Research
FOR FARMERS

WINTER — 1965

CANADA DEPARTMENT OF AGRICULTURE

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Cover Photo: **Predacious insect attacking bud moth larvae (See "Minimum Chemical Dosage for Selective Control of Orchard Insects," page 12).**

NOTES AND COMMENTS

Will the administration of lead arsenate to an insect deprive it of its ability to reproduce? Entomologist N. A. Patterson, (p. 3) reports that the newer insecticides such as DDT, Guthion and diazinon, while giving good control of the apple maggot, have brought forth somewhat unsatisfactory results and in some places there has been a return to the use of lead arsenate or a combination of lead arsenate and one of the newer insecticides. Patterson describes his research into apple maggot control, using lead arsenate, and reports: "The arsenical residue on the trees evidently acted as a chemostirilant, preventing development of eggs in the female flies."

* * *

"Microbial Examination of Poultry Hatcher Fluff", Dr. S. E. Magwood's article (*Research for Farmers, Winter '62*), aroused much interest and was reprinted by industry journals. Now he has come up with another story (p. 6) wherein he discusses how to get hatcheries biologically clean and describes a new method that reveals the contamination picture of hatcheries. Dr. Magwood writes: "An effective hatchery sanitation program is a 'must' for the successful hatcheryman. Government regulations require it. The probability that cleanly-hatched chicks and poults will outperform those in heavily contaminated plants has real significance for an industry beset by slim profits."

* * *

Errata: With reference to the second paragraph of the article, "Winalta—A Hard Red Winter Wheat" (p. 15, RfF, Fall '64) by Dr. M. N. Grant, Lethbridge Research Station, the final clause of the first sentence, and the second sentence, were meant to be deleted during proofreading but, unfortunately, the change was missed. The paragraph should have read: "Though winter wheat played a significant part in the opening of southern Alberta to wheat production, it has played a minor role during the past 50 years because of its relatively poor bread-making quality and the lack of sufficient winter hardiness. The development of high quality Winalta . . ." The lower photo caption (p. 15) should have implied that it was Dr. J. E. Andrews, now Superintendent, Brandon Experimental Farm, who actually selected Winalta at the Lethbridge Station, and that Dr. Grant was involved in purification of the line. In "Notes and Comments" (p. 2), the word 'spring' was erroneously used in describing Winalta; the latter, of course, is a winter wheat with hard red spring milling and baking qualities.

Lead Arsenate as an Apple Maggot Chemosterilant

N. A. Patterson

The female fly of the apple maggot.

THERE are several types of chemosterilants. As used for insect control, they may be defined as chemical compounds which, when administered to an insect, will deprive it of its ability to reproduce. Lead arsenate, as used for apple maggot control, is shown here to prevent development of eggs in the adult.

The adult feeds in the same manner as the house fly by rasping particles from a surface with its proboscis, exuding a droplet of saliva, and sucking in the saliva again along with dissolved or suspended particles. The fly is commonly seen feeding in this manner on the surface of the fruit and leaves. In the process of feeding, the fly laps enough of the insecticide from the surface of the fruit and foliage to cause its death before it reaches the stage for egg-laying or, in the case of lead arsenate, enough to prevent the development of the eggs.

Sprays of lead arsenate applied to the trees when the flies first become active in an apple orchard has been, for many years, the chief recommendation for apple maggot control. Generally the control was fairly good but sometimes irregular results were obtained. In recent years many of the newer insecticides have been used and a few of them, such as DDT, Guthion and diazinon, have given good control. However, the results have not been entirely satisfactory and in some places there has been a return to the use of lead arsenate or a combination of lead arsenate and one of the newer insecticides.

While working with apple maggot flies in the laboratory it was found that many that had eaten food containing a small amount of lead arsenate lived beyond the period of egg development. Upon dissecting some of these female flies it was found that they contained undeveloped ovaries while those fed unpoisoned food (soy hydrolysate and honey) contained normal, well developed ovaries and eggs. Tests on the fruit flies, *Drosophila melanogaster*, and *Drosophila hydei* and the house fly gave similar results. Concentrations of lead arsenate from 0.5 to 1.0 per cent in the food greatly reduced egg development but caused little mortality of the flies. Calcium arsenate and sodium arsenate acted in the same way. Apple maggot flies placed in cages with apple seedlings that had been dipped in suspensions of lead arsenate showed the same reduction in egg development even when supplied unpoisoned food and water.

To test the arsenate under field conditions, an orchard of about two acres was chosen because it was heavily infested with apple maggot and was well isolated from other orchards. Gravenstein, the main variety in this orchard, had a particularly heavy infestation in 1961, the year before the lead arsenate spray was applied, averaging more than six maggots per apple or about 15,000 per tree. The other varieties had lighter infestations. Most of the fruit was unmarketable and was left on the ground. In 1962 the orchard received fungicidal sprays and on July 17, when apple maggot flies were beginning to appear, an application of lead arsenate at three

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pounds per 100 gallons of spray. Although flies were numerous in the orchard throughout the summer (Table 1) the fruit was only lightly infested and was marketable. The Gravenstein drops averaged 57 maggots per 100 apples (Table 2). In 1963 the orchard was again treated with a single application of lead arsenate on July 11, when flies first appeared. The flies were less numerous than in the previous year yet plentiful enough to give a heavy infestation if unchecked. The Gravenstein drops, in this year, averaged about one maggot per 100 apples. In 1964 the single application of lead arsenate was applied on July 13, combined with the last application of fungicide. Apple maggot flies were scarce in the orchard throughout the season (Table 1) but because of the light crop of Gravenstein apples a much higher proportion was infested with maggots. The crop was light on all the Gravenstein trees, probably less than a twentieth of the previous year's crop and it is doubtful if the actual population in the orchard was as great as last year. The other varieties, all later, were free from maggots.

The female flies taken in the pans (Table 1) or collected from the trees were dissected to determine the stage of development of their ovaries and eggs. In each year, practically no flies taken in the orchard had fully developed eggs at any time during the five-week period after the lead arsenate had been applied. Even after that, ovary development was greatly suppressed. Flies taken over the same period from untreated trees had well developed eggs.

