

## Biology and Control of *Araecerus levipennis* Jordan (Coleoptera: Anthribidae)<sup>1</sup>

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Koa haole, *Leucaena glauca* (L.) Bentham, is a leguminous plant introduced into Hawaii prior to 1888 (Takahashi and Ripperton, 1949). Because of its high protein content, it is a valuable forage crop and many ranches have spread its seed over rangeland. In addition to this important use, it is of some value as a raw material in the manufacture of Hawaiian seed jewelry.

During 1954 a small beetle, previously unknown in Hawaii, was found to be damaging a large percentage of the seed of koa haole (Ford and Chilson, 1955; Sherman, 1955).

Specimens were sent to the U.S. National Museum and were identified as *Araecerus* sp., evidently *simulatus* Gyllenhal. However, additional specimens sent to Dr. H. E. Karl Jordan were identified by him as *Araecerus levipennis* Jordan. This species was described from the Philippines and Cochin China (Jordan, 1924). In a letter to Dr. D. Elmo Hardy of the University of Hawaii<sup>3</sup> Dr. Jordan wrote, "It is a near relative of *Araecerus simulatus* Gyllenh. 1833 (Java), which is a species of very wide distribution in the Oriental Region and varying much in size and pattern. . . . *Araecerus levipennis* differs from the four other species of *Araecerus* known from the Hawaiian Islands in the following combination of distinctions: club of antennae almost symmetrical; upper side pale tawny (ochraceous) with diffuse grey spots, impressed stripes, and their punctures distinct only at sides and bases, absent dorsally from before middle to apex of elytra, which gives the elytra a smooth appearance; legs pale testaceous, tibia without dark markings; anterior tibia of ♂ hairy on underside, without teeth; sutural area sometimes dark (as happens also in *A. simulatus*). . . . The area of distribution of *A. levipennis* probably includes Indochina and Formosa."

In the Hawaiian Islands this species is abundant throughout Oahu and has been found on Maui, Kauai, and Hawaii. Jordan earlier (1946) had stated that the four species of *Araecerus* present in the Hawaiian Islands were: *A.*

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<sup>3</sup> See: HARDY, D. E. Notes and exhibitions. PROC. HAW. ENT. SOC. 16 (1): 11, 1956.

*constans* Perkins, *A. fasciculatus* (Degeer), *A. varians* Jordan, and *A. vieillardii* (Montrouzier).

Until the arrival of *A. levipennis* the seeds of koa haole were free of any important insect pest (Sherman and Tamashiro, 1956). However, this insect, within a comparatively short time, has spread throughout Oahu where koa haole grows. The damage is caused by the grubs feeding in and completely destroying the seeds. There are times when practically 100 per cent of the seed pods in certain stands of koa haole is infested. This, of course, reduces the number of seeds available for propagation and for jewelry.

This study was undertaken to investigate the biology and control of this beetle.

