in the Hendricks orchard, drought-spot was also found in the Waite orchard but only on untreated trees or limbs. All trees or limbs which had been injected with boric acid in 1935 or in the spring of 1936 were free of this disorder. Previous to harvest an examination of fifty apples from each treatment showed the following percentages of cork:

Boric acid injection	0
Boric acid soil broadcast	76
Check	81

In every instance where boric acid had been directly injected into the trunk or into individual limbs the apples were completely free of cork disorders, but the soil broadcast application of one-quarter pound of boric acid per tree did not give control in the year of application. It was believed that the broadcast rate of application for these adult trees was not sufficiently high, especially on the Waite alkaline soil which had free carbonates occurring in all soil horizons. As proof of the insufficiency of application, analysis of treated soil from this orchard showed the water soluble boron in the surface soil to be 0·5 p.p.m. and in the 12—24 in. horizon only 0·2 p.p.m.

Boron analyses of leaves and fruit from untreated and boron injected trees of this same orchard gave the following results on a dry-matter basis in p.p.m. boron.

	Fruit	Leaves
Boron injected into trunk	35·7	15·0
Check	1	1

In the untreated Hendricks orchard the fruit contained an average of 1·09 p.p.m. and the leaves, 4·2 p.p.m. of boron.

From these analyses and the fact that the Hendricks orchard comprised 7 varieties more or less severely affected, it was considered that this location offered excellent facilities for conducting experimental remedial measures. Plots and treatments were commenced in the fall of 1936 and the spring of 1937.

Soil moisture was adequate throughout the 1937 season. Cork disorders were not severe as borne out by the boron levels found in fruit from non-treated trees (Table 21).

TABLE 21.—BORON ANALYSES OF FRUIT, 1937

Variety	Treatment	p.p.m. Boron Dry-Matter Basis
McIntosh	Check	17·0
McIntosh	1 lb. boric acid per tree broadcast fall 1936	38·3
McIntosh	1 lb. boric acid per tree broadcast spring 1937	25·7
McIntosh	Boric acid, trunk injection, 20 grams, spring 1937	36·0
McIntosh	0·25% boric acid sprays at calyx and second cover	40·0
Fameuse	Check	20·0
Fameuse	1 lb. boric acid per tree broadcast fall 1936	43·0
Fameuse	1 lb. boric acid per tree broadcast spring 1937	25·5
Fameuse	Boric acid trunk injection, 20 grams, spring 1937	41·0
Fameuse	0·25% boric acid sprays at calyx and second cover	41·5
Salome	Check	13·7
Salome	0·25% borax spray at calyx and second cover	37·5
Salome	0·25 % boric acid spray at calyx and second cover	41·2

A comparison of the two broadcast applications, fall of 1936 and spring of 1937, indicates a considerably higher level of boron in the fruit of trees receiving the fall application. In some of the trees directly injected with boron a certain amount of foliage injury was observed. In an injured leaf the green colour along the midrib disappeared and the area subsequently turned yellow.

Boron analyses of affected and non-affected leaves from boron injected trees and leaves from non-treated trees were as follows:

Variety		Boron (p.p.m.)
Fameuse	Injured leaves from injected trees	240
"	Healthy leaves from injected trees	60
Ben Davis	Injured leaves from injected trees	120
"	Healthy leaves from injected trees	60
Stark	Healthy leaves from untreated trees	10

The injured leaves from treated trees had two to four times the boron content of the uninjured; leaves from the untreated trees had one-sixth the boron content of healthy leaves from treated trees.

In the spray applications of borax or boric acid, the chemicals were included in the regular lime sulphur arsenical sprays. Particular care was taken to record the effects on the foliage. No foliage injury resulted from this method of application, and apparently the efficiency of the spray material was not impaired.

On the basis of the results secured in the Waite and Hendricks orchards, the following interim recommendations for the control of cork disorders were made to the growers: "Cork disorders may be corrected by boron applications to the soil

at the rate of four to eight ounces of borax per tree, worked into the soil if possible. If the soil is alkaline, immediate results may be obtained by incorporating borax with the regular lime sulphur sprays. Two applications should be sufficient, one at the time of the calyx spray and the other in the second cover spray, using borax at the rate of 2½ lb. to 100 gallons of spray mixture" (1).

Further treatments were made in the Hendricks orchard in 1938 and 1939, and the residual effects of the 1936 or 1937 treatments were recorded. Results are given in Table 22.

TABLE 22.—BORON ANALYSES AND INCIDENCE OF CORK DISORDERS IN HENDRICKS ORCHARD, 1937-1939

Variety	Treatment	1937		1938		1939	
		p.p.m. Boron	% Cork	p.p.m. Boron	% Cork	p.p.m. Boron	% Cork
McIntosh	Check	17·0	.....	3	45·6	4	50
McIntosh	Boric acid broadcast fall 1936	38·3	.....	16	00·0	24	00·0
McIntosh	Boric acid broadcast spring 1937	25·7	.....	20	9·0	23	00·0
McIntosh	Boric acid trunk injection 1937	36·0	.....	10	00·0	8	8
McIntosh	Boric acid spray 1937	40·0	.....	10	9·0	7	4
McIntosh	Boric acid spray 1937, 1938, 1939	.....	.....	.....	.....	19·6	00·0
Fameuse	Check	20·0	0·33	16	18·3	6·6	20·3
Fameuse	Boric acid broadcast fall 1936	43·0	.....	25	00·0	23·8	00·0
Fameuse	Boric acid broadcast spring 1937	25·5	0·33	17	00·0	20·8	00·0
Fameuse	Boric acid trunk injection 1937	41·0	1·0	11	0·66	11·6	2·3
Fameuse	Boric acid spray 1937	41·5	.....	13·5	00·0	15·0	00·0
Fameuse	Boric acid spray 1937, 1938, 1939	.....	.....	.....	.....	32·6	00·0
McIntosh	Borax deep drilling in soil, 1937, 1938	22·5	.....	10	00·0	.....	00·0
McIntosh	Boric acid deep drilling 16 oz. 1937, 1938	27·5	.....	16	00·0	.....	00·0
McIntosh	Check	13·0	.....	4	48·0	.....	75
Wealthy	Boric acid spray 1937, 1938, 1939	.....	.....	.....	00·0	.....	00·0
Wealthy	Borax spray 1937, 1938, 1939	.....	.....	.....	00·0	.....	00·0
Wealthy	Check	.....	.....	.....	6·5	.....	15
Salome	Boric acid spray 1937, 1938, 1939	.....	.....	.....	00·0	.....	00·0
Salome	Borax spray 1937, 1938, 1939	.....	.....	.....	00·0	.....	00·0
Salome	Check	.....	.....	.....	34	.....	53

TABLE 23.—INCIDENCE OF WATER-CORE IN NORTHERN SPY AFTER THREE ANNUAL TREATMENTS FOR CORK DISORDERS

Treatment	Water-Core	Boron
	%	p.p.m.
Check	4	4·1
Boric acid 8 oz. per tree	4	.....
Boric acid 16 oz. per tree	10	42·0
Boric acid 32 oz. per tree	22	.....
Boric acid 64 oz. per tree	24	62·0
Borax 12·5 oz. per tree	6	.....
Borax 25 oz. per tree	0	20·0
Borax 50 oz. per tree	12	.....
Borax 100 oz. per tree	18	63·3

In addition to those treatments in Table 22 broadcast applications of borax and boric acid were made for three successive years (1937-1939) to trees of the Northern Spy variety. The rates employed did not produce any injurious effect on the trees, but after the third successive year of application, water-core and water-core breakdown of the fruit appeared to be more prevalent as indicated in Table 23.

Spray treatment of the variety Salome for three successive years gave the following further evidence of the deleterious effect on fruit quality:

Treatment	% Water Core
Boric acid sprays	30·2
Borax sprays	15·0
Check	1·5

Because these studies indicated that with repeated applications of boron-carrying compounds there was a danger of creating toxic conditions leading to water-core in the fruit, the recommended control measures were slightly modified as follows:

Boron should be applied either in the early spring or fall to orchards in any area where cork has been found and where no application of boron has yet been made. The treatments should not be made annually. A single treatment has been found effective for a period of three years under fairly normal conditions. The safest procedure would be to forgo further applications until the first reappearance of the disorder is again recorded, since with annual treatments there is a possibility of creating toxic concentrations of boron.

The specific recommendations were:

Orchards on Acid Soils.—Four ounces of borax to trees up to 10 years of age, 8 ounces to trees from 10 to 20 years of age, and 8 to 16 ounces to older trees. If boric acid is used, the rates should be two-thirds of those mentioned.

Orchards on Alkaline Soils.—If the soil is alkaline and high in calcium carbonate, effective control may not be obtained by applications to the soil in a season when very low soil moisture conditions exist. Under these conditions more effective control may be obtained by incorporating borax with the regular spray at the rate of 2½ lb. borax to 100 gallons of spray, applied at the time of the calyx and second cover sprays.

From 1939 to date, either the soil application or foliage spray recommendations as given have been employed every three years in the Hendricks orchard. Complete control of cork disorders has been obtained, and there has been no evidence of deterioration of fruit quality.

In the province of Quebec, boron is applied as a foliage spray. Recommendation for treatment is made through the spray service calendar every third year and this serves as a convenient means of maintaining the necessary boron supply without the possibility of creating an excess.

The foregoing experiments covered a period of nine years, but results have been definite and gratifying. By following the remedial measures, cork disorders no longer reduce the yield and quality of fruit in the commercial apple orchards of Canada.

Bitter-Pit

Seasonal climatic conditions that favour the prevalence of cork disorders also cause an increase in the severity of bitter-pit. Until it was known that cork disorders were directly due to a deficiency of boron, bitter-pit was grouped with the cork disorders and all were attributed to unfavourable water relations.

Although cork disorders were the more serious in the Hendricks orchard, certain varieties such as Spy and Stark were also affected with bitter-pit. Since bitter-pit was also present in other commercial orchards, a survey was made of

the incidence of this disorder in many of the commercial orchards of the two Ontario counties, Northumberland and Durham. An attempt was made to correlate certain factors such as soil characteristics, tree root growth and vertical distribution, soil management and fertilizer practice with the occurrence of this trouble.

Symptoms of two types of bitter-pit, typical bitter-pit and blotchy-pit, were recognized.

Typical Bitter-Pit.—Pitting does not show up until the fruit is approaching maturity or may not show up until the apples have been in storage for some time. The first cells to be affected are the pulp cells, and from these the disorder works outward so that in the initial stages dark spots may be seen through the skin before an actual depression or pit is formed. The areas over these spots become depressed or sunken and are comparatively small and regular in outline. Externally the spots are usually brownish but may vary from grey-green to reddish-brown. The small brown spots extend into the flesh, but are generally confined to a few layers of cells just underneath the skin. The pits are usually more numerous towards the calyx end. Sometimes late formed cork lesions may be confused with bitter-pit, but in cork the brown spot is generally surrounded by a very narrow zone of green tissue. Internally, and therefore not visible as pits on the surface of the apple, numerous lesions may be distributed between the skin and the core area.

A histological examination (4) of apple fruit affected with the various cork disorders and with bitter-pit showed the following similarities and differences: Starch retention in localized or diffuse necrotic areas is common to both cork disorders and bitter-pit. External papillations occur on the walls of cells in close proximity to the lesions. Abnormal meristematic activities occur in the cork disorders. These are (1) a cork cambium partially or completely walling off a lesion; (2) massed linear cells, heavily papillated, and (3) reactivated individual cells or groups of cells. All three types of abnormal cells may be present in internal cork and drought-spot but no cork cambium occurs in corky-core. Blotchy-pit is discussed as a border-line type since one end of a graded series is similar to internal cork and the other is indistinguishable from bitter-pit.

Blotchy-Pit.—In this expression of the disorder, the pits are less clearly defined, irregular in outline, larger in size, less sunken, deep green or mottled green and brown blotchy depressions. Large brown necrotic areas are found in the flesh near the core or close to the surface. Such lesions may be brown and spongy with an indefinite outline similar in appearance to a bitter-pit lesion, or the lesion may have a definite faded greenish border similar to that of internal cork. However, this type of lesion is not readily confused with internal cork because of the difference in external appearance.

The effect of boron on control of pit disorders is given in Table 24.

Branch unit injections of various mineral salt solutions were also made using the varieties Newton Wonder and Mr. Prothero while the author was stationed at the East Malling Research Station, England, in 1938. Details of these injections and their effect on bitter-pit incidence are given in Table 25.

These studies, the results of which are summarized in Tables 24 and 25, indicate that boron treatments have no effect on the control of bitter-pit. Neither was any control obtained by direct injection of the mineral salts listed in Table 25.

In the Hendricks and two other commercial Ontario orchards, branch unit injections of various mineral salts did not effect a reduction in the incidence of bitter-pit. In fact, in one orchard limbs injected with phosphorus, calcium or cobalt showed more severe symptoms of the disorder.

Analyses of pitted fruit had shown that in comparison with healthy fruit the calcium and iron content of the affected fruit was noticeably low, yet direct injections of calcium salts were of no assistance in controlling the trouble.

TABLE 24.—EFFECT OF BORON TREATMENTS ON THE INCIDENCE OF PIT

STARK VARIETY

Treatment	Bitter-Pit at Harvest	Bitter-Pit in Storage
	%	%
Soil application, deep drilling, borax	2·0	3·5
Soil application, deep drilling, boric acid	3·3	3·2
Check	.....	5·6
Trunk injection, borax	4·6	5·0
Trunk injection, boric acid	1·3	6·3
Check	2·0	5·6

SPY VARIETY

Broadcast applications, boric acid, 8 oz	13	.....
16 oz	8	8·6
32 oz	6	.....
64 oz	4	6·6
borax, 12·5 oz	4	5·4
25 oz	14	.....
50 oz	6	9·3
100 oz	8	6·1

TABLE 25.—EFFECT OF INJECTIONS OF MINERAL SALT SOLUTIONS ON THE INCIDENCE OF PIT IN TWO VARIETIES OF APPLES

Treatment	Newton Wonder	Mr. Prothero
	Pit	Pit
	%	%
Boric acid	60·9	42·2
Zinc sulphate	71·3	69·0
Nickel chloride	57·9	.....
Calcium acetate	45·8	44·6
Check	51·7	42·8
Ferric chloride	.....	64·0
Magnesium sulphate	.....	49·3
Potassium sulphate	.....	48·6
Manganese sulphate	.....	38·7
Mixture N. P. K. Mg. and Fe	.....	61·2
Mixture N. P. K. Mg. Fe. and B	.....	58·0

The Horticultural survey of some 160 orchards in the counties of Northumberland and Durham showed the following trends in reference to the occurrence of bitter-pit:

A small amount of bitter-pit is present each year on individual trees or on small groups of trees, but at intervals of several years it develops to a serious state. The principal varieties affected are Stark, Northern Spy, Baldwin, Baxter and Greening. Bitter-pit appeared to be at a minimum in permanent sod orchards compared with various systems of cultivation; it was more prevalent in young trees just beginning to bear; in seasons of light crop when the fruit size was abnormally large and when grown under high nitrogen conditions; it appeared to be more prevalent in orchards situated on the better, heavier, deeper soil types such as the Newcastle loam. On this soil type tree root systems were deep and well developed and tree vigour was high. Although there was a definite relation between the occurrence of cork disorders and the amount of free carbonates, this did not hold in the case of bitter-pit.

No direct cause or control of bitter-pit was established. With the onset of war and the consequent reduction of staff and channeling of effort further studies on this disorder were necessarily suspended.

On the basis of knowledge thus far, the only possible recommendation to the grower is to avoid those pruning, cultural and fertilizer treatments which promote excessive growth. If bitter-pit is present, the amount of nitrogenous fertilizer should be reduced or the use of manure forgone. In some cases it may be advisable to change from a clean cultivation system of management to a sod mulch. The fruit from trees showing bitter-pit at harvest time should be marketed immediately, since storage-pit may develop in fruit from trees apparently free of bitter-pit at harvest.

Water-Core

Another common name for water-core is glassiness. When this disorder is in the early stages or if it is not severe, it may be recognized only by cutting open the fruit. In these early or nonsevere stages, glassy areas occur close to the core, in lines radiating from the core, or around the vascular bundles. These areas appear to be water or sap-injected. Later, much of the flesh may become involved and the disorder progresses outward to the skin. All portions affected attain the characteristic glassy appearance. If the fruits are severely affected when picked, a general breakdown of the tissues occurs in storage, but if slightly affected only, the water-core areas may disappear. Although no systematic study of this disorder has been conducted, the following results from branch unit solution injections of the variety Duchess are of interest:

Treatment	% Water-Core
Check	22
Potassium	26
Nitrogen	46
Calcium	24
Phosphorus	18

These results bear out the commonly accepted view that water-core is more prevalent under high nitrogen conditions. It is also more prevalent on young trees just coming into bearing so that the growth of young trees of susceptible varieties should not be unduly forced by heavy applications of nitrogenous fertilizers or manure.

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The Histology of Physiological Disorders in the Apple Fruit

M. MacArthur

In general, diagnosis of physiological disorders in the apple fruit has been based on the gross appearance and location of the accompanying lesions. The histology of these lesions and the contiguous tissue was investigated in an attempt to supplement the gross diagnostic characteristics.

The disorders examined were internal cork, corky-core, drought-spot (superficial cork), bitter-pit (tree pit, normal type), blotchy-pit (tree-pit, blotchy type) and water-core. The first three are known to be boron amenable and the literature is in conflict as to alleviation by boron in the remaining types, but the experimental work conducted by the Division of Horticulture under the supervision of M. B. Davis and H. Hill has not shown that boron deficiency is associated with these remaining disorders.

Histologically, the lesions of internal cork, corky-core and drought-spot all showed abnormal growth. None was found in bitter-pit while blotchy-pit was intermediate; that is, there was a type gradation ranging from lesions similar histologically in all respects to those of bitter-pit to others resembling drought spot with the several classes of meristematic activity.

In all disorders except water-core there was cell collapse in the lesions, imprisoned starch grains and the cell walls of contiguous healthy cells were more or less papillated. The abnormal growth in internal cork consisted of heavily papillated linear cells, and re-activated cells. The lesion was walled off by a cambial layer. The linear cells were always found in corky-core; re-activated cells were found occasionally, but there was no cambial activity. In drought-spot linear cells were always present; re-activated cells and cambial activity occasionally present. In bitter-pit no abnormal growth and no cambial layer was found. Some lesions of blotchy-pit resembled bitter-pit; others drought-spot. Water-core differed from all others in that there was no cell collapse, starch retention, papillated cell walls or any meristematic activity.

The details of the comparative microscopy of these physiological disorders may be found in "Histology of Some Physiological Disorders of the Apple Fruit" by Mary MacArthur. Can. Jour. Res. C, 18:26-34. 1940.

Soil Management in Vegetable Production

H. Hill

In vegetable crop production, soil fertility maintenance presents a problem which is less easily dealt with than in most other types of agricultural production. The majority of vegetable crops require a quick and relatively short growth and maturity period, and therefore, demand a higher level of available plant nutrients than do the majority of field crops. Many of the crops are intertilled, and comparatively long periods of cultivation speed up organic matter losses. Vegetable growing has become highly specialized, and a grower has no need for pasture or little need for hay. When vegetable land is put into grass to build up the soil organic matter it means that high priced land is taken out of production. The problem is to strike a balance so as to secure the highest returns from cash crops and yet not cultivate so intensively that soil organic matter and fertility are eventually reduced.

Soil studies have been conducted during the last four or five years on a vegetable production area. In this area it has not been possible to follow what would be considered a suitable crop rotation, but the study has provided interesting information on the effect of certain cultivated crops on the levels of soil organic matter. All crops mentioned have received a medium quantity of commercial fertilizer.

Area I

1945: Soil organic matter 5·44 per cent; total nitrogen 0·21 per cent. Crop, onions.

1946: Strawberries for propagation.

1947: Crop, cucumbers. Application of 25 tons of manure per acre.

1948: Crop, carrots, beets. Soil organic matter 4·70 per cent; total nitrogen 0·18 per cent.

Following three cultivated crops and with 25 tons of manure per acre applied in this period, the organic matter decreased 0·74 per cent.

Area II

1945: Soil organic matter 4·84 per cent; total nitrogen 0·19 per cent. Crop, carrots and cabbage.
1946: Crop, peas. Manured in fall at 25 tons per acre.
1947: Crop, early carrots. After carrots, soil organic matter 3·92 per cent; total nitrogen 0·17 per cent. Seeded down to clover and timothy.
1948: Ploughed in August, sampled in October. Soil organic matter 5·40 per cent; total nitrogen 0·22 per cent. No hay removed.

A clover-timothy sod, not cropped and turned under, increased the soil organic matter to a higher level than was found previous to the cultivated crops.

Area III

1945: Soil organic matter 4·53 per cent; total nitrogen 0·15 per cent. Crop, carrots.
1946: Seeded to clover and timothy.
1947: Ploughed in August, sampled in October. Organic matter 6·10 per cent; total nitrogen 0·25 per cent.
1848: Crop, tomatoes. Sampled in October. Soil organic matter 5·62 per cent; total nitrogen 0·25 per cent.

Area IV

1945: Soil organic matter 4·22 per cent; total nitrogen 0·19 per cent.
1946: Seeded to timothy-clover.
1947: Ploughed in August. Soil organic matter 6·06 per cent; nitrogen 0·23 per cent.
1948: Crop, radish and spinach. Soil organic matter 5·24 per cent; total nitrogen 0·22 per cent.

Area V

1945: Soil organic matter 4·26 per cent; total nitrogen 0·18 per cent. Crop, tomatoes.
1946: Seeded down to clover, timothy.
1947: Ploughed in August. Soil organic matter 5·58 per cent; total nitrogen 0·25 per cent.
1948: Crop, corn. After corn, soil organic matter 4·56 per cent; total nitrogen 0·22 per cent.

Grassing down for two years with the total growth returned to the soil appears to be a good way of building back organic matter after a series of cultivated crops.

To answer some of the questions on suitable rotations in canning crop production, long-time experiments were set up at the Smithfield Substation in 1946. These rotations are designed on the assumption that sufficient manure is not generally available to maintain organic matter with cash crops of tomatoes, peas and corn. The trials consist of several rotations.

1. A four-year rotation with two canning crops, peas and tomatoes or peas and corn; a grain crop and timothy-clover hay.

2. A four-year rotation with three canning crops, green manure after peas and sweet clover the fourth year.

3. A four-year rotation with three canning crops, clover seeded in peas or corn, and one year clover hay.

4. A two-year rotation of tomatoes and peas or corn and peas, and two green manure crops following the pea harvest.

This study will necessarily be conducted for a prolonged period before any conclusions may be drawn. However, as the study progresses certain crop records and soil studies will provide a source of interim information.

Soilless Growth

For several years prior to 1935 the Horticultural Division, Central Experimental Farm, Ottawa, had studied the nutritional requirements of various plants by growing them in pots in sand and supplying nutrients in solution. Such marked success was obtained that the production of commercial crops in the greenhouse in beds of sand treated with commercial plant nutrients in solid form or in solution was considered feasible.

The first plant employed for conducting a study with this method of commercial production was the chrysanthemum. (Hill, H. and M. B. Davis, Chrysanthemums Thrive in Sand Cultures. Better Crops with Plant Food 20, No. 11:6-8, 36-38, 1936).

The method employed for growing chrysanthemums in beds of river sand and watering the surface with nutrient solution was as follows:

Before transplanting into sand, most of the soil was removed from the roots. Until the plants were about half-grown nutrient solution was applied at the rate of three-quarters of a pint per plant or approximately one gallon per square yard once a week. The application of solution was then increased to one and one-half pints of solution per plant or approximately two gallons of solution per square yard once a week. In addition to the nutrients the plants were watered when necessary. In order that harmful accumulation of salts did not occur the bed was thoroughly leached with water at biweekly intervals.

To prepare the nutrient solution the following quantities of salts were dissolved in 50 gallons of water.

Magnesium sulphate	8·7 oz.
Potassium phosphate (monobasic)	4·75 oz.
Calcium chloride	9·7 oz.
Potassium nitrate	10·5 oz.
Ammonium nitrate	23·75 oz.

Iron was supplied by adding a few drops of a 1 per cent solution of ferric chloride to a gallon of this solution before application.

Further studies were conducted employing commercial fertilizers in the formula as sources of nitrogen, phosphorus and potassium. The following formula proved very satisfactory:

Ammonium sulphate	35·5 oz.
Muriate of potash	9·6 oz.
Superphosphate 20 per cent	8·9 oz.
Magnesium sulphate	6·9 oz.
Boric acid	6·25 gm.
Manganese sulphate	0·82 gm.
Ferric chloride	18·0 gm.
Water	40·0 gal.

Instead of applying this solution once a week and watering in addition when necessary, very successful results were obtained by using the above formula at one-sixth strength whenever the bed required watering.

Studies were also conducted by applying the plant nutrients in solid form on similar sand beds. Since a time lag might be expected before these fertilizers would be available, an application of fertilizer was made some ten days to two weeks before the plants were set in the bed. During this period the sand was kept moist but not watered to such an extent that leaching occurred.

Very good results were secured with the following fertilizer mixture applied weekly at the rate of one-half ounce per square yard:

Ammonium sulphate	10 lb. 6 oz.
Muriate of potash	2 lb. 14 oz.
Superphosphate 20 per cent	2 lb. 11 oz.
Magnesium sulphate	2 lb.
Boric acid	8 gm.
Manganese sulphate	1 gm.
Ferrous sulphate	25 gm.

The carnation was also grown in beds of river sand, the surface being watered with a nutrient solution. In order to make the application of nutrient solution less laborious, use was made of a "hozon" attachment. This consists of a suctioning device which is attached to the water line and to which the hose is connected. The hozon has a tube which is allowed to dip into a container of concentrated nutrient solution. When the water is turned on a suction is created which draws up the nutrient solution and mixes it with water from the water line. If the water pressure is about thirty pounds the nutrient solution as applied is diluted fifteen times.

Formula for use with hozon attachment in growing carnations in sand—amounts required to make up four gallons of solution:

Ammonium sulphate	109·0	gm.
Nitrate of soda	136·0	"
Muriate of potash	70·0	"
Superphosphate 20 per cent	170·0	"
Magnesium sulphate	67·0	"
Calcium sulphate	93·9	"
Manganese sulphate	0·2	"
Boric acid	1·25	"
Ferrous sulphate	14·0	"

While very satisfactory results were secured with the sand culture methods described, sub-irrigation, aggregate (gravel, haydite, cinders, etc.) culture presented a great saving in labour. This system consists of a waterproof bed, preferably constructed of concrete, filled with gravel or haydite and a sub-irrigation method of mechanically delivering the nutrient solution. At a centrally located point, definitely lower than the bed, a waterproof tank is constructed to hold the nutrient solution. Alongside the tank is located an electrically driven centrifugal pump. A single run of pipe goes to each bed to be supplied from the tank and discharges at each bed under an inverted trough which rests on the bottom of the bed and extends its entire length.

A formula which has been employed successfully for this purpose is as follows:

Amounts of ingredients to make up 186 gallons:

Ammonium sulphate	12·5 oz.
Sodium nitrate	15·5 "
Muriate of potash	7·0 "
Superphosphate 20 per cent	24·7 "
Magnesium sulphate	6·2 "
Calcium sulphate	76·8 "

In addition, manganous sulphate was added to this solution when made up and at monthly intervals. One ounce of manganous sulphate was dissolved in one gallon of water, acidified with five drops of commercial sulphuric acid. Eight hundred and forty-five c.c. of this solution was added to the 186 gallons of nutrient solution. Iron was also added weekly in the form of ferrous sulphate at the rate of 21 grams to 186 gallons of solution.

A considerable variety of vegetables were also grown out-of-doors by the sand culture method. Some of the yields produced on an area of 42 square feet used for each crop were as follows: radish, 24 bunches of 12 to a bunch; cabbage, 72 pounds or 35 good marketable heads; potatoes, 28 pounds; tomatoes, 109 pounds or 4½ pounds per plant. The quality of all produce was excellent.

Although this study demonstrated the possibility of growing vegetables out-of-doors by soilless culture, it is not considered practical for commercial production where ordinary soil conditions exist. Soilless culture no doubt has a place in areas without normal transportation facilities where soil conditions are not suitable.

It was under such conditions that an extensive project was conducted for the Department of National Defence at Goose Bay, Labrador, during the last war.

ORNAMENTAL SECTION

Changes to Grounds

R. W. Oliver

During the past fifteen years the increasing scope of activities and expansion of the staff have led to many changes in arrangement of the buildings which in turn have necessitated changes in the layout of roads and ornamental plantings. The demolition of the three houses formerly occupied by Drs. Grisdale, Macoun and Shutt, together with the old administration building, did away with familiar landmarks and private areas. This, with the erection of the William Saunders building, has permitted the gradual creation of an open central campus surrounded by buildings. Plantings are being arranged in groups to set off buildings, an arrangement which will replace the former arboretum type of specimen planting. This transition will take a few more years to accomplish.

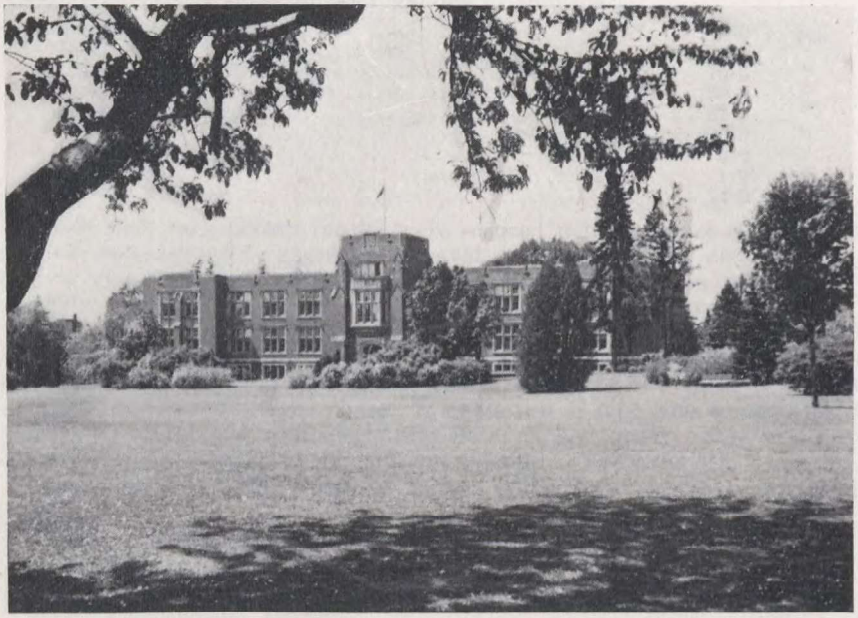


Fig. 13—William Saunders Building erected in 1936.

At the suggestion of those interested in the work of Dr. W. T. Macoun, who had been Dominion Horticulturist from 1910 until his death in 1933, a garden was built in his memory during the summers of 1935 and 1936. This garden is formal in nature and planted with many hybrid shrubs and flowers originated at Ottawa under his supervision. A memorial sundial purchased with funds contributed by various horticultural organizations was placed at the east end of the garden. The garden has become an interest spot on sight-seeing trips around the capital.

During the summers of 1935-6-7 the old rose gardens were replanned and changed to provide a more open though still formal arrangement of beds so that

the different classes and varieties could be displayed to better advantage. Hybrid Perpetuals and the older dwarf Polyanthas are now confined to one garden; Hybrid Teas and the newer Hybrid Polyanthas to another. A third separate garden has been built to accommodate the collection of old fashioned varieties and hardy species. This brings together the old Damask, Gallica, Moss and Cabbage roses with species and new hybrid bush roses all infrequently found in gardens to-day. An interesting feature leading from this garden is a walk running along the east side of the flower test plots flanked on either side by a row of Rosybloom crabapples planted in 1940. These trees have now reached sufficient size to create a good show each May and display all the worthwhile varieties of Ottawa origin.

In 1947, a start was made in rebuilding the rock garden along lines more suitable for both the display and culture of alpine plants. This work will not be completed until 1950. Already many plants, new to these gardens, have been included, supplying interesting information which will be reported later.

Since the extension of the Federal District Commission Driveway through the Experimental Farm, the grounds have taken on more than ever the place of a public park in the capital. This calls for a higher standard of maintenance as well as a different type of treatment than was used formerly. In all these new plantings and in the gradual replacement of old material which has passed its prime, the policy of introducing worthwhile material new to these grounds, as well as that which has proved of value in past years is being followed. These materials are now being used in such a way as to educate the public to their proper landscape value rather than on their value as individual specimens.

Trees and Shrubs

This work has been carried on in various projects and may be reported on briefly under four heads:

Forest belt
Variety testing as specimens
Winter hardiness
Propagation

Forest Belt

The forest belt was planted from 1887 to 1895. It consists of a strip sixty-five feet wide along the northern and western boundaries of the original tract of land. Approximately 23,300 trees were planted, made up of eighty-one species of native and exotic trees. Along the north boundary were blocks of mixed trees composed of six to ten different species to determine the best method of planting woodlots; along the west, blocks of single species for timber production. Spring versus fall planting, different spacing and different methods of pruning at the time of planting were tried.

Growth measurements and many observations were published in annual reports from 1891 to 1911. Interpretation of these data and of later observations furnish factual proof of what has been surmised on the effects of methods and time of planting, spacing and pruning on growth and length of life.

After fifty years, growth had become so irregular that no further accurate information could be gained by growth measurements. As all work of this nature is now carried on in Eastern Canada by the Department of Mines and Resources, the work here has been discontinued but as a summary of results has never been published it is given here as a matter of public record.

(1) There was higher mortality rate in fall-planted than in spring-planted trees due to sun scald and dying back of tips of fall-planted trees. This later has a marked effect on the growth of the tree and frequently resulted in the start of decay which shortens the tree's life and renders it useless for lumber.

(2) Trees planted 5′ x 5′ apart grew more rapidly in height at first, shaded the ground well and so kept down weed growth, lost their side branches earlier, and therefore would produce better quality lumber and, finally, were less damaged by storms.

(3) Trees planted 10′ x 10′ apart grew more slowly in height at the start but eventually reached greater height and girth measurements, and in most species lived longer.

(4) Thin foliaged trees such as walnut, butternut, ash and elm do not shade the ground quickly. For this reason growth of the trees is checked by weeds. This also applies to narrow tree belts when trees become tall.

(5) After ten years it was noted that many of the mixed blocks were not satisfactory either because the wrong trees had been planted together or they were planted on unsuitable soils. Spruce grew poorly on high gravelly soil where pines grew successfully. Where boxelder, Norway maple and other densely foliaged trees were planted together they grew rapidly and created such dense shade as to smother slower growing deciduous trees and even many of the evergreens. Norway spruce, white pine and arborvitae stood shade better than any others.

(6) Three blocks were pruned in different ways before planting: (*a*) no pruning; (*b*) trees headed at six feet; (*c*) laterals removed leaving a straight whip. Early records do not mention the effects of pruning, but in 1938 there were most living trees in the first block and fewest in the second. Most of the living trees in blocks (*b*) and (*c*) had decayed crotches.

(7) For combined shelterbelt and woodlot purposes a block of mixed conifers and deciduous trees is best. White pines and Norway spruce planted alternately 10′ x 10′ apart will make good timber. When young they shade the ground rapidly and form a good windbreak. These should be interplanted with birch, elm and ash. The first two grow up rapidly and in twenty years provide a good supply of fuel. Ash is also good for fuel and supplies tough lumber for repairing farm equipment.

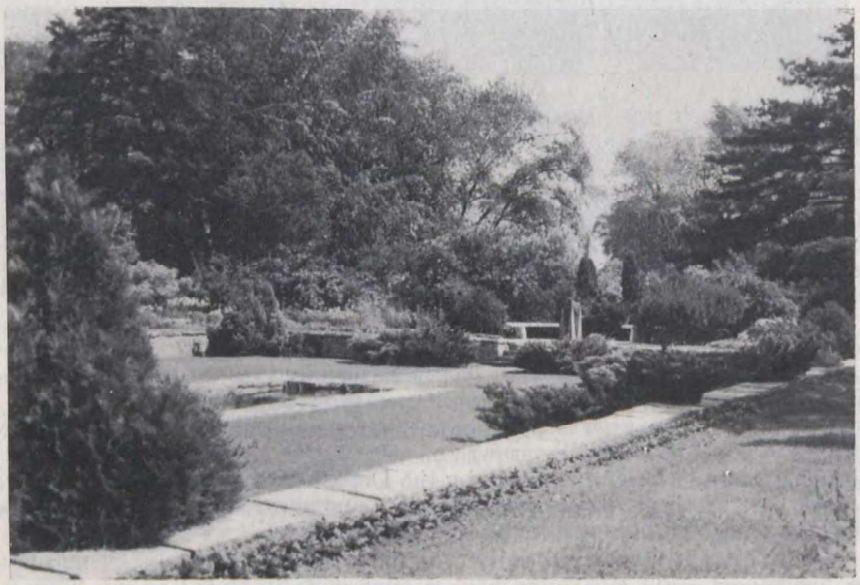


Fig. 14—Macoun Memorial Garden in June.

TABLE 26.—GROWTH MEASUREMENTS OF TREES IN EXPERIMENTAL FOREST TREE BELT

Species	Planted	Distance	1910		1933		Remarks, 1933*
			Av. Ht.	Diam.	Av. Ht.	Diam.	
			ft. and in.	in.	ft. and in.	in.	
Scotch Pine	1888	5 × 5	34–3	4·46	48–1	7·13	About at their end.
Scotch Pine	1888	10 × 10	29–7	5·83	41–3	8·07	Mostly dead.
Juglans nigra	1888	5 × 5	14–5	2·38	18–9	5·13	Only one tree alive.
Juglans nigra	1888	10 × 10	11–0	3·19	22–5	5·25	Only one tree alive.
Juglans cinerea	1888	5 × 5	11–4	2·13			
Juglans cinerea	1888	10 × 10	11–5	2·13	17–7	4·13	Top killed out.
Larix decidua	1888	5 × 5	36–4	4·33	42–9	6·00	No growth after 1926.
Larix decidua	1888	10 × 10	35–9	5·38	45–11	6·90	No growth after 1929.
Acer saccharum	1888	5 × 5	23–10	2·25	34–6	3·38	All dead but one.
Acer saccharum	1888	10 × 10					
Acer saccharinum	1888	5 × 5	33–0	3·37	39–2	4·60	All dead but one.
Betula papyrifera	1888	5 × 5	38–6	4·37	50–6	6·50	Growth stopped.
Betula papyrifera	1888	10 × 10	40–10	6·12	49–9	8·75	Growth stopped.
Betula lutea	1892	5 × 5	29–9	3.25	40–1	5.13	About ended.
Betula lutea	1892	10 × 10	32–9	5·00	45–11	7·00	Still growing.
Ulmus americana	1892	5 × 5	22–4	2·71	23–6	3·25	All about dead.
Ulmus americana	1892	10 × 10	28–7	5·21	44–8	8·25	
Thuja occidentalis	1888	5 × 5	23–3	3·79	27–3	4·60	All dead by 1918.
Thuja occidentalis	1888	10 × 10	22–6	3.96	33–0	5·75	Some still growing.
Fraxinus nigra	1888	5 × 5	30–2	2·83	35–2	3·25	All cut out 1918.
Green Ash	1889	5 × 5	33–2	3·87	42–3	6·80	All about dead.
Green Ash	1889	10 × 10	26–3	4·33	28–7	5·31	Tops all died out 1927.
Red Ash	1889	5 × 5	37–6	4·08	45–3	5·67	Tops all died out 1927.
Red Ash	1889	10 × 10	29–10	4·08	38–1	5·27	All but one died 1927.
White Ash	1889	5 × 5	32–10	2·92	46–5	6·25	⅔ still alive at top.
White Ash	1889	10 × 10	33–9	4·33	37–1	6·00	All about dead.
Austrian Pine	1889	5 × 5	32–0	5·37	49–6	7.58	Still growing.
Austrian Pine	1889	10 × 10	30–8	7·54	50–3	10·40	Still growing.
Norway Spruce	1889	5 × 5	30–7	3·87	52–6	6·54	All at end of life.
Norway Spruce	1889	10 × 10	34–1	5·96	52–8	9·70	
Black Cherry	1889	5 × 5	26–8	3·21	27–10	3·75	All dead by 1922.
Black Cherry	1889	10 × 10	39–5	5·50	50–0	8·87	⅔ still growing.
White Pine	1889	5 × 5	34–9	4·87	44–10	5·90	All about dead.
White Pine	1889	10 × 10	34–4	7·54	50–0	10·00	Still growing.

* These remarks refer only to trees on which measurements originally were made.

In 1910 and again in 1933 measurements were made of species suitable for timber. The trees were then approximately twenty and forty-three years of age. Measurements had been made throughout on certain definite trees. The column headed "Remarks" in Table 26 on growth data indicates that most of these trees had died or were damaged at the top.

Variety Testing as Specimens

Approximately six hundred varieties and species of ornamental woody plants exclusive of rose and lilac varieties have been grown successfully in the ornamental grounds. Notes on the most satisfactory of these will be found in "Deciduous Trees and Conifers More Commonly Used for Ornamental Purposes" by R. W. Oliver. Farmers' Bull. 49, reprinted 1945, and "Ornamental Shrubs and Woody Climbers for Canadian Gardens" by R. W. Oliver. Farmers' Bull. 100, reprinted 1948. Attention should be called here to the few following observations of interest which have been made since the publication of these bulletins.

Acer rubrum L.—Red swamp maple. This tree should be much more widely used than in the past. It is more rapid in growth than the sugar maple and more adaptable to heavy low soils, though at Ottawa it grows excellently on light sand. The fall colour is early and a most showy bright crimson.

Acer platanoides L.—The Norway maple is on its northern limit at Ottawa where it is subject to frost cracking. This in combination with the habit of forming bad crotches which split in storms makes the trees very susceptible to wood rotting fungi. At fifty-five years of age there is scarcely a sound specimen left.

Curagana microphylla Lam. var. Tidy.—A fine foliaged bud sport of the species which has proved interesting. The landscape value is much the same as *C. Lorbergii* but the shrub does not grow as tall and can therefore be used in different situations where a rather misty appearing foliage mass is desired.

Daphne Burkwoodii Burk.—A hybrid between *D. caucasica* and *D. Cneorum*, which makes a compact bush two feet in height with attractive foliage and a profusion of bluish-white fragrant flowers early in spring. So far since 1945 it has proved perfectly hardy.

Genista pilosa L.—A prostrate form of Dyer's greenwood which has made an attractive rock garden shrub. It carries short racemes of yellow flowers during June and July but the small shiny bright foliage is attractive all through the season.

Juniperus squamata Meyeri Rehd.—A juniper unlike others in foliage texture. It forms a compact vase-shaped shrub to a height of three feet. The narrow fine needles are packed in close tufts on fine branches giving it a dense form in contrast to other junipers. The glaucous underside of the needles also gives a contrasting silvery blue colour.

Juniperus virginiana Burkii Hort.—A juniper which has proved hardier than most forms of *J. virginiana*. It is an attractive columnar evergreen with steel blue foliage turning dull purple in autumn.

Lonicera tatarica L. var. Carleton.—A chance seedling from *L. tatarica* var. *speciosa* which was grown under the latter name in the ornamentals nursery at the Central Experimental Farm and resembles its parent closely. The individual flowers are larger, a deep bright pink in colour, with a red band along the centre of each petal. Cuttings have been distributed to interested nurserymen and others and the resulting plants have won much approval. It makes an erect shrub with neat dark green foliage.

Lonicera Periclymenum serotina Ait. var. Flame.—Another good seedling developed in the ornamentals nursery. It is a climbing honeysuckle much like the

species but the flowers are larger and deeper red-orange. So far it has proved perfectly hardy at Ottawa.

Maackia amurensis Rupr.—A small tree of the Leguminosae family which grows to a height of fifteen to eighteen feet. It has rather sparse pinnately compound foliage and erect panicles of white pea-shaped flowers. While it should not be recommended for general use, it makes an unusual addition to the list of small trees hardy in this climate.

Sorbaria Aitchisonii Hemsl.—More refined though slightly less hardy than *S. sorbifolia*. The stems are longer and more gracefully arching, the inflorescence more open and cleaner looking. The bright green foliage contrasts with the reddish-brown stems. Like *S. sorbifolia* it must be cut almost to the ground each spring and for that reason it can be used in any shady corner where it may be damaged by ice in winter.

Spiraea chamaedryfolia L.—A shrub which makes a very attractive low mound about three feet in height and eight in diameter. It is not the sort for the average small place but is very interesting at the front of a large shrub border.

Thuja occidentalis Rheingold Hort.—A very compact dwarf globular variety which has gold to copper coloured juvenile foliage. Unfortunately it suffers from sun scalding in winter and needs to be protected with burlap. It is particularly useful as an interest plant in the rock garden.

Tilia cordata Mill.—Small-leaved linden. Though this tree is discussed in the aforementioned Bulletin 49, mention should be made of it again as time has shown it to be one of the very best hardy shade trees for this climate.

Winter Hardiness

The winter of 1933-4 was of course a test case. Many trees and shrubs previously considered hardy were badly damaged, while borderline material was killed entirely or damaged so severely that it had to be cut almost to ground level. The following is a list of such trees and shrubs:

Acer Pseudoplatanus
Cercidiphyllum japonicum
Chaenomeles japonica
Deutzia scabra
Forsythia intermedia
Fraxinus excelsior
Liriodendron Tulipifera
Philadelphus in variety
Syringa chinensis
Syringa Henryi
" *Meyeri*
" *pekinensis*
" *pubescens*
" *reflexa*
" *Sweginzowii*
" *tomentella*
" *Wolfi*
" *yunnanensis*

All evergreens except *Picea pungens*, its varieties, and *Picea glauca*, were badly burned. They remained thin in appearance for the next two years then gradually regained normality. The following few never recovered sufficiently to make satisfactory specimens:

Abies concolor
Abies lasiocarpa
Chamaecyparis pisifera plumosa
" " " *aurea*
Juniperus communis hibernica
Juniperus communis suecica
" *virginiana*
" " *Schottii*
Thuja occidentalis cristata
" " *plicata*

This same burning of evergreens occurred in 1948 and to a less extent in 1939-44 and in 1947. It is apparently caused by a drying out of the foliage by cold winds or bright sunshine at a time when the roots are unable to supply the necessary moisture. Trees exposed to wind or which enter the winter suffering from drought show it on all sides. Those in moist or sheltered sites show it only on the south and west. It is more pronounced just above the snow line due to the reflection of sunshine.

This added light intensity just above the snow line has a drying and damaging effect also on the fine twigs of shrubs like *Spiraea, Philadelphus* and even *Lonicera.* Sometimes it shows up in years such as 1944 and 1948 as dead streaks along hedges and shrub borders about eighteen inches in width just above the snow line when there was no apparent damage to the top of the shrub.

The only work of an experimental nature on winter hardiness was done with roses. Measured samples of wood were taken from varieties of different types, placed in sealed test tubes and put in overnight storage at —20°F. A measured amount of distilled water was then added to each sample to permit exosmosis of the electrolytes freed from the sample by freezing damage to the cell tissues. The following day the electrical resistance of each was tested with a Wheatstone bridge. The following is the order of hardiness of the varieties tested; the higher the figure the more hardy the variety:

Rosa rubrifolia 596	Frau Karl Druschki 115
" F. J. Grootendorst 519	Carillon 99
" Edith Cavell 189	Gruss an Teplitz 96
" Doubloons 140	Joanna Hill 89

These figures do not represent any calibrated measurement; they are simply the average electrical resistance measurements of cold-treated samples and are indicative of the relative hardiness of the varieties at —20°F. which corresponds very closely with the field performance. This method could probably be used to determine the relative hardiness of any variety of woody ornamental material.

Propagation

Considerable experimental work has been done in the propagation of woody material by seed and by cuttings. The results in general have been published in the two previously mentioned Bulletins, 49 and 100. The results of some experiments were published in more detail in "Some Uses of Plant Hormones" by R. W. Oliver and N. H. Grace. Circ. 148. 1940. Separates of the articles, "Preliminary Tests with Plant Hormones in the Rooting of Greenwood Cuttings" by R. W. Oliver. Sci. Agr. 18: 379-387. March, 1938 and "Honey as a Stimulant to the Rooting of Cuttings" by R. W. Oliver. Sci. Agr. 9: 586-588. May, 1939, were printed and distributed.

Space here does not permit the publication of further work in any detail but a summary of results shows interesting facts which confirm established practice.

Napthaleneacetic acid at its optimum concentration has consistently produced the greatest rooting response but has a narrower range than indoleacetic or indolebutyric acid and therefore must be used more carefully.

The use of growth substances in combination with a fifteen per cent solution of levulose proved beneficial, which explains the advantage of using honey.

Growth substances have not proved to be so great an aid to propagation as was first anticipated. They speed the rooting of plants which root normally and readily, but effect little change in the rate of the rooting of those species which are difficult to root.

Cuttings of conifers taken in December at Ottawa root more satisfactorily than those taken in November or January. Lengthening the day by artificial light or adding either a nutrient solution of vitamin B_1 increases slightly the number of cuttings rooted but increases considerably the length of roots in a given period. From a practical standpoint of propagation, however, the increase is not sufficient to pay for the extra treatment. Spruce responds negatively to treatment with hormones.

In all work on propagation by cuttings, the balance between moisture and air supply in the medium and a humid atmosphere surrounding the top of the cutting seem to be the most important factors. Sand, loam, peat, peat and sand, crushed sandstone and vermiculite have all been tried and have given satisfactory

results. It has been found, however, that proper moisture-air balance could be maintained more easily in sharp sand or in coarse vermiculite with constant level sub-irrigation than in any other medium so that either of these is recommended.

Dormant cutttings taken in December, buried in moistened peat and sand and stored at 34° to 40°F., have produced consistently better results than those treated differently. For *Hydrangea paniculata gf.* and some Viburnums it has been found advisable to store at 55° to 60°F. until February 1 and then to plant in a closed frame in the greenhouse. This may prove useful with other difficult subjects.

