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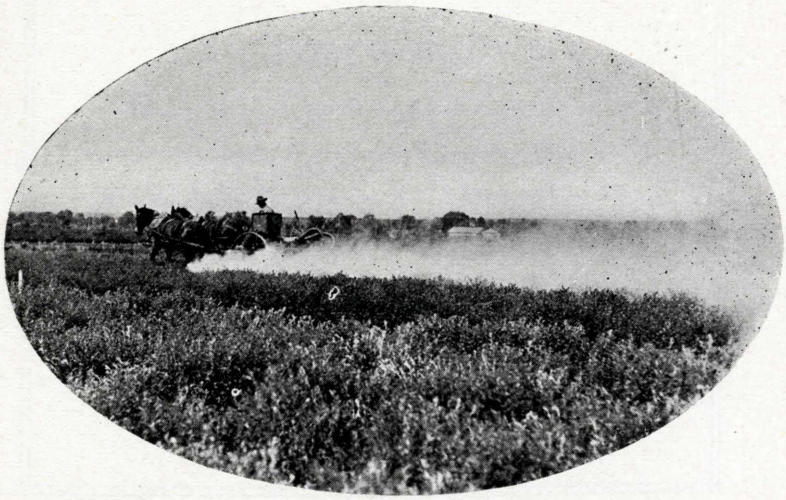

Traction duster in operation for control of alfalfa-seed insects, summer of 1931, Uintah Basin Alfalfa-seed Experimental Farm.

Utah Agricultural Experiment Station
Utah State Agricultural College
LOGAN, UTAH

FOREWORD

The results of investigations reported in this publication have been carried on, in the main, at the Uintah Basin Alfalfa-seed Experimental Farm at Fort Duchesne and in Western Millard County, as well as in other alfalfa-seed producing districts of the state.

Insects in Relation to Alfalfa-Seed Production[1]

Charles J. Sorenson[2]

INTRODUCTION

Various insect pests have been suspected of causing the unsatisfactory alfalfa-seed yields that have been obtained in Utah during recent years. No specific information was at hand giving the amount and nature of the damage which these insects were suspected of doing.

As a result of this situation, the Agricultural Experiment Station, in 1926, began investigations for the purpose of ascertaining the relationship of certain insects to alfalfa-seed production and of developing methods for their control. These investigations have been carried on, for the most part, at the Uintah Basin Alfalfa-seed Experimental Farm at Fort Duchesne, but studies have also been made each year in Western Millard County and in the other seed-producing districts of the state.

Up to the present time these investigations have dealt with chalcisflies, tarnished plant bugs, superb plant bugs, thrips, and aphids. The major portion of the study, up to June 1930, was devoted to the chalcisfly problem, the results of which were published as Utah Agricultural Experiment Station Bulletin 218(4). Since this date the principal study has been concerned with the tarnished and superb plant bugs, although partial time has been given to the study of thrips and aphids. These studies are still in progress.

In connection with the foregoing studies, observations on the damage done to alfalfa by blister beetles, alfalfa weevil, and grasshoppers have been made and efforts for the control of alfalfa weevil and grasshoppers have been necessary during the past two years at the Experimental Farm.

It is with the hope that at least some of the information and experience obtained in these investigations may be helpful to seed growers in the solution of their insect problems that the following is published prior to completion of the investigations.

Acknowledgments: The writer gratefully expresses his appreciation to the following: L. Floyd Clarke, Graduate Research Assistant, and R. L. Janes, Student Assistant, both of whom have assisted with the experimental work pertaining to the tarnished and superb plant bugs, thrips, and aphids; John W. Carlson, Superintendent, Uintah Basin Alfalfa-seed Experiment Farm, who cooperated in providing space on the farm for the field experiments and in furnishing other valuable aid; George Whornham, Assistant Field Agronomist who has assisted with the work in Western Millard County; Dr. J. R. Parker, Senior Entomologist, Bureau of Entomology, U. S. Department of Agriculture, for suggestions on grasshopper control; and Gerald Thorne, Associate Nematologist, Bureau Plant Industry, U. S. Department of Agriculture, for identifying the alfalfa stem nema.

[1]Contribution from Department of Entomology, Utah Agricultural Experiment Station.

[2]Associate Entomologist

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CHALCIS-FLIES

Description and Overwintering

Alfalfa-seed chalcis-flies[3] are small, jet-black, gnat-like insects about 1/12 inch long with a wing expanse of about 1/9 inch. These insects overwinter as full-grown larvae (worms) inside of infested alfalfa-seed. Some of this seed shatters and falls to the ground before and during the harvest and much of it is blown over into the chaff during threshing. With the coming of warm spring weather the larvae transform and emerge as adult "flies."

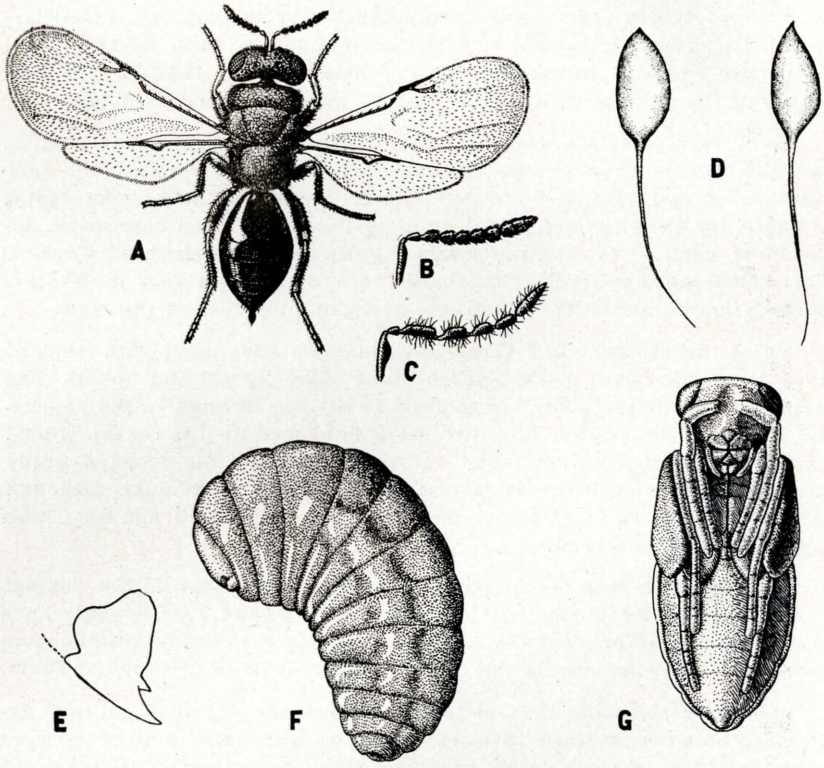

Fig. 1—Alfalfa-seed chalcis-fly: *A*-female; *B*-female antenna; *C*-male antenna; *D*-eggs (greatly enlarged); *E*-anterior view of right mandible; *F*-larva; *G*-pupa (enlarged). (From Utah Agr. Exp. Sta. Bul. 218. By C. J. Sorenson)

Feeding and Damage

Just as soon as pods begin forming on alfalfa the "flies" begin laying eggs. The eggs are inserted into the soft, jelly-like inner substance of the developing seed kernel where they hatch after about four days. Almost immediately after hatching the tiny worms begin feeding upon the soft, nutritious material in which they find themselves. Feeding proceeds

[3] *Bruchophagus funebris* Howard

rather slowly during the first three or four days, but thereafter it is comparatively rapid. In 10 to 15 days the entire kernel of the seed is eaten. Just one kernel is consumed by each worm and there is no migration from one seed to another by the larvae. After feeding has been completed the first-brood larvae pupate within the seedcoat. In about 12 days, on the average, the pupae emerge as "flies".

