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The Sweetpotato Weevils in Hawaii Their Biology and Control

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THE SWEETPOTATO WEEVILS IN HAWAII THEIR BIOLOGY AND CONTROL

By

MARTIN SHERMAN AND MINORU TAMASHIRO

INTRODUCTION

The sweetpotato, *Ipomoea batatas* Poir., is an important food crop throughout the subtropical and tropical regions of the world and is an especially important staple crop of many of the South Pacific islands.

The sweetpotato became commercially important in the Hawaiian Islands around 1849 *(10)*. In 1953, 833 tons, having a wholesale market value of approximately $125,000, were harvested. This figure does not take into account the small backyard plantings that are so numerous throughout the Territory.

The West Indian sweetpotato weevil, *Euscepes postfasciatus* (Fairmaire), and the sweetpotato weevil *Cylas formicarius elegantulus* (Summers) are the most destructive insect pests of the sweetpotato in the Hawaiian Islands. A conservative estimate of the loss due to these insects would be 10 to 20 percent of the crop. Their damage is not restricted to the field but may also occur during storage. The damage is caused by the feeding of adults and larvae on the roots and stems of the plant. The feeding of the larvae causes the greater economic damage. Their tunneling through the main stem often causes it to become greatly enlarged and cracked. This condition will, in cases of severe injury, interfere with the normal physiological processes. Of more direct importance is the injury to the edible root. The feeding tunnels are filled with frass. This makes the potatoes unmarketable, and the resulting bitter taste often makes the potatoes unpalatable even to livestock.

This study was undertaken to determine the biology and control of these weevils in Hawaii.

TAXONOMIC STATUS AND DISTRIBUTION

Euscepes postfasciatus (Fairmaire) (the West Indian sweetpotato weevil).

Cryptorhynchus postfasciatus Fairmaire, 1849, Rev. Mag. Zool., p. 513.

Cryptorhynchus batatae Waterhouse, 1850, Ent. Soc. London, Proc. 1849. p. lxix.

Hyperomorpha squamosa Blackburn, 1885, Roy. Soc. London, Trans. (ser. 2) 3: 182–183.

Euscepes batatae (Waterhouse) Champion, 1905, Biol. Cent. Amer., Coleoptera 4 (4): 497.

Euscepes postfasciatus (Fairmaire) Zimmerman, 1936, Bernice P. Bishop Mus., Occas. Papers 12 (23): 14–16.

The taxonomic status of the West Indian sweetpotato weevil was clarified by Zimmerman in 1936. Though both Fairmaire and Waterhouse described the species in the same month and year, June of 1849, Waterhouse's description was not published until 1850; and, therefore, his name *batatae* is a synonym of *postfasciatus.*

The distribution of *Euscepes postfasciatus* is restricted to portions of South America, the Carribean, and the Pacific area. The areas in which this pest occurs are listed below:

Barbados *(2)*	French Oceania *(8)*	Peru *(55)*
Bermuda *(54)*	Guam *(36)*	Puerto Rico *(28)*
Brazil *(7)*	Hawaii *(49)*	Santo Domingo *(31)*
British Guiana *(6)*	Jamaica *(36)*	Society Islands *(57)*
Caroline Islands *(56)*	Marianas *(58)*	Tonga Island *(15)*
Dutch Guiana *(40)*	New Caledonia *(41)*	Trinidad *(19)*
Fiji *(27)*	New Zealand *(36)*	Virgin Islands *(46)*

Cylas formicarius elegantulus (Summers) (the sweetpotato weevil).

Attelabus formicarius Fabr., 1798, Ent. Syst. Suppl., p. 163, Nos. 13–14 [in part].
Brentus formicarius Fabr., 1798, Ent. Syst. Suppl., p. 174, No. 5.
Brentus formicarius (Fabr.) Fabricius, 1801, Ent. Syst. II: 549, No. 13.
Cylas formicarius (Fabr.) Schönherr, 1826, Curc. Disp. Meth., p. 75.
Cylas turcipennis Boheman, 1833, Schönherr, Gén. et Spec. Curc. 1: 369–370.
Otidocephalus elegantulus Summers, 1875, New Orleans Home Jour. 10 (3): 68, Jan.; No. 26, Dec. 25.
Cylas formicarius elegantulus (Summers) Pierce, 1918, Jour. Agr. Res. 12 (9): 605–607.

The sweetpotato weevil in the broad sense was originally described by Fabricius in 1798 as *Attelabus formicarius,* but in the same work, in a later part, he redescribed the species as *Brentus formicarius.* In 1801, he synonymized his two names and placed *formicarius* in *Brentus.* Schönherr in 1826 placed the species in the genus *Cylas.* Summers in 1875 described the sweetpotato weevil as *Otidocephalus elegantulus,* but LeConte and Horn *(30)* in the following year stated that this species was conspecific with *C. formicarius.* According to Pierce, the Fabrician description of *formicarius* fits several species within the genus, and it is not known if the Fabricius species attacks sweetpotato. However, since the name *formicarius* had been associated with this weevil for so many years and in order to be technically correct, he adopted the name *Cylas formicarius elegantulus* for the sweetpotato weevil in the new world. *Cylas turcipennis* which was described by Boheman in 1833 has been considered conspecific with *C. formicarius* by LeConte and Horn *(30).* Kemner *(29)* in 1924, after comparing the types of the two species with specimens collected in Indonesia, considered the two to be conspecific. Pierce *(37),* however, in 1940 after studying the genitalia of *formicarius* and *turcipennis,* stated that they were two different species.

The present opinion among the coleopterists of the U. S. Department of Agriculture is that *Cylas turcipennis* is not specifically distinct from *Cylas formicarius formicarius (32).* They consider *C. formicarius elegantulus* as a variety limited to the western hemisphere, while *C. formicarius formicarius* is the variety found in Europe, Africa, Asia, and the South Pacific. *C. formicarius elegantulus* has been reported from the following areas:

Argentina *(32)*
Bahamas *(32)*
Barbados *(32)*
Brazil *(32)*
British Guiana *(32)*
Cuba *(13)*
Curacao, Dutch W.I. *(32)*
Dominican Republic *(16)*
Guatamala *(37)*
Haiti *(17)*
Hawaii *(5)*
Honduras *(32)*
Jamaica *(42)*
Mexico *(32)*
Panama *(32)*
Puerto Rico *(14)*
Ragged Island, B.W.I. *(32)*
St. Kitts (Lesser Antilles) *(32)*
United States *(47)*
Venezuela *(32)*
Virgin Islands *(32)*

HAWAIIAN DISTRIBUTION AND PLANT HOST RECORDS

Cylas formicarius elegantulus was first recorded in Hawaii by Blackburn and Sharp in 1885 from the islands of Maui and Oahu *(5)*. *Euscepes postfasciatus* was recorded in the Fauna Hawaiiensis as *Hyperomorpha squamosa* in 1885 *(35)*. Subsequently, the two species have been collected on all the major islands.

The Hawaiian host records of the two species are quite sparse. In addition to the sweetpotato, *Ipomoea batatas,* they have only been recorded from a few other plants of the same genus. *C. formicarius elegantulus* has been reared from *Ipomoea pes-caprae (34)* and *I. tuboides (9),* while *E. postfasciatus* has been found breeding in *I. pentaphylla (50),* Japanese morning glory *(34), I. triloba (33),* and *I. horsfalliae (51).* All varieties of sweetpotato are subject to attack by the two species, though some are more susceptible to attack than others.

LIFE HISTORY

The information for this portion of the study was obtained under laboratory conditions. The sweetpotato variety used to rear the insects was Onolena.[1] The sweetpotatoes were fumigated with methyl bromide to insure freedom from infestation. After allowing the fumigant to dissipate, the potatoes were cleaned. Six roots were placed in each of 18 glass battery jars, which were then covered with a double layer of cheesecloth. Several hundred weevils of one species were placed in one battery jar, while a similar number of the other species was placed in another. These weevils were allowed to oviposit for 24 hours. At the end of that time, they were transferred to another pair of jars. Care was taken to remove all of the weevils from the oviposition jars. This process was continued until the roots in all 18 jars had been infested. The species and dates of introduction and removal of the adults were recorded on each oviposition jar.

Freshly deposited eggs were dissected from the roots in the first pair of oviposition jars and placed in covered petri dishes containing moistened filter paper. Daily observations of hatching were made.

The number of larval instars and their duration were determined by dissecting larvae from the sweetpotatoes daily. Eight days after the start of oviposition, potatoes were removed from the jar, a large slice was cut out of each potato, and the larvae within each slice were dissected out. All larvae removed from each sweetpotato slice were killed in hot water and placed in a vial containing 75 percent alcohol. Dissections were continued until at least 20 larvae were removed from each oviposition jar. Larvae were taken from at least three separate oviposition

[1]This variety was developed by C. F. Poole, Vegetable Crops Department, Hawaii Agricultural Experiment Station, for outstanding baking qualities.

jars for each species each day. This procedure was continued until there were no roots left in a particular jar, at which time dissection was begun on the roots in the next oldest and unsampled jar. The species, the date of removal of the adults from the oviposition jar, and the date of removal of the larvae from the potatoes were recorded on each vial. The age of each larva was thus known to within 1 day.

This experiment was conducted from August 20 to September 28, 1953. The temperature in the laboratory during this period ranged from a maximum of 88° F. to a minimum of 73.5° F., with an over-all mean temperature of 80.3° F.

EGG

Table 1 summarizes the hatching record of both species of weevil. The mean period of egg hatch was 8.3 $\pm$ 0.8 days for *E. postfasciatus* and 8.2 $\pm$ 0.4 days for *C. formicarius elegantulus.*

The egg of *Euscepes postfasciatus* (see B in figure 9) is globular, with a grainy surface, having dimensions of 0.34 $\pm$ 0.02 by 0.38 $\pm$ 0.02 mm. The color ranges from grayish yellow to yellow.

The egg of *Cylas formicarius elegantulus* (see A in figure 9) is oval, with a grainy surface, having dimensions of 0.50 $\pm$ 0.03 by 0.79 $\pm$ 0.04 mm. The color ranges from white to cream.

TABLE 1. Summary of the number of days required for egg hatch. Average temperature, 80.3° F.

