Drosophila Survey of Hokkaido, XXXII.
A Field Survey of Fungus Preferences of Drosophilid Flies in Sapporo

By

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(*With 1 Text-figure and 8 Tables*)

As many investigators have indicated, the study of the food preferences of species of *Drosophila* is a fertile field, in order to understand the natural selection or competition among the species. Some studies concerned with the fruit or yeast preferences of drosophilid flies, have been made by trap collection using artificial baits (Dobzhansky and da Cunha 1955, Kaneko 1960, etc.). Dobzhansky and Pavan (1950) carried out collections from several kinds of natural fruits in Brazil in order to study the preferences of the flies. These workers observed that most of the flies have characteristic food preferences among these materials, but the preferences are not regid, and overlap among sympatric species. Pipkin *et al* (1966) reported that some of the flower-feeding neotropical *Drosophila* are monophagous, while some others are polyphagous.

Only a few studies have been made on the preferences of fungus-feeding *Drosophila*. Suzuki (1955) clarified fungus-feeding species in the Botanical Garden in Sapporo, and Momma (1965b) summarized the data obtained by collections from fungi and by sweeping on grasses in the Garden, and discussed the food habits of the flies. Okada (1954) studied the preferences of the drosophilid flies for fungi and fruits. The present paper is concerned with the fungus preferences of adult drosophilid flies.

Surveyed area and methods

The study was carried out in the Botanical Garden of Hokkaido University in Sapporo. The geographical and biotic characteristics of the area have been described by Momma (1965a).

The periodical collections were carried out in five collecting areas in the Garden. The general characteristics of the areas are as follows;

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A: about 2,600 m^2, containing a few fallen trees, and a lot of logs of *Ulmus davidiana* and some other trees.
B: about 2,670 m^2, containing a lot of logs.
C: about 220 m^2, almost covered with logs.
D: about 1,940 m^2 with a few fallen trees.
E: about 70 m^2, with many logs.

The collections were made from fleshy fungi, all members of Agaricales and two genera of Aphyllophorales, *Favolus* and *Polyporellus*, which grew in the areas. Other members of Aphyllophorales did not attract the drosophilid flies in the areas as far as was observed. In 1973 the collections were made for eight days in the end of May, and in the beginning of each month from June to October excluding rainy days. In 1974 the collections were made for four days at each collecting period in the beginning and middle of each month from May to October. The flies were collected from all of the fleshy fungi found in the areas by net sweeping three times a day, at 13:00, 15:00, and 17:00 hours. The reason why the collections were made in the afternoon was that only slight differences were found between the population structure of the flies collected in the afternoon and those which were collected between sunrise and sunset. At the same time most fleshy fungi were identified and counted, but some species difficult to identify were collected for accurate identification.

In order to study the successive change of the drosophilid fauna in relation to the decaying of fungi, the flies were collected from several kinds of fungi every day except rainy days from the appearance of the fungi to their disappearance by decaying. These collections were also made three times a day, at 13:00, 15:00, and 17:00 hours.

Fleshy fungi in the collecting areas

Of the fleshy fungi found in the collecting areas, 36 species were identified. Table 1 shows the total number and weight of the 13 competent species of fungi observed in two years. These 13 species of fungi can be said to be the main fungi utilized by the flies in the collecting areas, as the number of drosophilid flies collected from these fungi occupied about 97% of the total individuals obtained by the periodical collections (see Table 3).

In addition to these 13 species, the following species were observed in the areas, *Coprinus pliatilis*, *Psathyrella velutina*, *P. hydrophila*, *Laccarea amethystina*, *Mycena* sp., *Cademansiella radicata*, *Flammulina velutipes*, *Pluteus leonius*, *P. nanus*, *P. pellitus*, *P.* sp., *Agaricus campestris*, *A. placomuces*, *A. arvensis*, *Lepiota cristata*, *L. subamanitiformis*, *Pholiota squarrosa*, *P. terrestris*, *Gymnopilus spectabilis*, *Crepidotus* sp., *Rhodophyllus rhodopholius*, *Polyporellus picipes*, and *Favolus arcularius*.