Two full broods of larvae are produced during the seed-setting season and usually there is at least a partial third brood.

Chalcis-flies are found in the seed-fields throughout the entire growing season, their numbers increasing with the advancement of the season.

Microscopic examination of alfalfa-seed samples taken from representative seed fields of the state has shown seed losses due to chalcis-fly, as indicated in Table 1.

Table 1—Losses of alfalfa-seed due to chalcis-flies

Year	No. of Field Samples Examined	Percentage of Seed Destroyed
1926	75	9.13
1927	90	9.75
1928	123	11.51
1929	179	24.37
1930	139	18.08
1931	132	13.72
Weighted Average (6-year period)	123	13.07

Prevention and Control of Chalcis-flies

Perhaps the most important single factor in limiting chalcis-fly damage is cooperative action of all alfalfa-seed growers in the application of the known measures of prevention and control.

It is impractical for individual growers alone to control the chalcis-fly, even on their own farms because the 'flies" migrate from field to field.

Results of investigations indicate that it is advisable for seed growers of an entire district to select either all first-crop alfalfa or all second-crop for the production of the seed crop, rather than to leave part first-crop and part second-crop alfalfa for this purpose. Producing seed from first-crop alfalfa provides a longer breeding season for the "flies" than does seed production from second-crop. Usually two broods of "flies" develop in seed grown from first-crop. If a first-crop seed-field is in the near vicinity of second-crop alfalfa which is being left for seed, the first brood "flies" emerging from the seed of the first-crop migrate to the second-crop where they find conditions more favorable in the newly-forming seeds for egg-laying. The usual result is that the seed from the second crop is more heavily infested than that from the first crop. On the other hand, where all of the seed in a district is grown from second-crop alfalfa, the "fly" infestation is generally less than in districts where seed is produced from both first- and second-crop alfalfa in the same season.

If seed development and ripening on either first- or second-crop alfalfa can be managed so as to produce maximum uniformity, the period of "fly" infestation will be proportionately shortened. As the period of

seed formation is shortened, so also is the egg-laying period of the "flies". These insects lay their eggs in newly-developing seed while the kernel is in a semi-liquid or jelly-like condition. After the seed reaches the "dough" stage, the "flies" will not lay their eggs in it.

Uniform ripening makes it possible to harvest the seed before much shattering takes place in the field. All possible prevention of waste seed in the fields reduces the carry-over of the chalcids to the next year.

Volunteer alfalfa, when permitted to go to seed, ordinarily furnishes chalcis-flies with the earliest seed of the season in which to lay their eggs. Furthermore, individual volunteer plants usually produce a continuous succession of young seeds in which the "flies" find favorable conditions for the development of three or four broods of young during the growing season. Obviously, then, volunteer alfalfa should be prevented from seeding, either by timely cutting or by pasturing.

In threshing alfalfa-seed, much that is "fly"-infested is blown over into the chaff where favorable overwintering quarters are provided for these insects. If chaff stacks are left in the fields during the summer, chalcis-flies emerge from these stacks in great numbers to infest the new seed crop. To prevent infestation from this source, chaff stacks should be fed, composted, or burned in the spring (not later than about May 1 of average years).

Great numbers of chalcids are liberated in the fields when uncleaned alfalfa-seed, screenings, or blowings are planted. It is poor economy to use such seed for planting. If it seems necessary to use it for this purpose the seed should be held over for at least a year in seamless bags. During this time the "flies" will emerge from the seed, but being unable to pass through the tied sacks will die within them.

Another practical method of controlling chalcis-flies consists in the thorough cultivation of seed-fields, preferably in the fall, so as to bury the shattered seed to a depth of at least 2 inches. When thus buried, the "fly" larvae in the infested shattered seed are nearly all destroyed.

Results of five seasons' tests performed at the Uintah Basin Alfalfa-Seed Experimental Farm are shown in Table 2.

Table 2—Results of five seasons' tests performed on the Uintah Basin Alfalfa-Seed Experimental Farm to ascertain the effect on emergence of chalcis-flies when "fly"-infested alfalfa-seed is buried in a medium sandy-loam soil

Year	No. Chalcis-flies Which Emerged from the Following Depths in Inches					
	Not-Covered (Check)	0.5	1	1.5	2	2.5
1926	821	708	345	242	10	11
1927	7932	2625	1676	726	935	340
1928	4450	4702	2973	1874	1422	43
1929	19573	9967	5070	2502	639	475
1930	1219	392	129	80	37	29
Totals	33995	18394	10193	5424	3043	898
Percentage "flies" destroyed	0	45.89	70.01	84.04	91.10	97.36

Natural parasites do much toward decreasing the number of alfalfa-seed chalcis-flies, but in the past parasities have not been of sufficient importance to give satisfactory control of the "fly". Most of the natural parasites attack and destroy chalcis-fly larvae after these larvae have either partially or entirely destroyed the alfalfa-seed kernel. The benefit of the work of the parasites, therefore, results only in reducing the numbers of the succeeding brood of "flies" rather than saving the infested seed.

TARNISHED PLANT BUG

Occurrence in Alfalfa-seed Fields and Distribution

With the probable exception of thrips, the tarnished plant bug[4] has occurred in greater numbers than any other insect found in the alfalfa-seed districts during the past five years. It is widely distributed throughout the United States and in many other parts of the world.

Description

The tarnished plant bug varies in color from a dull dark brown to a greenish-or yellowish-brown and often has a mottling of darker spots on the wings. A characteristic V-shaped yellowish or whitish mark occurs on the thorax (that portion of the insect's back toward the head). The insect averages about 0.25 inch in length and is a little less than half as broad.

Nymphs or Young

The young of the tarnished plant-bug are called nymphs. These vary in color from various shades of yellowish-green to a mottled brownish-green. The average individual may have some difficulty in distinguishing the younger tarnished plant bug nymphs from aphids which the nymphs superficially resemble in some respects. There are five nymphal stages, each differing somewhat in size and color. Wing-buds occur in each of the last three nymphal stages. A mottling of the green color also appears in the third nymphal stage, which becomes more pronounced in the two following nymphal stages.

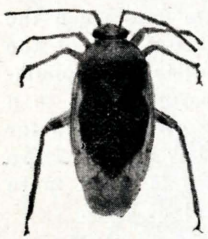

Fig. 2—Tarnished plant bug. *Lygus pratensis* (Linn.). (4 x)

Overwintering and Egg-laying

The tarnished plant bug overwinters as an adult bug in the fields hibernating in alfalfa crowns, in grass, and under weeds and rubbish.

Activity is resumed with the appearance of warm days in spring. Egg-laying begins in early April and continues throughout the summer until the occurrence of killing frosts in the fall. The eggs are laid in the upper 3 or 4 inches of the growing alfalfa stems.