DAYS AFTER OVIPOSITION	NUMBER OF EGGS HATCHING	
	EUSCEPES POSTFASCIATUS	CYLAS FORMICARIUS ELEGANTULUS
7	10	0
8	58	61
9	20	19
10	7	0
11	1	0

LARVA

The larvae (figures 5 and 6) of both species are of the typical curculionid form. They are crescent-shaped, subcylindrical, white, legless grubs.

The larvae of the two species are very similar in appearance and are difficult to separate by a cursory examination. However, the frontal aspect of the heads of each exhibits certain characters which, upon close examination, serve to distinguish the two species. These characters are the maxillary brushes and the position and strength of certain setae.

Figure 1 depicts the frontal aspect of the larval head of each species. The setae, which have been found to be important for separating the species, are numbered for convenience of discussion. Seta 2 is always ventrad to seta 1 in *E. postfasciatus,* but it is dorsad to seta 1 in *C. formicarius elegantulus.* In *E. postfasciatus* seta 3 is approximately parallel to seta 4 and, although shorter, is similar in thickness. In *C. formicarius elegantulus,* seta 3 is definitely dorso-mesad to seta 4 and is much smaller and weaker. The three lateral setae (1) in *E. postfasciatus* are longer than the corresponding setae in *C. formicarius elegantulus.* The maxillary

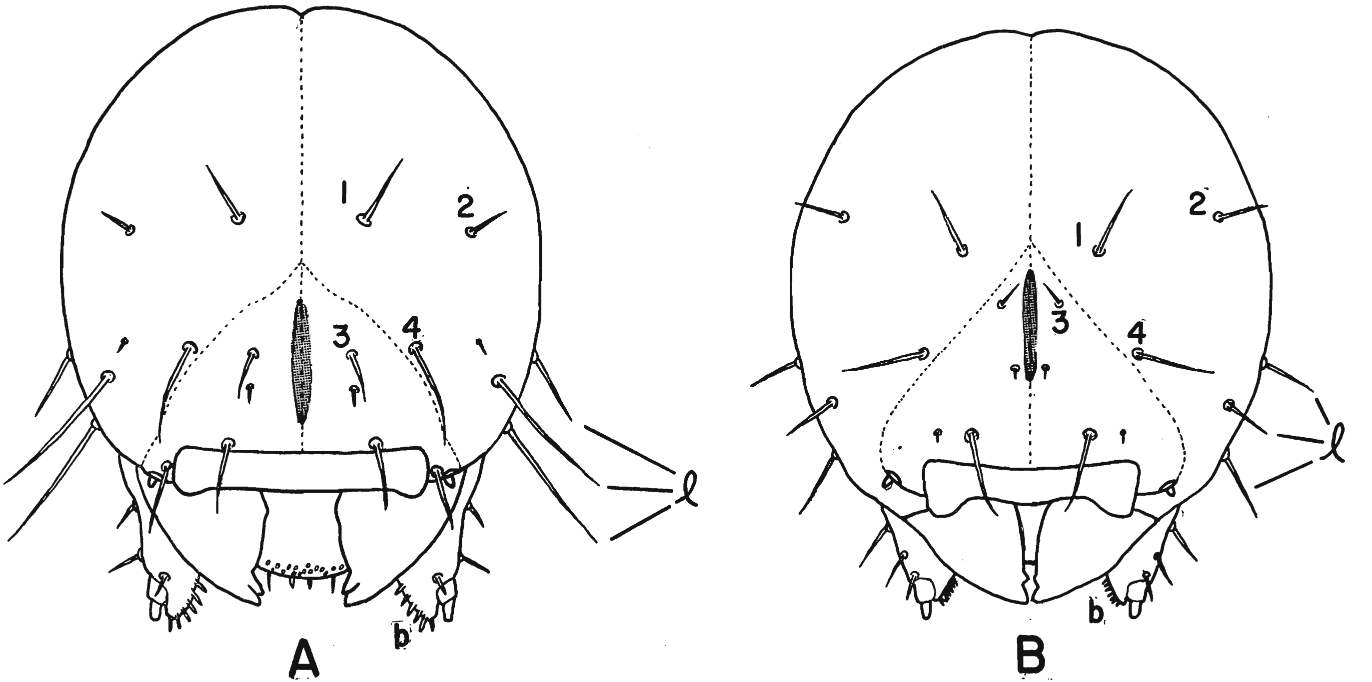

FIGURE 1. Front view of last instar weevil larvae. A, *Euscepes postfasciatus*; B, *Cylas formicarius elegantulus*. Numbers refer to paired setae, b to maxillary brush, and l to lateral hairs.

brush (b) in *E. postfasciatus* is composed of fewer, stronger, and more separated bristles than in *C. formicarius elegantulus*. These differentiating characters appear to hold true throughout the developmental period of these larvae.

NUMBER OF INSTARS. Dyar *(18)* propounded what is now known as Dyar's Rule. He stated that the head width of several species of lepidopterous larvae followed a geometrical progression in successive instars. This rule has subsequently been elaborated and applied to other groups. The dimensions of the heavily sclerotized portions of the insect body do not change during a stadium but increase only at ecdysis.

Since both species of sweetpotato weevils spend their entire larval period hidden within the stem or root, it is very difficult to observe directly the number of instars. The use of Dyar's Rule has been helpful in determining the number of larval instars of species whose immature stages are hidden within plant material.

Measurements were made of the widths of the larval head capsules. The head capsules were excised, mounted, and cleared in Hoyer's solution *(3)* on microscope slides. Twenty heads from larvae in the same vial were aligned and mounted on each slide. Small glass rods were used to support the cover slip and prevent distortion of the heads. The maximum width of each head was measured.

The frequency distributions of the observed head measurements of *Euscepes postfasciatus* and *Cylas formicarius elegantulus* are given in figures 2 and 3, respectively. The distributions fell into five distinct groups for *E. postfasciatus* and into three distinct groups for *C. formicarius elegantulus*. Each of these groups was assumed to be a different instar.

In order to support this assumption statistically, the observed data were analyzed by the method of least squares as outlined by Gaines and Campbell *(23)*. The results of the analysis are summarized in tables 2 and 3.

A geometrical progression may be plotted graphically as a straight line by the equation $\log y = \log a + x \log b$, where y is the width of the head capsule, a and b are constants, and x is the number of the instar. Any deviation of observed values from the calculated line would indicate variation from the geometric progression. The regression lines which were calculated as the best fit for the geometrical growth of *Euscepes postfasciatus* and *Cylas formicarius elegantulus* were $\log y = 0.09187 + 0.1609x$ and $\log y = 0.3062 + 0.1938x$, respectively.

The observed mean head widths of the assumed instars of each species were plotted as suggested by Forbes *(21)* and Harries and Henderson *(25)* in figure 4. The close agreement between the calculated and observed values corroborate statistically the number of instars in the larval periods of the two species.

Gonzales *(24)* in the Philippines claimed that *Cylas formicarius* had five instars. He based his findings on 12 larvae which he reared individually on thin pieces of sweetpotato roots. He considered the presence of the head capsule as the usual criterion of molting. However, at times, he could not find the capsule; but if the head was white, he considered that molting had occurred. According to his data, the width of the head of the five instars was as follows: 0.25, 0.42, 0.61, 0.64, and 0.66 mm. Fukuda *(22)* in Formosa claimed that *Cylas formicarius* had four instars, but he presented no physical measurements nor information how this was determined.

Our determination of the number of instars in *C. formicarius elegantulus* is

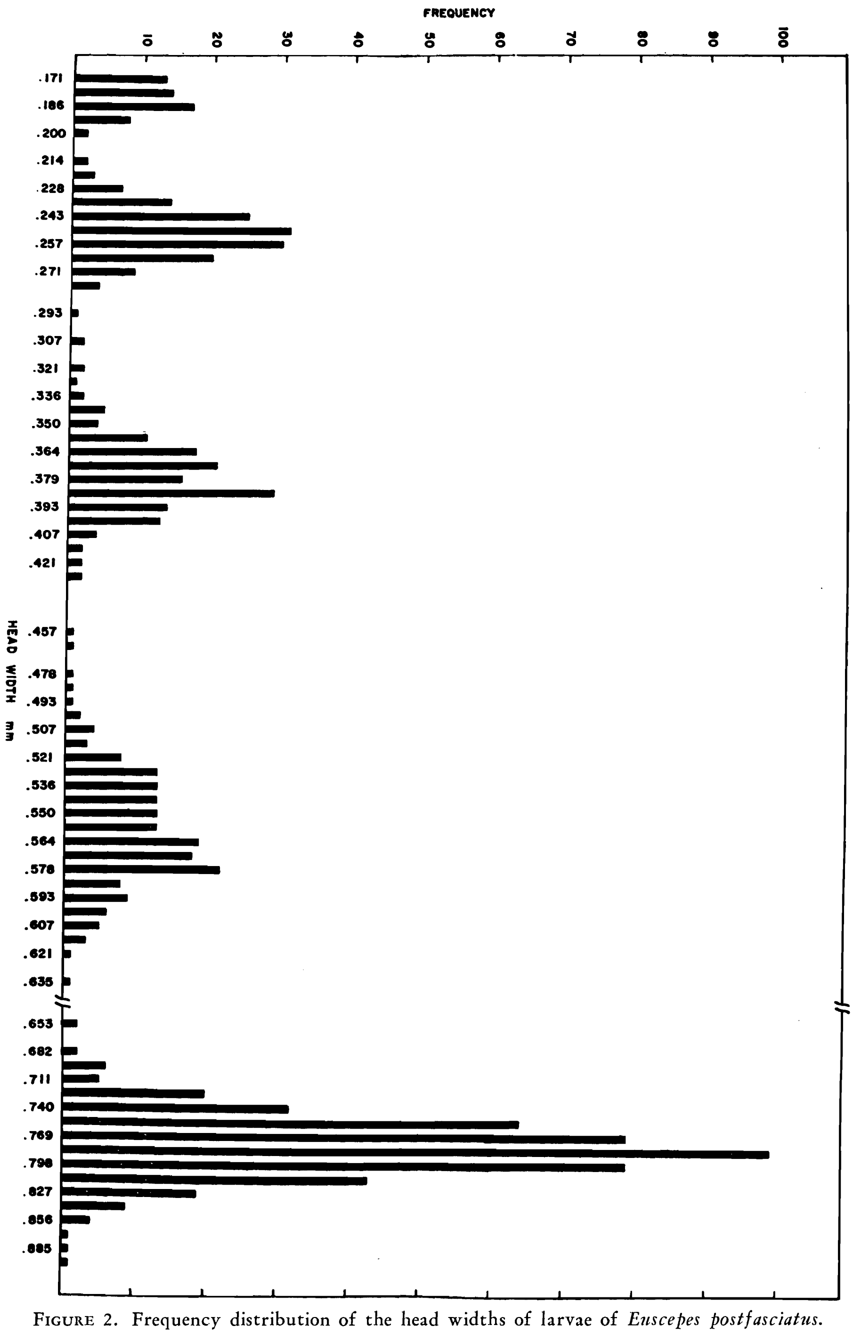

FIGURE 2. Frequency distribution of the head widths of larvae of *Euscepes postfasciatus*.