The effect of the lead arsenate on the development of ovaries in the flies was further tested by caging newly emerged flies on limbs in the orchard that had received the spray of lead arsenate. Checks were provided, in the same trees, by covering limbs while the lead arsenate was being applied. Very few eggs were laid in the apples in the cages on the limbs sprayed with lead arsenate until over a month after the spray had been applied even though the flies were given a constant supply of water and food so it was not necessary for them to feed on the foliage and fruit. In the cages on the limbs without arsenical residues, the number of eggs laid, and maggots maturing in the apples, were many times greater than in the cages on limbs which had been sprayed. The flies lived about the same length of time in both sets of cages.

The arsenical residue on the trees evidently acted as a chemosterilant, preventing the development of eggs in the female flies. In an orchard sprayed with lead arsenate, probably some flies are killed by the toxic action of the arsenate but these tests demonstrated that many of them lived for a month or more and evidently were prevented from infesting the fruit by the chemosterilant action of the arsenate. It is thought that the excellent results of the single annual application of lead arsenate was made possible by the substantial degree of isolation which limited the invasion of flies from outside the orchard. The variability in control obtained from lead arsenate in different orchards may reflect the amount of isolation from outside sources of flies. When using lead arsenate, close attention should be given to possible outside sources of flies that have not been exposed to arsenate and every effort should be made to remove these sources of infestation.

The application of lead arsenate will be continued in this orchard at least another year. Other chemicals that show promise as chemosterilants, or as direct toxicants, are being tested in other orchards and in the laboratory.

Table 1. Captures of apple maggot flies in bait pans (soy hydrolysate, 2%; wetting agent, 0.05%; water, 97.95%) hung in Gravenstein trees during the period of fly activity in 1962, 1963 and 1964.

	1962	1963	1964
Number of bait pans	5	6	6
Date first fly captured	July 30	July 15	July 29
Date of largest capture	Aug. 22	Aug. 2	Aug. 2
Date last fly captured	Sept. 21	Aug. 29	Sept. 10
Total number of flies captured	680	99	9
Average number of flies per pan	136	16.5	1.5

Table 2. Maggots emerging from samples of Gravenstein dropped apples collected in the Bennett orchard in 1961, when no arsenate spray was applied, and in 1962, 1963 and 1964, when the orchard received single applications of lead arsenate, 3 lb./100 gal.

1961		1962		1963		1964	
Date collected and number of apples	Number of maggots	Date of collection	Number of maggots per 200 apples	Date of collection	Number of maggots per 200 apples	Date of collection	Number of maggots per 200 apples
				Aug. 6	0		
		Aug. 16	1	Aug. 13	2	Aug. 12	5
		Aug. 20	5	Aug. 19	1	Aug. 20	10
		Aug. 27	18	Aug. 26	1	Aug. 28	8
Sept.		Sept. 4	67	Sept. 2	8	Sept. 3	2
1000	5795	Sept. 10	104	Sept. 9	2	Sept. 8	15
		Sept. 17	85	Sept. 16	4	Sept. 18	3
		Sept. 24	120	Sept. 24	2	Sept. 23	24
				Sept. 30	0		
Oct. 3				Oct. 8	1		
300	3786						
1300	9581		400		21		67
			Average number of maggots per 100 apples				
	737		57		1		34

Forms with chicken-wire bottoms contained maggoty apples and allowed mature maggots to enter the ground and where they pupate.

Traps captured apple maggot flies as they emerged from the ground where forms of maggoty apples were placed the previous fall.

Maggot flies, removed from the traps as soon as they emerged from the ground, were put into this type of cage that encloses the limb of an apple tree. Some limbs were treated with lead arsenate.

The author hanging a bait pan in an apple tree to catch the apple maggot flies during a period of fly activity in the orchard. The counts of flies caught by this method are shown in Table 1.

GETTING HATCHERIES BIOLOGICALLY CLEAN

New Method Reveals Reservoirs of Contamination

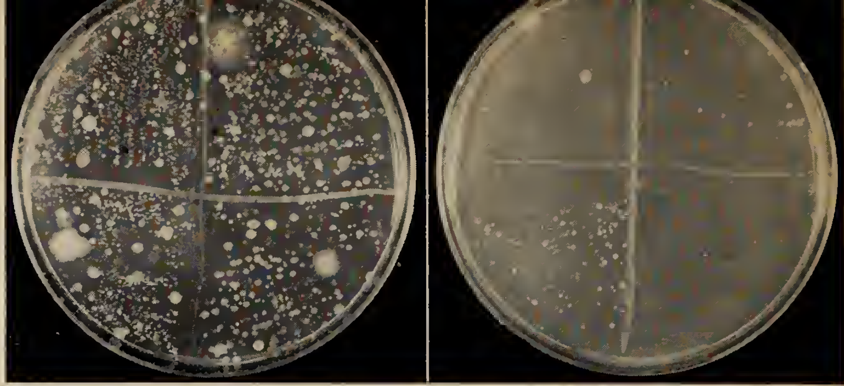

Figure 1.—Left: Swabs of heavily contaminated hatchery floor produced many colonies on plate quadrants. Right: Degree of pollution, a major source of air-borne contamination of hatching embryos, was minimized by regular sanitizing of floors, as shown by fewer colonies on the plate.

S. E. Magwood

An effective hatchery sanitation program is a 'must' for the successful hatcheryman. Government regulations require it. The probability that cleanly-hatched chicks and poults will outperform those hatched in heavily contaminated plants has real significance for an industry beset by slim profits.

The first test designed to measure this contamination was the microbiological examination of hatcher fluff (*Research for Farmers, Winter '62*). It was introduced only a few years ago and soon was in regular use on a Canada-wide basis. Periodic examinations showed that some hatcheries were biologically much cleaner than others. Subsequently while improved conditions were found in some of the previously unsatisfactory plants, little improvement was observed in a considerable number. In these 'problem' hatcheries, the fluff test and the more recently introduced air sampling procedure, reflect the end-product of all sources of contamination in the hatching environment. They are useful for surveillance but cannot be expected to either identify the reservoirs of contamination with certainty or reveal where bacterial multiplication occurs.

