The Biology and Laboratory Culture of Thyreocephalus albertisi (Fauvel) in Hawaii

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In 1947 the Territorial Board of Agriculture and Forestry of Hawaii sent Q. C. Chock to Luzon, in the northern Philippines, to search for natural enemies of the oriental fruit fly, *Dacus dorsalis* Hendel, a serious pest which had recently appeared in Hawaii. Numerous adults and larvae of *Thyreocephalus albertisi* (Fauvel) [2], a common staphylinid predator of fruit fly larvae in rotting fruits in Luzon, were shipped to Honolulu. Efforts to propagate the predator by the Territorial Board of Agriculture and Forestry were successful and widespread releases were made in Hawaii during the next three years.

T. albertisi is known to occur in Australia, New Guinea, the Aru Islands, Ternate, in the Moluccas, and the Celebes. Nothing concerning its life history and habits has ever been published.

The work reported on in this paper was the outgrowth of a need for even greater numbers of the predator for field release, and for orientation in methods of handling staphylinids in anticipation of additional shipments from parasite and predator explorers. The studies were made in the quarantine laboratory of the Pineapple Research Institute in Honolulu.

ADULT STAGE

The adult beetles are striking in appearance, having coal-black, iridescent bodies and gold elytra. The males can be distinguished by their broader heads, which average 2.74 mm. in width, as compared with 2.19 mm. for the females, and by their slightly shorter bodies—about 11.6 mm. long, as compared with 12.4 mm. for the females.

The adults are active, strongly negatively phototropic, and they do not fly readily. They emit a repugnant musty odor when handled or disturbed. As shown in table 1, they were rather long-lived in the laboratory when kept in moist soil with an abundance of fruit-fly-infested fruits. The females lived longer than the males, their adult period averaging 157 days, as compared with 109 days for the males. Mating has not been observed, but a single male can apparently mate with several females, since the number of fertile eggs laid in breeding jars was not influenced by the male ratio. This species apparently is not parthenogenetic, since unmated females isolated in separate jars laid only a few undersized infertile eggs.

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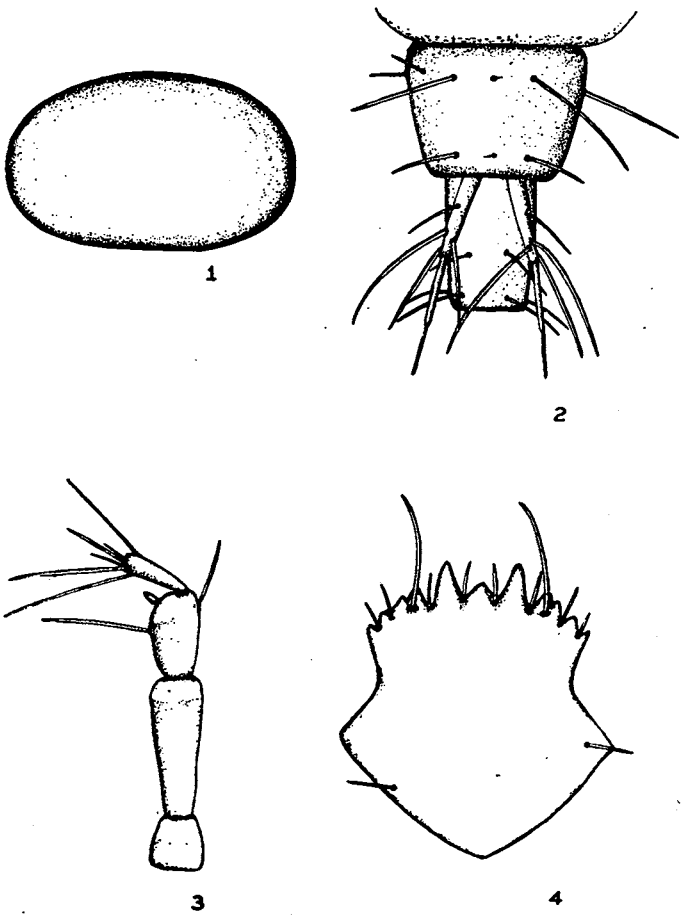

Figure 1.—Egg and second-instar larval characters of *Thyreocephalus albertisi* (Fauvel). 1. Egg. 2. Urogomphi region. 3. Antenna. 4. Nasale of second-instar larva. (Drawn by J. R. Holloway)

Throughout the laboratory rearings there was a very favorable female ratio, which averaged about 2.3 to each male. No apparent seasonal variations in the sex ratio have been observed under laboratory conditions.

