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HOST PREFERENCE AND POTENTIAL CLIMATIC RANGE OF *Cyanotricha necyria* (Lepidoptera:Dioptidae), A POTENTIAL BIOLOGICAL CONTROL AGENT OF THE WEED *Passiflora mollissima* IN HAWAIIAN FORESTS

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ABSTRACT

Passiflora mollissima is a cultivated vine, native to the higher Andes Mountains of northern South America. Introduced to Hawai'i, probably as an ornamental, the plant has escaped and become well established in mountain rainforests. Here, its uncontrolled growth--presumably due to the lack of any natural enemies--rapid rate of spread and impact on the native forest trees and shrubs have led to its being declared the most serious introduced weed in this unique ecosystem.

In an effort to establish biological control of this weed, a South American moth, Cyanotricha necyria, has been selected as a promising candidate for eventual release in Hawai'i. a colony of this insect was established in an insect quarantine facility at Hawai'i Volcanoes National Park and used to conduct oviposition, host preference, and climatic range studies.

The studies indicate that C. necyria, if released in Hawai'i, poses no threat to any native or agricultural plant, with the exception of a few other species of the genus Passiflora, all of which are introduced, and most of which are weeds. While a few larvae under laboratory conditions occasionally completed development on passionfruit, P. edulis, we feel C. necyria is not a threat to this small industry (9100 acres in 1984) based on (1) its expected climatic range 750m and above, (2) unsuitability of P. edulis foliage as a food source for larval development, and (3) nonacceptability of P. edulis foliage as an oviposition site by females. Cyanotricha necyria, if released, may pose a slight risk to the noncommercial P. ligularis in certain areas of the higher forests of Hawai'i, and a very small, but acceptable risk to the other species of Hawaiian Passiflora.

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INTRODUCTION

Passiflora mollissima (HBK) Bailey[1], locally referred to as banana poka, is a tendril, woody liana (vine) of the tropical mountain rain forests of the Andes of northern South America (Killip 1938). While no wild populations of *P. mollissima* have been identified in South America, this area is the center of its cultivation as a domestic plant. Under various local names such as curuba, tumbo, and tasco (Killip 1938) it is widely grown as both an ornamental around homes and in extensive vineyards of trained plants on permanent trellises. The elongated, yellowish fruit is squeezed for its juice which is used in a number of local fruit drinks and sherbets as well as for export (Martin and Nakasone 1970).

The exact date this plant was introduced into Hawai'i is unknown. It was present in the Kokee area of Kaua'i by 1910, reported on the island of Hawai'i, near Kona in 1921, and may have been introduced to the east side of Mauna Kea near Keanakolu around 1932 and to the Volcano Village area around 1955 (La Rosa 1984). A small infestation was first reported in the Kula area of east Maui in 1971. Aerial surveys in 1986 indicated that this pocket has spread over several square kilometers, usually in inaccessible stands of black wattle (pers. comm. W. Wong, Hawai'i Div. of Forestry and E. Tamura, Hawai'i Dept. of Agriculture).

The most recent estimates of distribution on Hawai'i and Kaua'i are that it is continuously distributed (heavy to moderate infestations) over 16,000 ha of forest lands (39,200 acres) with scattered patches occurring over an additional 33,000 ha (80,850 acres). In general, infestations are found between 900 and 1,950 m (3,000 and 6,500 ft.) elevation in native ohia-koa forests (Warshauer et al. 1983).

Where established, its impact on the native forest is devastating (Fig. 1). Once the vines reach the canopy, they spread and form a dense layer that can kill the supporting

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1 Some confusion exists on the exact scientific name of this plant. As a cultivated crop in South America, a number of commercial varieties are available, and the particular variety present in Hawai'i at one time was elevated to species rank under the name *P. tripartita*. The most recent taxonomic work on this subgenus, however, both in Colombia (Escobar 1980) and Hawai'i (La Rosa 1984, 1985) recognizes it only as a variety and retains the original name of *P. mollissima*.

trees by shading or felling them by their added weight. Blow down of trees during windstorms is also increased due to their increased surface area. In open areas, such as logged-over areas, P. mollissima forms dense mats that cover the ground and quickly smother and kill most tree seedlings and shrubs. When well established, densities are so great that P. mollissima comprises the majority of the vegetative cover (Wong 1971, Warshauer et al. 1983). Its rate of spread is unknown, but probably is relatively rapid in view of its present range and limited time it has been in the islands. Long distance distribution has been by man, spreading it for its fruit or showy flower. Once established in an area, its local spread is by wild pigs or birds feeding on the fruit and disseminating seeds in their droppings (La Rosa 1984).

In view of the current and potential impact of P. mollissima on the remaining native Hawaiian forests, numerous suggestions for its control have been made. However, in view of its wide distribution, its inaccessibility in native forests and the potential impact that most control methods (mechanical cutting, herbicides, grazing, etc.) might have on the forest to be protected, it was concluded that the only feasible method of control is by biological control, i.e., the introduction and establishment of its native enemies from South America (Waage et al. 1981, Warshauer et al. 1983).

To meet this objective, a multi-agency federal and state program was organized in Hawai'i to initiate biological control of noxious weeds of Hawaiian forests, with the control of P. mollissima its first priority. A new insect quarantine facility was constructed at Hawai'i Volcanoes National Park (HVNP) and an expedition to South America was conducted to survey the insects associated with P. mollissima (Pemberton 1982). Arrangements were made with Dr. M.R. de Hernandex, entomologist, of the University of Cali, Pasto, Colombia, to study the local insects associated with the plant and to collect and ship to HVNP's quarantine facility the species that appear most promising. At the HVNP quarantine, methods of propagating each new species were determined and laboratory colonies established. Limited biological studies were conducted on each insect species, but the main purpose of the laboratory colonies was to furnish material to conduct host specificity testing to determine the suitability of each species as a biological control agent in Hawai'i. Of the six species of insects received at HVNP, a moth Cyanotricha necyria Felder, appears to be the most promising (Fig. 2).

Before any biological control agent can be released, it must first be conclusively demonstrated that this agent is incapable of developing on any species of plant other than the target weed, and possibly a few closely related species in the same genus if they are also undesirable plants. The process of determining the degree of selectivity of a candidate biological control agent is referred to as host preference studies (or sometime as host specificity testing, (Huffaker 1963).

Three levels of host testing were performed. First, oviposition tests were conducted to determine if female C. necyria would identify any other species of Hawaiian Passiflora as a potential host and lay eggs on it as readily as she would P. mollissima. Second, we conducted feeding tests using very small larvae to determine what would happen if an egg laid on another species of plant should hatch, or if larvae should accidentally migrate to it, could the larvae develop and become adults? This study included 85 species of native and introduced plants representing 35 families.

A third series of tests was aimed at a more detailed examination of the ability of C. necyria to develop on the commercial passionfruit, P. edulis. Since this plant is in the same genus as P. mollissima, it is a primary candidate for attack, and is also a minor agricultural crop in Hawai'i (Anonymous 1985).