### BIOLOGY

#### *Oviposition and the Egg*

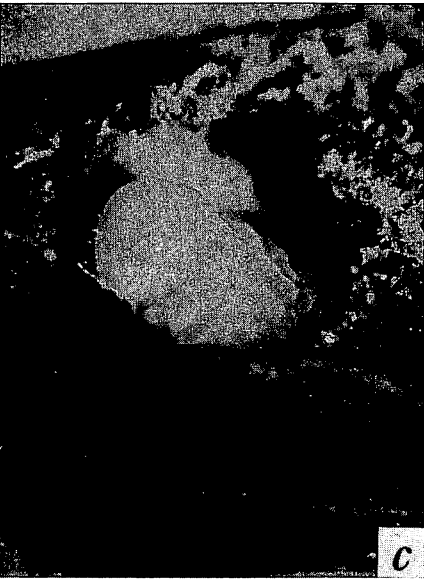
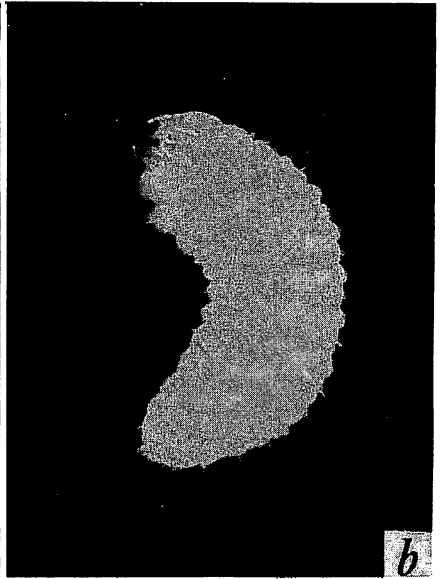
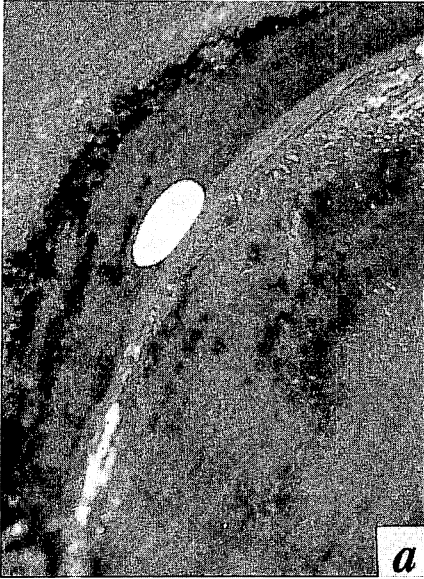
The female is selective regarding the pod in which she will deposit an egg. Only green pods which have grown to their maximum length and contain seeds which have swollen are attacked. The female, after mating, chews a hole in the pod at the swelling caused by a seed, turns around and places a single egg next to the seed (fig. 1A) through the hole she has made, then defecates over the hole. Although there is usually but one egg placed at the seed, occasionally as many as three eggs have been observed at a single oviposition site. Each seed in the pod may have an egg deposited on or near it. Sap is secreted by the pod at the points of feeding and oviposition. Damaged pods are easily detected because of the small dried globules of resin on their surface.

The egg is oval, glabrous, shiny, cream in color, and averages 0.75 x 0.30 mm. in size.

Observations were made of egg hatch between March 24 and April 8, 1955. Field-collected pairs of mating adults were taken into the laboratory and each pair was placed in a test tube together with a pod. Deposited eggs were removed daily and placed in a petri dish containing damp filter paper until they hatched. During this period a total of 238 eggs was laid. Table 1 summarizes these data. The average time for egg hatch during this period was 4.4 days. During November, 1955, egg hatch was again determined, and during this period 65 per cent hatched in four days, 25 per cent in five days, and 10 per cent in six days.

TABLE 1. Summary of number of days required for egg hatch.  
Average temperature, 75°F.

DAYS AFTER OVIPOSITION	NO. EGGS HATCHING	PER CENT HATCH
4	171	71.8
5	35	14.7
6	29	12.2
7	3	1.3



### *The Larva*

The larva (fig. 1B) is a crescent-shaped, cylindrical, cream-colored, legless grub. The newly hatched larva remains outside the seed while feeding, but within a day or so bores into the seed at the point where the egg was laid. It feeds on the embryo tissues, leaving the seed coat intact except for the entry site. As the larva matures the entire embryo is consumed, and prior to pupation the mature larva constructs a pupal chamber within the seed. The seed is usually hollowed out so that only the edges of the seed coat remain. The chamber is then sealed with frass. Within this chamber the mature larva becomes a prepupa, its body constricts, and the digestive tract is cleared prior to pupation.

### *Number of Instars*

Dyar's Rule (Dyar, 1890) has been helpful in determining the number of instars in insect larvae which feed hidden within plant tissues. Although this rule, which states that the head widths of the larvae follow a geometrical progression in successive instars, was originally developed from observations on lepidopterous larvae, it has since been extended to include other insect groups. For this study, the method described by Sherman and Tamashiro (1954) in determining the number of instars in sweet potato weevil larvae was used. Infested pods containing larvae in all stages of development were brought into the laboratory. Infested seeds were opened and the larvae removed, killed in hot water, and preserved in 75 per cent alcohol. The larvae were decapitated, the heads mounted on a microscope slide in Hoyer's solution (Baker and Wharton, 1952) and their widths measured.