The adult females of *T. albertisi* have a rather long and variable preoviposition period, which ranges from 11 to 30 days with an average of about 19 days (table 1). The eggs were laid singly, usually under the fruit. Although the adults constructed terrestrial channels 6 inches deep, most of the eggs were laid at or near the soil surface. In a series of weekly counts 154 eggs were found in the first inch of soil, 46 in the second inch, and none below 2 inches.

The abundance of prey seemed to have a direct effect on the number of eggs laid, the greatest number being deposited when food was plentiful.

Table 1. The longevity, preoviposition period, and egg production of *Thyreocephalus albertisi.**

Breeding jar No.	Adult population ♀♀	Adult population ♂♂	Longevity of adults (days) Females Individual records	Females Ave.	Males Individual records	Males Ave.	Preoviposition period (days)	Egg production Total	Egg production Average per female	Egg production Week of maximum production
1	8	5	79, 169, 176, 197, 225, 223, 250, 307	203	36, 94, 128, 169, 218	129	30	425	53	19th
2	10	5	61, 125, 149, 156, 177(2), 184, 198(2), 253	168	61, 77, 111, 184, 253	137	23	237	24	16th
3	10	2	25, 116, 172, 239, 179, 232, 246(2), 260(2)	198	239, 253	246	14	851	85	24th
4	11	8	31, 55, 104(3), 132(2), 139(2), 187, 195	119	21, 35(2), 55, 70, 111, 153 (2)	79	18	650	59	8th
5	13	14	16, 79, 107(2), 114(2), 135, 142(2), 149(2), 156, 163	121	16, 30(2), 44(2), 51, 107(2), 114, 121, 128, 149(3)	89	11	940	72	3rd
Average			157	...	109	...	19	620	59	...

* The variations shown in this table were partially the result of seasonal temperature fluctuations in the insectary.

The presence of fruit also seemed to stimulate oviposition. A total of 388 eggs were deposited in one week by 131 gravid females supplied with heavily infested fruits, but they laid only 18 eggs the following week when provided with fruit fly larvae only. When infested fruits were again added during the third week, oviposition increased to 237 eggs.

A test was made to determine how long the gravid females can retain eggs in the absence of fruit, and to estimate more precisely the importance of the presence of fruit in egg production. Twelve gravid females of equal ages, which had just begun to lay eggs, were divided into two equal lots. One group was supplied with large numbers of fruit fly larvae without fruit, while the other received infested guavas containing an equal number of larvae. In the first week the predators caged with both guavas and oriental fruit fly larvae deposited 40 eggs. Those in the cage without guavas laid only 18 eggs. In the second week, however, the staphylinids in the cage with fruit laid only 24 eggs, as compared with 40 eggs produced by the staphylinids in the cage without fruit. The number of eggs laid during the third and fourth weeks was 29 and 9 for the beetles in the cage containing fruit, and 32 and 7 for the females without fruit. These results indicated that gravid females are able to retain their eggs for no more than a week in the absence of favorable conditions. During the 4-week period, the staphylinids supplied with fruit deposited a total of 102 eggs, while the beetles in the other group laid 97 eggs.

The fecundity of *T. albertisi* is rather low. As shown in table 1, the minimum number of eggs per female was 24, the maximum 85, and the average 59. The adults generally required a long time to reach maximum oviposition rates, but they continued to deposit fertile eggs until death. In most of the breeding jars maximum oviposition did not occur until after the fifteenth week. Several females produced fertile eggs after they were 7 to 10 months old.

IMMATURE STAGES

The records on the periods required for the various developmental stages are summarized in table 2.

Egg Stage: The egg (fig. 1,l) is milky white in color, with a thin, faintly sculptured and relatively opaque chorion. In shape and appearance it resembles a very large ant egg and measures 2.26 mm. in length and 1.29 mm. in width. Infertile eggs, of which there are usually very few, are considerably smaller and have a yellowish tinge. About 80 per cent of the eggs hatched when kept in moist soil.

Larval Stage: The hatching first-instar larva cuts a neat slit through the chorion, which it never consumes, and almost immediately begins an amazingly active and vicious life. One newly hatched larva was observed to kill four small melon fly larvae within 4 minutes. These young predators are able to subdue fruit fly larvae of any size, and will attack puparia when active larvae are not available. They are also cannibalistic, eating eggs, pupae, and even active larvae of their own kind. They are generally found within the first inch of soil, and often within infested fruits on the

soil surface. The campodeiform newly hatched larvae average 6.67 mm. in length, the head being about 1.18 mm. wide by 1.40 mm. long.

Newly moulted second-instar larvae are about 13.33 mm. long. The head is about 1.56 mm. wide and 1.75 mm. long. Except for their larger size, they bear a general resemblance to those of the first instar. *T. albertisi* appears to have only two larval instars.

