Notes on the Life History and Ecology of Blossom Midge, Contarinia lycopersici Felt (Diptera: Cecidomyiidae)

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Contarinia lycopersici Felt was described in 1911 (2)[2] from specimens reared from tomato flowers at St. Vincent, West Indies. What is apparently the same species has been known to infest tomato blossoms in Hawaii since 1906 (7) when it was reported under the name *Contarinia solani* (Rübsaamen). In a recent paper (5) the writer reported this to be the same species that was described from hibiscus in 1933 (3) under the name *C. maculipennis* Felt. It was shown further that the species infests an exceptionally wide range of host plants in Hawaii. The determined hosts include several species of *Lycopersicon* (tomato), *Capsicum frutescens* L. (garden pepper), *Solanum melongena* L. (eggplant), *Solanum rantonnetii* Carr. (Paraguay nightshade), *Solanum tuberosum* L. (Irish potato), *Momordica charantia* L. (bitter melon), *Hibiscus* sp., *Jasminum sambac* Soland. (pikake) and *Brassica chinensis* L. (white mustard cabbage or pak choy).

Specimens reared in Hawaii appear to be indistinguishable morphologically from those in Trinidad (5). The primary inconsistency between the two areas is that in the West Indies the species has thus far been recorded only from tomato. The name *C. lycopersici* is being applied tentatively to the species in Hawaii. Should this species prove to be distinct from *lycopersici* of the West Indies, then the name *C. maculipennis* will be the valid name for the Hawaiian species.

The present paper summarizes the investigations carried out on the life history and ecology of *C. lycopersici* which were not reported in previous papers (5, 6). The study was made while the writer was at the University of Hawaii during the years 1944-1946.

BLOSSOM MIDGE INJURY

Tomato blossoms infested with midge larvae usually develop characteristic symptoms. The outside of the syngenesious androecium (formed by a fusion of the stamens) frequently develops a yellowish brown color and may show brown and necrotic longitudinal streaks. Inside the androecium the stamens have similar streaks and the tissue is partially broken down and moist. The basal portion usually shows the most injury. The ovary is frequently partially destroyed and becomes brown about the

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[2] Figures in parentheses refer to literature cited at the end of the article.

injured areas. The pistil is less frequently damaged. The petals of infested blossoms often fail to open normally but wilt and crumple down against the androecium. When heavy infestations reach advanced stages before the buds mature, the buds fail to open and are killed.

Blossom drop of tomato due to this midge has been reported several times in Hawaii. In 1944 it was listed by Holdaway (4) as a submajor pest of eggplant and pepper as well as of tomato. Callan (1) believes that in Trinidad it is the most important factor in the destruction of tomato flowers and the resulting loss of crop.

LIFE HISTORY

EGGS. The eggs of *Contarinia lycopersici* are normally deposited on the inside walls of the tube formed by the fusion of the stamens into the syngenesious androecium of the tomato bud. In most cases the eggs are placed in the narrow distal neck portion, but they may also be laid near the base. The adults do not penetrate the walls of the androecium but insert the ovipositor through the open distal end. In two instances dead females were found with their ovipositors still inserted through this aperture. In a few instances eggs have been laid on the outside of the androecium, but this is relatively rare and probably occurs when entry into the androecium is prevented and when the impulse to oviposit is too strong for the female to inhibit until a favorable bud is found.

The eggs usually occur in masses with varying numbers of eggs per mass. They are whitish to cream colored, 0.17 mm. long and about 0.085 mm. wide at the middle. The ends are somewhat tapered and rounded and the egg as a whole is slightly bowed.

The exact incubation period of the eggs has not been determined. It must be very short, however, because the eggs hatch and most of the larval development occurs in about five to seven days.

LARVAE. The larvae are whitish in color while young, but as they mature they become yellow and sometimes have a pink cast. Mature individuals vary in length from 1.75 to 2.3 mm. and are about 0.45 mm. wide.