Studies were conducted in 1985 and 1986 at the HVNP Quarantine Facility (HVNPQF) located at an elevation of 1,140 m (3,800 ft.) in a native koa-ohia-tree fern rain forest (2,550 mm precipitation, average January temperature 15°C, August 17.5°C). The locality closely represented the preferred climatic habitat of P. mollissima (Warshauer et al. 1983), although the nearest infestation of this weed was 2 miles away. The facility is an insect-tight building maintained at ambient temperature and humidity by circulation of filtered outside air. Insects were reared in the quarantine in sleeve cages or perforated plastic sacks containing bouquets of freshly picked P. mollissima foliage held either on benches or in environmental chambers. Colonies used in the study all originated from the Pasto and Epiallis areas of Colombia near the Ecuador border. Most observations were made on either wild collected insects shipped to the quarantine or on the first or second generation reared from them.

OVIPOSITION TEST

Methods

Oviposition testing is an effort to measure the degree of specificity a female insect exhibits in selecting a potential host plant by the frequency with which she lays eggs on it. Female C. necyria do not mate until 5 days after emergence from the pupa and then begin laying eggs at a rate of approximately 3.7 per day for the rest of their lives (mean 64.6 eggs per female, range 0 to 184 eggs). Egg development and laying by C. necyria is very constant, and females not offered P. mollissima foliage will deposit their daily component of eggs on the under surface of any plant or object available. However, given a choice, females should deposit their eggs almost entirely on the undersides of leaves of their preferred host plant, ignoring other plants.

The procedure to determine the attractiveness of various species of Hawaiian Passiflora was by simultaneously placing similar bouquets of freshly-picked P. mollissima and the test species of Passiflora in a cage containing 10 to 20 breeding pairs of C. necyria, examining the foliage after 2 or 3 days, and counting all eggs on each bouquet. Each test was replicated at least 5 times, each with a cage containing a different population of females.

Results and Discussion

Results of these tests are shown in Table 1. In most experiments, the number of eggs laid on the Passiflora species being tested when expressed as a percent of the total of all eggs laid was very low. Almost the same percent of eggs was laid on a totally nonsuitable plant (mustard cabbage, 5.1%), indicating that on these species, eggs were probably being laid at random. Oviposition on P. edulis was slightly better with an average of 6.9% of the eggs being deposited on bouquets of this plant. Only on P. pulchella (22.6%) and to a lesser extent on P. malva (15.6%) were appreciable numbers of eggs laid. From this it could be concluded that P. pulchella might be an acceptable host; an observation that agrees with other results that show P. pulchella is one of the few Passiflora species C. necyria can successfully complete its development on (Table 3). By contrast, host testing showed P. malva to be a totally nonsuitable host (Table 3) on which C. necyria would barely feed, and could not grow or develop.

FEEDING TESTS

Methods

Feeding tests were conducted using late first- or early second-instar larvae (3 to 5 mm long) (Fig. 3), although when a shortage of larvae occurred in the middle of a series of tests, mid-sized second-instar larvae (7 mm) were included. Fifteen larvae were usually utilized for each feeding test of a different plant species. Foliage was offered in the form of small seedlings grown in soil-filled cups, as bouquets of cut foliage with their bases placed in a water-filled flask, or as individual leaves in a petri dish. For each test, two bouquets or potted plants were used. One was placed in a glass gallon jar with five larvae and the top covered with a fine mesh muslin screen to allow air to circulate for a drier environment (Fig. 4). The second potted plant or bouquet also had five larvae, but was enclosed in a lightly-perforated plastic sack to retain a high constant humidity. Bouquets always included shoots with newly-opened leaves as well as older foliage, so larvae had a variety of foliage of different degrees of maturity to choose from.

It was noticed early in the study that larvae placed in a large enclosed space such as a plastic sack or gallon jar with a nonsuitable test plant, usually spent most of their time searching off the plant until they died. In this situation, a larva might become hungry enough to have attempted feeding on the test plant but be too weak or distant from the foliage to find it before it died. To force the larva into almost constant contact with the host plant foliage until it had either fed or died, a third method of confinement was included in which leaves of the host plant were placed in 15 x 100 mm plastic petri dishes with the bottom covered with a damp paper tissue. A single large leaf or enough small leaves were added to cover at least 75% of the bottom of the petri dish. This was replicated five times with a single larva being placed in each dish. This arrangement provided a method of confining the larva in the immediate vicinity of the foliage and forcing it to encounter it frequently if it should start a searching behavior.

For each plant species tested, the design used exposed a minimum of 15 larvae at two population levels (individuals or groups of 5) to the foliage of five or more different plants under three methods of physical confinement. Using this design, it was hoped that if the larvae had any inclination to accept the plant being offered, the right combination of plant substrate and physical factors necessary to induce feeding would occur.

Tests were examined every 2 to 3 days, potted plants watered, leaves or shoots replaced when they had begun to wilt, and each container examined for live or dead larvae and any signs of feeding. When signs of feeding occurred, additional observations were made to determine if the larvae could actually utilize the foliage as a source of nutrition and grow, molt to the next instar, and complete their development and pupate. If any sign of feeding was observed the entire test was replicated a second and often a third time. Tests were usually conducted on nine different species of plants at a time, with one test of P. mollissima foliage as a check.

Results and Discussion

Results of host testing for 85 plant species, representing 34 different families other than Passifloraceae, are shown in Table 2. The response by C. necyria larvae to test plants in the majority of tests was totally negative and larvae made no effort to feed or even taste the plant. They simply wandered about the containers until starving to death in 8 to 12 days.

However, in four families, starving larvae made an effort to taste the host plant (consuming enough foliage to produce a definitive hole, usually less than 1 mm square) or consumed enough foliage to be judged to have conducted light feeding (an area of foliage equal to the body size of the larva, and produce droppings). However, all larvae on these plants were dead in 8 to 16 days, showed no growth, and were usually smaller at the end of the tests than when it was set up. Light to moderate feeding, where a larva would consume up to 1 sq cm of foliage, occurred on only two families; Cucurbitaceae (phylogenetically the family generally believed to be most closely related to Passifloraceae, Takhajan 1980), and Cruciferae. Some of these plants appeared to provide enough moisture or nutrition to extend the life of a larva up to 21 days. However, all larvae appeared to have derived only minimal sustenance; none showed measurable growth and none molted to the next instar. The results of testing plants outside the family Passifloraceae, therefore, are all considered negative; none were suitable hosts capable of sustaining growth and development of C. necyria.

Table 3 shows the results of host testing on nine species or varieties of Passiflora found in Hawai'i (Neal 1965). As expected, in testing plants closely related to the target weed, the insect recognized them as a possible food source and some feeding was recorded on all of them. However, larvae were unable to complete development and pupate on three of the species of Passiflora and these plants were considered negative. Four species, and their varieties, were considered positive when at least one larva completed development on these plants and pupated. Of the four species judged positive, P. foetida and P. pulchella are considered weeds in Hawai'i (Haselwood et al. 1983). Any attack on them by released C. necyria would probably be considered beneficial. Such an attack on either species is unlikely since their distribution is restricted to below 500 m (1,500 ft.), well below the expected climatic range of C. necyria in Hawai'i.