Table 2. Duration of egg, larval, and pupal stages of *Thyreocephalus albertisi.*

Stage	Number	Length of Stage (days)		
		Range	Average	Number
Egg	15	4- 6	5	5
First-instar larva	148	4- 8	6	5
Second-instar larva	154	8-24	13	13
Pupa	127	8-18	11	12

The morphological characters generally used in the identification of larval Staphylinidae (Mank 1923), namely, the nasale or "upper lip," the pygopod and urogomphi, and the antennae, are illustrated in figure 1.

During the first half of their existence, second-instar larvae are as active as those of the first instar, but they later become sluggish as their bodies increase in size. They are generally found deeper in the soil and are less often seen in fruits. The full-grown larva has a greatly distended abdomen about 17 mm. long, and in this stage it constructs a cell where it may remain as long as 10 days, apparently without feeding, until it finally pupates. The quiescent prepupal stage is very easily injured, and often a slight disturbance of the earthen cell or of the larva itself may result in an aborted pupa or death.

Pupal Stage: The pupa ranges in color from light yellow to almost brick red, and measures about 3.65 mm. in width and 8.25 mm. in length. The head and thorax are fused, but the abdomen is capable of vigorous side-to-side and circular motion. Should the cell wall collapse, the pupa can restore its shape with abdominal movements. The pupal cell also provides ample aeration, which probably prevents the growth of harmful molds often associated with pupae in imperfect cells. The emerging adult does not consume the pupal case. Its first activity is that of constructing terrestrial channels.

FEEDING POTENTIAL OF THE PREDATOR

A series of laboratory feeding tests were conducted with both larvae and adults of *T. albertisi,* to determine their potential capacities as fruit fly predators. Individual first and second-instar larvae and adults were placed in pint jars half-filled with soil and supplied at weekly intervals with papaya sections containing known numbers of half-grown oriental fruit fly larvae. Similar units were held without the staphylinids, to serve as checks. Predation was then estimated by comparing the surviving fruit fly populations in the different series of jars. The indicated destruction of prey by each stage of *T. albertisi* is shown in tables 3 and 4.

As noted in table 3, about 11 fruit fly larvae were apparently killed per predator in 6 days by first-instar *T. albertisi,* as compared with 15 in 12 days per second-instar predator. An average of approximately 26 fruit fly lavae were thus destroyed by each larva of *T. albertisi.*

With regard to adult predation (table 4), each mature gravid female destroyed about 28 *Dacus dorsalis* larvae per week, as compared with only 10 per week by mature males of the same age. Young females consumed fewer larvae than did older ones, and predation was greatest at the peak of oviposition. An average female may therefore theoretically consume or destroy from 500 to 600 oriental fruit fly larvae during her entire larval and adult life span.

In separate tests both larvae and adults of *T. albertisi* were successfully reared on oriental fruit fly larvae and puparia in the absence of fruit, indicating that this species is very largely or entirely carnivorous.

Table 3. Destruction of third-instar oriental fruit fly larvae by first- and second-instar larvae of *Thyreocephalus albertisi.*

	First-instar larvae		Second-instar larvae		
Jar No.	Period (days)	Fruit fly destroyed	Period (days)	Fruit fly destroyed	Total
1	5	9	16	21	30
2	8	15	13	9	24
3	5	9	20	22	31
4	5	10	16	14	24
5	5	6	13	17	23
6	6	13	8	13	26
7	7	13	7	14	27
8	6	10	8	14	24
9	7	15	7	13	28
10	7	8	7	13	21
Total	61	108	115	150	258
Average	6	11	12	15	26

Table 4. Destruction of third-instar oriental fruit fly larvae by adult *Thyreocephalus albertisi.*

Predator adults		Larvae destroyed				
Sex and age (days)	Number	1st week	2d week	3d week	4th week	Average per adult per week
Females, 70	2	111	31	37	35	26.8
	1	53	12	15	..	26.7
	2	102	16	..	..	29.5
Males, 70	2	45	6	9	21	10.1
	1	15	5	7	..	9.0
	1	10	0	..	..	10.0
	1	16	..	..	..	16.0
Females, 2	1	22	6	11	30	17.3
	5	62	..	..	..	12.4
Males, 2	2	24	18	..	..	10.5
	2	32	..	..	..	16.0

LABORATORY CULTURE

Heretofore staphylinid larvae have been reared in individual salve tins—a laborious method—to prevent cannibalism. This method greatly restricts the number of adult insects that can be produced for field release. It was therefore hoped that cannibalism might be largely eliminated in community cultures by supplying the predators with excess numbers of prey upon which to feed.

