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DOMINION EXPERIMENTAL SUBSTATION

WOODSLEE, ONTARIO

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PROGRESS REPORT
1947-1953

The nitrogen requirements of corn are high. Corn on left shows nitrogen deficiency; corn on right has a good supply of nitrogen.

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DOMINION EXPERIMENTAL SUBSTATION
WOODSLEE, ONTARIO

TECHNICAL STAFF 1953

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55611—1

CONTENTS

55611—1½

INTRODUCTION

The Experimental Substation at Woodslee was established in 1946 as a specialized soils Substation of the Experimental Station at Harrow. The Substation is composed of 100 acres of Brookston clay and is centrally located in the area of Brookston clay soil in Essex county. The farm at Woodslee was chosen for experimental purposes because it was typical of the majority of farms in the area and the experimental results would be applicable to the average farm on heavy textured soil.

There are approximately one and three-quarter million acres of clay, clay loam and silt soil in the counties of southwestern Ontario. Of the total land area in these counties, about 75 per cent of Essex, 51 per cent of Kent, 78 per cent of Lambton, 47 per cent of Middlesex, and 45 per cent of Elgin is made up of these problem soils. Brookston clay comprises the greater part of this acreage of heavy soil.

Brookston clay usually has an extremely flat topography and poor natural drainage. A large proportion of the farms on Brookston clay have been drained by means of tile, and tile drains are being installed on a certain amount of untiled land in this area each year. New drains are being placed at intervals of either 2 or 3 rods and at a depth of about 24 inches. A number of farmers whose land was tiled every 4, 6, or 8 rods apart some years ago are now having tile drains installed between these older drains to provide more uniform drainage throughout the field.

Tile drains have increased the productivity of heavy textured soils during dry years as well as during wet growing seasons. At the same time tile drains have permitted a more intensive production of row crops because tile-drained soil can be worked earlier in the spring thus extending the planting season and allowing for the production of larger acreages of row crops.

Corn and soybeans take a prominent place in the economy of southwestern Ontario. In 1953 the Ontario Department of Agriculture reported that farmers in Essex, Kent, Lambton, Elgin, and Middlesex counties grew a total of 293,600 acres of husking corn and 203,800 acres of soybeans. The combined value of the corn and soybeans produced in this area was $32,045,300 in 1953. In view of the importance of corn and soybeans, particularly to the areas of heavy textured soil, the greater part of the experimental work at Woodslee is in connection with the production of these crops.

Forage crops also are of considerable importance in southwestern Ontario, particularly in the maintenance of soil physical condition in clay soil. For this reason new varieties of legumes and grasses are being tested in a general way at Woodslee to determine whether they are adapted to the soil and weather conditions in the district. In addition to this a breeding program has been started in an attempt to develop an improved variety of sweet clover that could be used for soil improvement purposes in southwestern Ontario.

Soil physical condition is a term that is used to define how loose, crumbly, or friable a heavy textured soil will become under certain tillage treatments. This condition has received a considerable amount of attention in recent years on clay soil in Essex and Kent counties. A number of factors have an influence on soil physical condition among which are the organic matter level of the soil, tillage treatment and activity of the soil micro-organisms. Although a temporary improvement in physical condition can be produced by means of tillage, a more permanent type of improvement is produced through the breakdown of organic matter in the soil. This action produces what are known as water-stable aggregates in which the smallest soil particles are held together in larger crumb-like structures. These crumb-like structures that are set up as a result of biological activity in the soil are more or less resistant to the washing action of rain which will cause clay soil to run together where water-stable aggregation is poor.

The organic matter level in clay soil has been used as one of the criteria of physical condition. On Brookston clay it has been noted that virgin soil or soil from old fence rows exhibits good physical characteristics while soil that has been under cultivation for many years shows less favorable physical properties. Early studies indicated that the total organic matter content had decreased from an average of 10·8 per cent in the fence rows to an average level of 5·3 per cent in the cultivated fields.

The nitrogen content in Brookston clay soil has shown a decrease corresponding to that of the organic matter. Studies at Woodslee have indicated that the nitrogen level is usually low in soil that has been cultivated many years and where no clover has been grown for a few years. Soil tests and crop response have also indicated that the available phosphorus in Brookston clay may be somewhat lower than the level thought desirable for the production of certain crops, particularly small grains, soybeans, and legume hay. On the other hand, soil tests have shown that potash is generally in good supply on Brookston clay soil. There appears to be a good reserve of this mineral in the soil.

The main purpose of the work at Woodslee is to perform research and experimental work with a view to improving the productive capacity of Brookston clay soil. The work is designed primarily to study the effect of cropping systems and fertilizer use on crop yield and soil physical condition. Some preliminary work is also being undertaken relative to the effects of tillage on crop production. Studies on soil physical condition also include work with synthetic soil conditioners which recently have been made available to the public.

From the time the Woodslee Substation was started in 1946 Mr. J. W. Aylesworth, working under the direction of Mr. H. F. Murwin who is the Superintendent of the Harrow Station, has supervised the experimental work at Woodslee. In 1947 Mr. J. M. Fulton was placed in charge of the soils laboratory at Harrow and undertook the soil physical and soil fertility studies in connection with the experimental work at Woodslee. A further division of the work was made in 1951 when Mr. E. F. Bolton was placed in charge of the soil physical studies at Woodslee working under the supervision of Mr. Fulton. A laboratory was started at Woodslee at this time to undertake more intensive studies relative to physical condition on Brookston clay.

METEOROLOGICAL REPORTS

Meteorological records have been taken at the Woodslee Substation since January 1, 1947. Daily readings were taken of maximum and minimum temperatures, relative humidity, precipitation, and wind velocity and direction. Precipitation data, average monthly temperatures and extremes in temperature are presented in Table 1, 2 and 4, respectively. The frost records and frost-free periods for the seven years 1947 to 1953 are given in Table 3.

Weather conditions often have a greater influence on crop yields than cultural or fertilizer treatments. For example, the average corn yield in 1951 was 16·5 bushels lower than in the good corn year of 1949. On the other hand, average corn yields during the years 1952 and 1953 at Woodslee were approximately 22 bushels higher than the poor corn year of 1951.

Temperature and rainfall are of extreme importance in the production of corn. Low temperatures, heavy rainfall, or a combination of these two factors during the growing season on the clay soils in the area will tend to decrease the yield of corn. In 1947 the corn crop in the district was generally poor. In this connection the records show that rainfall was high, particularly during May and August, and also the average monthly temperatures during May, June, and July of 1947, were lower than the seven-year average. The corn crop was also generally poor in 1951. Although the rainfall was not excessive during 1951 it will be seen in Table 2 that the average monthly temperature was lower than the seven-year average during the growing months of May, June, July, and August.

The corn crops for the years 1949, 1952, and 1953 were good. Table 2 shows that the average monthly temperatures during the growing season for these three years were higher than the seven-year average. Corn yields on the average were higher on the Woodslee Substation in 1952 and 1953 than in 1949 in spite of the fact that there was approximately 5·6 inches less rainfall during May, June, July, and August in 1952 and 1953 than in 1949. The corn crop was not quite so good in 1953 as it was in 1952 because the reserve soil moisture was low in the spring of 1953. This condition resulted from a particularly dry fall and winter. The moisture shortage became critical in August of 1953 when only 1·06 inches of rain were recorded during this month. In general, however, it is expected that corn yields on the clay soils of the area will be higher during a dry year than during a year of excessive rainfall.