Table 1. Numbers and weight of the main fungi utilized by the flies in the collecting areas

	1973		1974	
	Number	Weight (g)	Number	Weight (g)
Coprinaceae				
Coprinus micaceus (Cm)	805	4, 680	1, 990	10, 080
C. atramentarius (Ca)	240	4, 560	135	2, 565
C. disseminatus (Cd)	600	25	1, 700	70
Psathyrella candolleana (Pc)	150	420	553	1, 550
Tricholomataceae				
Pleurotus cornucopiae (Plc)	62	150	185	450
P. ostreatus (Plo)	59	627	359	3, 805
Tricholomopsis platyphylla (Tp)	29	240	76	630
Armillariella mellea (Am)	59	210	15	55
Mycena haematopus (Mh)	20	8	140	55
Leutinus ursinus (Lu)	100	530	66	350
Amanitaceae				
Pluteus cervinus (Puc)	15	275	5	90
Crepidotaceae				
Crepidotus mollis (Crm)	200	50	823	215
Polyporaceae				
Polyporellus squamosus (Ps)	16	8, 000	29	14, 500

Results and Conclusion

Species collected from fleshy fungi

During the periodical collections in two years, a total of 6,689 individuals representing 33 species of drosophilid flies were collected from 27 species of fleshy fungi. The total number of each species collected is shown in Table 2. Of the total, the individuals belonging to the subgenus *Hirtodrosophila* constitute about 37%, and the individuals of the *quinaria* section of the subgenus *Drosophila* constitute about 60%. Among the members of *Hirtodrosophila*, *D. sexvittata*, *D. trivittata* and *D. confusa* were abundant, and among the members of the *quinaria* section, D. *nigromaculata*, *D. brachynephros*, *D. unispina* and *D. testacea* were abundant. In addition to these species a few individuals belonging to the genus *Mycodrosophila* and the *melanogaster* group of the subgenus *Sophophora* were collected.

As mentioned in the introduction Okada (1954) divided the flies into four types according to their preferences for fungi and fruits; MF type: strongly attracted to both fungi and fruits, Mf type: strongly attracted to fungi, but little to fruits, mF type: strongly attracted to fruits, but little to fungi, and mf type: little attracted to either of them. Such preferences of the drosophilid flies dwelling in the Botanical Garden in Sapporo were studied by a comparison of the results of the periodical collections of this survey with the results of ten years of collections from

Table 2. Species and number of flies by periodical collections from fungi (A) and trap collections from 1953 to 1962 (B), and the types of preferences

	A	B	Type
Stegana coleoptrata (Scopoli, 1763)	3	-	—
S. unidentata Takada, 1968	1	-	—
Amiota elongata Okada, 1971	1	-	—
Leucophenga maculata (Dufour, 1839)	10	10	—
L. sternomaculipennis Okada, 1968	1	-	—
L. quinquemaculipennis Okada, 1956	1	-	—
Mycodrosophila poecilogastra (Loew, 1874)	19	-	Mf
M. japonica Okada, 1956	19	-	Mf
M. shikokuana Okada, 1956	5	1	—
Scaptomyza pallida (Zetterstedt, 1847)	31	42	mf
S. consimilis Hackman, 1959	2	12	mf
Chymomyza caudatula Oldenberg, 1914	1	-	—
Drosophila (*Lordiphosa*) *collinella* Okada, 1968	1	2	mf
D. (*Hirtodrosophila*) *sexvittata* Okada, 1956	1, 781	5	Mf
D. (*H.*) *trivittata* Stroble, 1893	288	1	Mf
D. (*H.*) *alboralis* Momma & Takada, 1954	44	2	Mf
D. (*H.*) *quadrivittata* Okada, 1956	2	-	—
D. (*H.*) *confusa* Staeger, 1844	369	394	MF
D. (*Scaptodrosophila*) *coracina* Kikkawa & Peng, 1938	5	123	mF
D. (*Sophophora*) *bifasciata* Pomini, 1940	1	1, 097	mF
melanogaster species group			
D. (*S.*) *lutescens* Okada, 1975	7	4, 170	mF
D. (*S.*) *suzukii* (Matsumura, 1931)	16	823	mF
D. (*S.*) *auraria* Peng, 1937	52	18, 065	mF
D. (*S.*) *biauraria* Bock & Wheeler, 1972	6		mF
D. (*S.*) *nipponica* Kikkawa & Peng, 1938	9	28	mf
quinaria section			
D. (*Drosophila*) *testacea* van Roser, 1940	1, 001	1, 635	MF
D. (*D.*) *brachynephros* Okada, 1956	2, 220	3, 332	MF
D. (*D.*) *unispina* Okada, 1956	310	208	MF
D. (*D.*) *nigromaculata* Kikkawa & Peng, 1938	347	11, 894	mF
D. (*D.*) *immigrans* Sturtevant, 1921	90	3, 303	mF
D. (*D.*) *histrio* Meigen, 1830	10	74	MF
D. (*D.*) *multispina* Okada, 1956	29	1	—
D. (*D.*) *makinoi* Okada, 1956	5	-	—
virilis section			
D. (*D.*) *lacertosa* Okada, 1956	2	950	mF
others	—	447	—
Total	6, 689	46, 619	

