organizations in Florida on one hand, and officials of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture on the other, before any change is made in the present manner of inspecting passengers and baggage from Puerto Rico.

GRASSHOPPER CONTROL IN CITRUS GROVES IN FLORIDA

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In May, 1947, grasshoppers of the species *Schistocerca americana* (Drury) were reported as doing damage in citrus groves in southeastern Hillsborough County. Since this grasshopper was formerly thought to cause damage only in the fall of the year, the situation was regarded as abnormal and potentially serious. A survey indicated that grasshoppers were abundant over a fairly wide area and that some control measures would be necessary. The following is an account of the 1947 infestation and a review of the control program proposed for this pest.

In the fall of 1946, heavier than normal populations of grasshoppers were present in western Polk and southeastern Hillsborough Counties. Benzene hexachloride was used as a dust (0.6% gamma isomer) and as a spray at the rate of 2 to 3 pounds of wettable powder (6% gamma isomer) per 100 gallons of spray. This proved to be an effective control measure. In January and again in March of 1947 casual observations were made and it was noted that adult grasshoppers were in the fields. It is not known at present whether these represented relatively newly emerged adults or whether they were left from the fall generation. The fall of 1946 was abnormally warm and it is suggested here that there may have been at least a partial or possibly a complete extra generation in the fall. In any case it appears that the warm fall and winter offered favorable overwintering habitats and this was a major factor in the abnormal increase in grasshopper numbers in 1947.

There was a heavy hatch of grasshoppers about May 1, 1947. The last of May showed a population which was generally about 1/3 to 1/2 grown. By late June a few of these individuals had grown wings and were present as adults. Adults continued to mature and in late July most of the grasshopper population was in the adult stage. There was some oviposition in late July and eggs began to hatch shortly after August 1. Through the cooperation of the Bureau of Entomology and Plant Quarantine, Mr. Andrew Frazier came into the state in July and he was able to make a thorough survey of the infestations. He found the grasshoppers mainly in the area south of Plant City in Hillsborough County,, both north and south of Lakeland in Polk County. and in scattered places from Bartow to Wachula in Polk and Hardee Counties. There were occasional infestations on the east coast, but they were of minor importance. In the central part of the state, it appeared that grasshopper infestations were associated with areas where crab grass was the predominant type of cover crop and where groves were adjacent to old vegetable fields. Groves had become infested both from adja-

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cent fields and from hatch within the grove itself.

The second generation of hoppers hatched throughout August with the bulk of the hatch occurring between August 15 and August 25. From 50 to 100 individuals hatched from each egg pod and these remained clustered together in a colony for more than a week. These nymphal grasshoppers grew and began to reach maturity in mid-September. October 10 marked the peak of maturation and following that date the bulk of the population was present as adults. Up to November 1, no copulation or oviposition has been observed in the field. Whether a partial third generation may occur remains to be determined. Damage was most serious in June and early July and again in September and October. These periods coincided with times when young grasshoppers were more than half grown. Apparently they feed most heavily at that time in their life history. As very small individuals and as adults they do a minimum of damage to citrus foliage.

Control by Insecticides

A review of recent literature on grasshoppers control (Hinman, 1947; Weinman, 1947; and List, 1947) indicated that 3 new chlorinated hydrocarbons were showing promise for grasshopper control. These were benzene hexachloride at about 0.3 lbs. of gamma isomer per acre, chlordane at 1.0 lb. per acre and chlorinated camphene at 3.0 lbs. per acre. These dosages are arbitrary averages, but they seem to represent approximate figures at which other workers were obtaining control. Since citrus groves ordinarily require more spray or dust than vegetable or field crops, it was decided to try these materials for toxicity to grasshoppers and if they appeared satisfactory, they would be applied at the rate of 50% more toxicant per acre than the figures cited above. A total of 9 experiments were performed on a field scale. Plots varied in size from 1 to 5 acres. These tests were performed between July 15 and October 25.

The first 2 experiments were performed in mid-July in a grove where a heavy grasshopper population was present. The dusts were applied by airplane both in the grove and in adjacent grasslands. It was determined from these preliminary tests that an airplane flying each middle of a grove was a satisfactory method of application for grasshopper control; benzene hexachloride, chlorinated camphene, and chlordane were satisfactory toxicants; and that results were much better where the cover crop was chopped prior to treatment.