TABLE 1—PRECIPITATION RECORDS

Mean Monthly Precipitation, 1947 to 1953, Experimental Substation, Woodslee, Ontario

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual snowfall (in.)	Total annual rainfall (in.)	Total annual precip-itation (in.)
1947	3·26	·41	1·57	6·82	4·90	1·98	2·56	6·31	2·38	1·31	2·07	2·52	23·0	33·79	36·09
1948	1·94	2·06	3·47	3·04	5·19	3·33	1·65	1·69	2·49	2·07	4·82	2·07	17·6	32·06	33·82
1949	2·74	3·11	3·20	2·32	3·17	3·47	2·61	4·02	2·70	3·61	1·71	3·55	19·0	34·31	36·21
1950	5·77	3·30	3·02	4·26	1·76	2·01	3·91	2·63	2·57	3·75	3·57	3·69	43·1	35·93	40·24
1951	3·31	3·49	2·55	2·02	1·87	2·42	1·96	2·44	1·09	2·88	3·10	3·18	56·6	24·65	30·31
1952	3·32	1·33	3·29	2·19	2·78	1·01	1·99	1·95	1·63	0·73	2·04	1·77	29·0	21·13	24·03
1953	2·97	0·64	2·91	2·35	2·48	2·58	1·88	1·06	1·40	·69	·98	1·61	26·9	18·86	21·55
7-year average	3·33	2·05	2·86	3·29	3·16	2·40	2·37	2·87	2·04	2·15	2·61	2·63	30·7	28·68	31·75

TABLE 2—AVERAGE MONTHLY TEMPERATURE

Experimental Substation, Woodslee, Ontario

(Degrees Fahrenheit)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Av.
1947	30·0	23·2	31·0	46·4	54·1	65·2	71·1	75·0	64·8	59·5	36·8	27·4	48·7
1948	14·0	24·2	34·5	51·7	55·9	67·0	72·6	70·6	65·2	49·1	45·6*	30·9	48·4
1949	31·3	29·5	35·0	45·7	59·6	72·4	74·9	71·1	58·5	56·0	38·4	31·5	50·3
1950	31·3	25·0	28·8	39·9	56·4	65·8	68·6	68·0	61·8	53·6	34·3	23·8*	46·4
1951	25·7	25·6	34·8	44·5	59·1	65·6	70·7	68·2	60·6	53·7	33·6	27·1	47·4
1952	28·0	28·1	33·8	48·3	56·3	71·2	79·2	69·1	62·4	46·0	41·1	32·4	49·7
1953	29·0	31·4*	37·7*	43·7*	57·6	68·6	71·1	71·2	63·4	54·1	42·4	31·9	50·2
7-year average	27·0	26·7	33·7	45·7	57·0	68·0	72·6	70·5	62·4	53·1	38·9	29·3	48·7

* Thermometers out of order and Harrow temperatures inserted.

TABLE 3—FROST RECORDS, EXPERIMENTAL SUBSTATION, WOODSLEE, ONTARIO

Frost—32°F or lower   Killing frost—28°F or lower

Year	Last frost in spring		First frost in fall		Number of frost-free days	Last killing frost in spring		First killing frost in fall		Number of days free from killing frost
	Date	Temp.	Date	Temp.		Date	Temp.	Date	Temp.	
1947	May 10	28·8	Sept. 26	30·6	139·0	Apr. 28	27·4	Oct. 1	27·3	156·0
1948	Apr. 18	31·2	Oct. 18	26·4	183·0	Apr. 10	24·7	Oct. 18	26·4	191·0
1949	Apr. 29	31·4	Oct. 25	31·7	179·0	Apr. 17	26·8	Oct. 27	24·2	193·0
1950	May 21	31·0	Oct. 5	31·0	137·0	Apr. 22	28·0	Oct. 26	26·0	187·0
1951	Apr. 27	31·0	Sept. 29	30·0	155·0	Apr. 20	27·0	Oct. 29	26·0	192·0
1952	Apr. 16	32·0	Oct. 3	31·0	170·0	Apr. 12	27·0	Oct. 7	25·0	178·0
1953	Apr. 28	31·0	Oct. 8	27·0	163·0	Apr. 21	27·0	Oct. 8	27·0	170·0
7-year average	Apr. 30	—	Oct. 8	—	160·9	Apr. 19	—	Oct. 17	—	181·0
Shortest crop season	May 10 1947	28·8	Sept. 26	30·6	139·0	Apr. 28 1947	27·4	Oct. 1	27·3	156·0
Longest crop season	Apr. 18 1948	31·2	Oct. 18	26·4	183·0	Apr. 17 1949	26·8	Oct. 27	24·2	193·0

TABLE 4—AVERAGE TEMPERATURE READINGS FOR PERIOD 1947 TO 1953
WOODSLEE, ONTARIO

Month	Mean monthly temperature	Highest record		Lowest record	
		Temp.	Year	Temp.	Year
January	27·0	63·5	1950	−6·0	1951
February	25·9	56·0	1951	−11·0	1951
March	33·0	70·5	1949	−6·5	1948
April	46·1	80·0	1951	17·0	1950
May	57·0	87·0	1949	30·0	1950
June	68·0	100·0	1952	35·8	1947
July	72·6	96·0	1952	42·0	1950
August	70·5	96·0	1953	41·0	1950
September	62·4	98·0	1953	30·0	1951
October	53·1	88·0	1951	20·0	1952
November	37·8	77·0	1950	6·4	1947
December	30·2	60·0	1951	−7·0	1951
Annual	48·6	100·0	1952	−11·0	1951

CROP ROTATION STUDIES

In 1947 experiments were begun to study the effects of different cropping systems on yield of crops and physical condition of the soil. A number of two-, three-, four- and five-year rotation experiments were started on a field that had produced corn and oats in a two-year rotation for some years previous to 1947. All crops in every rotation were grown each year. Corn was included in all rotations and was used as a basis for comparing the effects of the different crop rotations. Half of each rotation plot was fertilized with an application of 300 pounds per acre of a 2-12-10 mixture every time a crop was planted. The other half of each plot in all rotations received no commercial fertilizer during the period covered by this report.

With the exception of the rotations where manure was applied for the corn crop, all crop residues such as corn stalks, soybean straw, oat straw, and hay crop were returned to the soil and incorporated by disking or plowing. In the rotations where manure was applied for the corn crop all crop residues were removed from the plots to simulate a system of cropping that included the maintenance of livestock. The soil was plowed only for the corn crop and was done during the fall season.

The yields of corn reported here were calculated on the basis of shelled corn at 15 per cent moisture. The cereal and hay crops are reported in bushels per acre and tons per acre respectively. Because the four-year rotations completed their first cycle in 1950, only the yield data for the years 1951 to 1953 were used as a basis of comparison for the two-, three-, and four-year rotations reported here. The five-year rotations being tested at Woodslee have yielded only two years of data at the present time and therefore are not included in this report.

Two-year Rotations

Table 5 gives the yield of crops in the two-year rotations at Woodslee on Brookston clay soil. Included in this group of two-year rotations are the treatments where continuous corn and continuous soybeans were grown.

TABLE 5—CROP YIELDS IN TWO-YEAR ROTATIONS, WOODSLEE, ONTARIO

(Average yields over three-year period 1951 to 1953)

Rotation	Fertilizer[1]	Corn	Oats	Soybeans
		bu.	bu.	bu.
Corn—oats plus red clover	None	46·2	35·4	—
	300 lb.	54·3	43·9	—
Corn—oats plus alfalfa plus brome	None	44·8	35·3	—
	300 lb.	55·4	42·4	—
Corn—oats plus sweet clover	None	43·0	34·6	—
	300 lb.	53·7	41·2	—
Corn—soybeans	None	42·6	—	21·5
	300 lb.	51·9	—	27·5
Corn—oats	None	37·0	27·5	—
	300 lb.	40·8	31·7	—
Continuous corn	None	23·4	—	—
	300 lb.	23·6	—	—
Continuous soybeans	None	—	—	18·0
	300 lb.	—	—	20·2

[1] 300 lb. per acre of 2-12-10 fertilizer applied on one-half of each plot in the rotations.

