A Survey of Host Ranges of Thrips in and Around Hawaiian Pineapple Fields[1]

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A survey of host ranges of thrips, in and around pineapple fields, relating to the study of the transmitting vector of the pineapple yellow spot, was undertaken during 1930 and 1931, and incidental data have been collected since. The data on *Thrips tabaci* Lind., the proved transmitting vector (11), were reported (17) and a preliminary report on some other thrips was published (18). All the available data are presented here and their host ranges will be discussed in relation to the disease.

The first revision of Hawaiian Thysanoptera was published by Bagnall (1) in 1910. Since then various local workers sent specimens to Moulton (12, 13, 14, 15) for determination, which has enabled him to publish 4 papers on descriptions of new species. The specimens of new or heretofore unrecorded species collected during the present investigation were also sent to him, and in his last three papers (13, 14, 15) such materials are included. (The writer wishes to express appreciation for Mr. Moulton's cooperation).

MATERIALS AND TECHNIC

Various weeds, shrubs, trees, crop and ornamental plants (301 different samples, comprising 104 species in 36 families) in and around pineapple fields were checked. A fairly good number of other plant samples were found not associated with thrips. The series of host plants presented in this paper well covers the list of principal weeds in pineapple fields surveyed by other workers (16). Special attention was paid to the host range, population, breeding plant, food preference and source of feeding of the thrips. The majority of the samples was collected on Oahu; several, on the other islands. Efforts were exercised to collect dupli-

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[2] The present investigation was conducted under the direction of Dr. Walter Carter.

cate samples from different localities or at different times. Plants were collected in the fields, packed in large mailing tubes or bags and brought to the laboratory, where the thrips were shaken off. Thus records of the number by stages (larva and adult) and of the sources of feeding (flower or leaf) were made. Occasionally the ordinary method of collecting with a brush directly from standing plants was practiced.

RESULTS

Little less than 500 lots of thrips specimens were collected and all the available data are presented in Table 1. Table 1 also includes those recorded in the references (1, 12, 13, 14, 15), whose source of specimens is not from the Pineapple Experiment Station collection (20 plants and 9 thrips), but excludes the ones published by the writer (17, 18). However, the species collected on the bark of dead trees, mostly of the suborder Tubulifera, are omitted because they bear little relation to the present topic.

TABLE 1. HOST RANGES OF THRIPS IN AND AROUND HAWAIIAN PINEAPPLE FIELDS, WITH RECORD OF DISTRIBUTION.

Aeolothrips fasciatus (Linn.). Maui.

Onion
Cyathodes tameiameiae *

Heliothrips haemorrhoidalis Bouché. Oahu, Hawaii.

Hibiscus sp.
Croton *
Fuschia *
Metrosideros polymorpha *

Heliothrips rubrocinctus (Giard). Oahu.

Mango
Calophyllum inophyllum
Croton *

Hercothrips femoralis (Reuter). Oahu.

Chrysanthemum sp.
(7 other plants in (18), larva was collected from all plants.)

* Cited from the references 1, 12, 13, 14.

Chirothrips fulvus Moulton. Oahu.
Paspalum orbiculare

Chirothrips mexicanus Crawford. Oahu.
Chloris paraguayensis *
Eragrostis variabilis *

Chirothrips sacchari Moulton. Oahu.
Sugar cane *

Limothrips cerealium Halid. Kauai, Hawaii.
Various grasses *

Scirtothrips antennatus Moulton. Oahu.
Panax

Anaphothrips orchidii (Moulton). Oahu.
Anthurium
Commelina nudiflora *

Anaphothrips swezeyi Moulton. Oahu, Molokai.
(4 other plants in (18), larva was not collected from 1 plant)
Panicum torridum *
Setaria verticillata *

Scolothrips sexmaculatus (Perg.). Oahu.
† *Xanthium canadense*
Psidium sp.*

Frankliniella flavens Moulton. Oahu.
Corn *

Taeniothrips alliorum Pr. Oahu, Molokai, Lanai, Maui, Kauai.
Onion
† *Emilia sagittata*

Taeniothrips frici (Uzel). Maui.
Taraxacum officinale

Taeniothrips gracilis Moulton. Oahu.
Hymenocallis declinata

† Adults only were collected from these plants.