Population and Broods

At intervals of two weeks during the summer of 1931 sweepings with an insect net in 25 representative seed fields of the Uintah Basin showed

[4] *Lygus pratensis* (Linn.)

that the activities of tarnished plant bugs in the tops of the alfalfa plants increased from May 15 to August 1. On the latter date the greatest number of bugs for the season was taken, when an average of 231 bugs were caught with 100 sweeps of the net for each of the 25 fields swept. There were more than twice as many bugs in the fields about August 1 than there were either two weeks prior to this date or two weeks following it.

In only four of the 25 fields was the first-growth alfalfa cut for hay. In 21 of the fields, therefore, there was no interruption of the reproductive activities of the bugs due to cutting of the alfalfa.

In the seed fields of Western Millard County the tarnished plant bug population reached its peak about June 10, 1931, when the number of bugs caught in 100 sweeps of the insect net averaged 128 for each of the 18 representative fields swept.

Between June 10 and 20 the first-growth alfalfa in all but two of these fields had been cut for hay, which resulted in reducing the bug population caught on July 1 to an average of 29 per field. On this date (July 1) 90.91 per cent of the catch was adult bugs, whereas prior to cutting adult bugs constituted but 29.09 per cent of the number taken by net. This seems to indicate that the sudden change in environmental conditions, due to cutting of the alfalfa, was responsible for a high mortality of the young nymphal bugs and a marked migration of adults. On July 10 the bug population averaged 102.33 per field. Of the 1842 bugs taken on this date, 44.41 per cent were adults and 55.59 per cent were young nymphs. There had been ample time by July 10 for the hatching of a new brood of young bugs from the second-growth alfalfa.

The maximum number of bugs taken on any single date when the fields were swept in Western Millard County was 44.59 per cent of the maximum number taken in the Uintah Basin. The smaller bug population in the fields of Western Millard County was apparently due to a great extent to the general practice of cutting the first-growth alfalfa for hay, whereas in the Uintah Basin the general practice has been to leave the first growth for seed production. This latter practice is much more favorable to the reproduction and multiplication of the plant bugs.

Although many plant bugs remain active in the fields until the occurrence of the first frosts of fall, yet after September 1 there is a considerable reduction in their numbers.

Three to four broods of young are produced during the growing season.

Feeding and Damage

The tarnished plant bug is a sucking insect feeding upon the sap of its host plants. Although this bug feeds upon a wide range of plants, alfalfa seems to be one of its favorite hosts in this region.

Close observations of the feeding activities of tarnished plant bugs on alfalfa both in the open field and in experimental cages in the field indicate a choice for the flowers. Although no particular part of the flower seems to be selected, yet most of the feeding appears to take place at the basal parts of the flowers.

Results of tests performed at the Alfalfa-seed Experimental Farm in the Uintah Basin during the past two summers (1930 and 1931) indicate that tarnished plant bugs are responsible for some of the "stripping," or flower-drop, of alfalfa, which is usually pronounced in the alfalfa-seed fields. Studies made on the Experimental Farm of 25,000 flowers showed that under natural conditions of growth, only one-fourth of them formed pods. Thus, three-fourths of the flowers "stripped" off either from natural or environmental causes. Data obtained to date in experimental field cages indicate that when the ratio of tarnished plant bugs and flowers is 1 to 20, or about the same as they are estimated to have occurred in the alfalfa-seed fields during the past two years, these insects caused approximately 9 per cent of the "stripping" of the alfalfa flowers which otherwise would have formed seedpods.

Control of Tarnished Plant Bug

No satisfactory method for the control of the tarnished plant bug is yet known. It may be prevented to some extent by cleaning up weeds, rubbish, and any other places which may afford the overwintering adults protection.

SUPERB PLANT BUG

Description

The predominant colors of the superb plant bug[5] are black and red, the mid-portions of both dorsal (back) and ventral (under) surfaces being black and the sides red. These colors are lighter-toned in some bugs, the black being brownish or brownish-black and the red orange or brownish-yellow. These bugs are somewhat larger than tarnished plant bugs; the average length of the superb plant bug is approximately 5/16 inch and its breadth about 1/8 inch.

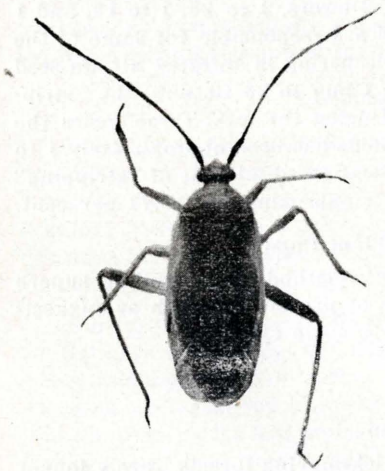

Fig. 3.—Superb plant bug, *Adelphocoris superbus* (Uhler) (4 x)

The young nymphs are usually black and red in color. However, variations occur in which the red color is displaced by green. There are five nymphal stages in which size increases with each successive stage and wing-buds occur in each of the last three nymphal stages.

Occurrence in Alfalfa-Seed Fields

Superb plant bugs are found in alfalfa-seed fields from April to the time of the occurrence of killing frosts in the fall. The young nymphs have been found to be more numerous than adults in April and May.

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[5] *Adelphocoris superbus* (Uhler)

Egg-laying

In alfalfa fields superb plant bugs have been observed to lay their eggs in the alfalfa stems, usually below the upper 3 or 4 inches. The eggs are inserted singly, relatively close together within the tissues, and at approximately right angles with the length of the stems. After being inserted, the ends of the eggs are approximately parallel with the surface of the stem and usually may be seen only after splitting the stem open.

Population and Broods

Information with respect to numbers was obtained in the same manner as described for the tarnished plant bug. Maximum numbers of superb plant bugs were taken on June 15. Before this date, superb plant bugs were more numerous in fields than were tarnished plant bugs. After June 15, however, tarnished plant bugs became several times more numerous. On August 1, nine times as many tarnished plant bugs were taken as of superb plant bugs. On September 1, there were slightly less than one-third as many superb plant bugs as tarnished plant bugs.

In alfalfa-seed fields three to four broods of superb plant bugs are produced during the growing season.

Damage

Superb plant bugs feed on plant juices which they suck up with their sharp bristle-like mouth-parts.

Results of experimental tests on the Alfalfa-Seed Experimental Farm at Fort Duchesne, in which superb plant bugs were caged for 24 hours on alfalfa flowers in ratios of 1 bug to 50 flowers, 1 to 25, 1 to 10, and 1 bug to 5 flowers, showed that these bugs are responsible for some of the "stripping," or dropping, of the flowers occurring in infested alfalfa-seed fields. In those cages where the ratio was 1 bug to 50 flowers, the "stripping" was found to be 27.42 per cent. During the past three years the ratio of bugs to flowers in most alfalfa fields has been approximately 1 to 100. Using these findings as a basis, the estimated amount of "stripping" caused by superb plant bugs in the field is approximately 13.71 per cent.

Control of Superb Plant Bugs

Up to the present time no satisfactory method of controlling superb plant bugs has been developed. Measures of prevention, such as suggested for the tarnished plant bug, may aid to some extent.

THRIPS

Description

Thrips are small, yellow, or brown, quick-moving insects, rarely longer than 1/10 inch. Most thrips have four narrow bristle-like fringed wings, which can be observed usually only with the aid of a hand-lens or microscope. These insects[6] are most noticeable in alfalfa after the flowers have opened. Usually at this time large numbers of them may be seen to scurry out and away if a cluster of flowers is bumped on the hand or on a sheet of white paper.