traps baited with fermenting banana in the Garden (Momma 1965a). Table 2 gives the results of both collections and the type of preference of each species.

All the members of *Mycodrosophila* and *Hirtodrosophila* except *D. confusa* were collected chiefly from fleshy fungi. These species are considered Mf type. *Drosophila multispina* is also collected more from the fungi. On the other hand, *D. coracina*, *D. nigromaculata*, *D. immigrans*, *D. lacertosa*, and all the members of

Sophophora except *D. nipponica* were collected mostly by traps, and they are considered mF type. Among them *D. nigromaculata* and *D. immigrans* were collected more from the fleshy fungi than the other species. *Drosophila confusa*, *D. brachynephros*, *D. unispina* and *D. testacea* were attracted to both of them, and they would be MF type. *Drosophila histrio* is also considered MF type, but seems to be attracted to fermenting fruits in a larger proportion than the above four species. Four species, *D. nipponica*, *D. collinella*, *S. consimilis*, and *S. pallida*, were attracted to fleshy fungi and fruits to some extent in this survey, but as they are collected chiefly by sweeping on grasses as reported by Momma (1965b) and Kimura (1976), then they are rather mf type.

Fungus preferences

The numbers of the main flies collected from the main 13 species of fungi are shown in Table 3 (as the collected number of each species belonging to the genus *Mycodrosophila* and the *melanogaster* group was small, they are totalled respectively). Fig. 1 shows the proportions of the main species to the 4 main fungous families. A glance at this figure well shows that the members of *Hirtodrosophila* have species-specific preferences for fungi, while the members of the *quinaria* section have similar preferences.

Three species of *Mycodrosophila*, *M. poecilogastra*, *M. japonica*, and *M. shikokuana* were collected chiefly from *Leutinus ursinus*, and the first two species were also collected from *Polyporellus squamosus*. *Drosophila alboralis* shows a similar pattern of visiting to the members of *Mycodrosophila*.

One of the abundant species, *D. sexvittata*, was collected from *P. squamosus*

Table 3. Numbers of flies of the main species collected from the 13

Fungus species	Cm	Ca	Cd	Pc	Plc	Plo
Mycodrosophila spp.	2	-	-	-	2	2
S. pallida	5	25	-	-	-	-
D. sexvittata	65	6	-	46	33	96
D. trivittata	-	-	-	-	9	247
D. alboralis	4	1	-	1	1	-
D. confusa	112	1	1	1	-	-
melanogaster gr. spp.	53	19	-	4	-	-
D. testaeca	574	150	11	38	2	4
D. brachynephros	986	639	43	226	7	46
D. unispina	200	25	2	30	1	6
D. nigromaculata	173	105	10	42	-	2
D. immigrans	74	4	-	-	-	-
D. histrio	7	2	-	1	-	-
D. multispina	26	-	-	-	1	-
Others	15	1	2	1	2	1
Total	2,296	978	69	390	58	404