Hedges

Since 1889, approximately one hundred and seventy-five different woody plants have been tested as hedge material. The results of this work appeared in "Hedges and Their Uses" by W. T. Macoun. Bull. 142 N.S. 1931. Since that time only a few plants have been added and of these the only one recommended is *Ulmus pumila,* Chinese elm, which has proved outstanding as a quick growing deciduous hedge which stands clipping well and can be grown to almost any desired height. *Prinsepia sinensis* which is highly recommended in the West has not been satisfactory at Ottawa.

Fig. 15—Hedge collection at Central Experimental Farm.

The following observations on culture made during the past years are herewith published for the guidance of prospective planters.

Selection of Hedge Material

Selection of material will depend on several factors, largely determined by personal desires, but governed by an appreciation of fitness. One may desire a deciduous or an evergreen hedge. That is largely a matter of choice, unless an all-year-round screen is needed. The height, colour, and texture of a hedge should be governed by the size of the property and the type of garden it is to surround.

A large garden needs a taller hedge and one more coarse in texture than a small garden. A tall or medium hedge should be of mid or dark green colour, since its purpose is to provide a background. Under average conditions a golden,

red, or grey foliaged hedge is so conspicuous that it kills the appearance of any plant in the foreground. Low hedges, which are used only to give emphasis to the design of the garden may be of brighter shades, particularly in conjunction with formal work.

The texture of a hedge is largely a matter of coarse or fine foliage and the degree of shininess. Large shiny leaves are seen in more detail than small dull ones, and consequently, seem to be nearer at hand. This tends to reduce the apparent size of the area surrounded by such a hedge, whereas a hedge of fine texture and dull colour tends to increase the size.

Type of soil, degree of sunshine, amount of moisture and freedom from disease, should influence the choice also. White pine will make an excellent hedge on sandy soil but is useless on heavy clay. Lilacs are spindly and covered with mildew in shade, while the wayfaring tree under similar conditions may be quite dense. *Caragana* would be sickly and yellow in a moist situation, where laurel willow would be excellent. Though hawthorn makes one of the best hedges, it is so subject to attack from all insects affecting apple trees that it should only be used where facilities for spraying exist.

Directions for Planting

The site for a new hedge should always be carefully prepared by digging out a trench about 18 in. deep and considerably wider than the spread of the roots of the young plants to be used. A liberal dressing of thoroughly rotted manure should be dug into the bottom of this trench and covered with a few inches of finely pulverized rich loam soil. As each plant is set in place with the roots spread out naturally, more of the fine soil should be placed around the roots and firmly tramped down before being watered liberally.

The plants should be set in a single row rather than in a double row planted alternately (staggered), as has been frequently recommended. The double row uses more plants, more space, is harder to trim to a good shape, and frequently leaves an uneven end at a gate or path where it is most easily noticed.

The distance apart will vary with the kind of plant used and the height to which one wishes the hedge to grow. For average purposes 18 in. apart has proved most satisfactory for hedges four feet or more in height. But for low hedges, or where erect growing plants are used, they should be placed closer together. Truehedge columnberry, for instance, should be planted 6 to 9 in. apart.

Proper Time to Plant

Deciduous hedges should be planted in the spring before the leaf buds begin to burst, but they may be planted in the fall as the leaves are falling off. Evergreens should be planted in early September or in May, though the native cedar may be moved almost any time except midsummer if it is well watered.

Size of Plants

Generally speaking, fairly small plants should be used. Deciduous plants which are two years old from seed and which have been cut back at the end of the first year to make them bush out, are excellent. Four year old evergreens which have not been cut back, or just lightly trimmed, are about the right size. Larger plants may be used if they are bushy to the ground, but tall spindly plants should never be used unless one is prepared to cut them almost to ground level.

Trimming

At the time of planting, deciduous hedges should be cut back to a point two or three inches above the base of last year's growth. This should be repeated the following season, and is the only way to develop a thick bushy hedge. In the

case of conifers, only the tips of branches should be cut back since they do not readily put out new foliage from old wood. Consequently they will not stand severe cutting back.

An established hedge should be trimmed each year to keep it in neat shape and within bounds. If it is allowed to grow until it reaches the desired height before trimming, it will develop a bushy top but thin sides. Hedges must be built from the ground up, not from the top down.

Old deciduous hedges may be cut back severely in the spring and will revive in a few years. Evergreen hedges which have grown out of bounds should be removed and replaced by young plants.

Time to Trim

The exact time to trim will vary with the locality and season. The most economical method is to trim when the hedge has almost finished its annual period of active new growth. At Ottawa this means the end of June or early in July for deciduous hedges, and at the end of August for evergreens. If possible, hedges should be trimmed during a period of dull weather to decrease the amount of "tip burning."

Most of the popular hedges require a second trimming the first week in September though many hedges trimmed in July rarely grow enough afterwards to require a second trimming and so they are ragged for only two or three weeks in June. If hedges are trimmed in late fall or in spring, the uneven rate of growth keeps them ragged all summer unless they are trimmed a second time.

Proper Shape

The shape to which the hedge is trimmed has a cultural as well as an aesthetic value. The hedge should be trimmed with the sides sloping so that it is wider at the bottom than at the top. This enables more light to reach the lower foliage and so keep it healthy. The hedge should be pointed or rounded on top to assist in shedding snow and ice in winter.

Fig. 16—Forms of hedges.

Good Forms. Hedges which are broadest at bottom retain lower foliage. Snow does not damage rounded tops.

Bad Forms. Hedges which are narrower toward the bottom lose their lower foliage because of reduced light. Flat topped hedges are broken by ice and snow.

Fertilizing

Because thick vigorous growth is desired, it is advisable to fertilize a hedge every second or third year by spreading a liberal top-dressing of well-rotted

manure over the ground in the fall and working it shallowly into the surface the following spring. Deep digging destroys roots. If good manure cannot be obtained, a complete chemical fertilizer such as 9-5-7 may be used at the rate of from two to four pounds to twenty-five feet of hedge. The chemical fertilizer should be applied in conjunction with leaf mould or pulverized peat.

Rows of Flowering Shrubs

Hedges which are trimmed as described will not flower to any extent. Where a flowering hedge is desired, plants should be placed two to three feet apart and should be pruned immediately after blooming by completely cutting out some of the oldest branches as close to the ground as possible. *Spiraea Vanhouttei,* Tartarian Honeysuckle and Mock Orange are among the best shrubs for this purpose.

Table 27 summarizes information on the most highly recommended materials for hedges in Eastern Canada.

Roses

The results of the work with these plants are all covered in "Outdoor Roses in Canada" by R. W. Oliver, Farmers' Bull. 133. 1946. Since the publication of this bulletin, however, many new varieties have been grown in the Ottawa gardens and of these the following, which are adequately described in nursery catalogues, have proved most valuable:

Hybrid Teas

Crimson Glory
Golden Harvest
Heinrich Gaede
Lily Pons
Mandalay
Mme Chiang-Kai-Shek
Mrs. H. M. Eddie
Peace
Pink Princess
Rose of Freedom
Soeur Thérèse

Hybrid Polyanthas

Goldilocks
Mrs. A. M. Finch
Mexico
Red Ripples

Annual and Perennial Flowers

A great number of different species and varieties of herbaceous flowering plants have been grown during the past fifteen years and their performance noted.

In addition to large mixed perennial borders established in 1936, variety collections of a few of the well known sorts have been maintained. During the period under discussion approximately four hundred varieties of garden iris, fifty varieties of Siberian iris, two hundred peonies, eighty hemerocallis and sixty phlox have been grown.

Summaries of all worthwhile information gathered were published in the form of bulletins. These are "Annual Flowers for Canadian Gardens" by Isabella Preston and R. W. Oliver, Farmers' Bull. 143. 1947, and "Herbaceous Perennials for Canadian Gardens" by Isabella Preston, Farmers' Bull. 138. 1948. These two bulletins contain lists of recommended inexpensive varieties suitable for the average garden, rather than the expensive new varieties grown by specialists for the show table.

Previous to 1936, several of the old varieties of "English border chrysanthemums" had been tried at Ottawa and proved unsatisfactory. The development of the Korean hybrids by Mr. Alex Cummings of Bristol, Connecticut, in the early 1930's, revived interest in garden chrysanthemums and opened up a new field for hybridists. In the last fifteen years, hundreds of new varieties have been brought out which has made it necessary to try out some two hundred varieties to determine their value under local conditions.

TABLE 27.—BEST HEDGES FOR EASTERN CANADA

Common Name	Botanical Name	Height	Texture	Colour	Soil	Light	Moisture	Growth	Disease and Insects	Remarks
Evergreen										
Arborvitae or common cedar	*Thuja occidentalis*	3 ft. and up	Solid	Mid. G.			Moist			Best all-round evergreen.
Hemlock	*Tsuga canadensis*	3 ft. and up	Fine	Yellow G.		Part shade		Slow		
Japanese Yew	*Taxus cuspidata*	1–3 ft.	Solid	Dark G.		Part shade		Slow		Best low hedge.
Pine—white	*Pinus strobus*	4 ft. and up	Fine	Yellow G.	Sand		Dry		Blister rust	Trim in mid June.
Spruce—Norway	*Picea Abies*	4 ft. and up	Solid	Dark G.				Rapid	Gall aphis	
Spruce—white	*Picea glauca*	4 ft. and up	Solid	Blue G.				Slow		
Deciduous										
Alpine currant	*Ribes alpinum*	2–4 ft.	Fine	Mid. G.			Dry	Slow		Good low hedge.
Asiatic elm	*Ulmus pumila*	4 ft. and up	Medium	Dark G.				Rapid		Excellent hedge.
Barberry—dwarf	*Berberis Thunbergii*	1–3 ft.	Fine	Mid. G.		Part shade				Excellent low hedges, all thorn and colorful, very erect.
Barberry—redleaved	*Berberis Thunbergii atropurpurea*	1–3 ft.	Fine	Red		Sun				
Columnberry	*Berberis Thunbergii parvifolia*	1–3 ft.	Fine	Mid. G.						
Hawthorn	*Crataegus* (several species)	4 ft. and up	Coarse	Mid. G.	Clay			Slow	Various insects	Stands wind well.
Honeylocust	*Gleditsia triacanthos*	4 ft. and up	Fine	Bright G.	Clay					Very thorny.
Honeysuckle	*Lonicera tatarica*	3–7 ft.	Coarse	Blue G.	Clay	Part shade		Rapid	Mildew	
Laurel-leaf willow	*Salix pentandra*	4 ft. and up	Coarse	Dark G. sh.			Moist	Rapid	Gall aphis	Most rapid, needs trimming twice a year.
Privet	*Ligustrum amurense*	2–5 ft.	Fine	Dark G. sh.				Rapid	Too tender at Ottawa.	
Siberian pea	*Caragana arborescens*	4 ft. and up	Fine	Yellow G.	Sandy	Sun	Dry	Rapid	Lace fly	Stands wind well.
Siberian pea—dwarf	*Caragana pygmaea*	2–4 ft.	Fine	Dark G.	Sandy	Sun	Dry	Slow		Excellent low hedge.
Wayfaring tree	*Viburnum Lantana*	4–7 ft.	Coarse	Bronze G.		Part shade	Moist			

NOTE:—All plants mentioned here grow best in good garden soil, with plenty of sunlight and moisture. Where specific conditions are mentioned, such as dry, moist, shade, etc., it means that the particular plant will stand these conditions better than most. Blanks in these columns indicate that good average conditions are necessary.

The practice has been to grow varieties for at least three years before condemning them and to retain beyond that time only those which showed good promise of excellent rating. To prove consistently satisfactory over a period of at least three years, a variety must be not only attractive in bloom and habit of growth, but also hardy enough to survive the average Ottawa winter and early enough to reach full bloom by September 7 so that it will make a good show before frost. These conditions exclude many of the varieties popular in lists published in American garden magazines, as well as a few seemingly very good varieties which have been introduced recently but have not been tried here long enough. The following list is comprised solely of those chrysanthemums meeting the foregoing conditions:

Yellow	Algonquin	d.m.
	Barnegat	d.m.
	Mrs. Dunnington-Grubb	s.m.
	Pigmy Gold	p.l.
	Yellow Cushion	d.l.
	Yellow Iowa	d.t.
Bronze	Bronze Cushion	d.l.
	Karl Borgstrum	d.m.
	Karen Frederickson	d.t.
	Mrs. E. Sparre	d.m.
	Sept. Bronze	p.l.
	Sheridan Bronze	d.m.
White	Dropmore 41A	p.l.
	Prushek 253	d.m.
	Seminole	d.m.
	Sept. Cloud	p.l.
	White Cushion	d.l.
Purple	Matawin	s.m.
	Purple Star	d.m.
Pink	Clara Curtiss	s.m.
	Pink Cushion	d.l.
	Rose Glow	p.l.
Buff	Thalia	s.l.
Red	Cheyenne 428	s.m.
	Red Cushion	d.m.

Note: s : single, d : double, p : pom-pon; t : tall, m : medium, l : low

Bulbous Plants

Large variety collections of gladiolus, narcissus and tulips have been kept up in much the same manner as herbaceous perennials.

Gladiolus

The collection of gladioli is not large at present, containing only seventy-three varieties, but all of very good quality and the majority of recent introduction. Formerly, a collection of about three hundred varieties was maintained but for several years during the war no attempt was made to keep up with the very rapid production of new varieties so that two years ago it was decided to make a fresh start retaining only a few of the old varieties that had stood the test of time.

An interesting bit of work in the germinating of gladiolus cormels carried out in 1946 is worth describing because of its interest to commerical growers.

On March 7 fifty cormels of each of ten varieties were placed in separate cheesecloth bags in a fruit sealer. A forty per cent solution of anhydrous ethylene chlorohydrin at the rate of 2 c.c. to 150 grams of cormels was poured on a pad of cheesecloth and placed in the sealer before closing the top. As a check, a

similar lot of cormels was placed in a second sealer with no chemical added. The sealers were stored at room temperature (70°F.) for four days, after which time the tops were removed and the bags containing the cormels spread on a bench and allowed to air for ten days before planting in flats and grown at a night temperature of 50-55°F.

Table 28 shows results in the percentage of germination and average height of the plants on May 30.

TABLE 28.—EFFECT OF ANHYDROUS ETHYLENE CHLOROHYDRIN ON GERMINATION AND GROWTH OF GLADIOLUS CORMELS

Variety	Per Cent Germination		Average Height (in.)	
	Treated	Untreated	Treated	Untreated
Arctic Snow	88	13·2	6	4
Bingo	94	80	9	9
Corona	82	79·7	8	7
Elizabeth the Queen	66	9·3	4	2
Greta Garbo	88	60	8	7
Jeannie	92	13·6	6	4
King William	96	19	6	5
Lady Jane	82	37	6	4
Myrna	88	33·6	8	4
Red Charm	84	3·3	4	2
Average	86	34·9	6·6	4·9

This treatment proved of outstanding value for the propagation of slow germination varieties.

Tulip

The tulip collection contains approximately two hundred varieties and is the most up-to-date of all the collections, as new varieties for test were received from Holland each fall until 1939, and have been received since the cessation of hostilities.

Prior to 1939 it was thought that stocks of tulips could not be maintained in this district because of the short growing season in the spring. In order to maintain the collection during the war and preserve stocks of the new varieties, a considerable amount of experimental work was done to determine the optimum cultural treatment. If good procedure is followed, satisfactory bulbs for garden use can be produced here. In many varieties, however, the increase in average years is not sufficient to make commercial culture practical. The following outline of cultural recommendations is based on the experimental work done here from 1939 to 1945.

One of the most important factors in the production of uniform results in both bloom and bulb production is proper storage conditions between the time when tulips are dug and when they are planted. Free circulation of air is necessary to dry bulbs rapidly and so avoid heating and the spread of fungus diseases due to moist conditions. High temperature, 75-80°F., for six weeks is also important to produce normal flower bud formation. In the case of bulbs to be used for greenhouse forcing, this high temperature is followed by four to six weeks at 40-45°F. Experiments are outlined which should give the needed information on exact times and temperatures.

Digging just before the leaves are completely ripened off results in a paler colour but preserves the tunic so that bulbs are less damaged during grading and storage.

Planting before October 1 resulted in slightly increased bulb production over later planting, but made no apparent difference in flowers or foliage.

Fertilizer trials showed that so long as soil fertility is reasonably good, little difference is made by the presence of extra amounts of one or another element. Nitrogen some years and phosphorus others seemed to be the important element, while potash did not seem to have a positive effect. This has also been found at other Experiment Stations. Yields were increased by spring applications of barnyard manure at twenty tons to the acre followed by eight hundred pounds of superphosphate at the time of planting in September, but the increase was not nearly sufficient to warrant the expense of application.

Table 29 gives the average bulb production of different varieties at Ottawa over a period of four years, 1942 to 1945 inclusive. It is based on the returns per one hundred bulbs of six and seven centimeter circumference planted; that is, six and seven centimeters in circumference or approxiamtely $\frac{3}{4}$ to $\frac{7}{8}$ inches in diameter. A circumference of twelve centimeters is equal to a diameter of one and one-half inches.

TABLE 29.—OTTAWA BULB HARVEST OF VARIED SIZES PER ONE HUNDRED PLANTED BULBS

Variety	12 cm. and up	10 to 11 cm.	8 to 9 cm.	Under 8 cm.
Lucifer	15·4	41·2	44·2	32·4
Arethusa	10·9	44·7	34·3	25·3
Inglescombe Yellow	4·9	44·9	76	55·4
Tokay	6·5	41·2	44·6	30·8
Giant	18·6	32·2	41·9	35·1

The only figures from British Columbia comparable with the above are three-year averages for two varieties, Inglescombe Yellow 1941, 1942, 1943, and Clara Butt 1942, 1943, 1944. Other varieties listed for the British Columbia harvest are for the years 1944 and 1945. The bulbs planted were six and seven centimeters in circumference. Results are given in Table 30.

TABLE 30.—BRITISH COLUMBIA BULB HARVEST OF VARIED SIZES PER ONE HUNDRED PLANTED BULBS

Variety	12 cm. and up	10 to 11 cm.	8 to 9 cm.	Under 8 cm.
Inglescombe Yellow	11·3	43·3	47·6	43 + peas
Clara Butt	2·3	47	44·3	54·6 + peas
William Pitt	10·25	52·5	38·5	42 + peas
Bartigon	4	42·5	70·25	37 + peas

It seems hard to believe that the Ottawa figures show up so well beside those from British Columbia. Two points must be considered: Inglescombe Yellow is the only variety common to both and produced considerably more top-sized bulbs in British Columbia, 11·3 against 4·9; Clara Butt and Bartigon each produce small bulbs compared with varieties such as Giant and Lucifer. The results, nevertheless, show that good bulbs can be produced at Ottawa if proper care is taken.

ORNAMENTAL PLANT BREEDING

D. F. Cameron

During the years 1934 to 1948, the breeding and selection of ornamental plants has been an important project in this Division, and several seedlings of *Lilium, Iris, Rosa, Syringa* and *Malus* have been named and distributed to the public through commercial nursery firms.

This work, which was started in 1920 by Miss Isabella Preston under the direction of the late Dr. W. T. Macoun, was continued by Miss Preston until the time of her retirement in 1947. Because of the shortage of labour during the recent war years, no crosses were made after 1943 until this work was resumed in the summer of 1948 by D. F. Cameron.

As Miss Preston's plant breeding was concerned mainly with the five genera mentioned above, this report presents descriptive summaries of those varieties which, to date, have been considered worthy of introduction.

Awards

Several varieties of *Lilium, Iris, Syringa* and *Malus* have received honours; in London, England, from the Royal Horticultural Society (R.H.S.), and in the United States from the Massachusetts Horticultural Society, Boston, Mass. (M.H.S.). The details of these awards are given with the variety descriptions.

Some of the seedlings which are described in this report have been mentioned in reports prior to 1934, and others have been described in various horticultural publications and periodicals.

Colours given in capitals refer to Ridgway's "Color Standards and Color Nomenclature", except where it is stated that the colours refer to the R.H.S. colour chart.

Lilium Hybrids

L. × *davmottiae* var. Lady Byng (L.22.05.01).—A selection from a group of seedlings resulting from a cross made in 1920 between *L. Davidi* and *L. Davidi* var. *Willmottiae*. Originally, this group of lilies was named and described under "Ottawa Hybrids", but the name was later changed to the present form. This variety was the first of the lilies raised at Ottawa to receive recognition in England, the Award of Merit of the R.H.S. in 1931. The plant is vigorous and very hardy, with rich orange-scarlet flowers spotted with deep purple. Flower segments are broad and reflexed. Leaves dark green, long and narrow. Height 4 to 5 feet. Blooms late in July.

L. Davidi var. Oriole (L.29.18.02).—An open-fertilized seedling of *L. Davidi*, very similar to that species except for the colour, which is orange-yellow with chocolate spots. The pedicels have a drooping habit, and the plant reaches 3 feet or more. Blooms in July. Award of Merit, Chelsea Show, England, May 25, 1937. Vote of Commendation, M.H.S. July 11, 1945.

The "Stenographer" Group

From a cross made in 1929 between *L. Davidi* var. *Willmottiae* and a seedling of *L. dauricum*, a new group of lilies has been developed. Seven seedlings of this cross, now known as the "Stenographer" lilies, were selected and named, and subsequently distributed widely to nurserymen and lily fanciers.

They are all hardy, even in very cold districts and make strong vigorous plants. They are easily propagated from the bulblets that grow at the base of

the stem, and from bulb scales. They are all stem-rooted and bloom from late June through the early part of July. Descriptions of varieties are as follows:

L. × *Edna Kean* (L.29.01.06).—A very handsome plant, having rich dark red flowers which face outwards and have somewhat reflexed segments. The foliage is dark green and stems are dark greenish brown. Propagates easily. Height 3 to 4 feet. Award of Merit, M.H.S. July 11, 1945.

L. × *Brenda Watts* (L.29.01.17).—A tall vigorous plant with large heads of brilliant orange-red flowers on strong stems. The flowers face outwards and have the tips of the segments reflexed. This is the tallest of the seven, and under ideal conditions grows to a height of 5 feet. Award of Merit, M.H.S. July 11, 1945.

L. × *Grace Marshall* (L.29.01.23).—Similar in colour to *L.* × Edna Kean, between Grenadine Red and Scarlet, with brown spots which extend to within an inch of the tips of the broader segments. The outside of the petals is brownish. The foliage is dark glossy green, and the stems are speckled brown. This is the last of the seven to bloom, and it reaches a height of from 3 to 5 feet, bearing up to 30 blooms on mature plants. Award of Merit, R.H.S. July 2, 1935. Vote of Commendation, M.H.S. July 11, 1945.

L. × *Muriel Condie* (L.29.01.29).—Attractive orange flowers of open habit and with reflexed tips. The flowers are well spaced around the stem and face outwards. The leaves are long, narrow, hairy on the edges and crowded on the stem. It grows to 4 or 5 feet.

L. × *Phyllis Cox* (L.29.01.33).—Brilliant light orange-red flowers, whose colour inside deepens towards the tips, the outside of the flower being a golden orange. The whole flower has a waxy sheen and faces outwards. This variety makes a very handsome plant and grows to a height of 3 or 4 feet. Award of Merit, R.H.S. July 19, 1945.

L. × *Lillian Cummings* (L.29.01.48).—Light orange-red flowers with small dark brown spots. The perianth segments tend to be reflexed and most of the flowers are horizontal. This variety increases rapidly and does not take long to make a good sized clump in the garden. It is the earliest to bloom, and reaches a height of from 3 to 5 feet.

L. × *Lyla McCann* (L.29.01.50).—Very attractive orange flowers of open type with reflexed tips. The foliage is somewhat drooping and has a soft feeling, differing from that of Grace Marshall and of Lillian Cummings, which is harsh and stiff. This is the lowest growing variety of this group, seldom exceeding 3 feet in height. Award of Merit, R.H.S. May 25, 1937.

The "Fighter-Aircraft" Group

While the "Stenographer" lilies have met with extraordinary popularity among lily fanciers and the general garden-minded public, their importance in plant breeding may very well outweigh their ornamental value, which, at present, is considerable. In addition to the named varieties of the "Stenographer" group, three unnamed seedlings from the same cross have contributed their share in the development of new types of garden lilies, six of which were named after British fighter aircraft.

From Edna Kean, open-pollinated, three fine varieties have been developed. These are Spitfire, Hurricane and Mosquito.

L. × *Spitfire* (L.32.09.09).—Upright-facing, vase-shaped flowers of medium size. The inner face of the expanded bloom is a little more orange than Flame Scarlet (Ridgway), and between Orange 12 (R.H.S.) and Saturn Red 13/1 (R.H.S.), with a few dark spots. It grows to a height of 2 or 3 feet and blooms in late June and early July.

Fig. 17—*L.*×Corsair. Upward-facing flowers, well spaced on long pedicels.

L. × *Hurricane* (L.32.09.13).—Dark red medium-sized flowers which are open vase-shaped and face upwards. In number they vary from 10 to 30. The plant grows 3 to 4 feet tall and blooms in June and July. Award of Merit, M.H.S. July 11, 1945. Award of Merit, R.H.S. June 18, 1946.

L. × *Mosquito* (L.33.07.01).—Orange flowers showing a few very dark spots. The flowers droop, have reflexed segments, and are well placed on strong stems. It grows to 4 feet and blooms in July.

L. × *Typhoon* (L.35.29.04).—An open-pollinated seedling of the variety Lyla McCann. The flowers are open vase-shaped and the inner face of the expanded bloom may be described as a blending of Nopal Red and Scarlet, lightening to Flame Scarlet from the tip about half way down the segments, with small elongated dark spots. The throat has a light mealy appearance. Flowers face upwards in a rather close cluster at the top of the stem which reaches 2 to 3 feet in height. Increases very rapidly and blooms in June.

The two remaining varieties in this group are Corsair and Lysander.

L. × *Corsair* (L.35.27.01).—An open-pollinated seedling of L.29.01.27, one of the unnamed "Stenographer" group. Corsair has medium-sized vase-shaped flowers which face upwards and have slightly reflexed tips. The colour is unusual, being yellow, more or less flushed with red. It grows to a height of 2 or 3 feet and blooms in July.

L. × *Lysander* (L.33.06.03).—An open-pollinated seedling of L.29.01.05, another unnamed sister of the "Stenographer" lilies. The flowers are upright, vase-shaped, with slightly reflexed tips, and the colour of the inner face of the segments is Saturn Red 13 (R.H.S.)—a little lighter than Grenadine Red (Ridgway), with a medium amount of small dark spots. There are upwards of 12 buds. The plant reaches a height of from 4 to 5 feet, and blooms in early July.

The Yellow-Flowered Group

One of the most important developments in the lily breeding work at Ottawa was the variety Coronation, the forerunner of a new race of yellow-flowered lilies. It was obtained from open-pollinated seed collected in 1932 from L.29.01.07, a "Stenographer" sister-seedling, and flowered for the first time in 1934.

L. × *Coronation* (L.32.10.01).—Clear bright yellow flowers, faintly spotted with brown. The flowers, which may number up to 20, are nodding and have reflexed segments. It blooms in late June or early July and grows to 3 feet. This variety increases very rapidly from bulblets or scales, and is useful in a garden because of its colour, but it is not so robust as any of the "Stenographer" group. Award of Merit, R.H.S. July 3, 1945. First Class Certificate, M.H.S. July 11, 1945.

The second yellow lily to be developed and named at Ottawa was Sovereign. This variety was selected from open-pollinated seedlings of L.35.29.05, an open-pollinated seedling of Lyla McCann.

L. × *Sovereign* (L.38.18.02).—Open bowl-shaped flowers with reflexed tips. The colour is Saffron Yellow (R.H.S.) with a medium amount of dark flecking. The height of this variety is between 2 and 3 feet and it blooms in July. It increases rapidly from bulblets.

From L.29.01.07, in addition to Coronation, came L.37.12.01, which has upright-facing lemon-yellow flowers with many small dots, but unfortunately with weak stems. Because of its attractive colour and the upward-facing habit of its flowers, this variety has been used to cross with other yellows, with good results—the weak stem having been eliminated in the progeny.

By crossing Coronation with L.37.12.01, a fine upward-facing yellow was obtained. This seedling, L.42.06.01, as yet unnamed, is one of the finest lilies produced here to date, and was used widely in the lily breeding work in the

summer of 1948 in an effort to produce more yellow lilies of desirable flowering habit. Stock of this variety is being increased for field testing and future plant breeding.

An unnamed seedling, L.35.26.01, crossed with Coronation produced L.38.07.01, which has nicely-spaced flowers hanging down at an angle of 45 degrees. They are clear lemon-yellow with fine speckles and the segments are reflexed. Very effective for mass plantings.

Several other yellow-flowered lilies have resulted from different crosses, as well as from open-pollinated seed. From Coronation × Lyla McCann came L.38.01.01, a tall stately plant, much like Coronation, but with a lighter throat. Open-fertilized seed from Coronation gave two good yellow seedlings, L.39.58.03 and L.39.58.06, both of which are being propagated for field tests and for use in breeding work.

In addition to appearing in the parentage of Typhoon and Sovereign, the variety Lyla McCann shows up in the pedigrees of six very good yellow varieties. When pollen of Lyla McCann was used on the variety Grace Marshall, one of the seedlings had upward-facing, fairly large flowers, on plants about 2 feet tall. This seedling is still under the seedling number L.39.08.01 and has been sent out to selected growers for field testing.

Fig. 18—L.39.08.01. A fine upward-facing light yellow selection from the cross Grace Marshall×Lyla McCann.

From Lyla McCann, open-pollinated, came the seedling L.37.10.01, a tall, late-flowering, bright yellow variety whose flowers face out. This variety appears more resistant to Botrytis blight than many others, and for this reason it has been used recently in plant breeding.

Lyla McCann × Brenda Watts resulted in L.38.08.02 and L.38.08.06, two very good yellows, the second of which bred to pollen of L.37.12.01, produced L.43.02.01, an excellent variety with well-formed, light yellow flowers which face out. This seedling was used in a number of crosses made in 1948.

The accompanying chart shows the genealogy of the descendants from the original *Willmottiae-dauricum* cross. The progeny from seed of Brenda Watts, Muriel Condie and Lillian Cummings are not shown, as they were in most respects so similar to other named varieties that they were not selected for propagation and distribution.

As there are so many lily varieties of orange and reddish tones already in commerce, the present lily-breeding program at the Central Experimental Farm is being directed towards improvement in the form, size and disease resistance of yellow-flowered types of lilies; in particular, those with upward-facing flowers.

Iris sibirica Hybrids

In 1920, reciprocal crosses were made between *Iris sibirica* var. *maxima* and *I. orientalis* var. Snow Queen. From the 92 seedlings resulting from these crosses, several varieties were selected and named. These varieties along with two open-fertilized seedlings of the second generation from the original cross, were described in the Annual Report for 1928.

Other varieties, selected from the second and third generations, which have been named and distributed, are described hereunder.

I. × *Kenogami* (I.24.19.115).—A tall, late, dark variety. The standards are blackish violet, the falls bluish purple, velvety, with a white line around the edge. The blade has a white blotch with purple lines. Haft cream, heavily lined with grey. Blooms in the latter part of June.

I. × *Matane* (I.28.05.61).—A fine white-flowered variety. The standards are white except at the base which is faintly yellowish. The falls are round, white, with the edges crimped or fluted in a most distinctive manner. The haft is Wax Yellow. Blooms in the middle of June.

I. × *Matapedia* (I.28.05.05).—A tall well-branched plant with attractive white flowers. Blooms a week later than other white-flowered varieties.

I. × *Pickanock* (I.24.16.412).—A tall dark early variety with large flowers. Standards large, dark violet, notched at the top. Falls broad and round, Violet Ultramarine with a distinct white blotch one-third the length of the blade, with violet lines. The falls have a very velvety appearance when opening. Haft Olive-Ocher, heavily lined and reticulated with Warm Sepia. Blooms during the first two weeks in June.

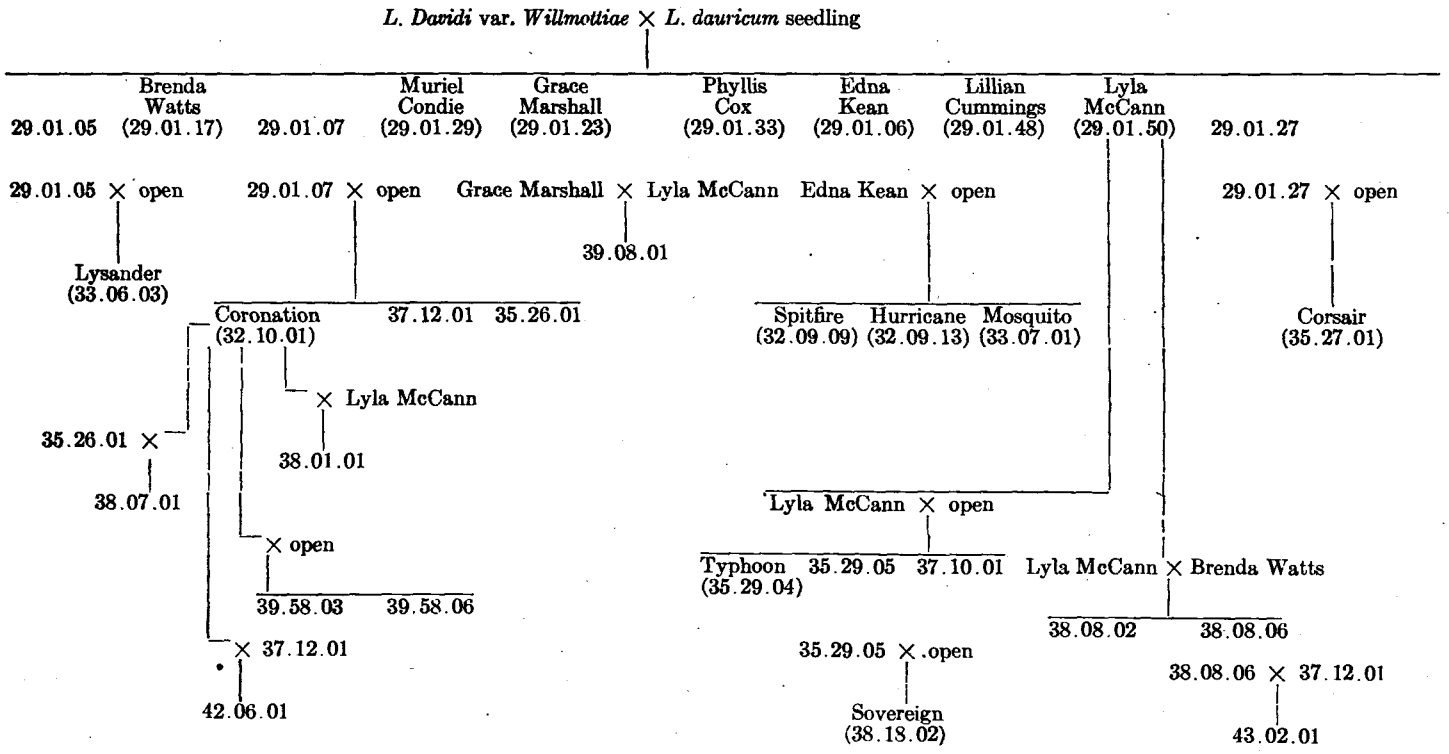
I. × *Rimouski* (I.24.17.588).—An early variety of medium height. Standards white, except at base which is faintly flushed yellow. Falls white, with distinct yellow line down centre and yellow triangular blotch. Haft rich yellow. The flowers stand well above the foliage and the plant has a striking appearance. Is very floriferous and blooms during the first and second weeks of June.

I. × *Skeena* (I.24.15.632).—A richly coloured variety somewhat similar to Kenogami but not so tall. In form it is like a large *sibirica*. Standards Blue Violet with light speckles at the base. Falls Deep Blue-Violet with some inconspicuous white markings. Blooms the second and third weeks of June.

Rosa

The development of hardy roses through plant breeding has received considerable attention at Ottawa since before 1900. The more recent phase of the work since 1920 has yielded a number of worthwhile new varieties, several of which were described in the Reports of the Dominion Horticulturist for 1928, 1930 and 1931-33. In addition to those which have been described, a small number of other varieties have been named and distributed after being tested for hardiness. These are:

GENEALOGY OF THE PROGENY OF THE ORIGINAL WILLMOTTIAE-DAURICUM CROSS MADE IN 1929, COVERING THE PERIOD 1929–1943



R. × *Algonquin* (R.28.13.02).—An open-pollinated seedling of R.20.29 *(R. rubrifolia* × *R. rugosa)*. This variety makes a tall shrub reaching a height of 10 feet and covering an area 8 feet across. Foliage dull yellow-green; leaflets 7, large, leathery in texture. Flower: bud ¾ inch; calyx 1½ inches, widening towards the tip; expanded bloom 2½ inches across, flat, 5 petals, deep pink (Rhodamine Purple) at edges, shading to white at the centre, faintly fragrant. The fruit is large and bottle-shaped, very ornamental, and the shrub is very hardy. Blooms the second and third weeks of June.

R. × *Caribou* (R.34.02.08).—An open-pollinated seedling of R.30.08.03, Ross Rose × (*R. rugosa* × *R. Eglanteria*). An attractive medium-sized shrub with dark green rugose foliage which has the Sweetbrier fragrance. The single flat flowers which are white, faintly tinted pink at first, are 3 inches across and are borne profusely all along the arching branches. The fruit is scattered in small clusters and gives the plant a fine appearance in early autumn. This variety blooms for about two weeks during the latter part of June and is hardy without protection at Ottawa.

R. × *Chippewa* (R.23.04.01).—(*R. rubrifolia* × climbing rose White Tausendschon). A tall-growing plant with purplish foliage. The flowers are small, 1¾ inches across, semi-double, Rose Pink with a white centre and moderately fragrant. They are borne in clusters all along the stems which are strong and sturdy, bending over a little at the top. This variety remains in bloom from mid-June for about a month. The old wood is less hardy than the younger growth and sometimes winter kills.

R × *Conestoga* (R.34.21.01).—An open-fertilized seedling of the hybrid *blanda* variety "Betty Bland". Conestoga is a shrub rose reaching 7 feet or more with small, soft, light green foliage; leaflets 7 to 11; bark bronze. Individual flowers are small, 2 inches across, white and slightly fragrant, very double and borne 6 in a cluster. Buds small, flushed pink. An attractive plant. Blooms the last week of June through the first week of July.

R. × *Erie* (R.35.14.04).—An open-fertilized seedling of R.30.08.01, Ross Rose × (*R. rugosa* × *R. Eglanteria*). A shrub rose with large clusters of large single pale pink flowers. The foliage is fragrant. The fruit is bottle-shaped and red, and its attractiveness is increased by the persistent calyx. This variety spreads rapidly.

R. × *Langford* (R.30.19.09).—Parents—*R. setigera* × polyantha pompon var. Aanchen Müller. A climbing rose with clusters of double red flowers. This variety is quite floriferous, blooming for a period of 4 to 5 weeks. While the form of the flower is poor, the plant appears to be hardier than many climbing roses and may be useful where better varieties will not grow. Blooms from the latter part of June.

R. × *Micmac.*—Pedigree unknown, probably the F_2 of *R. rubrosa.* This is a bush rose about 4 to 6 feet tall. The foliage is rugose in texture and deep purplish red, much richer in colour than the foliage of any other rose at the Central Experimental Farm. The single flowers, which are borne in clusters, are white with faint pink streaks, and stand out against the attractive dark foliage. It blooms in the middle of June. This plant is hardy, but some stems die out occasionally.

R. × *Millicent* (R.28.05.01).—Parents—*R. rubrifolia* × *R. Harisonii.* A shrub of medium height, hardy at Ottawa but not very vigorous. Foliage Dark Ivy Green with reddish brown veins. Flower: bud Flesh Pink, borne singly on pedicels 1″-1½″ long; expanded bloom 2 5/16 inches across, flat, semi-single, 10-13 petals; light Coral Red fading to Flesh Pink within, Napthalene Yellow without. The fruit is round, flattened at the ends, bright red in colour. Blooms early in June.

R. × *Mohawk* (R.26.18.04).—An open-pollinated seedling of R.20.01.29 (*R. rugosa* × *R. rubrifolia*). A small, shapely, rounded shrub with dull green leathery leaves and single bright red flowers with white centres. The flowers are 2 inches across, from 1 to 3 in a cluster, and the plant is hardy. Blooms in mid June. Seldom sets fruit, and rarely produces sucker growth. A good variety for the front of a shrub rose border.

R. × *Nascapee* (R.35.15.09).—An open-pollinated seedling of R.30.08.03, which was the seed parent of the variety "Caribou". A very hardy vigorous shrub, making a tall plant reaching a height of 7 feet with a spread of 5 to 6 feet. This variety blooms more or less continuously from mid-June throughout the summer. The flowers are single, white, 1¾ inches across, borne in clusters of 10 to 15. The stems are light green and are less thorny than most shrub roses. The leaves have 5 or 7 leaflets, are fragrant, and remain attractive until the first hard frosts. The fruit is bright red. In late summer this variety has buds, open bloom and both green and red fruit at the same time.

R. × *Ojibway* (R.35.14.28).—An open-pollinated seedling of the same parentage as "Erie", Ross rose × (*R. rugosa* × *R. Eglanteria*). A large bushy shrub rose reaching 5 feet with a spread of 12 feet. Foliage Spinach Green, slightly rugose, profuse. Bark and twigs green flushed red, with many small thorns. Flowers semi-double, white, 3 inches across, produced abundantly. Attractive either in bloom or in fruit. Suckers very freely. Blooms towards the end of June or early in July.

R. × *Poliarchus* (R.24.17.03).—An open-pollinated seedling of *R. Harisonii*. A shrub rose reaching 4 feet in height and making a spreading bush with salmon-pink single flowers which fade to cream. Flowers are 2 inches across and open flat. They are moderately fragrant and are produced in abundance in the second and third weeks of June. The plant is hardy without protection at Ottawa.

Syringa

Syringa Prestoniae

The report for 1928 contained descriptions of several varieties of the then recently named group of *Syringa Prestoniae*, originated at the Central Experimental Farm from a cross made in 1920 between *S. villosa* and *S. reflexa*. Since the publication of the 1928 report, the named varieties of *Syringa Prestoniae* which were distributed have been grown under test in all sections of Canada, in several of the States of the United States and in Great Britain, and reports have been received as to their hardiness, disease resistance and, in general, their ornamental value. From the list of the named varieties described in the 1928 report, the following have proved themselves as being the most suitable and desirable:

Isabella	(S.20.14.114)
W. T. Macoun	(S.20.14.51)
Audrey	(S.20.14.195)
Desdemona	(S.20.14.179)
Elinor	(S.20.14.172)
Miranda	(S.20.14.38)
Ursula	(S.20.14.214)
Virgilia	(S.20.14.211)

The varieties Audrey and Isabella received Awards of Merit from the Royal Horticultural Society, London; Audrey, June 6, 1939; Isabella, June 17, 1941.

Two varieties, Celia (S.20.14.176) and Jessica (S.20.14.22), mentioned but not described in the 1928 report, are described as follows:

S. × *Celia* (S.20.14.176).—Flower panicles large, loose, 10½ inches long by 9 inches wide, drooping at the tips, with regular even branching habit, frequently

with two lateral panicles. Bud Light Perilla Purple; expanded bloom Pale Vinaceous-Lilac within, Light Vinaceous-Lilac without. Flowers small, having a slight pleasant fragrance. Very showy variety, floriferous, later than most of the others.

S. × *Jessica* (S.20.14.22).—Flower panicles quite large, being 10 inches long and 11 inches wide, conical in shape and tapering from base to tip; branching habit open, the terminal panicles often having four laterals. Bud Light Perilla Purple; expanded bloom Argyle Purple within, Purplish Lilac without. Flower long tubular, broadening at the mouth, lobes opening at right angles, $\frac{5}{8}$ inches long and $\frac{3}{8}$ inches across. This is one of the darkest varieties. It is late and has a pleasant fragrance.

Fig. 19—*Syringa Prestoniae* varieties. Front to back—Audrey, Virgilia and Ursula.

Other satisfactory named varieties of *S. Prestoniae* are:

S. × *Calphurnia* (S.20.15.18).—Panicles large, 9 inches long by 10½ inches wide, conical in shape and somewhat drooping, with a loose spreading branching habit. Bud Light Perilla Purple; expanded bloom Bishop's Purple within, Purplish Lilac without, fading to Light Pinkish Lilac. Individual flowers small. This is one of the best dark coloured varieties, blooming earlier than Jessica, and keeping its colour late in the season. Unfortunately, the bush has an ungainly habit, which calls for judicious pruning.

S. × *Oberon* (S.24.05.82).—An open-pollinated seedling of *S. Prestoniae* seedling No. S.20.14.66. This variety makes a tall upright-growing shrub with quantities of pale pink flowers well distributed over the plant. The panicles are large, 10 inches long and 7 inches wide, open and upright. Individual flowers are small. Small buds Tourmaline Pink, large buds Pale Laelia Pink; expanded bloom Pale Laelia Pink to whitish within and Pale Laelia Pink without, fading to almost white. From a distance the open bloom appears to be white.

S. × *Romeo* (S.26.05.23).—An open-pollinated seedling of Diana (S.20.03.01), the only progeny of the reciprocal cross *S. reflexa* × *S. villosa*. This

shrub is upright-growing, with decidedly pink flowers and dark reddish stems which give the plant a distinctive appearance and intensify the pink colour of the flowers. Small buds Indian Lake, large buds Pale Rosolane Purple; expanded bloom Rosolane Pink within, Rosolane Purple without, fading to Rosolane Pink. Individual flowers single, $\frac{3}{8}$ inch tube, $\frac{5}{16}$ inch tip to tip. Flower stems Dark Indian Red. This is a very attractive variety.

Syringa josiflexa

A cross made in 1920 between *S. Josikaea* and *S. reflexa* was named *S. josiflexa,* and the only plant obtained from this cross was given the variety name of Guinevere.

S. × *Guinevere* (S.20.06.01).—Flower panicles 8½ inches long, 8½ inches wide, conical, with tips of panicle divisions drooping. Bud Light Perilla Purple; expanded bloom Purplish Lilac within, Argyle Purple without, fading to Light Pinkish Lilac. Tube narrow with petals spread wide.

From open-pollinated seed of *S. josiflexa* var. Guinevere, three seedlings with decidedly pink flowers were selected for progagation and distribution. These are Bellicent, Enid and Lynette.

S. × *Bellicent* (S.24.02.05).—The most ornamental of this group. Makes a bush 7 to 8 feet tall, and as the stems and branches are somewhat finer than in many of the other hybrids, this variety has a light graceful and attractive habit.

The central flower panicles are 5 or 6 inches long and about 4 inches wide, with many leafy laterals which also carry bloom. These numerous small drooping panicles on the long lateral branches give this variety a distinctive charm. Bud Corinthian Purple or Hellebore Red to Pale Rhodonite Pink; expanded bloom Pale Rhodonite Pink within, a slightly deeper shade without. Individual flowers small, the tube $\frac{3}{8}$ inch long; petals $\frac{3}{8}$ inch tip to tip, opening at right angles to the tube. First Class Certificate, R.H.S. May 28, 1946.

S. × *Enid* (S.24.02.43).—Upright habit of growth and presenting a very attractive appearance. The flower panicles are somewhat larger than in Bellicent, being 6 to 9 inches long and 6½ inches wide. There is usually a central cluster which is followed by two laterals. The colour is a good shade of pink, described as follows: Bud Deep Hellebore Red or Rocellin Purple to Pale Rhodonite Pink; expanded bloom Pale Rhodonite Pink edged white within to Pale Rhodonite Pink without. Individual flowers small, tube $\frac{9}{16}$ inches long, funnel-formed; petals $\frac{7}{16}$ inches across, opening at right angles. The odour is not unpleasant.

S. × *Lynette* (S.24.02.25).—This variety is quite different from its two sister varieties in foliage, habit and individual bloom. The leaves are mottled and the flower panicles are loosely branched, 7 to 10 inches long by 4 to 6 inches wide. There is usually one central panicle with several long leafy laterals carrying bloom. The tips of the unopened bloom are very pale, but the colour deepens to a good pink in the open bloom. Small bud Vernonia Purple, tips of larger buds Laelia Pink, tube Daphne Red; expanded bloom Tourmaline Pink within and without. Flowers self-coloured, fading to a paler shade. Tube narrow, ½ inch long; tips of the corolla reflexed, ½ inch tip to tip. The plant has an upright habit of growth, somewhat like Enid.

S. × *Elaine* (S.30.01.47).—An open-pollinated seedling of *S. josiflexa* var. Guinevere. A tall vigorous upright-growing shrub with large coarse leaves, quite distinct from any other *Syringa* at the Central Experimental Farm. The flowers are arranged in upright-growing panicles, 6 to 12 inches long and 5 inches wide, with several laterals. In bud the colour is Vinaceous to Pale Rose-Purple; expanded bloom white within, faintly flushed Pale Rose-Purple without, fading to white. The flowers have a thick texture, and the flower stems are quite brown before the buds open, but turn to green as the flowers open. The flowers have a faint sweet fragrance. This would be one of the best of the very pale varieties if it were not for its unfortunate upright habit of growth.

S. × *Kim* (S.26.01.09).—The origin of the parent of this variety is lost, but its tall habit of growth and other characteristics show a strong resemblance to *S. Josikaea*. The panicles are long, open, 10 inches by 5½ inches, the flower bunches opposite, almost in whorls, with one or two inches between. Bud Dark Vinaceous-Purple on one side, very pale coloured tips on the other side; expanded bloom Purplish Lilac within, tips pale, Purplish Lilac without. Individual flowers small; tube $\frac{5}{16}$ inches long, $\frac{3}{8}$ inches across, tip to tip.