The yields of corn from the two-year rotations, as listed in Table 5, show the effect of seeding clover or alfalfa in the crop of oats. When no fertilizer was applied an increase of 9·2 bushles per acre of corn was obtained where red clover was seeded in the oats and plowed in the fall of the same year. Increases of 7·8 and 6·0 bushels were obtained with no fertilizer where alfalfa plus brome and sweet clover, respectively, were seeded in the oats. It will also be noted that an increase of 5·6 bushels per acre of corn was obtained where soybeans were included in the rotation instead of oats. This difference in yield is probably due to the nitrogen fixing ability of the soybeans. It is also interesting to note that the unfertilized corn yield in the corn—oats rotation was higher by 13·6 bushels than the average yield of unfertilized continuous corn.

The application of 2-12-10 fertilizer at the rate of 300 pounds per acre to each crop in the rotation improved the corn yields by 8·1, 10·6, 10·7, and 9·3 bushels per acre where red clover, alfalfa plus brome, sweet clover, and soybeans, respectively, were included in the rotation. On the other hand, little or no increase in yield of corn resulted from the use of 300 pounds per acre of 2-12-10 fertilizer where oats were grown alone in the corn—oats rotation and where corn was grown continuously on the same soil.

The corn yields in Table 5 would seem to indicate that a low nitrogen fertilizer such as a 2-12-10 mixture had a greater effect in improving corn yields where clover or alfalfa was included in the rotation. The improvement in corn yield was possibly due to a more favorable supply of nitrogen in the soil where the larger growth of clover was obtained in response to the 2-12-10 fertilizer. In addition to the improvement in nitrogen supply the larger growth of the clover crop probably resulted in a greater improvement in the physical condition of the soil on these plots.

The yield of oats on plots that were seeded to alfalfa or clovers was higher than where no clover seeding was made. There was a greater increase in the yield of oats due to 300 pounds per acre of 2-12-10 fertilizer when clover or alfalfa was seeded in the oat crop than where the oats were grown alone in the corn—oats rotation.

FIG. 1—Even a short rotation is better than continuous cropping to corn. The plot on left is in a two-year rotation of corn-soybeans; plot on right is in continuous corn. Fertilizer and other treatments were identical on both plots.

A higher yield of soybeans was obtained from the corn—soybeans rotation than from the continuous soybean plots. The soybean crop in the corn—soybean rotation also gave a greater response to the 2-12-10 fertilizer than the soybeans that were grown continuously on the same plot.

Three-year Rotations

Included in the group of three-year rotations being tested at Woodslee is a rotation in which all crops and crop residues were removed at the time of harvest and manure was applied for the corn crop. In this case approximately 15 tons per acre of barnyard manure were spread on the soil before the alfalfa plus brome sod was plowed for the corn crop. The remainder of the three-year rotations are based on a "cash" cropping system of farming and in these all crop residues were returned to the soil at the time of harvest.

Table 6 shows the yields of crops in some three-year rotations on Brookston clay at Woodslee. The data presented here are the average for the three years 1951 to 1953, inclusive.

In Table 6 it can be seen that the yields of corn and oats, particularly those in the rotations that include a crop of alfalfa or clover, are higher than the corn yields in the two-year rotations. This would seem to indicate that when a crop of clover remained for the second year there was a greater soil improvement than when it was plowed under in the first year. This soil improvement was not only reflected in higher corn yields the year following but also in the higher yields of oats that followed the corn crop.

TABLE 6—CROP YIELDS IN THREE-YEAR ROTATIONS, WOODSLEE, ONTARIO

(Average yields over three-year period 1951 to 1953)

Rotation	Fertilizer[1]	Corn	Oats	Soybeans first year	Soybeans second year	Hay
		bu.	bu.	bu.	bu.	tons
Corn (manured)—oats—alfalfa plus brome	None	63·1	52·5	—	—	1·50
	300 lb.	66·3	68·6	—	—	2·23
Corn—oats—mammoth red clover	None	52·4	37·2	—	—	·59
	300 lb.	66·3	51·3	—	—	1·56
Corn—oats—alfalfa	None	51·2	48·6	—	—	1·05
	300 lb.	59·1	67·0	—	—	2·32
Corn—oats—soybeans	None	54·3	36·1	24·3	—	—
	300 lb.	55·2	47·4	25·6	—	—
Corn—soybeans—oats	None	46·8	24·4	19·5	—	—
	300 lb.	50·2	34·4	25·0	—	—
Corn—soybeans—soybeans	None	49·1	—	17·6	18·2	—
	300 lb.	51·3	—	24·5	23·0	—

[1] 300 lb. per acre of 2-12-10 fertilizer applied on half of each plot in the rotations.

Where no fertilizer was applied the rotation corn (manured)—oats—alfalfa plus brome produced 11·9 bushels per acre more corn than the corn—oats—alfalfa rotation. This difference in yield was largely due to the nitrogen that was supplied by the manure. On the other hand, where 300 pounds per acre of 2-12-10 fertilizer was applied at the time of planting each crop in the rotation there was no difference in the yield of corn in the two rotations corn (manured) —oats—alfalfa plus brome and corn—oats—mammoth red clover. The largest increases in yield of corn due to the application of a low nitrogen fertilizer were obtained where clover or alfalfa was included in the rotation. This is also true in the case of oat yields in the three-year rotations at Woodslee.

It will be seen in Table 6 that the corn yield in the rotation corn—oats—soybeans was 7·5 bushels and 5·0 bushels higher in the unfertilized and fertilized treatments, respectively, than in the rotation corn—soybeans—oats. The only difference between these two rotations is that the corn crop followed the soybeans in the one case and followed oats in the other. Also it will be noted that the yield of oats both unfertilized and fertilized was higher in the rotation where oats followed corn than when oats followed soybeans. In the study at Woodslee it would seem that all the crops in the corn—oats—soybeans rotation gave as good if not better yields than those in the corn—soybeans—oats rotation.

In this experiment the second year of soybeans in the corn—soybeans—soybeans rotation gave as high a yield on both unfertilized and fertilized plots as the first year of soybeans following the corn crop. Where 300 pounds per acre of 2-12-10 fertilizer was applied in the rotations corn—soybeans—oats and corn—soybeans—soybeans the increase in yield of soybeans ranged from 4·8 bushels to 6·9 bushels per acre. Little or no increase in yield of soybeans due to fertilizer was obtained in the corn—oats—soybeans rotation. The yield of beans on the unfertilized plot in this case was much better than the soybean yields from the unfertilized plots of the other rotations containing soybeans.

The hay crop showed a considerable increase in yield due to the application of 300 pounds per acre of 2-12-10 fertilizer on the rotation plots at Woodslee. Increases of 0·73, 0·97, and 1·27 tons per acre were obtained in the first three rotations listed in Table 6. These increases were due to the 300 pounds of fertilizer that was applied to the oat crop at the time of planting. The clover and alfalfa were seeded at this time and received no further fertilizer application.

Four-year Rotations

The four-year rotations tested at Woodslee all contained alfalfa or clover which was grown for hay during one or two years of the rotation. These rotations did not complete as many cycles as the group of two- and three-year rotations; however, it was noted that the corn yields for the first year of corn in the rotations were somewhat better on the whole than the corn yields in the two- and three-year rotations.

