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LABORATORY STUDIES OF HAWAIIAN SCIARIDAE

(DIPTERA)

Wallace A. Steffan

Department of Entomology
Bernice P. Bishop Museum
Honolulu, Hawaii 96818

ABSTRACT

Fourteen Hawaiian Sciaridae (Diptera) were studied in the laboratory and reared in constant temperature cabinets at $20^{\circ}C \pm 2^{\circ}$. Six of these species are possibly endemic. The mean developmental time in days of eggs, larvae and pupae for each species, except Hyperlasion magnisensoria (Hardy) is given. Total mean developmental time for each species was as follows: Bradysia, sp. 1 - 18.8; B. impatiens (Johannsen) - 16.3; B. molokaiensis (Grimshaw) - 16.2; B. spatitergum (Hardy) - 17.9; B. tritici (Coquillett), "monogenic" - 18.5; B. tritici (Coquillett), "digenic" - 22.2; Corynoptera brevipalpis Steffan - 34.0; Ctenosciara hawaiiensis (Hardy) - 29.0; Lycoriella hoyti (Hardy) - 33.0; L. mali (Fitch) - 20.0; L. solispina (Hardy) - 19.8; Phytosciara, sp. 2 - 21.5; Plastosciara perniciosa Edwards - 27.3 and Scatopsciara nigrita Hardy - 24.5.

The probable ecological role for each species is given. Most Hawaiian Sciaridae are either phytosaprophagous or mycetophagous or both. Some are known to be facultatively phytophagous elsewhere and several species are probably facultatively coprophagous. One or more species may be corticolous feeders.

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INTRODUCTION

During investigations on the ecology and systematics of Hawaiian
Sciaridae, 14 species have been reared in the laboratory from December
1967 to March 1971. Laboratory studies are essential for both systematic
and ecological research on Sciaridae. The females of many species are
impossible to identify until they have been definitely associated with males
by rearing. Also study of immature stages will undoubtedly elucidate some of
the problems in the higher classification of this family. Ecological research
is likewise dependent upon supportive data from laboratory studies, since larvae
of Sciaridae are generally very difficult to find in the field.

Most Sciaridae reared in the laboratory by other investigators have
been those of economic importance (Del Guercio, 1905; Hungerford, 1916; Gui,
1933; Ellisor, 1934; Madwar, 1934 and 1937; Wisely, 1959; Wilkinson & Daugherty,
1970 and Kennedy, 1971) and those studied cytologically (Butt, 1934; Metz,
1938a,b; Carson, 1944; McCarthy, 1945; Fahmy, 1949; Gabrusewycz-Garcia, 1964;
Pavan et al., 1965; Rieffel & Crouse, 1966; Mattingly & Parker, 1968; and
others). Several different rearing methods have been used and are reviewed
by Steffan (1966) and Kennedy (1971).

Two types of reproduction, as indicated by the sex ratio of the progeny
from a single female, are found in Sciaridae. One is characterized by pro-
duction of "monogenic" families; that is progeny from one female are either
all males or all females. Exceptional males or females do occur rarely
(Crouse, 1960). The other is characterized by a more typical sex ratio, the
progeny from one female including more or less equal numbers of both sexes.
These are referred to as "digenic" families. Some species have strains

displaying both types of reproduction, but most species are characterized by only one.

METHODS

Several different techniques were used for collecting stock for laboratory cultures. Since it is generally easier to start cultures from gravid females, most field collections were of adults. Adults were usually collected by sweeping various types of vegetation or extracting them from decomposing organic debris. Adults were also attracted to black light and to white sheets placed on the ground. Larvae were collected from rotting wood and under the bark of dead branches.

Laboratory cultures were started from gravid females or larvae collected in the field. The adults or larvae were placed in glass shell vials (25 X 95 mm) containing an agar substrate. This is a modification of a culture method used by Metz and his students (Smith-Stocking, 1936) for genetic studies of Sciaridae and is described below. It was reported in Steffan (1966, 1973) and is referred to as the "standard rearing medium" in this paper.