Syringa hyacinthiflora

In 1922 crosses were made between *S. vulgaris* var. Negro, and Lamartine, one of the improved forms of *S. hyacinthiflora*. Four seedlings from this cross were selected and named Norah, Muriel, Grace and Maureen. Open-pollinated seed of Lamartine was also sown and from the resulting seedlings two plants were selected. These were S.22.17.13, named Patricia, and S.22.17.07, named Peggy. These forms of *S. hyacinthiflora* are all early-flowering, coming into bloom three or four days before the *S. vulgaris* varieties. In foliage and growth habit they are similar to the varieties of *S. vulgaris* with the exception of Norah, which makes a rounded bush, well furnished to ground level. Brief descriptions of the five varieties other than Grace were given in the report for 1931-33. More complete descriptions of these six varieties are as follows:

S. × *Norah* (S.22.04.16).—Panicles 7 inches long and 7 inches wide. Terminal panicles have considerable irregular branching, and are round, closed, with large individual flowers. Buds Magenta to Liseran Purple; expanded bloom Dull Magenta Purple within, Magenta without, fading to Rose-Purple. Individual flowers large, single, 1 inch in diameter, with a long slender tube. This is a very attractive variety and bears bloom to the ground.

S. × *Muriel* (S.22.04.09).—Panicles large, 6 inches long by 6 inches wide, usually V-shaped (i.e., double-branched), open in habit. Buds are large, dark. Flowers large, $\frac{7}{8}$ inches in diameter with a long, slender tube. The colour of both buds and open flowers is between Petunia Purple 32/3 and 32/1 (R.H.S.), the open bloom having a border of the lighter shade on the inner surface, the outer surface of the expanded bloom being somewhat lighter.

S. × *Patricia* (S.22.17.13).—One of the earliest varieties of lilac. Panicles large, 8 inches long, 5½ inches wide, closed, terminal panicles upright. Irregular branching habit. Small buds Purplish Lilac, large buds Hay's Lilac; expanded bloom Light Dull Bluish Violet to Hay's Lilac within, Pale Laelia Pink or Purplish Lilac without, fading to Pale Aniline Lilac. The individual flowers are large and double. This variety is distinctly blue and very attractive.

S. × *Peggy* (S.22.17.07).—A large-sized shrub, with foliage an attractive shade of light green. Flower panicles are large, 8 inches long and 5½ inches wide, long, loose and open, terminal branching. A very free bloomer. Buds Laelia Pink, deeper at the tips; expanded bloom Verbena Violet streaked white in throat, changing to Argyle Purple, Laelia Pink without; flower fading to Verbena Violet. Individual flowers large, single; tube $\frac{7}{16}$ inches long, 1⅛ inches wide, open flat. This is a choice pale variety.

S. × *Grace* (S.22.01.08).—Flower panicles 7 inches long, 7 inches wide, loose, and very attractive. Flower large, single. Bud light Perilla Purple to Bishop's Purple; expanded bloom Bishop's Purple within, Vinaceous-Pink without. A distinctive variety.

S. × *Maureen* (S.22.01.03).—In this variety the foliage is of the *S. vulgaris* type. The flower panicles are large and loose, 10 inches long by 6 inches wide. Flowers single; colour in bud Vernonia Purple; expanded bloom Bishop's Purple, fading to deep lavender. Award of Merit, R.H.S. May 19, 1942.

Other Syringa Hybrids

Two outstanding syringa hybrids produced at Ottawa are Ethel M. Webster and Fountain.

S. × *Ethel M. Webster* (S.30.07.01).—A hybrid of *S. reflexa* and a species which was incorrectly named when received, and which has not been satisfactorily identified. This is a very floriferous variety and makes a symmetrical bush. The flower panicles are large and compact, from 8 to 10 inches long and 6 inches wide at the base, tapering to a point, frequently in two's and three's at the ends of the branches, and with the nodding habit of the *S. reflexa* parent. Small buds Deep Hellebore Red, large buds Pale Rhodonite Pink; open bloom Pale Laelia Pink within and Pale Persian Lilac without, fading to Pale Laelia Pink.

Fig. 20—*Syringa* × Fountain.

S. × *Fountain* (S.33.11.01).—The parents of this variety were S.28.02.05 (*S. reflexa* × *S. Sweginzowii*) and *S. reflexa*. This is another floriferous variety, with panicles which resemble those of *S. reflexa* in their shape and drooping habit. The central panicles are from 6 to 8 inches long and about 2 inches wide, with as many as four or more laterals. Remains in bloom over a longer period than *S. reflexa*. The colour is Purplish Lilac in bud, paler upon opening except in the tube where the deeper colour is retained. It makes a rounded bush about five feet tall, blooms early in June, and is covered with flowers for about two weeks.

Fig. 21—Rosybloom crabapple var. Simcoe.

Malus Hybrids

The Reports of the Dominion Horticulturist for 1928 and for the years 1931-33 contained descriptions of several varieties of the Rosybloom crabapples, whose development started in 1920 by crossing *Malus pumila* var. *Niedzwetzkyana* with different forms of hardy crabapples. One of the first generation hybrids not previously described is Huron.

M. × *Huron* (M.21.11.02).—*Malus pumila* var. *Niedzwetzkyana* × *M. baccata*. This variety differs from most of the other Rosybloom crabapples in its habit of growth which is upright. The foliage is bronze, the leaves large and numerous. Flowers are large, flat, in clusters of 5 to 7 and have a strong fragrance. Colour, Amaranth Pink with red anthers. The fruit is very ornamental, bright red, oval in shape, bitter, hard and juicy, with flesh of a Shrimp Pink colour.

A number of crosses made between the darker foliaged varieties, with the object of intensifying the bronze summer colour of the foliage for ornamental planting, resulted in an interesting group of seedlings, two of which have been named and distributed.

M. × *Baskatong* (M.32.10.01).—A seedling of Simcoe × Meach. This variety has very dark, small to medium-sized leaves. In spring the foliage is Hessian Brown, Madder Brown and Olive-Green, overlaid with Hay's Maroon. In bud the plant is most attractive, as the flower buds are highly coloured. The summer foliage is dark bronze. Flowers are large, Spinel Red to Pomegranate Purple, in clusters of 3 to 6. This is a very useful plant where bronze foliage is required for summer effect.

M. × *Tomiko* (M.32.08.10).—A seedling of Meach × *Malus pumila* var. *Eleyi*. When grown on its own roots this variety makes a very dwarf shrub not more than 3 feet tall, but when grafted to other rootstocks it develops into a crabapple tree of normal size. The flowers of Tomiko are a pale washed-out pink—which is not a pleasing combination with the rich red or purple colour of the foliage, but, because of its hardiness and its rich foliage colour, this variety is useful as a substitute for *Prunus cerasifera* var. *atropurpurea* (*P. Pissardii*) in those districts where this Prunus is not hardy.

The following varieties have given good results and are recommended:

Early: Athabasca, Cowichan.

Medium: Amisk, Erie, Muskoka, Temiskaming.

Late: Makamik, Scugog, Huron.

Very Late: Sissipuk.

Awards to *Malus* Hybrids

M. × Athabasca: *M. pumila* var. *Niedzwetzkyana* × *M. baccata*. Award of Merit, R.H.S. Sept. 1, 1936, for ornamental fruit.

M. × Simcoe: *M. baccata* × *M. pumila* var. *Niedzwetzkyana*. Award of Merit, R.H.S. Apr. 30, 1940, for its bloom.
Award of Merit, R.H.S. July 24, 1945, for ornamental fruit.

Storage of Bermuda Lily Bulbs

A. W. S. Hunter

At the request of the Bermuda Department of Agriculture, experiments were begun in 1934 on the storage of bulbs of the Bermuda lily (*Lilium longiflorum* var. *eximium* Nichols = *L. Harrisii* Carr.). The Bermuda lily makes a fine plant for the Easter trade but complaints had been received that, unlike the Japanese lily (*L. longiflorum* var. *giganteum* Hort.), the number of flowers per plant was sharply reduced if the bulbs were held in cold storage for any length of time before planting.

Immediately after harvest, the bulbs were packed in boxes of ground coral and shipped from Bermuda. As soon as the bulbs reached Ottawa, usually some time in September, a check lot was removed and planted in the greenhouse, the remainder being placed in storage at the desired temperatures. The bulbs were kept in the ground coral during the storage period. Bulbs were withdrawn from storage at six-week intervals and planted in five-inch pots in the greenhouse, using a good potting soil mixture. The plants were placed on the floor in a cool house until stem growth began, when they were benched for flowering.

The effect of storage and storage temperature upon the performance of plants is illustrated by the results of the 1934-35 experiments summarized in Table 31.

TABLE 31.—EFFECT OF LENGTH AND TEMPERATURE OF BULB STORAGE ON THE INTERVAL BETWEEN PLANTING AND FLOWERING, AND ON THE AVERAGE NUMBER OF FLOWERS PER PLANT

Storage Treatment	Average No. Days to First Open Flower	Average No. Flowers per Plant
No storage	195·9	6·1
6 weeks at 32° F.	150·0	4·5
6 weeks at 36° F.	149·7	3·5
6 weeks at 40° F.	150·8	3·8
12 weeks at 32° F.	117·0	3·1
12 weeks at 36° F.	121·1	2·6
12 weeks at 40° F.	119·7	2·8
18 weeks at 32° F.	104·8	2·5
18 weeks at 36° F.	111·1	2·0
18 weeks at 40° F.	109·2	2·1
24 weeks at 32° F.	97·0	1·9
24 weeks at 36° F.	107·6	1·5
24 weeks at 40° F.	104·9	1·3
30 weeks at 32° F.	82·4	1·8
30 weeks at 36° F.	107·1	1·1
30 weeks at 40° F.	88·1	1·0

It is evident from the results that 32°F. is the best of the three storage temperatures tried, that stored bulbs flower in a shorter time than bulbs planted as soon as received, and that the longer the period of storage, the greater is this reduction in time, thus effecting a considerable saving in greenhouse space. However, it is also evident that even six weeks' storage materially reduces the number of flowers produced. Bulbs stored for six weeks at 32°F. may give plants with a commercial number of flowers, but the reduction caused by longer periods of storage renders it impractical to spread out the season of flowering by holding the bulbs in storage beyond this time.

A comparison of the effect of bulb storage on the Bermuda and Japanese varieties was obtained in 1936-37 and is given in Table 32. The same commercial size of bulbs of both varieties was used. From these results it can be seen that storage of the Japanese bulbs results in a useful saving of greenhouse space with a negligible reduction in the number of flowers produced. This is in contrast with the more than fifty per cent flower reduction in the Bermuda lily over the same storage period.

Between 1935 and 1940 attempts were made to discover a storage treatment for the Bermuda bulbs that would prevent this reduction in the number of flowers. Included in these experiments were storage of the bulbs in artificial atmospheres consisting of different combinations of high, normal and low carbon dioxide and oxygen; storage of the bulbs at 20, 50 and 90 per cent relative humidity; storage for 6 and 12 weeks at approximately 70° F. followed by 6, 12 and 18 weeks

in cold storage; immersion of the base of the bulbs, after storage, in solutions of indolebutyric acid for 24 hours, and illumination of the bulbs during storage by means of fluorescent lights. None of these treatments resulted in any improvement in comparison with similarly stored, untreated bulbs—with the one exception that continuous ventilation of the bulbs with a normal atmosphere in the gas storage experiments did appear to delay, at least until after 6 weeks' storage, the reduction in number of flowers. This might suggest that the products of metabolism, which would be retained by the ground coral in which the bulbs were packed, were responsible for the deleterious effect of storage. Owing to the inability to obtain supplies of Bermuda lily bulbs during the war, this lead was not followed up.

TABLE 32.—EFFECT OF LENGTH OF BULB STORAGE ON THE INTERVAL BETWEEN PLANTING AND FLOWERING AND ON THE AVERAGE NUMBER OF FLOWERS PER PLANT OF THE BERMUDA AND JAPANESE VARIETIES

Storage Treatment	Bermuda Lily		Japanese Lily	
	Av. No. Days to First Open Flower	Av. No. Flowers Per Plant	Av. No. Days to First Open Flower	Av. No. Flowers Per Plant
No storage	226·6	6·1	205·5	5·2
6 weeks at 32° F	186·9	3·3	170·3	5·3
12 weeks at 32° F	162·1	3·1	141·3	5·0
18 weeks at 32° F	135·5	2·9	123·4	4·5

A study of flower bud formation by MacArthur (1) on stored and unstored bulbs revealed no formation of meristems followed by their degeneration, and indicated that "the factors causing the reduction in the number of flowers associated with storage of the bulbs must lie farther back in the ontogeny of the plant".

In 1937 reciprocal crosses were made between the Bermuda and Japanese varieties in an attempt to combine the storage behaviour of the Japanese lily with the flower and plant characteristics of the Bermuda lily. A good set of seed was obtained from which 334 plants were grown. These flowered in 1939, and 32 were selected for further testing. An effort was made to multiply the selected seedlings outdoors at Ottawa. The bulbs over-wintered quite well in a protected area, but under field conditions loss from winter killing was high and the rate of increase of all seedlings was low. However, a sufficient quantity of bulbs of ten seedlings was obtained to permit a small storage trial in 1944-45. Three of these, which were also of good forcing type, showed relatively little reduction in number of flowers following eight weeks in storage at 39°F. This material has been transferred to the Dominion Experimental Station, Saanichton, B.C., where some of the seedlings are attracting considerable attention from bulb growers and greenhousemen.

Reference

1. MacArthur, Mary. Development of the lily. Sci. Agr. 22:104-107. 1941.

Development of the Lily

M. MacArthur

Bulbs of the Bermuda lily, *Lilium longiflorum* var. *eximium* Nichols, subjected to storage before planting, give a reduced number of blossoms. Increased storage further reduces the number of flowers. A morphological investigation of the developing lily was undertaken to determine the effect of storage on the initiation of floral primordia.

The unstored bulbs were greenhouse-planted immediately after receipt on August 12; the stored bulbs were dark-stored at 39° F. for 12 weeks, then greenhouse-planted. Samples from both lots were taken periodically; axial elongations and the width of the terminal meristems were measured, and finally, a series of slides was made from longitudinal and transverse sections of the growing tip to obtain evidence of differentiation of floral primordia.

Five to six flower buds were formed in the unstored material, and not more than three in the stored material. Floral primordia appeared in the stored material 84 days after planting and in the unstored 105 days after planting. There was no evidence whatever of initiation with subsequent degeneration of floral primordia in the stored bulbs.

The results appeared in "Development of the Lily" by Mary MacArthur. Sci. Agr. 22: 104-107. Oct., 1941.

FLORICULTURE

A. P. Chan

This report deals with research which was initiated in December, 1947, when the writer was appointed as the Assistant in Floriculture Research. Earlier work on floriculture is dealt with in the section on Plant Nutrition and Physiology. Since 1947, experiments covering a broad field of commercial floriculture have been initiated and most of these are still in progress. A new greenhouse 25 x 60 was completed in the spring of 1948 and is equipped with both concrete and steel V-bottom benches. One-half of these benches is designed for gravel culture and is in use. A new laboratory for testing greenhouse soils has been set up and is now in operation.

The major investigations now in progress are cultural experiments on carnation, rose, poinsettia, snapdragon, chrysanthemum, aster and gladiolus. Fundamental work on flower bud initiation of chrysanthemum is also in progress.

Carnation Culture

Main Objects

1. A comparison of various automatic watering systems on carnation culture.
2. A comparison of Ohio State WP nutrient with Division of Horticulture CH solutions.
3. Tests on the suitability of various carnation varieties for second year crops.
4. Studies on the effects of various watering systems and types of culture (i.e., sand, soil, gravel) on second year crops.

The watering systems used are constant water level, Nelson Master Nozzle and manual overhead watering. In the same experiment, a plot of sand culture is included. Gravel plots employing the WP and CH nutrient solutions with Haydite, a synthetic gravel, form the other treatment plots.

TABLE 33.—EFFECTS OF WATERING SYSTEMS AND NUTRIENT SOLUTIONS ON FLOWER PRODUCTION IN CARNATIONS—SEPTEMBER 20 TO MAY 15

Method	Flowers Per Plant		
	Northland	William Sim	Light Pink Virginia
Constant Water Level	4·5	4·9	5·7
Nelson Master Nozzle	5·0	5·3	6·5
Manual O.H. Watering	5·2	5·3	6·2
Sand Culture	4·3	4·4	4·7
WP Nutrient Solution	4·3	4·1	4·6
CH Nutrient Solution	4·0	4·0	4·7

The varieties used in these studies are Northland, William Sim and Light Pink Virginia. Rooted cuttings were planted directly into greenhouse benches on May 25, 1948. These were pinched continually until July 10 to build up the plants. The effects of the various watering systems and the two nutrient solutions on flower production are given in Table 33.

From Table 33 it can be seen that the Nelson Master Nozzle and manual overhead watering are superior to other methods. The flower size and stem

length are fairly constant with the variety regardless of treatment. In these experiments the average widths of Northland, William Sim and Light Pink Virginia were 3·8, 3·6 and 3·4 inches respectively. Stem length averaged 24 inches in all plots. The quality of flowers was exceptional, each stem averaging over one ounce in weight.

Rose Culture

Main Objects

1. A comparison of Ohio State WP nutrient solution with Division of Horticulture CH solutions.

2. A comparison of various automatic watering systems on rose production.

3. A comparison of the effects of gradual cutbacks or knife pruning with the standard method of drying-off and pruning.

The rose plants used in these studies were grafts planted on May 10, 1948. The gravel plots were planted a week later. The systems of watering were constant water level, Nelson Master Nozzle, Revere copper pipe system, and manual overhead watering. The plants were built up during the summer by regular pinching. Top breaks were "soft pinched" and bottom breaks were "hard pinched" in order to induce more than one heavy break from the pinch. The variety Better Times is used in the watering and nutrient studies. In the pruning studies, the varieties Happy Day and Starlite are used. Table 34 indicates flower production in the first year of testing the four methods of watering and the two nutrient solutions.

TABLE 34.—EFFECTS OF WATERING SYSTEMS AND NUTRIENT SOLUTIONS ON ROSE PRODUCTION, AUGUST TO MAY

Method	Flowers per Plant	Average Stem Length
Constant Water Level	18·6	21 inches
Revere Copper Pipe	18·6	21 "
Manual O.H. Watering	17·2	21 "
Nelson Master Nozzle	16·7	21 "
CH Nutrient Solution	13·6	18 "
WP Nutrient Solution	11·8	18 "

The various watering methods in soil culture did not show great differences in the first year of production. The figures for the gravel culture plots using WP and CH nutrient solutions are not indicative of the merits of the system. The plants were checked before they were planted because of a delay in the delivery of necessary equipment for the gravel culture method. No results can be shown for the pruning and cutback experiment at this date because the experiment has been under way for only one year.

Chrysanthemums and Asters

Chrysanthemums are investigated from the standpoint of spring production and crop rotation with spring asters.

Main Objects

1. Investigation of the possibilities of flowering a spring crop of chrysanthemums by cutting back plants which flowered for a fall crop.

2. Demonstration of a rotation plan of late chrysanthemums and asters.

Mid-season varieties (Little America, Bronze Masterpiece, Tally-ho, and Brocade) were chosen as material for the fall-spring crop. Flowers were cut

from November 10 to 15. The stock plants were to be lighted from 1 to 2 a.m., and shoots arising from the stock plants were to be pruned to three stems.

However, the original plants were badly infected with Verticillium wilt and the experiment was discontinued. It is planned to repeat this experiment in 1949-50.

In the second block, December varieties (Imp. Tobin's Yellow, Pink Mistletoe, Vibrant and Prosperity) were lighted to delay them for the Christmas market. These, too, were so badly infected with Verticillium that the experiment was discontinued.

The asters were benched in late December as planned. These were the Royal types. Shell Pink, Royal Purple, White and Deep Rose were the varieties used. Additional illumination was used from 5 to 10 p.m. daily until the blooms were ready for cutting. The plants were in bloom in March but the bulk was cut in April. As the results in Table 35 show, this is an ideal crop to follow chrysanthemums.

TABLE 35.—ASTER PRODUCTION FOLLOWING CHRYSANTHEMUMS IN ROTATION

Variety	Flowers per Plant	Flowers per Sq. Ft.	Average Stem Length	Average Flower Size
Deep Rose	6·2	13·9	26 inches	3·5 inches
White	6·3	14·2	23 "	3·3 "
Royal Purple	6·4	14·4	22 "	3·3 "
Shell Pink	7·4	16·6	18 "	3·0 "

Poinsettias

Main Objects

1. Studies on the differences in cuttings produced from stocks at Ottawa and those which were rooted in California and flown here by air cargo.

2. Studies on the effects of various dates of propagation and panning.

The varieties Oak Leaf and Albert Ecke are used in these studies. Cuttings were propagated from July 26 to September 18. Two shipments from California were made. The first arrived on August 28 and the second arrived on September 24. It appears that any date prior to September 15 is too early for shipping. Before that time the temperature is too high and losses are liable to be correspondingly great. Late shipments (after September 15) are satisfactory and the cuttings may be panned directly. By panning directly, labour is saved, and the unevenness of height of the plants is too slight to be of great importance. Cuttings propagated at Ottawa prior to September 18 were stuck in sand and potted in 2½'s when rooted. Cuttings propagated after September 18 were panned directly on October 5.

TABLE 36.—GROWTH OF POINSETTIAS PROPAGATED AT OTTAWA

Date of Propagation	Date of Panning	Average Height of Plants	Average Bract Size
July 26	October 2	20" - 24"	11·5 inches
August 31	October 18	15" - 18"	10·2 "
August 31	October 21	12" - 15"	10·2 "
September 18	October 5*	15" - 18"	10·2 "

* Panned direct from propagation bench.

As the results in Table 36 show, the date of panning seems to have an important effect on the height of the plants. The date of propagation, too, has an effect, but this effect can be controlled to a limited extent by nutrient levels.

TABLE 37.—GROWTH OF POINSETTIAS FROM CALIFORNIA CUTTINGS

Date Cuttings Received	Date of Panning	Average Height of Plants	Average Bract Size
August 28	(Shipment lost through heat).	.....	.....
September 24	September 24	12″ – 15″	9·0 inches

It should be borne in mind that the data presented are not complete. It is proposed to repeat this work in 1949 with special reference to dates of shipments, propagation and panning, and to temperature control.

Snapdragons

Main Objects

1. Studies on the effects of timed-pinching on blooming date of winter flowering snapdragons.

2. Evaluation of hybrid tetraploid snapdragons in comparison with line bred and diploid hybrids.

Five commercial varieties and three tetraploid hybrids were used in these studies. Two sowing dates, July 20 and August 20, were employed. The July 20 sowing was planted and grown to maturity in flats. The second sowing was planted in a ground bed. Table 38 shows how the experiment was conducted.

TABLE 38.—METHODS AND PROCEDURES OF SNAPDRAGON EXPERIMENTS

Operation	First Sowing	Second Sowing
Sow seeds	July 20	August 20.
Prick out	August 20	October 1.
Flat or bed	September 20	November 24.
Pinch	September 25, October 1, October 6	November 26, December 1, December 6.
Flower	February-March	March-April.

The flatted snapdragons were left out in cold frames until November 24 because of a lack of greenhouse space. The plants were exceptionally sturdy when brought into the greenhouse.

At the time of writing only the results of the first sowing have been studied. These indicate that the physiological mechanism of timed-pinching of snapdragons is quite different from that of chrysanthemums. Although there was a variation of 15 days between the dates of the pinch, the blooming dates of the various plots were quite similar. This was in contradiction to claims made by some growers that a pinch made 5 days earlier or later would cause flowering to be altered by weeks. The second experiment appears to indicate quite similar results. Some other factor, such as physiological age of the seedling at the time of pinch or the temperature, may be involved. This work will be continued in 1949.

Gladiolus Culture Under Glass

Gladiolus corms were planted in mid-February, 1948, and came into bloom in May. The main objects were studies on the effects of pre-heat treatments, ethylene chlorohydrin, and additional illumination on earliness of flowering of forced gladiolus.

Since the checks flowered at the same time as the treated plots, the 1948 results indicate that corms planted in mid-February need no special treatment. Of the varieties used (Snow Princess, Picardy, Early Dawn and Red Charm), Early Dawn and Red Charm were outstanding.

This work is being repeated in 1949. Although the results are not yet complete, it would appear that even those corms planted in January need no special treatment. The use of additional illumination indicates better quality blooms. The varieties, Red Charm, Rosa van Lima, and Elizabeth the Queen, were especially good.

Miscellaneous Studies in Greenhouse Floriculture

H. Hill

Sleepiness in Carnations

The term "sleepiness" as applied to flowers is usually confined to carnations. It is characterized by a partial closing of the flower due to an incurving or curling of the petals. This condition progresses until the flower is frequently almost closed. The disorder has been encountered irregularly, usually when flowers are shipped by train a considerable distance. The flowers do not recover after they have become sleepy.

Ferguson (1) found that the gas, ethylene, definitely caused sleepiness. This gas is one of the constituents of pintsch gas used frequently for lighting and cooking in some of the express cars in which shipments were made during these investigations. Exposure of carnations to such small concentrations of pintsch gas as 100 p.p.m. for 24 hours and 250 p.p.m. for 10 hours caused severe sleepiness. These concentrations are within the figures obtained for analyses of gas samples collected in the express cars. There is no reason to believe that sleepiness is the result of growing or cultural conditions.

Artificial Lighting

Intensity.—Several different types of plants were grown for comparison under lights of intensities varying from five to four hundred foot candles. In no instance did intensity of light influence significantly the date of bloom of long day plants. Chrysanthemums were not satisfactorily retarded by the extremely low intensity, and many shoots continued to make vegetative growth until intensity reached twelve foot candles. It was indicated that greater intensities were not necessary.

Quality of Light.—Mercury vapour and fluorescent tubes giving light of different quality were compared with Mazda lamps as supplementary to natural daylight period and as total illuminations.

As supplementary lighting they proved effective in the following order: Mazda, Daylight, Blue, Green, Red and Mercury Vapour. As total illumination none proved satisfactory except in the sprouting of seeds of cereals.

Photoperiodism Studies with the Chrysanthemum

Studies of photoperiodism showed that most mid-season varieties of chrysanthemums will not form flower buds until the daylight falls below fourteen hours. This occurs at Ottawa about the end of the third week in August and rises above it again about April 25. Therefore, if bloom is required before the natural

season, dark shade cloth should be applied about seventy days before the bloom is desired. Pinching should be done about thirty-five days before shade is applied. If bloom is to be delayed, artificial light at ten to twelve foot candles should be provided daily from five to ten p.m. prior to the end of the third week in August. It should be applied as many days before this time as it is intended to delay the normal bloom period. Lighting should be discontinued about seventy days before bloom is desired.

The following plants were also grown with additional artificial light, and are divided into two groups according to whether their response was earlier blooming or they were not materially influenced:

Earlier Blooming.—Aster, Calceolaria, Centaurea, Cineraria, Gypsophila, Larkspur, Nasturtium, Pansy, Salvia.

No Material Influence.—Calendula, Geranium (Pelargonium), Primula, Zinnia.

Effects of Supplementary Lighting on Growth and Production of Asters

Certain greenhouse flowering plants react favourably to supplementary electric lighting in the seedling stage. Seed of asters was sown on January 17 and pinched out into flats on February 6. Half the flats were placed under electric lights for four hours of supplementary lighting each day. Four flats were set under a 100-watt Mazda lamp suspended at a height of three feet. After five weeks the lighting was discontinued, and the lighted and non-lighted plants were benched. After being benched for two weeks, the lighted plants were judged as being approximately one month in advance of the untreated plants in growth and vigour. This difference was very marked in the production of flowers. Yield at the time the first main cut was taken from the untreated plants was 23 blooms per 100 plants. In the meantime the light-treated plants had yielded 733 blooms per 100 plants, and had been undergoing cropping for a month. The final total from the treated plants was 833 blooms per 100 plants made up of 203 No. 1 grade, 315 No. 2 grade and 315 No. 3 grade, and from the untreated plants 393 blooms per 100 plants made up of 97 No. 1 grade, 50 No. 2 grade and 246 No. 3 grade.

Subsequent studies were conducted to show whether lighting would be of advantage at other seasons of the year. Sowings were made at monthly intervals, and half the populations were subjected to the same intensity and period of artificial light. The period from sowing to bloom was reduced for all monthly sowings except April, May, June and July. In these four months temperature was probably the deciding factor. However, when sowings were made from May to October, the quality of plants and flowers was unsatisfactory.

Reference

1. Ferguson, Wm. Sleepiness in Carnations. Sci. Agr. 22:509-518. Apr., 1942.

LOW TEMPERATURE RESEARCH

W. R. Phillips and P. A. Poapst

Storage Plant, Laboratory and Equipment

Historical Development

Concurrent with the development of mechanical refrigeration and more efficient methods of transportation and communication at the beginning of the twentieth century, food storage became more important in world and national economy. So it was realized that a scientific approach to the solution of problems arising in storage would be necessary. Thus laboratories in different parts of the world were designed for such studies.

For the purpose of dealing with such problems and the dissemination of information relevant to the storage of Canadian horticultural crops, the Low Temperature Laboratory in the Division of Horticulture, Central Experimental Farm, Ottawa, was established.

Origin of the Laboratory

In 1931, six chambers of about 1,000 cubic feet each were built. One of these chambers was devoted to freezing work while the remainder was used for observing the storage behaviour of fresh fruits and vegetables. Ammonia was the prime refrigerant with direct expansion in dry coils for the freezer, and for the other chambers, circulated calcium chloride brine was the secondary refrigerant.

For the storage rooms the various types of temperature control devices included motor switch (on and off type) thermostatically operated heating coils, and modulation valves. From a laboratory point of view the modulation type of valve provided the most satisfactory control where brine circulation is employed, for accurate temperatures can be obtained without materially lowering the relative humidity under fluctuating load conditions.

Growth of Storage Facilities

Since more space was required to deal with the various phases of the many storage problems in the fruit, vegetable and florist industries, the premises were expanded in 1936 to the present 21 rooms. These rooms are more or less flexible as to their use but are primarily arranged as follows:

		Temp. Range
Normal Refrigerated Storage	11 rooms	30 to 50°F.
Gas Storage	3 rooms	32 to 40°F.
Freezing	3 rooms	−50 to +15°F.
Ripening	1 room	60 to 75°F.
Sample Storage	1 room	32 to 39°F.
Precooling	1 room	30 to 40°F.
Grading and Packing	1 room	Room
Total	21 rooms	

Types of Control

Temperature control was designed to give accuracy and results comparable with those in industry. Ammonia was retained as the prime refrigerant. In those rooms classified as being normal refrigerated storage, brine circulation, direct expansion and air circulation types of cooling were used. Based on previous experience, thermostatically controlled motorized modulating type valves are used for brine circulation rooms. However, both installation and maintenance

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of the brine circulation system is costly. In spite of this, brine circulation has two advantages: (1) no harmful refrigeration gas enters the room, and (2) close temperature control can be more easily obtained. (The gas storage rooms are also cooled by brine circulation with thermostatic modulation valves.)

Several of these rooms are refrigerated by direct expansion for which dry coil evaporators are equipped with expansion valves. Reasonably good temperature control with minimal moisture condensation can be obtained by using back pressure control and thermostatic solenoid valves in conjunction with adequate cooling surface. One disturbing feature in the operation of these rooms was that considerable off balance existed between evaporator and compressor capacity. When one compressor operates on several rooms with fluctuating loads, as is common in experimental storages, the capacity of a compressor may be many times that of a single evaporator. This condition puts a great strain on back pressure control valves resulting in faulty temperature control which was corrected by having the return mains from the evaporators enter a brine cooler evaporator. (This brine cooler is used to cool the brine for the brine circulation rooms). A steady and continuous suction pressure was maintained by keeping the brine temperature several degrees below the room evaporator-temperature. Thus, the brine cooler functions as a surge drum or an intermediate condenser, so that the compressor does not operate directly on the room evaporator. This particular feature appears to have considerable merit where several small evaporator units are operated by a single compressor.

The evaporator on the air circulation unit is controlled by the same system as the direct expansion evaporators. The essential difference is that the evaporator coils are sprayed with brine and air is circulated over the wetted cooling surface through ducts to the room.

The refrigeration system used in the freezers is direct expansion. Two rooms are controlled by the usual thermostatically operated solenoid valves along with an expansion valve. The other room used for extremely low temperatures and fast-freezing studies is refrigerated by a flooded coil. The liquid ammonia refrigerant in this coil circulates by convection from a float controlled ammonia collector. Originally two $3\frac{1}{2}$ x $3\frac{1}{2}$ compressors were operated in tandem to provide the low suction pressures required but later experience proved this to be unnecessary.

The ripening room is normally heated by a thermostatically controlled heater. High humidity is obtained by atomizing moisture with air pressure.

The method of temperature control in the pre-cooler has been described in "Storage of Apples" by W. R. Phillips. Farmers' Bull. 132. 1946. Direct expansion coils, with thermostatic solenoids are used. A modulating air damper operated by thermostat in turn controls the temperature of the air passing to the room through ducts and a false floor.

Gas Storage

In experimental gas storage work with apples, the first step is to find the most suitable gas mixture (concentration of CO_2 and O_2) for a given type or variety. For commercial application, however, a large quantity of apples is required in order to control the CO_2 and O_2 concentrations within reasonable limits. This latter procedure involves large expenditures for the handling of the volume of fruit as well as extra equipment required for the gas rooms. To circumvent these factors, some means of small-scale trials had to be devised.

Essentially the problem was to control CO_2 and O_2 concentration in a small gas-tight container by a method other than periodic ventilation or scrubbing of the air in the chamber. M. B. Davis, Dominion Horticulturist, surveyed the various methods employed and decided in favour of the one still used in the gas storage rooms of the Division.

Gas concentration is controlled by allowing gas of the desired composition to flow through the containers of apples at a rate which compensates for the change in gas atmosphere brought about by the respiration of the fruit.

Preliminary Gas Storage Equipment

The apples are packed in five gallon tin plate cans which are placed in a controlled temperature storage room. Gas of known composition is allowed to flow from a cylinder through these cans at a rate of one cu. ft. per container per day. Fig. 22 is a diagrammatic sketch of this setup.

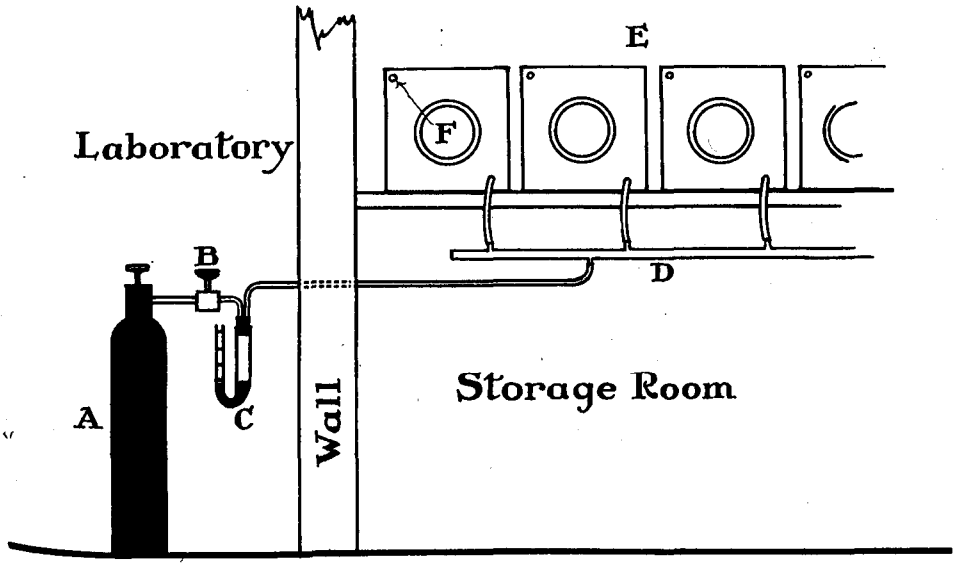

Fig. 22—Preliminary gas storage equipment—gas of desired concentration flows from cylinder (A) through tubing to cans (E) containing apples.

Gas mixtures are compressed in the cylinder (A) to about 1000 lb. pressure (about 70 cu. ft.). A needle valve (B) permits throttling of the flow from one to 20 cu. ft. per day. The flow is measured by a manometer (C) consisting of a 20 mm. glass tube with a two mm. bore side-arm. The air flows into the top of the larger arm of this manometer via a large bore tube and out to the line again via capillary tubing. The pressure build-up so developed causes the liquid to rise in the side-arm. The side-arm is then calibrated with the aid of a gas meter and graduated for different flow rates. Even flow from the distributor (D) shown in Fig. 22 is accomplished by the insertion of small bore outlets. The gas mixture flows into the can via a copper tube nipple through rubber tubing to the back (or bottom) of the can and out into the room by another nipple (F). The flow of one cu. ft. per day per can was determined by interval analyses of the gas in the can. At slower rates CO_2 build-up was noted.

Preparing Gas Mixtures

Making the gas mixtures is the most important and critical part of the procedure. Briefly, the gases are measured into a closed tank by water displacement, then circulated to obtain a homogeneous mixture. If analyses indicate the proper concentration, the gas is compressed into a cylinder.

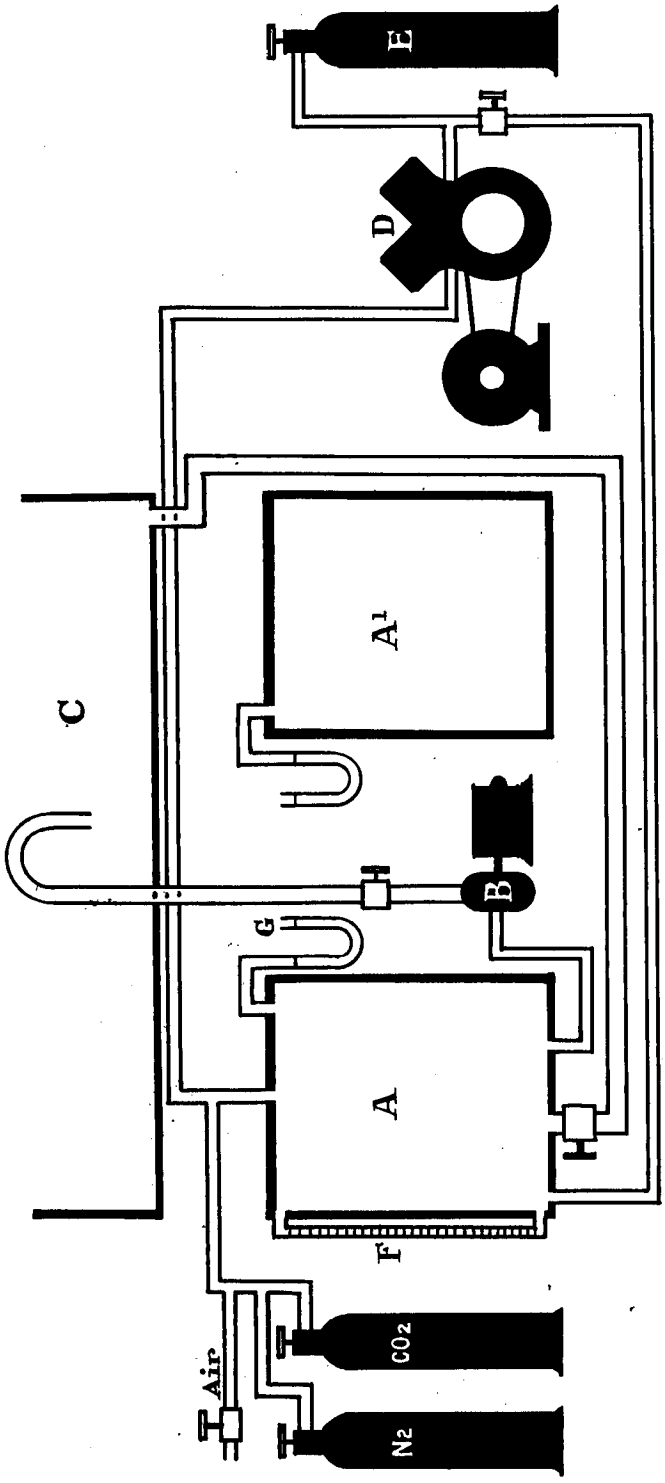

Fig. 23—Gas mixing equipment—various gases are measured into tanks (A)—(A¹) replacing water which is pumped by (B) to tank (C). Compressor (D) is used for mixing and compressing into cylinder (E).

Fig. 23 shows diagrammatically the essential parts of the equipment. Tank (A) (Tank (A^1) is a twin to tank (A) in all respects) is a closed cylindrical tank of 200 Imperial gallons capacity. This tank is equipped with a sight glass (F) and U-tube manometer (G). At the outset tank (A) is filled with water which can be pumped to open tank (C) by pump (B). Simultaneously CO_2 is admitted to tank (A) until the desired amount is indicated on sight glass (F). During this step care should be taken to see that the pressure in the tank does not deviate from atmospheric. This is done by regulating the flow of gas and the discharge of water from pump (B) according to indications of manometer (G). Having the control valves located conveniently and by exercising care this can be done quite easily. When the desired amount of CO_2 has been collected in tank (A) the procedure is repeated for N_2 and finally for air. (With most gas mixtures used, air can be utilized for supplying the required O_2 and part of the N_2). Compressor (D) is then used to mix the gas by pumping it out of the top of tank (A) and returning by the bottom. A small sample is drawn off and analysed by the Orsat gas analysis equipment. If the analysis reveals an error (which frequently occurs with a new operator or an unusual mixture) adjustments can be made by releasing some gas and adding either CO_2, N_2 or air as required. When analyses indicate the correct mixture, the gas is compressed into cylinder (E). The gas is drawn off the top of tank (A) by means of compressor (D) and discharge is opened to (E). Simultaneously, water is allowed to flow by gravity from tank (C) to tank (A). Care should be taken to avoid undue pressure strain being placed on tank (A). Regulating the valve on the water line so as to maintain atmospheric pressure on manometer (G) will effect pressure control. To prevent pulling water over into the compressor it is safer to stop the compressor before tank (A) is completely filled.

Tank (A^1) is an exact duplicate of tank (A). Connections to tank (A^1) have been omitted to reduce confusion. This tank provides an alternate for making up a gas mixture at the same time as the gas contents of tank (A) are being compressed. The contents of the two tanks make a convenient charge for a cubic foot gas cylinder at 1000 lb. pressure.

Respiration

Since the storage of fresh fruits and vegetables is effected by reducing metabolism it is axiomatic that measuring metabolic rate is an important phase of storage investigations. CO_2 output of plant tissue, commonly called respiration, is an expression of its general metabolic activity.

Considerable work has been done along these lines at the Division of Horticulture, Central Experimental Farm, Ottawa. H. C. Aitken set up the original equipment and formed a basis for future work by confirming the findings of other workers. The essential conclusions were as follows:

1. Several weeks after harvest McIntosh apples assumed approximately the same rate of respiration regardless of time of harvest.
2. Respiration rates varied directly with storage temperatures.
3. Apples with higher respiration rates appear to be more susceptible to fungal invasion.

During these experiments and these conducted later by W. Ferguson it was learned that slight changes in temperature produced considerable variation in respiration rate.

Respiration Equipment

To overcome variability in air-temperature control and also to avoid locating respiration equipment in different rooms to obtain different temperatures, refrigerated double tank water baths were designed as in Fig. 24. The

outer tank (A) is cooled by circulating cold brine through an iron pipe (C and D) immersed in a weak brine solution. The inner tank (B) is heated with an immersed high resistance heating cable (E). The latter is controlled by a sensitive mercury contact thermostat (G) operating a relay (I) which in turn is actuated by transformer (H). At either end of the inner tank an air-operated agitator is located (F). Both spatial and temporal temperatures of the inner tank can be controlled to $\pm 0{\cdot}1°C$. By insulating the outer tank, temperatures as low as 32° F. can be maintained in the inner tank of water (or weak brine). Thus respiration rates may be studied at either room or storage temperatures without changing the location of the apple.

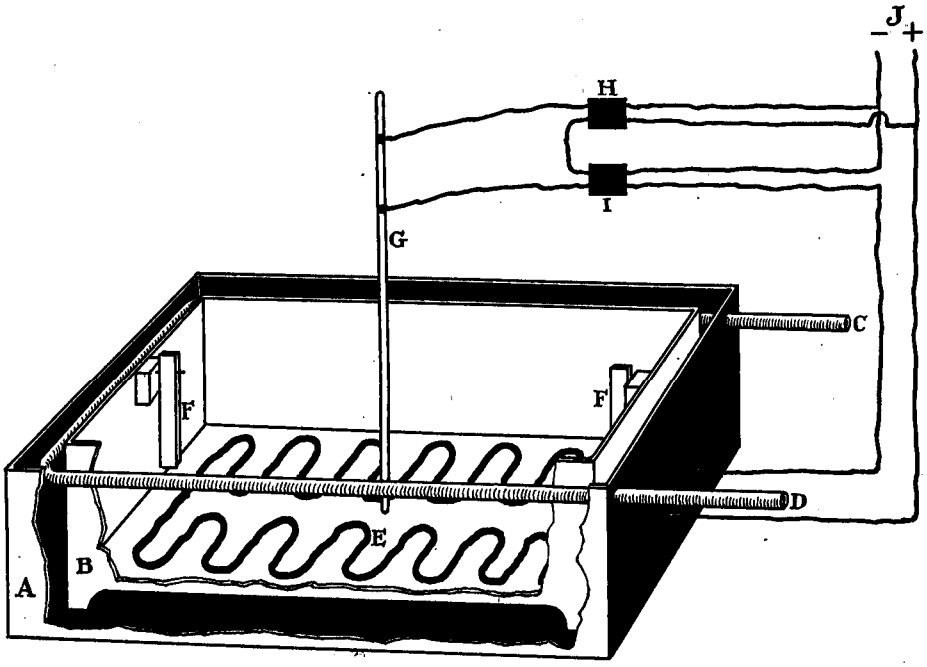

Fig. 24—Double tank water bath for refrigeration studies; outer tank (A) cooled with refrigerated brine; inner tank (B) heated with submerged electric heating cable (E).

Measuring CO_2 Output

Each apple is located in the usual glass sphere chamber which is immersed in the water of the inner tank. Air bubbled through KOH solution to remove all traces of CO_2 passes over the apple and enters a Pettenkofer tube. There the air stream is slowly bubbled through $Ba(OH)_2$ solution. The CO_2 of respiration is calculated by titrating the contents of the Pottenkofer tube against HCl of known concentration, using phenolphthalein indicator. For the most part, these measurements were made at 24-hour intervals. A shorter interval was sometimes required when the rates were exceptionally high.

Respiration Findings

The most valuable application of respiration trends is the measurement of maturity. A study of the respiration rates of tomato fruits from plants fed varying amounts of boron (controlled solutions in greenhouse) revealed that another important function of these studies would be to differentiate keeping

behaviour of different classes of fruit. As reported in "The Effect of Boron on the Respiratory Behaviour of Tomatoes" by W. R. Phillips, Sci. Agr. 18: 685-694, August, 1938, it was shown that fruits fed excessively high or low boron produced respiration curves decidedly different in type from those receiving normal boron. Furthermore, the normal boron treatment produced fruit of longest storage life. When applied to nutritional work on apples, however, the contrast was not so great. Nevertheless, there was a tendency for high nitrogen plots to have higher respiration rates, but individual variation eliminated any significance. If a technique can be devised whereby respiration studies can be made on a larger scale, individual variation may be more accurately measured and significant results obtained.

Another function of these studies is to relate keeping behaviour to temperature. The rate of sugar consumption in McIntosh apples, calculated from respiration rates, at temperatures from 32°F. to 65°F. indicated that a definite trend was assumed (see previously mentioned Bull. 132, p. 5). This trend, being a smooth curve, is representative of the usual relationship between length of storage life and temperature. Some apples, however, showed a slight disturbance in rates when the temperature was raised or lowered. An attempt to associate this condition with storage behaviour revealed no particular significance but future studies on a larger scale may reveal physiological phenomena.

Respiration and Maturity

As mentioned previously, measuring maturity is the most important function of respiration data. Most of the work on maturity measurement has been done with McIntosh previous to and after harvest. In "Respiration Curve for McIntosh Apples" by W. R. Phillips, Sci. Agr. 19: 505-509, April, 1939, it was shown that ideal harvest for storage is definitely associated with the climacteric rise in respiration rates. The curve was established by measuring the respiration of detached apples at 55°F. in the laboratory. After 7 to 10 days the respiration trend could be determined. From these trends respiration rates at time of picking (for a particular fruit) can be calculated. From a series of these so-called initial rates of apples picked at frequent intervals, respiration trends as they occur on unharvested apples can be established. It was shown that immature McIntosh apples are characterized by level or falling rates. This is followed by a definite rise to a peak (climacteric) after which rapidly falling rates occur. The fact that at least a week is required to establish respiration trends makes direct application of respiration technique by the fruit grower decidedly impracticable.

How Can the Climacteric be Measured?

Thus it may be seen that a reliable, quick and easy technique for determining the climacteric would be very valuable. Starch tests, ground colour, and pressure tests all are attempts at measuring maturity but these tests have their weaknesses, for in most of them there is no abrupt change as maturation proceeds. Most of the changes are somewhat slow and gradual, making definite decisions difficult. Other factors also contribute to unreliability; for example, it was found that the starch content of apples has a daily as well as a seasonal trend. The lowest point in this diurnal trend is the early afternoon; the highest, early morning. Therefore, it is quite possible that an early afternoon starch test would indicate that apples were ready for harvest while a test the following morning would indicate that they were still immature.

It was decided to make a thorough study of all known methods which might have practical application. The approach was to follow through such trends prior to and after harvest and establish the co-relation between these trends and the occurrence of the respiratory climacteric.

Methods of Measuring Maturity Trends

Full maturity in apples is brought about by many complex physiological reactions. Some of these reactions through interdependence are tied into systems; others are independent and proceed at a definite rate of change regardless of other factors. It is for this latter reason that seed coat colour was found unreliable. The seeds may change in colour regardless of the quality of the tissues.