Table 7 gives the average yields for the crops in some four-year rotations at Woodslee for the period 1951 to 1953, inclusive. The rotation where manure was applied for the corn crop is based on a livestock system of farming where the hay is utilized by cattle. The remaining rotations follow a "cash" cropping system where all crop residues and the hay crop are returned to the soil.

As was the case in the three-year rotations a treatment of manure for the crop gave the highest yield of corn where no fertilizer was applied. Where no fertilizer was applied the application of barnyard manure increased the yield of corn by 10·2 bushels. This is the difference in yield of corn per acre between the two rotations corn(manured)—soybeans— oats—alfalfa, and corn—soybeans —oats—alfalfa where no fertilizer was applied in either case. On the fertilized treatments of these same rotations the corn yield was just as good if not a little better in the "cash" cropping system of corn—soybeans—oats—alfalfa where all the crop residues were returned to the soil.

TABLE 7—CROP YIELDS IN FOUR-YEAR ROTATIONS, WOODSLEE, ONTARIO

(Average yields over three-year period 1951 to 1953)

Rotation	Fertilizer[1]	Corn first year	Corn second year	Oats	Soybeans	Hay first year	Hay second year
		bu.	bu.	bu.	bu.	tons	tons
Corn (manured)—soybeans—oats—alfalfa	None	67·8	—	53·1	32·9	1·62	
	300 lb.	63·6	—	66·2	33·4	2·09	
Corn—corn—oats—mammoth red clover	None	65·0	33·3	42·7	—	·86	
	300 lb.	65·4	43·6	50·2	—	1·92	
Corn—oats—alfalfa—soybeans	None	63·0	—	42·0	30·4	2·00	
	300 lb.	63·3	—	55·9	29·7	2·85	
Corn—soybeans—oats—alfalfa	None	57·6	—	43·7	30·1	1·55	
	300 lb.	65·3	—	61·0	34·2	2·28	
Corn—oats—alfalfa—alfalfa	None	57·0	—	56·3	—	1·96	2·34
	300 lb.	61·3	—	69·6	—	3·06	2·45

[1] 300 lb. per acre of 2-12-10 fertilizer applied on half of each plot in the rotations.

Where no fertilizer was applied the corn yields on the two rotations corn—soybeans—oats—alfalfa, and corn—oats—alfalfa—alfalfa were somewhat lower than in the first three rotations listed in Table 7. When 2-12-10 fertilizer at 300 pounds per acre was applied to each crop in the rotation, however, the differences in corn yields between the five rotations listed were not significant.

The yield from the second year of corn in the rotation corn—corn—oats—mammoth red clover was considerably lower than the first year of corn. In this case an increase of 10·3 bushels per acre was obtained where 2-12-10 fertilizer was applied in the rotation.

Oat yields on the unfertilized rotations were increased by about 10 and 12 bushels per acre, respectively, where manure was applied and where two years of alfalfa were grown. This indicated the favorable effect of an improved nitrogen supply and physical condition on oats for these two treatments. Substantial increases in oat yield were obtained in all rotations where fertilizer was used.

The yields of soybeans were substantially higher in the four-year rotations than soybean yields in the three- or two-year rotation plots. This would seem to indicate a more favorable physical condition in the soil under a longer cropping system. The effect of 2-12-10 fertilizer on soybean yield was small in the four-year rotations. The highest increase in this case was 4·1 bushels.

A striking improvement in yields of hay due to fertilizer application was also evident in the four-year rotations. These increases ranged from 0·47 tons to 1·10 tons per acre in the first hay year. The second year of hay showed little increase in yield due to the fertilizer applied with the oat crop.

Clover and alfalfa were used in the rotations at Woodslee for soil improvement because of their deep rooting characteristics. Earlier studies on soil physical condition have indicated that there is a compacted layer of soil at a depth of 8 to 12 inches in the Brookston clay at Woodslee. Deep rooted legumes have proved to be very effective in opening up this compacted layer of soil.

The amount of soil improvement obtained through growing clovers and alfalfa would seem to depend upon the frequency of these crops in the rotation. Table 8 gives an indication of the time required and the amount of soil improvement that was achieved through crop rotation at Woodslee. The average yields of corn for all crop rotations in each of the two-, three- and four-year rotations are shown for each year since the start of these experiments. The amount of time devoted to growing clover or alfalfa and corn is also shown. Each of the two-, three- and four-year rotation experiments includes nine different cropping systems.

The cropping system previous to 1947 was similar for all rotations in the two-, three- and four-year rotation experiments. The area for these tests had been cropped to a corn—oats rotation for a period of years previous to 1947.

TABLE 8—AVERAGE CORN YIELDS FOR ALL TREATMENTS IN THE ROTATION EXPERIMENTS, WOODSLEE, ONTARIO[1]

Year	Rotation experiment			Average corn yield
	Two-year	Three-year	Four-year	
	bu.	bu.	bu.	bu.
1947	32·8	26·3	26·5	28·5
1948	42·3	36·7	41·5	40·2
1949	48·9	60·0	60·7	56·5
1950	44·0	49·2	55·0	49·4
1951	36·9	38·3	45·0	40·1
1952	58·2	63·9	64·9	62·3
1953	44·2	63·0	76·6	61·3
Average percentage of total crop area in clover or alfalfa[2]	22	48	50	
Average percentage of total crop area in corn	50	37	28	

[1] Each of the two-, three- and four-year rotation experiments contain nine different cropping systems.
[2] This figure includes clover or alfalfa in the seedling year as well as the hay year.

The average corn yields in the three- and four-year rotations were somewhat lower than in the two-year rotation experiment in 1947 and 1948. In 1949, however, the three- and four-year rotations yielded respectively, 11·1 and 11·8 bushels more corn than the two-year rotations. These differences in corn yield can be attributed to the greater percentage of clover or alfalfa grown in the three- and four-year rotations. At the same time a lower percentage of the land area was devoted to corn production in the three- and four-year rotations.

The corn yields in the three- and four-year rotations continued to be higher than the corn yields from the two-year rotations throughout the years 1950 to 1953. The two-year rotations showed some increase in average yield during the seven-year period 1947 to 1953, however, the three- and four-year rotations showed a much greater increase in yield over that in 1947 for this same period of time.

The data in Table 8 would suggest that soil improvement was rather rapid when favorable treatment was used on soil that was very low in productivity. As yields increased the rate of improvement in soil productivity became slower.

General Considerations

The type of crop rotation or cropping system that an individual will use on his farm will depend for the most part upon the market prices of the various farm crops. The area of southwestern Ontario, particularly Essex and Kent counties, has a favorable climate for the production of "cash" crops such as corn, soybeans, and fall wheat. These crops will be grown to a large extent in this area as long as it is profitable to do so. One of the disadvantages of this area is that there is generally a poor distribution of rainfall and scarcity of rainfall during the midsummer when crop requirements are at a high level. The production of cattle other than for the production of fluid milk for local consumption in the Essex-Kent area has been limited because of the difficulty of maintaining pasture during the summer.

Other considerations should be kept in mind, however, when planning a crop rotation. It has been noted that where high percentages of corn and soybeans have been grown continuously on heavy clay soil serious weed problems frequently arise. Milkweed, Canada thistle, and sow thistle spread rapidly in intertilled crops, particularly during wet seasons when it is difficult to perform cultivation. It has been demonstrated that a good crop of alfalfa hay on the heavy soils will tend to keep these weeds under control and in some cases practically eradicate the weed species. Severe competition is offered to weed growth when the second cutting of alfalfa hay grows during the dry part of the summer. Where drainage is adequate it would appear that the growing of a thick stand of alfalfa is a very effective method of controlling milkweeds on the clay soil in the area.