Taeniothrips hawaiiensis (Morgan). Oahu, Lanai, Maui.

† *Tricholaena rosea*
Asparagus
Yucca sp.
† *Tritonia potsii*
Senebiera didyma
Cassia mimosoides
Delonix regia
Leucaena glauca
Alfalfa
Soy beans
† *Waltheria americana*
Dombeya spectabilis
Ipomoea indica
Ipomoea pes-caprae
Ipomoea tuberculata
† *Solanum nodiflorum*
Spathodea campanulata
Tithonia rotundiflora
(11 other plants in (18), larva was not collected from 1 plant)
Canna *
Cotton *
Psidium *
Aster *

Taeniothrips simplex Morison. Oahu.

Gladiolus

Thrips abdominalis Crawford. Oahu.

† *Ipomoea indica*
Lipochaeta integrifolia
(7 other plants in (18), larva was not collected from 1 plant)
Lantana *
Verbesina encelioides *

Thrips nigropilosus Uzel. Oahu, Maui.

Lettuce
Hypochaeris radicata

Thrips panicus Moulton. Oahu, Molokai.
(6 other plants in (18), larva was not collected from 1 plant)
Echinochloa sp.*
Rice *
Sugar cane *

Thrips saccharoni Moulton. Oahu, Molokai, Kauai.
Sugar cane
Panicum barbinode

Thrips tabaci Lind. Oahu, Molokai, Lanai, Maui, Hawaii, Kauai.
† *Tricholaea rosea*
Asparagus
Nicotiana glauca
† *Spathodea campanulata*
Callistephus chinensis
Lettuce
(66 other plants in (17), larva was not collected from 16 plants)
Rose *
Ipomoea indica *

Thrips trehernei Pr. Oahu.
† Pineapple

Isoneurothrips antennatus Moulton. Oahu.
Metrosideros polymorpha *

Isoneurothrips dubautiae Moulton. Oahu.
Delonix regia
Dubautia sp.*

Isoneurothrips fullawayi Moulton. Oahu.
Ipomoea indica
Broussonetia papyrifera *

Microthrips piercei Morgan. Oahu.
† *Delonix regia*
Xanthium canadense

Stulothrips trespinus Moulton. Oahu.
Pandanus sp.
† Panax

Suborder TUBULIFERA

Hoplothrips paumalui Moulton. Oahu.

† *Emilia sagittata*
† *Lantana camara*
† *Paspalum conjugatum*

Aleurodothrips fasciapennis (Frank.). Oahu, Molokai.

(1 plant under the name of *Aleurodothrips* sp. in (18), larva was collected)
Coconut *

Haplothrips flavipes Jones. Oahu.

Acacia koa *
Lantana camara *

Haplothrips fusca Moulton. Oahu, Molokai.

Batis maritima *

Haplothrips gowdeyi (Frank.). Oahu, Molokai, Lanai, Maui, Hawaii, Kauai.

Digitaria pruriens
Tricholaena rosea
Amaranthus albus
Phytolacca acinosa
Senebiera didyma
Cajanus cajan
† *Malva* sp.
† *Ipomoea pes-caprae*
† *Bothriospermum tenellum*
Pluchea indica
(41 other plants in (18), larva was not collected from 7 plants)
Panicum torridum *
Paspalum conjugatum *
Cotton *
Vernonia cinerea *

Haplothrips melaleuca (Bagnall). Oahu, Molokai.

Digitaria sanguinalis
† *Tricholaena rosea*
† *Senebiera didyma*
† *Bothriospermum tenellum*
(6 other plants under the name of *Dolerothrips* sp. in (18), larva was not collected from 3 plants)

Haplothrips (Hindsiana) sakimurai Moulton. Oahu.

† *Emilia sagittata*

Kentronothrips hawaiiensis Moulton. Oahu.

Sugar cane

Phloeothrips claratibia Moulton. Oahu.

† Pineapple

Stephanothrips occidentalis H. & W. Oahu.