An important point is that most of the physiological changes are trends as represented by decreases or increases of certain constituents in the tissues. This makes absolute values somewhat unreliable. Therefore it was assumed that more success could be anticipated from a chronological series of values rather than from a spot determination.

The several methods of measuring maturity have been studied for three years, and from these studies it appears that some may have future application.

The methods under test were:

1. Ground colour,
2. Percentage blush,
3. Pressure test,
4. Starch content,
5. Ethylene content of tissue,
6. Titratable acidity,
7. Peroxidase content of juice, and
8. Refractometer reading of juice.

The first four methods, namely ground colour, blush, starch and pressure tests have all been used by growers and maturity committees. They have met with a certain degree of success but none either individually or collectively has been regarded as absolute. The last four, ethylene, acidity, peroxidase and refractometer, have been used in the laboratory but have not been tried commercially. From the results of the aforementioned three years' work it would appear that certain of these may have merit in accurately measuring maturity, particularly in McIntosh.

Evaluation of Maturity Tests

The criteria in placing a value on the various tests was that to be of value there had to be a strong co-relation with the respiration climacteric and, a sharp change in values associated with this co-relation. Ease of application was also considered. Evaluations on these bases were as follows:

Ground Colour.—Loss of green and the onset of yellow colour are associated with the climacteric rise but the change is a gradual one making it somewhat difficult to establish a definite maturity point. This index of maturity is useful in a general way but lacks precision.

Percentage Blush.—The red colour increases gradually as maturation progresses. Although storage quality and behaviour are definitely associated with the quality and amount of blush the progress of blush is associated with factors other than the climacteric. Hence blush is a means of segregating apples on the basis of storage quality but is not a reliable maturity index.

Pressure Tests.—These changes were, if anything, more gradual than ground colour. With the ideal picking date (according to climacteric) being about September 24, pressure test readings ran from 19 down to 18·3 with some intermediate readings of 19·6 to 17·6. This was followed by a sharp fall to 14·8 on September 30, six days after ideal harvest. Thus the pressure test is of little or no value in determining maturity.

Starch Content.—This test is more or less a laboratory test although it is used by some growers. A median horizontal section of the apple is dipped in an iodine solution. The iodine produces a dark blue (almost black) colour in the presence of starch. Immature apples have a high starch content, but during the climacteric rise the rate of starch disappearance is quite rapid. This is reflected in the decrease of blue colour in the apple sections under test. A chart was made up from photographs of apples harvested at all points through the climacteric rise and fall (numbered from 1 to 9). At the beginning of the climacteric rise, about five days before ideal harvest, values of 3·3 were obtained. Values increased to 4 at ideal harvest. It has been mentioned previously that the starch content changed materially during the day as well as having a day-to-day variation. This diurnal trend was found more or less by accident and the change in starch content amounted to as much as two stages on the chart. This test is probably the most reliable of any tests used but again the trend is gradual and the diurnal change must be taken into consideration.

Ethylene Content.—Many research workers have shown that ethylene increases maturity. In "Effects of Ethylene and of Apple Vapours on the Ripening of Fruits" by F. Kidd and C. West, Food Investigation Board Report, p. 55-58, 1932, the authors showed that ethylene production of the apple is associated with the climacteric rise. Ethylene determinations of the tissues of McIntosh apples were made at Ottawa following the technique of R. C. Nelson in "Quantitative Study of the Production of Ethylene in Ripening McIntosh Apples," Plant Phys. 15: 149-156, Jan., 1940. A distinct increase was consistently obtained at the commencement of the climacteric rise. Values rose from near zero to 0·34 mg. per kg. Since this rise in ethylene occurred approximately five days before ideal harvest, it was thought to have possibilities in measuring maturity. The technique is so complicated, however, that there does not appear to be any likelihood of practical significance.

Titratable Acidity.—It is common knowledge that the acidity of apple tissues decreases with maturity. Titrations of apple juice prior to and during harvest indicated a definite trend. From September 10 to 13 rapid decreases were encountered, then a level phase was assumed for eight days followed by decreases. Titratable acidities can be readily obtained in the laboratory. Thus by following the acidity content, the levelling-off phase could be determined and so provide a forecast of five days for ideal harvest. This appears to have promise of being a reliable maturity criterion in the hands of a maturity committee or where laboratory facilities are available.

Peroxidase Content of Juice.—Enzymes perform a direct function in the advance or retardation of maturity. It was, therefore, thought that peroxidase trends might reveal a means of measuring maturity. From the results obtained peroxidase content appeared to have little or no value for this purpose.

Refractometer Reading of Juice.—The Zeiss refractometer readily indicates the percentage of soluble solids in expressed apple juice. These soluble solids are mainly sugars, and so the refractometer readings provide trends of the sugar content of apples. The sugars normally increase as maturation progresses. The data on McIntosh apples showed that the soluble solids trend was the converse of the acidity trend. Previous to ideal harvest there is a rapid increase in soluble solids followed by a level phase. After the climacteric peak the soluble solids again increase. There was a lag of two days, however, between the beginning of the soluble solids level phase and that of acidity. Thus a shorter forecast period for ideal harvest was indicated by refractometer readings.

Summation.—Of all the maturity tests tried, it appears that soluble solids and titratable acidity appear to have most promise as methods of determining

the climacteric in McIntosh apples. Both are reasonably easy to apply, and both furnish definite points in the progress of maturation of the fruit. Fig. 25 shows these trends as they are related to the respiration climacteric.

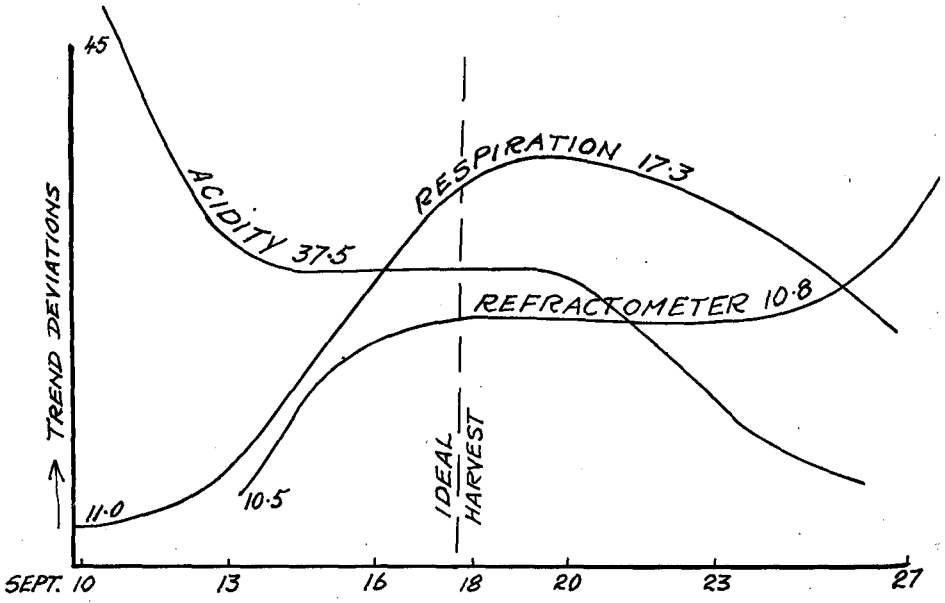

Fig. 25—Acidity and refractometer trends in McIntosh apples as related to respiration rates and ideal harvest date. Figures indicate actual readings at points shown. Respiration in mg. CO_2/kg./hr.; refractometer readings as per cent soluble solids; acidity as c.c. 0.1 N $Ba(OH)_2$ to neutralize 25 c.c. juice.

Freezing Rate Studies

The development of the frozen food industry in Canada presented a variety of problems, most of which have been dealt with elsewhere in this publication. There remains, however, one feature of a semi-engineering nature and that is—how long will a packaged product take to freeze?

The answer to this question is essential for good plant management and to the design engineer. The marketing of poor products or bottle-necks in the production line will ultimately affect the primary producer.

Unfortunately, the time required for the freezing of foods is not tabulated in engineering data nor can it be calculated from laws of thermodynamics. It was undertaken along with related work to get an appreciation of the rules which govern freezing rates and to tabulate data on the freezing times of various produce for different pack sizes and types of refrigeration application.

The various methods of freezing foods fall into three broad classifications: (1) Immersion in liquid, gas or air; (2) Plate or surface contact; (3) Vacuum or self-refrigerated. As over sixty per cent of industrial freezing is immersion freezing in air the greater part of this Division's effort has been channeled in this direction.

Published data by M. MacArthur, "Freezing of Commercially Packaged Asparagus, Strawberries and Corn", Fruit Prod. Jour. 24: 238-240, Apr., 1945, lists rates on specified produce. "Freezing Rates of Fruits and Vegetables at Various Air Velocities" by W. R. Phillips, Refrig. Eng. 53: 401-403, May, 1947, gives rates for asparagus, peaches, raspberries and strawberries. These data and unpublished material of other workers are at present being compiled in separate form and will be of service to the processor.

In the study of freezing rates some difficulty was experienced in temperature recording equipment and MacArthur stated that it was necessary to replace large surface sensitive thermocouples by small ones as the depression of recorded temperatures below the true freezing line was too pronounced for obtaining useful results. Original equipment consisted of a 32°F. junction connection with calibrated ammeter readings—in latter work a potentiometer connection was found more satisfactory. All observations were recorded manually.

Both MacArthur and Phillips supplemented electrically recorded results with actual observations on comparative packages. Phillips established a curve relationship to show the discrepancy introduced by the use of thermocouples in apparent shortening of freezing time. As expected the discrepancy diminished with shorter freezes.

In examining the mode of behaviour in air blast freezing it is well to keep in mind that truly static air is incapable of any heat transfer other than the small amount accomplished by radiation. Inasmuch as air is turbulent it is capable of heat transfer—convection is the sole effective agent. Under normal conditions of cooling in air a package will set up its own convection currents and thus effect a heat transfer. The degree of development of these air currents will depend on temperature differentials operating.

Using cut green stringless beans packaged in rectangular paper and metal end packages, a relationship for rate of freezing as affected by air velocity was for practical purposes established.

Plotting velocities in l.f.p.m. and freezing time in minutes it was found that the resultant function conformed to the expression for a rectangular hyperbola: $xy = C$ or Velocity x Time = Constant.

It was found in general that three rates determined with some discretion were quite sufficient to ultimately calculate the freezing time for any velocity under the particular conditions of freezing.

In general, for packaged produce, both MacArthur and Phillips reported that air velocities up to 50 l.f.p.m. were effective in reducing freezing time and velocities over 500 l.f.p.m. tended to be superfluous. This is clearly evident from the hyperbolic function—which becomes asymptotic on both axes.

In low velocity regions it would appear that the limiting function in the thermal transfer was between package surface and air. At higher velocities, according to MacArthur's findings, the insulation value of the dead air spaces within the package becomes apparent.

This latter point has been clearly borne out in the findings of MacArthur and Phillips on syrup and brine packs. Phillips reported reductions in freezing time up to twenty-six per cent by the addition of syrup to strawberry packs. MacArthur continued to find reductions in freezing time on brine-packed corn up to velocities of 1100 l.f.p.m. It is to be noted that these reductions were effected in the face of a much larger required B.t.u. transfer by virtue of added weight material to the package.

MacArthur indicated that the physiological condition of a packaged produce is an important factor in the consideration of freezing rates. Her findings showed that for corn, which had progressed beyond the "milk stage", 190 l.f.p.m. was equivalent to 550 l.f.p.m. (at −20°F.) for corn in the "milk stage".

Phillips reporting on the effect of freezing temperature and air velocity indicated a lateral shift of the $f(y) = \frac{c}{x}$. In general, a drop from 0°F. to −20°F. accomplished a 48 per cent reduction in freezing time.

The foregoing information is based on the findings using pint (uni-walled paper) packages. In no case was the material construction of the container itself found to be a limiting factor in thermal transfer.

An investigation of thermal transfer for the various pint packages in popular use revealed no significant differences in single-walled containers. However, the addition of a cellophane liner as used in some cartons virtually doubled the freezing time.

Some work was done with air blast directly on the product. MacArthur found that for zero freezes on strawberries, air blast on product required sixteen to twenty-five minutes, whereas on the dry packaged product five hours and thirty minutes was required to reduce the strawberries from 60°F. to the end of the freeze. These are typically comparative figures and obviously show that the former technique is far more efficient in the use of refrigeration. Unfortunately the air blast on product technique is largely confined to lima beans, berries and produce of a similar nature because of post freeze packaging difficulties.

Contact freezes have been investigated for performance in effecting heat exchange in packaged produce. The results were the same as those for high air velocities. This might be expected for apart from radiation (a negligible factor) the limiting conditions are the same.

Vegetable Storage

Although fruits, particularly apples, are the main products studied some work has been done on vegetables. Investigations have included certain aspects of potato storage, storage of beet and carrot stecklings, celery, and studies on the behaviour of tomatoes.

The salient features relative to these experiments will be treated individually according to products.

Potatoes

Since 1942 experiments have been in progress to study the effects of temperatures and humidities on the behaviour of potatoes both during and after storage. Lower temperatures (32°F.) induced breakdown and reduced the subsequent yield when planted. These and other data such as sweetening, the effect of relative humidity on moisture retention, and varietal influence, appeared in "Low Temperature Breakdown of Potatoes in Storage" by L. T. Richardson and W. R. Phillips. Sci. Agr. 29: 149-166. Apr., 1949.

Potato Bags.—During World War II, jute was in short supply and a substitute was sought. Paper appeared to be the most promising alternative, but the chief obstacle to paper as bagging material for potatoes was the inherent loss of strength when moist.

Preliminary investigations revealed that the condensation which occurs on loading cold potatoes into warm cars or trucks was unavoidable. This meant that the paper used for bagging would have to be strengthened. Through the co-operation of the paper industry bags of various kinds, sizes, and types were supplied for trial. These included multiple-walled bags and bags with various types of laminations, glues, and methods of seaming. The only bag which withstood the trials was made of wet strength paper sealed with a special moisture resistant glue. Specifically the best type of bag was a 60-lb. (test) kraft lined with an 80-lb. (test) wet strength paper, designed to hold 50 lb. of potatoes. The advantages of the kraft outerliner appeared to be in the stronger seam resulting from better glue penetration of this paper and the reduced cost of the bag.

Storage Surveys.—For the purpose of finding information on which to publish plans and specifications for commercial potato storages, a survey was undertaken in the provinces of New Brunswick and Prince Edward Island.

After the preliminary investigations it was thought that further work could be conducted more effectively from the Dominion Experimental Station, Charlottetown, P.E.I.

The surveys which were made, although not intended to solve problems, did reveal certain pertinent information such as the fact that with very few exceptions existing storages were built by rule-of thumb methods. The most common errors were associated with insulation and ventilation. In this respect it should be kept in mind that past practices were influenced by economics.

In storage practice it is good insurance to provide a source of heat against the occurrence of an exceptional cold snap during the winter. However, it was common practice to heat these storages almost continuously during the winter, a definite indication of inadequate insulation. To determine the damage caused by such practices, observations were made on potatoes after being stored for the winter in what was considered a better-than-average storage. Loss in weight averaged 3·5 per cent with a maximum of 5·77 per cent, and in the same storage freezing occurred near the outside walls. By calculation weight loss could be reduced to one per cent and freezing eliminated by proper insulation.

Ventilation was invariably effected by chimney vents which at best could only change the air once every hour with a five degree differential. Properly controlled mechanical ventilation could readily increase this fourfold and so make temperature control more positive. Furthermore, lower temperatures could be maintained for a longer period which would control the development of sprouts, which is quite common after April first in present storages.

The preliminary findings along with proposed layouts of track-side storages are included in "Practical Potato Storage" by W. R. Phillips. Potato Section of Addresses and Proceedings of The Ontario Crop Improvement Association, pp. 73-79. Feb. 5, 1945.

Other improvements to existing storages consist of changing methods of handling and operating. This, of course, is accessory to the main object of storage design. It was found that as high as 25 per cent of the potatoes in these samples had been mechanically injured. From observation most of this injury appeared to have been caused in the storage itself, which shows the need for improved methods of handling.

The intended procedure in solving these problems is to have part of a storage, which was originally designed for apples, converted to what is calculated to be a well insulated and ventilated potato storage. If it appears profitable from the standpoint of increased quality and reduction of weight loss, plans and specifications will be drawn up for publication.

Celery

Storage experiments on celery during 1941 and 1942 were of an exploratory nature. Material grown on muck soil at Ste. Clothilde was used. Since the storage was 143 miles from the growing area this offered a transportation problem which materially affected the experimental results.

In spite of this handicap certain information was gleaned from the work. Based on the percentage of marketable celery, green types appeared better than the yellow or self-blanching types. Variety also had an important influence on behaviour. Pascal, a green type, although inferior in general quality, was superior in storage behaviour to Salt Lake, a second green type. Of the yellow types, Paris Golden Yellow (Macdonald) and Morse Masterpiece were better than others tried.

Air circulation within the storage room appeared to be a critical consideration in that variations from 50 to 60 per cent marketability were brought

about by virtue of position in the room, in spite of using the best practical methods of dunnaging. It would be expected that poor stacking would increase this spatial variability.

Precooling did not provide the expected contrast. It was thought that this was caused by faulty experimental procedure.

The main feature learned from these results, however, was that future storage trials should be conducted at a storage plant adjacent to the growing area. As a consequence, precooling and storage equipment has been installed at Ste. Clothilde. Future work relative to determining ideal storage conditions for this crop is planned.

Root Crops

Storage of Stecklings.—Experiments were conducted on beet and carrot stecklings grown in 1942 (for seed production in 1943), to determine the best storage conditions for such crops. The stecklings were size-sorted and stored in orchard boxes with and without dampened sphagnum moss at 32°, 36° and 39°F. After storage the stecklings were planted, and growth and inflorescence development observed. Various methods of cutting the stecklings, ostensibly to promote root growth, were carried out at time of planting.

With carrots lower storage temperatures reduced loss in weight and rot development. Dampened moss reduced weight loss at all temperatures; samples at 32° and 36°F. lost less weight without moss than did the 39°F. sample with moss. Larger carrots lost more weight than smaller carrots. This condition is as would be expected. What did appear significant was that both the reduced size of carrots and dampened moss increased rot development.

Based on field behaviour subsequent to storage, it appeared that the size of the carrot is the most important factor, larger stecklings being better than small. The best storage temperature was 36°F. (or slightly lower). Even though dampened moss increased rots in storage, this procedure did enhance growth in the field. Cutting did not encourage root growth. As a matter of fact this practice would appear to be harmful in that the cut surface increased vulnerability to rotting.

Beets reacted somewhat differently in storage. Rots in the stored stecklings were inconsequential regardless of treatment. Slight growth was noted as early as February (carrots remained dormant throughout storage). The only significant features were that larger stecklings had a higher percentage survival, and slight cutting promoted root growth and more vigorous plants in the field.

Turnips.—Intermittent studies have been made for the past four years on turnip storage. Attempts were made to find a better wax for coating the roots or develop a superior technique in handling. About ten different waxes and wax combinations were tried. All had faults of various kinds; brittleness, immiscibility with water or impermeability to CO_2 and O_2. Therefore, nothing has been found so far which could be considered superior to the paraffin and resin mixture now used. Similarly no superior technique of handling was evolved.

Tomato Ripening

Fall frosts bring about an early termination of outside grown tomatoes in many Canadian areas. The ripening of such immature fruit is then a problem involving temperature of ripening, methods of packaging, maturity determination, artificial ripening, and the suitability of varieties.

Work on these phases of ripening the immature fruit was conducted at Ottawa and at Kentville, Nova Scotia. The findings at both laboratories were in quite close agreement.

No satisfactory method could be found for determining maturity of the green fruit. A percentage of solid green fruit could be ripened satisfactorily but the only guide to the degree of maturity of these particular fruits lies in the

harvester's judgment. That is, no workable test was devised whereby the immature green fruits could be separated into lots that would and would not ripen in subsequent storage.

For normal ripening, temperatures should not be permitted to go below 50°F. Although the fruit develops colour and is saleable if held at lower temperatures, the flavour is lacking and soft textures develop. Even 50°F. is deleterious when the fruit changes from green to red. Hence the fruit should be observed from day to day and those showing colour removed to 65°F. temperature.

Such procedures provide a storage life of about six weeks without exceeding ten per cent wastage.

Tomatoes could be kept for a much longer period by holding the fruit for prolonged periods at 40° to 45°F. This procedure would result in poor flavour development, and the percentage of rots liable to develop would make this procedure commercially prohibitive.

Gas Storage

Gas storage, frequently referred to as controlled atmosphere storage, has been used to advantage with apples and pears in different parts of the world. On account of the recent high demand for fruit, the Canadian fruit industry has not found it necessary to improve present storage practices, but this situation is likely to change. Gas storage would then be applied to further the retention of quality in certain apple and possibly in certain pear varieties for more extended periods.

Principles Involved

The principles of gas storage have been outlined in various publications of the Division of Horticulture, Central Experimental Farm, the most recent being "Storage of Apples" by W. R. Phillips, Farmers' Bull. 132, 1946. Essentially, gas storage consists of storing the fruit in a refrigerated chamber in which the concentration of carbon dioxide is controlled by ventilation.

Normal air contains about 79 per cent nitrogen, 21 per cent oxygen and 0·03 per cent carbon dioxide with minute traces of argon, ozone, etc. (the latter are usually ignored). Apples or other living material convert the oxygen in the air to carbon dioxide. Thus, it is obvious that if these products are placed in a gas-tight chamber the oxygen concentration will be reduced and carbon dioxide increased. The accumulation of carbon dioxide, if held within certain limits, slows down fruit activity thereby prolonging the storage life of the fruit. The resulting increase in storage life at a given temperature usually is of the order of 50 to 100 per cent.

Since storage temperature and gas concentration generally differ for different varieties, one object of research in gas storage is the determination of the most suitable temperature and atmosphere for a particular variety. Equipment used for establishing these data is described on p. 165.

Making the Room Gas Tight

After finding the best gas mixture in relation to temperature and variety, trials are made on a semi-commercial basis. Rooms of approximately 175-bushel capacity are used for this purpose. There are three such rooms in the storage section of the Division of Horticulture.

Two of these rooms were made gas tight by the application of rubber base paints to the walls, ceilings and floors of the rooms. The third room is lined with soldered galvanized sheet metal, crimped at the edges. This room was designed for subnormal oxygen mixtures which require the more efficient gas retention supplied by the metal lining.

Door Seal

Although the previously mentioned bulletin, "Storage of Apples", recommended an inflated rubber gasket as being satisfactory for a door seal, this is not necessarily correct. It is satifactory for normal oxygen mixtures while the door and door frame remain reasonably true, and the gasket is lined up properly. However, in commercial practice it is quite difficult to obtain a satisfactory door seal with the inflated rubber gasket. Not only do wooden doors and frames warp slightly, but modern tubing is moulded and it is much more difficult to line up a gasket made from this modern than from the old fashioned type of inner tube.

These factors made it necessary to adopt another type of closure for the gas rooms. The one selected, and later found satisfactory, was an aluminum plate bolted and gasketed to an iron (boiler plate) frame.

The frame was lagged to the inner surface of the existing wooden door frame in such a manner that two inches of metal protruded into the door opening. Felt soaked in petrolatum was used as a gasket between the metal and wooden surfaces.

Handles on the aluminum plate facilitate placement and a plate glass window enables inspection. Sponge rubber was used as the gasket between the aluminum plate and the metal frame and bolting of plate and frame was done from the outside. Bolts at six inch centers were inserted through holes drilled in the plate to correspond with threaded holes in the frame.

Room Operation

The operation of gas storages is described in the bulletin, "Storage of Apples". Briefly, it consists of controlling room temperature in the normal way and ventilating daily. In ventilating, an electric fan draws air through a duct from the room, discharging it outside while a second duct permits outside air to enter the room. The amount of ventilation required is determined by analysis of the storage air by an Orsat or similar gas analysis apparatus. If the gas storage atmosphere is a sub-normal oxygen mixture a carbon dioxide scrubber is an essential part of the equipment.

CO_2 Scrubber.—If a five per cent CO_2 and five per cent O_2, (sub-normal oxygen) mixture is desired, the apples in a sealed room will develop the CO_2 concentration quite readily within a few days. If normal ventilation is used to prevent exceeding the five per cent level, the O_2 level will continue to be too high. In this situation, instead of bringing in outside air, the storage atmosphere is circulated through a scrubber containing a five per cent sodium hydroxide solution which removes the CO_2. By continual scrubbings the CO_2 level is maintained at five per cent while the apples reduce the O_2 concentration to the level required. From this point onward the O_2 level is maintained by ventilation.

Difficulties Encountered

By virtue of air leakage, sub-normal oxygen mixtures were more difficult to maintain than normal mixtures. In this respect it can be assumed that it is practically impossible to obtain an absolutely gas-tight room. Other workers have found by experience that the best that can be hoped for is 95 per cent gas tightness. The smaller the room the more important gas tightness becomes since the ratio of fruit quantity to room surface (floor, walls and ceiling) is reduced. In the metal-lined room at the Division of Horticulture this ratio amounted to 1 bushel to 3 square feet of surface. (Commercial storages would run about 1 bushel to ·75 square feet of surface.)

The metal lining in the room was thoroughly tested for leaks. This was done by blowing smoke (titanium tetrachloride) through a small hole in the metal lining. Leaks were detected where smoke came back into the room. The leaks were sealed, and CO_2 was allowed to flow into the room until the atmosphere

was an 8 per cent CO_2 concentration. Day-to-day analyses of the room atmosphere indicated that the seal was 98 per cent efficient.

Even with this degree of gas-tightness it took somewhat more than six weeks to reduce the O_2 to five per cent. In commercial storages the five per cent O_2 level should be reached in two to three weeks at the most. A ratio of one bushel per square foot of surface or less should quite easily accomplish such result with the same degree of gas tightness.

Basically, the reasons for requiring more effective gas tightness with sub-normal O_2 mixtures are:

1. The greater differences between outside and inside O_2 (21 to 5 for sub-normal O_2 and 21 to 16 or 14 in normal O_2 mixtures);

2. Scrubbing out CO_2 induces negative pressures within the room, creating pressure differentials, and so increases the tendency for air to leak inwards.

General Results

Since 1933 in the trials on varieties suitable for gas storage, high quality is retained for a longer period in gas storage than in ordinary storage at the same temperature. Moisture loss as indicated by shrivelling or shrinkage of the fruit is reduced by gas storage. This reduction is brought about by the confined nature of such storage.

On the other hand excess carbon dioxide may cause CO_2 injury. This injury may be internal or external. Illustrated descriptions of these disorders are shown in "Functional Disorders of Apples" by C. A. Eaves and H. Hill. Tech. Bull. 28, 1940.

The choice of gas mixture, therefore, lies between the mixture providing maximum storage life and that which might cause CO_2 injury just as the choice of temperature lies betweeen that which is low enough for maximum storage life but not low enough to cause freezing or other low-temperature injury.

On the basis of experiments since 1933 fruit tolerance to gas storage mixtures is influenced by:

1. Temperature,
2. Maturity,
3. General condition of the fruit which in turn is influenced by growing conditions, and
4. Variety.

The Influence of Temperature

It is now accepted that temperatures from 38° to 40°F. should be used in conjunction with gas storage. This possibly stems from the original function of gas storage in the United Kingdom where it was developed. Many varieties of apples which are susceptible to low-temperature breakdown at or near 32°F. storage are grown in that country. Gas storage solved this problem since these varieties could be gas-stored at higher temperatures and still have a reasonably long storage life. Moreover, the higher storage temperatures eliminated the danger of low-temperature breakdown.

At Ottawa, indications are that some varieties can be gas stored to advantage at 32°F., but tolerance to CO_2 is reduced at the lower temperature. This is usually of the order of two to three per cent; for example, McIntosh will tolerate 7·5 to 8 per cent CO_2 at 39°F., but concentrations in excess of five per cent are liable to cause damage at 32°F. This relationship was found to apply with other varieties.

Because most apple storages are designed to operate at or near 32°F. the use of a 39° to 40°F. temperature for gas storage would present complications. Where more than one room exists in a storage plant it would probably mean more insula-

tion and independent control of temperature for the room being converted to gas storage, but this would not apply in all instances.

Another complication concerned with commercial application, although not one of temperature, is the conversion of the forced air circulation type to gas storage. The only two apparent solutions for this situation are (1) an independent circulation device for the converted room or (2) circulation of refrigerated air around a metal type room (or large box) built within the main storage room.

The Influence of Maturity

It is apparent that metabolic drift during ontogeny has a considerable influence on susceptibility to gas storage injuries. McIntosh when harvested in the pre-climacteric stage develops considerable external and internal CO_2 injury. In preliminary studies, using seven per cent CO_2 and 14 per cent O_2 at 39°F., the highest percentages of apples affected were:

First pick	34%
Second pick	10%
Third pick	0%

There was a tendency for smaller fruit to be more susceptible to injury than larger fruit in second pick material. On the basis of maturity records the third pick could be considered ideal maturity; i.e., harvested almost at climacteric peak.

In other studies conducted in semi-commercial rooms scald and external CO_2 injury when present were more pronounced on fruit with the 'greenest' ground colour.

With Bartlett pears, however, susceptibility to gas storage injury increased with advanced maturity. Pears had to advance to a stage of maturity well beyond what would be considered suitable for ordinary storage before gas storage injury would develop.

In general, the correct maturity for gas storage in all fruits is the same for both gas and ordinary refrigerated storage. In other words, the maturity which provides highest quality and best storage also provides the maximum resistance to gas storage injuries. The important feature is that an error in maturity may result in more injury to fruit in gas storage than to fruit in ordinary refrigerated storage.

It should not be overlooked that the injury discussed is specifically carbon dioxide or gas storage injury. The effect of gas storage as related to other injuries will be discussed later.

In further studies on maturity versus CO_2 injury, McIntosh apples were subjected to high concentrations of CO_2 at one or another stage of storage at 39°F. as follows:

(A) *Ascending CO_2*. Started at three per cent CO_2 and 18 per cent O_2; the CO_2 was increased and O_2 decreased at the rate of one per cent every two weeks until 11 per cent CO_2 and 10 per cent O_2 was reached and this was maintained until the end of storage.

(B) *Descending CO_2*. Converse of (A), starting at 11 per cent CO_2 and reduced at the rate of one per cent every two weeks, until five per cent was reached.

(C) *Peak CO_2*. Started at five per cent CO_2 and 16 per cent O_2; increasing CO_2 and reducing O_2 by one per cent steps to November 15, at which time 11 per cent CO_2 and 10 per cent O_2 was reached. After being held at these concentrations two weeks the CO_2 was decreased and O_2 increased by one per cent steps.

Treatment (B), high CO_2 concentration at the beginning of storage life, was the only one producing any injury. This bears out previous findings to the effect that tolerance to gas storage injury increases with maturity. In other words, apples were more resistant to gas storage injury in the latter part of storage life. This increase in tolerance appears to continue until the end of storage life.

The Influence of Growing Conditions

Orchard practices which affect the growing conditions of apples influence the storage behavior of the fruit through their indirect effect on the progress of maturity.

Critical observations along these lines were not made to any great extent in gas storage work. Information which might be relevant, however, was gleaned from the gas storage of apples from plots which had consistently produced high core flush. One plot receiving high quantities of sulphate of ammonia developed 38 per cent core flush in ordinary storage at 32°F., but in gas storage of 7 per cent CO_2 and 14 per cent O_2 at 39°F. this was reduced to four per cent. Another plot receiving sulphate of ammonia with additional phosphorous produced 16·6 per cent core flush which was reduced to zero per cent under the same gas storage conditions as for the previous plot.

When growing conditions are such as to produce core flush, this disorder in McIntosh is more severe at 32°F. than at 39°F. When such low-temperature reactions exist, gas storage is instrumental in controlling the disorder with no further loss in other storage properties.

The Influence of Variety

Varietal influence on storage behaviour is probably one of the most important factors in gas storage. In preliminary studies the tolerance of certain varieties to gas storage conditions was nil while other varieties tolerated CO_2 concentrations as high as 11 per cent without damage. It appears, however, that 7 per cent CO_2 and 14 per cent O_2 at 39°F., which might be regarded as a 'compromise' gas mixture, is suitable for most varieties amenable to gas storage.

From a commercial standpoint, it is often expedient to store different varieties in the same room. Although the effect of such conditions in a gas room have not been studied, studies have been made on mixed varieties in five-gallon cans, using the preliminary gas flow technique. Fameuse, McIntosh and Golden Russet, selected because they matured at different times, were stored together. No difference in effect was noted when storage in separate compartments was compared with storing together.

Another aspect of gas storage is that it may be used commercially as a corrective for storage disorders. It has been mentioned previously that gas storage at 39° to 40°F. has been used elsewhere for varieties susceptible to low-temperature breakdown in ordinary storage at 32°F. Most Canadian-grown varieties do not suffer in this respect. The two most outstanding exceptions are Cox Orange Pippin (a variety planted in Nova Scotia for export purposes) and McIntosh when harvested or grown under conditions which induce core flush. In both varieties gas storage at 39°F. is effective in controlling the disorders which occur when stored at a low temperature.

Certain varieties are susceptible to superficial scald. In these varieties gas storage is liable to increase the amount of this disorder. Even a variety like McIntosh which does not develop superficial scald in ordinary storage is liable to suffer seriously when gas stored. It is recommended that practically all varieties be protected by an oil paper wrap or at least packed with shredded oil paper. As an example of what may happen the following percentages of superficial scald were found at the end of the storage season (March 17) after gas storage with 7 per cent CO_2 and 14 per cent O_2 at 39°F.

No protection	96% scald
Shredded oil paper	14% scald
Oil paper wrapped	0% scald

Specific information on varieties compatible with gas storage is outlined in the aforementioned Bulletin 132.

The essential data in this respect are as follows:

McIntosh.—A five per cent CO_2 and five per cent or 2·5 per cent O_2 mixture at 39°F. is best. However, a 7 per cent CO_2 and 14 per cent O_2 mixture

produced good results. The latter has the advantage of being an easier gas mixture to maintain. Trials have been made with a 5 per cent CO_2 and 16 per cent O_2 mixture at 32°F., but the findings indicate that these last conditions are somewhat hazardous.

Cox Orange.—This variety suffers from low-temperature breakdown at temperatures from 32° to 36°F. At higher temperatures the storage life is limited by advanced senescence at about December 15. A five per cent CO_2 and five per cent O_2 gas mixture at 39°F. extended storage life to the end of January. A possible compromise is a five per cent CO_2 and 16 per cent O_2 mixture at 39°F. until December 1 followed by ordinary storage at the same temperature. Such storage would make this variety available for the Christmas market. Unlike McIntosh, Cox Orange increases in susceptibility to gas storage disorders near the end of storage life.

Golden Russet.—A five per cent CO_2 and 16 per cent O_2 gas mixture at 32° to 33°F. was best for this variety. Shrinkage characteristic of this variety, and quality loss were controlled until April 1 by gas storage.

Lobo.—In preliminary trials Lobo did not give very satisfactory results in gas storage. However, when packed at the correct stage of maturity good results were obtained with a 9 per cent CO_2 and 12 per cent O_2 mixture at 39°F. Based on ground colour, the correct maturity was #1 on the starch content chart referred to on page 171. Slight deviations from this standard increased susceptibility to gas storage injury considerably.

Gravenstein.—This variety has been tried out in preliminary gas flow studies only. A 10 per cent CO_2 and 2·5 per cent O_2 mixture at 39°F. was best.

Fameuse.—Gas storage had a tendency to produce a woody texture in Fameuse. A five per cent CO_2 and 16 per cent O_2 mixture at 39°F was best.

Northern Spy.—Responds well to 7 per cent CO_2 and 14 per cent O_2 if not too mature. With maturity beyond a starch test of 3, the variety is liable to injury.

Delicious.—Not suitable for gas storage. Low oxygen (2·5 to 5 per cent) in the absence of CO_2 was beneficial in preliminary tests. However, it is doubtful if the effort necessary to maintain this mixture would be justified by the results.

Cortland.—This variety must be fully matured if it is to be gas stored. With a ground colour of 5 and starch test in excess of 5, good results were obtained in 7 per cent CO_2, 14 per cent O_2 at 39°F. If less mature, a five per cent CO_2 and 16 per cent O_2 gas mixture is suggested. If immature, gas storage is hazardous.

Bartlett Pears.—In the prolongation of storage life and in quality retention, Bartlett pears showed a greater response than any of the apple varieties tried. The mixture tried on a large scale was 7 per cent CO_2 and 14 per cent O_2 at 32°F. Preliminary trials of a sub-normal mixture of five per cent CO_2 and five per cent O_2 indicated that this mixture would give even better results than the normal mixture used on a large scale. However, the present production of this crop does not meet the immediate demand. Therefore, until such time as production is increased, there is little necessity for commercial gas storage.

Ordinary Storage

The storage life of fruits and vegetables in their natural state (i.e., unprocessed) is terminated by (1) fungal invasion, (2) physiological disorders and (3) loss of quality. These factors are in turn influenced by both pre-storage and storage environment. Hence it is frequently necessary for the storage investigator to consider conditions associated with orchard practices as an explanation

for certain storage problems. Conversely, investigators concerned with orchard problems have to consider the storage behaviour.

Thus, it is obvious in the treatment of storage problems that close liaison has to be maintained between the storage and orchard. Such a treatment of storage problems would become involved, confusing and beyond the scope of this section of the report. Hence the treatment of pre-storage aspects will be left to other authors. Reference will be made to these pre-storage aspects only when referring to published information and when needed for continuity of context. This will apply particularly to the section dealing with physiological disorders.

Fungal Invasion

Apples are said to have reached the end of storage life when the percentage of unmarketable fruit has increased to a point where further storage becomes unprofitable. Therefore, the determining factors causing fruit to become unmarketable are the bases of most storage investigations. One such determining factor is fungal invasion.

Organisms other than fungi, such as yeasts and bacteria, may be found on apples; but only rarely do these attack the tissues.

At this Division the original investigation work relative to fungal invasion was published under the title, "Cold Storage Problems with Apples" by M. B. Davis and D. S. Blair, Sci. Agr. 17:105-114. Nov., 1936. The types of fungi and their prevalence at various storage temperatures are discussed. It has been shown in both this publication and in "Functional Disorders of Apples", by C. A. Eaves and H. Hill, with illustrations by Arthur Kellett. Tech. Bull. 28, May, 1940, that orchard fertilizer applications have an effect on fungal rot development in storage.

More recently, attempts have been made to curb the distressingly high percentage of fungal rots occurring on Linda apples. These attempts may be more or less resolved into three patterns of procedure; (*a*) fumigation, (*b*) application of a fungicide to the apple surface and (*c*) impregnation of the fungicidal material into the wrap. Of the three techniques listed only the latter two (*b* and *c*) have led to any measure of success. Application of fungicides to apple surface has been confined to dipping in water-soluble reagents. The following compounds on preliminary test showed marked reduction of rot: (I) bordeaux mixture, (II) copper-oxy-chloro-sulphate plus lime, (III) ferric dimethyl-dithiocarbamate plus lime, (IV) sodium orthophenylphenate and (V) calcium propionate.

Conjunctive laboratory tests to evaluate fungicidal activity revealed that there is little likelihood of the above copper compounds being used because the necessary concentrations appear to be well above public tolerances.

Moderately volatile organic compounds and metal-organic compounds which are alkaline in nature appear to offer the most likely control.

In type (*c*), ortho hydroxybiphenyl dissolved in sunflower seed oil on a weight ratio of 8 to 200 and impregnated in apple wraps in the quantity of 0·2 gm./sq. ft. gave the best results. Preliminary tests gave a 70 per cent reduction of rots.

Physiological Disorders

Descriptions and methods of control of physiological disorders are contained in "Functional Disorders of Apples", Tech. Bull. 28, May, 1940. This publication indicates the importance of these disorders in storage through a description of the varietal, orchard and storage effect upon their prevalence and occurrence during and after storage.

Core Flush.—More investigational work has been conducted with core flush at the Division of Horticulture than with any of the other physiological disorders. The reason for this is that core flush is the most usual disorder occurring in McIntosh, the most extensively grown Canadian variety.

Earlier work, reported in the previously mentioned publications, has shown that variety, maturity, storage temperature, and orchard treatments all have an influence on core flush development. Low storage temperatures, immaturity at harvest and high nitrogen fertilizer were the main contributing factors in McIntosh. The Fameuse variety reacted somewhat differently in that higher storage temperatures and senility appeared to be contributing factors. These factors suggest two different circumstances under which core flush might develop. In McIntosh it seems to occur when physiological behaviour is abnormal whereas in Fameuse it is principally associated with the normal onset of senility.

Core Flush and Quality.—On the basis of these early findings it was thought that a measurement of core flush incidence in McIntosh would provide a reliable indication of storage quality. Unfortunately, only a very weak correlation was found between these factors; quality variation was indicated by only extreme differences in core flush values. However, inasmuch as core flush is sufficiently serious in itself, it has a definite value in measuring storage behaviour.

Cultural and Storage Practices.—Using core flush as such an index, it was found from storing apples grown in the nutritional plot at Chateauguay that the original findings relative to the influence of pre-storage factors were substantiated. Where high nitrogen was applied, core flush was heavy, but this was reduced somewhat when phosphorous was applied with high nitrogen. Samples from injected limbs suggested that calcium also reduced the susceptibility to core flush.

Apples were selected from some of the most susceptible plots, and core flush development was observed during storage life. The pattern differed from year to year in that in some instances 36°F. was worse than 32°F., but usually at 32°F. there was more core flush. Curves based on development trend throughout storage indicated that once core flush started within a sample its development was very rapid, in some instances as high as two per cent per day until maxima were reached. By statistical sampling studies reported in "A Study in the Variation in Keeping Quality of Apples in Store" by T. N. Hoblyn, Jour. Roy. Stat. Soc. Suppl. 5:129-170, 1938, it was shown that the coefficient of variability within samples was extremely high until core flush development reached 40 per cent. It is possible that this initial stage represents rapid increment of core flush, and that temperature discrepancies may be attributed to making measurements during this stage. These trends also showed some differences in rate of increase between samples of different susceptibilities. In other words, examinations at different points in the storage life would indicate that one lot would be better than another, while at another time the same lot would be worse than the other. In general, however, samples of greatest susceptibility would show greatest increase in core flush development until the maxima were reached. These factors suggest that to provide a complete comparison it would be advantageous to follow development trends during storage life.

Maturity at Harvest.—Harvesting McIntosh at the correct stage of maturity was found beneficial. Frequently, however, holding apples on the tree, particularly in "high core flush" orchards, is hazardous. As a matter of fact the fruit may never reach correct maturity. Apples of this type were stored at 39°F. for thirty days and were subsequently stored at 32°F. When examined after 147 days of storage the core flush index was reduced from 46 to 6. Thus delayed storage, although not generally recommended for obvious reasons, may be used for controlling core flush in susceptible fruit.

Observations made on McIntosh apples grown on nutritional plots in the Northumberland-Durham area in Ontario provided very complete evidence on the effect of picking maturity and temperature on core flush development. A

summary of these detailed findings is therefore presented in Table 39. Plot 1 produced apples highly susceptible, plot 2 moderately susceptible, and plot 3 only slightly susceptible to core flush.

TABLE 39.—TEMPERATURE OF STORAGE AND PICKING MATURITY EFFECT ON CORE-FLUSH INDEX OF McINTOSH APPLES GROWN ON NUTRITIONAL PLOTS IN THE NORTHUMBERLAND-DURHAM (ONTARIO) AREA

Temperature Effect			Maturity Effect (at 32° F.)		
Plot	Storage °F.	Core Flush Index	Plot	Maturity	Core Flush Index
1	39	10·2	1	1	87·1
1	36	42·4	1	2	69·5
1	32	50·0	1	3	86·9
2	39	0	2	1	11·8
2	36	2·9	2	2	17·2
2	32	7·9	2	3	2·5
3	39	0	3	1	16·1
3	36	1·5	3	2	8·8
3	32	5·4	3	3	1·7

It can be seen from these data that 39°F. controls core flush when susceptibility is not too great; also advanced maturity reduces core flush. What should be noted is that delaying harvest does not exert much control when the susceptibility to core flush is as high as exists in plot 1.

Influence of Boron.—McIntosh apples from plots receiving various boron treatments were stored and core flush developments observed. The results appeared as "The Effect of Boron Applications on the Subsequent Storage and Physiological Behaviour of McIntosh Apples" by W. R. Phillips and F. B. Johnston, Sci. Agr. 23:451-460. April, 1943. Essentially the findings were that boron increased core flush development (although controlling corky core). Respiration and ethylene content trends revealed that the boron treatment delayed maturity. Delayed harvest reduced the subsequent development of core flush. However, the reduction in core flush was not proportional to retardation in maturity.

Influence of Growing Area.—Once having exhausted probable means of control of core flush by harvesting and storage procedures, it was planned to study the effect of growing area. Samples of McIntosh apples were drawn from the main apple growing regions across Canada. An attempt was made to procure samples representative of each particular district. In this way it was felt that any differences in core flush would be a composite effect of weather, general soil type, fertilizer, pruning and other cultural factors peculiar to the district.

As expected, maturity at harvest exerted a profound influence. In each area later harvesting delayed core flush. Another interesting point was that a definite West to East trend existed, as shown by examining apples stored to January 29 which had been harvested at approximately the same stage of maturity as follows:

Area	Core Flush Index
Okanagan (B.C.)	77·3
Northumberland-Durham (Ont.)	16·1
St. Lawrence River (Ont.)	47·0
St. John River (N.B.)	0·7
Annapolis (N.S.)	0·0

Current work on the influence of growing area involves more intensive studies within the area. It is hoped that such work may reveal probable contributing factors associated with growing conditions or climatic factors within the area.

Superficial Scald

A description of superficial scald as well as the contributing factors are outlined in "Functional Disorders of Apples". Since these findings have a bearing on subsequent work they are summarized as follows:

1. Immature apples are more susceptible.
2. Lower storage temperatures induce superficial scald.
3. Odourless mineral oil impregnated into a paper wrap or shredded packing paper reduces the amount of this disorder.
4. Air circulation exerts a controlling influence.

Subsequent efforts were designed to find more effective and more easily applied controls as well as to make a more accurate evaluation of present control measures. For such an approach, some knowledge of the fundamental physiological principles had to be considered.

Many workers have induced superficial scald with acetaldehyde, amyl acetate, and other volatiles. It is also felt that acetaldehyde is tied up directly or indirectly with ethylene production. When apples are exposed to low temperatures or when allowed to proceed towards senility, the form of metabolism changes from normal aerobic to what appears like anaerobic metabolism. It is characteristic that during the anaerobic phase volatiles are liberated. If these are allowed to accumulate at the skin surface the cells are damaged.

Thus, the principle of methods of control is to reduce the concentration of these volatiles at the skin surface. This has been accomplished by an absorbent (oil) or by air circulation.

Many tests were made to compare the effectiveness of oiled wraps and shredded oiled paper. Such varieties as McIntosh, Fameuse, Baldwin, Rhode Island Greening, and Wagener, were used. In every instance the wrapper was considerably more effective. On an average the shredded paper ranged from 60 to 70 per cent as effective as oiled wraps. The effectiveness of the oiled wrap in most instances was over 90 per cent (i.e., less than 10 per cent of apples were affected with superficial scald).

Tests were made to determine the quantity of shredded oiled paper required for McIntosh. Effectiveness of control increased by using varying amounts up to ½ lb. of shredded oiled paper per bushel. Amounts over this showed no increase in control.

During one series of tests, it was found that wrapped apples were tainted. On investigation the taints were attributed to the use of old wraps. Considering the absorbing properties of the oil, it is natural that wraps will eventually pick up odours particularly if they are not kept in a sealed container. Subsequent tests definitely showed that apples wrapped in old wraps were tainted, whereas those in new wraps were not. Thus it would appear advisable to use freshly made wraps each year.

Although superficial scald appears fairly late in storage life and although it frequently becomes evident only after removal from storage, it is felt that the actual damage is caused early in storage life. As a means of ascertaining this point Rhode Island Greening apples were wrapped at different periods during storage life. This variety was selected because of its high susceptibility. To make contrasts more decisive, immature fruit was used. Three series of 50 apple samples selected at random were made up as follows:

Series 1: All samples wrapped at outset of storage, unwrapping one sample every two weeks for a sixteen-week period.

Series 2: All samples unwrapped at outset of storage, wrapping one sample every two weeks for the same period as in Series 1.

Series 3: At the outset and thereafter at intervals of two weeks for sixteen weeks samples were wrapped for a six-week period only.

The results of these tests indicated that the most effective control was obtained by having a wrapper in continuous contact. Almost as effective control was obtained by wrapping during the first two months. In Series 2 there appeared to be two critical points. A delay of four weeks before wrapping apples produced an increase of superficial scald at the end of six months' storage. No further increases were noted in samples wrapped up to ten weeks, but apples wrapped after this time had as much superficial scald as the unwrapped control sample. Thus, it would appear that for best results the oiled wrapper (or shredded paper) should be applied before storage. If not wrapped prior to ten weeks in storage, little or no control may be expected.

The apples used in these tests were classified into four groups on the basis of superficial scald, viz., free, slight, moderate and severe scald. A critical examination of these groups indicated that the severely affected apples tended to be those which were large and hard, and the moderately affected tended to be those which were large and immature (based on percentage yellow). Results were as follows:

Scald free	50 per cent yellowed,	10·70 lb. pressure,	2·58″ diameter
Slight scald	38 per cent yellowed,	10·75 lb. pressure,	2·59″ diameter
Moderate scald ..	15 per cent yellowed,	11·05 lb. pressure,	2·71″ diameter
Severe scald	16 per cent yellowed,	10·91 lb. pressure,	2·73″ diameter

Air Filtration.—Among the more recent methods of controlling scald, the activated charcoal system appeared promising. Canisters designed by Dr. R. M. Smock of Cornell University and the Connor Engineering Co., New York, were used. Four canisters were located in a room of 1400 cubic feet. A blower fan forced air from the storage room through these canisters at about 55 c.f.m. (about one change of air in 25 minutes). This air was distributed by a duct with openings on either side, extending the length of the room at ceiling height.