Agar substrate: Mix 4.2 g of Bacto-Corn Meal Agar and 2.0 g of Bacto-agar in 200 ml of distilled water. If excess fungal growth is detrimental to the sciarid culture, a plain Bacto-agar medium can be used. This is prepared by mixing 8 g of Bacto-agar in 200 ml of water. Heat mixture in a pan of boiling water for 10 minutes. Pour approximately 3 cm of this mixture into each vial, plug with cotton and autoclave for 15 minutes. Prepare slants by cooling vials in a diagonal position. Slant cultures are preferred as they provide more surface areas for the larvae and adults so that they are easier to observe and manipulate.

Table 1. Preoviposition and developmental time of Hawaiian Sciaridae at $20^{\circ}C \pm 2^{\circ}$.

Species	Preoviposition Period in Days	Mean Developmental Time in Days			
		Egg	Instars I-IV	Pupa	Total
Bradysia, sp. 1	2-3	3.5	12.0	3.3	18.8
Bradysia impatiens	1-3	3.5	9.6	3.9	16.3
Bradysia molokaiensis	3	3.8	9.4	3.0	16.2
Bradysia spatitergum	2-3	3.4	10.9	3.6	17.9
Bradysia tritici "monogenic"	N.A.	3.0	12.2	3.3	18.5
" " "Digenic"	2-3	4.4	14.2	3.6	22.2
Corynoptera brevipalpis	N.A.	10.0	18.5	5.5	34.0
Ctenosciara hawaiiensis	1-3	4.2	18.2	6.6	29.0
Hyperlasion magnisensoria	N.A.	6.0	8.0 +	+	+
Lycoriella hoyti	1-2	6.5	23.0	3.5	33.0
Lycoriella mali	2-4	3.3	13.6	3.1	20.0
Lycoriella solispina	1-3	3.5	12.8	3.5	19.8
Phytosciara, sp. 2	1-4	3.9	12.8	4.8	21.5
Plastosciara perniciosa	N.A.	5.7	18.1	3.5	27.3
Scatopsciara nigrita	2-3	4.1	16.8	3.6	24.5

N.A. = information not available.

+Culture died out before pupating.

Development was not synchronous as adults from one egg batch will emerge over a 3-5 day period, although eggs hatch on the same day. Larvae tended to remain on the surface of the agar and construct individual cocoons prior to pupation. Males generally emerged a day before the females. Adults live about 3 days in the culture tubes.

Bradysia, sp. 1 is frequently collected at light in the lowlands on Oahu. This is probably a phytosaprophagous or mycetophagous species. Several adults were reared from a bracket fungus collected on Oahu.

Bradysia impatiens (Johannsen)

B. impatiens is monogenic and also easy to colonize on the standard rearing medium. The parents of this colony were collected in Honolulu and some males were reared from a rotting Acacia koa log from Mt. Tantalus, Oahu. The colony was maintained for 14 generations (253 days). Mean developmental time of eggs, larvae, and pupae at $20^{\circ}C \pm 2^{\circ}$ was 16.3 days (Table 1) with a preoviposition period of 1-3 days. Adults from one egg batch generally emerged over a 3-4 day period. Larvae tended to remain on the surface of the agar and prior to pupation would construct individual cocoons. Males generally emerged a day before the females. Longevity of the adults was not determined.

B. impatiens is an introduced species commonly found in the lowlands of all major Hawaiian islands, but it is occasionally found up to 2200 m in disturbed habitats. We have reared it from rotting Acacia koa and Freycinetia. B. impatiens is probably a phytosaprophagous or mycetophagous species, but in some cases can be phytophagous.