Since plowing is a costly operation and since the corn crop requires a considerable amount of nitrogen it is thought that the most practical place in the rotation for the plowing operation would be for corn where a crop of clover is to be turned under.

On clay soil, a good structure or physical condition will make the soil easier to work and will ensure good emergence of crops when weather conditions are conducive to crust formation, or when a period of drought follows planting. It is also well known that crops planted on clay soil that is in good physical condition will make better growth during unfavorable weather conditions than where they are grown on soil of poor structure. A major purpose of a crop rotation on a clay soil, therefore, should be to improve physical condition. Hence, all crop residues should be utilized for this purpose if crop rotation is to be effective in this regard. No crop residues should be burned where it is at all possible to return them to the soil. The experiments at Woodslee have indicated that where crop residues are turned back into the soil at every opportunity, a cropping system that does not include livestock has as good a chance of maintaining soil productivity as a system of farming where manure is available for soil improvement.

On clay soil in southwestern Ontario, where early crops such as oats are used mainly for the purpose of seeding the land to a hay crop, it may not be possible to maintain a fixed rotation, particularly during wet springs. The results of experiments at Woodslee would suggest that flexibility in a cropping system can be used to good advantage in order to get a crop planted during a late spring. The main consideration in planning a cropping program would seem to be to grow a deep-rooted legume every four or five years in order to maintain the physical condition in the soil at a level that will assure economic production of crops.

The use of fertilizer in a rotation is an important consideration and one that has not been fully worked out as yet on clay soil. As will have been noted, a low nitrogen fertilizer was used in the rotation experiments. This type of fertilizer has not been too effective in increasing corn yields on Brookston clay at the Woodslee Substation. The present work would suggest that the bulk of the phosphorus and potash fertilizer could be used to good advantage on oats or fall wheat that are to be seeded down to hay, and on soybeans. Phosphorus or potash fertilizer should be used for the corn crop where a soil test indicates that one or both of these elements are at a low level in the soil.

It will be shown in a later section of this report that nitrogen fertilizer was extremely effective in increasing and maintaining corn yield, particularly on soil that had not grown a crop of clover the previous year. Nitrogen has also increased the yield of wheat and oats considerably. The use of nitrogen fertilizer in a rotation could change the results of the present study considerably. Nitrogen fertilizer would eliminate dependence on legumes for a supply of nitrogen. However, it would be necessary to use deep-rooted legumes with the same frequency in order to promote a good physical condition in the lower depths of the surface soil. But it would seem possible, with the use of nitrogen fertilizer, to bring about a greater increase in organic matter in clay soil through growing better crops and subsequently turning under a larger volume of crop residues. A more favorable nitrogen supply in the soil would also tend to channel a greater amount of this organic matter into a more permanent state of humus than where nitrogen supply was at a lower level. It can readily be seen that the possibilities for soil improvement and maintenance of productivity will be greatly enhanced with the use of nitrogen fertilizer.

GREEN MANURE EXPERIMENTS

In 1946 an experiment was started to study the effect of cover crops or green manure crops sown in the corn crop. The field selected for the experiment had been cropped in a corn—oats rotation for many years. The cover crops were seeded in the last cultivation of corn, i.e., when the corn was about two feet in height. The cover crops were then plowed for corn in the spring of the next year. Fertilizer was applied for the corn crop in each year at the rate of 300 pounds per acre of a 2-12-10 mixture.

The corn yields in the experiment on cover crops are shown in Table 9. These yields are in bushels of shelled corn at 15 per cent moisture. The yields reported are for the corn crop the year after the cover crop was sown.

TABLE 9—YIELD OF CORN IN EXPERIMENT ON COVER CROPS SEEDED IN CORN, 1947 AND 1948

(Two-year average)

Cover crop	1947	1948	Av.
	bu.	bu.	bu.
Check—no seeding made	28·3	33·2	30·8
Red clover	33·2	43·3	38·3
Yellow blossom sweet clover	34·8	36·4	35·6
White blossom sweet clover	33·2	37·8	35·5
Alfalfa	30·1	38·8	34·5
Rye	26·1	34·8	30·5

It will be noted that corn yields were low, showing resemblance to yields of corn on the continuous-corn plots in the two-year rotation experiments. The effect of the cover crop or green manure crop was apparent only in the case of red clover, sweet clover, and alfalfa. A green manure crop such as rye gave no increase in yield of corn. In this experiment an increase in corn yield was obtained only where a nitrogen supplying crop such as clover or alfalfa was seeded in the corn.

This would indicate that the increase in yield was due primarily to the increased nitrogen supplied by the legume cover crops.

The practice of seeding legumes such as red clover and sweet clover in the last cultivation of corn has been used occasionally by various farmers in the district. This experiment indicates that some benefit is derived from the clover seedings by the corn the following year. The amount of benefit derived would depend on the thickness of stand and amount of top growth obtained before winter of the first year. Difficulty may be experienced in obtaining a stand of clover when the weather is very dry following the seeding of the cover crop. When the corn is planted in thick stands there is serious competition for light and the cover crop may not grow because of excessive shading by the corn.

During recent years a number of farmers have seeded sweet clover in stands of soybeans with variable degrees of success. Here, too, benefit may be expected for the corn crop the following year only if a good stand is obtained.

RATES OF PLANTING CORN

Investigators in the United States have demonstrated that plant population has a decided influence on corn yield. During the past twenty years the best planting rate was determined for a number of soil types and for a number of varieties of corn in the corn belt. Since little work has been done in southwestern Ontario on planting rates for corn, it was thought desirable to test various plant populations in conjunction with nitrogen fertilizer applications to determine the best plant population for Brookston clay soil.

Tests were made in 1952 and 1953 in which the plant population was varied from 8,000 to 20,000 plants per acre and each plant population was tested with four different applications of nitrogen ranging from 0 up to 800 pounds per acre of ammonium nitrate. A test was conducted in 1952 on soil that had grown two crops of corn in succession. In 1953 tests were made on two different soils. One test was run on soil that had been in alfalfa hay for two years previous to 1953 and the other test was on the same plots as the 1952 test for a fourth successive year in corn.

In 1952 an application of 1,000 pounds per acre of 2-12-10 fertilizer was made for all treatments and in addition to this another 1,000 pounds per acre of 2-12-10 fertilizer was applied on the plots that received 800 pounds per acre of ammonium nitrate as a side-dressing. Although it was thought that this heavy application of phosphorus and potash fertilizer was not necessary for corn on Brookston clay, the application was made to ensure an adequate supply of phosphorus and potash for all rates of planting and for all levels of nitrogen.

The corn yields from soil that produced the third successive corn crop are shown in Table 10. In 1952 there was little or no increase in yield when nitrogen fertilizer was applied on 8,000 plants per acre. On the other hand, nitrogen produced a significant increase in corn yield at plant populations of 12,000

TABLE 10—YIELD OF CORN IN TEST ON RATES OF PLANTING, EXPERIMENTAL SUBSTATION, WOODSLEE, ONTARIO

(Third year corn, 1952[1])

Number of plants per acre	Pounds per acre of ammonium nitrate			
	0	200	400	800
	bu.	bu.	bu.	bu.
8,000	60·5	62·7	63·4	60·6
12,000	69·6	77·0	81·2	84·3
16,000	70·8	75·3	80·4	87·8
20,000	61·0	72·9	75·0	86·7
Average	65·5	72·0	75·0	79·9

[1] Third successive crop of corn following two years of alfalfa hay.

plants per acre and above. Where no nitrogen fertilizer was applied an increase in yield of 10·3 bushels per acre was obtained when plant population was increased from 8,000 to 16,000 plants. Increases of 14·3, 17·8 and 27·2 bushels per acre due to an increased plant population were also obtained where a nitrogen application of 200, 400, and 800 pounds per acre, respectively, was made.