A total of 1,137 head widths was determined. The frequency distribution of the measured larval head widths is given in figure 2. The distribution fell into three distinct groups and each group was assumed to be an instar. This assumption was analyzed statistically by the method of least squares as described by Gaines and Campbell (1935). The results of the analysis are summarized in table 2.

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 line calculated as the best fit for the geometrical growth of the larvae of *A. levipennis* was  $\log y = 0.2610 + 0.1994x$ .

The observed mean head widths of the assumed instars were plotted as suggested by Forbes (1934) and Harries and Henderson (1938). The similarity

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FIG. 1. The stages of *Aracercus levipennis* Jordan. *a*, the egg, adjacent to a koa haole seed; *b*, the larva; *c*, the pupal chamber uncovered, showing the pupa; *d*, the adult.

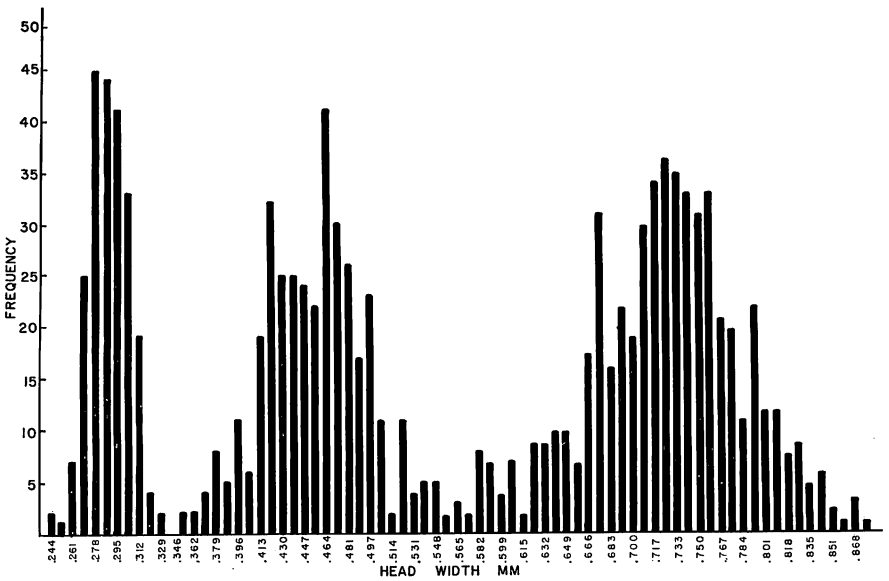


FIG. 2. Frequency distribution of the head widths of larvae of *Araecerus levipennis* Jordan.

between observed and calculated values corroborated statistically the number of instars in the larval stage.

TABLE 2. Head measurements of larvae of *Araecerus levipennis* Jordan.

MEASUREMENT	LARVAL INSTAR		
	I	II	III
Observed mean head width (mm.) . . .	0.289 ± 0.013	0.456 ± 0.040	0.724 ± 0.063
Log value (×10) . . . . .	0.46090	0.65896	0.85974
Calculated mean head width (mm.) . .	0.28870	0.45695	0.72322
Log value (×10) . . . . .	0.46045	0.65987	0.85929
Growth ratio (observed) . . . . .	.....	1.578	1.588
Growth ratio (calculated) . . . . .	.....	1.583	1.583
Number measured . . . . .	223	362	552
Size range (mm.) . . . . .	0.244-0.337	0.354-0.556	0.565-0.877

*Duration of Stadia*

An experiment was conducted in the fall of 1955 to determine the length of time spent in the larval stage. On November 1, thirteen ripening pod clusters were bagged in polyethylene bags. These bags were punctured with fine holes, too small to allow the entry of the adult beetle, but large enough to allow for aeration and drainage of water of transpiration. On November 18, field-collected adults were placed in the bags for approximately 24 hours and then removed. Egg deposition was high in most of the pods. A number of pods were taken into the laboratory to determine the hatching period.