This information could only be gained by periodically surveying the microbial populations of the many objects and surfaces which may harbor microorganisms in the hatchery. To obtain this information on these unevenly contaminated surfaces by conventional methods would be too laborious to be practical under field conditions.

Dr. Magwood is with the Animal Pathology Division, Health of Animals Branch, CDA Animal Diseases Research Institute, Hull, Que.

As a possible substitute, A Danish method based on swabbing many areas of a surface directly to solid media was studied at the Animal Diseases Research Institute. The bacteriological part of the technique was modified and Mr. H. Marr of the Statistical Research Service constructed special nomograms which simplified the statistical treatment of the data. The combined bacteriological-statistical technique was made flexible to accommodate a variable number of swabs of a surface and reliable, reproducible results were obtained experimentally.

Several commercial hatcheries were examined by this method. Some of these were sanitary and others were relatively contaminated, judging by previous fluff test results. The surfaces swabbed included room floors and walls, table and counter tops, setting and hatching-machine trays and walls, egg shells and membranes before, during and after hatching and the body surface of newly-hatched birds. Air sampling and fluff tests were also conducted. This broad coverage gave a comprehensive picture of the changes in bacterial populations throughout the hatchery during the complete hatching process.

In the sanitary plants, the counts of most surfaces and of the air remained low throughout the cycle of setting and hatching. By contrast, in the contaminated plants high counts were observed on large horizontal surfaces such as floors and table tops. At hatching time and when employee activity was maximal, very high air-borne counts were recorded both within the machines and throughout most of the hatchery rooms. During periods of minimum employee activity, the air-borne populations fell markedly but the horizontal surfaces, except immediately after washing, continued to show high counts.

These findings were studied in relation to routine hatchery procedures. Normally, the eggs are held in a cooled room until, at least twice weekly, they are placed in the setters. After eighteen days in this first stage of incubation, the eggs are transferred to the hatchers. Both of these types of incubating machines circulate large volumes of room air. After three days in the hatchers, the young birds have emerged and are removed, graded, sexed and shipped amid clouds of fluff and dust particles. The microorganisms on this fluff and dust are those enumerated in the fluff test. Could this material, drifting through the rooms, or, made air-borne by employee activity, be drawn into other hatchers in sufficient quantity to contaminate the next hatch? This seemed likely because some of the birds of the next hatch, wet with nutritious egg fluids, would be emerging before the dust from the earlier hatch had settled.

Evidence to support this hypothesis was obtained in the following experiment. Two hatcheries, one having low and the other having high air-borne bacterial populations and referred to respectively as having "clean" and "contaminated" air, were utilized to study the effect of four environments or sequence of environments on the bacterial ecology during incubation and hatching. The experimental environments were as follows: (1) set and hatched in clean air; (2) set in clean air but transferred to hatch in contaminated air; (3) set in contaminated air and hatched in clean air; (4) set and hatched in contaminated air. When the eggs were to be set in the clean environment, chicken eggs which were known to have low counts were used. Conversely, when the first environment was the contaminated one (Exp. 3 and 4), turkey eggs which had much higher counts were used. This procedure ensured that the effect of the environments would be clearly defined. The surfaces swabbed were those mentioned previously and the examinations were made five times during the cycle. The first was at the time of setting (S), the next approximately midway in the setting period (M), on the eighteenth day when the eggs were transferred to the hatchers (T), early in the hatching period when approximately 20 per cent of the chicks had hatched (EH) and at the time of removal of the birds from the machines (LH).

The counts of all surfaces were markedly influenced by each environment as indicated by the essential portion of the data which has been charted in Figure 2. Reading the row of graphs from left to right it is striking that in Exp. 1 near zero counts were recorded throughout the cycle. When the cycle was divided as shown in Exp. 2 and eggs which had been set in clean air were transferred to hatch in contaminated air, high counts were observed on all of the surfaces subsequent to the transfer. Conversely, when eggs were set in contaminated air and hatched in clean air (Exp. 3) the high counts on the shell surfaces which were observed during the setting period dropped markedly after transfer to the clean hatchery (3 days before the M examination in this experiment) and low counts then prevailed on all surfaces. Setting and hatching in the contaminated environment (Exp. 4) resulted in high counts throughout the cycle. The latter have not been included in the chart.

Most surprising was the abrupt fall from the high counts on eggs in contaminated air to low counts after transfer to clean air (Exp. 3). These results, which confirm field observations, indicate that eggs which are sufficiently clean to be generally acceptable to hatcheries—and this does not include very dirty or improperly washed eggs—are "automatically" almost freed of bacteria during incubation in clean air. There was no evidence, either in this study or from the field work, that bacteria on the shell contributed significantly to the general microbial population in a clean environment. Under our conditions these bacteria must have perished because they were not recovered from the inner surfaces of the shell membranes at any time before hatching. Additional supporting evidence was the fact that the commercial hatchery with the lowest environmental counts had the highest counts on its eggs prior to incubation.

These findings and the results of other bacteriological examinations of eggs during hatching indicate that the following sequence of cause and effect determines the magnitude of the bacterial contamination of newly hatched birds.

At the time of hatching, air-borne bacteria on dust and fluff have easy access to a generous, if temporary, food supply in the nutritious fluids which surround the hatching embryos. If these bacteria are few in number, and the hatching period is not unduly prolonged, the resulting build-up in numbers of bacteria is relatively small. On the other hand, if the air-borne inoculum is large, very many bacteria are produced while conditions are favorable. The key factor is the relative size of the air-borne inoculum, and this is directly related to simple cleanliness throughout the hatchery.