On tomato the larvae feed on the inside walls of the fused stamens and to a lesser extent at the base of the androecium and on the ovary. When present in large numbers in green buds the larva are literally bathed in the fluids released from the injured plant tissues. In heavily infested hibiscus flower buds, the larvae occur among all of the flower parts, such as between the unexpanded petals and around the base of the reproductive organs. The young tight buds are very moist inside when infested, but the larvae find the environment favorable. In the buds of *Jasminum sambac* Soland. the larvae occur anywhere within the flower buds but are found most commonly in the basal portion around the reproductive organs. Some infested buds contain a considerable amount of liquid on the tissue surface. The liquid layer may almost completely envelop the larvae in heavily infested buds which are being severely damaged.

The number of larvae per infested tomato bud varied from 1 to 44 in 104 infested buds for a mean of 7.2 per bud. This was based on dissection of 2089 buds representing several species of *Lycopersicon.*

Midge larvae travel in the soil and within the blossoms by crawling. On an open, exposed surface, however, they jump readily. This is accomplished by drawing the two ends of the body together, thus arching it in the middle, and then flipping the body into the air. By this means they can, in one jump, be thrown into the air about two inches and alight several inches from the starting position.

LENGTH OF LARVAL PERIOD. The normal duration of larval life has not been precisely determined. However, in previously reported breeding experiments on tomato with midge adults reared from hibiscus, pikake and tomato, eggs were laid, hatched and some of the larvae attained mature size within five to seven days (5).

As supplementary evidence that the time required for hatching of the egg and for larval development is short, the results of an experiment on the control of blossom midge with DDT are pertinent. Bounty tomato plants were sprayed or dusted with DDT on May 13, 1944. Three days later 303 buds and blossoms were picked and dissected for larvae and eggs. Records were kept according to the size of the bud. Typically the eggs are laid in the small buds (1-5 mm.). In the 303 treated buds and flowers examined, not a single egg was found, and young larvae occurred in only one.

The results of the examination, according to bud size and larval stage follow: 66 small buds with none infested; 82 medium sized buds, 1 infested with medium sized larvae and 7 with near-mature larvae (0.097 per cent); 81 buds ready to open, 7 infested with medium sized larvae and 14 with maturing larvae (26 per cent); 74 mature flowers, 1 flower with small larvae, 6 with medium sized larvae and 18 with large larvae (34 per cent).

In another planting of Bounty tomatoes, free from DDT treatment, having 37 per cent of the mature flowers infested with larvae, 24 per cent of the young buds were infested with eggs.

DDT prevented oviposition on the treated plants, but apparently did not affect the hatching of eggs already laid or the development of the larvae in the buds. These data indicate that the eggs hatched and the larvae developed at least half way to maturity within the three-day period between treatment and examination except in the case of one mature flower which still carried small larvae. If a longer period for hatching and larval development were required, unhatched eggs and a greater proportion of small larvae would have been present.

When larval maturity is reached, or if the flower begins to dry, or for some other reason becomes unsuitable for the larvae, they leave the flowers and buds and drop to the soil in which they pupate.

Typically adults emerge 14 days after the larvae enter the soil. The length of time normally spent in the soil as larvae, before pupation, was not determined, but the fully mature larvae probably pupate within a day or two. Callan (1) found pupae on the third day after entry of the larvae into the soil, but did not determine how much earlier than the third day pupation occurred.

The present studies revealed that in some circumstances the larvae may remain in the soil for a number of days without pupating. Lack of adequate soil moisture apparently is one factor responsible for retarding or preventing pupation. Larval immaturity also may delay pupation.

Effect of Larval Immaturity at Time of Soil Entry. An experiment was conducted to determine if larvae which had not attained maturity while in the host flowers could develop into adults. On January 12, 1945, small and medium sized larvae from pikake flowers were placed in a pupation vial. All mature larvae were excluded. On January 26, 14 days after the larvae entered the soil, 18 adult males and 6 females emerged. Seventeen days after entering the soil 9 females and 6 males were found in the vial and removed. During the same evening 3 more females emerged. On the 18th day in the soil 3 more females and 2 males emerged.