Cyanotricha necyria also appears to be marginally capable of developing on P. ligularis, although this appears to be an unsuitable host, since only five larvae (8%) of the 60 tested developed into pupae (and all of those were from a test using half-grown larvae) as opposed to 65% pupation on P. mollissima checks. While P. ligularis is an unsatisfactory host, it is still possible that under certain field conditions, attacks by C. necyria could occur. P. ligularis has the highest elevation range of all the Passiflora in Hawai'i (500 to 1,000 m). In certain areas, such as between 750 to 1,000 m (2,500 to 3,500 ft.), on the west side of Mt. Hualalai near Kona, the ranges of P. mollissima and P. ligularis overlap and the plants can be found intermingled. If C. necyria could exist at this low an elevation, and could develop high populations on P. mollissima, it is possible that starving larvae while searching for additional food could encounter P. ligularis and begin feeding. However, in view of the very poor survival of larvae that develop on this species, and its unsuitability for oviposition (Table 1) it is doubtful that P. ligularis by itself could support a permanent population of C. necyria and would therefore only be attacked by an overflow from surrounding P. mollissima plants. While P. ligularis has flavorful fruit which is occasionally picked, it is never grown commercially or used as an ornamental in Hawai'i. Also, since it is an invader in our native forests, it can be considered an introduced weed species and attack by C. necyria could be viewed beneficial.

Sixteen other species of Passiflora, not including the edible commercial passionfruit (P. edulis) are listed by Neal (1965) as occurring in Hawai'i. None are of commercial value, most are uncommon and are tropical plants that can live only below 450 m (1,500 ft.) elevation. It is expected that since none are in the same subgenus, Tacsonia, as P. mollissima (Killip 1938), none are probable suitable hosts.

ACCEPTABILITY OF P. ASSIFLORA

In Hawai'i, the passionfruit (lilikoi) P. edulis, occurs in a purple-fruited an a yellow-fruited form. The yellow form is grown both as a commercial crop or harvested from wild plants, and marketed to food processing plants that extract the juice for local use in a number of drinks. In 1984, the most recent year for which statistics are available (Anonymous 1985), 100 acres were planted to this crop. However, only 40 acres were in production and in combination with wild collected fruit had a market value of $95,000 (Anonymous 1985). Passionfruit is presently cultivated on all islands where P. mollissima is established, but is grown at elevations of less than 300 m (1,000 ft.). Of the eight fields identified during this study, all were at least 20 or more km from the nearest P. mollissima infestation. At three plantations, where the owners would discuss cultivation, all admitted having problems with other insects, including scales, mealybugs and the immigrant butterfly Agrellis vanillia, that were severe enough to require the use of chemical insecticides several times a year.

In host testing at the HVNP quarantine facility, C. necyria was found capable of completing larval development and pupating on P. edulis although this plant was definitely not a suitable host since of the 90 larvae tested only four developed into pupae, none of which emerged as adults (Table 3). Due to the economic value of passionfruit and the ability of at least a few larvae in the first series of feeding tests to develop, a second series of feeding tests was conducted.

Methods

The second series of feeding tests utilized a pair of P. mollissima and P. edulis plants, each in a separate cage. Plants used were large, mature plants containing all ages of foliage as well as bud, flower and green fruit. Two hundred larvae all of the same age were collected from the breeding colony, randomly divided into the group and 100 larvae (75 in one test when we had a shortage) placed in each cage. The test was repeated 5 times, each time using a different pair of plants. Plants were then observed at weekly intervals, until all larvae had died or pupated.

Results and Discussion

Results of this second series of feeding tests (Table 4) agree with those of the first. In all tests, feeding on P. edulis was minimal, while the check P. mollissima plant would be entirely stripped of foliage (Fig. 5). On P. edulis most larvae disappeared within 21 days and less than 2% survived to pupal stage (as opposed to 32 to 81% pupation on P. mollissima checks).

Any threat the introduction of C. necyria may pose to the passionfruit industry is minor. Climatically, the insect is not capable of surviving below 300 m (1,000 ft.) where passionfruit is grown, except possibly for brief periods during winter months. Infestation would require that adults, which are poor fliers, migrate or be carried at least 20 or more kilometers down a gradient of 1,000 m to reach the fields. Even if a fertile female should reach a passionfruit field, passionfruit leaves are not an attractive oviposition site and the female would probably migrate on after depositing only a few eggs. Any larvae that might hatch would find passionfruit an unsuitable host and none would survive to pupation. All of this indicates that while an occasional larva might be found in passionfruit fields, this plant is an unsuitable host incapable of supporting a self-perpetuating population and too distant from a permanent source of C. necyria to sustain a population by migration.

CLIMATIC RANGE

In South America, C. necyria are restricted to the cool wet slopes of the Andes Mountains between 2,700 and 3,300 m (9,000 to 11,000 ft.) (Pers. comm. Dr. M.R. de Hernandez). Here, nighttime temperatures range from 5°C to 10°C and daytime temperatures from 15°C to 20°C with extremes of 25°C when the sun is out. In the quarantine in Hawai'i, adult activity began at 15°C and we observed flying by adults between 20°C and 25°C, mating from 15°C to 25°C and egg laying from 15°C to 25°C. Above 25°C, adults became totally immobile and hid under leaves. In the quarantine facility, adult infertility occurred in late summer when temperatures regularly exceeded 25°C for more than a few hours a day.

One of the major questions concerning the biology of C. necyria was whether its climatic range was great enough that it could survive and reproduce at elevations between sea level and 300 m where most other species of Passiflora are found, including the commercially grown edible passionfruit, P. edulis.

Methods

To investigate the ability of this insect to survive and develop under temperatures representative of various locations on the island of Hawai'i, National Oceanic and Atmospheric Administration weather station records were examined and five sites at various elevations or locations on the island of Hawai'i selected. Environmental chambers were set to the average August temperature of each of these five locations (Table 1). Next, all the eggs laid over a period of 2 days by several large laboratory breeding colonies of C. necyria were collected, combined together and randomly divided into five equal sized batches. One batch of eggs was then placed in each of the environmental chambers. This was repeated at two- or three-day intervals until each chamber contained about 100 eggs. Eggs were allowed to develop and hatch and the resulting larvae reared in petri dishes on P. mollissima foliage until pupation. The percent of the eggs that eventually developed to pupa was estimated to be the rate of survival that might be expected at each of the island locations.

An additional test was also conducted using a chamber set at 10°C which was close to the average January temperature (11.1°C) for Kulani Camp to determine if the insect could develop at this low temperature. This elevation and location is representative of the main infestation of P. mollissima on the island of Hawai'i and represents the winter temperature which the insects could be expected to encounter in the field if released. One additional temperature, 7.5°C, was chosen not on the basis of any climatic stations (none were located above 1,560 m) but was added to observe the response of the insect to a very low temperature, and one that might be encountered in winter at some of the highest elevations at which P. mollissima has been found, 2,100 m (7,000 ft.).