Originally the canisters contained brominated charcoal. This material gummed up, causing deterioration of the canisters. On the advice of the designers, canisters of special type and size containing plain activated charcoal were substituted. Still later the fan was changed to pull the air instead of blowing it through the canisters. These modifications were a mechanical improvement with no reduction in effectiveness.

The first year's work (original design) was conducted with Rhode Island Greening apples. The room was filled to approximate capacity (about 200 bu.) with these and other varieties. The canister air circulation method did not exercise appreciable control of superficial scald. Unwrapped apples packed in hampers had an index of 58 as compared with 82 in ordinary storage. Oiled wraps reduced the latter index to 0·7. Unwrapped apples stored in open trays had an index of 0·6 in the canister room against 2·9 in ordinary storage.

Although in these tests this method did not effectively control scald, there are other commendable features such as the reduction of taints and odours. It also appears to prolong storage life (presumably through the absorption of ethylene).

Oil Dipping.—Recently, attempts have been made in Europe and the United Kingdom to control superficial scald by dipping apples in oil emulsions. Investigations were made at the Division of Horticulture to study such methods.

Initially, Rhode Island Greening apples at a storage temperature of 32°F. were used. Sunflower seed oil was selected on the basis of being a stable, relatively neutral-flavoured edible oil produced in Canada. Two emulsifiers were used: Nacconol (alkyl-aryl-sulphonate) and Unemul (a form of aluminium oxide). Unemul appeared more satisfactory from a practical application standpoint.

Emulsions from two to 100 per cent were used, and all proved very effective in controlling superficial scald. Emulsions over 12½ per cent were noticeably

oily but not objectionably so. One unfortunate feature was a lenticel injury, which was similar to external CO_2 injury (described in "Functional Disorders of Apples"). Further investigations are being conducted to ascertain the cause of this injury.

Other Types of Physiological Disorders

In addition to core flush and superficial scald, there are other disorders probably equal in importance. Major experiments have not been conducted on these because control and cause have been obvious or because they have been so inconsistent in occurrence that a study of the disorder would be futile.

Low-temperature breakdown occurs occasionally in the form of deep or soft scald. This has occurred on Northern Spy and Wealthy. Other varieties such as Jonathan which are not grown to any great extent in Ontario and Quebec, are also susceptible. Soggy breakdown, another form of low-temperature breakdown, is not common on Ontario and Quebec apples.

When such low-temperature disorders occur consistently, as with Cox Orange Pippin grown in Nova Scotia, as has been shown in a previous section, gas storage at higher temperatures (39° to 40°F.) is an effective control.

Water-core and Bitter-pit are disorders associated with orchard conditions which often increase in storage. The former disorder, if only slight, will disappear in storage. If severe it will increase and predispose the apple to internal breakdown. Such apples should be disposed of as quickly as possible after harvest. Bitter-pit, as an orchard disorder, is dealt with in the physiological section of this report by H. Hill. So far as storage observations are concerned, careful elimination of pit-infected apples at harvest or shortly after will preclude the further development of this disorder. There has been no known case of bitter-pit occurring in storage from trees that had no evidence of pit at harvest.

Lenticel spot frequently occurs on certain varieties, mostly when the apple is senile and actually worthless. Linda is an exception. Experiments now under way on this variety have been discussed previously under "Fungal Invasion" (p. 183).

Cortical Flushing is a problem frequently encountered with Newton apples, a variety grown mainly in British Columbia. From experiments conducted at various temperatures it is best controlled by low temperature (32° F.) storage. At this temperature it occurs only when the fruit is well advanced towards senility. Unfortunately, low temperatures are inclined to induce core flush in this variety.

Internal breakdown is a broad term and has often been used for several different types of physiological storage disorders. Most commonly internal breakdown is used to indicate breakdown associated with senility. If an apple passes through all the normal stages of maturity and is sufficiently fortunate to avoid fungal infection, it will eventually lose its aromatic flavour and acidity, become mealy in texture, and senile breakdown may possibly occur before the apple has quite reached the above stage of advanced maturity; but in most instances the fruit is so far advanced in senility that it is unmarketable. From an investigational standpoint, a senile breakdown measurement provides a datum for measuring ontogenetic advance in storage. Likewise the presence of senile breakdown is used to indicate the general condition of commercial samples submitted for diagnosis.

Loss of Quality

Quality Evaluation.—The third limiting factor in storage life is quality. Unfortunately quality is somewhat indefinable making definite measurements difficult.

The general transition of quality is that flavours proceed from starchy acidic to sweet aromatic, followed by general degradation to insipidity, and finally, to objectionable mustiness. Parallel to these changes is a transition of texture which is a general softening, passing from hard, lumpy textures through crisp, soft and ultimately to mealy conditions.

Attempts have been made to measure these transitions by chemical and other means. To date nothing has been found to replace the somewhat biased and prejudicial organoleptic method. Some of the methods used for measuring quality transition in storage are as follows:

Pressure Test.—In storage, pressure test readings show a general decline and so have certain value in measuring quality trends. The weakness is, however, that the transition is gradual and does not bear a direct relation to the quality in all instances. Tasting reveals greater differences than is measurable by pressure tests.

Acidity Trends.—Titratable acidity (using standard $Ba(OH)_2$ against a known volume of extracted apple juice) provides a general downward trend in storage. Like pressure-test readings this trend is also gradual. Poor storage McIntosh showed a more rapid fall in trend than good storage apples indicating a degree of relationship, but this was not sufficiently definite to provide an absolute indication of quality.

Soluble Pectin.—Other investigations have recently indicated that quality trend is associated with soluble pectin changes in storage, hence investigations of this nature have been initiated. The results so obtained are reported in another section. One criticism of such methods is lack of specific knowledge on the behaviour and nature of pectins. This has caused many unexplainable discrepancies in the technique of the determinations.

Organoleptic Tests.—Originally an attempt was made to have weighted values for the various features associated with quality. This is outlined in "Storage of Apples", Farmers' Bull. 132, 1946. This method of evaluating quality has been modified to a certain extent. Instead of making deductions on a score sheet for deleterious factors as was done originally, it was decided to give a specific score for definite quality characteristics. This was done primarily to co-ordinate quality scores at this laboratory with the scores of other Department of Agriculture investigators of apple storage problems. Sufficient records have not as yet been compared to see how it is going to work out. From preliminary observations, however, three independent scorers came within five per cent on an identical (as far as could be procured) sample.

Such methods of measuring quality are satisfactory in the hands of specialists only. Less complex methods have to be used when resorting to taste-panels. It might be said here that, on the whole, taste-panel procedures did not prove very satisfactory. In instances where public reaction has been sought, best results were by an overall general taste reaction. A special type of score sheet was given to each member of the panel; each sample was identified by a number and alongside this number was a four inch line with "good" marked on the left and "bad" on the right of centre. Each taster placed an X on the line proportional to his estimate of quality between "good" and "bad". By calibrating this line numerically, quality figures have been obtained which bear a fair degree of consistency.

Results of Quality Studies

At no time did the quality of McIntosh exceed 90 per cent at 32° F. as compared with 100 per cent at 36° or 39° F. At 39° F. maximum quality (100 per cent) was maintained for a four-week period (middle of October to middle of November) after which it fell off very rapidly. At 36° F. the approach to full quality was slower, lasted slightly longer (November 1 to December

10), and was followed by a slightly less rapid drop. At 32° F., although 100 per cent quality was not reached, the apples were over 75 per cent quality for 3½ months (November, December, January and part of February). From observation it appears that texture is favoured at lower temperatures whereas flavour develops more fully at higher temperature.

The most important contributory factor in quality is harvest maturity. With McIntosh, later harvest is definitely conducive to high quality. This applies in general to other varieties except those varieties which are inclined to hold on the tree until their quality peak has passed. On one occasion, Northern Spy had a slightly lower eating quality with later harvest, even though the appearance was better. As an example of the influence of maturity, the mean quality of McIntosh apples from all Canadian growing areas at or near the end of storage life was as follows:

Maturity 1	49.8
Maturity 2	60.2

Maturity 2 was harvested one week after maturity 1 in all samples. Examination of the apples showed that maturity 2 could have been harvested still later and so produce further gains in quality. In areas where quality was highest the difference in quality of the two maturities exceeded 24 per cent.

Nutritional conditions also influence quality. Three plots in the Northumberland-Durham area which rated high (Plot 1) intermediate (Plot 2) and low (Plot 3) in relation to core flush, which was previously shown to be influenced by orchard nutritional conditions, rated in quality as follows:

Plot 1	40%
" 2	53%
" 3	67%

As previously mentioned, this precise association between core flush and quality does not always exist.

Miscellaneous Investigations

Packaging

The object of packaging investigation with apples was to design a consumer package which could be packed at production centres. Several sizes ranging from one gallon to half-a-bushel were tried. The various difficulties encountered eliminated all except the half-bushel. Specifically, this was a 90-pound test corrugated carton with waxed liner. This container has been adopted by the trade (although frequently used without the liner) and has proved satisfactory. Further details and descriptions of packages and packaging work with apples were reported in "Packaging Investigations: Where Do We Go From Here?" by W. R. Phillips. Food in Canada, 4: 26-35. Sept., 1944.

Other investigations designed to find a more suitable package for peaches have been conducted in co-operation with T. B. Harrison, Dominion Experimental Station, Harrow, Ontario. No appreciable information has been forthcoming from these experiments except that paper wrapping and shredded packing materials appear to offer greater protection than package design.

Fumigation

Investigations were conducted in co-operation with the Division of Entomology to find a means of killing insect life in and on apples for export. At present, apple maggot and other pests could form a basis of discrimination against the importation of Canadian apples.

Methyl bromide as a fumigant was tried. The results of such trials have appeared in "Some Observations on the Fumigation of Apples with Methyl Bromide" by W. R. Phillips, H. A. U. Monro and C. E. Allen. Sci. Agr. 19:7-20. Sept., 1938. It was shown that methyl bromide can be effective in killing insects in apples but if the fruit is not at the proper maturity it is liable to injury.

Soluble Pectin Trends in Cold Stored Apples

In the search for a mechanical test to gauge optimum maturity and keeping quality of cold stored apples, a test run on soluble pectin trends was conducted during the 1948-49 season. The procedure employed was essentially that outlined by Carré and Haynes (1).

Previous work by others (2, 3 and 4) has indicated that soluble pectin trends in stored apples are bound up with the maturing phase as well as the subsequent decline as the apples pass into the senescent stage. Classical theory suggests that the protopectin or insoluble pectin of the cell wall and middle lamella is hydrolysed or by other means converted into soluble pectin. This results in a softening of the apple tissues which up to a point (here designated as optimum maturity) is highly desirable. However, continued production of soluble pectin on a high level can only lead to a rapid decline in fruit quality.

Soluble pectin determined at two-week intervals for the varieties McIntosh and Wagener and evaluated on the basis of grams per 100 grams of juice indicated a typical and almost continuous trend. Fig. 26 is an example.

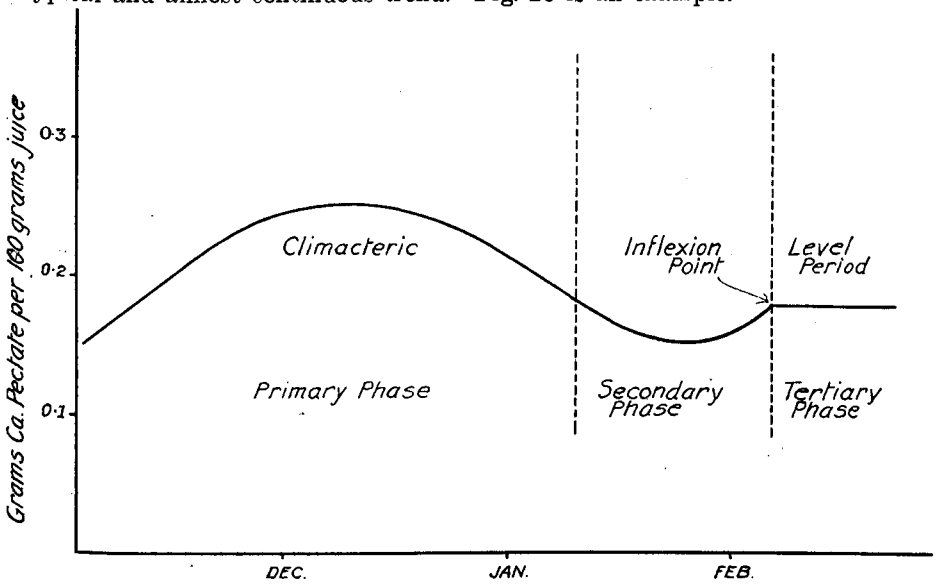

Fig. 26—The general trend of the pectin line.

For purposes of further reference the curve will be referred to in its primary, secondary and tertiary aspects as indicated in Fig. 26. The use of the word climacteric will be strictly confined to the summit of the pectin trend of the first phase.

Commercial samples of McIntosh apples drawn from the Brighton and Iroquois areas of Ontario formed the principal test material. Other samples used were McIntosh taken from Central Experimental Farm, Ottawa, nutritional studies orchard; Wagener apples from Kentville, Nova Scotia, harvested from fertilizer plot studies; and finally, gas-stored McIntosh from the Iroquois area. All apples were held at 32° F.

Reviewing compiled data from the points of view of eating quality, maturity and keeping quality, the commercial samples of McIntosh suggested the following points:

1. Maximum eating quality coincided with the climacteric (pectin) of the primary phase. Quality evaluations on sharp ascents or descents differed widely from those registered at the climacteric.

2. Lower levels of soluble pectin appeared to concur with higher apple quality and longer storage ability.
3. Long gentle declines from the climacteric toward the inflexion point appeared desirable. In effect this meant a slow decline in quality with time as the apple passed optimum maturity.
4. The climacteric of the primary phase was delayed by as much as 24 days in early picks.
5. The inflexion point in the secondary phase occurred simultaneously in all samples regardless of pick, though the secondary phase varied considerably in length.

An attempt was made to link quality evaluations with the tertiary phase but no sharp delineations were evident here. It appeared that subsequent quality values in the secondary and tertiary phases were largely reflections of performance in the primary phase.

In the consideration of the Central Experimental Farm McIntosh from nutritional plots the foregoing enumerated information was confirmed. In particular it was found that high nitrogen plots scored the lowest on average quality and keeping ability. It was also noted that the high nitrogen treatment produced a marked effect on the pectin line—moving the climacteric so high that the primary phase assumed conical proportions. Highest average quality, best keeping ability and lowest pectin levels were recorded for the McIntosh on high potash treatment.

The striking feature in connection with soluble pectin trends on the Wagener apples was the delay or lag in the development of the phases subsequent to the primary. Assuming that the foregoing observations on McIntosh samples are correct this would, of course, be a logical deduction, as the Wagener is a longer storage variety.

Wageners taken from a starvation plot showed an extraordinary low level of soluble pectin and scored the highest quality. High nitrogen treatment again elevated the pectin line.

Two samples of gas-stored McIntosh formed the last of the group for soluble pectin studies. The ratios of CO_2 to O_2 employed were 5 and 16, and 5 and 5. Differences from previous results were noted here and were probably consequential or related to disturbance of normal metabolic drift.

The general pattern of the pectin line for the gas-stored samples (Fig. 27) was the same as before, but a marked depression of levels was noted. The 5 and 16 line was depressed the most, and changes were very gradual, indicating a healthy state. Carré and Horne (2) reported that CO_2 atmospheres actually accelerated pectin changes, and it would appear from examination of Fig. 27 that the 5 and 5 ratio was a marginal case. Probably higher ratios would have produced this reported acceleration.

Post pectin climacteric quality evaluations showed that the control sample and the 5 and 16 sample scored approximately the same; the 5 and 5 gas sample ran a poor third. Quality scores for the middle of March indicated erased differences. There was a suggestion of delayed eating quality in the 5 and 5 sample, with higher scores well to the right of the primary phase climacteric.

In Fig. 27 it is observed that the primary phase of the 5 and 5 gas sample goes into a long deep decline and that the tertiary also declines sharply. Physiological examination on March 8 showed moderate breakdown. The tertiary phase of the control sample dips slightly—this particular sample showed a low index of core flush. On the other hand, the 5 and 16 gas sample levels off in the tertiary and it showed no evidence of any physiological disorder whatsoever.

The material chosen for gas storage was a third maturity pick from the Iroquois area. Comparison of trends with the previously mentioned McIntosh

lots showed that these apples reached a climacteric intermediate to the first and second maturity picks. The inflexion point of the secondary phase and levelling off in the tertiary, however, were coincident in all cases.

Acidity and soluble solids trends were established on all samples for pectin work.

The acidity trends revealed nothing specific except that there was a tendency towards high acidity in high quality apples. Within broad limits there was a suggestion that rapid decline in acidity indicated shorter storage life.

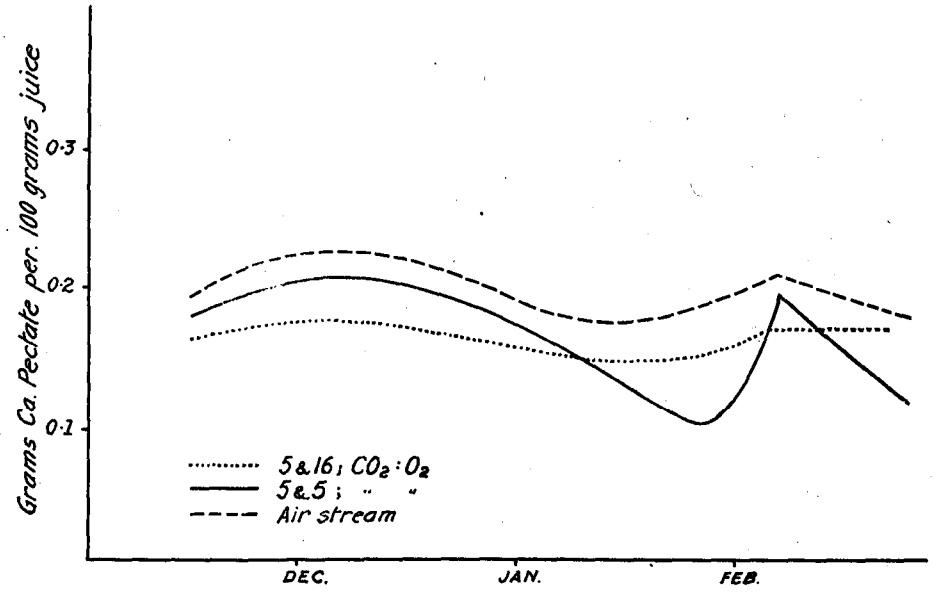

Fig. 27—Pectin levels for McIntosh apples stored in two different gas mixtures.

Soluble solids remained constant with time for all samples except for one peculiar deviation termed the "bump". This so-called bump was one point above the true line, and in a number of cases it coincided with the inflexion point of the pectin line. No explanation was found.

In summation, evidence appears to show that soluble pectin trends give a fair indication of quality and storage ability of the apple. That is, small areas under pectin curves are desirable. High and sharp climacterics suggest rapid quality shifts (shortened marketing periods) and abrupt changes in the apple metabolism. Nutritive deficiences and the effects of gas storage are reflected in the pectin trend. Since soluble pectin trends appear to give an indication of quality with storage, it is felt that with a refinement of technique a record of pectin performance of the apples during storage would help in getting apples of quality on the market at the proper time.

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Preliminary Results on Exosmosis of Electrolytes as a Measure of Plant Hardiness

M. MacArthur

The development of hardy strains of plants is one of the principal means of combating losses caused by injury from cold. Most of the work on development of these strains has been based on breeding, using a parent known to be able to withstand the rigors of the Canadian climate. The degree of hardiness of these crosses is usually determined by the visual "freeze and wait" method which in developing a suitable hardy apple variety involves a protracted period of time. Any reliable method of eliminating the tender seedlings in the first year or two of growth would be economical.

It is generally accepted that in cold injury the cell loses its capacity to regulate the diffusion of its cell contents. Injury of such tissue may be estimated by degree of recovery or by microscopic observation. Injured plant material (cold or other injury) placed in distilled water can be expected to show some outward diffusion of electrolytes, and an increase in injury will appear as an increase of the diffused electrolytes in the solution. Increasing the strength of the solution decreases the resistance; that is, a low resistance indicates a strong diffusion of electrolytes, and therefore, tender material. Conversely, a high resistance indicates weak diffusion and therefore, hardy material.

Method of Testing

In all the experiments, the material was washed quickly in distilled water, dried, then snipped into approximately half-inch lengths. Five grams were weighed at once into a perfectly clean 75 c.c. test tube. This material was then subjected to varied cold treatments, usually but not always —20°F. for overnight, removed to a 0° or 10°F. room, then to a 32° or 39°F. room for definite periods before removal to the laboratory. After a specified time at laboratory temperature, 50 c.c. of distilled water was added and the tubes of material were placed in an oven at 67° or 80° F. for exosmosis. Frequently, several readings were made. Extending the exosmosis period increased the concentration of electrolytes (and other materials) in the water extracts. Resistance decreased, but the relative positions remained approximately the same.

In untreated tissue practically the only cells involved in loss of electrolytes are those ruptured by cutting, but with cold-treated tissue losses from the cells are in proportion to the injury. In the latter instance there is little reference to cut-surface relations. However, the smaller the diameter of material of unit weight the greater is the proportion of living cells in that unit. Increase of injury shows up in a decrease of resistance.

Hardiness of McIntosh and M. baccata

Late in October resistance measurements were made of water extracts of McIntosh and *M. baccata*. Whips and seedling tops were exposed to —20° F. for 17 hours and roots to 10° F. for the same period. *M. baccata* material had a higher resistance than the corresponding McIntosh material. The higher resistance indicates a lower concentration of electrolytes in the water extract; that is, *M. baccata* was less injured by the cold treatment and therefore, hardier. That *M. baccata* is hardier than McIntosh by the field test is well known. In *M. baccata* the order of hardiness was whips, tops and roots; in McIntosh, tops, whips and roots. One of the duplicate samples of McIntosh whips was

made up in part of slender material from close to the tip of the leader. This sample would have more living cells per unit weight and did have a lower resistance. This brought the average resistance for McIntosh whips below that of tops.

Other Varieties Compared

On January 7, 1941, one-year wood from the orchard was treated 17 hours at —20° F. The tubes of cold-treated tissue were brought through four temperature stages during six hours with exosmosis for 21·5 and 22·75 hours at 67° F. Table 40 shows the resistances. Measurements were by the Wheatstone bridge. With the exception of the three varieties of Ottawa origin, 0-202, 0-205 and 0-2010, each figure is the average of two samples. The varieties of Ottawa origin were single samples.

TABLE 40.—AVERAGE RESISTANCE IN OHMS OF THE WATER-EXTRACTS FROM APPLE TISSUE COLLECTED JANUARY 7, 1941

Variety	R. at 21·5 hr.	R. at 22·75 hr.
Hibernal	482	451
Osman	471	448
Anis	402	378
Printosh	402	375
Atlas	381	362
Jewel	359	332
0-205	326	317
Rosilda	309	282
0-2010	200	185
0-202	178	188

The varieties are arranged in order of hardiness according to the average resistance (R) of the exosmosed electrolytes with 21·5 hours of exosmosis. At the second reading, 22·75 hours, the order of hardiness is essentially the same.

Additional material of other varieties was collected from the field the following day, treated in the same manner with exosmosis periods of 21·5 and 23 hours. Results are listed in Table 41.

TABLE 41.—AVERAGE RESISTANCE IN OHMS OF THE WATER-EXTRACTS FROM APPLE TISSUE COLLECTED JANUARY 8, 1941

Variety	No. Samples	R. at 21·5 hr.	R. at 23 hr.
Antonovka	3	609	609
Piotosh	5	471	448
M. baccata	2	469	429
Lobo	6	461	437
Columbia	3	432	412
M. robusta No. 5	3	423	404
Pioneer	1	416	406
0-224	2	398	?
Wapella	4	398	377
Rameuse	2	356	344
Robin	1	351	337
McIntosh	6	345	334

Again on January 20, prepared apple top tissue was exposed to -20°F. for 17 hours; to 0°, 10° and 67° F. for one, three and three hours respectively and finally, exosmosis for 18 and 21 hours at 67°F. Table 42 indicates the results.

TABLE 42.—AVERAGE RESISTANCE IN OHMS OF THE WATER-EXTRACTS FROM APPLE TISSUE COLLECTED JANUARY 20, 1941

Variety	No. Samples	R. at 18 hr.	R. at 21 hr.
Lobo	2	455	425
Anis	2	451	416
Hibernal	2	438	430
O–224	1	437	404
Columbia	2	403	398
Piotosh	2	377	368
Antonovka	2	366	352
Osman	2	345	335
M. baccata (*a*)	2	335	310
Robin	1	333	316
Printosh	2	329	319
M. robusta (*a*)	2	316	306
McIntosh	2	302	276
Wapella	2	285	269
Fameuse	2	280	264
Jewel	1	275	269
Atlas	2	250	240
Rosilda (*b*)	2	246	232
O–2010	1	208	199
O–205	1	205	193
O–202	1	162	164

(*a*) Samples thin and spindly, small in diameter.
(*b*) Samples quite thick.

On the varieties listed in Tables 40 to 42 the following information is of value:

1. or 2. Antonovka—Russian origin
1. or 2. Anis—Russian origin
1. or 2. Hibernal—Russian origin
2. or 1. *M. baccata*—Hardy, Russian origin
2. or 1. *M. robusta*—Hardy
3. Osman—first cross, *M. baccata* × Osimoe
3. Columbia—first cross, *M. baccata* × Broad Green
3. Pioneer—first cross, *M. baccata* × Tetofsky
3. Robin—first cross, *M. baccata* × Simbirsk No. 9
3. Jewel—first cross, *M. baccata* × Yellow Transparent
4. Rosilda—second cross, Prince × McIntosh
4. Printosh—second cross, Prince × McIntosh
4. Piotosh—second cross, Pioneer × McIntosh
5. Wapella—second cross, tender (Dean × Ontario).
   Dean = *M. baccata* × Wealthy
   Ontario = Wagener × N. Spy
6. Lobo—Ottawa origin; open-pollinated seedling of McIntosh, considered hardier than McIntosh
6. Atlas—Ottawa origin, considered hardier than McIntosh; seedling of Winter St. Lawrence
7. McIntosh—Considered hardier than Fameuse
7. Fameuse—Considered more tender than McIntosh
8. 0-224—third cross
8. 0-205—third cross
8. 0-2010—third cross
8. 0-224—third cross

The twenty-two varieties are arranged in eight groups more or less in group order of hardiness. The several varieties in a group are not necessarily in order of hardiness.

Discussion

It is unfortunate that the tests of January 8 were not a repetition of the tests of January 7. With only one additional day of exposure to the outdoor temperature, a repeat test with conditions being equal should give approximately equal results. Nevertheless, Tables 40, 41 and 42 indicate a range of resistances. In Table 40, the highest resistance and hence the hardiest tissue is Hibernal

and at the other end of the scale is the variety 0-202. Hibernal is of Russian origin and 0-202 is a third cross (see grouping in the table of information). Similarly in Table 41, Antonovka, the hardiest according to resistance figures, is also of Russian origin, while McIntosh originated in Ontario.

The highest resistance in Table 42 was in Lobo tissue, and the lowest in 0-202. Thus the table designates Lobo as the hardiest of the 21 varieties and 0-202 the most tender. Lobo is of Ottawa origin, an open-pollinated seedling of McIntosh. It would not be expected that Lobo is hardier than most of the varieties of Russian origin, although hardiness differences most certainly do exist between the Russian varieties and between the first crosses. For example, by the "freeze and wait" method at Morden, Manitoba, Pioneer, a first cross of *M. baccata*, is listed as a very hardy crab while Osman, Robin and Columbia, also first crosses, are recommended as "general hardy—for trying conditions". Antonovka, originating in South Russia, is considered "medium hardy—for favourable locations". *M. baccata* originating in the colder regions of Russia does not head either Table 41 or 42; 0-224, a third cross of *M. baccata*, is, on the basis of resistance, listed as hardier than that variety in Table 42. Therefore, in Tables 41 and 42, Lobo and 0-224 appear to be out of position. However, the *M. baccata* tissue as tested in Table 42 probably contained a greater proportion of living cells per unit weight than most of the other varieties, since these tissue sections were small in diameter. This would show up in a lower resistance, as has been mentioned previously.

In Table 42, tests of January 20, all the tissues tested earlier are included, but the conditions were somewhat different. The thawing periods, temperatures and initial exosmosis periods differed. The test was after 12 and 13 additional days of exposure to winter weather. Because of these several variables, the figures are not comparable. It is possible that for all tests 17 hours at a temperature of —20°F. was much too severe, and that most of the living tissue in every variety was killed. The figures would then be an expression of the amount of killed tissue in a variety, but because no microscopic examinations were made, the relative volumes of protoplasmic tissue per variety tested are not known.

Rootstock Tests

On January 22, 5-gram samples of rootstock material brought in from the field were placed at 10°F. for 17 hours then six hours at 67° F. Exosmosis was for 19 and 22·5 hours at 67°F. The resistances are given in Table 43.

TABLE 43.—AVERAGE RESISTANCE IN OHMS OF WATER-EXTRACTS FROM EXOSMOSED APPLE ROOTSTOCK TISSUE

Rootstock	No. Samples	R. at 19 hr.	R. at 22·5 hr.
E. Malling IX	1	120	107
M. robusta	2	104	92
E. Malling II	1	93	84
E. Malling I	2	90	84
Anis No. 322	1	81	75
Mixed Apple No. 452	2	79	71
E.M. Crab C	1	75	67

Based on the measurements in reading 1 (19 hours' exosmosis) East Malling IX is the hardiest and East Malling Crab C the most tender. By the "freeze and wait" method at the Division of Horticulture the winter hardiness of these and other vegetative rootstocks was determined over a six-year period immediately preceding this exosmosis experiment. In the field test the snow

was removed from the test area and the rootstocks deprived of the snow blanket were continuously exposed to the viccisitudes of winter climate. The data on the field test for hardiness are given in Table 44.

TABLE 44.—WINTER HARDINESS TEST OF VEGETATIVE ROOTSTOCKS

Rootstock	A	B	C	D	E	F	Av. Hardiness	Per Cent Injury
Anis No. 46	10	8	10	6	10	10	9	10
Anis No. 322	7	10	10	10	10	8	9	10
Anis No. 376	8	8	8	8	10	7	8	20
M. robusta	10	10	10	10	10	10	10	0
Mixed Apple 452	10	8	0	6	10	0	6	40
Mixed Apple 462	10	10	0	7	6	6	6·5	35
Mixed Apple 466	6	0	0	0	0	0	1	90
Mixed Apple 472	8	8	6	6	6	8	7	30
Mixed Apple 478	8	0	5	6	6	10	6	40
E. Malling I	5	0	4	0	0	0	1·5	85
E. Malling II	0	4	0	5	0	4	2	80
E. Malling IX	4	0	0	0	4	0	1	90
E. Malling XII	4	0	4	0	6	5	2·5	75
E. Malling Crab C	0	5	0	0	6	0	2	80

Through the years A to F the figures indicate the extent of resistance to winter injury, 10 indicating no injury down to zero, killed. Table 44 indicates that by the exposure and observation method, *M. robusta* was the hardiest, and E. Malling IX, very tender. By the exosmosis method (Table 43) E. Malling IX was the hardiest. Since by the field test E. Malling IX was severely injured, the results by this exosmosis test are not at all reliable.

A repeat (Table 45) on some of the vegetative rootstocks was made a week later. The samples were exposed to 15° ±1°F. for 17·75 hours then six hours at 67°F. Exosmosis was for 19 hours at 67°F.

TABLE 45.—AVERAGE RESISTANCE IN OHMS OF WATER-EXTRACTS FROM VEGETATIVE ROOTSTOCK TISSUE

Rootstock	No. Samples	R. at 19 hr.
Anis No. 322	2	154
Mixed Apple No. 452	3	114
M. robusta	1	101
E.M. Crab C	1	98
E. Malling I	2	92
E. Malling II	1	92

In this test, Anis 322 was hardier than *M. robusta*. E. Malling I, II and Crab C were more nearly alike and the most tender of the group. This corresponds with the 80-85 per cent injury by the field test. The higher resistances for the same variety in the second test are partly the results of later treatment and of less severe treatment temperature.

The several experiments indicate that the method of determining hardiness by cold treatment and subsequent exosmosis of electrolytes is not a completely reliable tool for the purpose. It is probable that most of the treatments were too severe and the resistances obtained were probably a measure of total killed protoplasm. It may be that a refined technique would give figures more nearly in line with field observations. However, it must be remembered that the climatic and nutritional conditions to which a perennial plant is subjected

during the preceding growing and hardening-off season have a very definite effect on how that plant will withstand the low and drying temperatures of winter; that is, the plants in one variety subjected to differing conditions of moisture and feeding could have widely varying resistances. Plants from one area and subjected to similar conditions tested at any one time could, with a refined technique, give merely comparable results, which again would differ at another test period. In other words, one plant of a variety may, and often does, harden off more rapidly than another.

Measuring Untreated Tissue

Since resistance is presumed to be a measure of the extent of injury, then without further treatment tissue tested at the end of winter should show the effect of winter injury. In addition to the electrolytes from the cells at the cut surfaces, electrolytes from winter-injured cells should also diffuse into the water extracts. A hardy material would have fewer injured cells and so show a higher resistance while the more tender material would have a lower resistance.

To test this theory, unfrozen and cold-treated tissue of the same varieties were tested on April 7. The unfrozen tissue was allowed to exosmose for 19 hours at 80°F. The cold-treated was exposed 17 hours at —20°F., one hour at 0°F., one at 10°F., two at 32°F. and four at laboratory temperature. The distilled water was added and exosmosis was at 80°F. for 19 hours, with further exosmosis at laboratory temperature for 1·25 hours. The average resistances of these lots of material are given in Table 46.

TABLE 46.—AVERAGE RESISTANCE IN OHMS OF WATER-EXTRACTS FROM APPLE TISSUE COLLECTED APRIL 7

Variety	Unfrozen Tissue		Frozen Tissue		Difference
	No. Samples	Av. Resistance	No. Samples	Av. Resistance	
Antonovka	6	1,264	4	265	999
Hibernal	9	1,078	7	282	796
M. baccata	6	997	6	213	784
Anis	8	971	4	302	669
M. robusta	5	931	4	266	665
Osman	5	897	4	287	610
Columbia	6	856	4	252	604
Lobo	3	778	4	191	587
Atlas	11	713	4	189	524
McIntosh	4	655	3	206	449

In the unfrozen material there is some indication of hardiness rating in that the varieties of Russian origin appear to be the hardiest; that is, they have the higher resistances. Following these are Osman and Columbia, both first crosses of *M. baccata,* and finally the three varieties, Lobo, Atlas and McIntosh, known to be less hardy. The resistances of the frozen material are not in the same order. *M. baccata* and McIntosh are close in average resistance and so fall into the comparatively least hardy group. Such is not the position for *M. baccata* by field test. In differences between frozen and unfrozen tissue the order of hardiness is practically the same as in the unfrozen tissue.

Also in the spring five samples each of Linda, Hume and Sandow were cold-treated 17 hours at —20°F. with 7·5 hours through several temperatures to 80°F. and 19 hours exosmosis at that temperature. The results are given in Table 47.

From these figures the order of hardiness is Linda, Hume and Sandow. In the cursory examination of the thawed frozen material, all samples were some-

what browned, but very marked browning was visible in Sandow. This is an indication of the extent of killing by the cold treatment.

Measurements were made of the resistances in water-extracts of a series of co'd-treated rose bush tissue. The results may be found in that section of the report dealing with Ornamental Horticulture.

TABLE 47.—AVERAGE RESISTANCE IN OHMS OF WATER-EXTRACT FROM FROZEN AND UNFROZEN APPLE TISSUE OF THREE VARIETIES

Variety	Unfrozen Tissue Av. Resistance	Frozen Tissue Av. Resistance	Difference
Linda	611	229	382
Hume	551	204	347
Sandow	397	169	228

Since the figures obtained on woody apple tissue do not indicate specifically the degree of known hardiness, either measuring the resistance of exosmosed electrolytes does not have the required precision, or modifications of the technique are necessary to attain that preciseness.

Effect of Freezing on Mature McIntosh and Golden Russet Apples

A theory had been advanced that freezing intensified the oxidase and peroxidase reactions of apple tissue. If such were the case, then apples which had been frozen could be readily detected by a simple test. Carrick (2) showed that extreme freezing of McIntosh apples markedly reduced the catalase activity, but the immediate influence of milder degrees of freezing was neither conclusive nor consistent, and results with Baldwin were not generally comparable.

At the laboratory, N. Spy apples exposed to 19 hours at 25°F. had the appearance of a slight scald. In five days at 36°F. this defect had disappeared. Both immediately after thawing and later, the oxidase reactions of the frozen apples were similar to the controls in all respects. The test was the development of blue coloration when a median cross section was flooded with a tincture of gum guaiacum.

At this time apples suspected of freezing in transit were examined. These apples were badly bruised and the browned internal areas under the surface discoloration extended in a cone-shaped manner towards the core, similar to the freezing injury figured by Carrick (1).

In an attempt to duplicate the injury, McIntosh apples were withdrawn from 39°F. storage in mid February. Controls, bruised and unbruised, were placed at 32°, 40° and 60°-65°F. Samples were frozen without bruising, bruised before freezing, while frozen, and after thawing. Some difficulty was experienced in the freezing room. With a week's exposure not all apples were frozen. The internal temperature of the unfrozen fruit was 28·2°F. while air temperature was 28°F. Therefore, all samples were removed to a controlled 26°F. room and freezing was complete in 24 hours. They were left at 26°F. a further 24 hours then removed to 32°. 40° and 60°-65°F. Thawing was complete in four, two and one days respectively.

Only those apples bruised while frozen had brown spreading watery areas internal to the pressure point (Fig. 28). The watery browning of the tissue of these apples increased with storage, till finally in many samples the whole apple was involved. In no other treatment did the internal browned area increase in this manner.

Externally the bruised while frozen apples were discoloured (browned) at the pressure point, and the surface of the bruised area was distinctly furrowed (Fig. 29). These furrows or wrinkles did not disappear with storage.

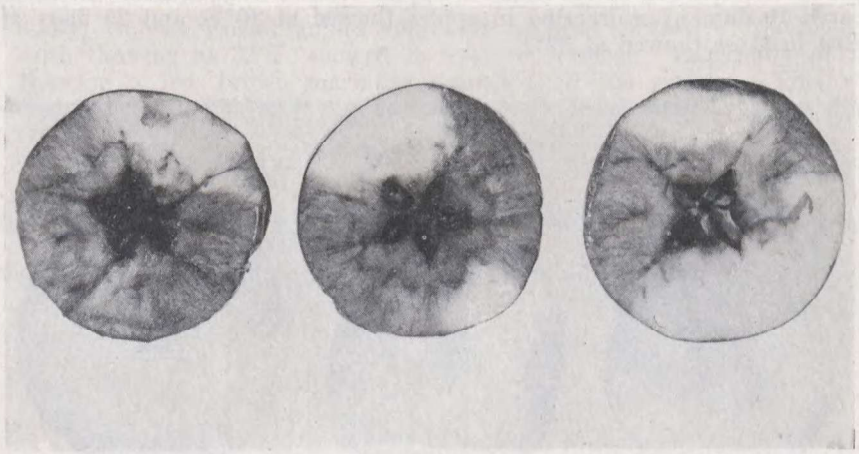

Fig. 28—Cross sections of McIntosh apples bruised while frozen and thawed at 60°-65°, 40° and 32°F.

Apples bruised before freezing had a slight tendency to this external wrinkling of the bruised area. This disappeared rapidly at 60°-65°F. storage, more slowly at 40°F., but had not disappeared with 8 weeks at 32°F. Neither those apples bruised after thawing nor the bruised controls exhibited this surface furrowing at the pressure point.

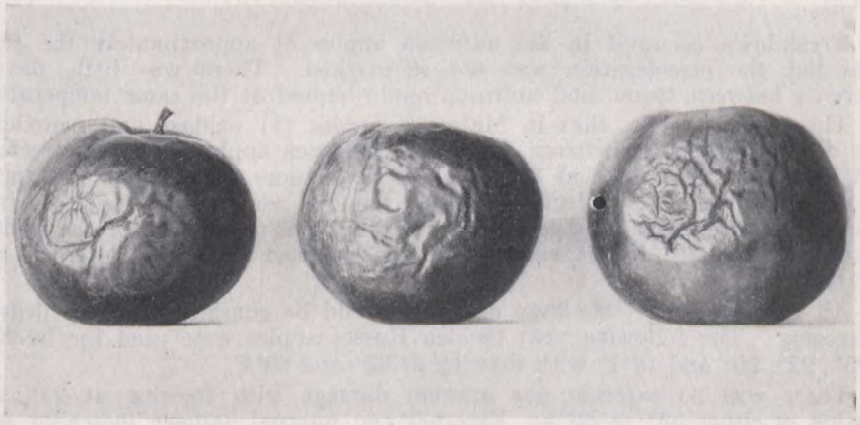

Fig. 29—McIntosh apples bruised while frozen and thawed at three temperatures.

In the oxidase tests unbruised controls at the three temperatures showed the same intensity of reaction over the whole surface. In bruised controls and all frozen apples there was a more intense reaction in the samples at 60°-65°F. than in those at 40° and 32°F. Differences between high and lower storages were not evident in the peroxidase test (tincture of gum guaiacum + hydrogen peroxide). With longer storage, differences in oxidase reactions of samples at the several temperatures were no longer evident.

A breakdown, either senile or low temperature, first appeared in the apples thawed at 60°-65°F. (Fig. 30). This was a light browning of the outer cortex with deeper browning of the vasculars and was not at all similar to the darker spreading discoloration of the tissue in apples bruised while frozen. Breakdown appeared 19 days after freezing in apples thawed at 40°F. and 25 days after freezing in those thawed at 32°F.

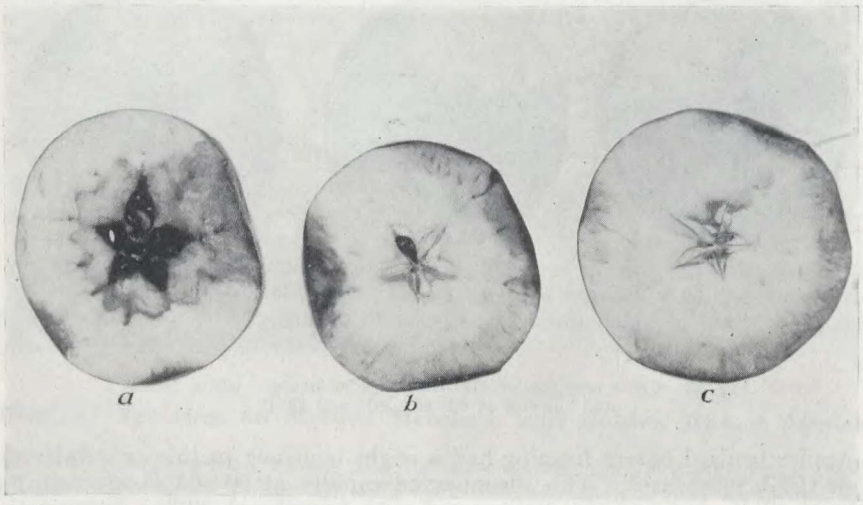

Fig. 30—Senile or low temperature injury in apples thawed at 60°-65°F. (*a*) Apple bruised while frozen. (*b*) Apple bruised after thawing. (*c*) Apple frozen, not bruised.

Breakdown occurred in the unfrozen apples at approximately the same times but the discoloration was not so marked. There was little flavour difference between frozen and unfrozen apples stored at the same temperature.

These results show that in McIntosh apples (1) oxidase and peroxidase tests do not distinguish between frozen and unfrozen apples; (2) mild freezing, that is, a complete freeze at 26°F. for 24 hours does not damage the apple; (3) damage occurs if the fruit is roughly handled while frozen, and (4) fruit bruised while frozen may be detected by wrinkling of the surface of the bruised areas and internally, by the extension of the browned areas both laterally and towards the core.

All the foregoing tests were on what would be considered milder degrees of freezing. The following year Golden Russet apples were used for freezing at 25°, 22°, 20° and 18°F. with thawing at 32° and 60°F.

There was no external nor internal damage with freezing at 25° and thawing at either 32° or 60°F. External and internal damage increased with lowering the temperature of freezing and generally more damage occurred with thawing at 60° than at 32°F. The surface was browned in patches to all-over browning as a scald with darker, sunken brown patches and internally there was browning of vasculars to a flesh browning with definite softening of both cortex and core.

Apples packed in half-bushel hampers and frozen at 25°F. took 9 days for complete freezing. Only with thawing at 60°F., did a few small browned patches appear. There were no internal defects, but the apples at both temperatures 60° and 32° F., shrivelled severely with storage.

Samples frozen at 25° F., and held at that temperature for 72 and 144 hours before thawing at 32° and 60°F. did not show any internal damage. Externally the brown patchy markings were evident. These apples also shrivelled extensively with storage.

Finally, Golden Russet apples subjected to four successive freezings at 25°F. with thawing at 32°F. showed no internal damage. Externally at the third thawing a few brown markings appeared on the surface. This was intensified at the fourth thawing and may have been caused by handling while frozen.

References

1. Carrick, D. B. Some effects of freezing on the mature fruits of the apple. Cornell Univ. Agr. Exp. Sta. Memoir 81. Dec., 1924.
2. Carrick, D. B. Effect of freezing on the catalase activity of apple fruits. Cornell Univ. Agr. Exp. Sta. Memoir 122. March, 1929.

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FRUIT AND VEGETABLE PRODUCTS

M. MacArthur

Dehydration

Limited experiments on the dehydration of vegetables at the laboratory date back to the latter years of World War I, but these first experiments were all on home methods. In the 1920's the Annapolis Valley of Nova Scotia was supplying the dried apple market with evaporated apples produced by drying the apples on slatted wood trays in heated air containing sulphur fumes. The Dominion Experimental Station at Kentville, Nova Scotia, undertook the improvement of the process and was so successful in the engineering phases and the methods that their work, "Principles and Methods Involved in the Dehydration of Apples" by. C. C. Eidt, Tech. Bul. 18, 1938, has become a standard reference.

In 1936, two commercial dehydration plants were established in Ontario and assistance, especially on engineering and plant layout, was supplied by the staff at Ottawa and by the Kentville Station. After production was started, the Ottawa laboratory co-operated with one of the firms in a test round-the-world shipment in an attempt to determine the reason for quality deterioration with storage. All samples were packed in tins, atmospheric pack and vacuum pack. One-half of the lots were stored at 32°F. in Ottawa, the remainder were placed on a slow freighter to Hong Kong. All were examined in six months on the return of the freighter to Canada. Conclusions drawn from the test were that elevated storage temperatures resulted in serious deterioration but even at 32°F. the products underwent detrimental changes.

It was not until 1941 that serious consideration was given to the dehydration of vegetables. At that time Britain wished to place contracts with Canadian firms for supplies for her armed forces. In the earlier years vegetables, except potatoes, were not blanched. Consequently, the role of those enzymes present in unblanched vegetables on the loss of flavour during storage had not been recognized. Further, although the round-the-world shipment and stored dehydrated products were analysed for moisture and ascorbic acid content after the six months' storage period, they had not been given an initial analysis. Therefore, the significance of moisture difference between pack types and between lots from the two storages was not recognized. In contrast, dehydrated apples with two to three times the moisture content of these vegetables kept well in storage. However, in the three-year interim some knowledge had been gained on these points, the inhibitory effect of blanching on enzymes and the value of gas-packing and low moisture content.

The dehydration tunnel at the Kentville Station was used for the initial experiments. Dehydrated vegetables produced at that laboratory were tested for cooking quality, and duplicates were packed in air and nitrogen and shipped to the Division of Horticulture for storage tests and further examinations. From these initial experiments and examinations of the stored material, sufficient valuable information was obtained which served as a guide to the industry in methods of production and handling. However, much more information was needed on this method of food preservation; information that would ensure highly nutritious palatable vegetables with a reasonable storage life.

Equipment for Experiments

A dehydrator, single tunnel of the forced draught type, was built at the Ottawa laboratory in 1942 and was ready that fall for experimental runs. During the last four years of World War II, the laboratory worked intensively on vegetable dehydration. Larger quarters and a second tunnel were ready early in 1944. This second tunnel was a two-stage model with a primary end utilizing a parallel air current and a secondary end with counter current. This was essentially a scale model with one-fortieth the production capacity of the commercial dehydrator.

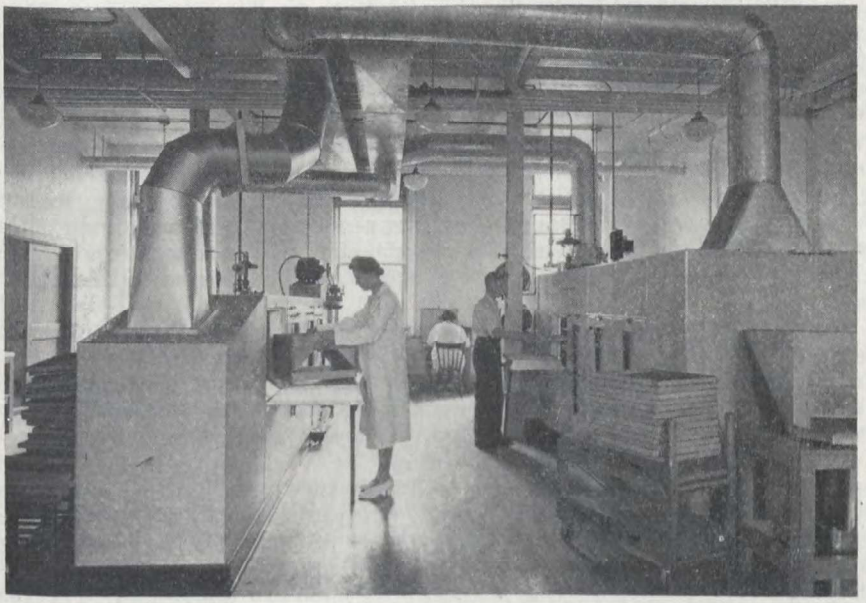

Fig. 31—Experimental tunnels in the dehydration laboratory.