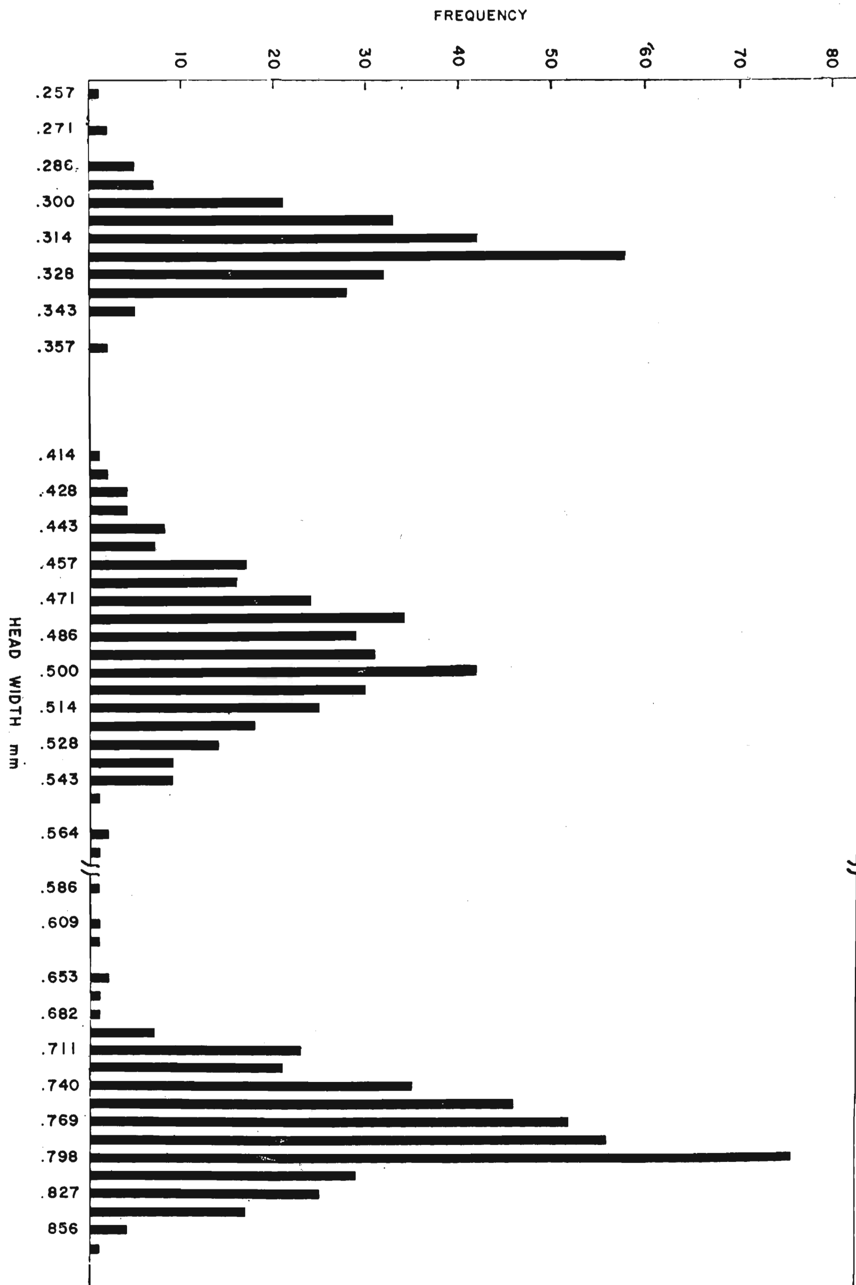

FIGURE 3. Frequency distribution of the head widths of larvae of *Cylas formicarius elegantulus*.

TABLE 2. Head measurements of *Euscepes postfasciatus*.

MEASUREMENT	LARVAL INSTAR				
	I	II	III	IV	V
Observed mean head width (mm.)	0.182 ± 0.008	0.251 ± 0.014	0.376 ± 0.021	0.558 ± 0.030	0.778 ± 0.032
Log value (×10)	0.26007	0.39967	0.57519	0.74663	0.89098
Calculated mean head width (mm.)	0.1790	0.2592	0.3754	0.5437	0.7875
Log value (×10)	0.25275	0.41363	0.57451	0.73539	0.89627
Growth ratio (observed)		1.379	1.498	1.484	1.394
Growth ratio (calculated)		1.448	1.448	1.448	1.448
Number measured	54	146	146	187	466
Size range (mm.)	0.171–0.200	0.214–0.293	0.307–0.428	0.457–0.635	0.653–0.899

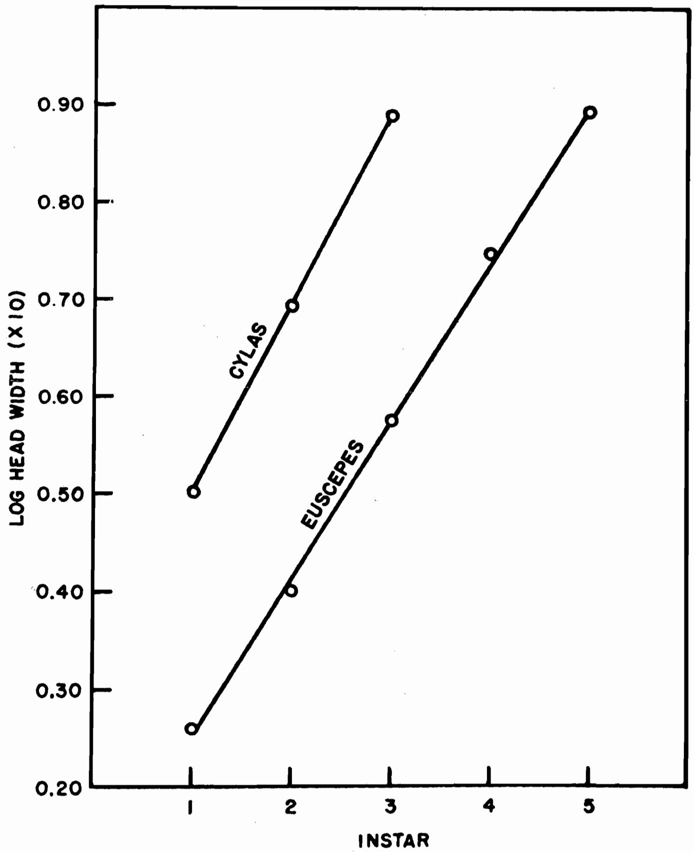

FIGURE 4. Geometrical progression of growth of larvae of *Euscepes postfasciatus* and *Cylas formicarius elegantulus*. Logarithms of the observed mean head widths plotted against the corresponding instar.

TABLE 3. Head measurements of *Cylas formicarius elegantulus*.

MEASUREMENT	LARVAL INSTAR I	II	III
Observed mean head width (mm.)	0.317 ± 0.014	0.492 ± 0.027	0.774 ± 0.041
Log value (×10)	0.50106	0.69197	0.88874
Calculated mean head width (mm.)	0.3162	0.4941	0.7719
Log value (×10)	0.5000	0.6938	0.8876
Growth ratio (observed)		1.552	1.573
Growth ratio (calculated)		1.563	1.562
Number measured	236	328	400
Size range (mm.)	0.257–0.357	0.414–0.571	0.586–0.870

based on the actual measurement of 964 head capsules. At one time, attempts were made to rear the larvae individually, but this approach was found to be impractical because the larvae died despite all precautions taken.

Gaines and Campbell *(23)* reviewed the literature regarding the effect of food on the number of instars. Their general conclusion, based on the examples cited, was that individuals reared on food of poor nutritive value or of poor quality had a greater number of instars than individuals of the same species reared on more nutritive or better quality food. This may explain the conflicting results reported in this paper and the papers of Gonzales and Fukuda. The frequent handling of the sweetpotato weevil larvae would no doubt interfere with their normal feeding and could also have stimulated excessive molting. The dessication of the thin sweetpotato slices may have been considerable and thus affected the nutritive as well as the physical qualities of the food. This drying out of the exposed surface of the cut sweetpotato was often observed in the laboratory. Within 24 hours of being cut, the surface hardened considerably, and in the case of small pieces this was accompanied by appreciable shrinkage. The conditions under which the experiments were conducted in the Philippines and probably in Formosa were, therefore, not natural, and the data obtained probably did not represent the normal situation.

The variety in the Philippines and Formosa is probably *Cylas formicarius formicarius* and not *formicarius elegantulus (32)*. However, since they are varieties of the same species, the number of larval instars should be the same in both.

There was a definite prepupal stage in *C. formicarius elegantulus* and *E. postfasciatus*. The prepupae could not be separated from the last instar larvae on the basis of the width of the head capsule, because they were actually last instar larvae that had stopped feeding and were preparing to pupate. The prepupae are easily distinguished from the actively feeding last instar larvae by the cessation of feeding and the shortening and clearing of the body. The larval body changed from a reddish or purplish cast to a clear, deep yellow when entering the prepupal stage.