All rates of planting received an application of 1,000 pounds of 0-12-12 fertilizer in 1953 and the rates of planting side-dressed with 800 pounds of ammonium nitrate received an additional application of 1,000 pounds per acre of 0-12-12. Fifteen tons per acre of barnyard manure were applied on the alfalfa sod before plowing in the fall of 1952.

TABLE 11—YIELD OF CORN IN TEST ON RATES OF PLANTING, EXPERIMENTAL SUBSTATION, WOODSLEE, ONTARIO

(First year corn, 1953[1])

Number of plants per acre	Pounds per acre of ammonium nitrate			
	0	200	400	800
	bu.	bu.	bu.	bu.
8,000	68·4	73·7	70·9	74·2
12,000	75·4	80·6	84·4	79·6
16,000	79·0	83·8	81·0	78·3
20,000	72·6	78·6	80·5	76·2
Average	73·9	79·2	79·2	77·1

[1] First crop of corn following two years of alfalfa hay.

The corn yields on alfalfa sod in 1953 are shown in Table 11. The supply of nitrogen in this soil was high as a result of the crop of alfalfa and application of barnyard manure. Because of the good supply of nitrogen in the soil the increases in corn yield due to further applications of ammonium nitrate were small.

When the plant population was increased to 12,000 and 16,000 plants substantial increases in yield of corn resulted where no nitrogen was applied and also where 200 and 400 pounds per acre of ammonium nitrate was applied. When 800 pounds of ammonium nitrate was applied a smaller increase due to an increase in plant population was obtained.

TABLE 12—YIELD OF CORN IN TEST ON RATES OF PLANTING, EXPERIMENTAL SUBSTATION, WOODSLEE, ONTARIO

(Fourth year corn, 1953[1])

Number of plants per acre	Pounds per acre of ammonium nitrate			
	0	200	400	800
	bu.	bu.	bu.	bu.
8,000	47·1	62·1	68·2	61·8
12,000	43·1	66·8	74·7	73·9
16,000	33·4	66·1	71·6	75·4
20,000	31·6	68·9	66·4	76·3
Average	38·8	66·0	70·2	71·9

[1] Fourth successive crop of corn following two years of alfalfa hay.

Table 12 shows how effective nitrogen was in increasing yield of corn grown on soil low in nitrogen. The corn in this test was grown on the same plots as in 1952. The area of soil for this test had produced three successive corn crops previous to 1953 hence the low nitrogen supply in the soil for the corn crop in 1953.

Where no nitrogen fertilizer was applied the yield of corn was lowered by 13·7 bushels when the population was increased to 16,000 plants per acre. Apparently the nitrogen supply in these plots was critically low and this factor together with the extremely dry weather in 1953 resulted in a large decrease in yield when the plant population was increased above 12,000. Where nitrogen fertilizer was used at the rate of 200 and 400 pounds per acre there was a small increase due to an increase in plant population in each case. An increase in plant population up to 16,000 gave an increase of 13·6 bushels per acre where

800 pounds of ammonium nitrate were applied. It is thought that there would have been a more favorable increase in yield due to increased planting rates had the rainfall during August in 1953 been more plentiful. In general, however, where nitrogen fertilizer was used, the test summarized in Table 12 showed increased corn yields due to an increase in plant population above 8,000 plants.

The increase in yields due to nitrogen fertilizer in this test averaged 27·2, 31·4, and 33·1 bushels per acre respectively where 200, 400, and 800 pounds per acre of ammonium nitrate were used.

The results of the tests in both years on Brookston clay would suggest that where the nitrogen in the soil was in adequate supply the optimum number of plants per acre was between 12,000 and 16,000. In general, when stand was increased above 16,000 plants per acre the corn yields decreased considerably. The increase in yield of corn due to the application of ammonium nitrate was more economical at the 200 pound rate than at higher rates of application. It is probable that on soil fairly well supplied with nitrogen, such as where corn followed directly after a clover or alfalfa sod, smaller applications of nitrogen would be more economical.

In growing a commercial crop of corn on Brookston clay the 1,000 pound application of 2-12-10 or 0-12-12 fertilizer would not be recommended. This fertilizer would be used in smaller amounts or on other crops in the rotation since the data at Woodslee have indicated that the greatest increases in yield of corn are obtained through the use of nitrogen fertilizer.

TIME OF APPLYING NITROGEN FERTILIZER FOR CORN

With the rapid increase in use of nitrogen for corn in southwestern Ontario, the need has arisen for information concerning the most efficient methods of nitrogen application. At present the most common form of nitrogen in commercial use is ammonium nitrate and it has been applied either before planting by means of a fertilizer drill or as a side-dressing at the first or second cultivation.

Experiments on times of applying ammonium nitrate for corn were carried out at Woodslee during the 1952 and 1953 growing seasons to measure differences in crop response between a broadcast application and side-dressing applications at the first and second cultivations. These applications were made on alfalfa sod as well as on third and fourth year corn. The corn plant population used was approximately 15,000 plants per acre in drilled rows.

TABLE 13—YIELD OF CORN FOLLOWING APPLICATION OF NITROGEN FERTILIZER AT THREE DIFFERENT TIMES

250 pounds ammonium nitrate applied	On alfalfa sod			On soil previously cropped to corn		
	1952	1953	Av.	Third year of corn 1952	Fourth year of corn 1953	Av.
	bu.	bu.	bu.	bu.	bu.	bu.
Before planting	88·5	71·5	80·0	74·2	54·7	64·5
Side-dressed on corn 4 inches high	83·2	70·0	76·6	74·1	56·4	65·3
Side-dressed on corn 12 inches high	82·9	72·5	77·7	72·6	52·8	62·7
Check—no fertilizer applied	78·7	67·3	73·0	55·4	25·0	40·2

Results from the tests on times of applying nitrogen fertilizer appear in Table 13. There were no large differences in corn yields resulting from the three times of nitrogen application either on alfalfa sod or on soil previously cropped to corn. There was a trend, however, in favor of earlier nitrogen application on alfalfa sod in 1952 and on soil previously cropped to corn in 1952 and 1953.

Where the corn followed alfalfa, the greatest increase due to nitrogen fertilizer was 9·8 bushels in 1952 where the nitrogen fertilizer was applied before planting. The greatest increase over the check plots obtained in 1953 on alfalfa sod was 5·2 bushels where the nitrogen was applied as a side-dressing on corn 12 inches high. If no manure had been applied in these two experiments it is probable that the plots that received no nitrogen would have given a lower yield and a greater increase in corn yield due to the nitrogen fertilizer would have been recorded.

On the third and fourth successive crops of corn striking increases in corn yield over the check plots were obtained for each of the three dates of nitrogen application. On the soil previously cropped to corn the yields from the nitrogen treatments were lower by 17·7 to 19·8 bushels per acre in 1953 than the same treatments in 1952. On the other hand, where no nitrogen fertilizer was applied the corn yield in 1953 was 30·4 bushels lower than in 1952. This fact would indicate that where nitrogen fertilizer was used the corn yields were affected less by adverse weather conditions than where no nitrogen fertilizer was used. The growing seasons of 1952 and 1953 were extremely dry. These experiments indicate that nitrogen fertilizer is effective in maintaining corn yields even when rainfall is low.