B. impatiens was described from adults reared from larvae found in earth adhering to the roots of Impatiens (Johannsen, 1912). Carson (1944)

reared specimens from various eastern and midwestern U. S. localities for

his studies on chromosome variability. He indicated that it is common in

and around greenhouses and breeds abundantly in the earth and compost mix-

tures used in greenhouses. He suggests that it may be cosmopolitan since

Metz (1929, and unpublished) obtained specimens from California and Berlin,

Germany. This supports Steffan's opinion based on morphological studies,

that B. impatiens may be conspecific with the Palearctic species B. fungicola

(Steffan, 1973). Roberts & Lavigne (1959) report that the larvae of B. impatiens

were observed feeding on the fine root hairs of the turf grass species, Poa

protensis and Festuca rubra. Wilkinson & Daugherty (1970) observed the larvae

of B. impatiens feeding on the roots of soybean plants in Missouri. They also

studied the life history of this species in the laboratory. At 23.9°C, the

mean developmental time of B. impatiens was 21.6 days. The larvae were reared

on a ground soybean medium. Kennedy (1971) studied the importance of fungi

in the development of B. impatiens and at 20°C reported a mean developmental

time of 21.6 days. He compares his results with those of Wilkinson & Daugherty.

The mean developmental time of 16.3 days at 20°C of the Hawaiian B.

impatiens is considerably faster than that reported by Kennedy or Wilkinson &

Daugherty. In part, experimental methods could account for this discrepancy.

The data for the Hawaiian populations was based on the first observance of

each stage; the mean developmental time for the progeny from any one batch

of eggs would be at least 1 or 2 days longer. A number of factors could

influence the development of these various strains in the laboratory.

Kennedy (1971) mentions variations in laboratory strains, photoperiod and

larval diet. The cytological investigations of Carson (1944) certainly

indicate this is a highly variable species. A complex of very closely related

species may also be involved. In any case, these discrepancies in developmental time point out the importance of standardizing rearing methods for comparative studies.

Bradysia molokaiensis (Grimshaw)

B. molokaiensis is monogenic and difficult to colonize. During 1968, 1969, and 1970, 30 cultures were attempted and only 17 (57%) yielded F_1 progeny. Only one colony produced a 4th generation, which died out. Part of the difficulty was caused by the fact that this species is monogenic. Colonies were frequently lost when only one sex was produced. However, other monogenic species such as B. impatiens were very easy to colonize so other factors are involved. All colonies were started from adults collected on Oahu. Mean developmental time of eggs, larvae and pupae at $20^{\circ}C \pm 2^{\circ}$ was 16.2 days (Table 1). Preoviposition period was 3 days. Mated females frequently died before oviposition possibly indicating that the oviposition site was not favorable. Adults emerged over a 3-5 day period. Larvae remained on the surface and constructed individual cocoons prior to pupation. Males usually emerged one day before females.

B. molokaiensis is a common lowland species on all major Hawaiian islands and is usually collected at light. It has been collected up to 2200 m. We have collected it by sweeping low herbs and grasses in cattle pens and from rotting sugar cane. B. molokaiensis may also be phytosaprophagous or mycetophagous.

Bradysia spatitergum (Hardy)

B. spatitergum is monogenic, but exceptional males or females will occur occasionally. It is easy to colonize on the standard rearing medium. Eleven

cultures were attempted and 10 (91%) were successful. One colony was maintained for 9 generations (195 days). Mean developmental time of eggs, larvae and pupae at 20°C $\pm$ 2° was 17.9 days (Table 1) with a preoviposition period of 2-3 days. Adults from one egg batch emerged over a 3-4 day period. Larvae tend to remain on the surface of the agar and construct individual cocoons prior to pupation. Males generally emerge one day before females.