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[6]*Frankliniella occidentalis* (Pergande)

Seasonal History

Thrips overwinter in the adult stage, hibernating under crop refuse and in other protected places in the fields. Activity is resumed with the occurrence of warm weather in spring.

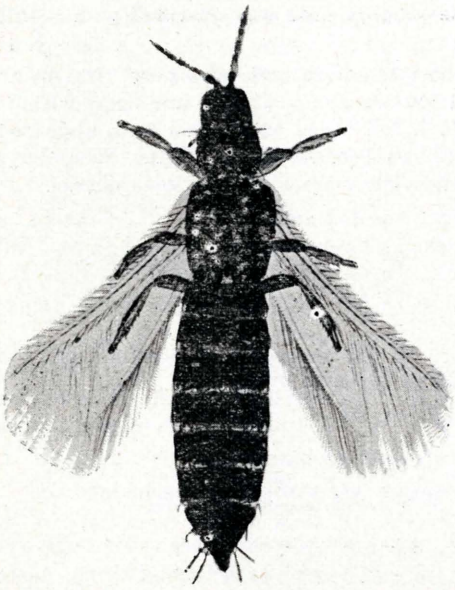

Fig.4 .—Thrips, *Frankliniella occidentalis* (Pergande). (50 x)

Egg-laying begins in April or May, varying with climatic conditions. The eggs are laid in the tissues of the alfalfa leaves and stems. Newly-hatched thrips are yellowish-white in color with red eyes and are similar in general form to the adults excepting that there are no wings in the young nymphs. Wing-buds occur in later nymphal stages.

A new brood of thrips is produced about every two weeks during the summer; eight to ten broods develop during the growing season. This rapid rate of reproduction accounts for the large numbers of thrips usually found in alfalfa, and particularly in first-growth alfalfa which is left for the production of seed.

Feeding and Damage

Thrips have mouth-parts somewhat intermediate between the chewing (grasshopper) type and the sucking (mosquito) type. Their mouth-parts, however, resemble more closely the sucking than the chewing type. When feeding, thrips make rasping movements with the mouth-parts which ruptures the outer surface of the plant tissue. Sap oozes into the tiny depressions thus made, and from these the thrips suck it up.

During the summers of 1930 and 1931 at Fort Duchesne and in 1930 at Delta, in Millard County, flowers on growing alfalfa in the field were caged and infested with thrips in various ratios. The cages were so constructed and arranged over the racemes (clusters) of flowers in such a way that the thrips had access to no other food than that provided by the flowers and flower stalks. Caged flowers on the same plats but uninfested with thrips served as checks.

The first noticeable results of the feeding of the thrips in all cages was the destruction of the pubescence on the petals of the flowers. That rich, purple, velvet-like covering of the flowers was consumed, leaving the petals pale-blue in color, or almost white, and spotted with the purple excreta of the thrips.

Dissection of flowers under a microscope showed several thrips, particularly young ones, moving freely about in the small inner cavities of the flowers. Examination of 1395 embryonic seeds from infested cages and 859 from check cages was made three to six days after infestation; little or no apparent damage to the developing seed was observed as a result of the activities of the thrips.

In many of the cages where the infestation ratio was 4 or 8 thrips to 1 flower, the flower stems showed considerable scurffing and some withering after a week of infestation. In a few cages where new buds appeared they were "blasted" as a result of the feeding of the thrips. Many eggs were observed which had been laid in the tissues of the flower-stems.

Although the present studies are limited and further data need to be obtained before definite conclusions can be drawn with respect to the full relationship of thrips to alfalfa-seed production, yet the data thus far obtained indicate that these tiny insects are responsible for rather appreciable losses to the seed grower.

A summary of results obtained in the experimental studies of 1930 and 1931, as described, is included in Table 3.

Table 3.—Weighted averages of results obtained in field tests at Fort Duchesne in 1930 and 1931 and at Delta in 1930 to ascertain the relationship of thrips to "stripping", or flower-drop, and to seed development in alfalfa

No. of Caged Flowers	Percentage Loss	No. of Caged Thrips per Flower			
		1	2	4	8
4520	Flowers	19.36	25.13	23.56	54.38
4000	Seed	21.54	34.23	46.80	45.28

Control of Thrips

The use of nicotine sulphate applied either in the form of a spray or as a dust is the usual recommendation for thrips control. A second application of this material about a week after the first application is necessary for the destruction of the young thrips which hatch out after the application of the first treatments and are not affected by it.

Some measure of prevention of thrips may be obtained by good farm sanitation in which all crop refuse is cleaned from, or burned in, alfalfa fields, thus destroying some of the protective overwintering quarters of these insects.

Cutting the alfalfa for hay destroys immense numbers of thrip eggs which have been laid in the tissues of leaves and tender portions of stems.

APHIDS OR PLANT LICE

Description and Reproduction

Aphids, or plant lice, are small, slow-moving insects whose bodies are unusually easily crushed. They obtain their food by sucking out the sap from host plants with their sharp bristle-like beaks.

Aphids overwinter in the egg stage in alfalfa fields. The eggs hatch in spring, producing females which soon give birth to living young. Reproduction is prolific and rapid, each viviparous female producing 6 or 7 young a day until 50 to 100 or more are born. There are 10 to 12 broods in a year. In the fall males and oviporous females are produced; the females lay eggs on the leaves and stems of alfalfa. These eggs carry the species over winter and produce the first brood of the next spring.

Prevalence in Alfalfa-seed Fields

The most prevalent species of aphid found in the alfalfa-seed fields is the green-pea aphid[7]. This plant-louse feeds on many different plants, but it seems to prefer alfalfa, red clover, and other plants of the legume family.

Although aphids have been present in practically all alfalfa-seed fields of the Uintah Basin during the past five years, yet at no time were they sufficiently numerous to cause any serious or even noticeable damage. In the summer of 1929 reports of serious aphid damage were received from Western Millard County. Special observations were made during the summers of 1930 and 1931 to find aphid injury, but none of any importance was discovered.

Relation to Weather Conditions

The character of the weather, particularly in early spring, exerts a marked influence on the multiplication of aphids. If the spring season is late and cool it favors the increase of aphids. On the other hand, if the spring opens up warm and fairly dry, the multiplication of aphids is retarded largely because of the work of parasitic enemies which are largely inactive except in warm weather.

Experimental Tests

During the summer of 1930 experimental field tests were made at Fort Duchesne and at Delta for the purpose of ascertaining the relation of aphids to alfalfa-seed production. Growing-alfalfa stems bearing the normal number of leaves and a selected number of racemes (clusters) of flowers were caged and infested with aphids in ratios of 5, 10 and 20 to 100 flowers in the different cages; 213 cages and 21,300 flowers, including those infested and those which served as checks, were used in these studies.

Symptoms of injury became noticeable only after several days of feeding by the aphids. The first conspicuous symptom to appear was a yellowing of the leaves, followed by a general unhealthful and weakened appearance of all foliage. Later most of the leaves dropped off. As a result of "stripping," or dropping, of the flowers the loss in pod production was found to be 33.33, 69.44, and 89.55 per cent, respectively, in the infested cages when compared with the pods produced in the check cages.

The aphids multiplied appreciably inside the cages. This was probably because of protection from natural enemies afforded by the cages. It was found impracticable to maintain the original ratio of infestation in the cages. The ratio in the open field was not determined, but it is estimated that it was less than 5 aphids to 20 flowers.