Controlled storages of 100°, 80°, 65°, 32° and 0°F. had been available from 1942 on. In addition, fluctuating laboratory temperatures were used. The 100°F. storage was used for accelerated trials, and the remaining temperatures were for testing the effects of summer, warehouse, cold and freezing storage on the products.

The laboratory was equipped with preparation machinery, peelers, slicers, dicers, strippers, a batch-type steam blancher, a water blancher and a special blancher for SO_2 treatment of potatoes.

General Procedure

More than 2,000 experimental runs were made. The dehydrated material was analysed, then generally packed in air, nitrogen or carbon dioxide, placed at the several storage temperatures and withdrawn at definite periods. These stored samples were first analysed for oxygen and carbon dioxide content, then the cooked products were subjected to palatability assessments. Aliquots or duplicates of the dry material with the same oxygen content were analysed for moisture and vitamin contents. If the material had been given certain pre-treatments, other chemical analyses were made. Frequently a whole series—fresh, processed, dehydrated and stored—also underwent microbiological examinations. Commercial material in bulk lots was obtained, repacked and subjected to the storage trials.

Field of Investigation

The bulk of the material dehydrated commercially under contract was cabbage, carrots, potatoes and turnips with smaller quantities of other vegetables. Experiments on all phases of dehydration and on storage were conducted on these four vegetables and on parsnips, string beans, spinach, asparagus, cauliflower, beets, corn, peas, onions and sauerkraut. In fruits, work was done on apples, blueberries and rhubarb.

Preparation experiments, pre-treatments, peeling methods, blanching, periods of drying, tunnel conditions such as air velocity, per cent R.H., one-, two- and 3-stage drying, "ripening" and moisture equalization were all investigated. The use of SO_2 in vegetable dehydration, its role in the retention of colour in potatoes and in green vegetables; its effect on the vitamins, ascorbic acid, B_1 and carotene, were assessed.

Blanching

Effect of Enzymes.—In the first examinations of both the dehydrated material from Kentville and early commercial products, it was discovered that although most of the samples were catalase- and oxidase-negative, some were peroxidase-positive. Some samples of commercial material were even catalase-positive. Those samples with the positive enzyme reactions were lower in palatability and the catalase-positive commercial carrots were bleached and stale.

In the blanching process, it was found that if the treatment was at that temperature and of sufficient duration to give a negative reaction in the test for peroxidase, the treatment was more than adequate for catalase-oxidase inactivation. Therefore, a factor in attaining quality and extending longevity was efficiency of blanching as measured by enzyme inactivation.

The storage trials of unblanched and of variously blanched vegetables confirmed the initial findings on the importance of blanching. Unblanched vegetables lost their palatability very early in storage life. Over-blanched vegetables were difficult to dry, lost a greater proportion of their soluble solids during the blanching process and did not keep so well as those blanched to that point at which there was only a trace of peroxidase remaining. The role of enzymes is discussed in detail in "Modern Dehydration of Foods. II. Variables Affecting Storage" by M. MacArthur. Can. Chem. & Proc. Ind. 28: 525-527. Aug., 1944.

Plant Test.—A quick, semi-quantitative test for peroxidase was necessary for plant use. Briefly, the test is based on the presence or absence of colour change in either the blanched, cooled product or the refreshed dehydrated product. It is made by adding five ml. of a two per cent tincture of gum guaiacum or a one per cent alcoholic (50-95 per cent) solution of guaiacol to five c.c. of material in triplicate and covering with an equal volume of one to three per cent C.P. hydrogen peroxide. The amount of colour change developing in the vegetable in five minutes is an indication of the peroxidase content. No change indicates a negative content of the enzyme. It must be stated that although these tests have a definite value for estimating the peroxidase content, they do not have absolute specificity. Certain other compounds also present in some vegetables react with the test materials to give the same colour change as occurs with peroxidase. Corn, turnips and certain squashes are three vegetables which after steam blanches of 10 to 15 minutes at 212° F. still give a slight to definite, positive reaction. However, in most cases the colour change due to these so-called aldehydes is insignificant in the designated initial five-minute period. The method of testing which has general applicability may be found in "Dehydration of Fruits and Vegetables in Canada" by C. C. Eidt, Mary MacArthur and M. B. Davis. Food in Canada, 2:20-24. Nov., 1942.

Moisture Content Requirements

Low Moisture Increases Storage Life.—It became evident early that rapid dehydration to a low moisture content was necessary. One example of this is the difference in keeping quality of cabbage under accelerated trial. The samples with a moisture content adjusted to 7·5 per cent reached the threshold of palatability in one month while those redried to 3·5 per cent moisture had a longevity of six months. Similar results were found with other vegetables. Moreover, with storage deterioration the moisture content of the hermetically-sealed samples increased. Such increases were quite measureable in air-packed products at accelerated storage.

The effect of moisture content on the keeping quality is given in more detail in "Advances in Canadian Vegetable Dehydration, I. Cabbage" by Mary MacArthur and F. B. Johnston. Food in Canada, 5:23-24, 26, 28, 30, 32. May, 1945, and "II. Carrots", by the same authors, Food in Canada, 5:25-30. July, 1945.

Moisture Reduction During Dehydration.—In the tunnel dehydration, moisture loss of the blanched vegetables is rapid in the first stages, but slows up with time. Experimentally, cabbage was reduced from 93 to 7 per cent moisture in the primary tunnel in 100 minutes at 170° F. with a parallel air-flow of 1,000 l.f.p.m. Reducing this same cabbage from 7 to 4 per cent moisture required an additional 100 minutes in the secondary tunnel at 135°-140° F. with counter-current air-flow of 700 l.f.p.m. plus 100 minutes at 140° F. in a through-flow tunnel with through-flow of 250 l.f.p.m. Potatoes were reduced to 7 per cent moisture in two hours at 184° F. plus three hours at 154° F. Generally lower finishing temperatures for potatoes are necessary and in a five-hour drying period with 2·5 hours at 170° F. plus 2·5 hours at 137° F., the moisture content was 10 per cent. This moisture is too high for a good keep, but the experiments indicate the extension of the drying period required to reach satisfactory low moistures at lowered finishing temperatures.

The change in temperature during drying is necessary when the lower moistures are approached and the "critical temperature" of the product is reached. Otherwise scorching results. The details of the operation of a vegetable dehydrator for drying various products is given in "The Mechanics of Dehydration" by C. C. Eidt, Food in Canada, 3:14-16. Feb., 1943, and "Modern Dehydration of Foods. I. Historical and Physical Aspects" by C. C. Eidt. Can. Chem. & Proc. Ind. 28:523-525. Aug., 1944.

Infra-Red Drying.—The possibility of drying by the infra-red method was examined. Blanched cabbage and potatoes were tested in an infra-red cabinet. This, of course, was batch drying. In exposure to infra-red rays a product or material is heated throughout, internally as well as at the surface. In the conventional dehydration tunnel where the trayed product is exposed to a heated air blast the surface of the product is heated and as it dries, moisture is drawn from the centre of the layer and is, in turn, evaporated. Although internal and surface heat of infra-red heated material are approximately equal, the outer layers of the trayed vegetables in these experiments were always scorched before drying was complete. This was probably due to the surface unevenness; that is, thickness differences in the layer. It appears that infra-red drying is suitable for a thin even-surfaced homogeneous mass, such as a layer of paint or enamel but is not suitable for drying a one- to four-inch layer of loosely packed, blanched vegetable tissue.

Redrying Methods.—Tunnel redrying to a low moisture content was quite satisfactory if this was done immediately after moisture equalization, but redrying products one to two weeks after the initial dehydration lowered the palatability. The use of silica gel in cabinet redrying was too slow and even with care the silica gel became contaminated with vegetable particles. An

effective method of obtaining low moistures on a laboratory scale was the insertion of a container of anhydrous CaO in the packed tin, but this was useful only when, for example, it was desired to lower the moistures slightly as from five to three or from four to two per cent. The CaO container required too much of the volume of the package and there was always the danger of CaO sifting into the product.

Rapid Method of Determining Moisture Content.—Because of the importance of low moisture for keeping quality it was essential that the industry be provided with a quick, accurate method of moisture determination. The method put into practice was "Rapid Moisture Determination in Dehydrated Vegetables" by F. B. Johnston. Can. Chem. & Proc. Ind. 27:100-102. Feb., 1943. It is basically a 15-minute chloroform distillation of a definite weight of ground material passing a 100-mesh sieve. Most vegetables require 15 minutes but potatoes are distilled 50 minutes.

Preparation Losses

Peel and Trim Losses.—With the high costs of the raw vegetables, it was necessary that the preparation losses be cut to a minimum. With root vegetables the greatest losses are in peeling. In experiments on losses by peeling and trimming potatoes, loss by abrasive peel averaged 24·7; by steam, 18·4; by lye, 16·5 and by brine, 8·0 per cent. However, heat peeling of potatoes—that is by steam, lye and brine—tended to discolour the outer portions of the tuber, the temperature below the surface being at the optimum for enzyme activity and consequent discoloration. Discoloration occurred in abrasive peeled potatoes but this was superficial and generally easily controlled. A dip in a 0·2 per cent sodium sulphite solution after peeling was usually sufficient to hold the colour for half an hour. Detailed results on peeling experiments may be found in "The Peeling of Fruits and Vegetables for Processing" by C. C. Eidt and Mary MacArthur. Food in Canada, 4:31-35. July, 1944.

Losses in Soluble Solids.—Other preparation losses are losses of soluble solids during blanching and cooling, and in stripped potatoes, losses of starch granules from the cut cells of the unblanched material and the loss of gelatinized starch which must be washed from the blanched strips to prevent case-hardening during drying. Up to about 15 per cent of the dry matter of the peeled potato may be lost during the washing and blanching. No attempt was made to analyse chemically the collected condensate during the steam blanching of vegetables (potatoes were water blanched generally). Therefore, losses in sugars, proteins and the minerals were not determined. However, total leaching losses by blanching ranged from 0·12 to 0·5 per cent of the prepared weight

Vitamin Losses.—Losses of certain vitamins during blanching and drying were determined. Ascorbic acid, a water-soluble and heat-labile vitamin, was lost to a greater degree in water blanching than in steam blanching. Less ascorbic acid was lost when a sulphite salt or sulphurous acid was used as part of the preparation process, but when SO_2 treatments were part of the processing, the B_1 content was either reduced or completely absent in the dried product. In potatoes subjected to cold sulphite dips of varying periods prior to blanching, when the SO_2 content of the dehydrated product was 90 p.p.m., B_1 retention was 75 per cent; with an SO_2 content of 125 p.p.m., retention of B_1 was 50 per cent and with 200 p.p.m. SO_2, the B_1 retention was 15 per cent. Blanching in sulphites, sulphurous acid or a combination of these solutions to give 100 p.p.m. SO_2 in the dehydrated potatoes reduced the B_1 content to a range of 30 to 10 per cent of its original value. Frequently, blanching in such solutions to give 125-200 p.p.m. SO_2 meant only traces of B_1. Although B_1 analyses of refreshed and cooked SO_2-treated potatoes were not made, it

might be reasonable to expect that during these final preparations the B_1 content would be further reduced.

Ascorbic acid losses in 1942 at commercial plants during all dehydration operations—that is, preparation, treatments, blanching and drying—amounted to an average of 47 per cent for cabbage, 50 for turnips and 34 for potatoes. Losses at the laboratory were considerably lower. From 1943 on the commercial plants used those methods of dehydration worked out by the laboratory. These may be found in "Methods of Dehydrating Vegetables" by C. C. Eidt and Mary MacArthur. Food in Canada, 3:22-25. March, 1943.

Carotene is not soluble in water and is stable to heat. This was reflected in the frequent 100 per cent retention during processing, although losses up to 23 per cent did occur. Details on losses during dehydration were published in "Factors Affecting the Quality of Dehydrated Vegetables" by M. B. Davis *et al.* Proc. Inst. Food Tech. pp. 90-98, 1942, and in "Food Value and Keeping Quality of Dehydrated Vegetables" by M. B. Davis and Mary MacArthur. Food in Canada, 3:11-13. May, 1943.

The Role of SO_2 in Dehydration

Colour Control in the Potato.—The effect of sulphuring dehydrated apples on the retention of colour was well known, and the process was adapted for control of colour in the potato, not only for the peeled raw potato but also for control during dehydration and storage. Sulphurous acid and sulphite solutions were used during blanching. Potatoes with 150-200 p.p.m. SO_2 in the dried product held their colour during storage and in soaking and cooking for the table. This amount left no SO_2 flavour in the cooked product; 250 p.p.m. SO_2 in the dry product was detectable without seasoning in the cooked; 350 p.p.m. was definite in the cooked but could be covered up by seasoning, while 400 p.p.m. was excessive and could not be disguised without heavy seasoning. The procedure for incorporating SO_2 in potatoes was outlined in a mimeographed leaflet, "Sulphiting Directions for Potatoes" by H. C. Aitken.

Colour Retention in Green Vegetables.—Much of the early green vegetables were dull in colour when dehydrated and brown tinges were apparent in the cooked product. It was found that sulphite dips of the prepared product prior to blanching gave a much better colour. The same results were obtained with Na_2CO_3 dips, but products treated with Na_2CO_3 were often excessively softened, flat in flavour and low in ascorbic acid. Minimal sulphite treatments for colour and ascorbic acid retention which would not impart an SO_2 flavour to the cooked dehydrated product were worked out and supplied to the trade. The procedure for sulphiting green leafy vegetables may be found in "Methods of Dehydrating Vegetables" by C. C. Eidt and Mary MacArthur. Food in Canada, 3:22-25. March, 1943.

Method of Determining SO_2 Content.—In order to enable the plants to determine the SO_2 content of their products, which content must fall within certain limits, a method utilizing inexpensive apparatus was evolved. By the method, "Determination of Sulphur Dioxide in Dehydrated Vegetables and Fruits" by F. B. Johnston. Can. Chem. & Proc. Ind., 28:568-569. Aug., 1944, the SO_2 content was calculated from the titration of the distillate from a weighed amount of ground and sieved dehydrated product.

Microbiological Aspects of Dehydration

The Division of Bacteriology and Dairy Research of the Department of Agriculture co-operated with the Fruit Products Laboratory in all experiments. In both the laboratory and at commercial plants, heavy loads of microflora were found at first in sulphited cabbage. The contamination occurred when sulphiting after blanching was practised. Steam cleaning of the sulphiting tanks was not

sufficient to eliminate the heavy load, and the technique for sulphite dips prior to blanching was worked out. This alteration in processing procedure was successful in reducing the microbial load. Laboratory and plant investigation on other phases enabled the bacteriologists to indicate that certain faulty practices resulted in high microbial counts in the finished product.

With the correction of the practices a marked decrease in contamination occurred; that is, only 40 per cent of the samples in 1939 were under 50,000 per gram whereas 97 per cent of the samples were under that count in 1945-46 and similar improvements were found in the coliform content. The improvement and the methods of acquiring better quality are outlined in "Microbial Aspects of Dehydrated Vegetables and Fruits" by A. H. Jones, Food in Canada, 3:16-23, July, 1943, and "Quality Control Effects Improvement in Canadian Dehydrated Vegetables" by A. H. Jones and M. E. Pierce, Food in Canada, 6:30-32, Nov., 1946.

Plant Test.—The plant laboratories were guided in their effort to reduce the loads by simple plant tests which enabled them to get a rough estimate of the bacterial load in their products. The details of the plant tests are outlined in "Plant Tests for Determining the Microbial Content of Dehydrated Vegetables" by A. H. Jones and M. E. Pierce. Food in Canada, 5:18-22. Dec., 1945, and "Methods for the Bacteriological Analysis of Dehydrated Vegetables", a mimeographed leaflet prepared by the Division of Bacteriology and Dairy Research, July, 1945, for plant use.

Gas Packaging

Superior Quality of Gas-Packed Vegetables.—The value of packing the dehydrated products in an inert gas was realized very early. In February, 1942, after three months' storage, air- and N_2-packed products at 100° and 32° F. were withdrawn for examination. Air-packed samples at both temperatures were lower in palatability and vitamin content. The effect of air versus inert gas packaging was particularly striking in carrots. For this vegetable the atmosphere of the pack was more important than the temperature of storage, but proper blanching of carrots was also important. Unless blanching was to that point at which only a trace of peroxidase remained, the keeping quality was inferior.

Specifically, gas packing delayed the onset of discoloration, off-flavours, off-aromas and vitamin losses. Thus it made possible an attractive, palatable product of high food value for a considerable time after processing. What was actually accomplished in gas packing was replacement of air with an inert gas. Since it was essential to have as low an oxygen content as possible it was necessary that the gassing procedure be executed with maximum efficiency. It was also necessary that the operation be carried out at the plants. Therefore, a method of packing suitable for plant use had to be devised.

Method of Gas-Packing.—As the containers for export were large, 5-gallon size, collapse of the packages was prevented by placing them in a vacuum chamber or "iron lung" and drawing the vacuum. At first, a small hole was punctured in one corner of the can. This was soldered when the can was removed after displacement of the air by the gas. Later, unsealed containers with the can covers covering the opening but held up by a wedge were vacuumized and gassed. On removal from the lung the wedge was withdrawn and the can sealed automatically. The method of gas packing for plant use was prepared by W. R. Phillips. Although this was not published, the mimeographed instructions, "Gas Packing Methods for Dehydration Plants", was supplied to the industry.

Method of Gas Analysis.—Since in the contracts with Britain, gas packing was obligatory for certain vegetables and since the maximum oxygen permitted in gas packing was two per cent, a quick method of determining the oxygen content of the pack was necessary. The method put into practice, "Simple

Methods for Determining Oxygen in Gas-Packed Dehydrated Vegetables" by C. C. Strachan, Food in Canada, 2:11-13, May, 1942, utilized portable apparatus. Inspectors supplied with this equipment were able to conduct the analyses at several plants. Laboratory apparatus was designed by F. R. N. Conlin of the Divisional staff for both the gas packing and gas analyses of the experimental packages, generally 28-oz. tins. The details of this apparatus are described in the above article.

Containers

The packaging of dehydrated vegetables is vitally important. Since a low moisture content is imperative for keeping quality, the container must of necessity be moisture-vapour proof. Moreover, as longevity of the product is increased when an inert gas (N_2 or CO_2) is used, the package should be gas- or air-tight so that the oxygen of the external air cannot replace the inert gas atmosphere of the pack.

At first the export container used was a 5-gallon plug lid tin with a soldered over-cover (cap). To speed up packaging technique and to avoid high costs of labour and solder, investigations were started in co-operation with the American Can Company to develop an automatic closing seamed lid. The container developed eliminated much of the gas leakage troubles encountered with the hand sealed type.

During this period of development the short supply of tin plate threatened to become very serious. Containers made of bonderized iron were tried. Because of soldering difficulties these were not satisfactory for vegetables requiring gas-packing, but they were used for potatoes. Fortunately, sufficient tin plate was available to supply the needs of the wartime dehydration industry for those vegetables requiring gas-packing.

The dehydrated vegetables were filled into the containers through a chute and settled by rocking, since ramming or pounding broke up the material excessively.

Investigational work to locate a satisfactory substitute for the metal container was carried on, but none was found that was absolutely moisture-vapour proof and gas-tight. However, with products packed for domestic use and placed in short controlled storage until release, and then with a quick turn-over, certain moisture-vapour-resistant materials were of value. Foils were of definite value but presented problems in gas-packing because gas leakage occurred at the seams when even slight pressure, as pressure from the weight of a low stack of packages, was exerted.

Compression of Dehydrated Vegetables.—Compression of vegetables, especially with packaging of the compressed blocks in tin, was of very definite value in decreasing metal weight, container cost and shipping space. All were important in the war economy with tin in short supply and shipping space at a premium. The vegetables had to be heated slightly. This rendered them plastic and cut down breakage during compression. Atmospheric volume in the container was reduced since generally a four-fold volume of compressed product could occupy the same space. In an ungassed tin of compressed dehydrated vegetables the ratio of oxygen weight to weight of product is decreased. The effect of this decrease of oxygen in experimentally packed carrots was parallel to the effects of gas packing on the palatability, carotene content and longevity. However, in Canada, the compression of dehydrated vegetables did not go beyond the laboratory stage because of the difficulties of the machine tool industry in apportioning time, manpower and steel in time of war for turning out the necessary industrial machinery. The experimental compression of potatoes was unsatisfactory. Either excessive breakage occurred or a higher moisture content plus heat was necessary to render them plastic for compression purposes.

This necessitated redrying the blocks to ensure a long keep. In preparation for the table, disintegration of heavily compressed blocks of potatoes was difficult even with long boiling periods.

More details of the packaging and compression experiments at the Division of Horticulture appear in "Packaging Methods for Dehydrated Vegetables" by M. B. Davis and W. R. Phillips. Food in Canada, 3:23-25. Apr., 1943.

Fruit Dehydration

Blueberries.—Certain areas of Quebec, New Brunswick and Nova Scotia are large producers of native blueberries. These are generally shipped in the fresh or frozen state. Frequently, because of softness, moulds develop. Losses could be avoided by processing at the areas of production. Canning is one method of preservation but in wartime, tin was in short supply. The laboratory developed a method of dehydrating the fruit which could then be packed in boxes lined with waxed paper. In such a container the fruit held initial quality for extended periods. The laboratory method was tried out in a commercial plant in the Lake St. John area of Quebec. The blueberries were dried to 12-14 per cent moisture with a drying ratio of 5·8:1.

Dehydration of huckleberries and high-bush blueberries in the United States at this time required 13 hours or longer. The new Canadian treatment permitted drying of the fruit in three and one-third to four hours. The treatment was a controlled two-second 0·3 to 0·47 per cent lye dip at 200° F. before traying and drying.

The drawback to dehydrated blueberries is their refreshing value. Just as with vegetables and most fruits, the moisture removed during dehydration is usually not completely replaced during refreshing. In most cases the weight of the cooked drained product is approximately 50 per cent of the fresh. Market prices of dehydrated blueberries are necessarily much higher and this is a definite deterrent. However, these dehydrated blueberries have a long shelf life. Packaged in wax wrapped cartons they were still palatable with two years' storage at laboratory temperatures. At eight months dehydrated blueberries were superior to blueberries frozen in six-quart baskets and stored the same length of time. The details of the work on blueberry dehydration may be found in "Dehydration of Lowbush Blueberries" by C. C. Eidt and Mary MacArthur. Food in Canada, 4: 22, 26, 28. Dec., 1944.

Rhubarb.—In the rhubarb dehydration experiments, an exceptionally good product was obtained when the raw rhubarb was sliced in a Sterling bean slicer. Dehydration was rapid. Moisture was reduced to 4·0 to 5·0 per cent in three hours in a two-stage tunnel. The product did not require a refreshing period. Merely adding hot water and then bringing to a boil and cooking with sugar as fresh rhubarb gave a very good sauce. However, this rhubarb sauce was similar in appearance to cooked sieved fresh rhubarb. When rhubarb was sectioned, then dehydrated, the cooked individual pieces were somewhat tough; that is, the re-absorption of water was not as efficient. These products kept well in waxed paper bags. Sealing hermetically was not necessary.

Apples.—The dehydration of both apple rings and sections after a pretreatment in sulphite solutions gave a product quite as satisfactory as treatments with gaseous SO_2. Stored sulphited dehydrated apples retained the original colour except when placed in accelerated storage, 100° F. With low moisture contents the sulphited apples had a long keep, but these low moisture apples required a long cook. A deterrent to treating in sulphite solutions is the danger of slight to severe "inky" discoloration in the drying apple. Iron contamination in the processing water increases the hazards of discoloration.

Fruit Juice Products

At the time of publication of the 1931-33 Progress Report, the laboratory had perfected a method for the manufacture of bottled cider in closed curveé using commercial equipment available without royalty rights attached, and had also been investigating the possibilities of apple by-products. The details of cider manufacture may be found in "The Manufacture of Sweet and Fermented Cider by the Closed Curvée Method" by M. B. Davis, Fruit Prod. Jour. 12:294-298, 315. June, 1933. About this time, fruit production in Canada had increased. This necessitated more rigid grading which created a demand for an outlet other than the fresh fruit market for the lower grade and cull fruit. Since fruit juices appeared to offer an opportunity, the laboratory undertook the following investigations: (1) Development of a method for the manufacture of a satisfactory cider from Canadian apples; (2) Examination of the vintage quality of Canadian varieties; (3) Exploration of the possibilities for utilization of fruit juices; and (4) Solution for difficulties in bottle sterilization, pectin cloud, enzymatic control and related problems.

Cider

Ciders prepared in the 1933-34 season darkened in the bottle, were cloudy or opaque, and harsh in flavour. Fined lots showed less sedimentation than unfined lots. Calcium carbonate as a neutralizer in the reduction of acidity had no ultimate effect. High alcohol content (12·65 per cent) did not have any effect in reducing the objectionable flavour. The conclusions were that the detrimental changes were caused by the action of enzymes which were not removed in the sterilization filtration.

With this in view juices were treated with Pectinol A to coagulate the major portion of the pectic matter. After coagulation the juice was clarified and fermented. At the desired stage of fermentation, filtration was followed by flash pasteurization at 165°-170° F. and passed to the cooling tank. The cider was bottled by the established method. At cellar storage no sediment occurred; at 90°F. a slight sediment appeared, but at both storages the flavour was excellent. Trials on the desirable amount of fermentation for sweet cider indicated that a ten point drop in specific gravity was the maximum for retention of fresh fruit flavour.

Frozen Juice for Cider.—With batch production of cider, freshly pressed apple juice is not always available. The feasibility of using frozen juice was studied. The frozen product was quite satisfactory, for with five months' freezing storage the sp. gr., acidity and per cent tannin was practically the same as before freezing.

Discoloration, Sedimentation and Their Control.—Since a greenish discoloration appeared in some of the ciders, it was suspected that there was copper contamination. This proved to be the case and the different pieces of machinery used for cider processing were investigated to determine their effect in increasing the copper content. Centrifuging removed copper as expected. Most of the contamination occurred in passage through the filter plates, especially where the silver plating was worn to the copper base and when the speed of filtration was slow.

In studies on obtaining absolute sterility in cider processing, the Seitz germ-proofing filter was efficient up to pump pressures of 24 pounds. No contamination resulted from the Seitz sterilizing filter or the bottling machine when these were steam sterilized before using and no contamination occurred from the air filter. The sources of contamination were in the crowns and in

bottle sterilization. Air pockets during sterilization of these were the chief offenders but inefficiency of the caustic rinse of new bottles, especially at low temperatures, also contributed.

Although darkening of bottled ciders was entirely controlled by flash pasteurization (two minutes at 170° F.) prior to bottling, sedimentation still occurred.

In bottle washing, a chlorine rinse was used as the final stage of sterilization. In studies on the effect of chlorine concentration in the rinse with its consequent increase of residual chlorine in the bottle, increasing the concentration always meant that a sediment was thrown down in the bottled cider. Moreover, with the higher concentrations, sedimentation occurred earlier. A limit of 250 p.p.m. chlorine in the rinse followed by efficient draining avoided this sedimentation.

Sedimentation was then controlled by:

1. Treatment of the fresh juice with Pectinol A,
2. Flash pasteurization for two minutes at 170° F. under anaerobic conditions,
3. Prevention of contact of the cider with metals or minerals it is able to dissolve and,
4. Thorough rinsing or draining of the bottles treated with chlorine solutions.

Sterilization.—When difficulties were being experienced in achieving complete sterilization, several processes purported to give the desired results were investigated. Among these was one based on sterilization by ionic silver. In the exhaustive tests it was discovered that not ionized silver but low temperature pasteurization was the effective agency. Studies on low temperature pasteurization were continued and the results enabled the simplification of processing certain types of cider. Pasteurization prior to bottling at 140° F. for four minutes with processing of the cooled bottled product by a gradual rise to 135° F. and holding for 30 minutes at that temperature eliminated the need for sterility of crowns and for chlorine treatment of the bottles. These ciders so treated did not throw down any sediment and retained excellent flavour. The advantages over the cold sterilization (sterilizing-filtration) method for those cider types where heat treatment could be used were:

1. Economy in the use of coarser filtering films,
2. More body and flavour in the cider as a result of rougher filtration,
3. Elimination of sterility requirements in equipment and container, and
4. Increase of stability in the bottled cider.

Cider Apples.—From the earlier investigations on suitability of apples for cider processing, it was known that high sugar content coupled with an acidity of about 0·5 and tannin about 0·1 per cent were desirable features. In the first series of tests on the suitability of Canadian apples, three Rosthern seedlings gave juices with these desired characteristics. In co-operation with the Quebec government thorough trials were made on the value of Quebec-grown apples. In most cases juice from a single culinary or dessert apple variety did not give a good cider, but blends of juices could be adjusted to give better products. Deficiency of tannin can be corrected by the addition of crabapple juice. The best Canadian ciders were made from blends of culinary or dessert and bittersweet types.

Methods of preparation and processing the various types of fermented cider were perfected. The several methods may be found in "The Preparation of Fermented Ciders" by R. W. Arengo-Jones. Fruit Prod. Jour. 20: 300-303, 321; 338-9, 353, 355. 372-374. June, July and August, 1941.

Carbonation of Cider.—In the preparation of sparkling ciders there was occasionally a need for carbonation of the product, especially when dry ciders were being handled and it was not desired to re-ferment. A method for carbonation with dry ice or solid CO_2 was developed to replace carbonation with compressed gas. The new method was so simple that the laboratory adopted it almost exclusively in cider carbonation. The method is described in "Carbonation of Cider with Dry Ice" by R. W. Arengo-Jones. Fruit. Prod. Jour. 18:297. June, 1939.

Cider manufacture is a latent Canadian industry. There are two main impediments to full scale industrial processing. The first is that it is an alcoholic beverage and as such comes under liquor control regulations. Second, cider as a beverage is little known in North America. This lack of familiarity has meant a decidedly limited demand.

Vinegar

Since vinegar is an important juice product of the apple the manufacture of this commodity was also explored. The method of manufacture is included in the cider article. Although cider vinegar is one of the best flavoured of the vinegars, the brownish colour is a sales deterrent. A process, "The Production of Distilled Cider Vinegar" by R. W. Arengo-Jones, Canadian Food Packer, 12:13, June, 1941, was developed by the laboratory whereby cider vinegar is vacuum-distilled to give a colourless product. There is a 98 per cent recovery with virtually no loss in acetic acid strength and the distilled product retains the flavour, aroma and softness of cider vinegar. Several Canadian plants produce distilled cider vinegar by the method developed in the laboratory.

Apple Juice

Fining.—Small lots of "still" apple juice were occasionally prepared when cider was made. Indifferent success resulted from the first enzyme treatments of the fresh juice for the precipitation of the pectinous compound. Experiments showed that the enzyme preparations were variable. Gelatin-tannin treatments for the same purpose—gelatin to precipitate the pectin and tannin to replace the natural tannin thrown down during pectin precipitation—often resulted in a juice of lighter colour, but at the sacrifice of some of the flavour. With stabilization of the enzyme preparations by the supply companies enabling duplicate reactions, and when juice was not too highly fined if gelatin-tannin was used, either the enzymic or the tan-gel treatment could be used with excellent results.

Sterilization.—At first apple juice was sterilized by a filtration method but this was not always satisfactory. Frequently the juice lost its clarity and deteriorated in flavour. Flash pasteurization prior to sterilizing-filtration overcame these defects but it was still difficult to bottle the juice under completely aseptic conditions. After-processing the bottled juice gave a stable, sterile product.

The three steps to get sterility in bottled apple juice—flash pasteurization, sterilizing-filtration and after-processing—meant that the total processing period was long and each step naturally reduced the fresh flavour. The laboratory made a steam jacketed, flattened block tin flash-pasteurizer which solved the problem. Both sterilizing-filtration and after-processing could be eliminated when filtered juice was flash-pasteurized 10 seconds at 180° F., filled hot into bottles and capped without headspace at once.

Containers.—Mainly because of breakage, bottles were not completely satisfactory, so a search was made for other suitable containers. Plain cans effectively coated with mineral oil resisted corrosion, but there was always danger of an oil scum on the juice. Untreated plain tins corroded, and the

R-enamelled cans picked up a distinct flavour from the lining. Finally, re-enamelled Type L charcoal tins were found to be the most suitable.

A complete bulletin on apple juice processing was prepared. The bulletin, "The Preparation and Preservation of Apple Juice" by R. W. Arengo-Jones, appeared in The Fruit Products Journal, 19: 327-330; 356-358, 375, 377. July and Aug., 1940 and 20: 7-9, 23; 47-51. Sept. and Oct., 1940.

Immediately after solving the difficulties in apple juice processing, canning lines for this product were designed for several Canadian plants. The laboratory provided supervisory assistance during their construction, installation and at the initial operation. Establishment of these plants in 1939 and 1940 and of many others since that date has necessitated the grading of apple juice. Quality is based mainly on specific gravity and flavour. At first the laboratory assisted the Marketing Service in routine testing of all Canadian produced apple juice. This assistance is now generally limited to those inspectors serving plants in Ontario and Quebec.

Fortification of Apple Juice.—In the early years of World War II, as a result of the paucity of citrus juices on the Canadian market the laboratory at Kentville initiated experiments on fortifying apple juice with ascorbic acid as a move towards supplementing the alimentary intake of this vitamin. In a series of co-operative experiments by the Dominion laboratories at Kentville and Ottawa and by Macdonald College, methods of fortification and handling that would ensure a definite ascorbic acid content for at least one year after processing were developed.

A patent was taken out and assigned to the Dominion Department of Agriculture. This is a service patent only and as such merely regulates fortification and protects consumers. During the war years fortification of tinned apple juice was mandatory. A number of Canadian plants have since continued to fortify their apple juice because of public demand for this type. Details on vitamin C fortification may be found in "Vitamin C Fortification of Apple Juice" by F. B. Johnston. Fruit Prod. Jour. 22:195-197. March, 1943.

The apple juice industry of Canada has expanded to a present annual production of approximately three and three-quarter million gallons.

Apple Syrups and Esters

Initially, Stark apple juice was used for the experiments. The acidity of the juice was reduced with $CaCO_3$, then Pectinol-treated, filtered, but not pasteurized, and sugar added. The sugared juice was concentrated under vacuum to sp. gr. 1·320. In the series, the syrup with 20 per cent added sugars, sucrose or glucose to sucrose in a 1 to 1 ratio, was the best.

Pasteurization was investigated next. Either the filtered juice was pasteurized or the concentrate was after-pasteurized, and in one case volatiles (esters) from distilled juice were added to the concentrate before final pasteurization.

Where no pasteurization was employed, the syrups not only developed yeasts and moulds but also threw a sediment within a month. This sediment was caused by the continued action of the Pectinol. Where the juice alone was pasteurized, the syrups developed yeasts and moulds but these did not appear in the after-pasteurized concentrates. Added apple esters definitely improved the flavour.

However, with longer periods of storage, sedimentation occurred in the pasteurized syrups. This sediment was mainly calcium malate. It appeared in those juices treated with $CaCO_3$ for acidity reduction. Such sedimentation did not occur when activated carbon was used for decolorizing and sodium bicarbonate for deacidulation.

These first apple syrups were all the added sugar type, but apple juice concentrates without sugar addition were also made. Some of these were merely

boiled ciders, all of which were dark in colour and highly acid. These were produced commercially as was a decolorized deacidulated apple juice concentrate. Boiled cider and deacidulated apple juice concentrate were used industrially. Only the latter had local consumption as a table syrup.

Some further work on ester recovery from fresh apple juice was done at the Ottawa laboratory in 1939, but the main part of this project and its commercial application was carried out by the Summerland laboratory. One commercial plant in Nova Scotia has been practising ester recovery as an adjunct to apple juice concentration. The esters are used as flavouring agents especially in the bakery and beverage trades.

Berry and Soft-Fruit Juices

The preparation of fruit juice syrups and beverages was a natural adjunct to the work on development of apple juices and syrups. Preliminary experiments on extraction were conducted on strawberries, raspberries and black currants. In strawberries, fermentation of the pulped fruit alone could break down the pectin and still leave a good strawberry flavour in the expressed juice. In the other two fruits the pectin content was so high that the fresh fruit flavour was destroyed by the time pectin was broken down. The most satisfactory product was obtained by heating the pulped fruit to 160° F., pressing, then treating the juice with Pectinol to precipitate the pectin. Syrups of 60° Balling were made merely by adding sugar to the decanted depectinized juice or to the filtered, depectinized juice.

The following year red currant and gooseberry were hot press extracted only. Repeats on hot and cold press extractions were made on strawberries, raspberries and black currants. Slightly higher yields were obtained by fermentation and cold extraction of the first two while cold pressing of the black currants gave an increased yield of almost fifty per cent. In later hot press extractions of black currants, water was added during heating. This facilitated extraction and increased the yield to the equivalent of yields by the cold press method. Syrups, density 55° Balling, made from cold pressed juices clouded in the bottle, indicating incomplete pectin breakdown. Some of the first lots of bottled syrups showed fermentation, which was effectively checked in the later lots by the addition of 200 p.p.m. SO_2.

Since an outlet for such natural syrups is the "Milk Bar" where synthetic syrup is usually the flavour vehicle, an effort was made to interest such establishments in the new products. The natural syrups were admittedly much superior in flavour but the obstacle to their use was the cost. Under conditions prevailing in 1937 the cost of synthetic syrups was so much lower that on the basis of costs alone pure fruit syrups could offer no competition.

Beverages and Nectars.—Nevertheless, the extracted juices had such good flavour that the five were bottled as beverages, using the flash pasteurization process. With five months' storage all juices except strawberry had thrown some sediment, again indicating difficulties with the depectinizing enzyme. The juices retained excellent colour and flavour. Flavour was very pronounced and the acidity was generally too high. Amelioration was effected by adding an equivalent volume of 25 or 30 per cent sugar syrup.

Cherry, peach, rhubarb and cranberry were added to the list tested in 1938. The last three were not good enough in quality to recommend. However, a peach nectar prepared in 1939 was outstanding in quality. Elberta peaches were peeled and pitted, cooked and sieved. An equal volume of 25 per cent sugar syrup was added. The nectar was heated to 170° F., filled into No. 1 tall plain tins and after-processed for six minutes.

The cold press black currant cocktail was also outstanding. The stemmed fruit was crushed, and 0·2 per cent Pectinol was added. After standing three

days the juices were expressed, filtered, water-diluted to one per cent acid and the sugar content adjusted to 15 per cent. The mix was flash heated at 180° F. into enamelled cans. This was the only juice or cocktail that did not throw a pectinous precipitate within six months of bottling or canning.

Cloudiness and Precipitation.—During the war years the laboratory concentrated on dehydration and no further work was done on fruit juices. However, with the harvest following the cessation of hostilities fruit juice investigations were resumed. So far it has not been possible at this laboratory to produce an undiluted juice or a fruit cocktail using Pectinol A at rates up to 0·4 per cent of fruit or juice weight which does not throw a sediment with a year's storage at 50° F. These products become cloudy at 6 to 10 months and sedimentation occurs shortly thereafter. Cloudiness and precipitation were generally avoided by zero storage of the products. These difficulties are not encountered to any extent when the juice is used for fruit syrup in a juice to sugar ratio of one to one. Here the addition of SO_2 has not been necessary. Only very occasionally does a hot press syrup cloud or form a precipitate with upwards of 18 months' storage at 50° F.

Clarification by heating to 190° F. before filtration and gelatin-tannin treatments were tried. Results were quite similar to the Pectinol A treatments.

It is clear that the treatments so far tried have failed to prevent precipitation of pectinous compounds in the fruit juices and beverages. Clouding precedes precipitation and at precipitation some of the characteristic colouring matter of the juice is also thrown down. Further work is necessary before a reasonable shelf life can be guaranteed.

Canning

Investigations in canning were in progress at the laboratory during the latter years of the First World War. A home economist was appointed to the staff of the Division to determine the best methods of home canning. Several bulletins on this subject were published by the Department of Agriculture in the following years.

When the 1931-33 Progress Report was published, varieties of fruits and vegetables grown at the Central Experimental Farm were being tested for their canning and freezing qualities. Varietal work and home canning methods were continued at the laboratory as part of the investigations through 1936. The expansion of other phases of fruit and vegetable processing and the demands of the by-products field necessitated curtailment of investigations on home canning. The home canning section was taken over by the Consumer Service Section of the Department thus permitting this laboratory to devote more time to the requirements of the commercial field.

Tomatoes

Canned Tomatoes.—The sanctions of 1935-36 imposed by Great Britain against Italy created a strong demand in Britain for canned tomatoes. Hitherto, Italy had supplied a large volume of Britain's requirements, and the public taste in this commodity was for the Italian style. The Italian style differed from the Canadian pack in that the fruits were usually whole, firm, small, bland, and usually flavoured with spices such as basil, onion or garlic.

In the 1935 season, an effort was made by some Canadian canners to pack Italian style tomatoes for the British market. A laboratory examination of the three packs, Italian, Canadian-Italian style and standard Canadian, showed that the main difference between the Italian pack and the standard Canadian pack was in sugar content and acidity. The Canadian-packed Italian style was less sweet and rich than the Italian pack. Italian pack tomatoes were uncored, and incised to prevent bursting.

Following this technique, the small fruits of a number of standard Canadian varieties, a Spanish variety, an Italian variety and a small-fruited hybrid were canned. These were examined at the Ottawa laboratory and in London and Liverpool by dealers in such commodities. Results indicated that the Canadian standard varieties could not be packed for export to Britain but that the remaining varieties would find a market.

Tomato Juice.—Because of the variability in quality of the Canadian pack of tomato juice, experiments beginning in 1937 were undertaken to determine what constituted quality in this commodity. Commercially packed juice from all parts of Canada and juice packed in the laboratory were analysed for total sugar, pH, titratable acidity and suspended solids. The samples were judged by colouring, flavour and consistency.

Much variation was found in the quality of the commercially packed samples. Good quality was not associated with any sugar-acid balance, but good flavour was generally found associated with good colour. Exceptions in the laboratory pack were where a poorly-flavoured but highly-coloured variety was used. The colour was found to be affected by the presence of fibrous matter, indicating that the extraction treatment should not be too severe. It was also affected by over-processing; that is, dull brownish colours were produced by over-processing. Juice from unripe tomatoes was poor in colour and had a distinct "core" flavour, but varieties of good canning quality made uniformly good juice if used when red ripe.

Proposed standards for the grading of tomato juice were then prepared for the Fruit and Vegetable Division, which standards were incorporated in the Marketing Service regulations.

Later there was considerable discussion as to the advisability of making specific gravity one of the determining factors in the quality evaluation of tomato juice. For this investigation, samples of the juice with various processing dates were obtained from eight Canadian sources. These juices had been plant-graded as Fancy and Choice on the basis of the regulations in force. Specific gravity was determined on juice and filtrate of each sample. The highest specific gravity was 1·0336; the lowest, 1·0233; therefore, the difference between highest and lowest was 0·0103. The addition of one per cent salt to an aqueous solution increases the specific gravity by 0·0053 and two per cent by 0·0125. Almost two per cent can be added before the saltiness becomes marked, and salt and sugar addition is permitted by regulation. Therefore, unless there was a further regulation defining the maximum addition, it would be possible merely by salt addition to change the specific gravity of a juice sufficiently to move it into a higher classification.

For several years the laboratory has been amassing data on tomatoes. Very good retention of ascorbic acid is possible with modern methods of processing. Therefore, it should be possible by tomato breeding for yield, disease resistance, high ascorbic acid content and canning quality to find varieties which when canned or made into juice will provide a substantial part of the dietary requirements in ascorbic acid. The vegetable breeding section of the Division has this project well in hand.

That tomatoes, canned and as juice, are important from the standpoint of Canadian producer and consumer is evidenced by the 1948 commercial production figures: Nets of over 137·5 million pounds of canned tomatoes and over 190·5 million pounds of juice.

Tomato Juice Concentrates.—Vacuum concentration of tomato juice was studied with the specific purpose of obtaining a commodity of high quality which had been reduced to a fraction of its original volume. This would effect economies in the consumption of tin plate, in shipping and in storage, all important in wartime.

Tomato juice was prepared for concentration by the usual commercial process of mixed varieties. As soon as the juice was extracted by the hot-break, it was taken to the vacuum pan and concentrated. When the desired stage of concentration was reached, the vacuum was broken sufficiently to raise the temperature to 170° F., at which temperature it was filled into cans, sealed and boiling water processed. Concentration caused a partial loss of fresh tomato flavour, a reduction in apparent sweetness which meant a development of sharpness and a change in texture. This texture change was a loss of "graininess" resulting in a smoothness in the suspended solids. The colour was only slightly affected.

Concentration at atmospheric pressure gave a rehydrated product considerably inferior to that from the vacuum concentrate. Lots vacuum concentrated at 28·5 in. were superior to those concentrated at 27 in. The rehydrated vacuum concentrates were quite acceptable to the taste panel. Vitamin C retention was much greater in the high vacuum lots, and amounted to 12 mg./100 c.c. in the rehydrated product.

A solids content of 22·5 per cent could be obtained readily. In trials for a higher solids content by vacuum concentration, the product stuck to the walls of the vacuum pan. Such concentrates were scorched in flavour and inferior in colour. By concentration, the weight was reduced 70 per cent and the volume 74 per cent. The sterilization period was an important factor in quality. Reduction in process time was accomplished by agitator cooking.

Apples

Apple Sauces.—Canned apple sauce had not attained universal popularity in Canada mainly because of the form in which it was commonly prepared and the practice of using any available variety. To improve the product and so popularize it, investigations were undertaken on process and variety to attain that combination of flavour, colour, texture and consistency which would meet with consumer approval.

Eastern Canadian apples were tested. Properly ripened Gravenstein made the finest sauce. Good quality Northern Spy was considered the next in value. Cox Orange made a sauce of intense flavour, and certain early sorts such as Crimson Beauty, Duchess, Transparent, Melba and even Blenheim could be blended to give satisfactory sauces.

Colour is governed by variety and process. For retention of colour and flavour the cooking treatments should be as short as possible and to avoid stackburn the final cooling should be thorough. The most pleasing texture is the "lumpy" type since it more closely resembles home-made sauce, and consistency should be such that it will flow without being "sloppy".

The laboratory developed a process for the "home-made" style of sauce. In brief, it consisted of preparation of the proper variety or blend of varieties, holding the segments in brine to prevent discoloration, washing, blanching just sufficient to inactivate enzymes and soften the fruit for ready crushing, crushing in a roller-crusher, cooking to 180° F. in a steam-jacketed kettle with or without water to adjust the consistency, adding 12·5 to 15 per cent sugar, dissolving and bringing with stirring as quickly as possible to 200° F. or slightly over. If it is filled at not under 185° F., no after-processing is needed; if under this temperature, the processing time depends on the closing temperature. The cooling must be prompt, thorough and rapid.

The process was immediately put into operation by two Canadian manufacturers. The details may be found in "A Process for Canning Apple Sauce" by R. W. Arengo-Jones. Fruit. Prod. Jour. 19:234-235. April, 1940.

Solid Pack Canned Apples.—Much difficulty was also experienced by the canners in the lack of fresh fruit flavour in their solid pack canned apples. This

product is the pie pack and spices were usually added by the bakers to provide flavour. In processing, the usual practice was a cold brine soak of 24 hours or a hot brine soak of about 25 minutes, followed by a steam or water blanch, packing, topping with water, exhausting, closing and processing.

The brine soak removed some air from the intercellular spaces; blanching dissipated the brine, removed more air and wilted the segments enabling firm packing. A 12-hour brine soak followed by a three-minute steam blanch reduced the estimated air space in the segments by about 90 per cent while a five-minute vacuum reduced it even more. A steam blanch of three minutes without previous soaking reduced the air space by about 75 per cent. Samples of apples were canned by the first two treatments. Both lost considerable flavour.

In steam blanching, a condensate is formed. In the experiments, this liquid contained approximately four per cent sugars. A second series of apples was canned after a steam blanch of four minutes at 190°-200° F. Three of the lots were cooled to 135°F. or lower, topped with either the condensate or the diluted condensate, exhausted and processed. A fourth lot was given the same blanch, but was filled hot into cans, topped with the undiluted condensate, sealed and processed. These four lots were definitely superior in flavour to lots given pre-treatments in brine, and the hot-filled lot had the best colour. However, in these four lots there was heavier corrosion of the container than in those lots with brine pre-treatments.

It is quite possible that vacuumizing in an ester-treated condensate followed by a short blanch, filling hot and topping with further condensate would give a solid apple pack of superior flavour. Vacuumizing and blanching would practically eliminate the air in the tissues, and so tin corrosion would be reduced, but the total process would be more expensive.

Cranberries

Special work was done on sauce quality and storage behaviour of upwards of 30 lots of cranberries from New Brunswick, Nova Scotia and Quebec. The best sauce was obtained from fruits with 2·50 to 2·65 per cent acidity (as citric) with a tannin content of 0·5 to 0·6 per cent. Fruit with lower tannin contents usually made flat- or mild-flavoured sauces and those with high tannin contents gave astringent sauces. Cellar storage of low humidity adversely affected the keeping quality of the fresh cranberries so that with 8 to 10 weeks storage there was a range of spoilage from 3·5 to 51 with an average of 25 per cent in 23 lots. In only five of the 23 lots were the unspoiled berries firm after the storage period. Spoilage and shrivelling could not be associated with fruit size or wall thickness.

