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Original Article

Abundance and distribution of thrips (Thysanoptera: Thripidae) in mangosteen (*Garcinia mangostana* L.) grown in single- and mixed-cropping systems

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Abstract

We investigated the abundance and distribution of thrips in a farmer's mangosteen orchard by comparing single- and mixed-cropping systems at Nakhon Sri Thammarat province, the main planting area in southern Thailand, between April 2005 and January 2006. A monitoring program at two-week-intervals was done to measure the number of thrips by using twenty yellow sticky traps per each cropping system. The mean number (223.5±23.4 thrips/trap) of thrips throughout the period of study in the monocrop mangosteen sites was significantly ($P<0.01$) higher than 69.1±8.3 thrips/trap in the mixed-crop mangosteen sites. Scarring on the fruit surfaces damaged by thrips was visually quantified, with average percentages of scarring 32.2% and 19.8% in the mono- and mixed-cropping systems, respectively. Distribution of thrips in the upper and lower halves of the plant canopy in the four cardinal directions was studied by assessing scarring on the fruit surfaces. The percentage of scarring occurring in the upper canopy was significantly ($P<0.01$) higher than in the lower canopy. In the single-crop system, the average percentages of scarring were 46.6% and 25.4% on the upper and lower canopies, respectively. In the mixed-cropping system results obtained were similar to those in the single cropping system, with 31.5% and 20.4% on the upper and lower canopies, respectively. The severity of damage to the fruits caused by thrips seemed to be higher in the North and East directions than in the South and West. In conclusion, mixed-cropping mangosteen orchards are recommended for reducing fruit damage caused by thrips. Fruits occurring on the upper canopy, in the North and East sides, should be underlined for thrip control to meet the criteria for high quality mangosteen production from the south of Thailand.

Keywords: mangosteen, thrips, abundance, distribution, single-and mixed-cropping systems

1. Introduction

Mangosteen is often referred to as the "Queen of Tropical Fruits" because of its delicious taste. It is a popular choice for orchards where conditions are good for its growth, such as in southern Thailand. By the year 2006/2007, the total planting area of mangosteen in Thailand was 316,413 rai (~6 rai = 1 ha), mainly planted in the east and south of Thailand (DOAE, 2007). Mangosteens are favorit fruits not only for domestic consumption but also for the export such as to Hong Kong, Taiwan, China, Japan and Canada. High quality in mangosteens for export is defined as a good fruit size (>70 g/fruit), without flesh translucent disorder, without scarring on fruit surface and calyx, and no fruit gamboges (DOA, n.d.). A common cause of scars on the fruit surface and calyx is thrip infestation.

Two important species of thrip found on mangosteens are *Scirtothrips dorsalis* Hood and *Scirtothrips oligocheatus* Karny (Poonchaisri, 1992; Ngampongsai, 2006). Nearly one hundred percent of mangosteen fruits produced in Nakhon Sri Thammarat province, the main production area in southern Thailand had thrip damage (Ngampongsai, 2006). Mangosteens have traditionally been grown in either single- or mixed-cropping systems. It has been speculated that these

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two different systems may result in different abundances and distribution of thrips in mangosteen, as inter-cropping has been shown to reduce the numbers of stem borers, *Chilo partellus* (Swinhoe) in sorghum, and thrips, *Megalurothrips sjostedti* (Trybom) in cowpea (Ampong-Nyarko *et al*., 1994). Also, full field undersowing of leeks with clover was shown in another study to suppress populations of adult and larval *Thrips tabaci* (Lindeman) (Theunissen and Schelling, 1998). Higher numbers of *M. sjostedti* oriented towards, and settled on, sole cowpea plants than on those mixed with maize (Kyamanywa *et al*., 1993). Colonization or settling of adult onion thrips, *T. tabaci* in monocropped leek (*Allium porrum* L.) and in leek intercropped with strawberry clover (*Trifolium fragiferum* L.) was studied in two-potted plant experiments. In both potted-plant experiments, there were consistently fewer adult thrips on intercropped leek plants than that on monocropped plants (den Belder *et al*., 2000). Nectarine orchards protected from wild areas by other orchards had the lowest densities of thrips, *Frankliniella occidentalis* (Pergande), in buds (Pearsall and Myers, 2000).