The eggs hatched in four to six days. When egg hatch was completed, a polyethylene-bagged pod cluster was brought into the laboratory, several pods opened and the larvae taken from within the seeds. The rest of the pods were resealed in the bag. When the pods were all dissected, another bag was brought in from the field for examination until eventually all of the bagged pods were inspected. The larvae which were removed from the seeds were killed in hot water and stored in 75 per cent alcohol. The larvae were removed from the pods over a period of 53 days. They were decapitated and the larval instar was determined from the head width measurements.

The number of days after oviposition on which the various instars were found is as follows: first, 4 to 12 days; second, 10 to 31 days; and third, 17 days to the end of the observation period. Pupae were first found 40 days after oviposition; however, on that same day an adult that was at least 2 days old was also discovered. It appears, therefore, that the minimum number of days required for the larval period was 27 days and that the minimum number of days spent within each instar was: first, 6; second, 7; and third, 14.

In connection with the control experiments described below, pods which were placed in cloth-covered jars so that no later oviposition could occur yielded living third-instar larvae. In one case a third-instar larva was found in a seed that had been sealed for 211 days. In several other jars that had been sealed for 180 days 12 living third-instar larvae were found. In these instances the seeds were extremely dry and hard.

The pods which were used in this larval duration study were green and succulent until December 15, 1955, when they began to dry and harden. The bagged infested pods which were brought into the laboratory after that date showed evidence of a high degree of oviposition, and most of the seeds were damaged; yet the seeds yielded very few living larvae. Instead, many desiccated larvae were found. In these instances the second- and third-instar larvae that were usually to be found feeding inside the seed were lying in the pod outside of but adjacent to the seed. The seeds showed evidence of deep feeding and it seemed as though the larvae had been forced out of the seeds. Some of the larvae seemed to be diseased, yet no definite disease organism was found in specimens taken to Dr. Y. Tanada of the University of Hawaii. They were semi-flaccid, exhibited little or no activity, and were definitely moribund.

### *The Pupa*

The pupa (fig. 1C) has the shed larval skin attached to the tip of its abdomen, and the larval head capsule is especially distinct. The pupa is approximately 4.0 mm. long and 1.8 mm. wide.

The duration of the pupal period was determined in the laboratory. Mature larvae in seeds were placed individually in test tubes which were sealed and stored in a darkened box. Daily observations were made and the dates on which the pupa and finally the adult was formed were recorded. Table 3

summarizes the number of days required for pupation by the male and female beetle. The male beetle averaged 7.8 days, while the female averaged 7.4 days.

TABLE 3. Summary of number of days required for pupation.

PUPAL PERIOD (days)	NO. OF PUPAE	
	♂	♀
6	2	3
7	12	20
8	3	11
9	4	4
10	2	0
11	1	0

Pigmentation of the pupa could be associated with age as follows: first to third day, the entire body cream colored, the eye when viewed laterally containing a black spot; fourth day, the eye facets light brown; fifth day, the eye facets well defined and brown and the tips of the mandibles brown; sixth day, the body turning light brown, the prothorax dark brown, the eyes very dark brown, mandibles completely brown, and the posterior half of the elytra grey; seventh day, the head and prothorax dark with the prothoracic margin black, eyes black, legs brown, and the antennae brown with three grey terminal segments. The teneral adult is reddish brown in color.

#### *The Adult*

The adult (fig. 1D) is dark brown and usually bears two broad grey elytral stripes of short scale-like setae that extend somewhat less distinctly along the prothorax. Occasionally the stripes are missing and the elytra have a speckled appearance. The adult ranges in length between 2.5 and 4.4 mm. when measured in dorsal aspect from the anterior margin of the pronotum to the tip of the pygidium.

In a preliminary attempt to determine the sex ratio, 236 field-collected adults were separated by sex into 133 ♀♀ and 103 ♂♂. The sexes could easily be distinguished from one another by examination of the pygidium which in the male has a rounded apex, while in the female it is longer and has a pointed apex. Mating is most active during the late morning hours.