Paspalum orbiculare

The major species with a wide host range and high relative population density are *Thrips tabaci, Taeniothrips hawaiiensis* and *Haplothrips gowdeyi.*

Thrips tabaci is polyphagous and feeds on flowers and leaves. It was collected from 74 plants (27 families) of which Compositae and Leguminosae are the predominant families. It breeds on 54 plants, and its biotic potential is very high (17). The general relative population density is high. The most preferred host is onion; large colonies were also found on Cruciferous plants, *Portulaca oleracea, Mimosa pudica, Bothriospermum tenellum,* Solanaceous plants, and several plants of Compositae including *Emilia sagittata.* Pineapple is one of the hosts and the insect also breeds on it, but only incidentally.

Taeniothrips hawaiiensis is polyphagous but a strict flower feeder. It was collected from 32 plants (16 families), but the preferred range seems restricted to Leguminosae and Convolvulaceae. It breeds on most of the plants mentioned above. Graminae and Compositae are not included in the range, although incidental plants were found infested. Pineapple and *Emilia* are not its hosts.

The general relative population density is very high and large colonies were found on the plants of Liliaceae, Cruciferae, Sterculiaceae, Verbenaceae and the two families mentioned above.

Haplothrips gowdeyi is polyphagous and a flower feeder. It was collected from 55 plants (22 families). It feeds on leaves sometimes, this being especially true on Gramineous plants. It breeds on most of the plants mentioned above. The general relative population density is very high and large colonies were found on the plants of Graminae, Chenopodiaceae, Amaranthaceae, Leguminosae, Euphorbiaceae, Sterculiaceae, Convolvulaceae, Cucurbitaceae and Compositae. Pineapple is not its host.

The other species are monophagous or polyphagous but with a smaller range or incidental species. The present distribution of *Aeolothrips fasciatus* seems restricted, and a wide host range, as is known in other lands, has not been found in Hawaii. *Heliothrips haemorrhoidalis* and *H. rubrocintus* have a moderate host range among shrubs and the latter is a common species. *Hercothrips femoralis* has not been found outside of greenhouses. Injurious *Hercothrips fasciatus* (Perg.) has not been reported in Hawaii. Three species of *Chirothrips* and *Limothrips cerealium* are incidental species and feed on Graminae. *Scirtothrips antennatus* is monophagous and common on panax. *Anaphothrips swezeyi* is strictly a feeder of Graminae and is very common on them. *Anaphothrips orchidii, Frankliniella flavens,* and *Scolothrips sexmaculatus* are incidental species and the last is a predator on other minute insects. *F. flavens* is the only species representing the genus *Frankliniella* which includes *F. moultoni* Hood in California, *F.* n. sp. Bagnall in Australia and *F.* sp. in South Africa, all of which are transmitting vectors of the spotted wilt virus in their respective regions. *Taeniothrips alliorum* is rather monophagous and is common on onion. *Taeniothrips frici* and *T. gracilis* are incidental species feeding on flowers. There is only one host at present known for each of the two above, although both have a large host range in other lands. *Taeniothrips simplex* is common but monophagous. *Thrips abdominalis* is a feeder of Compositae flowers but also feeds on the plants of Convolvulaceae and Malvaceae. *Thrips nigropilosus* was first recorded in Hawaii injuring lettuce and was recently collected from a wild host on Mt. Haleakala (6000 ft. above sea level) where it is isolated from cultivated

or populated areas. It appears to be widely distributed and well established in Hawaii. It has a moderate host range in the Pacific Coast region and is known to be injurious to various crops in Europe. It is also distributed in Australia, where an attempt to feed it on tomato for testing its transmitting capacity of the spotted wilt virus failed. *Thrips panicus* is a feeder of Graminae and is common on them. It was frequently observed feeding and breeding on pineapple especially on the seedlings and planting material. *Thrips trehernei* is a very incidental species and was once collected on pineapple. This species is known to have a moderate host range in the Pacific Coast region and its recent introduction from there is suspected. Three species of *Isoneurothrips* are incidental species and more or less specific flower feeders. *Microthrips piercei*[3] is rather monophagous and is common on cocklebur leaves. *Stulothrips trespinus* is common on pandanus flowers. Some evidence suggests that it must have other hosts; however, they are not known with the exception of panax. All of the above belong to the suborder Terebrantia.