DURATION OF STADIA. The time spent in the larval period is determined to a great extent by the food available and the temperature. This period, therefore, varies during the year. From a long series of records in Barbados, Tucker *(52)* found the minimum development period of the larvae of *Euscepes postfasciatus* to be 20 days and the maximum 30 days. Reinhard *(39)* found the minimum developmental period of the larvae of *Cylas formicarius* in Texas to be 10 days and the maximum 36 days. However, no information other than that given by Gonzales *(24)* and Fukuda *(22)* is available in the literature on the relative duration of each stadium.

The duration of each stadium was ascertained from the data used in the determination of the number of instars. The age of each larva was known, since daily dissection records were maintained. It was possible, therefore, to correlate the larval age with its instar. The larvae, as mentioned earlier, were reared between August 20 and September 28, 1953. The over-all mean temperature during this period was 80.3° F.

In this study the determination of the duration of the stadia was based on observations made on 2,291 larvae and 1,147 pupae of *Euscepes postfasciatus* and on 2,300 larvae and 305 pupae of *Cylas formicarius elegantulus.* By correlating the date on which they were removed from the sweetpotato with the instar, the duration was determined.

TABLE 4. Daily record of dissection of immature individuals of *Euscepes postfasciatus*.

DAYS AFTER OVIPOSITION	LARVAE IN VARIOUS INSTARS					PREPUPAE	PUPAE
	I	II	III	IV	V		
7	10						
8	42						
9	16						
10	17	6					
11	9	41					
12	0	71	1				
13	0	44	39	1			
14	1	3	72	0			
15		1	33	8			
16			4	51			
17				71	16		
18				57	23		
19				14	60		
20				2	74		
21				2	124	5	
22					30	3	
23					37	0	
24					142	62	
25					65	212	5
26					68	225	22
27					82	163	125
28					33	94	120
29					23	48	176
30					8	59	169
31					5	20	254
32						4	168
33							108

TABLE 5. Daily record of dissection of immature individuals of *Cylas formicarius elegantulus*.

DAYS AFTER OVIPOSITION	LARVAE IN VARIOUS INSTARS			PREPUPAE	PUPAE
	I	II	III		
8	67				
9	35				
10	16				
11	58				
12	91	10			
13	25	86			
14	5	69			
15	0	41			
16	2	116	2		
17		40	40		
18		8	91		
19		6	110	1	
20		12	182	2	
21		9	183	20	
22			201	14	
23			114	107	1
24			108	142	54
25			45	120	51
26			7	52	45
27			20	24	64
28			5	14	68
29					22

The daily records of the dissection of the immature individuals of *Euscepes postfasciatus* and *Cylas formicarius elegantulus* are given in tables 4 and 5. The number of days after oviposition in which the various instars of *E. postfasciatus* were found is as follows: first, 7 to 14; second, 10 to 15; third, 12 to 16; fourth, 13 to 21; fifth, 17 to 30; and the prepupal, 21 to 32. The first pupa was dissected out of the potato 25 days after oviposition. The minimum number of days spent within each instar was: first, 3; second, 2; third, 1; fourth, 4; fifth, 4; and prepupal, 4 for a total of 18 days.

The number of days after oviposition on which the various instars of *C. formicarius elegantulus* were found was: first, 8 to 16; second, 12 to 21; third, 16 to 28; and prepupal, 19 to 28. The first pupa was dissected out of the potato 23 days after oviposition. The minimum number of days spent within each instar was: first, 4; second, 4; third, 3; and prepupal, 4 for a total of 15 days.

The time spent in the larval stage was, therefore, somewhat longer in *E. postfasciatus* than in *C. formicarius elegantulus.* In both species, the longest period of time was spent in the last instar.

PUPA

Pupation occurs in the root or stem within a small pupal chamber prepared by the larva. The pupae of the two species of weevils are readily distinguishable from each other. The pupae of *E. postfasciatus* are smaller than *C. formicarius elegantulus,* averaging 4.9 mm. in length as compared to 6.5 mm. In addition, the morphological characters are quite distinct (see figures 5 and 6).

Tucker *(52)* found in Barbados that the period spent by *E. postfasciatus* as a pupa ranged from 7 to 9 days. Similarly, Reinhard *(39)* in Texas found that the pupal period in *Cylas formicarius* ranged from 7 to 28 days. This greater variation in Texas was no doubt due to the greater variation in temperature.

In order to determine the duration of the pupal period of the weevils, prepupae of the two species were placed individually in test tubes which were sealed and placed in a darkened box. Daily observations were made, and the dates on which the prepupa changed into a pupa and finally into an adult were recorded. Under the conditions of the experiment, the duration of the pupal stage of *Euscepes postfasciatus* was usually 9 days, although in a few instances it was 10 days. The pupal stage of *Cylas formicarius elegantulus* ranged from 7 to 10 days, with the majority of the individuals completing their transformation in 8 days.

There were distinct color changes in the bodies of the pupae of both species that were associated with age. The development of color in *Euscepes postfasciatus* occurred as follows: first and second day: the entire body is creamy white; the eye, when viewed laterally, contains a black spot; third day: the entire eye is tan due to pigmentation of the facets, the black spot is still visible; fourth to sixth day: the eye darkens from brown to black; seventh day: the mandibles are pink in color; eighth day: the body is cream colored, the eyes are black, the mandibles are brown, and the leg joints are pink; ninth day: the body, especially the elytra, is light brown. The teneral adult is light tan in color.

The development of color in *Cylas formicarius elegantulus* occurred as follows: first day: the body is creamy white, a black spot is visible in each eye, and it is possible to differentiate the sexes by differences in the structure of the antennae; second day: the eye facets are distinguishable as little brown spots starting at the

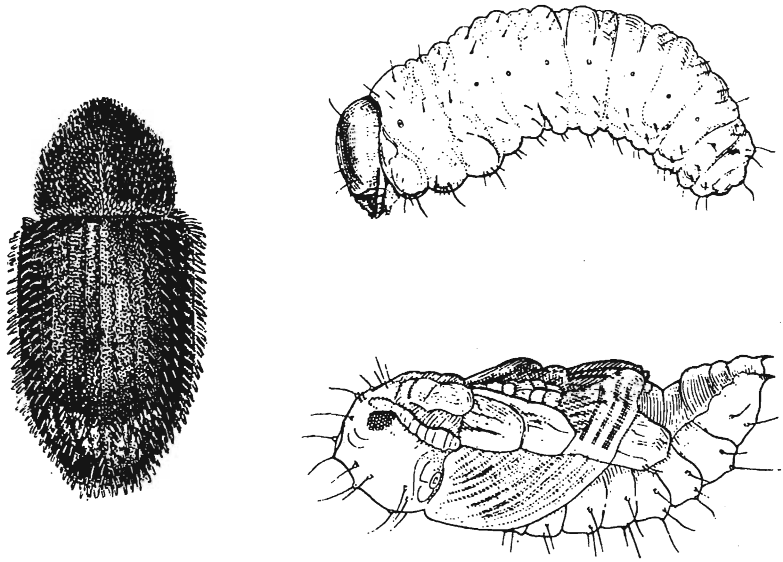

FIGURE 5. *Euscepes postfasciatus:* adult, larvae, and pupae.

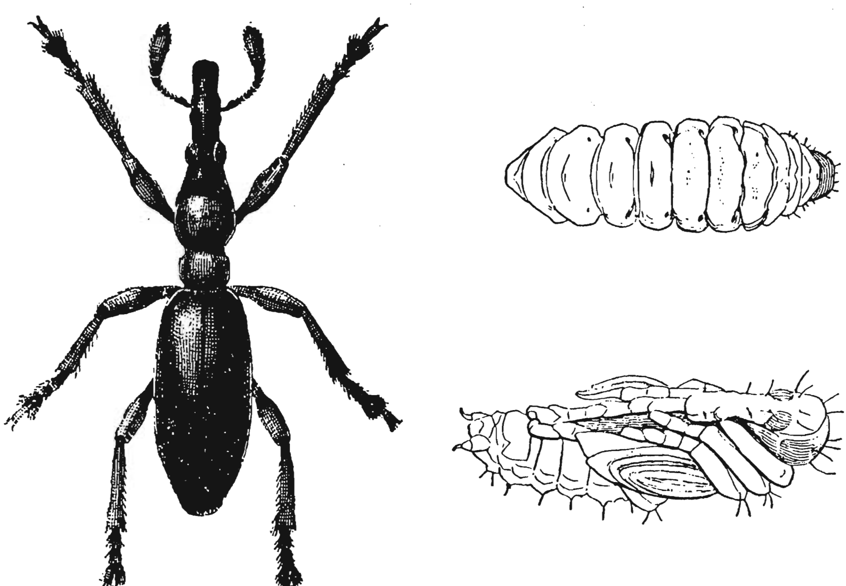

FIGURE 6. *Cylas formicarius elegantulus:* adult, larvae, and pupae.

dorsum of each eye; third day: the entire eye is light brown due to pigmentation of the facets; fourth to sixth day: the pigmentation of the eye darkens until it is a very deep brown, the appendages take on a yellow cast; seventh day: the eyes are black, the mandibles are brown, and the tarsal claws are black; eighth day: the mandibles turn black, the appendages are brown with pink joints. The teneral adult is a drab grayish color.

ADULT

Euscepes postfasciatus (figure 5) is the smaller of the two weevils infesting sweetpotatoes in Hawaii. It ranges in length from 3.2 to 4.0 mm. It is inconspicuous and easily overlooked because it resembles the soil particles surrounding the root. The body varies from reddish brown to grayish black and is covered with short, stiff, erect bristles and scales. The head has two black spots. A short distance from the apex of the elytra there is a distinct, transverse, broken, white bar. Both sexes are similar in appearance. Tucker *(52)* stated that the females are larger than the males but that nutritional effects may mask these differences. He further stated that they may be separated by examining the posterior ventral segment; in the male the segment is nearly flat, while in the female it curves upward. This, however, is a most unreliable character.

Cylas formicarius elegantulus (figure 6) is a much more colorful and conspicuous weevil. It is an apparently smooth, shiny weevil varying in length from 5.5 to 7.0 mm. Actually, the prothorax and the elytra are covered with microscopic punctures from the center of which protrude tiny grayish hairs. The head is black, the thorax is orange to reddish brown, and the posterior portion of the body, including the elytra, is dark metallic blue. The sexes can be readily determined by an examination of the antennae. In the male, the distal segment is longer than the other segments combined, while in the female it is shorter.