The adults feed on the pods and also the pedicel of the pod where they strip the bark to the cambium. They cause no important direct damage by their feeding; it is the larval stage that is most damaging. The holes they chew in the pods are similar to those produced during oviposition. Probably during the period of oviposition the females obtain much of their nutritional requirements in preparing the oviposition sites.

The tolerance of the adult to starvation was investigated. Mature pupae were placed in individual test tubes that were sealed with cotton plugs. The adults that emerged were kept from food and water, and observations were

made daily until death of the adult occurred. The average survival time of 50 individuals was  $17.7 \pm 4.6$  days.

The adults are good fliers. They are often reluctant to fly, however, and can be picked up by hand when they are actively feeding or ovipositing. This may account, in part, for the poor distribution of adults often observed in the field. It was commonly found, when sweeping for adults in a koa haole thicket alongside a road, that certain spots yielded more adults than others. This occurred despite the apparent similarity of growth of the koa haole and development of the seed pods. The damage to the pods, however, appeared to be much more uniform.

## CONTROL

### *Natural Control*

The physical condition of the koa haole seed appears to affect the development and maturation of the beetle. It has been observed that drying pods with hardening seeds slowed down the development of the larvae, and also under such conditions many larvae were found to be dead or dying. As mentioned earlier, it is not known whether some unknown disease organism had attacked the larvae or whether this condition was due to starvation. However, in numerous instances the pods showed external evidence of a high incidence of infestation, but when opened no living larvae were found although the seeds were damaged by feeding. This was also observed in the bagging experiments described below, where infested pods were taken into the laboratory and placed in cloth-covered jars. Upon examination five months later few adults had emerged, although in some instances the original infestation was high.

A predacious mite, *Pyemotes* (= *Pediculoides*) *ventricosus* (Newport), appears to be another important factor in reducing the beetle population. It feeds on the larvae, pupae, and teneral adults of *A. levipennis*. However, its effectiveness is probably restricted since it will attack the beetle only in mature dry seed pods.

Of negligible importance from a control standpoint is the hymenopterous parasite *Eupelmus cushmani* (Crawford), only four specimens of which were reared from infested seeds.

### *Chemical Control*

Since most of the koa haole grows wild, it would be difficult to control the beetle by conventional insecticide spraying methods. It might be possible to apply these control methods, however, where the koa haole was planted in a grove for the purpose of producing beetle-free seed. For the seed jewelry manufacturers, on the other hand, another method would have to be used, since they usually obtain their seed from plants growing along the roadside. In this regard, the practicability of insecticide dip treatment was investigated.

Mature green seeds were removed from field-infested pods, placed on cheesecloth, and dipped into an insecticide slurry until they were well wetted. The treated seeds were dried, placed in glass jars that were sealed with cloth, and held for a period of six months. Five insecticides were used in this experiment: DDT as a wettable powder, and lindane, aldrin, dieldrin, and malathion as emulsifiable concentrates. All insecticide treatments were replicated four times. During the storage period, frass was produced by the larvae not killed by the treatments. The effectiveness of the dip treatment was estimated by the amount of frass produced in the jars during storage.

The seeds that received no insecticide treatment were approximately 27 per cent infested. Lindane at 0.001 per cent, aldrin at 0.05 per cent, and dieldrin at 0.05 per cent showed no evidence of post-treatment feeding. However, DDT at 0.25 per cent and malathion at 0.10 per cent showed evidence of post-treatment feeding.

In connection with dip treatment it is important that the seeds, especially the green moist seeds, be dried to prevent damage by fungi during storage.

### *Boiling*

In the manufacture of koa haole seed jewelry the dried seeds are boiled to soften them before stringing. This suggested the possibility of boiling the mature green seeds prior to their being greatly damaged by the grubs. Infested pods that contained mature green seeds or seeds beginning to dry were collected. The seeds were removed from the pods and placed in boiling water for 10 seconds, 30 seconds, 1 minute, and 3 minutes. The seeds were then dried and placed in jars that were sealed with cloth. Unfortunately, although the larvae were killed, the hot water treatment fixed the green color in the seeds and prevented their natural browning. It appears, therefore, that the use of the hot water treatment would be restricted to drying brown seeds.