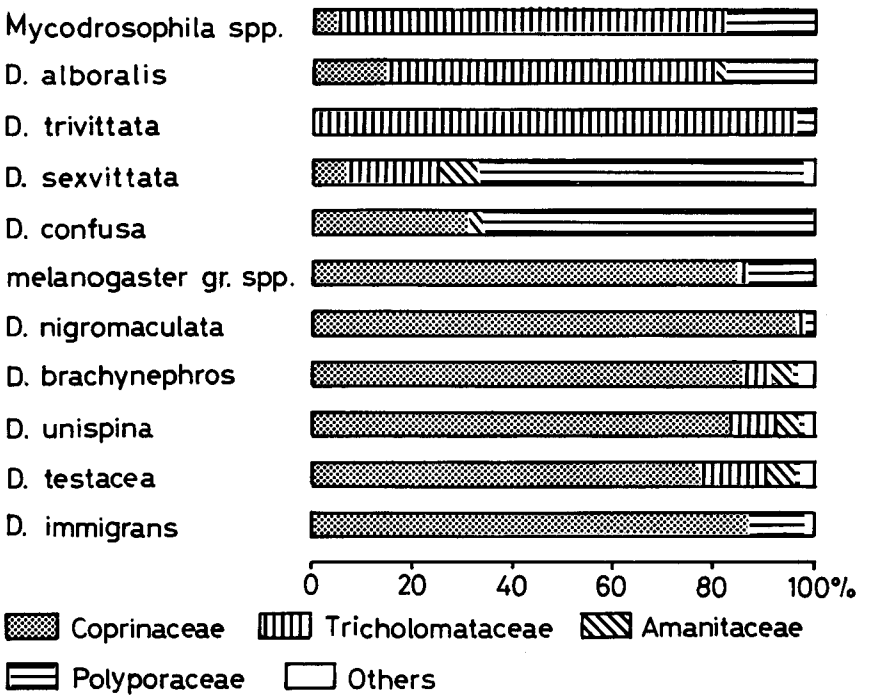

Fig. 1. Proportions of the main drosophilid species and groups to the 4 main fungous families. The members of the genus *Mycodrosophila* and of the *melanogaster* group are totalled for each group.

species of fungi. Abbreviations for fungus species are shown in Table 1

Tp	Am	Mh	Lu	Puc	Crm	Ps	Others	Total
2	-	-	27	-	-	6	2	43
-	-	-	-	1	-	-	-	31
104	68	34	5	99	43	1, 127	55	1, 781
12	6	-	-	-	-	13	1	288
8	1	-	19	1	-	8	-	44
-	-	-	-	9	1	244	-	369
-	1	-	1	-	-	12	-	90
3	5	-	113	59	6	12	24	1, 001
9	24	18	19	92	26	12	73	2, 220
5	13	-	2	16	2	4	4	310
1	4	1	1	-	-	5	3	347
-	-	-	-	-	-	9	3	90
-	-	-	-	-	-	-	-	10
-	-	-	-	-	-	-	2	29
2	2	-	1	-	2	6	1	36
146	124	53	188	277	80	1, 458	168	6, 689

most frequently, and also from the other various fungi it was collected in good numbers.

Most specimens of *D. trivittata* were collected from *Pleurotus ostreatus*, and a few from the other members of Tricholomataceae and *P. squamosus*. Suzuki (1955) also observed that this fly was extremely attracted to the fungi of genus *Pleurotus*.

There was only one MF type species in *Hirtodrosophila*, namely *D. confusa*, which was collected from *P. squamosus* and *C. micaceus* in the main, with a few from other fungi.

Five species belonging to the *melanogaster* group, *D. auraria*, *D. biauraria*, *D. suzukii*, *D. lutescens*, and *D. nipponica*, were collected mainly from *C. micaceus* and *C. atrimentarius*.