These findings have been applied experimentally in reducing the bacterial exposure of hatching embryos in several commercial hatcheries. The air-borne pollution arising from floors was reduced by regular washing with a disinfectant solution, and other obvious sources of air-borne contamination, when located, were eliminated. Bacterial counts of the air, the floor and on the hatching birds dropped markedly after the

Concluded on page 15

Figure 2.—Bacterial populations during setting and hatching in different hatchery environments. Counts were made when eggs were set in the incubator (S), 10 days later—midway through the incubation period (M), when eggs were transferred to hatchers (T), and early (EH) and late (LH) in the hatching period. Experiment 4 charts are not shown.

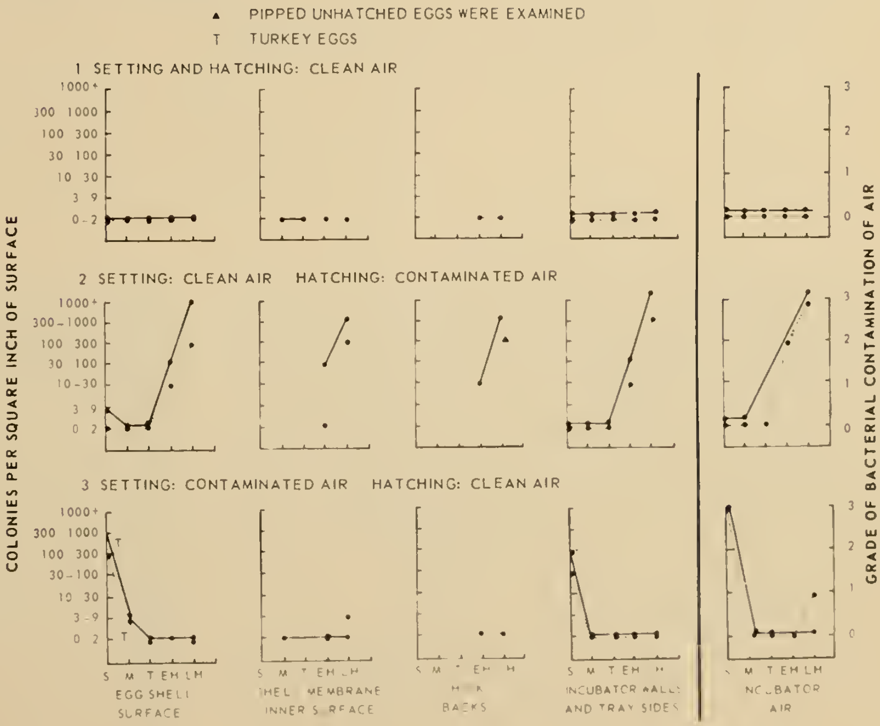

Figure 1.—Typical roadside habitat of clear-winged grasshopper showing marginal damage in the crop by grasshoppers that moved from the native prairie egg beds on the road allowance.

THE ROLE OF CEREAL CROPS AND NATIVE PASTURES IN GRASSHOPPER OUTBREAKS IN SASKATCHEWAN

The Food Plants Found In The Two Habitats Appear To Have Profound Effects On The Population Build-up Of The Clear-winged Grasshopper

R. Pickford

CEREAL GRAINS and native prairie are both involved in the development of grasshopper outbreaks in Saskatchewan. They form the two major habitats of the clear-winged grasshopper *Camnula pellucida,* the dominant species during the widespread grasshopper outbreaks of recent years. In general, its habitat consists of wheat, the main cereal crop grown in the province, and native prairie, as commonly found on undeveloped road allowances, pastures and slough margins. At the Saskatoon Research Station, we have studied this grasshopper for many years and have learned much about its egg-laying and feeding habits and other factors involved in the build-up of populations and outbreaks.

In its typical habitats (Fig. 1) the behavior of the clear-winged grasshopper is as follows: the eggs are laid in closely-cropped patches of native sod in egg beds that often contain enormous numbers of eggs (concentrations up to 10,000 per square foot are not uncommon). After hatching the young grasshoppers move into seedling grain fields where they may rapidly cause severe marginal damage if uncontrolled. They feed within the crop, usually spreading throughout the field where they grow to maturity. The adults then return to suitable native sod areas where they mate and lay their eggs among the fibrous grass roots.

The migration of grasshoppers from native prairie into crops has often caused concern to farmers, especially those whose land was adjacent to large community pastures or open rangelands. Little was known regarding the extent of infestation by grasshoppers within these large native prairie areas. This prompted us to make a series of investigations on the relationship of the two types of habitat to grasshopper growth, reproduction and general outbreak potential.

As the first step, we conducted an extensive survey of nymphal grasshoppers during the spring over a large area of the province

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where heavy infestations of the clear-winged grasshopper were known to exist. This survey was carried out shortly after hatching had taken place and was confined mainly to the native grassland areas, both large and small. Timing was important because the survey had to be delayed until most of the eggs had hatched and yet be made before dispersal of the nymphs had taken place. In this way we obtained a fairly clear picture of the location of egg-laying sites. This nymphal survey showed that the major infestations of grasshoppers on the native prairie were almost always associated with croplands. In most instances the egg beds were relatively close to areas of cultivation, but where the infestation extended for some distance into a large native pasture, populations invariably diminished rapidly. Not uncommonly we found a small pasture that was completely infested with grasshoppers, but it was nearly always within a farming area, partly or completely surrounded by cropland. The large community pastures and open ranges were not usually infested with this grasshopper except on the edges adjacent to cropped fields. In other words, the croplands and not the native prairies are mainly responsible for maintaining heavy infestations.

Further to this, we conducted a series of field cage experiments in which the clear-winged grasshopper was reared on vegetation that simulated the native prairie, cropland and a mixture of the two. Transplanted native prairie sod (comprising speargrass, western wheatgrass, blue gramagrass and low sedge) and seeded spring wheat provided the food in the cages. Young grasshoppers were placed in the cages (Fig. 2) in early June at approximately the same time that hatching was taking place in the field. Survival was checked periodically in the cages and at the end of the experiment when all the insects were dead the eggs were removed from the soil under the cages. These field cage experiments clearly demonstrated that the cereal grain was far superior as a food for all facets of growth, development, survival and reproduction of this grasshopper. This is well illustrated by the fact that grasshoppers reared on the wheat increased 60-fold in number while those reared on the native prairie barely maintained their number. Where the native grasses were included along with wheat the results were no different than when the 'hoppers were reared on wheat alone. This indicated that the native prairie added nothing to the nutrition of this grasshopper. The effects of wheat and native prairie on grasshopper growth and development are shown in the table below.