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[7] *Illinoia pisi* (Kaltenbach)

Control of Aphids

Aphid injury usually begins in spots in an infested alfalfa field. These spots may be recognized in early spring by an unhealthful appearance and light green color of the infested young alfalfa plants and by the presence of the cast skins of the aphids.

Such spots should be watched for in the spring and treatment applied immediately and before the aphids become scattered. If this is done it is unnecessary to treat the entire field. The aphids will be found in the first few feet of alfalfa bordering the "sickened" spots. Under some conditions the aphids in these spots may be destroyed by a thorough harrowing, followed by dragging which knocks the insects to the ground and crushes them.

Smith (3) found that aphids, while still confined to spots in an alfalfa field, could be effectively destroyed by the use of calcium cyanide granules applied at the rate of 25 to 30 pounds to the acre on the borders of the spots where the aphids were feeding. It is suggested that after the cyanide is applied that best results are obtained by dragging a pole, a brush drag, or some implement over the infested spots so as to knock the aphids to the ground where they will come in more direct contact with the cyanide fumes. One application gave almost complete destruction of the aphids. Calcium cyanide should be applied only when the plants are dry and when the air temperature is above 70° F. There is danger of burning the alfalfa if the application is too heavy or is such as to give a poor distribution of the calcium cyanide.

In experimental tests at the Alfalfa-Seed Experimental Farm in the summer of 1931, 4 and 6 per cent home-made nicotine dust gave a fair kill of aphids in a light infestation. The present cost of nicotine dust is rather prohibitive for the use of this material on large acreages of field crops such as alfalfa.

In cases where serious damage is threatened by aphids, immediate harvesting of the crop usually forestalls further injury.

Natural enemies do much to hold aphids in check. Most important of these enemies are lady-bug larvae and adults, the larvae of lacewings, and syrphus flies.

BLISTER BEETLES

Occurrence in Alfalfa-seed Fields

In early summer of recent years, considerable numbers of large gray blister bettles[8] have made their appearance in the alfalfa-seed fields of some districts of the state. In 1931, maximum numbers occurred about July 1; by July 15 more than half of them had left the fields; after August 1 individuals were seen but occasionally.

Feeding Habits

These insects were observed to feed ravenously on the first alfalfa flowers of the season. While flowers were relatively few in number, the petals were frequently completely devoured and the ovaries either partially or entirely eaten. When, however, alfalfa flowers become abundant the blister beetles fed lightly on individual flowers, merely taking a few bites from the margins of the petals while moving from one flower clus-

[8] *Epicauta sericea* Lec.

ter to another, with little or no apparent damage to the flowers. Occasionally, blister beetles become sufficiently numerous to cause serious damage, but during recent years this has not been the case in the alfalfa-seed fields of the state.

Fig 5.—Blister beetle, *Epicauta sericea* Lec. (2 x)

The larvae, or young, of many species of blister beetles feed exclusively on grasshopper eggs and hence are believed, by some people, to be beneficial. It is doubtful, however, whether blister beetle larvae are sufficiently beneficial to offset the damage done by the adult beetles. Destruction of grasshopper eggs destroys the food-supply of blister beetle larvae and, therefore if efficiently practiced eliminates damage from both grasshoppers and adult blister beetles.

Control of Blister Beetles

Dusting and spraying with arsenicals as well as the use of calcium cyanide are the usual recommendations for blister-beetle control.

The application of 2.5 pounds of calcium arsenate for the control of alfalfa weevil on the Alfalfa-seed Experimental Farm in 1931 had no apparent effect on the blister beetles.

Baerg (1) found that pure sodium fluosilicate and hydrated lime, mixed in equal parts and dusted on soybeans and alfalfa, was effective in destroying practically 100 per cent of a heavy infestation of blister beetles with no appreciable injury to the plants.

ALFALFA WEEVIL[9]

Damage and General Life History

Annual damage caused by the alfalfa weevil has made a notable increase during the past five years, culminating in 1931 in serious injury in all alfalfa-seed areas.

It is perhaps commonly known that the alfalfa weevil passes the winter in the adult or weevil stage. These insects hibernate in the fields under rubbish, in the alfalfa crowns, in cracks in the ground, or in other protected places.

With the coming of warm days in spring the adult weevils resume activity and soon begin laying eggs. The majority of eggs are laid in the growing stems of the alfalfa. Upon hatching, the tiny weevil larvae (worms) crawl up to and feed in the tender growing buds of the plants. Later in their development the larvae extend their feeding activities to the leaves of the plants. It is usually at this time that damage becomes noticeable or conspicuous.

Upon reaching their full growth, the worms crawl down the stems or drop to the ground where they spin their cocoons and transform into the pupal and weevil stages. The majority of the cocoons are usually found among the old dry stems and litter of the alfalfa crowns.

Ordinarily there is but one brood of larvae each year.

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[9] *Phytonomus posticus* (Gyll.)