Results and Discussion

The results of development at these various temperatures are shown in Table 5. At 7.5°C, no development was observed in eggs and very little larval growth occurred, with only small amounts of feeding noted. However while eggs, removed after 30 days, appeared to be inviable, larvae, pupae and adults held at this temperature for up to 30 days resumed normal development when moved to warmer temperatures. Egg hatch, larval feeding and larval growth proceeded normally from temperatures of 10°C to 20°C. However survival at 20°C had begun to decrease and stopped at 27°C. Based on the observations of lack of adult activity above 25°C, suspected infertility at higher laboratory temperatures, and the inability of eggs and larvae to survive at temperatures higher than 25°C, we expect that a mean daily temperature of 25°C is a maximum at which survival could occur.

The cool temperatures (10°C to 20°C) in which development takes place are typical of those we have observed at 900 to 1,950 m (3,000 to 6,000 ft.) in the forest of Hawai'i where P. mollissima is most abundant. Climatically, therefore, this insect should be well adapted to most of the present range of P. mollissima. Also if these data are truly representative of the natural climatic range of this insect, it would indicate that elevations between sea level and 900 m are totally inhospitable to this insect in summer and only marginally suitable for short periods during the winter.

CONCLUSION

Based on the studies conducted, it is our conclusion that any theoretical threat that C. necyria may pose to the passionfruit industry has no support based on the limited climatic range of C. necyria, the total unsuitability of its foliage as a food source for larval development and the unattractiveness of the plant to egg-laying females. The release of C. necyria therefore presents no threat to the passionfruit industry. Its release presents a slight risk to the noncommercial P. ligularis in certain areas of the higher forests of Hawai'i, and a small but acceptable risk to the other species of Passifloraceae in Hawai'i. It is our conclusion that the benefit to the Hawaiian forest of the successful establishment of C. necyria on P. mollissima as a biocontrol agent far outweighs the other small risks posed to other species of Passiflora in Hawai'i.

It should be noted that all tests utilized a colony of C. necyria that originated in the State of Narino, Colombia. This limited genetic pool should not be assumed to represent the potential variability that might be encountered over the entire range of this species in South America. Any future collection of additional insects for release in Hawai'i, therefore, should only come from this same wild population.

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Table 1. Ovipostion by female of _C_. _necyria_ when simultaneously offered a bouquet of _P_. _mollissima_ and another species of Hawaiian _Passiflora_.

Passiflora sp. being tested	Time replicated	Total no. of eggs: _P_. _mollissima_	Total no. of eggs: Test species	No. of eggs on test species as % of all eggs
_P_. _edulis_[1]	10	1386	96	6.50
_P_. _foetida_	5	828	0	0.00
_P_. _ligularis_	5	685	1	0.15
_P_. _malva_	5	313	59	15.60
_P_. _pulchella_	5	494	144	22.60
_P_. _suberosa_	5	430	7	1.60
Brassica sp.[2] (Mustard cabbage)	3	484	26	5.10

1 Include both purple and yellow varieties.

2 A nonperfered plant on which testing and light feeding (but no growth or development) occurred.

Table 2. List of plants (other than Passifloraceae) on which feeding tests of *C. necyria* were conducted.