Only 1 experiment is being reported in detail. In this test 4 materials, chlordane, chlorinated camphene, benzene hexachloride, and thiophos 3422, were used both as wettable powders and as dusts. The grove was composed of large grapefruit and orange trees and each plot contained 2 acres. Sprays were applied by a "Speed Sprayer" and dusts with a conventional ground duster. Treatments were randomized and they were adjacent to each other. In all instances the cover crop was chopped prior to spraying or dusting. Treatments were applied on the mornings of August 18 and 19. All 8 treatments gave excellent initial mortality. Counts were made by counting the number of adults seen while walking through a given number of rows. Initial populations found in the adjacent untreated areas were taken as standards and all percent reductions were based on these figures. Table I shows the dosages and the percent reductions at 3 intervals following the treatment. After 7-8 days the populations in the adjacent untreated areas were materially reduced. This was undoubtedly at least partly due to migration into the treated plots. It will be noted that chlordane and chlorinated camphene gave more prolonged control than did either benzene hexachloride or thiophos 3422. This fact was also substantiated by caging adult grasshoppers from each of the plots and observing mortalities at 24 and 48 hours after caging. No treatment was successful in preventing reinfestation from adjacent areas for more than a few days.

This fact emphasizes the importance of treatment not only of an infested grove, but of adjacent areas as well, if completely satisfactory control is to be obtained. In cases where both the grove and adjacent grasslands were treated in July, no further damage was done and the second generation produced only an occasional hopper in the area.

The experiment reported in detail above was typical of the results obtained elsewhere. Several factors were demonstrated conclusively by observations on these controlled experiments and also by observations where commercial groves were treated by caretaker or owners. Thiophos 3422 is not further considered in this paper because of its non-availability at present and because too little is known concerning its toxicity to fruit and to warm blooded animals. As later experiments developed, it was evident that some slight modifications could be made in the dosages noted in Table I. Table II shows the toxicant per acre required for control and the amount of dilute material for some of the standard formulations. All recommendations are based on pounds of actual toxicant per acre. Although this is a departure from usual recommendations for spray or dust on citrus, it was definitely established that this method works satisfactorily. The only requirement is that the material be dispersed evenly over both the trees and the cover crop. In young groves that are clean cultivated or in open fields the dosage may be reduced about 33 percent and still give satisfactory control. Dusters should be driven slowly and the dust applied primarily to the lower 6-8 feet of the tree and to the cover crop.

TABLE I.

CONTROL EFFECTED BY FOUR SPRAYS AND DUSTS ON GRASSHOPPERS IN A CITRUS GROVE

Treatment	Lbs. Toxicant per acre	% Reduction After—		
		1 day	3-4 days	7-8 days
Chrlordane spray[1]	1.5	95	82	81
Chlordane dust[2]	1.5	94	94	89
Chlorinated Camphene spray[3]	4.5	94	96	89
Chlorinated Camphene dust[4]	4.5	96	96	83
Benzene Hexachloride spray[5]	0.45	98	89	71
Benzene Hexachloride dust[6]	0.45	87	91	68
Thiophos 3422 spray[7]	0.45	96	90	74
Thiophos 3422 dust[8]	0.45	92	91	71
Untreated		0	0	71

[1] 50% wettable
[2] 5% dust
[3] 33 1/3% wettable
[4] 10% dust
[5] 6% wettable
[6] 1% dust
[7] 15% wettable
[8] 1% dust

All spray recommendations in this paper are based upon the use of a "Speed Sprayer." The number of gallons to be used per acre may vary from about 100 to as high as 1000 gallons. The number of gallons to be used per acre should be established first and sufficient insecticide added to the tank to insure the required amount of toxicant per acre. The authors obtained excellent results by using a double head with all the top nozzles cut off and with only about 25 nozzles open on each side. The sprayer was driven at less than 2 miles per hour and 500 gallons of solution were used per acre. The number of gallons and the number of nozzles may be adjusted to any given situation so long as uniform coverage is obtained and so long as the sprayer moves no faster than 2 miles per hour. Where hand sprayers are used it will usually be necessary to increase the dosage per acre in order to insure good results.

At the present time these materials can be recommended for use with either wettable or dusting sulfur. The possibilities for using them in other mixtures is being determined. None can be used with lime-sulfur and benzene hexachloride should never be used with oil. Chlordane and chlorinated camphene were found to be satisfactory when used as emulsifiable materials as well as in wettable form.