B. spatitergum is common in the lowlands of all major Hawaiian islands and is frequently collected at light. It was reported from rotting sugar cane, rotting sweet potatoes, and from coffee grounds (Hardy, 1960). It has also been reared from rotting logs, bracken fern, Pisonia logs, Reynoldsia stems, Urera wood and Marottia ferns (Montgomery, unpubl., Steffan, unpubl.) It has also been reared from the puparium of the New Guinea sugar cane weevil (Mitchell, unpubl.). Specimens from Panama were collected on Heliotropium peruvianum L. (= H. arborescens L.) and on flowers and fruit of Heliconia mariae Hook (Steffan, 1968). Both H. arborescens and H. mariae have been introduced into Hawaii. Specimens of B. spatitergum from Brazil were collected on fermenting sweet potato leaves (Steffan, 1968). B. spatitergum is probably phytosaprophagous or mycetophagous.

Bradysia tritici (Coquillett)

Both monogenic and digenic strains of B. tritici are reported in the literature (Metz & Lawrence, 1938; Crouse, 1939, as S. ocellaris). We apparently have both strains in Hawaii; however, the monogenic strain is more common. Both strains are easy to colonize on the standard rearing medium. The digenic B. tritici was maintained for 8 generations (210 days). Mean developmental time for digenic B. tritici (eggs, larvae and pupae) was 22.2 days

(range 14-23 days) (Table 1). The mean developmental time for monogenic
B. tritici was shorter (18.5 days, range 19-28 days). Adults from one egg
batch tend to emerge over a 2-5 day period. Larvae tend to remain on the
surface of the agar and construct individual pupal cocoons. Males usually
emerge before females in both strains.

B. tritici is a common lowland species on all major Hawaiian islands
and probably occurs on the smaller islands of the Hawaiian chain also.
Hardy (1960) indicated that it (as S. garretti Shaw) was probably an immigrant
species, and this has been confirmed. It is widely distributed in North
America and is probably cosmopolitan. B. tritici has been reared from decaying
sugar cane, pineapple, commercial mushrooms and other plants (Hardy, 1960).
B. tritici was originally reported destructive to wheat seedlings (Coquillett,
1895). Kennedy (1971) in his review of sciarid species attacking cultivated
crops lists the following plants attacked by B. tritici (as S. ocellaris):
campanula, carnations, corn, cucumbers, geraniums, lettuce, Nasturtium,
orchids, peas, potato tubers, primula and wheat. We have reared it from
rotting logs, rotting Acacia koa, and have frequently collected it at black
light and in Malaise traps. B. tritici is phytosaprophagous, mycetophagous
and, in some cases, phytophagous.

Corynoptera brevipalpis Steffan

C. brevipalpis is digenic and probably would be difficult to colonize
on the standard rearing medium. Four cultures were attempted and two pro-
duced F_1 adults. F_1 females oviposited but the temperature cabinet overheated
killing all colonies. The parent adults were reared from rotting Acacia koa
wood collected on Mt. Tantalus, Oahu, 20.XI.1968. Mean developmental time for
eggs, larvae and pupae at 20°C ± 2° was 34.0 days. High mortality rate was

noted in the larval stages. Larvae did not construct pupal cocoons. Pupae were bright yellow immediately after pupation and gradually darkened.

C. brevipalpis is probably a mycetophagous species. It is an introduced species and known from the Caroline Islands, Micronesia (Steffan, 1969).

Ctenosciara hawaiiensis (Hardy)

C. hawaiiensis is monogenic and difficult to colonize. Females usually do not oviposit readily on our agar slant cultures. Twenty-eight cultures were attempted and only 8 (28%) were successful. Of these, only one was maintained for 3 generations. Mean developmental time of eggs, larvae and pupae at $20^{\circ}C \pm 2^{\circ}$ was 29.0 days (Table 1), with a preoviposition period of 1-3 days. Adults from one egg batch emerge over a 5-8 day period. Larvae frequently burrow into the agar medium or between the agar and the glass vial. Larvae construct individual pupal cocoons. Larval development is not synchronous and larvae do not tend to be gregarious as are those of some sciarids.