Other Fruits

Canners stated that the raspberry variety Cuthbert was becoming increasingly affected by mosaic and that no strawberry variety grown in quantity was suitable for canning. In these fruits they desired varieties high in canning quality which would also be suitable for jam of second quality. To meet their requirements, canning tests were made on varieties of strawberries and raspberries from 1934 through 1938.

These samples were examined in the laboratory and the six best of each were shown at the Convention of the National Canners Association. This group in 1937 selected Madawaska and King as the outstanding raspberry and strawberry respectively. These two fruits had good cultural records. At the 1938 convention, King again received favourable comment but although exceptionally good for canning and jams, it is not considered a good marketing variety as it dulls quickly after harvesting. In 1938 Dunlap and Premier strawberries received very good and good ratings although both varieties softened more than King. Rideau raspberry rated good for canning and very good for jam quality while

a numbered seedling, although it rated very good for both purposes, was considered by the canners as having too much blackberry flavour to be classed as a raspberry.

In connection with the fruit breeding program, seedlings and varieties are tested for their canning, jam, jelly and freezing quality when in the opinion of the plant breeder the cultural records warrant such tests. The results of these tests are incorporated in their descriptions of the varieties.

SO_2 Preservation of Strawberries

Large quantities of strawberries preserved in SO_2 were imported annually into the United Kingdom from Holland and other nearby countries. Early in the 1930's Canadian shippers were searching for a suitable formula for preserving their fruit so that they might compete in this market. Experiments were made on strawberry preservation in solutions of potassium metabisulphite, calcium bisulphite and sulphur dioxide gas. Sulphur dioxide gas in solution was used with and without the addition of either calcium carbonate or calcium hydroxide. The first three chemicals provided the SO_2 preservative. Calcium compounds were added to the third for the purpose of firming the fruit.

In appearance, the strawberries treated with the SO_2 gas were cleaner and whiter (better bleached) than those packed with potassium metabisulphite or calcium bisulphite. The addition of calcium carbonate and calcium hydroxide resulted in a greater amount of sediment but this fruit was firmer when made into jam. A sulphur dioxide concentration as low as 200 p.p.m. was satisfactory for strawberries packed in jars but was insufficient for barrel packs.

The limit set on SO_2 content of berries imported into the United Kingdom is 2000 p.p.m. Approximation of this content when packing prohibits the use of either of the sulphite salts as sources of SO_2 since these salts in solution have both free and combined SO_2 and to give 2000 p.p.m. free SO_2 would mean a much higher concentration of total SO_2.

The experience gained and the results obtained permitted recommendations on this method of preservation. Briefly these are as follows:

1. Sound berries of uniform quality and one variety per barrel should be hulled and washed before packing.
2. The barrels should be sound and well coopered, preferably paraffined on the inside.
3. Depending on the variety and condition of the berries, calcium carbonate or calcium hydroxide from 0·03 to 0·07 per cent of the berry weight should be added for firming the fruit.
4. A six per cent SO_2 solution prepared by bubbling SO_2 gas through water should be added to give the mixture of solution and berries a concentration of 2000 p.p.m.
5. Water equal to 10 per cent of the amount of the berries should be measured in.
6. To ensure thorough contact and mixing, the container should be shaken frequently while berries, solution and water are added.
7. The tightly closed barrel should be stored in a cool place one to two days, then any empty space in the container filled either with bleached berries or with fresh berries, but when using the latter, 5·33 cz. of six per cent SO_2 solution per 10 pounds of added fruit should also be added.
8. The container should then be sealed tightly and stored in a cool place until shipment.

The outline of the process, "The Preservation of Strawberries in Sulphur Dioxide" was prepared in 1936 by Wm. Ferguson of the laboratory for the

guidance of processors. Further work on the SO_2 preservation of fruits was undertaken by the Summerland laboratory. A comprehensive article, "Preservation of Fruits with Sulphur Dioxide in British Columbia" by F. E. Atkinson and C. C. Strachan, appeared in Fruit Products Journal, 21, Nos. 1 to 5, September, 1941 to January, 1942. This deals with the methods for several kinds of fruit.

The SO_2 preservation of strawberries has several advantages; low cost, speed of handling fruit in bulk, suitability of the container for bulk shipments, easy removal of the preservative, and period of effectiveness of that preservative. This period is from one to two years which allows ample time for storage, shipment and manufacture. Much of the fruit preserved in SO_2 is for second grade jam manufacture and this type of preservation extends the processing season.

The SO_2 pack has generally increased yearly and over 26 million pounds were processed in Canada in 1946. Until very recently Britain was the largest importer but the present dollar shortage in that country has curtailed imports of this commodity.

Vegetables

Most of the vegetable canning from the year 1934 to the present has been in conjunction with tests on the canning and freezing quality of varieties and, to a limited extent, on the effect of canning on the ascorbic acid content. The vegetable canning industry of Canada is on a very sound basis. The larger canning companies have their own research laboratories as have the several canners' machinery and supply companies. The smaller companies, although they may not have individual research laboratories, enjoy the benefits of research provided by the can companies, equipment and supply firms, and the federal and provincial departments of agriculture.

Freezing

On completion of the original cold storage plant at the Division in 1932, investigations were made on the freezing of raspberries and strawberries for culinary purposes. With few exceptions the freezing of fruit in Canada had been confined to freezing pulp or small fruits in forty-gallon barrels for re-manufacture into jam or for pie-making. For several years loganberries and strawberries had been frozen in British Columbia for the consumer market. The public was not at all apathetic to the new product, but because of lack of advertising and inefficient distribution it did not gain in popularity.

First Eastern Commercial Production

From the result of the 1932 pack, the possibilities in development of an industry that would benefit producer, especially the primary producer, and consumer were immediately seen by the Dominion Horticulturist, M. B. Davis. Under his supervision sufficient quantities for a commercial trial of the two fruits were prepared and frozen in 1933. The support and co-operation of a local dairy was obtained. This dairy stored the products and marketed them in the Ottawa area. The enthusiastic response of the consumers prompted an extension of the marketing trials to Toronto in 1934.

At this time the first commercial concern in Eastern Canada to enter the field of freezing consumer packages of fruits and vegetables was established. Co-operation between the laboratory and this infant industry enabled the laboratory to verify methods of handling, packing and storage on the pilot plant scale, and at the same time continue the pursuit of solutions to the numerous problems arising from a new method of food processing.

Field of Investigation

Since the aim of the laboratory was greater improvement of the final product, varietal adaptability of fruits and vegetables, syrups and sugars for fruits, brines and dry packs for vegetables, methods of pre-treatment and containers, temperatures of freezing and storage, methods and rates of freezing and a host of other problems were investigated. Some of these problems could be undertaken at once, others had to wait till more facilities were available. This was forthcoming shortly with the expansion of the cold storage and provision for more freezing and storage rooms.

The war years with their urgent need for more information on vegetable dehydration necessitated the temporary transfer of priority in research to that field. Concerted investigation in the field of freezing was resumed when the war ended.

Varietal Adaptability.—Most of the new varieties tested or originated at the Central Experimental Farm are subjected to freezing preservation tests as part of the breeding program. The samples are withdrawn periodically from freezing storage and are assessed for palatability by a taste panel. If these fruits or vegetables have a good freezing value, the information is incorporated in the fruit and vegetable breeder's descriptions of varieties.

The best varieties of fruits and vegetables for freezing purposes are listed in "The Preservation of Fruits and Vegetables by Freezing" by R. W. Arengo-Jones, Bull. 12, 1937, and in "Frozen Fruits and Vegetables", a bulletin prepared for the Fruit and Vegetable Products Research Committee of the Dominion Department of Agriculture and published in 1949.

It must be stated, however, that although certain recommendations on varieties are made in these bulletins, they were varieties grown at Ottawa and a variety found suitable in one locality may or may not be suitable elsewhere.

Syrups and Sugars.—The sugar and syrup strengths found in the Marketing Service regulations governing frozen fruit were based mainly on the results of experiments conducted at the laboratory. No sugar or combination of sugars, and no syrup or combination of syrups or honey, gave the quality results found when sucrose or sucrose syrup was used. When cerelose was used alone or with sucrose either dry or as a syrup on strawberries, the strawberries developed a faint to offensive purplish off-colour. Glucose-treated strawberries were definitely lower in flavour value. Fruits packed with honey, diluted honey, or honey and syrup, took on the honey flavour.

In all the most recent tests the overall palatability value of fruits packed in syrup is slightly better than when packed with dry sugar, but frequently the flavour of sugared fruit is better. Although oxidation of the fruit is decreased, syrup dilutes the flavour of soft fruits.

Dry and Wet Packs.—The "wet" fruit pack is the syrup pack while the corresponding "wet" vegetable pack means packaging in brine. There is some virtue in brine packing. For extended storage as for over a year, brine packs are better than dry packs since there is less oxidation, and desiccation shows up more in a dry than a brine pack. However, the percentage of salt used is a factor in the flavour value. A three per cent solution generally imparted a pickled flavour, especially to green and wax beans; a two per cent solution was too salty; one to 1·5 per cent solutions were much better. Nevertheless, with good packages and with storages in which the temperature fluctuations are reduced to narrow limits, dry packing of vegetables gave consistently better results except in certain initial experiments where one palatability test only was made (see p. 227). When cooked, the texture of brine-packed vegetables is usually soft and the colour not so bright. The colour difference is caused partly by the longer period of time required for cooking, but the colour of the frozen or the thawed uncooked brined vegetable is not so good as the dry.

Inhibition of Browning in Peaches and Apples.—Certain fruits, notably peaches and apples, are very prone to oxidative browning especially during thawing. Experiments on the reduction of browning in peaches using Avenex, citric acid, ascorbic acid, ethylene and CO_2 gases, and certain industrial anti-oxidants, although these latter were mainly fat-antioxidants, indicated that ascorbic acid added to a covering syrup of 45° Brix at the rate of 200 mg./lb. of sliced or sectioned peaches was the most effective. Reduction of browning may be accomplished by the use of SO_2 compounds; but when SO_2 is added in sufficient strength to inhibit the browning, the thawed uncooked peach has an SO_2 flavour. Blanching or pre-cooking peaches before packing inhibits or destroys the browning enzymes but in this instance the peach has a "canned" flavour.

Internal browning appears in apple sections that have been covered with syrups containing as much as 500 mg. of ascorbic acid per lb. of apples. This internal browning is reduced materially if the apple slices are vacuumized in syrup with added ascorbic acid. Such quantities of ascorbic acid are expensive. A very effective method of inhibiting the browning in apples is by treating them with a solution of one of several SO_2 compounds, as a solution of potassium metabisulphite or sodium sulphite.

The treatment is basically a two- to three-minute dip of the sections in a 2500-3000 p.p.m. solution followed by draining before packing. If the packed product is held three to four hours before freezing, it permits penetration of the SO_2 to the centre of the section. This treatment, though it imparts an SO_2 flavour to the thawed raw apple, is very suitable for apples that are to be cooked before eating; that is, for use in pies and sauces since the after-cooking drives off the SO_2 flavour. The details of this treatment may be found in "Apples—Experiments in Freezing Preservation" and "Further Investigations on Freezing Apples for Bakers' Use" by Mary MacArthur. Canadian Food Packer, 16: April and August, 1945.

Superiority of "Crush" of Soft Fruits.—Some of the first experiments were on freezing whole, sliced or crushed strawberries with dry sugar. The flavour value of the crush is superior to the sliced which in turn is better than that of the whole fruit. The flavour of raspberry crush is also better than when the raspberries are packed whole with sugar. In crushing the fruit it is not necessary to reduce it to a pulp to bring out the flavour. All that is required is to break some of the fruit and mix in the sugar, permitting it to dissolve in the released juices.

It was thought that enhancement of flavour might be attained by coating prepared whole strawberries with sugar and holding before freezing. Holding for two hours did improve the flavour but holding for four hours imparted a "preserved" flavour. In freezing without holds the undissolved sugar is usually caked, either dry at the top of the carton or mainly partly dissolved at the bottom.

Importance of Blanching Vegetables.—The most important pre-treatment of vegetables is the blanch or scald. The freezing preservation of vegetables met with very indifferent success before blanching was practised. Blanching reduces or destroys the oxidative enzymes which would otherwise continue their reactions, although at a much reduced rate, during the freezing storage. Unless blanching is practised, objectionable "hay-like" flavours and odours develop in the product. Blanching also reduces the microbial load.

Blanching should be to that point at which only a trace of peroxidase remains in the product. The time element depends on the product. A steam blanch of peas at 212° F. causes "splits" which is avoided by water blanching at 190° to 200° F. Water blanching of spinach is superior to steam since steam blanching mats the product and frequently the internal layers of the spinach

are not blanched at all. They are insulated from the steam by the matted outer layers. However, most vegetables are steam blanched. Steam blanching reduces the leaching loss of soluble solids.

Pre-cooked Vegetables.—Certain vegetables are better in quality if they are given a complete pre-cook. Beets, carrots, pumpkin and squash belong in this group. Carrots were much better in flavour when peeled, diced, completely cooked by a steam blanch, cooled, packed and frozen; beets were better when cooked, peeled, diced or sliced, and frozen. Squash and pumpkin gave better results when the washed, split, de-seeded fruit was cooked by a steam blanch, then the pulp scooped from the rind if the rind was of the bony type. It is not necessary to scoop out the pulp in squash and pumpkin if the skin is yellow and softens during the blanch. The pulp was screened (pureed) and cooled before packing. In the pre-cooked vegetables, preparation for the table is merely by heating in a double boiler.

The specific recommendations on pre-treatments are given in the bulletin, "Frozen Fruits and Vegetables."

Containers.—A prime requisite of a good container for frozen products is the prevention of moisture loss. The ideal container is moisture-vapour-proof and is so shaped that it can be stacked without loss of space. The objections to the tin can are the space loss and the danger of treating canned frozen products as the usual sterile canned goods.

Tins were used in gas-packing tests; that is, replacing the air in the tin with N_2 or CO_2 to prevent oxidation. Only dry sugar-packed fruits were so treated. They were not so good in appearance as the checks because of collapse of fruit tissue during treatment. Heavily waxed cylindrical cartons are good consumer packages but the objection to these is waste space in stacking. A heat-sealed cellophane bag liner in a protective rectangular carton gave good results but this container requires a greater expenditure of labour in packing and sealing and takes longer to freeze. Tests on the new commercial rectangular wax-impregnated fibreboard carton with metal ends indicate that it is at least as good for quality retention as the heavily waxed cylindrical carton. This package, being machine sealed, lends itself readily to a mechanized packing line, and it stacks without space waste. The glass jar is not generally used commercially. Although it is a moisture-vapour-proof container there is danger of breakage, and it does not stack well.

The results of experiments to determine moisture loss from various packages of different products during freezing storage may be found in "Frozen Food Packaging Tests" by W. R. Phillips. Can. Food Ind. 18: 17-20. Dec., 1947.

Methods and Rates of Freezing.—Exhaustive experiments were made on the effect of temperatures, methods and rates of freezing, and temperatures of storage on the quality of fruits and vegetables.

Strawberries and raspberries in consumer packages were "satisfactorily" frozen at 12° F. (see "Freezing Small Fruits" by M. B. Davis. 39th Ann. Rep., Que. Pom. and Fruit Growing Soc. 1932). However, the same investigators obtained better preservation of the original properties and greater retardation in growth of micro-organisms with freezing at temperatures between 0° and —10°F. and holding at 0° F.

Initial Packaging and Freezing Experiments.—In 1939 and 1940 a comparative study was made of commercial methods of freezing. Asparagus, peas, wax beans, strawberries and raspberries were frozen at —50° and at 0° F. They were frozen by (1) direct airblast on the product and packaged after freezing; (2) airblast on the packed product; (3) immersion, with packaging after freezing and (4) contact. The pack types were dry and brine for vegetables, sugar and syrup for fruits. Solutions for immersion freezing of vegetables were 30 per

cent. $CaCl_2$ for —50°, and 30 per cent NaCl for 0° F.; for fruits at both temperatures, alcohol-glycerine-water in a 50-30-20 ratio. Storages were at —50°, 0° and 10° F. The material at —50° F. remained at that temperature one to three months only, the time depending on the processing date, because certain difficulties forced the raising of this room to 0° F. early in September. An ammonia leak occurred in the 10° F. room in the early fall. Subsequent examinations revealed that the ammonia had so affected both the colour and flavour of the samples that they were not subjected to the physical tests.

Results of the Physical Examinations of Initial Tests

Examinations were made after three or five months' storage with the following results:

Vegetables.—All immersion frozen lots were inferior. Even though the products were centrifuged after freezing for removal of the freezing solutions, they were either bitter or very salty. Enough of the solution remained to cause this flavour effect. It is quite possible that immersing packaged material in freezing solutions would give better results.

No one method of freezing gave consistently better quality in the three vegetables. Eliminating the immersion method, there was a tendency to better quality with low freezing temperature, and generally, with low storage temperature. There was no consistent superiority between packing before and after freezing. Packing before freezing was better in asparagus; packing after, in peas. Brine packs of peas and asparagus appeared to have a slightly higher value, but the dry pack of beans was best.

Frequently, there was a slight bleaching of the vegetables frozen at —50° F.

Fruits.—All immersion frozen samples were inferior. Packing in syrup before freezing gave the best results. Material frozen at —50° F. was not superior to that frozen at 0° F.; nor was storage at —50° F. superior to storage at 0° F. Bleaching occurred in immersion at —50° F. and in airblast on the unpacked product at the same temperature.

The samples were subjected to the one physical examination. In all later work samples were withdrawn periodically and assessed by a panel. Further sub-zero freezing and storage was at —20° F.

Comparison of Quality in Fast and Slow Frozen Products in Later Experiments

Vegetables.—Through 15 months' storage at 0°F., the average palatability value of fast frozen Stringless Green beans (airblast on the product at —20° F.) was only three points higher than the slow frozen (static at 0° F.). The time ratio for this slow to fast freezing was six to one. Again, throughout a year's storage, there was no difference in the average palatability of asparagus frozen by a fast, an intermediate and a slow method. Actually, the colour of the vegetable frozen by the slowest method was superior in that it was a deeper green, but the texture of the fast frozen material was the best, making the average palatability values equal.

Fruits.—The type of pack is more important than the temperature of freezing. In flavour value, a "crush" of strawberries or raspberries led, followed by the syrup, the dry sugar and the no sugar packs in that order. The crush packs of strawberries frozen at 0°F. frequently had better flavour than either the syrup or sugar pack frozen at —20° F. Fresh flavour in all fruits tested was retained better at —20° F. than at 0° F. storage. However, there was usually no more than a ten to fifteen point difference between the highest and the lowest palatability values when all samples were frozen from one lot of fruit.

An example is a 1947 experiment on Senator Dunlap strawberries. Samples of crush were not included. Freezing was limited to an airblast of 500 l.f.p.m. at —20° F. on the product with syrup and sugar packing after freezing; a similar airblast on the packed product, and a static at 0° F. freeze of the packed product.

All samples were stored at 0° F. The average values through 12 months' storage were 85, 81 and 80 respectively in the syrup packs; 79, 74 and 74 in the sugar packs. This shows that the method of packing was the more important; that is, in this instance a syrup pack gave overall better results than a dry sugar pack; but it also shows that fast freezing resulted in slightly better quality than slow freezing. The first lot was completely frozen in 45 minutes. Exact freezing times for the remaining two lots are not known, but from similar work the syrup pack froze somewhat more rapidly than the dry pack at the same temperature and static at 0° F. required about three times as long as an air-blast of 500 l.f.p.m. at —20° F. on the packed product.

Variation in Freezing Times.—At the laboratory complete freezing of cylindrical pint packages static at 0° F. took 8·5 to 12 hours. The differences in freezing time are accounted for mainly by differences in the kind of product, size of pieces in the pack, weight of pack and whether the pack type was wet or dry.

The statements already made on the quality of products frozen by the static at 0° F. method at the laboratory indicate that good results are obtained when the time element for freezing is up to 12 hours. There is danger in stating that freezing by static at 0° F. is completely satisfactory. Freezing time at this temperature is very much extended if containers are large, or if small containers are stacked.

The Importance of Fresh Quality.—Occasionally very wide differences were found in products frozen by different methods and rates. Where these differences occurred, the results were not comparative because of initial differences in the fresh product. The time differential required for setting up equipment in a freezing room to test the several methods coupled with the numbers of samples needed for periodic examinations frequently means that the first and last lots frozen have different initial values. It is virtually impossible to obtain comparative palatability values if the fruit or vegetable subjected to the experiment is drawn from different fresh lots.

A case in point was an experiment on three lots of Premier strawberries from one area very obviously different in their fresh quality. The best palatability of the frozen material was very definitely associated with the highest quality in the fresh material and not with either the method of freezing or the temperature of storage.

Leaching Losses.—The texture of fast-frozen products is firmer than the slow-frozen. Measurements of the drip from thawing fruits and vegetables showed that more juice with its contained solubles is leached from the slow-frozen product. This, in fruits, means a flabbier thawed fruit and in vegetables, a more limp cooked product. Attempts to firm fruits by vacuumizing in syrup containing varying concentrations of $CaCl_2$, pectins or alginates met with indifferent success.

There is little or no leaching during thawing of fast-frozen peas and related vegetables such as soybeans and lima beans. These vegetables are much lower in moisture content than leafy vegetables or fruits. The smaller quantities of water present when frozen *in situ* as occurs in very rapid freezing, and which will be discussed shortly, appears to be re-absorbed. However, the skin of peas was generally tougher when frozen either by immersion or unpackaged at a low temperature in high air velocity. In other words, rapid freezing tended to toughen the skins of peas.

The percentage of soluble solids in the cooking water of a weighed amount of asparagus frozen slowly (static at 0° F.) was higher than when the asparagus was frozen unpacked in an airblast at —20° F.; that is, there was greater leaching of soluble solids from the slow-frozen product. When either fast or slow frozen vegetables are cooked, just as when fresh vegetables are cooked, there is a certain amount of leaching of the nutritive constituents, sugars, vitamins,

minerals and soluble proteins, into the cooking water. This is the principal reason why housewives are urged by nutritionists to use such cooking liquids in soups and sauces.

Advantages of Fast Freezing.—From the standpoint of quality, fast freezing has a slight advantage, but one very important point in favour of this method is the removal of "bottlenecks" in the production line. Details on experimental work in freezing rates may be found in "Freezing of Commercially Packaged Asparagus, Strawberries and Corn", by Mary MacArthur. Fruit Prod. Jour. 24:238-240. Apr., 1945, and "Freezing Rates of Fruits and Vegetables at Various Air Velocities" by W. R. Phillips. Refrig. Eng. 53:401-403. May, 1947.

What Freezing Does to the Tissues.—Histological examinations on the effect of freezing and storage were made on those fruits and vegetables subjected to various methods of freezing and packaging. Detailed microscopic examinations were made on asparagus. This is reported in "The Effect of Method of Freezing, Type of Pack and Storage on Asparagus Tissue" by Mary MacArthur. Sci. Agr. 28:166-174. April, 1948.

The asparagus tissue examined was frozen in periods ranging from under two minutes to twelve hours. Very rapid freezing caused little damage to the tissue. In such, the ice crystals were situated mainly within the cells, but some were in the intercellular spaces. In slow-frozen tissue the ice crystals were few in the cells but massive ice formations were formed in the intercellular spaces. These accretions of ice pushed the tissues apart and formed small to larger lacunae.

The amount of moisture present had a very definite effect on the tissue rupture. In brine packed vegetables and syrup packed fruit there was much more damage to the tissues than dry packs frozen under the same conditions even though the wet packs froze more rapidly. The tissue in wet packs frozen at —50° F. was damaged quite severely but in dry packs frozen at that temperature there was only slight damage. In general, the more slowly either a wet or a dry packed product was frozen the greater was the extent of tissue rupture and the size of the individual ice crystals filling the lacunae. With storage, tissue rupture increased and this was more marked in wet than in dry packs.

The Effect of Fluctuating Storage Temperatures.—It appears that when storage temperatures fluctuate within quite narrow ranges some increase of tissue rupture is to be expected. Wet packs subjected to these conditions are more prone to the increase of tissue damage than the dry packs.

Dry packed products in sealed 450 M.A.T. cellophane bags placed in a common 0° F. storage have shown an increasing amount of loose ice crystals in the package. The products exhibit some desiccation. The formation and the increase of these ice crystals are caused by re-crystallization of the vapour in the package. The door of the common storage room is necessarily opened frequently and the air temperature oscillates rather widely. Vapour pressure in the pack changes and when the temperature is again lowered, deposition of ice crystals occurs. That moisture forming the loose crystals is drawn first from the surface of the product then from deeper in the tissues. With time the product in a package subjected to these conditions shows marked desiccation. The aforementioned packages have not been weighed. There is probably some loss of weight, but an insignificant weight loss in a good package does not necessarily mean that the condition of the product has remained static.

Purees and Desserts

Fruit pulps for jam re-processing were among the first commercially frozen horticultural products, and fruit purees have been used for ice cream flavours and water ices. More recently the U.S.D.A. Western Regional Laboratory

initiated work on the use of fruit purees as dessert bases. This laboratory has done considerable experimental work on frozen fruit desserts. Details on this product may be found in the bulletin "Frozen Fruits and Vegetables", and in "Frozen Fruit Desserts" by Mary MacArthur. Can. Food Ind. 18:37-39. Oct., 1947.

The frozen fruit dessert is essentially a fruit puree plus sugar, water and a stabilizer which may be gelatin. It is generally made in an ice cream freezer and has the velvety texture of ice cream, although no milk products are used in the manufacture.

Practically any fruit may be used as the base. At harvest time the laboratory prepared purees and also froze both whole and sectioned fruit for re-processing. The desserts may be made from fresh fruit and placed in freezing storage; they may be made from the thawed puree or from thawed frozen fruit which is run through a pureeing machine before making up the mix.

Preparation of Puree and Dessert Mix.—For pureeing, a screw extruder press of stainless steel to prevent anthocyanin discoloration is satisfactory. Plums, peaches and cherries should be pitted. They are washed, and peeling of peaches is not necessary. A screen preferably of stainless steel or other non-reactive metal should be used for removing the large seeds in raspberries and currants. If these are not removed, they are not only annoying in the finished dessert but may impart a woody flavour with storage.

The fruits may be hot-pressed or cold-pressed. For soft fruits the cold press is better, but a fruit like the peach which is prone to browning should have ascorbic acid added during the cold pressing. Apples and pears are not satisfactory when cold-pressed but make very good products if they are blanched to inactivate the oxidizing enzymes then pressed. These latter purees are, of course, thick sauces which are thinned with water in making the mix. Sugars may be added to the purees before freezing. This is not necessary. These may be added at the time the desserts are made.

Of more than 12 stabilizers tested, the best was gelatin. About one-half of one per cent of the total weight of the mix is used but because of natural jelling properties blueberries and black currants do not need so much. The gelatin is added to cold water. The water used may range from five to 20 per cent of the total mix weight depending on the consistency of the puree, the lesser amount for a thin, more for a thick puree. The gelatin in water is heated in a water bath to dissolve. The amount of sugar inclusive of the natural sugars in the puree may be 30 to 37 per cent of the total mix weight depending on taste requirements. The sugar is added to the cold or thawed puree and mixed to dissolve. The cooled, but not jelled, gelatin is added in a thin stream while beating, and the whole turned into an ice cream freezer. It is then frozen to the desired overrun, packed in cartons and stored; 0° F. for short storages, —20° F. for long storages.

The better all-round desserts were those in which the overrun was 85 to 100 per cent. Lower overruns gave a very concentrated flavour, and desserts with overruns of not more than 50 per cent were often "sticky". Products with overruns in the neighbourhood of 150 per cent, as is readily obtainable with cherries, were too fluffy. There was not enough body to volume.

Experiments were conducted on the form in which raspberries should be stored for these desserts. Purees with and without sugar were frozen and stored at 0° F. Similarly, whole raspberries were frozen and stored with and without sugar. There was practically no difference in the desserts made from these four lots, but a prepared mix withdrawn from storage at the same time, thawed, then finished in the freezer did not give an overrun equal to that produced in the other lots.

Outlet for Surplus Fruits.—It is believed that frozen fruit desserts offer a good means of utilizing surplus and over-ripe fruit, that is, fruit too ripe for

shipping. Even with high absorption of fruit by the fresh market, canners and freezers, there is a small percentage which, if not used for a product such as frozen fruit desserts, would be an economic loss.

Limited commercial trials have been made. The product has met with consumer approval, but in recent years there has been no glut of fruit in the various markets and, therefore, no compulsion towards the utilization of fruit for this purpose.

DOMINION EXPERIMENTAL SUBSTATION FOR MUCKLANDS

Ste. Clothilde, Quebec

F. S. Browne

The Substation was established in 1936 following a survey of organic soils in southwestern Quebec by the Quebec Soil Survey Committee, a joint Provincial and Dominion organization. This survey indicated that there were 51,000 acres of relatively high quality organic soils in a comparatively small area of southwestern Quebec, of which only a very small portion was under cultivation. In addition, there are other larger areas of organic soils in central and eastern Quebec and in eastern Ontario which are also largely undeveloped.

The Substation is situated near the village of Ste. Clothilde, Chateauguay county, Quebec, on an area of muck soil approximately 17,000 acres in extent and is within easy driving distance of another 20,000 acres. It is thirty-one miles south of Montreal and located on a good highway. The entire district is well served by good roads and railroads.

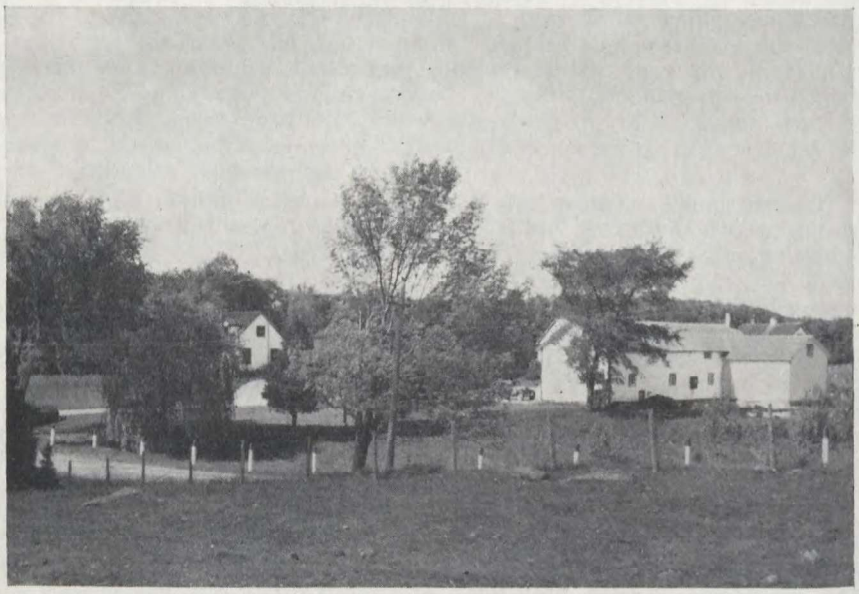

Fig. 32—Partial view of buildings and grounds at the Ste. Clothilde Substation.

The property of the Substation comprises eighty acres, twenty-six of which are rocky mineral soil; eleven, marginal muck and the remaining forty-three a deep muck soil of excellent quality. Twenty-one acres of this deep muck soil had been cleared and for at least ten years had been used for hay production. The other twenty-two acres was rather sparsely covered with a young scrubby growth of elm, ash, soft maple, poplar, red oak, tamarack and several species of native shrubs. On the comparatively wet areas, swamp willow and alder predominated.

Soil Origin

The soil on the deep muck area is characteristic of the predominant type throughout the region. For the most part, these deposits are situated along streams and overlay marl or clay of varying depth to bedrock. In general, these deep mucks are composed of three distinct layers of organic soil—aquatic muck, forest debris and surface layer. The lowest layer of the organic soil is usually an aquatic muck, the beginning of which was apparently formed from plants growing in salt or brackish water. Later the deposit was formed from fresh water plants, such as pond weed and water lilies. The depth of this aquatic layer varies from a few inches up to over twenty feet in deep depressions. The texture is gelatinous; it absorbs water readily but permits only very small quantities to pass through. Therefore, it forms an almost water-tight bottom to the soil situated above it.

The middle layer, from two to four feet in depth, is the forest debris laver. The large quantity of partially decomposed tree trunks, limbs and roots gives it a coarse, open texture which permits water to pass through readily. The top or surface layer, one to two feet in thickness, was formed after outlets became flooded and the water-table became too high for forest growth. This surface layer is largely decomposed sedges, carex and grass species. Here, the organic material is in an advanced stage of decomposition, fine in texture, and so can easily be compacted to facilitate the movement of water by capillary action.

Water Control

The capacity of organic soils to absorb and hold water is very high. At saturation, well decomposed muck will usually hold one and a half times its own weight and peat soils up to twice their weight. For this reason summer rains seldom penetrate more than an inch or two into the soil and, owing to the loose open texture which permits rather free aeration, such moisture is rapidly lost by evaporation. Accordingly, normal summer precipitation cannot be depended upon to supply moisture for maximum crop requirements on these soil types and water control is decidedly a limiting factor.

The Substation is situated close to Norton Creek, a permanent stream running through the entire bog area. From Norton Creek there is ample water available for irrigation, but at the time the Substation was established the creek bed was not low enough to provide adequate drainage. This condition prevailed until 1948 when the creek was deepened and it was possible to obtain complete water control. However, a system of open ditches was dug and several types of underground drains installed on the deep muck area. To provide water for irrigation, a power driven pump was installed and a fibre pipe line laid to carry water to the highest level on the muckland area. During the run-off period in the spring, provided that the creek was not in flood, the drains and ditches carried the surplus water off the land. However, from 1936 to 1947, flooding of the land was quite frequent during the spring break-up and occasionally throughout the season after heavy rains. The spring flooding necessitated late planting of all crops. Later in the season when the soil became dry, water was pumped back into the main ditch which was dammed at the several levels thus forcing water back into the covered drains and open ditches. From these, the water seeped laterally to saturate the porous layer of forest muck. By raising the water in this layer until it came in contact with the well decomposed surface layer of carex and grass muck, capillary action carried it to plant roots and to the surface. The amount of water made available in this way can be regulated by raising or lowering the water in the main supply ditch, for very little water is lost by sinking to lower levels since the lower layer of aquatic muck acts as a nearly water-tight bottom.

When the surface layer is too dry for crop requirements and the forest layer is moist, the lateral seepage from newly filled ditches is one hundred and eighty

feet in twelve hours and up to two hundred feet in fifteen hours. This means that for the soil conditions on the deep muckland at Ste. Clothilde, ditches or drains from three to four hundred feet apart are adequate for both drainage and irrigation.

Water Requirements

For ten years, 1937 to 1946, a record was kept of the amount of water pumped for irrigation, and necessary to keep the growing crops in good condition. This irrigation water was, of course, in addition to rainfall and occasional flooding by the rise of water in Norton Creek, both of which were also recorded. An average of these irrigation records indicates that approximately fourteen thousand gallons per acre are required each week from the middle of June until the second or third week in August. This figure varies with the kind of crop grown, some requiring more water than others. Onions, potatoes, beans, spinach and cabbage, crops which either have deeper root systems and can reach moisture at considerable depth when needed or require less than other crops, have produced normally with added water at a rate of ten thousand gallons per acre per week. Celery, peas and tomatoes require up to fifteen thousand. Lettuce, beets, carrots, sugar beets, peppers, muskmelons and asparagus, which are about average in water requirements, produce normally with from twelve to fourteen thousand gallons per acre per week.

Variations in water requirements per season have been less than would be normally expected. Even with occasional flooding and extremely heavy rains of two inches or more, the land drained quickly when ditches were opened and within a few days the crops required water again. In 1943 when summer precipitation was unusually high, irrigation requirements were eight thousand gallons per acre per week. In comparison, in 1946, a relatively dry season and with crop production on muck soils the highest to that time, irrigation requirements were slightly under fifteen thousand gallons per acre per week.

Cost of Irrigation

For the ten-year period the cost of irrigation has been low. Taking into account interest on the investment for ditches, drains, pipe line and pump; depreciation of equipment; cost of labour, repairs, gasoline and oil, the average cost has been fifty-nine cents per acre per season. With this set-up the lift of water was only forty-nine inches. Had it been greater, more power would have been required and the cost would be increased accordingly. However, the cost of moving water for irrigation by seepage is not great and, on the muck land areas of southwestern Quebec, it should be a highly profitable operation where required.

Nutrient Requirements of Muck Soil

The muck soils of southwestern Quebec contain a high percentage of organic matter and are relatively low in minerals. A typical analysis of this soil made from samples taken on the deep muck area at the Substation is as follows:

	0 in.-12 in. per cent	12 in.-24 in per cent
pH Value	6.27	6.11
Total ash	10.70	8.87
Calcium oxide	4.28	3.36
Magnesium oxide	0.72	0.72
Manganese oxide	0.031	0.023
Potassium oxide	0.033	0.019
Phosphoric acid	0.219	0.198
Sulphur trioxide	1.03	1.20
Nitrogen (total)	2.27	1.80

The analyses indicate a soil very low in mineral matter but relatively well supplied with calcium and phosphorus. Sulphur and nitrogen are unusually high while potassium and manganese are decidedly low. The pH value is satisfactory and is ideal for many kinds of vegetable crops.

Following a complete soil survey of the Substation farm area, a preliminary trial of all available plant nutrients that might be necessary on this soil type was started in 1936. In all, nineteen materials and combinations were tried with twelve vegetable crops. The experiment, continued for four years, demonstrated quite clearly the nutrient deficiencies in the soil, and the response of the various crops to the main and trace elements necessary for their nutrition.

In order to secure clear cut reactions, comparatively heavy applications of the several materials were used. These were as follows:

Superphosphate	800 lb. per acre
Sulphate of potash	500 " " "
Muriate of potash	500 " " "
Sulphate of ammonia	200 " " "
Nitrate of soda	250 " " "
Sulphur	200 " " "
Hydrated lime	4000 " " "
Manganese sulphate	50 " " "
Copper sulphate	40 " " "
Borax	15 " " "

Unless otherwise indicated the carriers of nitrogen (N), phosphorus (P), and potassium (K), were sulphate of ammonia; superphosphate, 20 per cent; and muriate of potash, 60 per cent.

Table 48 shows a four-year average of yields with five of the principal vegetable crops.

TABLE 48.—ELEMENT TRIALS WITH VEGETABLE CROPS 1936-1939

Fertilizer	Yield per Acre				
	Potatoes	Onions	Celery	Spinach	Cabbage
	bu.	bu.	tons	tons	tons
P	268·3	397·2	7·62	4·25	8·00
K	501·7	371·4	14·83	8·30	22·91
N	241·0	304·1	7·61	6·15	11·63
NP	263·4	302·7	8·53	7·15	11·07
PK	574·0	528·6	12·14	9·43	23·06
NK	506·0	421·6	14·43	10·03	11·01
NPK	583·1	589·3	16·03	11·06	24·02
NPK (Sulphate of potash)	498·1	441·4	10·16	9·98	23·18
NPK (Nitrate of soda)	522·0	557·1	16·14	9·16	7·98
Check (No treatment)	253·7	193·0	5·23	4·08	21·13
PK + Sulphur	428·3	503·1	10·13	7·43	20·06
NPK + Sulphur	408·9	507·3	11·06	8·12	20·91
NPK + Manganese	581·6	568·3	17·91	12·06	27·03
NPK + Lime	493·0	503·2	13·06	10·02	24·16
NPK + Boron	591·7	569·8	17·93	12·73	26·17
NPK + Copper	586·3	706·3	17·04	13·29	23·92
NPK + Manure 10 tons	588·2	431·8	14·61	10·93	24·17
Manure 20 tons	473·1	306·7	13·01	8·14	19·03
PK + Manure 10 tons	462·6	421·8	13·98	9·88	20·16

The results obtained with other crops including beans, peas, carrots, beets, lettuce, tomatoes and sweet corn were similar, and varied only in the normal requirements of these crops on other soil types. With peas and beans phosphorus is more important than potassium. Lettuce and spinach have approximately the same requirements, and cauliflower reacts in a manner similar to cabbage. With carrots and beets a balanced fertilizer high in potash is necessary.

Minor Elements

The importance of trace or minor elements is clearly indicated for most crops. Of these, boron is essential for celery, carrots and beets. Otherwise the crop may be unmarketable since boron deficiency produces the characteristic "cat scratches" on the petioles of celery, longitudinal splitting of carrots and transverse cracking of beets. With spinach, cabbage, beans and peas, if the boron deficiency is not severe the crop may be marketable but the yield will be definitely decreased. Further studies have shown that yearly applications of ten to fifteen pounds of borax per acre are satisfactory on the Ste. Clothilde muck soil for all boron-demanding crops except celery and turnips. These two crops may require annual applications up to twenty pounds per acre, or occasional applications up to forty pounds where the deficiency is extreme.

Apparently copper is essential for most crops on this soil type. Exceptions are cabbage and cauliflower and probably turnips. The response with potatoes and celery has not been significant, but copper has probably been supplied in more than sufficient quantities to meet crop requirements by the copper compounds used as sprays or dusts to control diseases. Similarly, with copper-demanding crops following potatoes or celery, where disease control had been effected with copper compounds, additional copper need not be applied to the soil. For the onion crop on muck soil, copper is apparently essential since it hastens maturity and improves the colour and texture of the skins. It has definitely increased yields at the Substation and on the other muckland areas in Quebec and Ontario. The usual application is forty to sixty pounds of copper sulphate per acre applied with the fertilizer.

Manganese has proved beneficial with cabbage, celery, beans and spinach. With yellow celery at Ste. Clothilde it is almost essential as it improves the colour and texture of the petioles and seems to increase resistance to "black heart", a rather serious physiological disorder induced by uneven water supply. Other minor elements tried for shorter periods included zinc, as zinc sulphate; iron, as iron sulphate and sodium, as sodium chloride or common salt. All were negative or nearly so in their effect on crops. Zinc appears to be slightly beneficial for spinach. Moderate increases in yield of sugar beets have been obtained with common salt at five hundred pounds per acre. However, where potash was increased by only a few pounds in the NPK fertilizer application, the addition of salt had no effect.

Major Elements

At the Substation, with all crops except onions, potassium is definitely the most important of the three main elements of plant nutrition. With onions, phosphorus is equal in importance to potash, although a combination of the two is superior to either one alone. Phosphorus, although generally secondary in importance to potash, is nevertheless essential to all crops. Nitrogen in large quantities is detrimental. Used in an available form, and in small quantities, it has proved beneficial particularly as a starter for crops in the early part of the season before nitrification in the soil can provide sufficient nitrogen for plant development.

Calcium in the form of lime has not proved beneficial at Ste. Clothilde, probably because of the favourable reaction of the soil and its relatively high calcium content. On other sections of the Ste. Clothilde bog and on small areas through the entire region where acid soil conditions exist, lime has proved very beneficial.

Under average conditions, sulphur, which is somewhat more than a trace element, has decreased yields at Ste. Clothilde. It is also significant that sulphate of potash has proved inferior to muriate of potash for onion, celery and spinach. With other crops its effect has been negative. However, on

burned over muck, where the sulphur in the soil has been lost by burning, moderate applications have helped to correct alkalinity and increased crop yields.

Barnyard Manure

Barnyard manure as a fertilizer on muck soils is obviously unnecessary since these soils contain up to ninety per cent or more organic matter. In comparison with a well balanced commercial fertilizer, applications of twenty tons per acre of well rotted manure always decreased yields of all crops at Ste. Clothilde. Combinations of manure and commercial fertilizer have been more effective, and usually produce a crop only slightly inferior to that obtained from the use of a complete fertilizer. On newly broken or recently drained areas of peat or muck, moderate applications of barnyard manure are beneficial as a source of inoculation for the first year or two that the land is cropped.

Fertilizer Trials, Vegetable Crops

The preliminary element trials of 1937 indicated in a general way the trend in fertilizer requirements for a number of vegetable crops on the typical black muck soils of western Quebec. With this information as a guide, a fairly extensive series of experiments dealing with the nutrient requirements of the principal vegetable crops was begun in 1938. These have been continued with various alterations and additions for the past ten years and have constituted an important and extensive part of the experimental work at the Substation.

General Fertilizer Trials

The largest of these was a replicated trial with six vegetable crops in which potash levels together with rates and methods of application were compared. The entire experiment occupied six acres and the individual plots numbered four hundred and thirty-two.

The fertilizer formulas used with all crops were 0-2-16, 2-8-16, 0-8-24 and 2-8-24. These were applied at rates of 1,000, 1,500 and 2,000 lb./ac. by broadcast and row placement methods.

During the three years that the experiment was conducted, the results were statistically analysed and a great deal of useful information obtained. In general, it was determined that application of a balanced fertilizer in excess of 1,500 pounds per acre was not practical with the crops, lettuce, spinach, carrots, onions and cabbage. Potatoes were an exception, since 2,000 pounds per acre of a 2-8-16 produced a profitable increase in yield over that obtained from smaller applications. It was also determined that liberal amounts of potash are necessary for the normal development of all six crops in this soil type. However, with the application of 1,000 pounds per acre, or more, there was no profitable increase in yield by increasing the potash in the formula from sixteen to twenty-four per cent. With onions and cabbage, a barely significant increase in yield was obtained by increasing the nitrogen application from two to four per cent. With other crops this increase had a negative or detrimental effect.

Highly significant results were obtained in the comparison of broadcast and row placement methods of applying fertilizer. With all rates and formulas the broadcast applications gave significantly better results as shown in Table 49.

Apparently in this loose open muck soil, roots spread easily and reach plant nutrient in solution more quickly than in ordinary mineral soil. Accordingly, it would seem that on muck lands similar to those in the Ste. Clothilde area growers need not invest in special equipment for the row placement of fertilizers, since application by row placement will probably result in lower yields than application by the broadcast method.

TABLE 49.—ROW PLACEMENT VERSUS BROADCAST METHOD OF APPLYING COMMERCIAL FERTILIZERS, AVERAGE OF RESULTS 1937–1939

Crop	Yield per Acre	
	Broadcast	Row Placement
	lb.	lb.
Lettuce	68,096	62,502
Spinach	23,147	21,036
Carrots	61,937	59,481
Onions	52,843	48,170
Potatoes	27,042	31,836
Cabbage	39,630	29,421

Because of rapid evaporation from the top few inches and wilting with even a high soil moisture content, plant roots in organic soils such as the Ste. Clothilde mucklands usually develop several inches below the surface. Also normal summer rains seldom penetrate more than an inch or two into these soil types. Therefore, soluble plant food of fertilizers in the top two or three inches may not reach the roots of plants during the growing season. The obvious answer to this problem seemed to be the placement of fertilizers deep enough in the soil to be in contact with sufficient free water to bring the nutrients into solution. Therefore, to find the most practical method of fertilizer placement for such soils, an experiment with potatoes was begun in 1942 and continued for four years. In the experiment, a 2-8-16 fertilizer was used at a rate of 1,000 pounds per acre for all methods. The methods employed were as follows:

1. Broadcast application harrowed lightly so as to mix the fertilizer with the top three inches of soil.
2. Broadcast application worked in with disk harrow to a depth of five inches.
3. Plough sole application; fertilizer applied in a band at the bottom of the furrow when ploughing; depth four inches.
4. Plough application eight inches deep.
5. Fertilizer applied with a grain drill five inches deep.

The average yields obtained during the four-year period are given in Table 50.

TABLE 50.—EFFECT OF FERTILIZER PLACEMENT ON THE AVERAGE YIELD OF POTATOES, 1942–45

Method	Yield per Acre		
	Marketable	Unmarketable	Total
	bu.	bu.	bu.
Broadcast, 3 in	386·1	39·2	425·3
Broadcast, 5 in	453·0	37·6	490·6
Plough Sole, 4 in	436·1	32·5	468·6
Plough Sole, 8 in	409·1	38·3	447·9
Grain Drill, 5 in	529·7	28·0	557·7

Similar results were obtained with cabbage, onions and carrots. The experiments indicate that on this soil type fertilizer should be placed about five inches below the surface of the ground or mixed thoroughly with the soil to a similar depth.

Placing fertilizer in the bottom of the plough furrow gave lower yields in this experiment. On other soil types with certain crops this method is developing into a standard practice. However, with the mucklands at Ste. Clothilde the complete turning over of the soil by ploughing has not proved as satisfactory for general crop production as relatively shallow working of the soil with harrows and cultivators. This detrimental effect of ploughing on the following crop has probably offset those benefits of the plough sole method of fertilizer placement which are found in other soil types.

Onion Fertilizer Trials

Onions are a highly productive and important crop on organic soils but, as with other crops, they require a rather carefully balanced nutrient supply to produce a maximum crop. In the first experiments conducted at Ste. Clothilde with this crop, it was determined that copper and boron were not present in this soil in quantities sufficient to meet onion crop requirements. Also, nitrogen was of little value but phosphoric acid was about equal to potash in importance. With this information as a guide, two extensive experiments were begun in 1940 to determine the proportion of the various nutrients necessary for optimum results with the onion crop.

In one of these, borax and copper sulphate were applied at different rates with a 2-12-16 fertilizer at 1,200 pounds per acre. The experiment was continued for four years and the results, which were clear-cut throughout, showed that a normal crop of onions required about 40 pounds of copper sulphate and 10 pounds of borax per acre per year on this soil. Also, these materials could be applied either in the fertilizer mixture or dissolved in water and applied to the land with a row crop sprayer before seeding. With either method they should be thoroughly worked into the soil.

In the second experiment, which was continued for five years in a replicated randomized trial, three different levels of nitrogen, phosphoric acid and potash were used alone and in all possible combinations. Borax at 10 pounds and copper sulphate at 30 pounds per acre were included in all applications and on the check plots.

The variety grown each year was Yellow Globe Danvers with a seeding rate of three pounds per acre. Following the usual practice on this soil type, the plants were not thinned but only those onions of marketable size were weighed for yield records.

The five-year average of results is given in Table 51.