Among the suborder Tubulifera, very few are known which feed on the present group of living plants. *Hoplothrips paumalui* is an incidental species and probably a flower feeder. *Aleurodothrips fasciapennis* is subincidental on pineapple, preying on minute insects. *Haplothrips fusca* and *H. flavipes* are incidental species and flower feeders. *Haplothrips melaleuca* is a predator found on a moderate range of plants and is subincidental on pineapple, especially on planting material, but quite incidental on other plants. *Haplothrips sakimurai* is a subincidental species and some evidences indicate that there may be other hosts besides *Emilia*. *Kentronothrips hawaiiensis* is known to feed on sugar cane only, on which it is common. *Phloeothrips claratibia* and *Stephanothrips occidentalis* are incidental species, the former being collected on pineapple.

DISCUSSION

Literature on thrips as the vector of virus diseases was recently reviewed by Bailey (2). Data on thrips vectors published up to the present are compiled in Table 2. *Thrips tabaci* is the most outstanding vector and two diseases were definitely proved to be transmitted by it; three other positive cases without suf-

[3] Identified by D. Moulton but not included in his papers.

ficient experimental evidence and six other negative cases are known. Three species of *Frankliniella* were proved to transmit a single disease at different localities. Five other species are known to transmit the diseases without sufficient experimental evidence, and three species showed negative for transmission of the diseases. As Bailey (2) has pointed out, little is known concerning thrips in relation to virus transmission and many other suspected vectors came into the consideration, because of the similarity of the insect's bionomics to those of the proved vectors, especially in food habits, life cycle, population density and host range. However, very few attempts have been made for a thorough search of more efficient or supplemental vectors of the disease. Concerning this point, the case of tomato spotted wilt is very interesting. The disease was found to be transmitted by four different vectors in different localities and two species are known to be vectors simultaneously at two respective localities. These three species (data of *Frankliniella* sp. in South Africa are lacking) have a wide host range and a predominant population in these respective localities. These data are quite suggestive of a probable existence of more efficient or supplemental vectors of the pineapple yellow spot in Hawaii in addition to *Thrips tabaci* which was definitely proved. This is further emphasized by the following: Some data on the relative incidence of *T. tabaci* and the disease seem somewhat difficult to explain on the strict assumption of the existence of a single vector known at present.

Twenty plants are known to be susceptible to the disease, beside *Emilia* and pineapple (8, 10, 11).[4] Table 3 presents these plants, and the relative population density of the 15 species of thrips assocaited with them. *Thrips tabaci* is the only species generally found throughout on these plants, and furthermore it breeds on them. This species was not collected from some of the plants but an experimental test (by Dr. Linford) suggests that the plants are within its host range. *Aleurodothrips fasciapennis, Haplothrips melaleuca, Aeolothrips fasciatus* and *Hercothrips femoralis* were collected from these plants but are excluded from the group because of their apparent predacious habits, or of their non-feeding on any susceptible plant, or their feeding restriction in greenhouses.

[4] In addition to these references Dr. Linford has kindly made available his unpublished data on this subject.

TABLE 2. LIST OF KNOWN THRIPS VEC

Vectors	Diseases transmitted	Major hosts	Localities where diseases are prevalent
Thrips tabaci Lind.	Mosaic	Spinach	Germany
	Spotted wilt	Tomato	Australia
		Tobacco	England
		Tomato	Calif. (U.S.A.)
		Tomato	Ont. Sask. (Canada)
		Pea	Wis. (U.S.A.)
	Tobacco mosaic Greenhouse streak	Tomato	England
	Yellow spot	Pineapple	Hawaii
		Pineapple	Philippines
	Mosaic	Tomato	Ind. (U.S.A.)
	Leafroll	Potato	Ind. (U.S.A.)
	Yellow stripe	Narcissus	England
	Yellow dwarf	Potato	Wis. (U.S.A.)
	A necrotic virus	Tobacco	England
	Yellows	Peach	U.S.A.
	Streak	Tobacco	Wis. (U.S.A.)
Thrips flavus Schrank	Mosaic	Beans	Germany
Thrips minuta var. *puttemansi* Costa Lima	Mosaic	Sugar cane	Brazil
Thrips sp.	Mosaic	*Capsicum*	India
	Stolbur disease	Tomato	Russia
Frankliniella n.sp. Bagnall	Spotted wilt	Tomato	Australia
		Tomato	New Zealand
Frankliniella moultoni Hood	Spotted wilt	Tomato	Calif. (U.S.A.)
Frankliniella sp.	Kromneck disease (Spotted wilt)	Tobacco	South Africa
Hemianaphothrips sp.	Spotted wilt	Tomato	Australia
Hercothrips femoralis (Reuter)	Yellows	Peach	U.S.A.
A greenhouse thrips	Streak	Tobacco	Wis. (U.S.A.)
"Thrips" (A mixture of *Thrips imaginis* Bag., and others)	Witches' broom	Lucerne	Australia
"Thrips"	Mosaic	Eucharis lilies	Bermuda
"Thrips"	Mosaic	Potato	Maine (U.S.A.)