C. hawaiiensis is common on all major Hawaiian islands and is generally found above 450 m. It has been reared from rotting wood and Freycinetia (Hardy, 1956, 1960). We have collected it from rotting Ohia, Pipturus and Acacia koa. In ecological studies on the island of Hawaii, C. hawaiiensis seems to be closely associated with Acacia koa, one of the dominant elements of the plant community (Steffan, 1973). Thousands of adults have been observed flying over the surface of a large, fallen Acacia koa. Most adults captured in this situation were males and they were apparently searching for females among the deep crevices of bark. In the same area, larvae of C. hawaiiensis were commonly found under the bark of dead A. koa branches. Seasonal fluctuations of C. hawaiiensis have also been studied (Steffan, 1973).

Adults have also been captured while resting in the axils of Freycinetia sp.
C. hawaiiensis is probably phytosaprophagous and, in some cases, may be a corticolous feeder.

Hyperlasion magnisensoria (Hardy)

H. magnisensoria was reared to the 4th instar only. Development time of the eggs at 20°C ± 2° was 6 days and the larvae lived for 8 days (Table 1). Larvae of H. magnisensoria were collected on fallen Coprosoma logs covered with moss. The larvae were feeding on the surface of the wood under the thick mat of moss.

H. magnisensoria occurs in the mountains of all major islands in Hawaii. It probably breeds primarily in litter and is phytosaprophagous or mycetophagous.

Lycoriella hoyti (Hardy)

L. hoyti is apparently digenic and easy to colonize on the standard rearing medium. The one attempt to colonize this species was successful and it was maintained for 7 generations. Records are available for F_4 only so the data in Table 1 are based on 3 cultures only. Mean developmental time for the eggs, larvae and pupae at 20°C ± 2° is 33.0 days with a preoviposition period of 1-2 days.

L. hoyti is known from the mountains of Oahu, Maui, and Hawaii I. It has been reared from moss. Adults have been collected from rotting haupu (Cibotium sp.) and rotting Acacia koa on Hawaii I. L. hoyti is probably phytosaprophagous or mycetophagous.

Lycoriella mali (Fitch)

L. mali is digenic and easy to colonize on the standard rearing medium. The one attempt to colonize this species was successful and the colony was

maintained for 12 generations (277 days). Mean developmental time of eggs, larvae, and pupae at $20^{\circ}C \pm 2^{\circ}$ was 20.0 days with a preoviposition period of 2-4 days. Larvae construct individual cocoons prior to pupation. Males generally emerge a day before females.

In Hawaii L. mali have been found at Kokee on the island of Kauai and may be a fairly recent introduction. It is widespread in North America where it is found in British Columbia, California, Ontario and from New Hampshire to Pennsylvania and New Jersey. In North America it has been reared from rotting apples and rotting potatoes and it is commonly found in greenhouses. This species has been studied cytologically (McCarthy, 1945). L. mali is probably phytosaprophagous or mycetophagous

Lycoriella solispina (Hardy)

L. solispina is monogenic and easy to rear on the standard rearing medium. Two cultures were attempted and both were successful. One was maintained for 10 generations (251 days) and was started from females collected on flowering Acacia koa in open range land on the north slope of Mauna Kea, Hawaii I., 1585 m, 3.XII.1968; W. Gagné collector. Mean developmental time at $20^{\circ}C \pm 2^{\circ}$ of eggs, larvae and pupae was 19.8 days with a preoviposition period of 1-3 days. Larvae tend to remain on the surface of the agar and prior to pupation construct individual pupal cocoons. Adults from one egg batch emerge over a 3-4 day period. There may be some genetic markers in this strain since adults with crumpled wings and deformed antennae frequently appear. Some of the adults in a few culture vials were occasionally destroyed by nematodes.