FEEDING

The adult weevils feed externally, singly or in groups, on either the vine or the root, but they seem to prefer the latter. *Euscepes postfasciatus* has a greater tendency toward gregariousness than *Cylas formicarius elegantulus* and is often seen feeding in groups of five or more. *E. postfasciatus* is thigmotactic. When placed with a sweetpotato in a jar, it tends to migrate to a point where the potato touches the jar and then squeezes into that area to feed. When placed in a petri dish with a slice of potato, the weevils of this species all move beneath the root, where they feed in groups. Even when feeding on the open surface of the root, the weevils tend to congregate. They apparently do not move around much once they settle down to feed. *Euscepes postfasciatus* often eats its way completely into the potato. *Cylas formicarius elegantulus* leaves a deeper feeding hole because of its longer snout, but it was never observed eating its way completely into the potato. It feeds until its head and snout are in the root and then moves off to a new feeding site. In laboratory cultures where large numbers of each species of weevil are confined with potatoes, it is possible to distinguish a potato fed on by *C. formicarius elegantulus* from one fed on by *E. postfasciatus.* The potato fed on by *C. formicarius elegantulus* is pitted with small feeding punctures over the entire surface, while the potato fed on by *E. postfasciatus* has few small pits but has a number of large holes in which several weevils feed.

FIGURE 7. Damage to sweetpotato caused by feeding of the weevils, *Euscepes postfaciatus* and *Cylas formicarius elegantulus.*

The adults of both species occasionally remain within the potato after emerging from the pupa. This is especially true when there is a low infestation in the potato and food is abundant.

The larvae of both species feed within the stem or root. After eclosion, the larva usually bores down into the potato from the crown tip, where the infestation in a root generally starts. The winding feeding tunnel is narrow at first but is enlarged as the insect grows. Behind the larva, the tunnel is packed solidly with frass. At the end of the feeding tunnel, the larva prepares a chamber in which it pupates. When a root is heavily infested, the entire root may be riddled and filled with fecal matter. It becomes dark in color, light in weight, and spongy in appearance. Figure 7 shows typical damage to the sweetpotato caused by the feeding of the weevils.

Very often the larvae bore their way around the root just below the epidermis, instead of tunneling down into the potato. When this occurs, the feeding tunnels are defined as sunken areas on the surface of the potato and can easily be traced without cutting the root open.

Feeding within the vine is similar to that in the root. Infested vines (figure 8) show evidence of feeding damage by darkening from the normal green color to brown or black. The external surfaces sink above the feeding tunnels. This results in the vine taking on a wrinkled appearance. Where the main stem is infested, it may become enlarged, malformed, and cracked.

Both species are often found infesting the same stem or root with their feeding tunnels close to one another.

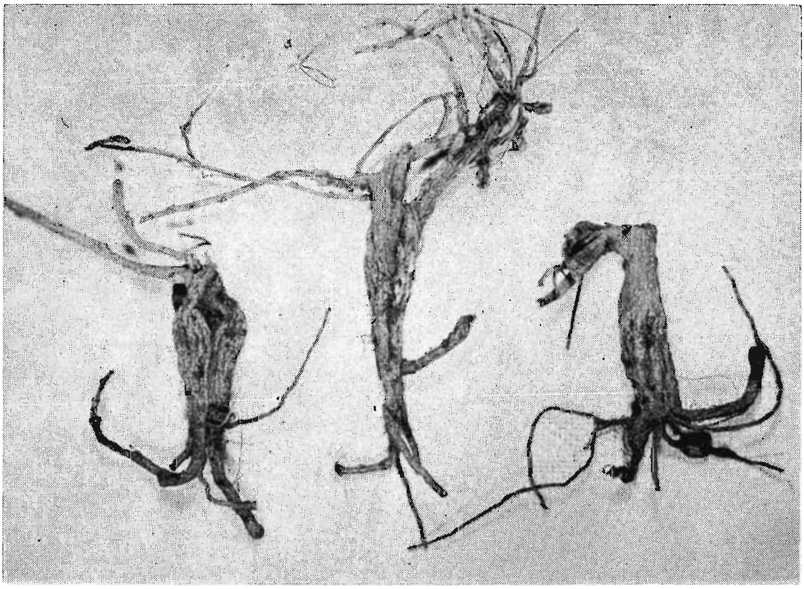

FIGURE 8. Vines damaged by sweetpotato weevils, *Euscepes postfaciatus* and *Cylas formicarius elegantulus.*

REPRODUCTION

The oviposition habits of the two species of weevils are very similar. The female excavates a hole in the potato or stem with its mouthparts. The egg is then placed within the cavity, and the entrance is plugged with fecal matter which turns dark brown or black on hardening (figure 9). The fecal plug of each species is characteristic. The *Euscepes postfasciatus* egg is almost entirely surrounded by the plug, which appears as a raised area on the surface of the potato. The *Cylas formicarius elegantulus* egg, on the other hand, has only one end covered by the plug. The outer surface of the *C. formicarius elegantulus* fecal plug lies slightly below the surface of the potato. The fecal plug serves to keep the egg in a moistened condition by sealing the hole and also protects the egg from mechanical injury and predators. Mites have been found attacking exposed eggs in the laboratory. Although the egg cavity produced by *C. formicarius elegantulus* is larger and deeper than the one produced by *E. postfasciatus,* neither is as deep as their respective feeding cavities. The oviposition sites are difficult to detect, because they resemble fecal spotting or dirt.

The eggs are usually laid singly, although on rare occasions two eggs have been found adjacent to one another, apparently under a single enlarged fecal plug.

The female will oviposit in both the root and the stem. The main portion of the stem will usually have a heavier infestation than the younger vines. The crown end of the root is probably attacked more readily than any other portion of the root, since this portion is more readily exposed to weevil attack.

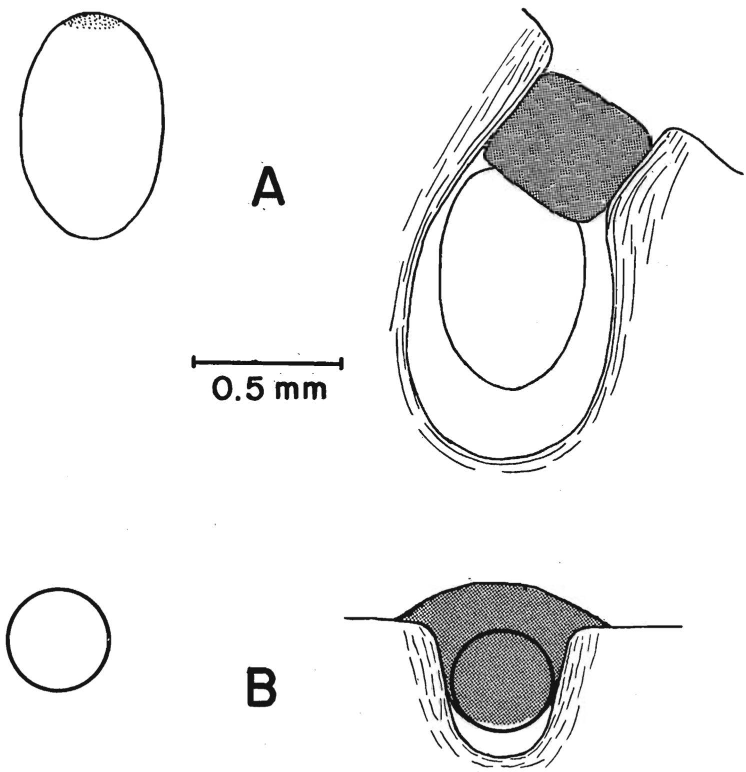

FIGURE 9. The eggs of the weevils dissected outside and inside the sweetpotato, showing the oviposition cavities and the fecal plugs. A, *Cylas formicarius elegantulus*; B, *Euscepes postfasciatus*.

Tucker *(52)*, after studying the reproductive habits of *Euscepes postfasciatus*, came to the following conclusions:

1. Fertilization is required for hatching of the egg.
2. The average time between adult emergence from the potato and oviposition is 15 days.
3. The average rate of oviposition is 106 eggs per female per month.
4. The female oviposits for 4 to 6 months.

Reinhard *(39)* in a similar study of *Cylas formicarius* found:

1. A number of matings occur during the lifetime of the weevil.
2. There is a definite feeding period prior to sexual maturation.
3. Fertilization is necessary for hatching of the egg.
4. The rate of oviposition varies from 1 to 17 eggs per female per day.
5. The female oviposits until shortly prior to death.

There are no distinct broods or generations in Hawaii. The climatic conditions are such that reproduction occurs throughout the year. Breeding will occur either outdoors or indoors, depending upon the availability of host material.

FEIGNING DEATH

Many Coleoptera, upon being disturbed, will suddenly feign death. The two species of sweetpotato weevils upon being disturbed will fall on their sides or backs and remain motionless. *Euscepes postfasciatus* will draw its legs tightly against its body, while *Cylas formicarius elegantulus* will keep its legs extended. It is possible to differentiate a dead *E. postfasciatus* from one feigning death, by the fact that a dead weevil has its legs somewhat extended and not held tightly against its body. A dead *C. formicarius elegantulus* will have its legs in a more relaxed position than a living one.

If left alone, the insect will resume activity within several minutes. They can be stimulated into earlier activity by breathing on them or holding them close to a hot surface such as a light bulb.

When these weevils are feigning death they are difficult to observe in the soil.

DISSEMINATION

Although both species have well-developed wings, only *Cylas formicarius elegantulus* flies; and it does so infrequently and with difficulty at best. The maximum distance *C. formicarius elegantulus* has been observed to fly in the laboratory was about 20 feet. Flight, therefore, is not a means of dissemination of *E. postfasciatus,* and it is probably only a minor one for *C. formicarius elegantulus.* Infestation of a field probably occurs primarily by means of infested cuttings, adults crawling from adjacent infested fields, and by other mechanical means. The planting of infested slips in a field will result in the development of a high weevil population within one season. Normally, however, if clean planting material is used in a field that has never been planted in sweetpotato, the build-up of the weevils is slow. In cases where sweetpotatoes are grown in an isolated area in which this crop had previously not been grown, the weevils probably move in from one of the alternate hosts; and, after several seasons, the population may increase to a very high level.