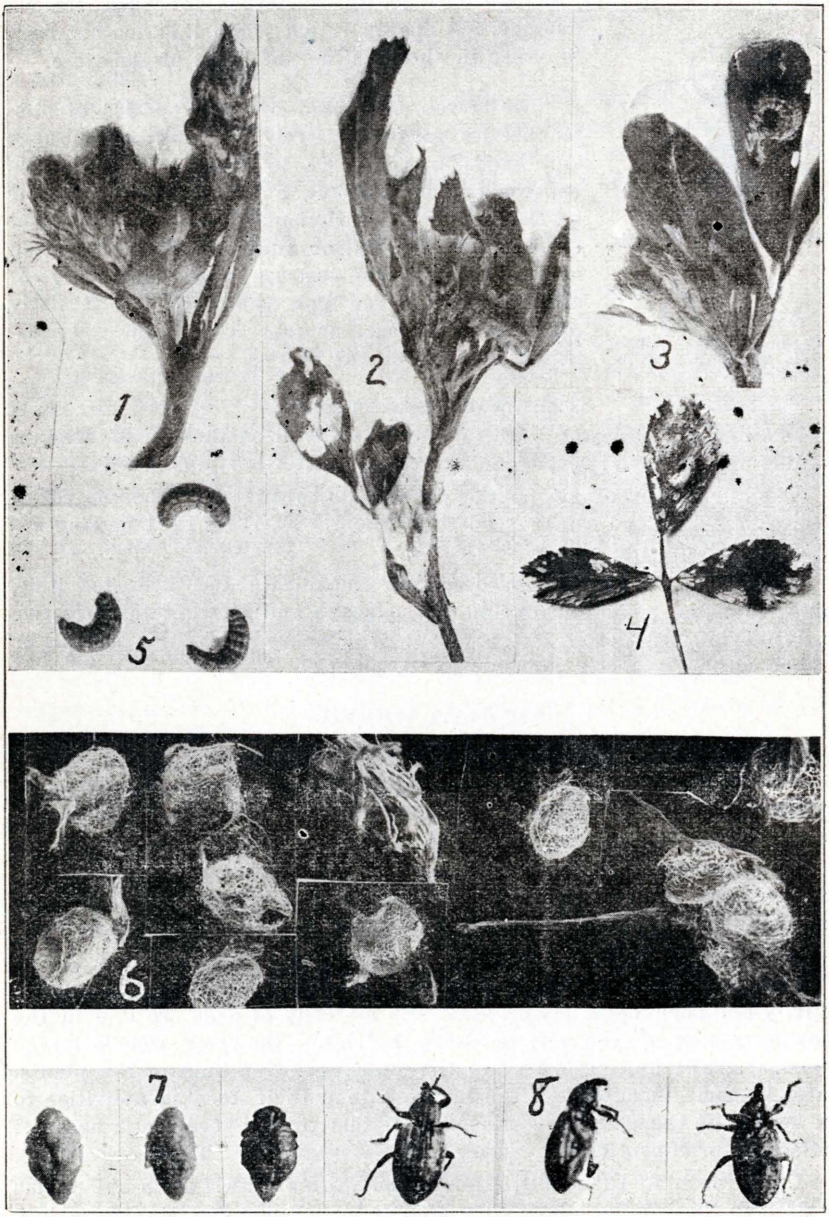

Fig. 6.—Alfalfa weevil *Phytonomus posticus* (Cyll.): 1 and 2-Larvae feeding in buds; 3 and 4-Larvae on leaves; 5-Larvae in natural position (2 x); 6-cocoons (2 x); 7- pupae (4 x); 8-adults (4 x). (From Utah Agr. Exp. Sta. Bul. 110. By E. G. Titus)

Control of Alfalfa Weevil

The alfalfa weevil may be readily and effectively controlled either by timely dusting or by spraying. Although satisfactory control can be obtained by either method of application, still the dusting method now seems to possess certain advantages over that of spraying.

Dusting

Calcium arsenate applied at the rate of 2 pounds to the acre gives satisfactory control of the alfalfa weevil. In 1931 the cost of this material to growers was $7 to $8 per hundred pounds, the price varying with the distance from the point of distribution.

In control work of the alfalfa weevil at the Uintah Basin Alfalfa-seed Experimental Farm during the summer of 1931, a dust was used consisting of 50 per cent calcium arsenate and 50 per cent dusting sulphur, applied with a dusting machine at the rate of 5 pounds to the acre, or 2.5 pounds of calcium arsenate. The cost of this material was $10.45 per cwt., delivered, or as applied, 52.25 cents per acre. The application was made after the weevil damage had become quite pronounced and four or five days later than it should have been applied; circumstances, however, prevented an earlier application. To obtain an index concerning the results of this treatment, daily observations of dead weevil larvae were made in the field and segregation counts of live and dead larvae made of those taken daily in 25 sweeps with an insect net over a period of one week and at the end of two weeks. The relative numbers of live and dead weevil larvae are shown in Table 4.

Table 4—Index of results obtained in alfalfa-weevil control work with a 50-50 per cent calcium arsenate and sulphur dust at rate of 5 pounds to the acre, equivalent to 2.5 pounds calcium arsenate (Applied on June 11, 1931)

Sweeping after Application	Treated Plats: Larvae Taken in 25 Sweeps of Net, Total	Treated Plats: Larvae Taken in 25 Sweeps of Net, Dead	Treated Plats: Percentage Dead Larvae	Untreated Plats (Check): Date of Sweeping	Untreated Plats (Check): Larvae Taken in 25 Sweeps of Net, Total	Untreated Plats (Check): Larvae Taken in 25 Sweeps of Net, Dead	Untreated Plats (Check): Percentage Dead Larvae
1 day	885	48	5.65				
2 days	1260	630	50 00				
3 days	888	366	41.20				
4 days	984	241	29.50	15	762	10	1.31
5 days	343	126	40.00				
6 days	110	37	33.63	17	583	8	1.37
1 week	123	53	43.10				
2 weeks	50	36	72.00	25	628	8	1.27
Totals	4643	1537			1973	26	
Weighted Average			33.10		628		1.318

The figures shown in Table 4 are only indicative of the complete results of the treatment because in sweeping over the alfalfa only those larvae which were in or near the tops of the plants would be captured in the insect net; many, if not the majority, of the dead larvae either would have fallen to the ground or to lower portions of the plant or would have crawled to the latter locations after becoming sick from the poison and before the sweepings were made. Examination of the ground under the dusted plants 24 hours after application revealed many dead,

dying, and sick larvae, with increased numbers daily thereafter during the two weeks of observation.

The greatest number of larvae were taken on the second day after the application of the poison; 50 per cent of these were already dead. The dying and sick larvae were not counted, although many such were observed during the daily counts.

The daily decrease in the number of larvae taken after the second day of sweeping is rather striking and perhaps more indicative of the efficiency of the poison than are the percentages of dead larvae taken in sweeping. The total number taken one week after the poison application, for example, is only 9.44 per cent of the maximum number taken the second day; those taken two weeks after the application were but 3.97 per cent of the maximum catch. That the decrease in numbers was due not chiefly to the migration of the larvae from the tops of the plants to the ground for pupation is evidenced by the numbers taken in sweeping the check plats where little change in the larvae population had taken place during the two weeks following the application of the poison to the treated plats.

Further analysis of the number of larvae taken in the sweeping seems to indicate that approximately 90 per cent of the weevil larvae were killed within one week after the treatment and that about 96 per cent were dead after two weeks.

It is fully realized that these results are based on tests which are undoubtedly too limited in scope to justify the drawing of definite conclusions. These data and their analyses are given merely as indicative of results which may be expected in the use of calcium arsenate for the control of the alfalfa weevil, since that was the poisonous ingredient of the dust used in control work last season.

Calcium arsenate alone was not used because of unsuccessful efforts in finding an available supply.

Time of Application

It is important that the poison be applied at the right time. This is largely a matter of experience and judgment. The best time of application is after the eggs have hatched and before serious damage to the crop begins. If the poison is applied before most of the eggs have hatched there will be sufficient new growth afterward to provide the newly-hatched larvae with harmless food; if application is postponed too long, damage increases daily.

When damage proceeds more rapidly than the growth of the plant, the best time for application has passed.

The poison may be applied as soon as all or most of the eggs have hatched, provided obvious damage has not previously occurred.

If most of the eggs are still unhatched and damage is exceeding growth, poison should be applied immediately.

At any time that weevil damage occurs it can be prevented by the immediate application of calcium arsenate; however, more than one application a season may be necessary unless an optimum time of application is selected, in which case one application is usually all that is necessary in one season.

Cultural Treatment

If the grower finds it impossible to dust or spray his alfalfa when weevil damage becomes serious, particularly if the injury is preventing further growth or even loss of that growth already attained, then it may be advisable to resort to cultural treatment similar to the following: **Cut the alfalfa and remove the hay as quickly as possible.** The field should be dry at this time. **As soon as the hay is off the field and while the ground is dry, springtooth it thoroughly;** follow this by dragging with a spike-tooth harrow, the teeth of which are tilted backward about half way and with a net wire or barbed wire entanglement underneath the harrow.

In cultivating the infested field in this manner a good dust mulch should be obtained; practically 100 per cent of the green growth will have been stripped from the alfalfa crowns. Such a condition leaves no food for the weevil larvae and exposes them to a fatal temperature created by the sun on the dry mulch. Under these rapidly changing environmental conditions few weevil larvae are able to survive. No irrigation water should be applied for at least two days after the cultivation, but after the elapse of that time water should be applied at once so that growth may begin immediately. Little or no weevil damage should be experienced during the remainder of the season.