[1] References not cited by Bailey (2) are listed in literature citation.
[2] There appears to be some doubt as to whether pineapple yellow spot actually exists in the Philippines.
[3] *Thrips nigropilosus* Uzel, *Haplothrips* sp. and *Physothrips* sp. failed to feed on tomato when tested.

Experimentally tested		Suspected of positive transmission	Authorities[1]
'ositive	Negative		
+?			Schaffnit (1927)
+?	—	Yes	Pittman (1927); Samuel, Bald, Pittman (1930); Samuel, Bald (1931)
++			Smith (1931)
++			Gardner, Whipple (1934)
nsect vector was not tested			Berkeley (1935)
++			Whipple (1936)
	—		Jarret (1930)
++			Linford (1931)
++			Serrano (1935)[2]
+?		Yes	Cleveland (1931)
	—		Cleveland (1931)
		Yes	Hodson (1932)
	—		Koch (1934)
	(Prelim. test)—		Smith (1935)
	—		Hartzell (1935)
	—		Johnson (1936)
+?			Böning (1927)
+?			Putteman (1926)
+?			Uppal (1929)
		Yes	Koratshevsky (1935)
++			Samuel, Bald, Pittman (1930); Steele (1935)
ısect vector was not tested			Chamberlain, Taylor (1936)
++			Gardner, Whipple (1934)
++			Moore (1933)
	—		Samuel, Bald, Pittman (1930)[3]
	—		Hartzell (1935)
	—		Johnson (1936)
+?		Yes	Edwards (1936)
		Yes	Whetzel (1923)
		Yes	Schultz, Folsom (1925)

TABLE 3. SPECIES AND POPULATIONS OF THRIPS ASSOCIATED W
YELLOW SPOT VIRUS.

HOST PLANTS	Naturally infected	Experimentally infected by *T. tabaci*	PHYTOPHAGOUS								
			Taeniothrips alliorum	Taeniothrips hawaiiensis	Taeniothrips frici	Thrips abdominalis	Thrips panicus	Thrips tabaci	Thrips trehernei	Hoplothrips paumalui	Haplothrips
Bromeliaceae											
Ananas comosus	+	+					3*	3*	1		
Liliaceae											
Allium sp.	—	—	4*								
Cordyline terminalis	+	+						4*			1*
Caryophyllaceae											
Drymaria cordata	+	+									
Leguminosae											
Pisum sativum	+	+						2*			
Labiatae											
Stachys arvensis	+	+						1			3*
Solanaceae											
Capsicum frutescens	+?	+									
Lycopersicon esculentum		+									
Nicotiana glauca		+						3*			
Nicotiana poncha	+	+									
Nicotiana tabacum		+									
Solanum melongena		+									
Solanum nodiflorum	+	+		1				3*			
Rubiaceae											
Richardsonia scabra	+	+						3*			2*
Compositae											
Ageratum conyzoides	+	+						3*			2*
Bidens pilosa		+				3*		3*			3*
Callistephus chinensis		+		C		4*		3*			
Emilia sagittata and 2 other species	+	+	1			3*	1	4*		1	4*
Erigeron canadensis	+	+						3*			4*
Galinsoga parviflora	+	+									
Taraxicum officinale		+			2*						