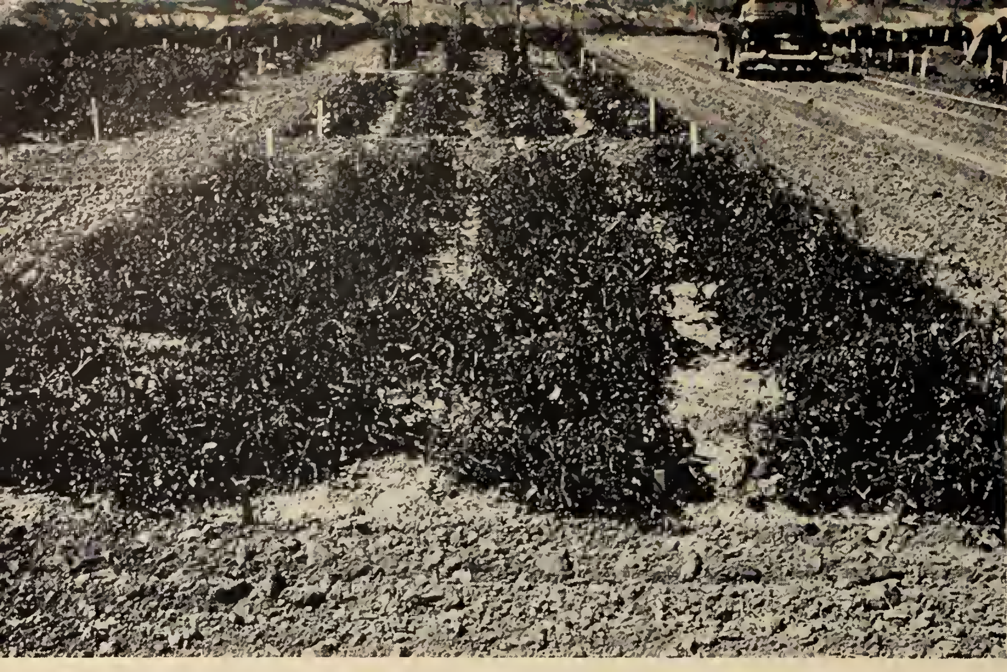
Carrying the experiment one step further to see whether the foods found in the two habitats had any effect on the next generation, we chilled a sample of eggs from each habitat group for several months to break diapause and then incubated them. Following hatching the grasshoppers were reared to the adult stage in laboratory cages (Fig. 3). The results showed practically no difference in the next generation, in percentage hatch of eggs, in percentage survival of nymphs or in weights of the newly-emerged adults.

The two habitats of the clear-winged grasshopper serve different purposes; the cereal grain crop provides the necessary food for optimum growth and reproduction while the native prairie merely provides a suitable sunny exposure for the breeding site where the adults mate and lay their eggs. It is probable that such breeding sites are not essential in the general ecology of this insect as shown by the fact that it often establishes egg beds within grain fields when suitable sod habitats are not available. However, where no suitable food is available in the native prairie, it is highly unlikely that this grasshopper would remain much of a problem.

	Wheat	*Native Prairie*
% survival of nymphs to adult stage	87	26
No. of days from hatching to adult	26	38
% survival of adults for 1 month	81	7
Average No. of eggs per female	138	7
Average No. of eggs per pod	21.3	10.9
Weight (mg.) of newly emerged adults ♀	264	176
♂	172	106

Figure 2.—Field cages for rearing grasshoppers.

Figure 3.—Cages for rearing in the laboratory.



Experimental plots of tomatoes at the Research Station, Summerland.

Milk Sprays Reduce Spread of Tobacco Mosaic in Tomatoes

Lyall G. Denby

AND

Jack M. Wilks

At the CDA Research Station, Summerland, B.C., we have found that simple and inexpensive precautions can be taken to reduce the spread of tobacco mosaic in tomato fields.

Tobacco mosaic is one of the most widespread and troublesome diseases affecting the tomato crop. It is not spectacular in its performance, like some of the blights which overnight can wipe out a field of tomatoes, but it causes stunting, retards early fruit setting, reduces potential yields, and increases cullage. Though effects vary from field to field, there is little doubt that tobacco mosaic involves the tomato industry in heavy financial losses each year.

In experiments at Summerland, tobacco mosaic infection reduced the early yield of tomatoes by over 34 per cent. This loss, representing early fresh-market fruit which brings a higher price than late fruit, would entail a severe reduction in profits. The late yields were comparable to those from healthy plants, but in total yield the losses sustained early in the season were never recouped.

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The symptoms of tobacco mosaic are not always apparent and clearly defined under conditions in the Okanagan Valley of British Columbia. They are usually most apparent in the young plants shortly after they have been established in the field. A severe infection at this stage is characterized by stunting, chlorotic mottling of the younger leaves, and various degrees of puckering or crinkling. New growth often becomes distorted. Some strains of tobacco mosaic induce a narrow or fern-like appearance of the leaves. As a result, growth is reduced, and flowering and fruit setting are severely affected. Usually, with the advent of hot weather in July, most of the infected plants grow out of the disease, and by August they appear to be quite healthy. However, the disease is still in the plants and the delay of growth early in the season has already affected fruit-set and resultant early yield. For this reason, control of infection up to and including transplanting time will greatly reduce losses from tobacco mosaic.

Most of the diseases affecting tomatoes are caused by fungi or bacterial organisms. Many of these can be prevented from entering the plants through leaves, stems or fruit by a protective coating of fungicide. Tobacco mosaic, however, is a virus disease which occasionally is in the seed, sometimes gets into the plant through insect injury, but most frequently gains entry through minute physical injuries. For example, as most cigarettes carry viable tobacco mosaic virus, a worker who has been smoking will introduce virus into the plants that he handles. A worker can also spread the virus if he touches an infected plant, then brushes against a healthy plant.