TABLE 51.—EFFECT OF NUTRIENTS ON THE AVERAGE YIELD AND MATURITY OF ONIONS, 1940-44

Nutrients per Acre			Maturity	Yield per Acre
Nitrogen	Phosphoric Acid	Potash		
lb.	lb.	lb.	Scale of 10	bu.
0	0	0	10	286
30	0	120	4·8	351
30	0	240	4·9	359
30	120	0	10	522
30	240	0	10	589
60	0	120	4·1	306
60	0	240	4·3	319
60	120	0	8·1	526
60	240	0	10	587
30	120	120	10	659
30	240	120	10	703
30	120	240	9	551
30	240	240	10	793
60	120	120	9	677
60	240	120	9	701
60	120	240	8	603
60	240	240	9	815

Difference required for significance (P = ·05) 19·1 bushels.

Table 51 shows clearly that on the Ste. Clothilde muck soils phosphorus and potassium are about equal in importance and are required in nearly equal amounts by the onion crop. Also, the maturity of the crop will be adversely affected unless the phosphorus is adequate. Nitrogen significantly increased yields when used in combination with phosphoric acid and potash, but at 60 pounds per acre, maturity was delayed, and the number of unmarketable "thick neck" onions was increased.

A 2-12-10 or 2-16-16 fertilizer along with the amounts of borax and copper sulphate previously stated should prove satisfactory for the onion crop on the muckland areas of southwestern Quebec.

Fig. 33—Typical crop of onions at the Ste. Clothilde Substation for mucklands.

Fertilizer Trials With Celery

In 1937, a series of fertilizer trials with celery was begun on the deep muck area at Ste. Clothilde, and continued for four years. Preliminary work had indicated that potash was the most important nutrient for the celery crop on muck soil, although nitrogen and phosphorus were required in smaller amounts. It was also indicated that boron, manganese and copper were not present in this soil type in sufficient quantity to meet the requirements of a crop of celery. Accordingly, the experiments were designed to determine the levels of the various nutrients required to produce a normal crop.

Potash Requirements

Previous work had indicated that potash in a fertilizer application was rendered unavailable by reaction with organic matter before the end of the growing season, and supplementary applications of this nutrient might be necessary to secure the best results. To determine potash requirements an experiment was begun in 1937. This included two basic rates of a balanced

fertilizer high in potash, supplied in both the muriate and sulphate form, with and without supplementary summer applications. The experiment was conducted in quadruplicate with randomized plots.

The variety Golden Self Blanching grown primarily for storage was used.

Table 52 gives the results for the three-year period, 1937-39.

TABLE 52.—EFFECT OF POTASH LEVELS ON THE AVERAGE YIELD AND QUALITY OF CELERY, 1937–39

Application per Acre		Source of Potash	Average Yield per Acre	Quality
Initial 2-8-16	Supplementary			
lb.	lb.		tons	
1,000	0	Sulphate	12·283	Stringy, poor colour.
1,000	0	Muriate	16·010	Good.
2,000	0	Sulphate	15·285	Stringy, poor colour.
2,000	0	Muriate	22·355	Good.
1,000	100	Sulphate	13·260	Stringy.
1,000	100	Muriate	18·750	Good.
2,000	100	Sulphate	19·980	Stringy.
2,000	100	Muriate	23·997	Good.
1,000	200	Sulphate	13·495	Stringy, poor colour.
1,000	200	Muriate	18·520	Good.
2,000	200	Sulphate	16·230	Fair.
2,000	200	Muriate	25·217	Good.

Difference required for significance (P = ·05) 1·02 tons per acre.

This experiment clearly shows that on the characteristic black muck soils of southwestern Quebec potash in the sulphate form is inferior to the same nutrient as muriate of potash. The reason for this is probably that the high sulphur content of the soil when increased by the sulphur in the sulphate of potash brings about a condition partly toxic to celery.

With muriate of potash the reaction has been decidedly favourable and, up to the maximum application, crop yields have increased in direct proportion to the amount of this material included in the fertilizer mixture. That an excess of potash, even in a satisfactory form (muriate), can be reached is indicated by the comparatively small increase in yield produced by increasing the supplementary application to the 2,000 pound application of 2-8-16.

The response to the summer supplementary application was very marked in the first two years of the experiment. However, in the third year, and in subsequent work, midseason applications following substantial spring applications have not given significant results. This would indicate that the tie-up of potash in these soils is only temporary and, after two or three crops which have been plentifully supplied with this nutrient in the spring, supplementary applications are not necessary.

The results of storage trials in a commercial storage were in close agreement with those from the field treatments. Celery grown with muriate of potash in the fertilizer application kept much better than celery grown with sulphate of potash. Also, with the heavier applications where muriate of potash was used, a further increase in keeping quality was obtained.

Nitrogen Requirements

Although muck soils contain a relatively large amount of nitrogen, only a comparatively small quantity may be in an available form at any one time. This is usually quite evident during the early part of the season when the soil is cool and nitrification is not rapid. For this reason a small amount of available nitrogen in the initial fertilizer applications is necessary to promote early growth. However, with celery a steady and adequate supply of nitrogen

in addition to other nutrients is required throughout the season for the development of satisfactory quality. In this experiment, increasing amounts of nitrogen are compared with fixed percentages of phosphoric acid and potash at two rates of application.

The experiment on nitrogen levels was conducted for three years, 1938 to 1940, with all treatments replicated three times and the plots in each replication randomized. The results on yield and on size of plants are given in Table 53.

TABLE 53.—EFFECT OF NITROGEN LEVELS ON AVERAGE YIELD AND SIZE OF CELERY, 1938–1940

Fertilizer Formula	Rate per Acre	Average Height	Average Girth	Yield of Crop per Acre
	lb.	in.	in.	tons
2–8–16	1,000	24·5	14·1	27·848
2–8–16	2,000	25·2	14·6	30·425
4–8–16	1,000	26·2	14·6	27·275
4–8–16	2,000	26·2	14·1	31·717
6–8–16	1,000	25·0	14·1	28·820
6–8–16	2,000	26·5	15·4	31·502
8–8–16	1,000	24·7	13·1	27·995
8–8–16	2,000	25·7	14·1	31·800
10–8–16	1,000	24·0	14·1	27·180
10–8–16	2,000	27·0	13·6	29·307

Difference required for significance (P = ·05) 1·63 tons.

From the results of this trial it is quite apparent that increasing nitrogen in the fertilizer application over two per cent has little effect on the yield of crop on this soil type. Furthermore, no difference in quality could be determined, although in storage trials the celery from the high-nitrogen plots did not keep well.

Phosphorus Requirements

To determine the necessary phosphorus level in fertilizers for the celery crop on the muck soils of western Quebec, an experiment was begun with the deep muck area at the Substation in 1938 and continued for three years. The variety was Golden Self Blanching and the crop was grown for storage celery. All treatments were replicated three times and the various applications randomized in each replication.

The results are shown in Table 54.

TABLE 54.—EFFECT OF PHOSPHORUS LEVELS ON YIELD AND SIZE OF CELERY, 1938–1940

Fertilizer Formula	Average Height	Average Girth	Yield of Crop per Acre
	in.	in.	tons
2– 8–16	26	14·0	27·947
2–16– 8	28	13·0	24·385
2–16–16	26	14·5	27·892
2–16– 0	24	14·0	21·292
0–16–16	24	14·0	23·775
2– 0–16	26	14·5	22·742

Difference required for significance (P = ·05) ·931 tons.

The necessity for phosphorus on this soil type in fertilizers for the celery crop is clearly indicated, although it is of less importance than potash.

General Fertilizer Requirements

It is apparent that on these black muck soils of southwestern Quebec a fertilizer for the celery crop should contain nitrogen, phosphoric acid and potash in the proportion of one, four and eight. A 2-8-16 is now recommended for celery on black muck soils and can be used in applications up to 1500 or 2000 pounds per acre. Where land has been newly broken supplementary summer applications of muriate of potash may be required for the first and second year that the land is in cultivation. For following crops ample potash can be supplied in the initial application. Sulphate of potash is not suitable as a source of potash for the muck lands of southwestern Quebec.

Fig. 34—Harvest of celery on the Ste. Clothilde mucklands.

Minor Element Requirements

For the first two years that celery was grown on the muck soils of southwestern Quebec very few symptoms of minor element deficiency were observed. However, with subsequent crops serious losses occurred from both boron and manganese deficiencies. There were also a few indications of copper deficiency. Previous to this an experiment was begun at the Substation in which a number of minor elements were included with the fertilizer for celery with a view to establishing their need and calibrating the amounts required. From this experiment, which was continued for four years and utilized a large number of plots, it was found that for a normal celery crop 10 to 15 pounds of borax and 30 to 40 pounds of manganese sulphate per acre were required as a soil application each year. Experiments in applying boron to foliage in the normal sprays for disease control were also successful. For this type of application up to five pounds of borax can be used with 100 gallons of bordeaux mixture.

Copper deficiency, which could be severe, is usually taken care of by copper in the fungicides. Such fungicides as bordeaux mixture and "fixed coppers"

contain a high percentage of copper and are customarily used for the control of celery blight. For early crops of celery which usually do not require disease control, copper deficiency can be corrected by applications of 50 or 60 pounds of copper sulphate per acre applied with the fertilizer. This is usually sufficient for two or three years.

Potato Fertilizer Trials

Potatoes have been grown on the muck lands of southwestern Quebec for many years but until the establishment of the Substation, the crops produced were largely of poor quality and of little importance commercially. Usually the fertilizer used was barnyard manure or a commercial fertilizer relatively high in nitrogen. Such fertilizers added to soil already high in nitrogen created a surplus of this nutrient which caused relatively poor quality in the potatoes and failed to produce satisfactory yields.

Following the preliminary trials which indicated that potash was decidedly deficient in these soils, a series of fertilizer experiments with potatoes were begun in 1937 and have been continued with various modifications and additions since then.

A very extensive replicated trial begun in 1937 and continued for four years indicated that nitrogen was of little importance and phosphorus only slightly more so for the potato crop. The main limiting nutrient seemed to be potash and significant increases were obtained with amounts up to 24 per cent in the fertilizer application for the first two years that the experiment was conducted. This probably indicated potash fixation early in the season. However, in subsequent seasons as more potash applied to potatoes or other crops accumulated in the soil, maximum yields were obtained with 16 per cent of this nutrient in the fertilizer application.

From this experiment it was established that a 2-8-16 fertilizer was the most suitable for the potato crop, but that additional potash was necessary for the first two or three years after the land was brought into cultivation

Effect of Fertilizer Applications on Yield and Quality of Potatoes

In 1942, experiments were begun to determine the effect of various levels of nitrogen, phosphoric acid and potash on the yield and quality of potatoes. Three levels of each nutrient were used alone and in all possible combinations. Actual cooking trials were made during the first two years, but since dry matter and starch content as determined by specific gravity are closely co-related with cooking quality, the dry matter and starch content method of expressing quality was used throughout this experiment. Table 55 summarizes the effect of nutrient levels on the yield and quality of the Green Mountain potatoes under trial.

Dry matter and starch content, which indicate cooking quality, have consistently increased with the increase of potash in the fertilizer application. Yield has also increased in almost the same manner up to a moderately heavy crop in unbalanced fertilizer applications. However, with all three nutrients included in the application, the yield has increased sharply and quality has been maintained where potash exceeds phosphoric acid. With phosphoric acid in excess, quality falls slightly and yields are low.. Nitrogen in excess of two per cent has adversely affected both yield and quality. Accordingly, it would seem that on the muck soils of the district maximum yield and quality of the potato crop can be obtained with a commercial fertilizer in the proportion of a 2-8-16.

Miscellaneous Fertilizer Trials

Since 1937, fertilizer trials have been conducted with a large number of vegetable crops that are at present of minor importance when compared with crops of celery, potatoes and onions on the southwestern Quebec mucklands.

TABLE 55.—EFFECT OF NUTRIENT LEVELS ON THE AVERAGE YIELD AND QUALITY OF POTATOES, 1942-48

Nutrients per Acre			Total Yield bu./ac.	Dry Matter	Starch
Nitrogen	Phosphoric Acid	Potash			
lb.	lb.	lb.		%	%
0	0	0	212	16·2	13·1
20	0	0	202	16·3	13·1
40	0	0	174	15·8	12·5
0	80	0	164	15·0	12·4
0	160	0	157	14·7	11·9
0	0	80	302	17·1	13·2
0	0	160	378	17·2	13·2
20	80	0	172	14·9	11·7
20	160	0	214	16·1	13·1
40	80	0	180	15·8	12·5
40	160	0	236	16·2	13·1
20	0	80	421	18·3	14·6
20	0	160	529	18·9	14·7
40	0	80	326	17·3	13·7
40	0	160	346	17·3	13·7
40	80	80	336	17·1	13·6
40	80	160	457	18·4	14·6
40	160	80	351	17·0	13·6
40	160	160	503	18·9	14·8
0	80	160	492	20·4	15·8
0	80	80	402	19·2	15·3
0	160	160	491	19·1	15·3
0	160	80	432	17·8	14·1
20	80	80	506	19·7	15·6
20	80	160	617	20·3	15·8
20	160	160	603	19·6	15·4

Difference required between yields for significance (P = ·05) 26·1 bushels per acre.

Most of these respond favourably to a 2-8-16 at rates of from 400 to 1,000 pounds per acre. Exceptions to this are beans, peas and tomatoes, which require more phosphorus and produce normally with a 2-12-10. Asparagus has not responded to nitrogen application and has produced maximum crops with an 0-8-16. Peppermint is also sensitive to an excess of nitrogen in this soil but requires a liberal amount of phosphorus in addition to potash. The best results have been obtained with an 0-16-16. Melons, squash, pumpkin and cucumber require a fairly liberal amount of available nitrogen and have produced the best crops with a 4-8-16.

Black Heart of Celery

Black heart of celery, a physiological disorder, is occasionally responsible for heavy crop loss and is particularly prevalent on muck soils. The effect of the disorder is the dying and subsequent blackening of the celery heart. When young plants are affected, growth of the heart will start later in the season with a number of small hearts forming in each plant; with a midseason or late attack the heart simply dies and dries up leaving nothing but the outer petioles. In either event, the celery is abnormal and of very little market value.

The disorder first appeared at the Ste. Clothilde Substation in 1938. In 1939, trials were begun to determine the effect of cultural practices and nutrient treatments as control measures and to learn if the disorder was caused, or its severity increased, by stings of the false tarnish plant bug.

On a large number of nutrient trials, it was observed that with a 2-8-16 fertilizer with boron and manganese included in the application the disorder was less severe than on plots fertilized with an unbalanced fertilizer. It was also observed that manganese induced greater immunity than boron. However, no fertilizer treatment either caused or completely controlled black heart.

By covering small plots of celery with tents to keep out the false tarnish plant bug and introducing numbers of this insect into other tents covering celery, it was learned that its stings had no influence on the disorder. However, plants that had received many stings developed a condition resembling black heart.

From the observations on cultural practices it was noted that when the moisture supply was irregular black heart was more prevalent; also that when large numbers of celery roots were at or near the surface of the ground, cultivation late in the season encouraged the disorder. By such cultivation a substantial part of the root system was destroyed which reduced moisture intake suddenly. This caused a collapse or weakening of the cells in the growing heart which developed into black heart.

Later, these conditions were duplicated under controlled conditions in the greenhouse at Ottawa and the disorder was produced by any sudden change in moisture supply in the plant tissue. Accordingly, the control for black heart on muck soils is the maintenance of an even supply of moisture to the plant throughout the season. Where seepage irrigation is available this is comparatively simple. On non-irrigated muck land complete control may not be possible in unfavourable seasons, although the use of a properly balanced fertilizer with minor element deficiencies corrected will reduce the severity of the disorder.

Trials of Potato Seedlings

Although under correct soil and crop management very large crops of high quality potatoes can be grown on the mucklands of southwestern Quebec, no variety at present available commercially is entirely suitable for the conditions prevalent in these areas. Of the large number of named varieties tested during the past twelve years, all had faults of one kind or another. These faults included lateness in maturing, roughness and unattractive appearance, poor quality and low yield. Also, when grown on this very fertile soil, many proved extremely susceptible to late blight. With others the ease with which they became infected with virus diseases proved the limiting factor.

During the past six years, over 400 seedlings, originated at the Dominion Experimental Station, Fredericton, New Brunswick, under the National Potato Breeding Program, have been carefully tested. Yield, quality, marketability and disease resistance of these seedlings have been studied and a number have proved highly suitable for the muck soils of the region. Among these are seedlings which appear to have complete resistance to potato blight, are high yielding, relatively early and of excellent quality. Others have outstanding resistance to potato scab, which can reach extreme prevalence on neutral or alkaline mucks. Still others have exhibited marked resistance to several virus diseases. When tests of these seedlings have been completed, and the best ones finally released, they will undoubtedly prove of great value to muckland growers and substantially reduce the production costs of this crop.

Potato Spraying Trials

With the strong lush growth that potato vines make when grown on muck soil, disease and insect control presents a serious problem. The large vines are hard to cover with spray or dust and the soft, tender growth is very susceptible to insects and disease.

In 1939, experiments were started in which all commonly used fungicides and insecticides were tried at different rates and numbers of applications. These experiments have been continued each year and newer insecticides and fungicides have been added to the trials as they became available.

In general, it has been found that "fixed coppers" are at least equal in effectiveness to bordeaux mixture, and DDT has definitely become the most satisfactory insecticide. Numbers of applications and the amounts applied are in excess of those necessary for the potato crop on ordinary mineral soil. For a ten-year period, 1939 to 1948, eight applications of "fixed copper" sprays per season have been necessary to secure commercial control of potato blight. In these applications, the volume ranges from 35 gallons per acre in the first spray to 110 gallons when the vines are fully grown.

Since DDT became available, complete control of the Colorado potato beetle, leaf hopper and flea beetle can be effected by including the wettable forms of the chemical in three or four applications. Fairly satisfactory control of aphids has also been obtained with applications of DDT emulsion. However, this material must be used with caution since there appears to be only a very narrow margin between the concentrations that will kill aphids and those that prove harmful to foliage.

Vine Killing Sprays

When the desired potato crop has developed, killing the vines to obtain maturity at digging has become a fairly general practice. On the muckland in southwestern Quebec, because of high soil nitrogen and moisture, all varieties of potatoes mature later than on mineral soils. Therefore, vine killing is necessary for at least part of the crop so that harvest may be completed before severe frosts occur. At the Substation, a large number of vine killing materials have been used on Green Mountain vines for the past ten years. Those that have given fairly satisfactory results include various dinitro chemicals, copper sulphate, sulphuric acid and Stoddard solvent.

In general, it has been found that quick killing of the vines with any of the chemicals tested or by a severe frost will cause stem end browning of the potatoes. However, even with very large lush tops, this trouble can be avoided by slow killing that should extend over a period of two or three days. To obtain this with muckland potatoes, it has been found necessary to use the water soluble or mixable materials, such as the dinitros, copper sulphate and sulphuric acid, at about two-thirds the commonly recommended concentrations. It has also been found advisable to avoid making application when the air temperature is above 75° F., otherwise the kill may be too rapid. Copper sulphate at 2 per cent or sulphuric acid at 1½ per cent have proved satisfactory. With Stoddard solvent the material should be applied in a fine mist at a pressure of about 100 pounds and at a rate of not more than 40 or 50 gallons per acre.

Weed Control

Muck soils, which under correct management produce excellent crops of vegetables, will also produce weeds of unusual proportions in almost unbelievable numbers. On the Ste. Clothilde mucklands, this situation has been aggravated by the occasional flooding of Norton Creek which runs through the area and thereby brings in weed seeds from neglected lands. This condition prevailed until 1948, when the creek was deepened and satisfactory water control could be maintained. However, from 1937 to 1948 weed control was one of the major problems of this district and portions of the Substation provided excellent sites for experiments in weed control.

Of the crops most difficult and costly to weed, carrots and onions are the most important of those grown on the southwestern Quebec mucklands. Increasing wage rates have increased the per acre cost of weeding carrots at this Substation from $37.55 in 1937 to $104.20 in 1948. Such an expense cuts deeply into profits and, under some conditions, is almost prohibitive.

Carrots.—Previous to 1944, various materials were tried as pre-emergence herbicides for the carrot crop. On the whole, these were not very effective since, although emerged weeds were killed, many emerged with or after the crop and so the situation was not greatly improved. In 1944, the first trials were made with a selective weed killer, Stoddard solvent, known variously under different trade names. This material proved very effective and when correctly used, it definitely killed weeds and caused only slight harm to the carrot plants. In 1947, on a one-acre field four weeks after seeding 128 weeds per square yard had reached a height of about six inches. The carrot plants at this time would not average a height of more than four inches and so were completely obscured. Stoddard solvent was applied with a weed boom at 65 gallons per acre, and 99·3 per cent of all weeds were killed within 48 hours without visible harm to the carrot plants. The cost of material for the operation was $17.55 per acre.

Stoddard solvent is also effective for the control of weeds in celery and parsnip, which vegetables are highly tolerant to the chemical. It is most effective when applied while the air temperature is below 70° F., since at higher temperatures evaporation is too rapid for satisfactory killing of weeds. Of the various application pressures tried, the most effective was from 40 to 50 pounds per square inch. Trials of various amounts per acre at different stages of weed growth have indicated that the quantity of the material can be substantially reduced if the application is made when the weeds are small. With such weeds as lambs' quarters, pigweed, mustard and smartweed averaging a height of two inches, complete kills can be obtained with 40 to 45 gallons per acre. With the same weeds six inches high, 65 gallons are required. However, in badly infested ground it may be more economical to use the later and heavier application, since a second crop of weeds may develop if the kill is made while the majority of the weeds are small, thus necessitating two sprays.

Onions.—Since onion plants are not so highly resistant to available herbicides as carrot plants are to Stoddard solvent, the problem of weed control is more difficult. As with the carrots, pre-emergence applications have been only partially successful as weed seeds in muck soils germinate both before and after the onion seeds. Even with preparation of the land ten days in advance of seeding and applying the herbicide at the time the onion plants were beginning to emerge, large numbers of weeds appeared later. Also such seedings are usually too late and affect crop yields adversely.

The most promising results with pre-emergence treatments insofar as actual weed killing was concerned were obtained with cyanamid at 100 pounds per acre. Over a three-year period weeds killed at time of application averaged 97·3 per cent, and weeds developing later averaged 11·2 per square yard. Other treatments, although effective against weeds when applied, seemed to have little or no effect on those emerging later as all late counts averaged from 50 to 100 per square yard. However, the use of cyanamid on muck soils is of doubtful value since it contains up to 22 per cent nitrogen. The addition of this nitrogen to a soil already high in this element has resulted in later maturity of the crop and an increased percentage of "thick necks".

For post-emergence control, the most effective results have been obtained with potassium cyanate at one per cent on young plants and at two per cent on plants three or more inches high. In one instance a count of 1,047 weeds per square yard was recorded prior to the cyanate application. Three days after a two per cent application at 65 gallons per acre, 14 weakened weeds remained. Injury to onion plants amounted to 4·7 per cent. On muck soils where onions are not usually thinned and run eighteen or twenty per foot of row in a full crop, a loss of 4·7 per cent of the plants is negligible.

Several dinitro compounds have given good results on weeds but they killed too many onion plants. Dusting with cyanamid when the plants were two to three inches high was quite effective against weeds and did little harm to onion

plants. However, as with the pre-emergence application, the nitrogen in the cyanamid has a detrimental effect on the quality of the onions.

Foundation Stock Seed Production

Since 1940 the Substation has co-operated with the Canadian Seed Growers' Association in the production of foundation stock seed of vegetable crops. Definite assignments have included one variety each of cabbage, sweet corn, carrot, beet, bean, onion, radish and spinach. The standards of these varieties have been maintained and, with few exceptions, sufficient seed has been produced to meet Canadian requirements for this grade of seed.

Tree Fruits

Part of the mineral soil at the Substation is well suited for the growing of tree fruits, and an excellent orchard of approximately 8 acres has been established. The first plantings were made in 1940. These consisted of an apple variety orchard and a small pear planting. In the apple orchard a number of promising rootstocks are being tried with various frame builders on which promising and popular varieties have been grafted. So far in this experiment, Antonovka and Virginia crab are proving the most compatible and generally satisfactory frame builders. *M. robusta* No. 5, a clonal stock originated by the Division of Horticulture at Ottawa, has also proved very satisfactory as both a rootstock and frame builder. A seed orchard composed of varieties which produce seed suitable for growing rootstocks has been planted and is nearing production.

The pear planting consists of hardy varieties, most of which were originated by the Division of Horticulture. In addition, several varieties of hardy frame builders are being top-worked with more tender varieties.

DOMINION HORTICULTURAL SUBSTATION SMITHFIELD, ONTARIO

D. S. Blair

The Dominion Horticultural Substation at Smithfield, Ontario, was established in 1944 and is located four miles west of Trenton and one mile north of No. 2 highway. It comprises 100 acres, 80 of which are under cultivation, and is operated as a unit of the Division of Horticulture, Central Experimental Farm, Ottawa. This Substation is designed to undertake experimental and research work in both fruits and vegetables and particularly on those grown in the region extending from Toronto to Kingston.

Fig. 35—General view of the Dominion Horticultural Substation, Smithfield, Ontario.

Prior to purchase, the Soils Department of the Ontario Agricultural College, Guelph, was requested to make a detailed soil survey of the property. The soil survey revealed that the farm contains three main soil types. Sixty per cent of the soil is classified as Percy fine sandy loam, 30 per cent Bondhead loam and 10 per cent Brighton sandy loam.

A general soil survey was made during the years 1937 to 1939 by the Dominion Experimental Farms Service and the Soils Department of the Ontario Agricultural College of the orchard growing area of Northumberland and Durham counties. In addition, a detailed horticultural and soil survey was made of 177 individual orchards. This survey showed that the orchard soils of Northumberland and Durham counties are characterized by a number of types occurring within comparatively short distances and varying greatly in physical and chemical nature. The ten different soils occurring in the two counties may be grouped into four broad divisions, the soils included in each division having the same general characteristics.

The Percy fine sandy loam representing 60 per cent of the area of the Smithfield Substation is found on 20,000 acres in Northumberland county while the group of soils in which it is included occupies 43,000 acres. Of the 177 orchards surveyed in detail in the two counties, 35 per cent fall in this group. A large percentage of the orchards in the Newcastle area are located on soils of this group.

The Bondhead loam soil constituting 30 per cent of the Substation constitutes at least one-third of the total land area of Northumberland county, and of the 177 orchards in the two counties which were surveyed in detail, 25 per cent belonged to the soil group in which the Bondhead loam soil is included. This is rolling, well drained soil characterized by a parent material with a high limestone content. The depth to the parent material has been affected by cultivation and erosion, and the organic matter is low. Part of the Bondhead soil area on the Substation is on steep slopes which offer excellent opportunity for soil conservation experiments.

The Brighton sandy loam, representing 10 per cent of the area of the Smithfield Substation, is found on 11,000 acres in Northumberland county, while the group of soils in which it is included occupies 34,000 acres. Of the 177 orchards surveyed in detail in the two counties, 26 per cent occurred in this group. These are level, well to excessively drained sands to sandy loams. The natural fertility is low and the underlying sand is highly alkaline.

Fig. 36—General view of orchard management studies.

It will be seen that the three soil types occurring on the Substation represent a large proportion of the orchard soils of the two counties. Of the 177 orchards surveyed in detail, 86 per cent have soils similar in general characteristics to those found on the Substation. Moreover, this offers a splendid opportunity to study soil management problems on three totally different soil types.

These surveys also revealed that the soils in many orchards in these two counties have been depleted of one or more essential plant food elements and that soil erosion has commenced in many hillside orchards.

Supplementary to these soil surveys nutritional studies were carried out over a period of 8 years in an orchard near the Substation, and orchard soil management experiments were conducted for 6 years in a commercial orchard at Bloomfield, Prince Edward county. As a result of these investigations recommendations of considerable value to the apple growers in the region have been made. Because of the many far reaching problems of long duration it was considered imperative that a government-owned station be established in the region.

Of the 50 acres allocated to fruit investigations at the new Substation, 35 have been set out to long-term apple experiments dealing with orchard management studies, including contour planting, rootstock and hardy tree building investigations and varietal trials. Some 5,000 apple and 6,000 raspberry hybrids, the results of specific crosses made at Ottawa, are under observation. Three of the rust-resistant black currants, Coronet, Crusader and 0-391, recently introduced by the Division of Horticulture, are under commercial trial.

Twenty acres are allocated to vegetable canning crop investigations. These include a series of rotation plots using peas, corn and tomatoes as cash crops; fertilizer application methods with tomatoes; blossom-end-rot control studies with tomatoes; chemical weed control in peas and corn; spacing trials with corn and tomatoes; tomato transplant studies, and pea, corn and tomato variety trials. Preliminary findings from several of these trials are reported in the nutritional and vegetable sections of this report.

A large collection of disease-resistant potatoes originated at the Dominion Experimental Station, Fredericton, New Brunswick, and at Cornell University, Ithaca, New York, are being grown for observation and multipication. A potato variety yield trial is being conducted.

Vegetable Canning Crop Trials

W. Ferguson, L. H. Lyall and J. J. Jasmin

Sweet Corn Variety Trials

At the Smithfield Substation, corn variety trials are conducted with a view to assessing the suitability of the many new and standard varieties for use in the canning trade in that area. All varieties are first placed in the preliminary trials. Any which show particular promise are then given a more extensive trial before recommendations are made. High yield and good uniformity of maturity and ear type are essential in canning varieties. For these reasons, chiefly hybrid types are considered in the variety trials.

A number of standard canning varieties are grown each year in comparison with as many of the newer introductions as possible. From the preliminary trials in 1947 and 1948 it is apparent that there are considerable differences in yield and quality between many of the new and highly rated hybrids. Golden Hybrid and Goldencross Bantam are two of the more widely grown hybrids. However, on the basis of the results of preliminary trials only, it would appear that certain of the newer hybrids may prove superior to these standard types. Some of the best of these new hybrids are North Star, Sencross, Golden Beauty, Tendermost, Early Tendermost and Vinegold.

The Ottawa hybrid CH-1 has proved superior in quality to most of the hybrids tested and although not an exceptionally heavy yielder, is equal to the moderate yielding types. The chief fault of this hybrid for the Trenton area is that it is an early variety in an area where midseason to late varieties of corn are used for canning.

Corn Spacing Experiment

A spacing experiment was begun in 1947 with the object of determining the most efficient planting methods to obtain maximum yields of corn for canning.

The variety Golden Hybrid No. 2439 (Asgrow) was used for this work in 1947 and 1948. Plots are set up for statistical analysis and comprise the following treatments:

Seed sown in hills 3 ft. x 3 ft. with 3 plants per hill
" " " " 3 ft. x 3 ft. with 4 plants per hill

Seed sown in rows 3 ft. apart with plants 8 in. apart in the row
" " " " 3 ft. apart with plants 12 in. apart in the row
" " " " 3 ft. apart with plants 16 in. apart in the row

In 1947, unfavourable weather conditions early in the season ruined the row plots for yield records. However, the results of the hill system of planting indicated that three plants per hill would produce larger ears, requiring less handling, and yielding as much kernel weight as corn grown with four plants per hill with the same spacing.

In the 1948 experiment, corn planted in rows three feet apart with the plants 8 in. apart in the rows produced a significantly higher number of marketable ears per acre. The highest weight of marketable ears was produced by the treatment with three plants per hill. Since differences in weight of kernels were not significant, it would appear that for growing, and for handling at both the farm and the canning factory, the system of planting in hills with three plants per hill would be the most satisfactory.

Pea Variety Trials

Pea variety trials at the Smithfield Substation are designed to give comparative tests of pea varieties and strains when grown as canning crops in the Trenton area. The testing process involves preliminary trials and replicated plot trials. In the preliminary trials, a large number of varieties are grown in small test rows. These varieties consist mainly of new introductions by seedsmen and experimental institutions, and are grown in comparison with the standard canning varieties for the area. If any of these varieties or strains show particular promise with one or two years of preliminary testing, they are then included in the replicated plot trials. In these latter, a variety plot consists of approximately 1/100 of an acre and is replicated five times. The peas are sown as a canning crop and the green pods are harvested at the optimum time for canning (as indicated by texture-meter readings). Vine weight, pod weight, and yield of shelled green peas are recorded for each variety.

On the basis of two years of replicated plot trials it appears that the Ottawa variety Alton is a very promising canning type. It is an early type coming in at approximately the same season as Alaska, Wisconsin Early Sweet and Thos. Laxton. In these tests, however, Alton has significantly outyielded the three standard varieties of the same season even when harvested at a lower texture-meter reading. Results for these early varieties are summarized in Table 56.

TABLE 56.—COMPARATIVE YIELD DATA ON FOUR VARIETIES OF PEAS

Variety	1947			1948		
	Texture-meter Reading	Shelled Peas (lb./ac.)	Days: Seeding to Harvest	Texture-meter Reading	Shelled Peas (lb./ac.)	Days: Seeding to Harvest
Alton	100	4,666	61	92	4,811	66
Alaska	125	4,160	56	.....	.....	.....
Wisc. Early Sweet	115	3,019	57	105	3,751	66
Thos. Laxton	100	3,834	60	91	3,583	70

Tomato Variety Trials

As with the other canning crops, tomato varieties are grown first in the preliminary trials and then any which appear particularly promising are placed in a replicated plot trial. In this trial quantitative records are taken on early yield and yield for the whole season, with marketable fruits being divided into Canada Grades 1 and 2.

Fig. 37—General view of vegetable canning crops rotation experiment.

In the 1948 trials, some of the newer varieties were tested in comparison with the standard varieties Geneva John Baer, Clark's Early, Bonny Best and Early Rutgers. Results are shown in Table 57.

TABLE 57.—MARKETABLE YIELD IN TONS PER ACRE OF NINE VARIETIES OF TOMATOES, 1948

Variety	Yield During First Two Weeks (To Aug. 17)	Yield for Season (to Sept. 22)
Ottawa TO-3	1·72	18·50
Gem	0·79	18·69
Ottawa TO-4	0·59	17·53
Longred	0·50	14·92
Geneva John Baer	0·48	13·47
Clark's Early	0·47	11·83
Red Jacket	0·43	16·22
Bonny Best	0·32	11·11
Early Rutgers	0·05	14·28

Necessary differences for significance are:

For yield in first two weeks..... 0·19 tons
For yield in whole season..... 3·50 tons

Ottawa TO-3 was outstanding for early yield, the next being Gem which was significantly higher than the other varieties. In total yield for the season,

Gem and Ottawa TO-3 were again at the top but were not significantly higher yielding than Ottawa TO-4 and Red Jacket. All other varieties showed significantly lower total yields.

The varieties, Gem, Red Jacket and Longred, are all originations from the New York Agricultural Experiment Station (Geneva) while Ottawa TO-3 and TO-4 are from the Division of Horticulture, Central Experimental Farm, Ottawa.

Tomato Fertilizer Placement Studies

H. Hill

Growers want to apply fertilizer in such a way that it will be used with the greatest efficiency. Fertilizer should be placed so that it is easily reached by the plant roots and is in contact with moist soil.

For the past ten years the United States has paid considerable attention to various methods of fertilizer placement, but the reports of the Committee on Fertilizer Placement of the National Fertilizer Council indicate that several factors such as extent and distribution of rainfall, kind of fertilizer employed and type of soil will affect the choice and effectiveness of the method. While concentrated application of fertilizer such as band placement may be particularly effective on heavy soils, plant nutrients may be unavailable on light sandy soils during periods of dry weather.

During the last three years of the period under review, studies of fertilizer placement with tomatoes were conducted at the Smithfield Substation, on light soils classified as Brighton sand or Percy fine sandy loam. These soils are typical of those employed for tomato production in the district.

A basic fertilizer, 2-12-6, applied at the rate of seven hundred pounds per acre was used, and, in addition, half the plants in each plot were treated with ½ pint of an 8-24-8 starter solution, the remaining plants receiving water only. The plants were of the Geneva John Baer variety and were planted four by four feet apart. The experiment consisted of three blocks with the fourteen treatments randomized in each block. The list of treatments in descending order of total yields is as follows:

1. 700 lb. 2-12-6 in bottom of furrow, two weeks before planting.
2. 700 lb. 2-12-6 broadcast and disked; side dressing, 150 lb. muriate of potash and 200 lb. sulphate of ammonia at last cultivation.
3. 700 lb. 2-12-6 applied with grain fertilizer drill.
4. 450 lb. 2-12-6 broadcast and disked, 250 lb. in bands at planting.
5. 700 lb. 2-12-6 broadcast and disked, side dressing of 150 lb. muriate of potash at last cultivation.
6. 450 lb. 2-12-6 placed in the bottom of the furrow, 250 lb. in bands at planting.
7. 700 lb. 2-12-6 broadcast and disked.
8. 350 lb. 2-12-6 broadcast and disked, two side dressings of 175 lb. three and six weeks after planting.
9. 700 lb. 2-12-6 in bands at planting.
10. 700 lb. 2-12-6 broadcast before ploughing.
11. 450 lb. 2-12-6 applied by grain drill, 250 lb. in bands at planting.
12. 450 lb. 2-12-6 broadcast and ploughed, 250 lb. in bands.
13. 450 lb. superphosphate in the bottom of the furrows, side dressing 70 lb. muriate of potash and 70 lb. ammonium sulphate three weeks after planting.
14. 250 lb. 2-12-6 in bands at planting.

Results

Broadcasting the fertilizer before disking and applying a supplemental dressing of 150 lb. of muriate of potash and 200 lb. of ammonium sulphate at the time of the last cultivation (Treatment 2) consistently produced the highest marketable yield, did not delay early ripening and produced a relatively low percentage of blossom-end rot. When a starter solution was used with this method of fertilizer application, marketable yields were increased and blossom-end rot was not appreciably increased. When potash only was used as a supplementary application with this basic treatment, total and marketable yield was increased in only one of the three years the experiment was conducted.

When no supplemental application of fertilizer was applied the highest total and highest marketable yield was obtained by placing all the fertilizer in the bottom of the row furrows shortly before or at planting. Blossom-end rot was relatively high compared with broadcasting all or a portion of the fertilizer before disking. Starter solution produced an appreciable increase in early and total yield, but blossom-end rot was increased to such an extent in two years that marketable yield was not significantly increased. With this method of application no advantage is to be gained by the use of a starter solution. Applying all the fertilizer with a fertilizer grain drill before planting produced the next highest total and marketable yields. Blossom-end rot was about the same as when fertilizer was applied in the furrow. This treatment appeared to promote early ripening. Starter solution increased early yields and its use may be of benefit.

Broadcasting previous to disking produced slightly higher total and marketable yields than did broadcasting previous to ploughing or band placement. Compared with all other basic methods of application this treatment produced the lowest percentage of blossom-end rot. Starter solution markedly increased marketable yields and did not increase blossom-end rot to any extent. The application of a portion of the fertilizer in bands increased total and marketable yields in one instance only. This was with the basic treatment, broadcasting before disking, and when a starter solution was used this advantage did not persist. In partial band placement, the use of a starter solution did not increase total yields to any extent and because blossom-end rot was increased the starter was of no advantage.

There did not appear to be any advantage from band placement on this light soil since total yields were lower than with other basic treatments, and marketable yields were further reduced. Band placement had particularly low production in a year when soil moisture was low. Placing superphosphate only in the furrow and side dressing with nitrogen and potash did not give good results. Total and marketable yields were considerably reduced when compared with placing the mixed fertilizer in the furrow.

With the total fertilizer application of 700 lb./ac., applying a portion (350 lb./ac.) as a broadcast application before disking and the remainder as side dressings three and six weeks after planting, (Treatment 8) did not increase yields. However, when the full quantity of fertilizer was used as a basic treatment at planting and supplemented with a side dressing the highest marketable yields were obtained.

Results obtained in this study indicate that on similar light soils in this district high marketable yields and a low incidence of blossom-end rot will be obtained by broadcasting the fertilizer before disking, employing a starter solution, and applying a side dressing of nitrogen and potash at the time of the last cultivation. If no supplementary side dressing of fertilizer is to be employed, placing all the fertilizer in the furrow row without the use of a starter, or applying the fertilizer with a grain fertilizer drill plus the use of a starter should provide efficient use of the fertilizer. Further studies are being conducted. In these a supplemental side dressing of nitrogen and potash is being employed with the basic application of fertilizer either placed in the furrow or applied with the grain fertilizer drill.

ORGANIZATION

OF THE

DIVISION OF HORTICULTURE

The Division is at present organized in sections covering the following fields of endeavour:

Pomology Section.—Rootstock and tree building studies, fruit breeding and variety testing.

Vegetable Section.—Breeding, seed production and variety testing.

Ornamental Horticulture Section.—Variety testing, culture, propagation and breeding of herbaceous and woody ornamental material.

Plant Nutrition and Physiology Section.—Nutritional and physiological studies with horticultural plants.

Low Temperature Section.—The preservation of fruits and vegetables by cold storage and related research.

Fruit and Vegetable Products Section.—The experimental manufacture of fruit and vegetable products; fruit juices, dehydration, canning and freezing.

Floriculture and Greenhouse Section.—A new section established in 1947, to cover the production of horticultural crops under glass.

Cytology and Genetics Section.—Cytological and genetical studies with horticultural material.

Biometrics and Statistical Section.—Plot technique and statistical interpretation where applicable.

Potato Section.—National potato trials and the evaluation and distribution of new varieties from the National breeding program.

Histology and Morphology Section.—Effects of cultural and experimental practices on the internal structure and development of horticultural plants.

Illustration Section.—The graphic recording of new varieties and of the visual results of nutritional and other studies on horticultural material.

Horticultural Substations

In addition to the work conducted at Ottawa, the Division is directly responsible for the operation of two Substations, one at Ste. Clothilde, Chateauguay Co., Que., and the second at Smithfield, Ontario, (near Trenton).

The Ste. Clothilde Substation is located on muckland and was established for the purpose of investigating the horticultural possibilities of this type of soil. A more complete reference to the work is found earlier in this report.

The Smithfield Substation was designed for research in fruit and canning crops and serves directly the fruit producing and canning crop regions of Northumberland, Durham, Hastings and Prince Edward counties. Specific projects at this Substation are referred to earlier in these pages.

Branch Farms and Stations

While this report only covers the work of the Division at Ottawa and the two Substations, horticultural investigations are conducted to some extent on all Branch Farms and Stations and results of their work will be found in their Progress Reports. The following stations conduct important horticultural studies:

The Dominion Experimental Station, Kentville, N.S., majors in fruit investigations for the Annapolis Valley. The Dominion Experimental Station, Fredericton, N.B., engaged in potato breeding, including disease resistance, and other phases of fruit and vegetable production. This station also operates a Substation in the Grand Lake region of New Brunswick largely for vegetables and small fruits, and another Substation in Charlotte county for investigations with the wild blueberry. The Dominion Experimental Station at Morden, Man., acts as headquarters for horticulture in the three Prairie Provinces and is engaged in a comprehensive fruit and vegetable breeding program, fruit and vegetable products research and extensive work with ornamental material. The Dominion Experimental Station at Summerland, B.C., is engaged in a comprehensive line of investigation surrounding the fruit and vegetable industry of the Okanagan Valley. This station also operates low temperature research and fruit and vegetable products research laboratories. The Dominion Experimental Station at Saanichton, B.C., on Vancouver Island, is largely engaged with investigations concerning the small fruit industry, the vegetable seed industry and the bulb industry of Vancouver Island.

LOCATION OF HORTICULTURAL PROJECTS THROUGHOUT THE EXPERIMENTAL FARMS SERVICE

	Ottawa, Ont.	Charlottetown, P.E.I.	Kentville, N.S.	Fredericton, N.B.	L'Assomption, Que.	Normandin, Que.	Ste. Anne de la Pocatiere, Que.	Ste. Clothilde, Que.	Harrow, Ont.	Kapuskasing, Ont.	Smithfield, Ont.	Brandon, Man.	Morden, Man.	Indian Head, Sask.	Melfort, Sask.	Scott, Sask.	Swift Current, Sask.	Beaverlodge, Alta.	Fort Vermilion, Alta.	Lacombe, Alta.	Lethbridge, Alta.	Agassiz, B.C.	Prince George, B.C.	Saanichton, B.C.	Summerland, B.C.	Smithers, B.C.
Tree Fruits—																										
Breeding, Selection, Genetical and Cytological Studies	x		x	x			x		x				x	x				x			x			x	x	
Prevention of Preharvest Drop	x						x																			
Propagation, Tree Building and Pruning	x		x			x	x		x				x	x										x	x	
Thinning	x		x																					x	x	
Variety Tests	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	
Bush and Small Fruits—																										
Breeding, Selection, Genetical and Cytological Studies	x			x									x									x				
Cultural Studies																	x					x				
Improvement and Culture of Native Fruits		x	x			x												x								
Variety Testing	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Vegetables—																										
Breeding, Selection, Genetical and Cytological Studies	x			x	x				x				x					x			x	x		x		
Culture and Methods of Growing			x	x	x			x	x	x	x		x	x			x	x			x	x	x	x	x	
Potato Breeding				x																						
Potato Seedling and Variety Tests	x	x	x	x	x	x	x	x			x	x	x			x		x		x	x	x	x	x		x
Seed Production and Foundation Stock Maintenance	x	x	x	x	x		x		x	x			x			x					x	x	x	x		
Variety Testing	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Weed Control					x		x	x														x				
Ornamentals—																										
Breeding and Selection	x	x											x												x	
Bulb Production	x																x							x		
Greenhouse Floriculture	x		x											x											x	
Variety Testing	x	x	x			x			x	x		x	x			x	x	x		x	x		x	x	x	
Propagation	x												x	x											x	
Fruit and Vegetable Products	x		x										x												x	
Low Temperature Research	x		x																						x	
Plant Nutrition and Soil Management—																										
Control of Soil Erosion											x														x	
Fertility Diagnosis of Horticultural Crops	x		x	x				x			x															
Fertilizer, Rotation and Soil Building Studies	x	x	x	x	x			x	x		x					x		x			x	x		x	x	
Physiological Disorders	x										x	x		x							x				x	
Soil Moisture and Irrigation					x								x			x	x				x				x	

EXPERIMENTAL FARMS SERVICE

Director, E. S. ARCHIBALD, B.A., B.S.A., LL.D., D.Sc.

Associate Director, E. S. HOPKINS, B.S.A., M.Sc., Ph.D.

Dominion Field Husbandman	P. O. Ripley, B.S.A., M.Sc., Ph.D.
Dominion Horticulturist	M. B. Davis, B.S.A., M.Sc.
Dominion Cerealist	C. H. Goulden, B.S.A., M.S.A., Ph.D.
Dominion Animal Husbandman	G. W. Muir, B.S.A.
Dominion Agrostologist	T. M. Stevenson, B.S.A., M.Sc., Ph.D.
Dominion Poultry Husbandman	H. S. Gutteridge, B.S.A., M.Sc.
Chief, Tobacco Division	N. A. MacRae, B.A., M.Sc., Ph.D.
Dominion Apiculturist	C. A. Jamieson, B.S.A.
Chief Supervisor of Illustration Stations	J. C. Moynan, B.S.A.
Economic Fibre Specialist	R. J. Hutchinson.

PRINCE EDWARD ISLAND

Superintendent, Experimental Station, Charlottetown, R. C. Parent, B.S.A., M.Sc.
Superintendent, Experimental Fox Ranch, Summerside, C. K. Gunn, B.Sc., M.Sc., Ph.D.

NOVA SCOTIA

Superintendent, Experimental Farm, Nappan, W. W. Baird, B.S.A.
Superintendent, Experimental Station, Kentville, A. Kelsall, B.S.A.

NEW BRUNSWICK

Superintendent, Experimental Station, Fredericton, S. A. Hilton, B.S.A., M.S.A.

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Superintendent, Experimental Station, Lennoxville, J. A. Ste. Marie, B.S.A.
Superintendent, Experimental Station, Ste. Anne de la Pocatiere, J. R. Pelletier, B.S.A., M.A., M.Sc.
Superintendent, Experimental Station, L'Assomption, R. Bordeleau, B.S.A.
Superintendent, Experimental Station, Normandin, A. Belzile, B.S.A.
Officer-in-Charge, Experimental Substation, Ste. Clothilde, F. S. Browne, B.S.A.

ONTARIO

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Superintendent, Experimental Station, Harrow, H. F. Murwin, B.S.A.
Officer-in-Charge, Experimental Substation, Delhi, L. S. Vickery, B.S.A., M.S.
Officer-in-Charge, Experimental Substation, Smithfield, D. S. Blair, B.S.A., M.Sc.

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Superintendent, Experimental Station, Morden, W. R. Leslie, B.S.A.
Officer-in-Charge, Pilot Flax Mill, Portage la Prairie, E. M. MacKey, B.S.A.

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Superintendent, Experimental Station, Swift Current, G. N. Denike, B.S.A.
Superintendent, Experimental Station, Melfort, H. E. Wilson, B.S.A.
Superintendent, Experimental Substation, Regina, J. R. Foster, B.S.A.
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Superintendent, Forest Nursery Station, Sutherland, W. L. Kerr, B.S.A., M.Sc.

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Officer-in-Charge, Experimental Substation, Fort Vermilion, V. J. Lowe.

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Superintendent, Experimental Station, Summerland, R. C. Palmer, B.S.A., M.Sc., D.Sc.
Superintendent, Experimental Station, Prince George, F. V. Hutton, B.S.A.
Superintendent, Experimental Station, Saanichton, J. J. Woods, B.S.A., M.S.A.
Superintendent, Experimental Substation, Smithers, W. T. Burns, B.S.A., M.Sc.
Officer-in-Charge, Range Experiment Station, Kamloops, T. G. Willis, B.S.A., M.S.A.

YUKON AND NORTHWEST TERRITORIES

Officer-in-Charge, Experimental Substation, Whitehorse, Y.T., J. W. Abbott.
Officer-in-Charge, Experimental Substation, Fort Simpson, N.W.T., J. A. Gilbey, B.S.A., M.Sc.