All of these adults were distinctly smaller than were the adults which developed from obviously mature larvae. Moreover, a number of them required from three to four days longer in the soil than is normally the case. Twenty-four, however, emerged on the 14th day, which is average for normal adults. These results suggest that full larval maturity is not essential for an individual to attain the adult stage. However, larval immaturity at the time of pupation appears to be reflected in smaller adults. Moreover, the pupation period apparently is somewhat extended in some instances.

Pupae. After entering the soil the mature larvae pupate below the soil surface. Rearing experiments indicated that for best results the soil should be moist but not wet. In these studies large glass jars were used for heavy infestations and shell vials three inches high and one inch in diameter were used when small numbers were involved.

A capsule-shaped hollow cell, in which pupation occurs, is formed in the soil by the larva. Some of the pupae visible through the glass of the rearing vials were yellowish white in color while others, presumably older, were brown.

Length of Pupal Period. The exact length of the pupal period has not been determined. The experimental results available deal only with the lapse of time from entry of the larvae into the soil until the adults emerge. Callan (1) reports this as being from 9 to 12 days in Trinidad. In Hawaii a longer period has been found. For apparently mature larvae in suitably moist soil the minimum time is 12 days and the maximum 15 days with a mean of 14 days. This was based on 28 different lots of insects at various times of the year. The plant hosts were tomato species primarily but also included *Capsicum frutescens* L. (pepper), *Solanum rantonnetii* Carr. (Paraguay nightshade), *Solanum tuberosum* L. (Irish potato), *Momordica charantia* L. (bitter melon), *Hibiscus* sp., and *Jasminum sambac* Soland. (pikake). The time used in these results was measured from entry of the larvae into the soil until the appearance of the first adults. In most cases adults continued to emerge for a few days in low numbers. However, it is probable that some of the retarded individuals developed from immature larvae.

When the adults are ready to emerge, the pupae work their way to the surface of the soil where three-fourths of the pupal body is extended almost vertically above the surface with the caudal one-fourth left inserted in the soil to hold the pupa erect. The adult then emerges, leaving the pupal skeleton protruding from the soil.

ADULTS. Typically the adults emerge during the early evening hours between sundown and darkness. A few emerge at other times during the day or night, but they constitute a small minority. In one experiment more than 60 adults emerged during a two-hour period in the evening, and only 15 emerged during the remaining 22 hours of the day.

Neither mating nor oviposition was observed in Hawaii. Callan (1) reports that in Trinidad oviposition begins about 5:30 p.m. and ceases at about 6:45 p.m. in July, when there is little light after 6:30 p.m.

The total number of eggs laid by a single female is unknown. It is probable that one female lays eggs in more than one bud. The number of eggs per infested bud in Hawaii was found to range from one to 37, with a mean of 11.3. This was based on egg counts in 94 infested tomato buds out of 2089 examined.

The blossom midge does not survive long in the adult stage in Hawaii, four days being the longest life recorded for adults caged on tomato plants.

EFFECT OF REDUCED TEMPERATURES. A preliminary experiment was conducted on the effect of reduced temperature on midge larvae and pupae in the soil. Larvae collected from tomato buds at Kipapa Air Field Farm, Oahu, December 7, 1944 were placed in four pupation vials containing moist soil on December 8. The vials, labelled "A", "B", "C", and "D", received the treatments described below.

A This vial was held at normal room temperature as a control.

B After 8 days at normal room temperature, this vial was placed in a room, at 50° F., for six days with a 24-hour period at room temperature between the second and third days in the cold room.

C After 12 days at normal room temperature this vial was exposed to 10 days at 50° F.

D After 12 days at normal room temperature this vial was kept at 50° F. for 26 days.

Group A. Adults began to emerge in the control vial December 22, 14 days after the larvae entered the soil.