1=Incidental population.
2 = Low population.
3 = Moderate population.
4 = High population.
C = Citation from reference.
* The insect is definitely known to breed on these plan

H THE SUSCEPTIBLE PLANTS OF

		PREDACIOUS OR UNCLASSIFIED				
Haplothrips sakimurai	Phloeothrips claratibia	Aeolothrips fasciatus	Hercothrips femoralis	Aleurodothrips fasciapennis	Haplothrips melaleuca	REMARKS
	1		3*	2*	2*	
		2*				Negative
						No sample
						No sample
			3*			
						No sample
						No sample
			3*			
1			3*		1	
						Negative

Taeniothrips frici, T. hawaiiensis, T. alliorum, Thrips abdominalis, Hoplothrips paumalui, Haplothrips gowdeyi and *Haplothrips sakimurai* were present on one or more of the susceptible plants but not on pineapple. The presence of *Thrips trehernei* and *Phloeothrips claratibia* on pineapple was very incidental and was not found on any other susceptible plant. *Thrips panicus* and *Thrips tabaci* are the only species collected from pineapple and other susceptible plants. *T. panicus* breeds on pineapple but its breeding on *Emilia* is doubtful. *T. tabaci* breeds on flowers or the succulent basal portion of young leaves of pineapple, and also very freely on *Emilia*. Furthermore, the evidence of frequent accompaniment of the initial spot (the earliest symptom of the disease) with its typical feeding scars or egg punctures on pineapple leaves confirms the definite relationship between this insect and disease on pineapple.

Taeniothrips frici, T. hawaiiensis, T. trehernei and *Phloeothrips claratibia* were present on one or more of the susceptible plants but not on *Emilia*. *Taeniothrips alliorum, Hoplothrips paumalui* and *Haplothrips sakimurai* were present on *Emilia* in small numbers but not on any other susceptible plants. *Thrips abdominalis, T. tabaci, T. panicus* and *Haplothrips gowdeyi* were collected from *Emilia* and also from other susceptible plants. All except *Thrips panicus* breed on *Emilia*. They, in addition to *Thrips tabaci*, are suspected strongly of acting as the vectors, at least between weed hosts, because *Emilia* is the major host of the virus and because the insects breed on *Emilia* and are polyphagous. The transmission of the disease by *T. tabaci* among weed hosts with a various host sequence was recently proved (8).

However, virus inoculation is possible with very short periods of feeding by the insect vector. Thus accidental feeding is sufficient for a successful inoculation, although the percentage of infection may be lower. Therefore, the susceptible plant can be infected whether or not it is a normal breeding plant of the vector. If the suspected vectors are similar to the proved vectors of yellow spot or spotted wilt, they can be infected only during their larval stage. Thrips larvae very seldom move away from the plant where they have hatched. Therefore, contiguity of the normal breeding plant and the susceptible plant is essential only for the vector to become infected and not for the plant to become infected. Con-

trary to the negligible migratory habits of the larval stage, the adults are usually and quite frequently dispersed by means of air currents. This is true for nearly all species, and evidence indicates that very large numbers of individuals and species are blown into pineapple fields. This will also be true in other ecological surroundings. Again if the suspected vectors are similar to the proved vectors, they can retain virulence for a long time in their adult life. Therefore, any thrips, which has a transmitting capacity of the virus and breeds on infected plants, can disperse to other plants of the same susceptible species and easily transmit the virus without subsequent recontamination from other sources of infection, and can also transmit to plants of other susceptible species if the insect is not a specific feeder. This is true for both the flower and leaf feeders. The influence of the host sequence of the virus upon the degree of virulence (attenuation or devirusing) (8) comes into consideration here.

The true host ranges of these thrips may be wider than those presented in the data. This is true especially because the adults are dispersed by air currents; in this way many species of thrips may be carried to a variety of plants and many plants may also act as sources of dispersal. Therefore, the suspected vector range must not be restricted to the listed species associated with the susceptible plants. In fact, there are many evidences which suggest the existence of other vectors of the yellow spot disease and a critical test of the transmitting capacity of these thrips should be undertaken.

SUMMARY

The record of host ranges of thrips in and around pineapple fields is presented and their possible relation to the vector of the yellow spot virus in Hawaii discussed.

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