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Anacardiaceae	*Mangifera indica* (Mango)	1	12/16/86	15/5	No feeding.
Apocynaceae	*Alyxia olivaeformis* (Maile)	1	11/18/86	15/3	No feeding.
Araceae	*Colocasia esculenta* (Taro)	1	12/09/86	15/5	No feeding.
	Anthurium andraeanum (Anthurium)	1	12/09/86	15/5	No feeding.
Bromeliaceae	*Ananas comosus* (Pineapple)	1	07/24/86	15/5	No feeding.
Caricaceae	*Carica papaya* (Papaya)	1	05/30/85	50/3-4	No feeding.
Chenopodiaceae	*Spinacia oleracea* (Spinach)	1	07/29/86	15/5	No feeding.
Compositae	*Lactuca sativa* (Lettuce)	1	06/25/85	30/4	No feeding.
		2	09/18/85	30/4	No feeding.
		3	07/29/86	15/5	No feeding.
	Arctium lappa (Burdock-Gobo)	1	08/20/86	15/5	No feeding.
	Dubautia arborea (Na'ena'e)	1	09/09/86	15/5	No feeding.
Convolvulaceae	*Ipomoea batatas* (Sweet Potato)	1	09/03/86	15/7	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Cruciferae	<u>Brassica</u> sp. (Kohlrabi)	1	05/30/85	30/3-4	Tasting or very minor feeding; all died after 13 days.
		2	01/27/87	15/3-4	No feeding.
	<u>Brassica</u> sp. (Brussel Sprouts)	1	05/30/85	30/3-4	No feeding.
	<u>Brassica</u> sp. (Cabbage-Earliana)	1	06/25/85	30/4	Some light feeding in all 3 treat -ments.None alive after 22 days.
		2	01/27/87	15/3-4	No feeding.
	<u>Brassica</u> sp. (Chinese Cabbage)	1	08/05/86	15/5	Moderate feeding in jar; light to moderate feeding in plastic sack and petri-dishes. No growth. All dead in less than 16 days.
		2	11/12/86	4/3	No feeding.
		3	12/10/86	5/5	No feeding on mature, store-bought cabbage.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Cruciferae	Brassica sp. (Mustard Cabbage)	1	08/05/86	15/5	Light feeding in all treatments. No growth, all died by 20 days.
		2	11/12/86	9/5	Some tasting. All died by 8 days.
	Nasturtium officinale (Watercress)	1	07/24/86	15/5	No feeding.
	Brassica sp. (Broccoli)	1	01/17/87	15/4	No feeding.
	Brassica sp. (Turnip)	1	01/27/87	15/4	No feeding.
	Raphanus sp. (Radish)	1	01/27/87	15/4	No feeding.
Cucurbitaceae	Cucurbita pepo (Zucchini)	1	05/30/85	30/3	Minor feeding in petri-dishes. All died in less than 21 days.
	Cucurbita pepo (Pumpkin-New Zealand)	1	05/30/85	30/3	Minor feeding in petri-dishes. All died in less than 21 days.
	Cucurbita pepo (Pumpkin-Small Sugar)	1	07/29/86	15/5	No feeding.
	Cucurbita pepo (Pumpkin-Tetsukabuto)	1	07/29/86	15/5	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Cucurbitaceae	Cucumis sativus (Cucumber-Straight-Eight)	1	05/30/85	30/3	No feeding.
		2	07/17/85	15/5	Some feeding in plastic sack and petri-dishes. All died in less than 15 days.
	Cucumis sativus (Cucumber-Burpee Hybrid)	1	06/25/85	30/3	Moderate feeding in petri-dishes. No feeding after 14 days. No growth, last larvae died by 22 days.
		2	07/31/86	15/5	No feeding.
	Cucumis sativus (Cucumber-F1 Hybrid)	1	07/29/86	15/5-7	No feeding.
	Cucumis sativus (Cucumber-Palace Pride)	1	07/29/86	15/5	No feeding.
	Cucumis sativus (Cucumber-Bush)	1	07/31/86	15/5	No feeding.
	Citrullus vulgaris (Watermelon-Charleston Gray)	1	08/09/85	30/3	No feeding.
	Citrullus vulgaris (Watermelon-Chilean Black Seeded)	1	08/09/85	30/3	No feeding.
	Citrullus vulgaris (Watermelon-Gold Baby)	1	07/31/86	15/3-5	No feeding.
	Cucumis melo var. Cantalupensis (Cantaloupe-Imperial 45)	1	08/09/85	30/3	No feeding.
		2	07/22/86	15/5	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Cucurbitaceae	Cucumis melo var. cantalupensis (Cantaloupe-Hale's)	1	07/22/86	15/5	No feeding.
	Momordica charantia (Bittermelon-S.Point-Wild)	1	07/22/86	15/5	No feeding.
	Lagenaria leucantha (Hyotan-Early Green Skin)	1	07/22/86	15/5	No feeding.
	Benincasa hispida (Toogan)	1	08/07/86	15/5	No feeding.
	Cucurbita maxima (Squash-Summer)	1	07/31/86	15/5	No feeding.
	Luffa sp. (Gourd-Hechima Sponge)	1	08/05/86	15/5	No feeding.
Dicksoniaceae	Cibotium chamissoi (Tree Fern)	1	12/09/86	15/5	No feeding.
Epacridaceae	Styphelia tameiameiae (Pukiawe)	1	12/02/86	15/5	No feeding.
Ericaceae	Vaccinium reticulatum (Ohelo)	1	07/22/86	15/5	Tasting on bouquet in plastic sack. All larvae died in less than 12 days.
		2	02/17/87	15/5	No feeding.
Gramineae	Saccharum officinarum (Sugarcane)	1	06/18/86	15/4-5	No feeding.
	Zea mays (Corn-Sweet, Mainliner)	1	07/29/86	15/5	No feeding.
	Pennisetum clandestinum (Kikuyu Grass)	1	12/16/86	15/5	No feeding.
	Bambusa sp. (Bamboo)	1	12/16/86	15/5	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Lauraceae	Persea americana (Avocado)	1	08/07/86	15/5	No feeding.
Leguminosae	Phaseolus sp. (Beans-Bush)	1	06/25/85	30/3	Some feeding in plastic sack and petri-dishes. No growth, all died less than 4 days.
		2	09/03/86	15/7	No feeding.
	Phaseolus sp. (Beans-Pole)	1	09/30/86	15/5	No feeding.
	Pisum sativum var. macrocarpon (Peas-Chinese)	1	06/25/85	30/3	Some minor feeding in plastic sack and petri-dishes. All died in less than 8 days.
	Glycine max (Soybeans)	1	08/12/86	15/5	No feeding.
	Arachis hypogaea (Peanuts)	1	08/12/86	15/5	No feeding.
	Acacia koa (Koa)	1	07/07/86	15/5	No feeding.
	Vicia manziesii (Hawaiian Pea)	1	09/09/86	10/5-7	No feeding.
	Sophora chrysophylla (Mamane)	1	12/02/86	15/5	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Liliaceae	*Allium cepa* (Onion-Maui, Granex)	1	06/25/86	30/3	No feeding.
	Allium fistulosum (Green Onion)	1	07/24/86	15/5	No feeding.
	Cordyline terminalis (Ti-Leaf)	1	08/12/86	15/5	No feeding.
Musaceae	*Musa* sp. (Banana-Williams)	1	07/24/86	15/5	No feeding.
Myoporaceae	*Myoporum sandwicense* (Naio)	1	12/02/86	15/5	No feeding.
Myrtaceae	*Psidium guajava* (Guava)	1	08/12/86	15/5	No feeding.
	Metrosideros collina subsp. *polymorpha* (Ohia)	1	07/11/86	15/3-5	No feeding.
	Eucalyptus saligna (Saligna eucalyptus)	1	12/02/86	15/5	No feeding.
	Eugenia uniflora (Surinam Cherry)	1	12/16/86	15/5	No feeding.
Orchidaceae	*Dendrobium* sp. (Dendrobium Orchid)	1	12/09/86	15/5	No feeding.
Palmae	*Cocos nucifera* (Coconut)	1	12/16/86	15/5	No feeding.
Polypodiaceae	*Sadleria cyatheoides* (Amaumau Fern)	1	12/09/86	15/5	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Proteaceae	Macadamia ternifolia (Macadamia Nut)	1	07/09/86	15/4-5	No feeding.
Rosaceae	Rosa sp. (Rose)	1	07/09/86	15/3	No feeding.
	Fragaria chiloensis (Native Strawberry)	1	06/16/86	15/5	No feeding.
Rubiaceae	Coffea arabica (Coffee)	1	07/07/86	15/5	No feeding.
Rutaceae	Citrus sp. (Meyer's Lemon)	1	08/07/86	15/5	No feeding.
	Citrus sp. (Navel Orange)	1	08/12/86	15/5	No feeding.
	Flindersia brayleyana (Silkwood)	1	12/02/86	15/5	No feeding.
Santalaceae	Santalum ellipticum (Sandalwood)	1	12/02/86	15/5	No feeding.
Sapindaceae	Dodonaea sp. (Aalii)	1	12/02/86	15/5	No feeding.
	Litchi chinensis (Litchi)	1	12/23/86	15/5	No feeding.
Solanaceae	Lycopersicon esculentum (Tomato)	1	12/02/86	15/5	No feeding.
	Lycopersicon esculentium var. cerasiforme (Cherry Tomato)	1	05/30/85	30/3	No feeding.

Table 2. (Cont'd)

Family	Plant Species	Test No.	Date Placement	Larvae #/Size mm	Comments
Solanaceae	Solanum tuberosum (Irish Potato)	1	07/31/86	15/5	No feeding.
	Capiscum annuum var. grossum (Bell Pepper)	1	11/18/86	15/3	No feeding.
	Solanum melongena (Eggplant-Japanese, Long-Black)	1	09/03/86	15/5	No feeding.
	Physalis peruviana (Poha)	1	12/16/86	15/5	No feeding.
Sterculiaceae	Theobroma cacao (Cocoa)	1	11/18/86	15/4	No feeding.
Violaceae	Viola tricolor var. hortensis (Pansy-Garden)	1	6/18/86	15/5-10	No feeding.
Zingiberaceae	Zingiber officinale (Ginger-Edible)	1	11/26/86	15/4-8	No feeding.

Table 3. Feeding test of C. necyria on representative species or varieties of Hawaii Passiflora.