About 80% of the total specimens of the members of the *quinaria* section, *D. nigromaculata*, *D. brachynephros*, *D. unispina*, *D. testacea*, *D. immigrans*, *D. histrio*, and *D. multispina*, were collected from the fungi of Coprinaceae, *C. micaceus*, *C. atramentarius*, and *Psathyrella candolleana*. Among these species *D. nigromaculata* seems to be more restricted to the fungi of this family than the others.

Successive change of drosophilid fauna according to decaying of fungi

The successive changes of drosophilid fauna according to the proceeding of fermentation of the food souce have been observed on fruits or cut palm trees (Lachaise and Tsacas 1974, Burla 1955). Such successive changes of fauna were also observed on fungi. Tables 4, 5, 6, 7, and 8 show the change of the fauna observed on *P. cervinus*, *P. cornucopiae*, and *P. squamosus* from their appearance to disappearance by decaying. Usually, *P. cervinus* begins to decay two or three days after appearance, and *P. cornucopiae* and *P. squamosus* do so a week or more after appearance.

In the two cases of *P. cervinus* observed in the survey, *D. sexvittata*, *D. brachynephros*, *D. unispina*, *D. testacea*, and *D. nigromaculata* had been attracted. At the fresh stage (one or two days after appearance), *D. sexvittata* was abundant, and this fly decreased as decaying progressed. On the other hand, *D. brachynephros*

Table 4. Numbers of the flies collected (on *Pluteus cervinus*) on different days following its appearance at 29th May, 1974

Date	29/M	30	1/J	3	Total
D. sexvittata	16	20	-	-	36
D. testacea	1	-	3	4	8
D. brachynephros	-	-	2	1	3
D. unispina	-	1	1	-	2
D. nigromaculata	-	1	1	-	2
Total	17	22	7	5	51

Table 5. Numbers of the flies collected (on *P. cervinus*) on different days following its appearance at 19th July, 1974

Date	19/J	20	21	22	24	26	Total
D. sexvittata	-	31	6	1	-	-	38
D. testacea	-	-	-	1	3	-	4
D. brachynephros	-	2	5	18	8	-	33
Total	-	33	11	20	11	-	75

Table 6. Numbers of the flies collected (on *Pleurotus cornucopiae*) on different days following its appearance at 12th July, 1974

Date	12/J	13	15	16	17	19	20	21	Total
D. sexvittata	70	28	7	2	-	-	-	-	107
D. trivittata	8	1	13	-	2	-	-	-	24
D. testacea	-	-	-	-	-	1	-	-	1
D. brachynephros	2	1	1	1	-	1	1	-	7
D. unispina	-	-	-	1	-	-	-	1	2
Total	80	30	21	4	2	2	1	1	141

Table 7. Numbers of the flies collected (on *Polyporellus squamosus*) on different days following its appearance at 1st June, 1973

Date	1/J	4	5	6	7	11	12	13	Total
D. sexvittata	30	113	161	189	114	42	33	4	686
D. confusa	-	15	9	18	20	21	7	1	91
Total	30	128	170	207	134	63	40	5	777

Table 8. Numbers of the flies collected (on *P. squamosus*) on different days following its appearance at 3rd June, 1974

Date	3/J	4	5	7	8	10	14	16	Total
D. sexvittata	3	5	13	24	20	-	1	-	62
D. alboralis	1	-	1	-	-	-	1	-	3
D. confusa	-	-	1	-	4	19	1	-	25
D. testacea	-	-	1	-	-	2	1	2	6
D. histrio	-	-	-	-	-	-	-	2	2
Total	4	5	16	24	24	21	4	4	98

increased as decaying proceeded, and *D. testacea*, *D. unispina*, and *D. nigromaculata* were collected at the decayed stage. Similarly, on *P. cornucopiae* found in July 1974, *D. sexvittata* and *D. trivittata* were abundant at the fresh stage and decreased as decaying progressed. The flies of the *quinaria* section, though few in number, were collected more at the decayed stage. On *P. squamosus* found in June 1974, *D. sexvittata* were abundant at the fresh stage as well, and the flies of the *quinaria* section were collected at the decayed stage. In addition, from *P. squamosus*, *D. confusa* was collected. This fly was collected simultaneously with *D. sexvittata* from the fungus found in May 1973, but from the fungus found in June 1974, it was collected at the intermediate period between the fresh and decayed stages.