The tests would suggest that there may be some advantage in applying ammonium nitrate before planting the corn crop on Brookston clay soil. A slight trend in favor of early application was recorded under certain conditions in both years; however the increases were not significant. Therefore, it would seem more practical to apply the ammonium nitrate with the fertilizer drill before planting than to buy special equipment for making side-dressing applications. This would not necessarily apply to coarse-textured sandy soils or on rolling land where leaching may be a problem. Where leaching is a problem it may be advantageous to apply nitrogen as a side-dressing.

While there appeared to be certain advantages to each method of application, i.e., applying nitrogen before and after the corn is planted, the most important consideration should be to have the nitrogen in the soil at the time the corn crop requires it. The corn crop would require the greatest amount of nitrogen during rapid and vigorous growth in June and July and perhaps the early part of August. It has been interesting to note that nitrogen deficiency symptoms usually appear in August on soils where the nitrogen supply is inadequate, indicating that the corn crop has exhausted the nitrogen supply at that time.

Recently, another source of nitrogen known as anhydrous ammonia has become available to farmers in southwestern Ontario. This material is ammonia gas which contains about 82 per cent nitrogen. When used, it is applied to the soil under pressure by means of special equipment having narrow applicator shoes that penetrate the soil to a depth of 5 to 6 inches. Where anhydrous ammonia has been applied with proper care tests have indicated that it is a satisfactory source of nitrogen for most crops. At the present time anhydrous ammonia is being tested for corn on Brookston clay at Woodslee.

SOIL PHYSICAL STUDIES

Soil physical condition is manifested by the manner in which the soil reacts to tillage. For example, a soil may be loose and crumbly when tilled or it may be hard and compacted, breaking into a number of large hard lumps or clods. A soil is said to be in a good physical condition or to have good structure when most of the smallest soil particles are grouped together in crumbs or granules. In a fine-textured clay soil it is considered desirable to have a large proportion of the smallest particles arranged in stable crumbs to permit the entry of air and water into the soil.

There are a number of physical measurements in use to describe the degree to which a soil maintains a loose crumbly structure. The proportion of stable crumbs in a soil sample may be determined by subjecting the sample to agitation on a nest of sieves immersed in water. The oven dried crumbs remaining on the sieves are known as water stable aggregates.

The open spaces between the soil crumbs are occupied by air and water and are referred to as the pore space. Space occupied by air is commonly known as non-capillary or air pore space while that filled with water is known as capillary or water pore space. The sum of the air and water porosities is, of course, referred to as total porosity. Ideal pore distribution is said to exist when total pore space is equally distributed into air and water porosity. Clay soils tend to be deficient in air pore space.

The soil physical condition may also be described by the volume weight, this being the weight of a certain volume of soil relative to the weight of an equal volume of water. For example one cubic foot of soil in its natural condition in the field may weigh 100 pounds. Since the weight of one cubic foot of water is 62·5 pounds the weight of soil is 1·600 times that of water and this value, 1·600, is known as the soil volume weight. A soil with plenty of pore space will have a low volume weight or in other words one cubic foot of a loose crumbly soil will weigh less than a cubic foot of soil which is hard and compacted.

Soil-moisture relationships are of great importance in plant growth and are usually described by soil-moisture equilibrium points. One of these is the wilting point, defined as the point at which soil cannot supply water at a sufficient rate to prevent the plant from permanently wilting. This moisture point is determined in the laboratory by several methods. Field capacity, another measurement of soil moisture, is normally that amount of moisture held within the capillary or water pore space of a soil. Field capacity is usually determined as the moisture equivalent, a measurement which involves the use of a centrifuge to remove the water held in the air pores. The maximum water-holding capacity, a third equilibrium point, is the amount of water held by a soil when all the pore space is filled. It is considered to be of value in assessing the capacity of a soil to take up moisture.

Of the three soil-moisture equilibrium points the moisture equivalent and permanent wilting points are more significant. Plants are unable to obtain adequate moisture at contents below the permanent wilting point and when the moisture supply exceeds field capacity the air supply is diminished. Because of these factors, plants obtain moisture from the soil at moisture contents between the permanent wilting point and moisture equivalent and this percentage moisture is usually referred to as the available moisture range.

Soil Physical Studies on Certain Cropping Systems

Some physical measurements were carried out on certain rotation plots in 1950 and the results from the continuous corn plots were compared with values from a blue grass sod area and from plots with second-year alfalfa sod. The blue grass sod had been established for over fifty years on forest soil while the alfalfa sod was in its second year on heavily cropped soil.

TABLE 14—SOME PHYSICAL MEASUREMENTS FOR THREE CROPPING SYSTEMS AT THREE DEPTHS, 1950

Cropping system	Coefficient of aggregation	Percentage total pore space	Weight of soil per cubic foot	Percentage organic matter
0-4 inch depth		%	lb.	%
Continuous corn	296	49·1	90·0	3·6
Alfalfa sod	518	49·0	91·9	5·3
Blue grass sod	834	59·2	73·1	8·1
4-8 inch depth				
Continuous corn	430	41·4	100·0	2·4
Alfalfa sod	506	51·5	90·6	4·7
Blue grass sod	746	51·7	89·4	4·6
8-12 inch depth				
Continuous corn	516	43·5	102·5	1·1
Alfalfa sod	599	49·5	95·6	2·2
Blue grass sod	847	50·2	90·6	1·8

The results in Table 14 indicate that a second-year alfalfa sod has had a beneficial effect on aggregation, especially at the 0-4 and 4-8 inch depth, when compared with continuous corn. This effect is less pronounced at the 8-12 inch depth. Blue grass sod maintained a relatively high degree of aggregation at all three depths.

TABLE 15—CORN YIELD FOR THREE CROPPING SYSTEMS USED IN THE PHYSICAL STUDY, 1950

Cropping system	No fertilizer	300 pounds 2-12-10
	bu.	bu.
Continuous corn	33·5	35·9
Alfalfa sod	57·1	62·4
Blue grass sod	55·2	59·6

In the porosity study continuous corn plots had a total pore space equal to that for alfalfa sod at the 0-4 inch depth. However, at the 4-8 and 8-12 inch depths second-year alfalfa sod produced a marked increase in total pore space over continuous corn and showed improvement equal to that received on blue grass sod at the two lower depths.

The weight of soil per cubic foot was no greater for the continuous corn plots than for alfalfa sod at the surface 0-4 inch depth. At the 4-8 and 8-12 inch depths the weight of soil per cubic foot was much greater for continuous corn plots than for alfalfa or blue grass sod. Meanwhile blue grass sod maintained a very low volume weight at the surface but resulted in only a small volume weight change at the 4-8 and 8-12 inch depth when compared with alfalfa sod.

At the 0-4 inch depth continuous corn plots showed a satisfactory physical condition as indicated by a total pore space and weight of soil equal to the values measured on alfalfa sod at the same depth. The fact that physical condition on corn plots was equal to that on alfalfa sod at the 0-4 inch depth may have resulted from surface tillage used on the corn plots and which was not required in producing the alfalfa sod.

Blue grass sod contained 8·1 per cent organic matter at the surface depth, a value twice as large as the 3·6 per cent organic matter present in continuous corn soil. Second-year alfalfa sod contained 5·3 per cent organic matter at the 0-4 inch depth. At the 4-8 and 8-12 inch depths, however, alfalfa sod resulted in organic matter contents equal to that of blue grass sod and of course, much greater than the percentage of organic matter in continuous corn soil.