Group B. This vial was held at room temperature for 8 days and then exposed to six days at 50° F. with 24 hours at room temperature between the second and third days in the cold room. Three days after being returned to normal room temperature, seven adult males and one female emerged above the soil surface and two additional adults failed to free themselves completely from their pupal skins. All appeared to be weaker than normal. Several other adults had emerged from their pupae within

the soil but failed to reach the surface. On December 29, 21 days after the larvae entered the soil, 13 more adults emerged. These appeared vigorous and normal. A number of larvae had not pupated by the time the vials were removed from the cold room. One larva began to move about within one hour after removal to a warm room. On December 29 it was moving about some in a cell in the soil visible through the glass. On January 4 it had still not pupated and was inactive. By January 16 the soil in the vial had dried out considerably and was remoistened. Within one minute after moisture penetrated to the visible larva it moved out of sight through the soil.

On January 29, 52 days after the larvae originally entered the soil, one female and five males emerged. The fact that emergence of a few adults was retarded for such a long time can be explained partially on the basis of dehydration of the soil. However, in these instances the larvae evidently did not pupate until long after the normal time period despite favorable moisture and temperature conditions during their first eight days in the soil. It is probable, therefore, that they entered the soil before passing that threshold of larval maturity which permits pupation immediately. The delay may thus have been initially due to larval immaturity and subsequently due to inadequate soil moisture.

Group C. This vial, containing larvae which entered the soil December 8, was placed at 50° F. on December 20, two days before the first adults would normally emerge if left at normal room temperature. After 10 days at 50° F. it was removed to room temperature and the soil moistened a little. On January 1 and 2 more than 20 adults emerged. In this experiment the 50° F. temperature held the pupae inactive, but did not kill them and the adults emerged after two more days at normal room temperature.

Group D. This vial was placed at 50° F. on December 20, two days before the adults would normally have emerged. It was left in the cold room for 26 days and then removed to room temperature January 16, 1945. At this time one larva was visible against the glass and within a few minutes in a warm room it began to crawl. By January 19, three days after removal from the cold room, several pupae had crawled through the soil to the glass walls and three had reached the surface of the soil where they died without adult emergence. The soil was moistened, and within a few minutes several larvae could be seen crawling about within the soil.

On January 29, 13 days after removal from the cold room, one live adult female and one live pupa were on the soil surface. By January 31, nine living adults were on the soil surface and five adults had emerged and were caught below the surface.

It appears that the individuals which had pupated and would normally have emerged two days after removal from the cold room, were so affected by the long exposure that they failed to develop into adults. Those which were in the larval stage during the cold period were able to pupate and emerge as adults two weeks after removal from the cold room.

SUSCEPTIBILITY AND RESISTANCE TO MIDGE ATTACK IN THE GENUS LYCOPERSICON

An interesting relationship was found to exist between the blossom midge and some of the species of tomato which it infests in Hawaii. The commercial tomato, *Lycopersicon esculentum,* variety Bounty, which was commonly grown in Hawaii was found to be a very susceptible host of the blossom midge. At Poamoho, Oahu, July 25, 1945, Bounty strains of tomato were so heavily infested with midge larvae that Dr. W. A. Frazier and Dr. J. S. McFarlane of the University of Hawaii Vegetable Crops Department found it difficult to obtain uninfested flowers to use in pollination work.

On the University of Hawaii campus, in Manoa Valley, the percentage infestation of Bounty buds and flowers commonly ranged from 30 to 50 per cent during the early summer of 1944. Several other species of *Lycopersicon* were being grown on the campus for use in tomato breeding. Midge counts in the buds and blossoms of these wild type tomatoes revealed a strikingly low percentage of infestation compared with Bounty tomatoes growing but a few feet away. *Lycopersicon peruvianum,* which produces a profusion of flowers, was found to have a consistently low infestation. Tables 1 and 2 present a comparison of the infestation in *peruvianum* and Bounty. The results of two days' sampling of each tomato are combined. May 3 was a sampling date common to both species. There was no significant difference in the percentage infestation between the sampling dates.