The allowing of volunteer growth of sweetpotatoes does much to maintain and increase a weevil population within a field. Both species are probably able to survive for several months in a field from which sweetpotatoes have been harvested. This has very serious implications, since it emphasizes the fact that sweetpotatoes planted in the same field during this period would be readily attacked by the weevils.

Tucker *(52)* in Barbados found that *Euscepes postfasciatus* which were kept in the laboratory with food and water survived for 6 months, while Reinhard *(39)* demonstrated that *Cylas formicarius* could live for over 200 days.

Since it was felt that some information on the longevity of these weevils without food or water would prove valuable, an experiment was conducted in the laboratory to determine the tolerance of these insects to starvation.

Mature pupae were placed in individual test tubes which were sealed with cork. Food and water were withheld. Observations were made to determine when the insects transformed into adults and when they died. Under these conditions, the average survival time for *Euscepes postfasciatus* was 30.3 days with a range of 15 to 44 days. The average survival time for the male of *Cylas formicarius elegantulus* was 28 days with a range of 8 to 39 days, while the average survival time for the female was 31 days with a range of 21 to 42 days. It appears, therefore, that both species can survive approximately a month without food or water. These insects had not fed since their larval stage. If they had been allowed to feed several days after becoming adults, they probably would have lived even longer.

The merchandising practices of the retail grocers in Hawaii also permit a build-up of weevils. The usual practice is to put fresh potatoes in the bin over the older potatoes. Digging into the bottom of the bin, one can find badly damaged potatoes and adult weevils crawling around. These may be taken home and disseminated in that manner.

NATURAL ENEMIES

There apparently are no effective natural or biological control factors of these insects in Hawaii. No parasites or predators have been reported attacking *C. formicarius elegantulus.* Bianchi *(4)* reported a wasp, *Eupelmus cushmani* (Crawford), attacking *Euscepes postfasciatus* larvae of all stages. However, the importance of this insect as a check is slight, since it can only reach those weevil larvae in the aerial branches of the sweetpotato. An unidentified mite has been found in the laboratory cultures, feeding on exposed eggs. However, its effectiveness under natural conditions is probably very limited due to the method of oviposition of the weevils.

During the rearing of laboratory colonies of the weevils in 1951, one culture jar was observed to have a number of dead *C. formicarius elegantulus* with a fungus growth on their bodies (figure 10). Infested specimens were sent to Dr. E. A. Steinhaus, insect pathologist at the University of California, for identification of the fungus. The fungus was identified as a species of *Beauveria,* probably *Beauveria bassiana* (Balsamo) Vuillemin. In the meantime, the fungus was cultured on potato dextrose agar, and the pathogen was successfully transmitted to *Euscepes postfasciatus.* Since that time, other outbreaks of this disease have occurred periodically in the laboratory.

In February, 1952, Mr. Philip Weber, of the Territorial Board of Agriculture and Forestry, reintroduced this fungus from Louisiana. The fungus was placed at Waimano Home, Oahu, and at Ulupalakua Ranch, Maui. To date no recovery of the fungus has been made at either of these two sites, although sweetpotatoes are in continuous production. This fungus probably will play only a minor role in the control of the weevils, since it appears that its success depends upon high humidity, temperature, and density of the adult weevil population.

CULTURAL CONTROL

Cultural methods were the earliest control measures recommended for these insects. Van Dine *(53)* suggested deep hilling as a method of preventing injury. Holdaway *(26)* summarized the cultural control of these insects in Hawaii and made the following recommendations:

1. Sweetpotatoes should not be planted in land from which sweetpotatoes have recently been harvested. Infested sweetpotato debris left in the field will serve to infest the new planting.
2. Uninfested stem cuttings should be used for planting. Tip cutting from a field where infestation is absent or at a low level is recommended. Bottom cuttings are to be avoided since they are more likely to be infested.
3. In dry regions where irrigation is necessary, it is recommended that cuttings be planted on the side of the irrigation furrow rather than on hills.

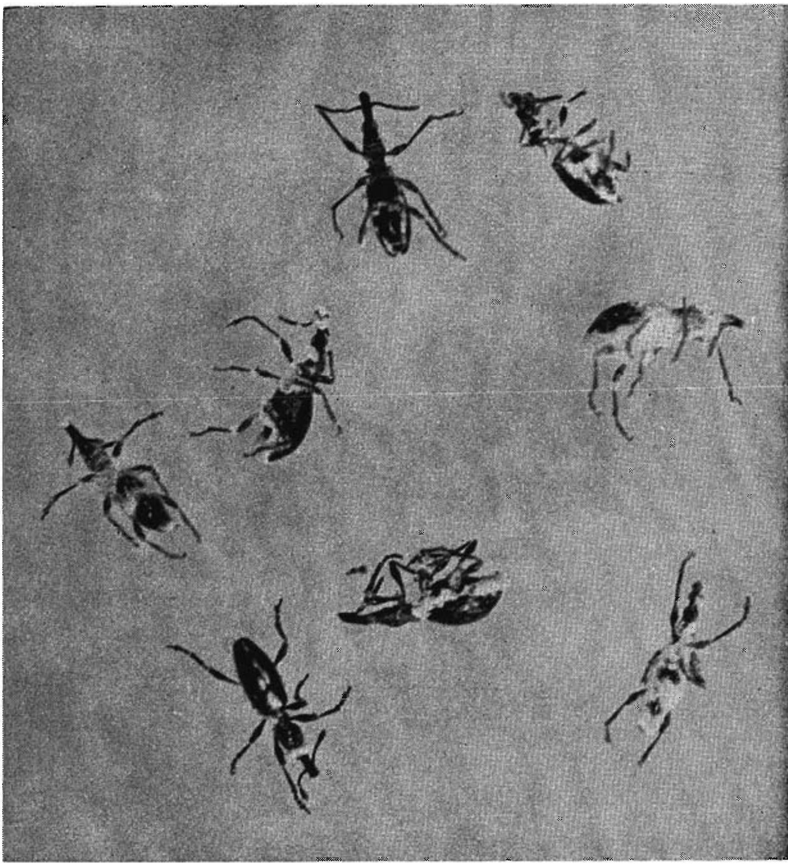

FIGURE 10. Adult *Cylas formicarius elegantulus* killed by fungus, *Beauveria* sp.

4. Sufficient irrigation to reduce soil cracking, as well as to provide sufficient water for plant growth, should be supplied. Holdaway conducted an experiment on the value of irrigation in decreasing weevil damage. At Poamoho Farm, which is situated in an area that has a definite dry season and where the soil has a tendency to dry rapidly, irrigation was applied at 4-, 3-, 2-, and 1-week intervals. These plots were compared with some to which no water was added. The plots receiving weekly irrigations yielded 2½ times more than the plots receiving no water. The infested potatoes ranged in one variety from 11.4 percent in the plots receiving no irrigation to 1.2 percent in those receiving weekly irrigation. In another variety, the infestation ranged from 40 percent with no irrigation to 5.6 percent with weekly irrigation.

5. Cultivation and hilling during the growth of the crop to reduce soil cracking and cover otherwise exposed roots are advised.

6. Sweetpotatoes should be harvested as soon as they are ready. The longer the crop is left in the ground, the greater will be the infestation.
7. Sanitation should be practiced. The old potatoes and vines should be removed from the field and destroyed by burning or by feeding them, preferably after boiling, to livestock. Volunteer growth should also be prevented or eliminated.

Unfortunately, clean cultural methods are not always practiced, so that volunteer potatoes may be present and infested in a field planted with another unrelated crop such as beets or cabbage. Under such circumstances, crop rotation is of little value because there is a continuous source of weevils in the volunteer growth.

VARIETAL RESISTANCE

Cockerham and Deen *(11)*, working in Louisiana, suggested that there is a possibility of breeding sweetpotatoes resistant to weevil attack.

Poole *(38)* in Hawaii showed differences in the susceptibility of sweetpotato varieties to weevils. In an experiment on sweetpotato seedling improvements he found that Porto Rico and Onolena were significantly more susceptible to weevil attack than HSPA 3 and HES 45. In another experiment, Onolena was found to be more susceptible than Porto Rico and HES 8.

CHEMICAL CONTROL

The early attempts to control these insects with chemicals consisted of the application of inorganic fluorine and arsenical insecticides. No attempt will be made to review completely the literature pertaining to the chemical control of these insects. The literature is extensive, particularly on the control of *Cylas formicarius*. A combination of cultural practices—field sanitation with the use of arsenicals or cryolite—were the general recommendations prior to 1945 *(12, 26, 52)*.

The greater potency of the insecticides now available suggested the possibility of obtaining a higher degree of control of these insects. A number of laboratory and field experiments were conducted to compare the effectiveness of several insecticides in controlling the two species of weevils.

LABORATORY STUDIES

The differential susceptibility of the two species of weevils to nine synthetic organic insecticides was investigated.

MATERIALS AND METHODS. The composition of the compounds tested was as follows: parathion, technical, 96.5 percent active ingredients; sp. gr. 1.26–1.28 at 25°/25°C; DDT, pp' isomer, recrystallized, m.p. 109.5°–110.5°C; benzene hexachloride, gamma isomer, recrystallized, m.p. 113.0°–113.5°C; chlordane, technical sp. gr. 1.61 at 25°C; toxaphene, technical chlorinated camphene; aldrin, technical 95 percent, 5 percent related compounds, m.p. 96.0°–99°C; dieldrin, technical 85 percent, 15 percent related compounds, m.p. 164°–167°C; isodrin, recrystallized 97.5 percent, sublimed at 98°C; and endrin, recrystallized 96 percent, sublimed with decomposition at 205°C. Standard stock solutions of these insecticides were prepared in redistilled acetone.

The sweetpotato weevils were reared in the laboratory. Sweetpotatoes were infested by exposing them in battery jars to mature weevils for 4 days. At the end of that time, the weevils were removed from the jars and the infested potatoes kept until the new generation of weevils matured and the adults emerged from the potatoes. A fresh sweetpotato was placed in the jar to serve as food for the emerging adults. Weevils were treated between 2 and 4 weeks after emergence.