From our investigations, we know that tobacco mosaic virus can be carried in fresh tomato seed, but loses its viability if the seed is held in storage for a year after harvest. For this reason, one simple precaution is to restrict sowings to seed which was harvested two years previously. It is common knowledge that the virus can also overwinter in plant ref-

The Inhibition of Plant Viruses

For many years, research workers have been studying the effects of various materials on the spread and virulence of plant viruses. A number of materials have been shown to have a decided inhibitory effect on viruses such as tobacco mosaic. One of the most effective of these is skim-milk because it is non-toxic to plant tissue.

It is not yet fully understood just what specific components in milk are effective in reducing the virulence of the virus. Neither has the mode of action been fully explained. One theory is that the milk particles form a protective film around the virus particles, and so prevent the virus from multiplying and spreading. This is borne out in part by indications that the casein fraction of milk, which is known for its adhesive properties, in itself is somewhat effective in inhibiting virus development.

use which is left in the field. Thus, a further precaution is the removal of plants after harvest, and crop rotation wherever possible.

Most of the mosaic infection takes place either in the greenhouse when the young seedlings are being pricked out, or during the planting-out process.

At Summerland, we have concentrated on devising practical ways of reducing the spread of tobacco mosaic during the early life of the tomato plant. We have verified that if healthy seed is sown, and if seedlings and transplants are sprayed with milk before they are handled, the spread of tobacco mosaic can be reduced effectively. Our research has confirmed natural skim milk, or reconstituted powdered milk prepared by the directions for table use are equally effective. We sprayed the young seedlings in the seed-bed on upper and lower surfaces of the leaves, with a fine mist until the milk started to drip. Then the plants were allowed to dry before being pricked out. We found that only those seedlings which can be handled in a day's operations should be sprayed at one time, as the milk spray becomes ineffective after 24 hours. Those handling the plants should also dip their hands in milk from time to time while the plants are being handled. Normal precautions, such as washing hands in soap and water, and refraining from smoking while handling the plants, should be observed as well. The same precautions with emphasis on the milk spray, should be repeated when plants are being dug and transplanted to the field.

Inoculated plant (left) and a comparable healthy plant (right). Note the stunting, puckering and chlorosis of leaves on affected plant.

Effect of tobacco mosaic infection at transplanting time: plant on right is stunted to about half the size of the healthy plant.

In our experiments at Summerland where the above procedure was followed, we obtained a 41 per cent reduction in the number of diseased plants in the field. The sprayed plants showed an increase of 32 per cent in early marketable yield, when compared with the unsprayed plants. Obviously those plants which had acquired the disease before pricking out continued to suffer from it despite the milk spray. The results do indicate, however, that the spraying reduced the spread of the disease to an appreciable extent.

From our studies, we consider the milk spray treatment to be practical because the operations can be conducted while the plants are concentrated, first in seedling flats, and later in the plant-beds. Thus, very little time and effort is required on the part of the grower. The cost of materials is so small, particularly if powdered skim milk is used, that it is almost negligible. One gallon of reconstituted milk, costing approximately thirty-five cents, will cover about 5000 seedlings or 1000 transplants, depending on size and spacing. The grower could recover this expenditure many times over if the milk spray reduced his losses resulting from tobacco mosaic.

Pathologists and plant breeders at several institutions throughout the world are trying to find a source of genetic resistance to tobacco mosaic in tomatoes. Some species of wild tomatoes have proved to be resistant to certain strains of the disease but to date none has proved satisfactory against all strains which commonly cause trouble. This work is continuing, and once a source of resistance is found, resistant varieties can be developed from it. This would be the ideal solution to the problem of tobacco mosaic in tomatoes. However, until this can be accomplished, the use of milk sprays is warranted as a means of helping to control the disease.

Green fruit worm nearly full-grown.

Injury caused by green fruit worm.

Minimum Chemical Dosage for Selective Control of Orchard Insects

K. H. Sanford

FOR 15 years now, apple growers in the Annapolis Valley of Nova Scotia have successfully used an integrated spray program to control apple pests. This program is based on the premise that most pest species are normally kept below economic numbers by predators, parasites and pathogens and, if pest outbreaks occur, it is because the natural balance has been altered in some way. Fortunately for Nova Scotia growers, sufficient beneficial species are usually present, if not supressed in some way, to provide natural control. This makes it worthwhile to protect these natural enemies. The integrated program is simply one of combining both biological agents and chemical sprays in a single program. Pest species must be kept at or below economic tolerance levels, otherwise profitable production is not possible. There is always a danger of pest outbreaks occurring in cases where the beneficial insects have been removed either as a result of using chemicals that are toxic to them or where insufficient food is available to maintain them. Because of these conditions, chemicals that are applied to control outbreaks must have selective qualities so that pest numbers are reduced to economic tolerance levels without drastically affecting the beneficial species.

In our research at the CDA Research Station, Kentville, N.S., we have found several ways of achieving selectiveness and have used these to help provide controls for all pests that may occasionally cause injury in Annapolis Valley orchards.

First, we search for chemicals that, when used at the regular dosage, have little effect on most predators and parasites while exercising control of the pest. This necessitates evaluation of the chemicals against many species of natural enemies and also against the pests involved before a particular chemical is recommended. Examples of our recommended control chemicals that exhibit this type of selectiveness include lead arsenate for apple maggot control, ryania for codling moth control, and nicotine sulphate for eye-spotted bud moth and aphid control.

Secondly, we rely on the timing of applications of some sprays in order to protect natural enemies. Often wide spectrum chemicals with short residual properties can be utilized if they are applied early in the season so that the residue is dissipated before many predator species hatch. For instance, many of the phosphate group of chemicals, applied during the delayed dormant stage, effectively control the apple sucker, case bearers, eye-spotted bud moth and aphids with no effect on unhatched predacious species. Some predacious species of thrips and mites that overwinter in an active stage may be destroyed by spring applications of this type. The unhatched species, if allowed to sur-

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vive, will often exercise sufficient control to maintain a natural balance.