### *Bagging*

It was felt that bagging the pods might prove to be one of the least expensive methods of protecting the seeds from beetle attack. An investigation was initiated to determine the feasibility of this method and the types of materials that could be used.

The use of three types of bags was explored<sup>4</sup>: (a) 20-pound kraft paper bags, (b) 25-pound multilined paper fertilizer bags, and (c) thin polyethylene bags. Uninfested pod clusters in various stages of development were enclosed within these different types of bags. Clusters of pods of similar age were marked and left unbagged to serve as checks.

The bagging procedure was as follows: the branch on which the pod cluster was to be bagged was first stripped of all of its leaves. Nearby branches,

<sup>4</sup> The authors wish to thank the Pacific Chemical and Fertilizer Co., Honolulu, Hawaii, and the Honolulu Paper Co. for their donation of the fertilizer bags and polyethylene bags, respectively.

which could possibly come in contact with the bags and rip them, were removed. The bag was slipped over the cluster in such a manner that the pods were in their normal position and the open end was closed with string. It was necessary to puncture the polyethylene bags with a series of tiny holes to allow for drainage of the water of transpiration and to allow for aeration and cooling. It was found that if this were not done there was an accumulation of considerable amounts of water within a few days. It was not necessary to puncture either type of paper bag.

The pod clusters were bagged on March 12, 1955, and weekly observations were made of the condition of the bags and the pods. The pods were collected between May 3 and June 2, 1955, taken into the laboratory, and held in sealed jars until November 28-29, 1955, when the final observations were made.

The 20-pound kraft paper bags soon proved impractical. Within a month the bags were so badly torn that no protection was afforded the pods, and these were badly infested.

All but one polyethylene bag withstood the weathering period of 10 weeks. The one damaged bag had three slight 2-inch tears along a crease. The seeds in the pods that were very young when bagged developed normally. No infestation occurred. All the seeds were of good size, shape, and color and were good material for jewelry.

None of the fertilizer bags was intact at the end of 10 weeks. One bag was punctured and badly torn; the pods were slightly moldy, but the seeds were uninfested and in good condition. The other six bags had all come apart at the seam. Apparently the bags were put together with a non-water-proof glue and rain water had caused the seams to separate. Despite this, an examination of the seeds in four of the bags showed excellent color and shape and no damage. The other two bags yielded a total of 36 pods, containing 407 seeds, of which 9.1 per cent was infested. Thirteen adult beetles emerged during the storage period.

The unbagged clusters contained 81 pods. An examination of 1,236 seeds showed a mean infestation of 43.4 per cent with a range of 13.0 to 98.5 per cent. Thirty-six adult beetles emerged during the storage period and 13 living third-instar larvae were found.

Bagging the pods, therefore, affords good protection from attack by the beetle provided the bags are such that they will withstand several months of weathering. No adverse effect upon the growth and maturation of the seeds was noted.

#### SUMMARY

The biology and control of *Araecerus levipennis* Jordan was investigated. This recently introduced beetle destroys the seed of koa haole, *Leucaena glauca* (L.) Benth.

The egg, which is usually laid singly through the pod so that it contacts the seed, hatches in 3 to 7 days.

There are three larval instars and the larval period ranges from 27 to over 211 days.

Pupation occurs within the seed. The pupal period varies from 6 to 11 days.

The adult is dark brown and usually has two broad grey elytral stripes that extend along the prothorax. Occasionally the stripes are missing and the elytra have a speckled appearance.

Drying pods with hardening seeds slowed down the development of the larvae, and in some instances under such conditions many larvae were found dying or dead. A predatory mite, *Pyemotes ventricosus* (Newport), was found destroying large numbers of larvae, pupae, and teneral adults in several localities in Manoa Valley.

Conventional insecticide spraying is impractical since koa haole is not usually grown in planned groves. Studies on seed treatment with insecticide dips and by boiling are described.

Enclosing ripening koa haole pods within polyethylene bags prevented damage by this insect.

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