Passiflora Species	Test No.	Date Placement	Larvae #/Size (mm)	+/-[1] Results	# to Pupate or Largest Larvae Stage Reared
P. edulis (Wild-type, purple fruit)	1	07/17/85	15/12-15	-	1 prepupa (died)
	2	07/24/86	15/5	-	No growth
	3	08/05/86	15/5	-	No growth
Total			45		1 prepupa
P. edulis f. flavicarpa (lilikoi, commercial passion fruit)	1	05/16/85	31/3	+	3 pupa - developed to to pupa in 40 days.
	2	08/14/86	15/5	-	Grew to 8mm in 29 days before dying.
	3	02/03/87	15/3-4	-	Grew to 10 mm in 52 days before dying.
Total			61		3 pupae
P. foetida (Green fruit)	1	05/16/85	30/3	-	No growth
	2	07/17/85	15/12-15	+	5 pupae
	3	07/11/86	15/5	-	No growth
Total			60		5 pupae
P. foetida (Red fruit)	1	05/28/85	30/3	+	19 pupae - developed to pupa in 36 days (ave.)
	2	11/10/86	15/5	+	18 mm - incomplete - foliage ran out, development normal at the time.
Total			45		19 pupae

1 + = Positive; - = Negative

Table 3. (Cont'd)

<u>Passiflora</u> Species	Test No.	Date Placement	Larvae #/Size (mm)	+/- Results	# to Pupate or Largest Larvae Stage Reared
P. ligularis	1	05/16/85	30/3	-	No growth
	2	07/17/85	15/12-15	+	5 pupae
	3	08/07/86	15/5	-	No growth
Total			60		5 pupae
P. malva	1	05/16/85	30/3	-	No growth
	2	07/17/85	15/12-15	-	No growth
	3	08/05/86	15/5	-	No growth
Total			60		
P. mollissima	1	05/16/85	30/3	+	19 pupae - developed to pupa in 33 days (ave.)
	2	06/16/86	15/5	+	12 pupae - developed to pupa in 28 days (ave.)
	3	07/11/86	15/3-5	+	10 pupae - developed to pupa in 31 days (ave.)
	4	07/22/86	15/5	+	11 pupae - developed to pupa in 33 days (ave.)
	5	07/31/86	15/5	+	13 pupae - developed to pupa in 25 days (ave.)
	6	08/12/86	15/5	+	12 pupae - developed to pupa in 29 days (ave.)
	7	09/03/86	15/5	+	14 pupae - developed to pupa in 29 days (ave.)

Table 3. (Cont'd)

Passiflora Species	Test No.	Date Placement	Larvae #/Size (mm)	+/- Results	# to Pupate or Largest Larvae Stage Reared
P. mollissima	8	11/12/86	15/5	+	6 pupae - developed to pupa in 43 days (ave.)[2]
	9	01/27/87	15/3-4	+	12 pupae - developed to pupa in 48 days (ave.)
Total			150		109 pupae
P. mollissima (Banana poka - dwarf variety)	1	05/16/85	30/5	+	15 mm (27 alive at 13 days when foliage ran out)
Total			30		
P. pulchella	1	11/12/86	7/5	+	4 pupae - developed to pupa in 43 days.
	2	02/03/87	15/4	+	9 pupae - developed to pupa in 45 days.
Total			22		13 pupae
P. quadrangularis (Giant Granadilla)	1	07/09/85	30/3-5	-	No growth
Total			30		
P. suberosa	1	11/12/86	7/2	-	No growth
	2	02/03/87	15/3-4	-	Several developed to third instar before dying
Total			22		

2 Possible microsporidium infected larvae.

Table 4. Comparison of survival of _C_. _necyria_ larvae on mature potted plants of _P_. _mollissima_ and _P_. _edulis_.

Test	Date	Host	No. of Larvae	Instar (Size mm)	% to Pupate	Days to 1st pupa
1	08/20/85	_P_. _mollissima_	100	early 2nd (5)	32[1]	27
		_P_. _edulis_	100	early 2nd (5)	0	--
2	08/26/86	_P_. _mollissima_	100	early 2nd (5)	81	28
		_P_. _edulis_	100	early 2nd (5)	0	--
3	10/01/85	_P_. _mollissima_	75	early 1st (3)	53	31
		_P_. _edulis_	75	early 1st (3)	0	--
4	12/05/86	_P_. _mollissima_	100	middle 3rd (10)	87	22
		_P_. _edulis_	100	middle 3rd (10)	5[2]	77
5	12/16/86	_P_. _mollissima_	100	early 1st (3)	64	41
		_P_. _edulis_	100	early 1st (3)	3[3]	62

1 Low survival was probably due to a microsporidian infection in the breeding colony.

2 From these 8 pupae, 5 adults emerged, all were 1/2 to 2/3 the size of normal adults.

3 From these 8 pupae, 5 adults emerged, all were 1/2 to 2/3 the size of normal adults.

Table 5. Average temperature from five NOAA weather stations for the Island of Hawai'i and the percent of larvae that survived from egg to pupa when reared at the average August temperatures of each. Two additional low temperatures, representative of the extreme winter low temperatures that might be encountered at the higher elevation where P. mollissima is presently found were also included in these tests.

Location	Elevation		Ave. temp. (°C) January	August	Insect rearing[1] Temp.	Survival
	m	ft				pct
Kona	15	50	23.0	27.2	27.2	0.0
Hilo	7.5	25	21.7	24.4	25.0	3.7
Mt. View	450	1500	18.7	20.8	20.0	12.3
Hawaii Volcanoes Nat'l Park[2]	1200	4000	14.7	17.3	17.5	56.0
Kulani Camp[3]	1560	5200	11.1	15.3	15.0	54.0
Kulani Camp	1560	5200	11.1	15.3	10.0	50.0
?	2100	7000	7.55[4]	?[5]	7.5	0.0

1 100+ eggs per test, replicated 5 times each with 20 eggs reared at constant temperature in environmental chambers.

2 Location of quarantine where study was conducted.

3 Located in wet native forest, typical of most favorable habitat for P. mollissima.

4 2100 meters is the upper elevation at which P. mollissima is normally found.

5 No NOAA weather stations are located near this altitude, this temperature was estimated by drawing a regression based on the four previous locations.

Fig. 1. Typical scene in native forest where P. mollissima has become established.