L. solispina is apparently an introduced species very similar to or con-specific with L. similans Johannsen. It has been collected only on Hawaii I.

at 1585-2134 m. L. similans, as investigated by Metz (1926), has both monogenic and digenic strains. L. solispina may be phytosaprophagous or mycetophagous.

Phytosciara, sp. 2.

Phytosciara, sp. 2 is digenic and easy to rear on the standard rearing medium. One colony was maintained for 11 generations (255 days). Mean developmental time at $20^{\circ}C \pm 2^{\circ}$ for eggs, larvae and pupae was 21.5 days with a pre-oviposition period of 1-4 days. Larvae seem to be gregarious and more or less synchronous in development. Single pupal cocoons are constructed prior to pupation. Generally from a single egg batch, one sex will be more common although both are always present. Males emerge about a day before females.

Phytosciara, sp. 2 has been collected in the mountains of Hawaii and Maui I. This is the only species collected in lava tubes by F. Howarth and it has been reared from decomposing rat feces. Phytosciara, sp. 2 is probably phytosaprophagous, mycetophagous and, in some cases, coprophagous.

Plastosciara perniciosa Edwards

P. perniciosa is digenic and very easy to rear on the standard rearing medium. Eight of 9 cultures attempted were successful and one colony was maintained for 28 generations. Mean developmental time at $20^{\circ}C \pm 2^{\circ}$ was 27.3 days (Table 1).

This is the most unusual sciarid encountered in that both males and females may be either normally winged or apterous. A detailed discussion of this species is given by Steffan (1973). The larvae of normally winged adults feed on the surface of the agar and construct individual cocoons prior to pupation. Larvae of apterous adults burrow into the agar and construct enlarged pupal chambers generally enclosing 2 females and 1 male.

P. _perniciosa_ (= P. _brevicalcarata_ Hardy) is commonly taken indoors. We have collected it in Malaise traps and have reared it from rotting wood. In England it is a common greenhouse pest and larvae are destructive on cucumbers, feeding in the roots and stems. On Mt. Kaala, Oahu, an apterous male was collected from the surface of a dead branch of _Coprosoma_ covered with moss. P. _perniciosa_ is phytosaprophagous, mycetophagous and, in some cases, phytophagous.

Scatopsciara nigrita Hardy

S. _nigrita_ is digenic and relatively easy to rear on the standard rearing medium. After the F_4 generation, the gravid females frequently died before oviposition. One colony was maintained for 9 generations (255 days), but with decreasing vigor. Mean developmental time at $20^{\circ}C \pm 2^{\circ}$ of eggs, larvae and pupae is 24.5 days (Table 1). Larvae tend to remain on the surface of the agar and prior to pupation construct individual cocoons.

S. _nigrita_ is known from the islands of Hawaii and Oahu and is fairly common at lights, on windows and in rotting vegetation (Hardy, 1960). The single colony was started from females collected at Peacock Flat, Oahu, 450 m, in a shaded creek bottom with kukui trees, _Pipterus_ and rotting logs. An additional collection from Peacock Flat was reared from rotting logs. S. _nigrita_ is probably phytosaprophagous or mycetophagous.

DISCUSSION

Most Hawaiian Sciaridae appear to be phytosaprophagous or mycetophagous or both. It is difficult to determine whether the larvae are feeding primarily on dead plant material or on fungi impregnating the dead plant material.

They usually consume both in the laboratory cultures. They also consume any other organic material in the culture vials, including the dead bodies of adult sciaraids. Occasionally, the larvae attack and consume other weakened larvae and in some cases, especially in crowded cultures, will attack and consume healthy pupae not enclosed in cocoons. C. hawaiiensis may be corticolous but is also phytosaprophagous or mycetophagous.

B. impatiens, B. tritici and P. perniciosa are reported to be phytophagous in some cases, but I suspect they are primarily phytosaprophagous or mycetophagous. Phytosciara, sp. 2 and B. molokaiensis and perhaps several other Hawaiian sciarids may be facultative coprophagous feeders.

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