Because of several objectionable features, the foregoing cultural method of controlling alfalfa weevil is not to be recommended except as a last resort. A few of these objections are: (1) Unchecked weevil damage to first crop until it is cut; (2) premature cutting of first crop usually necessary; (3) likelihood of injury to alfalfa resulting from severe cultivation in summer; (4) retardation of growth of second crop; (5) probable necessity of remarking the field for irrigation; and (6) this method is much more costly as well as inconvenient than is dusting or spraying with calcium arsenate.

Some measure of prevention of alfalfa-weevil damage may be had by thoroughly cleaning up the fields in the fall. All crop refuse, dead weeds, and other rubbish should be burned or removed from the fields, ditch banks, fence lines, stack yards, etc. This procedure eliminates protective quarters for the overwintering adult weevils.

Spring cultivation of alfalfa fields may stimulate an earlier and more vigorous growth, which may exceed weevil damage.

Parasites

Some alfalfa-weevil parasites have been imported by the United States Department of Agriculture from foreign countries. One of these, *Bathyplectes curculionis* Thoms., has become established in Utah; however, it is doubtful that it can be entirely relied upon as yet to give satisfactory control of periodic heavy outbreaks of the alfalfa weevil.

GRASSHOPPERS

Concurrent with the general drought conditions which have prevailed during the past two years and which have undoubtedly aided their development and increase, grasshoppers have become progressively more abundant in most of the alfalfa-seed areas of the state, resulting in damage beyond the usual annual average. The alfalfa on large acreages intended

for seed production in 1931 was eaten to the ground by grasshoppers, not to mention the less serious damage that was done in practically all seed fields.

It is commonly known that grasshoppers overwinter in the egg stage. Egg-laying takes place in late summer and in early fall. The eggs are usually laid in non-cropped or uncultivated ground within or adjacent to the alfalfa fields. Ditch-banks, fence lines, roadways, and waste land afford favorable places for egg-laying. Many grasshopper eggs are laid within the alfalfa fields, particularly if they remain uncultivated, or if the stand is thin or is intergrown with grass or weeds. The eggs are usually deposited by the female grasshoppers in holes dug in the ground. These holes seldom exceed 2 inches in depth. The number of eggs laid in each hole varies with the species of grasshopper, being from less than a dozen to more than a hundred. As the eggs are laid, a secretion is exuded from the insect's abdomen which envelops the eggs. When this secretion dries it holds the eggs together in a mass and forms a protective covering for them. In alfalfa-seed fields, especially where the alfalfa stand is thin, the egg-pods are sometimes placed in the alfalfa crowns.

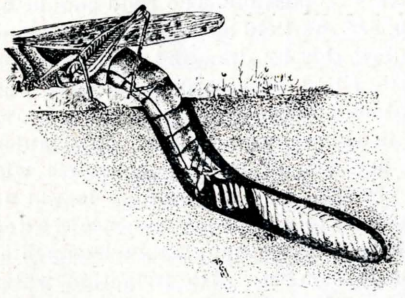

Fig. 7.—Grasshopper laying its eggs in the ground. (From Utah Agr. Exp. Sta. Cir. 54. By I. M. Hawley)

Prevention and Control of Grasshoppers

Destroying Eggs

One of the most effective methods of preventing the occurrence of grasshoppers is to break up the egg-pods and expose the eggs to the killing action of frost, moisture, winds, and sunshine. This is best accomplished late in the fall after egg-laying has been completed and before frost prohibits cultivation of the ground, or it may be done in the spring before hatching of the eggs begins. Land known to be infested with grasshopper eggs should be disked or spring-toothed, lengthwise, crosswise, and cornerwise, so as to stir the soil thoroughly to a depth of about 3 inches.

Poisoning

One of the most effective methods of controlling grasshoppers is to poison them soon after they have hatched and before they have scattered throughout the fields. It is particularly important that poisoning be done before the young hoppers develop their wings. The younger the hoppers, the less poison required for their destruction, the more likely they are to obtain it, and less injury results to the crop. For many years poisoned bran mash has been the standard grasshopper bait. Although satisfactory results have usually been obtained in the use of poisoned bran mash bait, yet the feeling has never been universal that formulas for and methods of its preparation were perfect.

One of the latest formulas to be recommended is reported by Dr. J. R.

Parker[10], in correspondence with the writer, who states: "The formula adopted for grasshopper bait at the conference held at Sioux City, Iowa, in December, 1931, was as follows:

"Coarse bran, free from shorts.....80 lbs.
Crude arsenic (finely divided) ..... 5 lbs.
Cane molasses .....15 lbs."

"These specifications . . . represent the opinion of the entomologists in Minnesota, South Dakota, Nebraska, and Iowa."

Suggestions on Preparation and Use of Grasshopper Baits[11] (2)

Sodium Arsenite

Sodium arsenite may be substituted for crude arsenic in the above formula using 1 quart if the solution contains 8 pounds to the gallon or 2 quarts if it contains only 4 pounds to the gallon.

Sodium arsenite, being readily soluble in water, gives a more uniform distribution of poison than is usually obtained in the use of crude arsenic. In some sections, however, difficulty is experienced in obtaining the sodium arsenite, in which case crude arsenic is used.

Two and a half pounds of dry sodium arsenite are equivalent to 1 quart of the liquid 8-pound sodium arsenite, or to 2 quarts of the 4-pound material.

Molasses

In bait tests conducted by the U. S.. Entomological Laboratory, Bozeman, Montana, with the two-striped grasshopper and with the red-legged grasshopper, cane molasses has proved to be decidedly more attractive than sugar beet molasses. "In fact, sugar-beet molasses for these species seems to be a repellant rather than an attractant since baits containing only bran, arsenic, and water attracted more grasshoppers than the same materials with sugar-beet molasses added to them[12]." Satisfactory results were obtained against the warrior grasshopper, *Camnula pellucida* (Scudder) by the use of sugar-beet molasses in the baits.

Amyl Acetate

Three ounces of amyl acetate may be added if desired. It is doubtful if it is necessary during hot, dry weather. However, further experimental work is needed before this point is settled.

Method of Mixing

The wet method of mixing is recommended. This consists in thoroughly mixing together the water, the molasses, and the poison before applying to the bran. If crude dry arsenic is to be used, it should be stirred to a thin paste in water before adding the full amount of water or the molasses.

Spread the bran evenly on a tight floor to a depth of 6 to 8 inches. "Distribute one-fourth of the liquid as evenly as possible over the surface of the bran and work it by a thorough raking. Do this four times, turning the bran with scoop shovels after the third raking in order to make sure that no dry bran remains at the bottom . . . . Two men rake from each end, working the bran from top to bottom with a chopping action, particular attention being given to breaking all lumps. After each raking the bran mash which generally has accumulated in two piles, one at each end of the mixing floor, should again be spread evenly over the floor before the next portion of liquid ingredients is added (2)". After the fourth raking the bran should be about right for use.

If not moist enough a little more water may be added to the bran followed by a fifth raking and more turning.

When to Scatter Bait

When mixing has been completed "the bait should be put out so that it will be fresh and moist when the grasshoppers first become active. In South Dakota this last summer, maximum feeding occurred when temperatures after sunrise first reached 75 to 80 degrees F. This was generally somewhere between 6 and 10 o'clock a. m. Putting out bait at temperatures below 70 or above 80 degrees F. is not to be recommended. Feeding habits of grasshoppers vary in different localities and with different species, and the time of feeding should be worked out for each. A general rule would be to put out bait

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[10]Senior Entomologist, Bureau of Entomology, U. S. Department Agriculture, Entomological Laboratory, Bozeman, Montana. In correspondence under date of January 22 and February 3, 1932.