In choosing the insecticide to use, several factors should be considered. Since all are effective, cost per acre should be taken into account. Chlordane and chlorinated camphene have greater residual toxicity, but present results do not indicate that this is of major importance. According to work in 1947, chlordane and chlorinated camphene may be used at any time. *However, benzene hexachloride should not be used on fruit prior to September* 1. In its crude form it may impart an undesirable flavor to fruit when used either as a dust or as a spray. This fact was first noted in 1946 when trees were sprayed with benzene hexachloride in oil. In 1947, there was an undesirable taste in early oranges in some of the groves dusted or sprayed in July and August. There had been no taste noted in fruit treated after September 1. Until this phenomenon is better understood, benzene hexachloride will not be recommended for use on citrus trees bearing fruit until after September 1.

Some growers have believed that sulfur

TABLE II.

RECOMMENDED DOSAGES FOR THREE MATERIALS TO BE USED FOR GRASSHOPPER CONTROL IN CITRUS GROVES

	Sprays			Dusts		
	% Toxicant in Stock Material	Lbs. Toxicant per acre	Lbs. Stock Material per acre	% Toxicant in Stock Material	Lbs. Toxicant per acre	Lbs. Stock Material per acre
Chlordane	50% wettable	1.5-2.0	3-4	5%	1.5-2.0	30-40
Chlorinated camphene	33 1/3% wettable	3.5-4.5	10.5-13.5	10%	3.5-4.5	35-45
Benzene hexachloride (gamma isomer)	6% wettable	0.4-0.5	7-8	1% 0.6%	0.4-0.5 0.4-0.5	40-50 70-80

acted as a repellant to grasshoppers. One experiment, performed in triplicate, was made where trees were dusted with sulfur, sprayed with wettable sulfur, and sprayed with lime-sulfur. There were as many grasshoppers on the treated as on the untreated trees during the following days. Casual observations on groves sprayed with sulfur showed no decrease in the grasshopper population. It was therefore concluded that sulfur on citrus has little or no repellency to the American or bird grasshopper under Florida conditions.

Cultural Practices

Many divergent opinions have been advanced as to the effect of discing or chopping on grasshopper infestations in groves. Enough general observations were made during the 1947 season to determine these effects with some degree of reliability. In general, grasshoppers were found in groves where the cover crop was composed of some type of grass. This grass was usually of the crab grass group. Apparently this type of sod offered a place which was satisfactory for oviposition and also a good food source for growing nymphs. Observations indicated that chopping or discing could be either detrimental or beneficial according to the timing of the operation and the age of the grasshoppers at the time. Thus, chopping or discing the cover crop should be avoided at a time when most of the grasshoppers are present as large nymphs. At this time since the nymphs cannot fly, they will migrate immediately to the trees and unless insecticide is applied, they may do serious damage.

As noted in the introductory paragraphs, the second generation of the bird grasshopper hatched mainly during the second and third weeks of August. By August 25 the bulk of the hatch had been completed. Two groves, both heavily infested, were selected as places to study the effect of discing on newly hatched nymphs. One grove was composed of 2 and 3 year old orange trees and the other of 10 year old Valencias on sour orange root stock. On August 18 half of each grove was disced in both directions. Results were checked by counting the colonies of newly hatched nymphs. Table III shows the results. On August 22 the number of colonies were counted in 10 checks or squares. A check or square constituted an area with 4 adjacent trees as corners. Three days after discing there was a reduction in 1 grove, but none in the other. The discing had not been sufficient to chop up and kill the cover crop which was present. Therefore on August 25 the areas were redisced and this time one discing was on the diagonal. Two days later nymph colonies were again counted and this time there was a significant reduction in

TABLE III.

Effects of Discing on Grasshopper Population

	Date	3 Year Old Trees		10 Year Old Trees	
		Chopped	Disced	Chopped	Disced
Three days after discing (Colonies per square)	8/22/47	7.4	7.6	6.9	2.1
Three days after second discing (Colonies per square)	8/28/47	4.6	0.3	8.6	0.1
Grasshopper nymphs per 100 sweeps	9/15/47	60	4	240	11

both groves. On September 15, a check was again made on the populations in these groves. This time the number of nymphs taken per one hundred sweeps with a standard insect net was taken as the criterion of infestation. As noted in Table II, there was at least a 90 percent reduction in both groves. In another grove which was disced clean about September 10, sweeps were made on September 15 and there were 56 nymphs per 100 sweeps in the chopped as compared with only 6 in the disced area. Thus, it appeared that discing at the end of a hatching period or within 2 weeks thereafter was a means of effectively reducing a potentially serious infestation to one of no economic importance. It should also be noted that these disced areas were not reinfested at a later date.