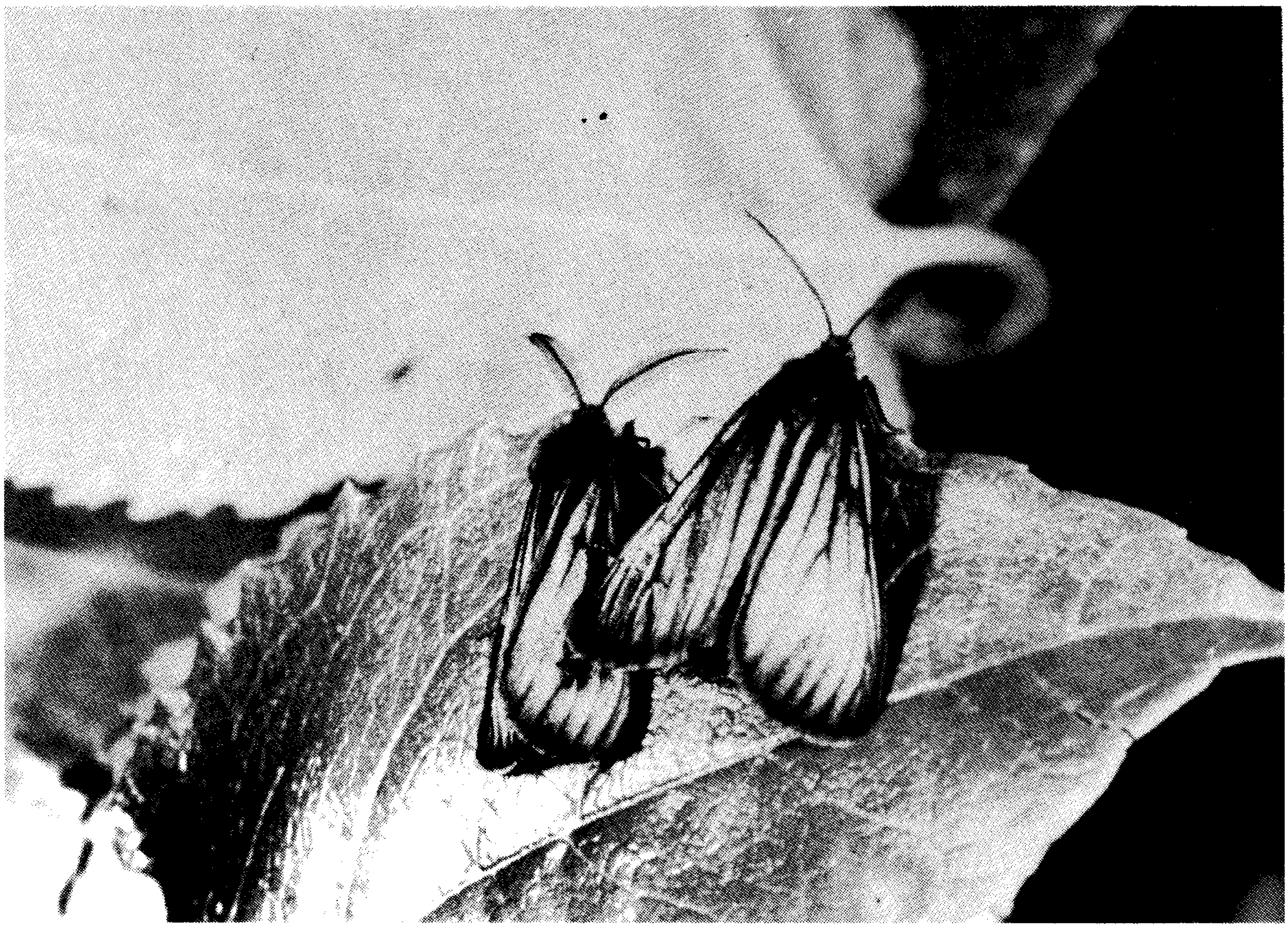

Fig. 2. Pair of adult C. necyria. Male is on left with feather-like antennae.

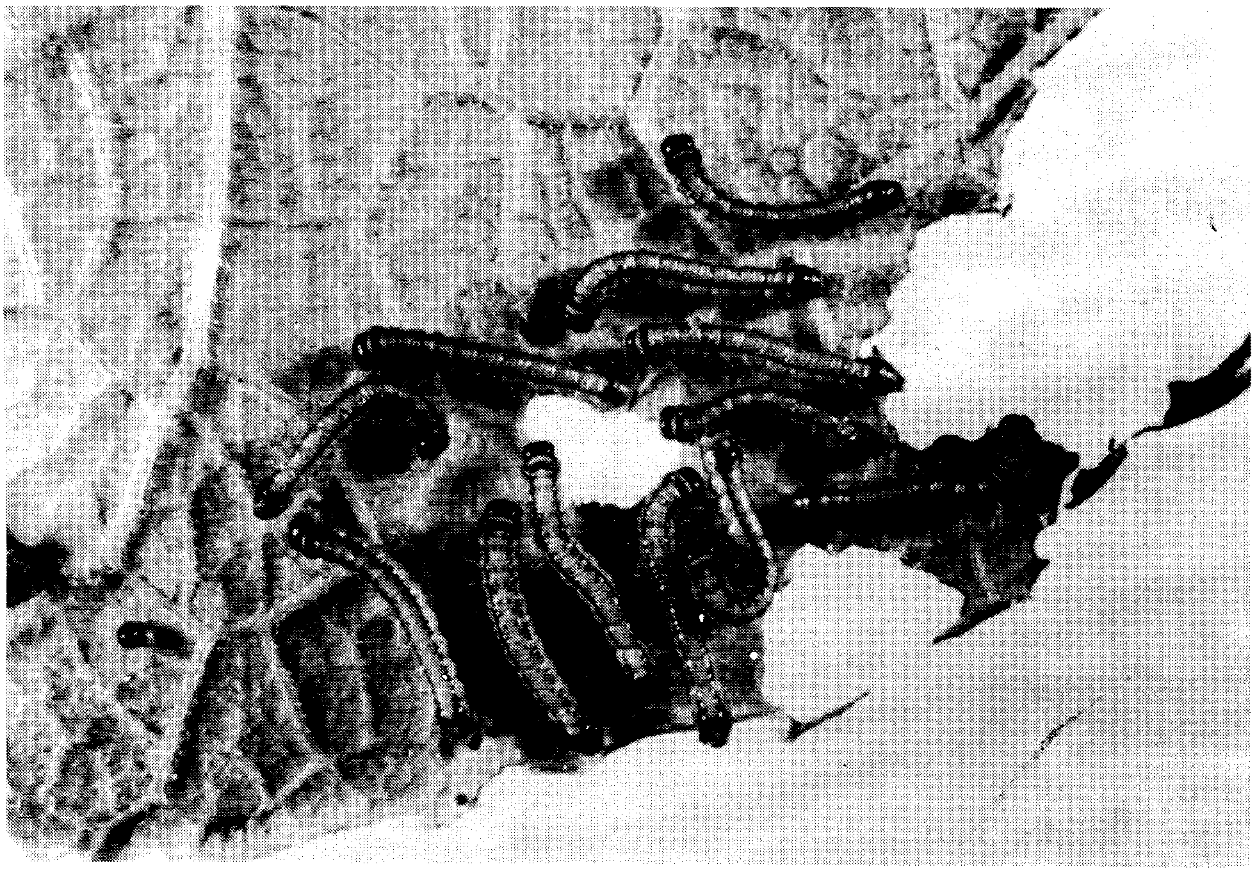

Fig. 3. Late first instar larvae of C. necyria feeding gregariously.