[11]See Footnote 10

[12]See Footnote 10

[13]See Footnote 10

only when the grasshoppers are actively moving about. If they are sluggish from low temperatures or are roosting on foliage to escape high temperatures, little feeding on bran mash can be expected."[13]

Amount of Bait to Use

"Twenty pounds of the prepared poisoned branmash (wet basis) per acre are recommended for an average infestation. This amount has to be modified in practice according to the number of grasshoppers present, an extremely heavy infestation taking 30 or even 40 pounds to the acre."[14]

Spreading the Bait

"The most common way of spreading is to broadcast the bait with the hand. Every precaution should be taken to see that it falls apart into flakes. Casting it in a light wind with a snap of the wrist will aid in this respect. The grasshoppers will eat the individual flakes to some extent even after they become dry. When the mash falls in lumps it soon hardens and is not touched by the grasshoppers. This not only results in a waste of materials, but the lumps are attractive to poultry, livestock, and birds, sometimes with disastrous results.

"When large quantities are to be distributed the mash can be scattered from the rear end of a wagon (2)."

Sawdust as a Substitute for Bran

"When bran is very expensive, difficult to obtain, or must be hauled long distances, it is sometimes advisable to use sawdust, provided the latter is easily available. Equal parts of bran and sawdust should be used or, if no bran can be obtained, sawdust alone rather than abandon control measures. Cottonwood or pine sawdust which has lain in the pile for several years in better than strong-smelling fresh sawdust. It should be run through a coarse screen to remove chips, sticks, and larger flakes. If 100 pounds of bran is to be replaced by sawdust, enough of the latter should be taken to equal the bran in bulk rather than in weight, since the latter varies considerably according to the moisture it contains. Sawdust dries out more rapidly than bran when scattered, and it is therefore recommended that the amount of molasses used in the ordinary formula be doubled.

"Our experience with the sawdust mixture has been that the addition of sawdust to the bran made it easier to mix and scatter, this being particularly true if the bran contained flour or shorts. We have obtained good results with it when scattered on damp ground in meadows, along irrigating ditches, banks of sloughs, etc. On dry ground, however, it dries out quickly and is by no means as effective as straight bran. If good coarse bran can be obtained at a reasonable price, we strongly advise against the use of sawdust (2)."

Amount of Water in Bait

The amount of water necessary to use in the above formula so as to produce about the right dampness of the bran mash is 8 to 9 gallons, varying with the natural moisture content of the bran. It is better to use a trifle too little than too much water in mixing the ingredients, because it is simpler to add a little more water later, if (after thorough stirring and turning) it is seen that the bran is not wet enough, than it is to rectify the condition if the bran gets too wet.

Just enough water should be used to moisten all of the bran without making it sloppy or even approaching sloppiness. When the mash is broadcast the bran flakes should crumble apart as they fall from the hand.

Time Necessary for Action of Poison

Results of the poisoning should not be expected before 24 or 48 hours after putting out the bait, because arsenic is a slow-acting poison and does not kill immediately. Sick and dying grasshoppers may be found for a week or ten days following the application of the bait. Grasshoppers stop feeding after eating a little of the poison. The majority of sick grasshoppers seek the cover of the densest vegetation where dead grasshoppers are usually found in greatest numbers.

Catching Grasshoppers

In cases of extremely heavy infestations of grasshoppers in alfalfa quick relief from damage is frequently obtained by the use of a hopperdozer. A simple hopperdozer consists of a metallic pan, 15 to 20 feet long, 2 to 3 feet wide, and about 3 or 4 inches deep, with a metallic, canvas or other fabric shield fastened in an upright position on the rear side

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[14]See Footnote 10

of the pan; both pan and shield, are mounted on skids. The pan is half filled with old oil drainings from automobile crank cases or with some other form of cheap oil. As the outfit is dragged over the field, with a horse at each end, the grasshoppers jump against the shield and fall into the oil which kills them. Many bushels of grasshoppers may be destroyed in a day by this method. However, in view of the cheapness, efficiency, and convenience of poison bran baits, the use of the hopperdozer is not generally recommended.

ALFALFA STEM NEMATODE

Although nematodes are not insects, a brief description of the alfalfa stem nematode and its damage is included here for the reason that it has caused serious damage in three or four alfalfa-seed fields of the Uintah Basin during the past two years and that the infestation may spread unless control measures are taken.

Symptoms of Infestation

The most conspicuous symptoms of nematode infestation observed in alfalfa-seed fields were: (1) The occurrence of occasional plants bearing albino stems in which all of the natural green color of stem, leaves, and buds and even the natural colors of the flowers had disappeared, leaving them white, or creamy-white in color and conspicuous in an otherwise green field; (2) sickening and dying out of the alfalfa in spots; and (3) when infested stems were taken hold of and pulled they broke off readily from the alfalfa crowns and were observed to be decayed and blackened. These symptoms are those which evidently had appeared some years after the initial infestation.

Description

Thorne (5), Associate Nematologist, United States Department of Agriculture, who identified nematodes found in alfalfa-seed fields in the Uintah Basin, gives the following description and information concerning them: "The stem nema is a slender, nearly colorless, active eel-like worm averaging 1/20 of an inch in length."

Reproduction

"Stem nemas pass the winter in the last young shoots of alfalfa produced in the fall and in the soil about the alfalfa crowns.

"Activity begins shortly before the young shoots of alfalfa appear and these are attacked as soon as growth begins. The nemas probably enter through the leaf axils or near the growing point . . . . . Each female produces a large number of eggs, which, under favorable circumstances, soon hatch, and in a few weeks the infested stem may contain hundreds, or even thousands, of nemas in all stages from egg to adults, several generations occurring during a season."

Damage

"The infested shoots are either killed or stunted in their growth, often being club-like and with the bases marked by tiny transverse wrinkles . . . Occasionally stems will present clubbed or swollen places as much as a foot above the ground where colonies of nemas have become established.

"Under ordinary conditions an alfalfa plant is not severely injured the first year of infestation, but in the second year the killing of many of its shoots and the penetration of decay into the branches of the crown cause it to weaken rapidly. Death may sometimes occur the first year, but usually the plant will survive two to four years, or even longer, depending upon its vitality and the severity of the infestation."

Control of the Stem Nematode

"Crop rotation is the only known method for control under ordinary field conditions. If a systematic crop rotation is practiced in which alfalfa is al-

lowed to remain not over three or four years there is less danger of serious loss. When an alfalfa field becomes infested to a point where serious loss occurs, it should be plowed up and planted with other crops for at least two or three years, care being exercised to eliminate all alfalfa plants and weeds. Suitable crops for rotation include sugar-beets, wheat, corn, barley, beans, peas, and some other cultivated crops.

"Fortunately the alfalfa stem nema is not yet known to readily transfer itself to other plants in this country, but in certain foreign localities it has been found to seriously infest oats, potatoes, and clover. Therefore, while it may not attack these crops in the western states, it may be advisable not to use them in a rotation on an infested alfalfa field if others in the above list can be grown just as advantageously" (5).

The alfalfa stem nematode is a different species than the sugar-beet nematode. The latter species is not known to attack alfalfa.

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