TABLE 16—SOME PHYSICAL MEASUREMENTS ON CERTAIN TWO-YEAR ROTATIONS AT WOODSLEE, 1950 AND 1951

Cropping system	Percentage total pore space	Weight of soil per cubic foot	Yield of corn per acre
	%	lb.	bu.
Continuous corn	41·8	102·2	23·4
Corn—oats plus alfalfa plus brome	48·7	89·6	44·8
Corn—oats plus red clover	51·1	84·1	46·3

Measurements on total pore space and weights per cubic foot were carried out on certain rotation plots of the two-year rotations in 1950 and 1951. The average results for two of the two-year rotations appear in Table 16 along with the average corn yield for the two seasons. Continuous corn plots were used as a check treatment with which to compare the rotations.

Oats containing red clover and alfalfa at the seedling stage were shown to improve the total pore space, lower the volume weight and to increase corn yield. Since these cropping systems were established on soil that had been heavily cropped to corn, the above results give some indication of the effectiveness of legumes even at the seedling stage in improving soil physical conditions.

It would appear that a continuous cropping system of corn has impaired the soil structure as indicated by a number of physical measurements. This impairment is great enough that decreased crop yields have resulted as shown in Tables 15 and 16. However, soil improving crops such as legumes have been shown to improve this physical condition to a marked degree within a relatively short period of time. This improvement has been reflected in corn yield as shown in Table 15 where corn yields on alfalfa sod are equal to corn yields on blue grass sod.

The results in Table 14 indicate that blue grass sod maintained a favorable soil physical condition but it would appear that blue grass sod had reached an equilibrium and had produced its maximum soil improvement at some time within the fifty years of growth. Alfalfa sod, on the other hand, produced soil physical improvement almost equal to that of the blue grass sod within a two-year period. In view of the fact that alfalfa is relatively easy to establish on clay soil and generally produces favorable growth during the first year of hay and throughout the dry period of the summer, this crop would seem to have considerable value in a soil improvement program. In areas such as south-western Ontario where high land values and production costs require the growing of high value crops it is important to use the most efficient soil improving crops when such crops are required to maintain soil productivity.

Soil Conditioners

The recent development of soil conditioners on a commercial basis has caused widespread interest in the possibilities of improving clay and other fine-textured soils where physical condition is a limiting factor in the production of crops. Two of the more effective synthetics that have been tested at other stations are a hydrolyzed polyacrylonitrile and a modified vinyl acetate maleic acid compound. Where these materials were incorporated in fine-textured soils, it was found that decided beneficial results were obtained in certain measurable physical properties and yields of various field crops were increased accordingly.

The effects of these two soil conditioners on some physical properties of a Brookston clay soil were investigated at Woodslee. The hydrolyzed polyacrylonitrile compound, formulation 931, and a modified vinyl acetate maleic acid compound, formulation 6, were the materials used in this study. The test was initiated in 1952 and a crop of corn was grown on the plots during the 1952 and 1953 seasons to measure any effects the conditioners might have on yield. Physical measurements were made on the plots during the latter part of both growing seasons.

FIG. 2—One soil conditioner (formulation 6) stabilized soil structure at Woodslee. Treated soil on left; untreated soil on right.

TABLE 17—EFFECT OF TWO SOIL CONDITIONERS ON SOIL AGGREGATION AND YIELD OF CORN ON BROOKSTON CLAY

Soil conditioner applied	Coefficient of aggregation		Corn yield in bushels shelled corn at 15% moisture	
	1952	1953	1952	1953
			bu.	bu.
Formulation 931 (hydrolyzed polyacrylonitrile compound)	851	481	54·7	27·2
Formulation 6 (modified vinyl acetate maleic acid compound)	2,048	583	46·4	33·8
Check—no conditioner applied	441	422	53·9	34·5

Soil samples from the plots treated with soil conditioner were tested for water stable aggregates and these results, expressed as coefficients, were compared with results from plots receiving no conditioner. Aggregation measurements in 1952 showed marked increases in favor of formulation 6. The same treatments showed increases in 1953 but the differences were less marked than in 1952.

Results of the porosity study on the conditioner plots appear in Table 18. This study also indicated formulation 6 to be the only treatment to produce significant changes during the 1952 and 1953 seasons. Percentage total and air pores were increased significantly by this soil conditioner. The fact that percentage water pore space was decreased would indicate that air pore space was increased partially at the expense of the water pores.

With the advent of soil conditioners some stations have reported that the moisture equivalent was increased without the permanent wilting point being changed. Should this be the case, it would be possible to increase the available soil moisture supply for plants. These three soil-moisture points were determined

FIG. 3—One soil conditioner (formulation 6) influenced emergence and growth of corn on soil that had been cropped continuously to corn since 1946. Treated soil on left; untreated soil on right.

TABLE 18—EFFECT OF TWO SOIL CONDITIONERS ON PERCENTAGE TOTAL, AIR, AND WATER PORE SPACE OF BROOKSTON CLAY

Soil conditioner applied	Percentage total pore space		Percentage pore space occupied by air		Percentage pore space occupied by water	
	1952	1953	1952	1953	1952	1953
Formulation 931 (hydrolyzed polyacrylonitrile compound)..........	57·6	53·9	18·3	12·5	36·8	36·4
Formulation 6 (modified vinyl acetate maleic acid compound)..........	58·0	57·6	26·0	19·4	31·4	33·6
Check—no conditioner applied..........	54·8	54·1	18·3	11·9	35·9	37·1

on the conditioner test at Woodslee in 1952 and the results appear in Table 19. In the Woodslee test the conditioners did not bring about significant changes as compared with the plots where no conditioner was applied, but the moisture equivalent was decreased slightly by formulation 6.

TABLE 19—EFFECT OF TWO SOIL CONDITIONERS ON PERCENTAGE MAXIMUM WATER HOLDING CAPACITY, MOISTURE EQUIVALENT AND PERMANENT WILTING POINT OF BROOKSTON CLAY

Soil conditioner applied	Percentage maximum water holding capacity	Percentage moisture equivalent 1952	Percentage permanent wilting points
Formulation 931 (hydrolyzed polyacrylonitrile compound)	63·22	27·64	14·92
Formulation 6 (modified vinyl acetate maleic acid compound)	62·54	26·38	15·16
Check—no conditioner applied	61·41	27·29	15·51

Only formulation 6, the modified vinyl acetate maleic acid compound, produced and maintained significant increases in properties associated with soil physical improvement. Where this physical improvement occurred in 1952 a significant depression in corn yield resulted and in 1953 this improved physical condition failed to increase yield. This lack of response to an improved physical condition may have been due to the very dry conditions during both growing seasons and to the fact that physical condition was improved in only the top six inches of soil. Previous study has indicated the existence of a compacted layer at the 6-12 inch depth in Brookston clay which may limit the effects of treatments designed to improve only the surface layer of soil.

These results indicate a need for further studies on soil conditioners before they could be recommended for general use on fine-textured soils.

FIELD DAYS AND MEETINGS

Since 1948, field days have been held at the Woodslee Substation for groups of farmers and other interested persons. In 1952 and 1953 the field days were organized in co-operation with the Ontario Department of Agriculture through the Agricultural Representative at Essex, Ont. These field days took the form of an afternoon program in which authoritative speakers were heard. A conducted tour was made of the plots and the experimental work on the Substatoin was described. These tours were followed by a discussion period. The field days have drawn an attendance of as high as 800 people.

Information on experimental results was also provided to individual visitors to the Substation throughout the years and also at farmers meetings which were held at Essex, Ont., sponsored by the Agricultural Representative for Essex county. Officials from the Woodslee Substation have taken part in these meetings each year and have presented experimental results and information to the farmers attending. About 1,000 farmers, mostly from Essex county, attended these meetings.

In addition, talks have been given to farmer groups in Kent and Lambton counties on a number of occasions to acquaint them with the experimental work on Brookston clay soil at Woodslee.

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