A third method designed to provide protection of natural enemies, as well as provide adequate control of specific pests, has been the practice of reducing the dosage of the control chemical to a minimum. This has been useful for control of several pests because some of the predacious species are less susceptible than the pest to the chemical. This may not protect all predacious species but sufficient numbers in the predator complex may survive to prevent a violent change in the natural balance between pests and predators. The use of low dosages was first considered in the control of a complex of lepidopterous pests occurring at the same time as, and including, the fall cankerworm, the winter moth and the green fruit worm.

A good example of the use of low dosages for selective control is the use of DDT or Guthion for winter moth. This pest, which is new to North America, has recently become established in Nova Scotia. It lacks natural enemies and requires chemical control in many orchards. Lead arsenate was first used as a control but subsequent testing has shown this material to be non-effective when the larvae are very young, and to be slow acting as the larvae near maturity. This slowness of action often results in fruit injury incurred during the calyx stage, the scars of which expand with the growth of the apple and are very prominent at harvest. Best control is obtained when application is made near bloom but because of pollinating insects, applications must be avoided during the bloom period. This necessitates a quick-acting, knockdown-type of control chemical; DDT or Guthion at the low dosage of 2-4 oz. per 100 gallons of water acts in this way.

The successful use of low dosages for winter moth control led to investigations into the possible use of low dosages of widely toxic chemicals to provide selective control for other pests. This has shown promise and has resulted in several recommendations that are practiced by many Nova Scotia orchardists, the main ones being: malathion 25 W.P. at 2-4 ounces per 100 gallons of water for *Atractotomus mali* (Meyer); DDT 50 W.P. at 2-4 ounces or Guthion 25 W.P. at 2 ounces per 100 gallons for winter moth, green fruit worm and cankerworm; Guthion 25 W.P. or malathion 25 W.P. at 2 ounces, or Dimethoate 43.6 E.C. at $\frac{1}{8}$ pint per 100 gallons for apple sucker and Guthion 25 W.P. at 2-4 ounces per 100 gallons for brown mite.

These low dosage controls are directed against pests that become vulnerable before bloom when most of the beneficial species are not present. Often one application of chemical is useful in controlling more than one species of pest. For example, Guthion applied ten days before bloom will control apple suckers, brown mite and some caterpillar larvae; malathion applied near bloom will control *A. mali* and apple sucker nymphs.

We realize that we have not found ideal chemicals for use against each pest, i.e. one that is innocuous to predators and toxic to the pest. But, by evaluating available materials against predator species and balancing the maximum dosage they will tolerate against the minimum dosage required to economically control the pest, chemicals have been selected for specific pests.

It has been suggested that the low dosages would speed up the development of resistance. Because this procedure acts as an aid to the control of pests by natural means it is believed the development of resistance would be slowed rather than speeded up. Low dosages have been applied as controls of some pests for about ten years and so far no evidence of resistance has become noticeable.

Predacious anthocorid preying on apple sucker nymph.

Predacious mirid preying on winter moth larvae.

Winter moth injury on pre-bloom foliage.

Upper left: Shredding of wheat seedling stems by wireworms indicated by arrows. Right-hand plant is undamaged.

Upper right: Wheat kernels taken from soil after being chewed by wireworms.

Lower: Wireworm tunnels in potatoes.

HIDDEN HABITS OF THE PRAIRIE GRAIN WIREWORM

Myriads Per Acre May Feed On Your Crops Out Of Sight In The Soil

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HUNDREDS of thousands of yellow worms per acre crawling over the surface of a field would give any farmer second thoughts about seeding it. Yet such fields have been seeded all because these voracious, soil-hidden plant feeders were not visible to the farmer's appraising eye. Later follows the devastating evidence in the form of badly thinned stands with large patches completely devoid of grain plants.

Wireworms attack all grain crops, reducing stands by burrowing into the planted seeds and shredding underground parts of seedling stems. Millions of dollars worth of grain crops have been lost from wireworm attack in a single year in Saskatchewan alone. Other field and garden crop seedlings are killed in the same way, and crops such as potatoes

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may be rendered unmarketable by unsightly wireworm tunnels. There are over 130 known species of wireworms in the Prairie Provinces, but only a few are important. Of these, the prairie grain wireworm, *Ctenicera destructor,* is by far the most destructive.

Wireworms have been known for over 40 years to be one of the most destructive soil insect pests of crops in the Prairie Provinces. During this time entomologists at Saskatoon and elsewhere have learned much about the life-history and behavior of this pest, and from this knowledge have been able to develop control methods. We are continuing these studies at the CDA Saskatoon Research Station.

The prairie grain wireworm larva takes in food largely in liquid form. It uses its mandibles to crush tissues and then regurgitates fluids which dissolve some of the solid plant matter. The fluid mixture of plant juices and dissolved solids is then swallowed. This accounts for the chewed-and-spit-out appearance of the remains of grain kernels attacked by wireworms, and for the fact that underground parts of stems are shredded but not cut off. The larvae show some selectivity in what and where they attack. We have found that they will attack germinating wheat seed more than dry wheat seed, and this suggests that a chemical diffusing from the germinating seed may attract them. They almost always attack a wheat kernel through the germ end, though they may go on to destroy the endosperm as well. Grain plants suffer less damage as they become older, and we have seldom observed larvae feeding on plants past the late seedling stage.

The wireworm larva moults, or casts its skin for a new one, from time to time. It feeds for a while immediately after moulting, and then ceases feeding for a variable length of time before moulting and feeding again. In the field we have found that moulting of a large proportion of the population occurs within each of two or three short periods during the growing season. This had resulted in two or three distinct peaks of feeding, the first one about the time the grain crops were becoming established—when they are most susceptible to attack. The others occurred in the summer and early fall. The later peaks of feeding suggest that volunteer grain and grass seedlings in the summer and fall may be important as food for wireworm survival and development.