The explanation for the marked reduction in young nymphal grasshoppers following clean cultivation was probably due to a combination of 2 factors. On one hot afternoon when the air temperature was above 95° F. and the soil surface was 115° F., newly emerged nymphs were thrown on this hot surface and they were able to survive for only a few minutes unless they were able to find an unkilled blade of grass upon which to crawl. The other factor concerned is one of food source. The tiny grasshoppers can only move short distances and if food is not readily available, they can be easily starved to death.

In late October another factor concerning discing became evident. Where almost the entire population was present as adults, it was found that thorough and clean cultivation caused the winged individuals to migrate from the grove into adjacent areas. This was tried with complete success in 2 groves. Although this method may not be completely effective in all circumstances, it offers a means of control in many places at a minimum of trouble and expense. However, the grower should be ready to apply insecticide if for some reason the grasshoppers fail to leave the grove.

Recommendations for Control

The following recommendations are based on only 1 season's intensive work and it is possible that some alterations will be necessary in the future. However, it is believed that the following suggestions will afford an effective and economically feasible program.

It is not known at present how the bird grasshopper passes the winter, but it is established with certainty that there will be a hatch in the spring of 1948. In 1947 this occurred in April and May. If groves are maintained in a state of clean cultivation from November until about May 15 to June 1, it is believed that no eggs will be laid there and the only grasshoppers which can attack the grove in June must of necessity come from adjacent fence rows and fields.

If grasshoppers appear in serious proportions in a grove in June, they may be controlled by the use of chlordane (1 1/2-2 lbs. per acre) or chlorinated camphene (3.5—4.5 lbs. per acre) used either as dusts or sprays. Where none develop in June, but where it is anticipated that there will be grasshoppers in the fall, cover crop management should be such as to assure a crop of seed by late August. This involves no chopping after mid-June. Then, if a hatch occurs in the grove in August, there will be no objection to discing in the cover crop within 2 weeks after the hatch has occurred and thus obtain control. If, in spite of these practices, there are infestations later in the fall, they may be controlled by the use of the 2 materials mentioned above or by benzene hexachloride (0.4—0.5 lb. gamma isomer per acre) either as a spray or dust. If the bulk of the population is in the adult stage, it may be forced out of the grove by thorough discing after mid-October. Discing or chopping when hoppers are about half grown should be avoided as they will not be killed by the operation, and since they cannot fly, they will move onto the trees where they may do excessive damage.

Groves should always be prepared for

dusting or spraying by first chopping the cover crop. This resulted in much better control than where cover crops were standing at the time of application.

SUMMARY

An account of the 1947 grasshopper problem on Florida citrus is presented. There were 2 generations which did damage particularly in June and early July and again in September and October. Experiments concerning the use of benzene hexachloride, chlordane, thiophos 3422 and chlorinated camphene for grasshopper control are described. The effects of cultural practices and the possibilities of control by judicious cultivation and cover crop management is discussed. Recommendations for control are outlined.

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NEW INSECTICIDES AND THEIR APPLICATION ON CITRUS

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During the past four years a number of organic compounds have been developed for use as insecticides. Some of these are already in use and others are still in the experimental stage. When a new insecticide is to be tested, there are a number of factors to be considered and two or three years of experimental work is frequently required before the material can be recommended for general use. Some of the important questions to be answered are:

1. Toxicity of material to various species of insects and mites?
2. Toxicity, if any, to the tree?
3. Minimum concentration which will give results?
4. Compatability with other materials in combination sprays?
5. Effect on beneficial insect population?

Until the research workers have had time to obtain at least preliminary answers to the above questions, it is not advisable to treat large acreages with any new insecticides.

Some of the new insecticides may have a limited but definite use in combating insects infesting citrus groves. Until recently there was no insecticidal spray or dust that could be used economically for the control of grasshoppers, plant bugs, ants and shothole borers. Now there are several materials which may be used effectively for the control of those insects. Fortunately, the above mentioned insects are not of major importance over a wide area, but any one of the above named group can be of major importance in one or more groves during certain years, and it is at least gratifying to know that there are materials which can be recommended for their control. One or two of the newer compounds may eventually replace some of the insecticides now in use, but only extensive experimental work plus commercial trials can determine their real value.

At the present time the Citrus Experiment Station is working with a number of the newer insecticides but it will take time