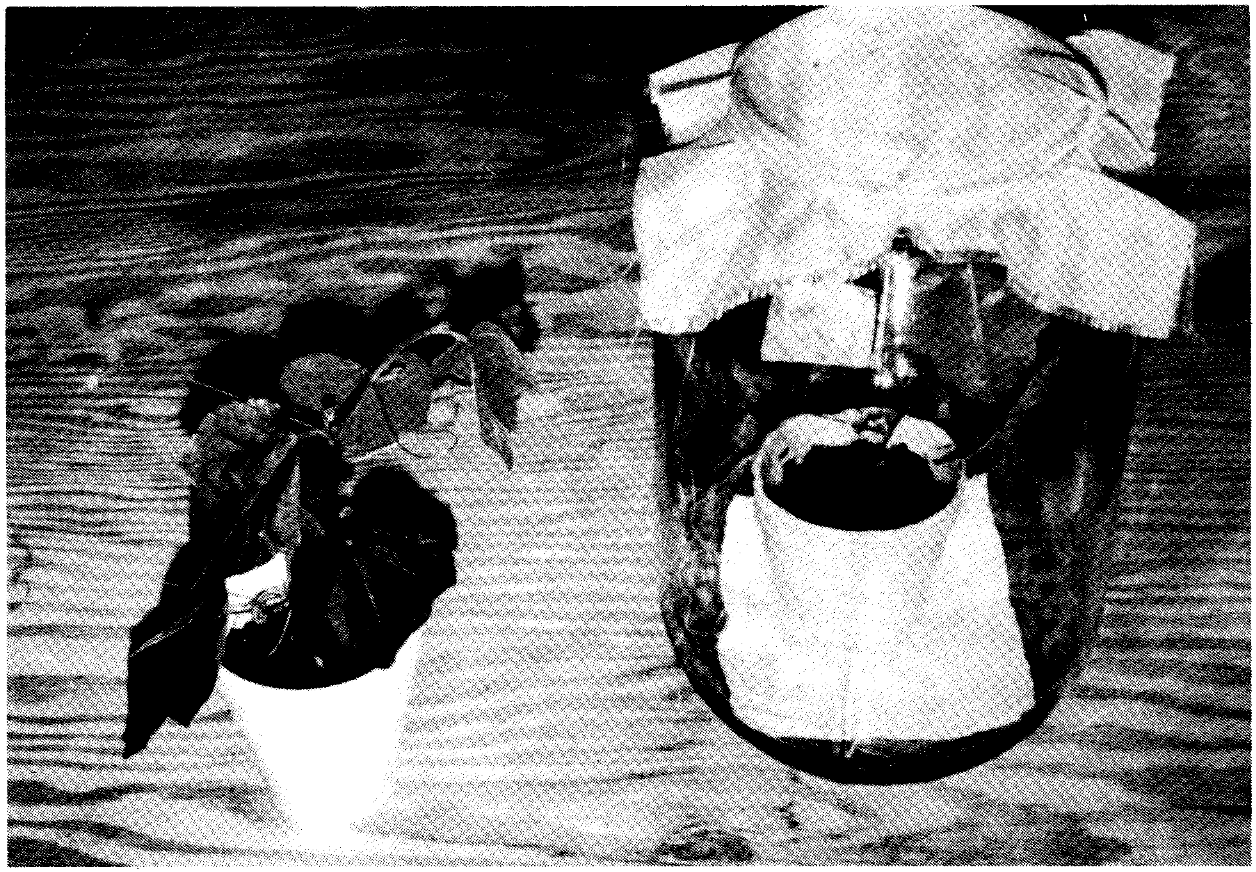

Fig. 4. Potted seedling plants ready for host testing.

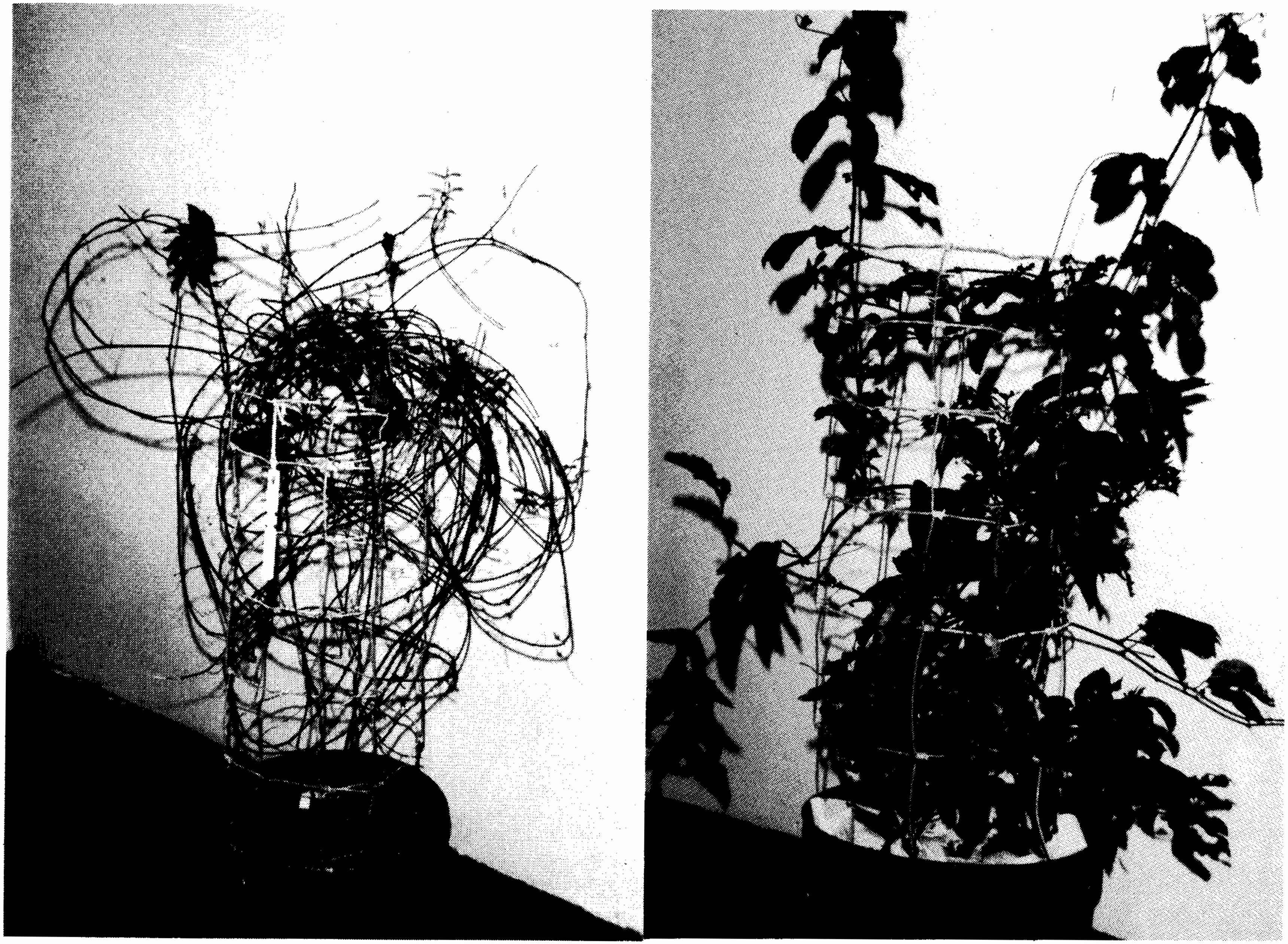

Fig. 5. Two equal sized plants, on left P. mollissima and on right P. edulis after 30 days feeding by 100 C. necyria larvae.