Fungi belonging to *Coprinus* are deliquescent; they begin to melt and decay the day after their appearance on the ground. Therefore it can be said that the flies attracted to the fungi of *Coprinus* in large numbers are those which are attracted to the decayed stage of fungi. As mentioned in the result of the fungus preferences, the members of the *melanogaster* group and *quinaria* section are observed to be attracted to these fungi in large numbers. *Drosophila confusa* was also collected from *C. micaceus* in considerable numbers.

Similar successive changes of fauna were observed on other fungi; *D. sexvittata* and *D. trivittata* were attracted to the fresh stage of fungi, while the members of the *quinaria* section and *melanogaster* group were attracted to the decayed stage. In this study it was not confirmed at which stage of fungi the members of *Mycodrosophila* and *D. alboralis* visit, but they were considered to be attracted seldom to the decayed stage, because few were collected from fungi of Coprinaceae.

Discussion

As mentioned in the introduction, the preferences of drosophilid flies attracted to fruits or yeasts are not rigid, and overlap among sympatric species. The preferences of the fungus-feeding species are also not rigid, and overlap. Among the flies studied, *D. trivttata* has rather narrower preferences than the others; this fly was extremely attracted to the fungi of the genus *Pleurotus*.

The members of *Hirtodrosophila* and *Mycodrosophila* except *D. confusa* seem to depend on fleshy fungi (Mf type) and to be attracted to the fresh stage of fungi. In addition, they showed species-specific preferences for individual species of fungi, although there was some overlap: *D. trivittata* was attracted to *P. ostreatus* most, *D. sexvittata* to *P. squamosus* most, *D. alboralis* to *L. ursinus*, and *D. confusa* to *P. squamosus* and *C. micaceus*. For these species which depend mostly on fleshy fungi the differentiation in their fungus preferences would be important to minimize their interspecific competition.

In contrast to the members of *Hirtodrosophila*, the members of the *melanogaster* group and *quinaria* section showed similar fungus preferences to each other as far as was observed in the present study; they were collected from fungi of Coprinaceae mostly. Furthermore, they are attracted to the decayed stage of fungi, and also

to fermenting fruits (mF or MF type). Therefore they seem to be attracted to yeasts or bacteria growing on fungi or to their products rather than to the fungus itself. With respect to the yeast preferences of these flies Kaneko (1960) experimented with five kinds of yeasts in this Garden. He observed that the seven abundant species, *D. lutescens*, *D. immigrans*, *D. brachynephros*, *D. suzukii*, *D. lacertosa*, *D. testacea* and *D. bifasciata*, showed chracteristic and different preferences for different yeasts, though *D. nigromaculata* and *D. auraria* showed similar preferences. Momma (1965b) and Kimura (1976) reported that *D. nigromaculata* is collected more by sweeping on the grasses than the fungi, and the larva of this fly is one of the most common species that breeds on the decayed leaves of various plants. *Drosophila auraria*, *D. brachynephros*, and *D. testacea* also breed on decayed leaves. Some species of the *melanogaster* group, *D. immigrans*, and *D. nigromaculata* were observed breeding on various natural fruits (Momma 1965b, Kimura unpuble.). For them the differentiation in their preferences for yeasts or bacteria growing on fungi, fruits, or leaves, may play an important role in the coexistence of species, thus they would not be expected to have different preferences for the fungus itself.

Among the species studied, *D. confusa* was very specific. This fly is the only species in *Hirtodrosophila* which is attracted to fermenting fruits. It is attracted to both the fresh and decayed stages of fungi, and is also attracted to *C. micaceus* which chiefly attracts the flies of the *quinaria* section, and to *P. squamosus* which attracts *D. sexvittata* in the main. This fly seems to have intermediate preferences for fungi between the other members of *Hirtodrosophila* and the members of the *quinaria* section.