There usually is considerable up and down movement of wireworm larvae in the soil during the growing season. Most of this appears to be caused by changes in soil moisture and temperature. In the spring, when the soil warms up and moisture is good, most of the larvae are quite near the soil surface. When temperatures become higher and the surface soil drier they tend to move downward, though they will move up again after the top soil has been moistened by rain. On a very few occasions we have trapped some of them moving on the soil surface at night, after rains following a period of drought, but this seems to be a very unusual occurrence. In the late fall, most of them can be found in the hard soil, just below the cultivated layer where they overwinter. In shallowly cultivated fields, we have found most of them in the top six inches of soil at any time during the season, though occasionally specimens

What Larvae Nutrition Studies Show

In our laboratory studies at Saskatoon, newly-hatched larvae have lived only a few weeks in soil where there was no plant food, but older larvae have lived over a year. Generally, they appear to do better on seeds or plant seedlings of grasses or grains than on those of broad leaf plants. Nutrition studies by Dr. G.R.F. Davis at this Station have shown differences in preference, survival, and rate of growth, of even the older larvae, between different grains. Our field populations have reached higher levels in cultivated soils seeded with grains than in sod, and higher with spring wheat than with oats, barley, or flax.

Prairie grain wireworm "click beetle," full-grown larva and pupa, more than twice natural size.

Wireworm eggs and first-instar larvae magnified about 40 times.

CLEAN HATCHERIES

from page 7

introduction of this measure. Examples of the numbers of colonies on plates before and after the beginning of the treatment are shown in Figure 1. At the close of the experiment, two operators continued with the floor sanitation treatment and their counts were maintained at low levels, whereas one operator who discontinued the treatment, found that the counts rose to their former levels.

The concept advanced here is overall biological cleanliness in hatcheries. It has been shown to be practical and effective and is in accord with recognized sanitation principles.

have been recovered more than 20 inches down. Thus, soil temperature and moisture, and soil compaction, appear to influence vertical movement. However, we have had less than 10 percent mortality of well-fed older larvae which were kept less than three inches deep during the growing season and winter as well. This indicates that the importance of vertical movement is not yet clear.

On the basis of the reproductive potential of known numbers of female adults, and existing populations, we have estimated that over 90 percent of every new population of the prairie grain wireworm die in the egg or early larval stages. If all survived, we should have several hundred per square foot, but to get 20 is very rare. Half a dozen per square foot can be very destructive. Modern control measures can reduce what nature has allowed to survive to very low numbers. But wireworms are seldom eliminated from a field. Within a few years they can build up from an inconsequential few to a serious many. The grower must watch continuously for signs of wireworm damage, and take immediate action if he expects to prevent serious losses from wireworm attack.

LIFE CYCLE STUDIES OF PRAIRIE GRAIN WIREWORM REVEAL DISCOVERIES

EXCEPT for limited adult activity, all stages of development—egg, larva, pupa, and adult—remain hidden in the soil where the insects may grow and multiply largely unnoticed. The name 'wireworm' comes from the slender, shiny, hard-bodied, wormlike appearance of the larva. This is the destructive stage, and the longest part of the insect's life.

The adults, or 'click beetles' are black and about ¾ of an inch long. They emerge from the soil in the spring, usually in April, after having spent the winter in cells in the soil. The females do not move about much initially, but emit a volatile substance which attracts the males. The males are very active on the soil surface on warm sunny days, running about as they search for unmated females. After mating, the females remain hidden in cracks in the soil for about three weeks before they begin to move about and lay eggs in the soil. Apparently they move entirely on foot, as we have never seen or caught them in flight. Yet, we have recaptured marked specimens up to 120 yards from the release point, so that an infestation could spread from one field to another. Egg-laying lasts for about a month in the field, but about 75 percent of the eggs are laid during the first two weeks. The eggs are laid in batches, the number per batch decreasing as time progresses. We have observed a single female to lay over 1,400 eggs, though the average number per female in our studies was about 900.

The females are not good diggers, and seem to prefer loose, fine-textured soil for egg laying. We found them unable to dig into undisturbed field soil which had settled and packed for several weeks after cultivation, and most of them died before they could escape the high soil surface temperatures. However, they dug down five inches and laid eggs in fine sifted soil which had been only moderately packed just before the beetles were placed on it. When cracks were made in the undisturbed field soil, the beetles laid most of their eggs about ½ inch below the bottoms of the cracks. Deep cracks greatly increased survival of the females and the numbers of eggs laid, so that cracks and crevices probably are important in population fluctuations and distribution in the field. Soil moisture is also very important to egg survival, particularly around the time of oviposition. Our studies have shown that an egg must absorb about one half of its original weight in water, and most of this shortly after it is laid. Later on, the eggs seem able to withstand much drier conditions. The eggs hatch in about three or four weeks after being laid in the field.

The newly-hatched larva is about 1/50 of an inch long and weighs less than 50 millionths of a gram. It grows very rapidly and by fall may be over 40 times its original weight. When it is full grown several seasons later it may be over an inch long and may weigh well over 1/10 of a gram—hundreds of times its original weight. The larval stage lasts for several years in the field, and one case of nine years has been recorded.

Life History Provides Practical Knowledge

Wireworms remain hidden in the soil, and the grower may not realize that he has a problem until serious damage occurs. Assessment of damage potential and planning of control measures depend greatly on an understanding of life history, habits and the factors which are good and bad for wireworm survival and development.

Studies of wireworm behaviour, development and survival indicate that method and timing of cultivation may influence wireworm numbers and damage. Soil moisture, texture, looseness and cracking appear to have important effects on numbers of eggs laid and on their survival. Suitable food plants seem particularly necessary for survival of newly hatched larvae. The presence of food plants during two or three times of the season, when feeding is at its maximum, likely influences feeding patterns and damage to seedlings the following spring. The more we know of the way of life of wireworms, the better chance we have to reduce the hazard by agronomic practices.