The tables show that 50 per cent of the buds and blossoms of Bounty were infested with either eggs or larvae as compared with only 6.0 per cent for *peruvianum.*

One probable cause of the marked difference in susceptibility to midge attack shown by these two tomatoes is found in the structure and type of development of the flower buds. The midge adults lay their eggs inside the androecium, usually in the distal portion. They are not able to puncture the tissue, but insert the ovipositor through the open distal end. In *L. esculentum* the petals on the flower buds do not fit tightly into the open end of the androecium and thus permit oviposition while the buds are very small. As indicated in Table 1 the eggs are laid primarily in the very young buds of Bounty and only rarely in the maturing buds and flowers. In contrast, the petals of *peruvianum* fit tightly together against the androecium and the distal ends of the green petals bend over and fit into the neck of the androecium so firmly that oviposition is mechanically obstructed. The petals usually remain in this position until the bud is almost ready to open. Accordingly, only rarely are eggs to be found in the young buds (where they predominate in *esculentum*) and the number of half grown buds is also only slightly infested. Most of the eggs cannot be laid until the buds are ready to open or are opening. In the case of three of the *peruvianum* buds infested with eggs, the midge had not been able to place them inside the androecium and had laid them on the outside.

Table 1.—Infestation of Bounty Tomato Buds and Blossoms with Eggs and Larvae of Contarinia lycopersici Felt (April 29 and May 3, 1944)

	Young buds (1-5 mm. long)		Maturing buds (5-10 mm. long)		Open flowers		Totals	
Number examined	26		40		45		111	
Buds and blossoms infested:	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Number	8	4	3	23	0	17	11	44
Per cent	30.7	15.3	7.5	57.5	0	38	10	40

Table 2.—Infestation of Lycopersicon peruvianum Buds and Flowers with Eggs and Larvae of Contarinia lycopersici Felt (May 1 and May 3, 1944)

	Young buds (1-5 mm. long)		Maturing buds (5-10 mm. long)		Open flowers		Totals	
Number examined	106		184		173		463	
Buds and blossoms infested:	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Number	1	0	11	2	4	10	16	12
Per cent	0.94	0	6.0	1.08	2.3	5.8	3.4	2.6

Since *peruvianum* is not suitable for oviposition until the buds are ready to open there is little time left for the eggs to hatch and for the larvae to mature before the open flower becomes unfavorable for the larvae. Nearly all the larvae recorded from *peruvianum* were small or medium in size.

On May 10, 1944, another sample of 384 buds and blossoms of *peruvianum* were dissected. Of the 26 small buds taken none was infested. One of 76 medium sized buds was infested with two small larvae. Four of 88 buds ready to open were infested with eggs (those in one case occurring on the petal), and two were infested with larvae. Of these two, those in one bud were small and those in the other bud were near maturity. Of 194 open flowers examined, three were infested with eggs. Six of the flowers were infested with larvae, four having small larvae, one with medium sized larvae and one with large larvae. Of the total 384 blossoms taken, 1.8 per cent carried eggs and 2.3 per cent carried larvae.

Lycopersicon chilensis was found to be similar to *peruvianum* in midge infestation. Of 159 buds and blossoms collected and examined May 1, 1944, 26 small buds were uninfested, two of 47 half grown buds carried eggs, 31 buds ready to open were uninfested and of 55 mature flowers examined one was infested with eggs and one with larvae. The combined infestation of eggs and larvae amounted to only 2.5 per cent of the sample.

The adults prefer to lay their eggs in young buds whose growth to maturity approximately parallels that of the larvae. The percentage of maturing buds infested with eggs is about the same in Bounty as in *peruvianum*. This indicates that the failure of the midge to infest a high percentage of *peruvianum* buds at a stage when they are ready to open, and

thus accessible to ovipositing adults, is not due to avoidance of *peruvianum* more than Bounty, but rather due to an inherent reluctance to lay eggs in late stage buds and flowers whether they be Bounty or *peruvianum*.