Summary

The fungus preferences of adult drosophilid flies were studied in the Botanical Garden of Hokkaido University in Sapporo. The members of *Mycodrosophila* and *Hirtodrosophila* excpet *D. confusa* are Mf type, and also *D. multispina* was collected more from fleshy fungi than from traps using fermenting fruits. *Drosophila immigrans*, *D. nigromaculata*, *D. lacertosa*, and the members of the *melanogaster* group except *D. nipponica* are mF type. *Drosophila confusa*, *D. brachynephros*, *D. unispina*, *D. testacea* and *D. histrio* are MF type. The members of *Hirtodrosophila* differed from each other in their fungus preferences, but the members of the *melanogaster* group and *quinaria* section did not differ as far as was observed. *Drosophila trivittata* and *D. sexvittata* are attracted to the fresh stage of fungi, but the members of the *melanogaster* group and *quinaria* section are attracted to the decayed stage of fungi. *Drosophila confusa* is attracted to both stages.

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References

Burla, H. 1955. The order of attraction of Drosophila species to cut palm trees. Ecology **36**: 153–155.

Cooper, D.M. 1959. Food preferences of larval and adult Drosophila. Evolution **14**: 41–55.

Da Cunha, A.B., Th. Dobzhansky, and A. Sokoloff 1951. On food preferences of sympatric species of Dorosphila. *Ibid.* **5**: 97–101.

Dobzhansky, Th. and A.B. da Cunha 1955. Differentiation of nutritional preferences in Brazilian species of Drosophila. Ecology **36**: 34–39.

——— and C. Pavan 1950. Local and seasonal variations in relative frequencies of species of Drosophila in Brazil. J. Anim. Ecol. **19**: 1–14.

Kaneko, A. 1960. Drosophila survey of Hokkaido, XVI. Some ecological notes on the attractiveness of different yeasts to drosophilid flies. J. Fac. Sci. Hokkaido Univ. VI, Zool. **14**: 493–498.

Kimura, M.T. 1976. Drosophila survey of Hokkaido, XXX. Microdistribution and seasonal fluctuations of drosophilid flies dwelling among the undergrowth plants. *Ibid.* **20**: 192—202.

Lachaise, D. et L. Tsacas 1974. Les Drosophilidae des savanes préforestières de la région tropicale de Lamto (Côte-d'Ivoire). II. Le peuplement des fruits de *Pandanus candelabrum* (Pandanacées). Ann. Univ. Abidjan E (Ecol.) **7**: 153–192.

Momma, E. 1965a. The dynamic aspects of Drosophila populations in semi-natural areas. 1. Associations and relative numbers of species. Part 1. Results of trapping. Japan. J. Genet. **40**: 275–295.

——— 1965b. The dynamic aspects of Drosophila populations in semi-natural areas. 1. Associations and relative numbers of species. Part 2. Results of sweeping. *Ibid.* **40**: 297–305.

Okada, T. 1954. Fungus feeding drosophilid flies in Japan. Jap. J. Appl. Zool. **19**: 78–82 (In Japanese with English summary).

——— 1962. Bleeding sap preferences of the drosophilid flies. Jap. J. Appl. Ent. Zool. **6**: 216–229.

——— 1967. A revision of the subgenus *Hirtodrosophila* of the old world, with descriptions of some new species and subspecies. (Diptera, Drosophilidae, Drosophila). Mushi **41**: 1–36.

Pipkin, S.B. 1965. The influence of adult and larval food habits on population size of neotropical ground-feeding Drosophila. Amer. Midl. Natur. **74**: 1–27.

———, R.L. Rodriguez and J. Leon 1966. Plant host specificity among flower-feeding neotropical Drosophila (Diptera Drosophilidae). Amer. Natur. **100**: 135–156.

Shorrocks, B and A.M. Wood 1973. A note on the fungus feeding species of Drosophila. J. Nat. Hist. **7**: 551–556.

Suzuki, K. 1955. A field survey of drosophilids which feed and breed on plants. Zool. Mag. **64**: 44–49 (In Japanese with English summary).