Promising results were obtained in preliminary experiments utilizing various numbers of newly hatched *T. albertisi* larvae in battery jar and beaker units supplied with heavily infested fruits. About 50 per cent of the predators survived to the pupal stage when their average density was one per cubic inch of soil. Weekly examinations showed an average of 8 to 10 oriental fruit fly larvae and puparia per cubic inch of soil in these units.

The need for an abundant food supply made it desirable to find a suitable host insect that would be easier to obtain and to rear in large numbers throughout the year than the oriental fruit fly. Tests were conducted using house fly maggots. They proved to be an excellent source of food for the predators, which developed normally until they reached the quiescent prepupal stage, when the ravenous house fly maggots reversed their intended role and attempted to attack the prepupae. The continual disturbance by the burrowing maggots caused a high percentage of aborted pupae, and in several tests the maggots actually consumed the staphylinids. Subsequent tests with house fly puparia and with inactivated maggots that had been killed by immersion in hot water were also unsuccessful.

The possibility of using larvae of the melon fly, *Dacus cucurbitae* Coquillett, was then investigated. Eggs were readily deposited in cucumbers that had been punctured with a dissecting needle, and when the melon fly larvae were nearly mature the cucumbers were split open and placed on the soil in the breeding units. It was soon noticed that, despite the use of sterile soil, many of the staphylinid larvae were infested with small brownish mites, which sometimes almost completely covered the larval epidermis. When numerous they prevented the normal moulting of *T. albertisi* larvae, causing high mortalities and many aborted pupae. These mites were identified by I. M. Newell, of the University of Hawaii, as the hypopi, or migratory nonfeeding stage of *Anoetus* (*Histiostoma*) sp., a common soil-inhabiting scavenger.

Tests with several acaricides showed that the mites could be effectively controlled by lightly spraying the cucumbers with a 5 per cent solution of benzyl benzoate and mixing about 1 gram of DMC[3] with each 1,000 cc. of soil. Neither material was fully effective when used alone, and higher concentrations were toxic to the predators.

An attempt was then made to mass-culture *T. albertisi* in standard metal holding boxes of the type in use at the Oriental Fruit Fly Laboratory. The boxes were 17 inches long, 13 inches wide, and 6 inches deep, and each contained about 3½ inches of sterile soil covered with a 1-inch

[3] Dimethylcarbinol.

layer of peat moss, to absorb excess moisture from the infested cucumbers. Acaricides were applied as indicated above, and from 200 to 400 staphylinid eggs were evenly distributed beneath the layer of peat moss in each box. New heavily infested cucumbers were added each week until the predators had pupated (about 30 days later), when the boxes were dismantled and the pupae were removed and placed in ice-cube-tray compartments on moist sand under glass, to await adult emergence.

Even with an excess of food, the predator larvae tended to congregate in the corners of the large holding boxes where they sometimes attacked one another. Removable metal baffles forming 3 and 6-cubic-inch compartments were placed in the boxes, but these failed to increase the survival rates and were later discarded. About 38 per cent of the staphylinids survived to the pupal stage in these units, as compared with approximately 75 per cent in the individual salve tins. However, this loss was more than offset by the saving in labor and greater overall efficiency of the mass-culture method.

Stock supplies of adult beetles of *T. albertisi* were kept in large battery jars half-filled with moist sterile soil covered with a 1-inch layer of peat moss and provisioned with heavily infested fruits. Eggs were removed each week, using a sieving and flotation technique, to prevent their destruction by newly hatched larvae. The soil was gently washed through successive 4-, 16-, and 32-mesh screens, which removed the adult beetles and debris on the first and second screens. The eggs and smaller particles remaining on the third screen were then placed in a saturated brine solution in a large shallow pan, where the eggs promptly floated to the surface. They were then skimmed off with a small 32-mesh screen scoop and were immediately rinsed in fresh water. Hatching of these eggs averaged 71 per cent, as compared with 74 per cent when the eggs were sieved but not placed in brine, and 79 per cent when they were collected by hand without either sieving or flotation on brine. About 20 per cent more eggs could be recovered by the sieving and flotation technique than by the former method of visual inspection.

LIBERATIONS

A total of 1,015 adults and 2,198 eggs and larvae of *T. albertisi* reared during these investigations were liberated in the Waiahole, Waimanalo and Moanalua guava areas on the island of Oahu from July 6 to November 10, 1950. Establishment was encouraged by placing the insects in large piles of infested guavas in favorable locations containing an abundant sequence of fruiting species. Although evidence of breeding was noted at these sites for several weeks after liberation, no recoveries have since been made and *T. albertisi* is not known to be established in Hawaii.

LITERATURE CITED

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