A study was made of the effect of carbon dioxide on both species of weevils in order to determine the feasibility of its use as an anaesthetic. Four Büchner funnels were connected through a glass manifold to a CO_2 tank. The CO_2 was allowed to flow through the funnels at a pressure of 5 pounds per square inch. The insects were exposed for periods of time varying from 5 minutes to 3 hours. After the exposure period, the weevils were placed in petri dishes containing sweetpotato slices. Observations were made on recovery time and mortality for a period of 12 days. Treatment and recovery time are shown in table 6. After 12 days it was found that there was no mortality in either species due to the CO_2 treatment, even after a 3-hour exposure period.

TABLE 6. Time (in minutes) required for recovery from anaesthesia.

EXPOSURE	*Euscepes postfasciatus*		*Cylas formicarius elegantulus*	
	RECOVERY TIME FOR FIRST INDIVIDUAL	RECOVERY TIME FOR ALL	RECOVERY TIME FOR FIRST INDIVIDUAL	RECOVERY TIME FOR ALL
5	3	6	3	5
10	4	5	3	8
15	4	7	3	37
20	6	14	2	17
30	7	27	9	41
40	10	17	10	22
50	19	24	10	20
60	10	23	8	17
120	16	23	16	36
180	16	—	20	35

Prior to treatment, the weevils were counted and weighed. The average weight per individual was used to calculate the dosage of insecticide applied. The over-all mean weight of *Cylas formicarius elegantulus* during the course of this experiment was 7.10 ± 0.58 mg. per weevil, while that of *Euscepes postfaciatus* was 5.17 ± 0.55 mg. per weevil. The standard stock solutions were diluted with redistilled acetone to the required concentrations and 0.001 ml. was applied directly to the insect body by the use of a micropipette *(43)*. The solution was applied to the dorsum between the elytra. The acetone was allowed to evaporate and the insects placed in petri dish bottoms which contained sweetpotato slices. The petri dishes were covered with cheesecloth. The sweetpotato was replaced by a fresh slice at the end of 4 days and mortality was observed at the end of 6 days. Whenever sufficient numbers of both species were available, they were treated on the same day. Ten or 20 insects were treated with each dosage per replication. The observed mortality for each test was corrected for natural mortality by the use of Abbott's formula *(1)*.

All dosages were calculated in terms of mg. of toxicant per g. of insect body weight. When the series of tests were completed, the dosages were combined by grouping them in increments. The mean dosage value, the total number of insects, and the mean percent mortality were computed for each group.

The ease of detection of death varied with the species. Dead or affected *Cylas formicarius elegantulus* were easily detected. Although both species were inactive or "played possum" when disturbed, the attitude of a normal *C. formicarius elegantulus* was such that it was easily distinguished from an affected or dead *C. formicarius elegantulus*. The normal *C. formicarius elegantulus* generally lies motionless on its side with its legs outstretched. However, breathing on the weevils or holding a 60-watt electric light bulb over them stimulated the weevils into action. *Euscepes postfasciatus* was usually more sluggish than *C. formicarius elegantulus* and generally did not wander about the container as did *C. formicarius elegantulus*. When normal, they congregated under the slice of sweetpotato. When affected, they lay on their backs and feebly moved their legs. When disturbed, the normal *E. postfasciatus* were difficult to separate from those affected by the treatment, because they feigned death. However, they could be stimulated into action by heat. Affected weevils of both species were tabulated as dead, since no affected insect ever recovered. A weevil was considered to be affected if it did not react normally when stimulated by heat or human breath. An additional check on the condition of the weevils was made by dropping them into acetone. The dead or seriously affected weevils floated while the normal weevils sank to the bottom with violent leg movements.

EXPERIMENTAL RESULTS AND DISCUSSION. Tables 7 and 8 summarize the toxicity of the nine organic insecticides to *Euscepes postfasciatus* and *Cylas formicarius elegantulus*, respectively. The median lethal dose (LD-50) of each insecticide to both species of weevils was calculated by the method suggested by Finney *(20)*. Table 9 presents these data together with the fiducial limits for odds of 19:1.

The relative resistance of the two species of weevil varied with the toxicant. There was no difference between the two species in their resistance to the gamma isomer of benzene hexachloride. The same relationship exists with toxaphene and endrin. On the other hand, *E. postfasciatus* was three times more resistant than *C. formicarius elegantulus* to isodrin, six times more resistant to pp' DDT, and five times more resistant to parathion. Yet *C. formicarius elegantulus* was six times more resistant than *E. postfasciatus* to chlordane, 14 times more resistant to aldrin, and 15 times more resistant to dieldrin.

The toxicity index *(48)* is an excellent tool for comparing the relative toxicity of the insecticides to each species of weevil. The median lethal dosages (LD-50) of DDT to each species was assigned a value of 100, and the LD-50 of each insecticide to that species was compared with DDT. Table 9 presents these data. Thus, it can be seen that the relative order of toxicity of these insecticides to *Euscepes postfasciatus* is: aldrin = dieldrin > parathion > endrin > isodrin = gamma BHC > chlordane > toxaphene = DDT. The relative order of toxicity to *Cylas formicarius elegantulus,* on the other hand, is: parathion > endrin = isodrin > gamma BHC = aldrin = dieldrin > DDT > toxaphene > chlordane.

FIELD STUDIES OF CHEMICAL CONTROL OF WEEVILS

Four experiments were conducted in 1950 to determine the efficacy of aldrin, chlordane, cryolite, dieldrin, DDT, lindane, methoxychlor, parathion, and toxaphene in controlling the weevils *(44)*. The insecticides were used as soil treatments, preplanting cutting dips, sprays, or combinations of these methods of application.

TABLE 7. Toxicity of insecticides to the West Indian sweetpotato weevil, *Euscepes postfasciatus*. Data taken 6 days after treatment. Dosage is in terms of milligrams of toxicant per gram of body weight.

MATERIAL	DOSAGE	INSECTS TREATED	CORRECTED PERCENTAGE MORTALITY *
	mg./g.		
Parathion	0.0385	60	95
	0.0310	40	97
	0.0263	60	71
	0.0193	60	40
	0.0143	40	32
	0.00965	50	21
	0.00442	10	0
Control	—	70	10
DDT	4.31	60	73
	3.23	60	75
	2.16	60	49
	1.61	60	46
	1.08	60	40
	0.539	60	31
	0.217	20	0
Control	—	80	11
Gamma BHC	0.435	40	98
	0.284	40	92
	0.256	40	93
	0.215	50	76
	0.196	20	80
	0.172	50	54
	0.129	60	47
	0.108	50	37
	0.0981	20	20
	0.0529	10	0
Control	—	100	5
Chlordane	0.658	20	100
	0.558	50	83
	0.458	50	45
	0.361	40	39
	0.218	30	21
	0.154	50	5
Control	—	60	7
Toxaphene	2.80	30	100
	1.79	40	84
	1.32	50	57
	1.08	20	43
	0.935	30	26
	0.490	20	20
Control	—	40	3
Aldrin	0.0325	20	100
	0.0258	40	93
	0.0207	40	89
	0.0161	50	67
	0.0112	50	37
	0.00488	50	15
	0.00241	30	4
Control	—	50	4

* Controls show actual mortality.

TABLE 7 (Cont'd)

MATERIAL	DOSAGE	INSECTS TREATED	CORRECTED PERCENTAGE MORTALITY *
	mg./g.		
Isodrin	0.382	40	100
	0.289	60	91
	0.241	60	86
	0.189	70	70
	0.141	70	49
	0.0976	50	43
	0.0433	10	0
Control	—	86	8
Dieldrin	0.0215	30	100
	0.0196	20	100
	0.0175	20	88
	0.0155	40	82
	0.0142	10	78
	0.0135	40	71
	0.0121	30	60
	0.0108	40	26
	0.00529	10	0
Control	—	60	8
Endrin	0.119	30	100
	0.0866	30	83
	0.0642	20	94
	0.0433	30	53
	0.0214	30	11
Control	—	30	10

TABLE 8. Toxicity of insecticides to the sweetpotato weevil, *Cylas formicarius elegantulus.* Data taken 6 days after treatment. Dosage is in terms of milligrams of toxicant per gram of body weight.

MATERIAL	DOSAGE	INSECTS TREATED	CORRECTED PERCENTAGE MORTALITY *
	mg./g.		
Parathion	0.0136	20	85
	0.0100	50	88
	0.00669	50	82
	0.00531	40	65
	0.00388	50	52
	0.00265	40	35
	0.00142	40	6
Control	—	60	2
DDT	1.47	10	100
	1.12	40	85
	0.748	40	78
	0.374	40	65
	0.150	40	34
	0.131	10	10
Control	—	60	7
Gamma BHC	0.735	10	100
	0.336	60	79
	0.199	30	63
	0.135	50	57
	0.0657	40	22
	0.0329	40	7
Control	—	80	4

* Controls show actual mortality.

TABLE 8 (Cont'd)

MATERIAL	DOSAGE	INSECTS TREATED	CORRECTED PERCENTAGE MORTALITY *
	mg./g.		
Chlordane	4.78	30	93
	3.99	30	86
	3.19	30	64
	2.39	30	58
	1.63	40	31
	1.31	10	20
	0.870	10	10
Control	—	60	5
Toxaphene	4.18	20	90
	3.46	30	80
	2.77	30	83
	2.08	30	67
	1.47	40	48
	1.11	40	43
	0.870	10	30
	0.435	10	10
Control	—	60	0
Aldrin	0.333	30	87
	0.266	30	90
	0.200	30	70
	0.139	40	51
	0.104	40	30
	0.0694	40	20
	0.0272	20	4
Control	—	83	4
Isodrin	0.131	30	93
	0.0990	30	79
	0.0771	20	74
	0.0667	40	60
	0.0381	50	35
	0.0263	30	19
	0.0155	40	24
Control	—	64	3
Dieldrin	0.333	20	80
	0.265	30	66
	0.199	30	50
	0.141	30	45
	0.103	40	28
	0.0691	40	10
Control	—	73	4
Endrin	0.0986	30	100
	0.0800	20	90
	0.0639	30	78
	0.0522	30	78
	0.0397	30	52
	0.0239	30	23
	0.0130	20	7
Control	—	70	7

* Controls show actual mortality.