CONTROL OF BLOSSOM MIDGE WITH DDT

In a preliminary experiment DDT was applied to Bounty tomatoes at the rate of one pound of 20 per cent DDT wettable dust to 100 gallons of water, 1 per cent DDT dust and 2 per cent DDT dust in pyrophyllite. Each treatment was replicated twice and two plants were in each replication. Check plants grew adjacent to the treated plants and were thus partially contaminated by the treatment. The treatment was applied May 13, 1944, and infestation counts were made three days later.

The pertinent results follow: No eggs were found in any of the buds or blossoms except in one flower on a control plant. From 19 to 25 small buds (1-5 mm.) were examined for each treatment and all were free of eggs and larvae—including those on the control plants.

DDT Spray: Of 32 medium buds examined none was infested. Of 57 maturing buds and open flowers 21 (36.8 per cent) carried larvae. *1 per cent DDT Dust*: Of 22 medium buds examined 2 (9 per cent) were infested with larvae. Of 57 maturing buds and flowers, 17 (30 per cent) were infested with larvae. *2 per cent DDT Dust:* Of 28 medium buds examined, 6 (21.4 per cent) were infested with larvae as were 10 (24.4 per cent) of 41 maturing buds and flowers. *Check*: 6 (17.1 per cent) of 35 medium buds were infested with larvae. Of 32 maturing buds 1 was infested with eggs and 12 (37.5 per cent) carried larvae. Of 33 mature flowers 8 (24.2 per cent) were infested with larvae.

Of a total of 423 buds and blossoms examined 81 were infested as follows: 1 bud with eggs, 2 buds with small larvae, 17 buds and blossoms with medium sized larvae, and 61 with maturing larvae.

It is evident from these results that DDT dust and spray prevented the adults from ovipositing. Of special interest is the fact that oviposition was prevented (except in one instance) on the control plants as well. They were adjacent to the treated plants and probably also became partially contaminatd during treatment. Moreover the presence of a predominance of treated plants would affect the midge activity on adjacent control plants. This was borne out later in the season when plots (four plants each) were treated with 1 per cent DDT dust, and 2 per cent DDT dust, each treatment being replicated six times. This was set up for thrips control studies, and the flowers were not examined until six days after treatment. In this case also blossom midge was controlled and no larvae were found in any plants except 2 flowers on control plants. The treatment, repeated every 8 days, resulted in an elimination of the midge population from the control plants as well as from the treated plants.

That the treatments applied were responsible for the above results is indicated by the fact that untreated Bounty tomatoes a few hundred yards removed continued to be infested during this period to about the same degree as before. On May 26, 30 per cent of the maturing buds on untreated plants were infested with larvae.

SUMMARY

The life history of blossom midge, *Contarinia lycopersici* Felt, in Hawaii is discussed. The eggs are laid inside the androecium of the tomato flower buds. They hatch and the larvae mature within five to seven days. They then enter the soil where they pupate. Adults normally emerge 14 days after the larvae enter the soil.

Larvae which are forced to leave the host plant before attaining full size and maturity are nevertheless able to pupate and become adults. The adults reared from such larvae, however, are smaller in size than normal. Moreover, such larvae may spend a longer time in the soil before pupating than do the mature larvae.

Data are presented on the effects of reduced temperature on survival and development of larvae and pupae in moist soil.

Commercial varieties of tomato, such as Bounty, were found to have 50 per cent of the buds and blossoms infested with larvae or eggs, while *Lycopersicon peruvianum,* growing in adjacent rows, carried only a 6 per cent infestation. The difference appears to be due to the fact that in *peruvianum* the petal tips fit tightly into the distal end of the androecium of the young buds and prevent the midge adults from inserting the ovipositor.

DDT dusts and sprays protected Bounty tomato plants from oviposition but did not prevent hatching of the eggs already laid or interfere with the development of the larvae inside the buds.

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