TABLE 9. The median lethal dosages, fiducial limits, and toxicity indices of nine organic insecticides to *Euscepes postfasciatus* and *Cylas formicarius elegantulus*.

INSECTICIDE	*Euscepes postfasciatus*			*Cylas formicarius elegantulus*		
	LD-50	FIDUCIAL LIMITS P = 0.05	TOXICITY INDEX	LD-50	FIDUCIAL LIMITS P = 0.05	TOXICITY INDEX
	mg./g.	*mg./g.*		*mg./g.*	*mg./g.*	
Parathion	0.0184	0.0161–0.0210	8804	0.00381	0.00330–0.00439	7585
pp' DDT	1.62	1.28–2.05	100	0.289	0.238–0.350	100
Gamma BHC	0.135	0.119–0.154	1200	0.133	0.109–0.162	217
Chlordane	0.394	0.321–0.483	411	2.20	1.76–2.75	13
Toxaphene	1.15	0.886–1.50	141	1.40	1.13–1.71	21
Aldrin	0.0116	0.00861–0.0158	13966	0.161	0.134–0.195	180
Isodrin	0.128	0.107–0.153	1266	0.0513	0.0415–0.0635	563
Dieldrin	0.0120	0.00974–0.0147	13500	0.178	0.134–0.233	162
Endrin	0.0408	0.0240–0.0693	3971	0.0365	0.0298–0.0446	792

DDT as a wettable powder at 2.0 pounds of active ingredient, lindane and parathion as wettable powders at 0.25 pound of active ingredient per 100 gallons, and aldrin as an emulsion at 0.25 percent active ingredient gave excellent control of the weevils up to 20 weeks after planting when applied as cutting dips in combination with five sprays during the season, despite poor sanitary conditions in the field.

None of the treatments resulted in the potatoes having appreciable residues or off-flavors.

Since DDT was found to be effective, is readily available to growers, and is comparatively inexpensive, additional field-plot experiments were conducted in 1951 and 1952 to determine the most efficient methods of applying DDT sprays and dusts to control the weevils. In these experiments, both the concentration of DDT and the number of applications during the season were varied. Two trials were also carried out to determine the effectiveness of DDT, lindane, aldrin, dieldrin, chlordane, and parathion when applied to the soil in controlling the two species of weevils. The results of these experiments were previously reported by Sherman and Mitchell *(45)*.

DDT as a wettable powder at 2.0 pounds of active ingredient per 100 gallons when applied as a cutting dip in combination with two sprays at 10 and 16 weeks after planting gave excellent control.

In the application of insecticidal sprays, it is important to penetrate the dense sweetpotato foliage. This can best be done by the use of a power sprayer operating at a nozzle pressure of 150 to 200 pounds per square inch.

In Hawaii, it is generally necessary to irrigate the sweetpotato crop. The irrigation furrows prevent the use of mechanized equipment in the field itself. In this experiment, a truck on which the sprayer was mounted was brought to the edge of the field and the spray hose carried into the field. Emphasis was placed on spraying the main stems of the plant and the surrounding soil.

DDT dusts were inferior to the sprays. Although the cutting dip treatment followed by five applications of a 5 percent dust gave some protection to the roots, the stems were all infested. With ordinary methods of dusting, the lack of penetrability of the dust through the dense sweetpotato foliage reduces its effectiveness. Although the dust nozzle was kept below the canopy, effective control was not obtained.

The soil treatment experiments gave contrasting results. In one, in which the cuttings were dipped prior to planting, all of the insecticides appreciably reduced the weevil infestation; while in the other, in which no preplanting cutting dips were used, only DDT at 10 pounds and dieldrin at 5 pounds of active ingredients per acre controlled the weevils. The use of DDT as a soil treatment gave control of the weevils comparable to that obtained with the DDT sprays. No off-flavors were detected in the potatoes from the soil-treated plots.

CONTROL OF WEEVILS IN A PREVIOUSLY UNINFESTED AREA. The previously mentioned studies were all conducted in areas which had been continuously planted in sweetpotatoes for several years. No particular attempt had been made to control the sweetpotato insects in these areas, and weevils were extremely abundant. The fields chosen for the experimental plots were usually those from which crops containing a high percentage of weevil-infested potatoes had recently been harvested.

One study, however, was conducted in an area which had never been planted in sweetpotatoes. On May 23, 1951, all cuttings were given a preplanting dip in a suspension of 2 pounds of actual DDT per 100 gallons just prior to planting.

DDT dusts were used at 5 and 2 percent concentrations. The dusts were prepared by diluting a 10 percent dust concentrate with pyrophyllite and dusting sulfur in such proportion that each experimental dust contained 50 percent sulfur. Each concentration was applied five, three, and two times during the growing season. The applications in the five-application schedule were made 5, 10, 13, 16, and 18 weeks after planting. The three-application schedule consisted of applications 10, 13, and 16 weeks after planting, while the applications in the two-application schedule were made 10 and 16 weeks after planting. The dusts were applied with a knapsack bellows duster to the base of the plants by keeping the flanged nozzle beneath the foliage canopy. Each experimental plot was 500 square feet in area. All plots contained four rows with 30 plants in each. The treatments were randomized and replicated four times.

Twenty weeks after planting (October 10), the stems and potatoes of the center two rows of each plot were harvested. The stems were cut 6 to 8 inches below the surface of the soil and approximately 1-foot lengths were examined for weevil damage. All potatoes 3 inches or more in length were examined for weevil damage. Twenty-four weeks after planting (November 6 and 7), the stems and potatoes from a third row of each plot were harvested and examined. The potatoes in the remaining row were harvested and examined 30 weeks after planting (December 17).

Table 10 summarizes the results obtained during the three harvests. The stem infestations increased rapidly. None of the treatments protected the stems from the weevils.

Twenty weeks after planting, the infestation in the roots of treated and untreated plots was too low to allow any conclusion as to the effectiveness of the DDT dust applications. There was a negligible increase in weevil infestation 24 weeks after planting. However, by 30 weeks after planting, the infestation in the untreated plots had increased to 31 per cent. Three applications per season of the 5 per cent DDT dust reduced the infestation.

TABLE 10. Control of sweetpotato weevils obtained by using DDT dusts applied at various intervals during the season.

TREATMENT[1]	APPLICATIONS PER SEASON	WEEKS AFTER PLANTING				
		20		24		30
		Infested stems	Infested roots	Infested stems	Infested roots	Infested roots
percent DDT		*percent*	*percent*	*percent*	*percent*	*percent*
5	5	57.3	5.8	81.7	17.9	11.5
5	3	51.8	1.2	59.0	2.1	9.9
5	2	56.1	4.2	50.9	7.0	20.3
2	5	48.4	2.8	49.4	13.9	14.9
2	3	64.8	6.2	79.2	17.0	24.2
2	2	65.5	4.3	67.1	6.0	24.3
Untreated	—	74.2	4.2	80.8	6.3	30.7

[1]DDT dusts contained 50 percent sulfur.

The large increase in infestation between 24 and 30 weeks after planting indicates that there is a definite correlation between the length of time the potatoes are left in the ground and the weevil infestation. The data further indicate that a grower might successfully produce and harvest a profitable crop within 20 weeks, without chemical treatment, if a field that has never been planted in sweetpotatoes is used. However, it would be necessary to harvest the crop as soon as it was mature, since allowing the crop to remain unharvested for as long as 30 weeks resulted in a high infestation of the potatoes.

SUMMARY

The bionomics and control of the two sweetpotato weevils, *Euscepes postfasciatus* (Fairm.) and *Cylas formicarius elegantulus* (Summ.), were investigated under laboratory and field conditions. These insects are the most destructive pests of sweetpotatoes in the Hawaiian Islands. Their damage causes the potato to be unmarketable and even unpalatable to livestock.

The eggs of the weevils which are laid singly in the vine or root are covered with a fecal plug. The egg period is approximately 8 days.

The larvae of the two species are very similar in appearance but can be separated by certain chaetotaxic characters of the head. There are five larval instars in *Euscepes postfasciatus* and three in *Cylas formicarius elegantulus.* At a mean temperature of 80.3° F. the larval period in *E. postfaciatus* ranged from 18 to 24 days, while in *C. formicarius elegantulus* it ranged from 15 to 20 days.

Pupation occurs within the root or stem. There are definite color changes that can be correlated with the age of the pupa. The average pupal period is 9 days in *Euscepes postfasciatus* and 8 days in *Cylas formicarius elegantulus.*

The adult *Euscepes postfaciatus* is a small, brownish or grayish weevil, while the adult *Cylas formicarius elegantulus* is larger and a bright red and blue color. When food and water were withheld from the newly emerged adult, both species survived for about a month. Both species will feign death when disturbed, and this habit makes detection of the weevils in the field extremely difficult.

The major means of infestation of a field are probably by means of infested cuttings and adults crawling from adjacent fields. *Euscepes postfasciatus* does not fly, and *Cylas formicarius elegantulus* flies infrequently. Infested volunteer sweetpotatoes within a field are a source of infestation for subsequent planting. No effective natural or biological control factors of these weevils are known.

Cultural control methods are discussed.

The relative susceptibility of the two species of weevils to nine synthetic organic insecticides was determined. The order of toxicity of the insecticides to *Euscepes postfasciatus* are: aldrin = dieldrin > parathion > endrin > isodrin = lindane > chlordane > toxaphene = pp' DDT. The order of toxicity of the insecticides to *Cylas formicarius elegantulus* are: parathion > endrin = isodrin > lindane = aldrin = dieldrin > pp' DDT > toxaphene > chlordane.

The results of the field trials on the chemical control of the weevils are discussed. Insecticides were applied as sprays, dusts, and soil treatments. DDT applied as a preplanting cutting dip in combination with sprays at 10 and 16 weeks after planting at the rate of 2 pounds of active ingredient per 100 gallons gave excellent control. DDT dusts were inferior to sprays. None of the chemical treatments resulted in off-flavors in the sweetpotatoes.

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