The study was carried out in order to offer guidance as to which of the two cropping systems, single-cropping or mixed-cropping systems, should be used to improve production both quality and quantity of mangosteens in the south of Thailand, particularly for export purposes. The experiments consisted of two main parts: monitoring the abundance of thrips in the two cropping systems and investigating the distribution of thrips in the canopy of the mangosteen trees. Later these two parts were considered to be integrated into a thrips management control stragy.

2. Materials and Methods

2.1 Site descriptions

This study was conducted during April 2005 - January 2006. The actual study site was a 13-year old mangosteen orchard of approximately 15 Rai (2.4 ha.) in size, comprising both single-and mixed cropping systems; the mixed system included durian (*Durio zibethinus* Merr, Bombacaceae) and longkong (*Aglaia dookkoo* Griff, Meliaceae) trees.

2.2 Abundance study

The number of thrips in the single- and mixed-cropping mangosteen systems was recorded by catching thrips, using yellow sticky traps. The study was conducted between April 2005 and January 2006. The sticky traps (20 cm x 20 cm), made from a plastic sheet, were placed in plastic bags coated with Cosfix® glue on both sides. Four traps were set on each of five trees, giving twenty traps in each cropping system. The traps were hung at a height of 1.5 meters in the tree canopy, one in each of the four cardinal directions (N, E, S and W). They were replaced at two-week intervals and the old ones were then taken to the laboratory for thrips counting on both sides of the trap. Comparisons of means of the number of thrips collected were made by using paired t-test for each collection and for the entire period of the study.

Fruits damaged by thrips in both cropping systems were visually quantified three times in May and June 2005. Light intensity, measuring with a light meter (Denki®, DK-211) at the sites of the yellow sticky traps, was recorded in each trap collection. Statistical analyses for comparisons of the thrip abundance in the two cropping systems were subsequently done. Correlations of light intensity and the numbers of thrips captured on the traps in both cropping systems were analyzed by applying Pearson's method.

2.3 Distribution study

Distribution of thrips in the lower half and the upper half of mangosteen canopy was investigated by assessing visually on the scarring of the fruit surfaces. Three assessments were done during May and June 2005. Five mangosteen trees were randomly sampled from each cropping system. Twenty fruits per tree were randomly sampled from each of the four cardinal directions from both the lower and upper halves of the canopy. Mean comparisons of the percentage scarring of the lower and upper canopies were performed with the paired t-test. One-way analysis of variance (ANOVA) of the scarring percentages among the four directions was done and means were compared by using the Duncan's Multiple Range Test (DMRT).

3. Results and Discussion

3.1 Abundance of thrips in two mangosteen cropping systems

The abundance of thrips in mangosteen was significantly higher in the single-cropping than in the mixed-cropping system. The average number of thrips throughout the period of study in the single-cropping system was 223.5±23.4 thrips/trap, significantly ($P<0.01$) higher than 69.1±8.3 thrips/trap in the mixed-cropping system (Table 1). The severity of damage to the fruits caused by the thrips was also higher in the monocropping system than in the mixed-cropped system. The percentage means of the scarring on the fruit surfaces was 32.2% in the single- and 19.8% in the mixed-cropped systems, respectively (Table 2). Light intensity was found to be significantly different between the single- and the mixed-cropping systems (Table 3), but there was no linear correlation between thrip abundance and light intensity ($P>0.05$), with correlation coefficients (r) of 0.3 in the single-cropping system and -0.1 in the mixed-cropping system (Table 4), indicating that light intensity was not a key factor governing the abundance of thrips in mangosteen orchards in the aspect of linear correlation. The complexity and composition of the cropping system, micro-environment, emission of volatile chemicals into the system and orchard exposure to wind flow, which carries dispersing thrips, also play a role in thrip abundance. Results obtained from the study of the thrip abundance in the single-cropping and

Table 1. Number of thrips caught from two different cropping systems by yellow sticky traps in farmer mangosteen orchards between April 2005 and January 2006 at Promkeeree District, Nakhon Sri Thammarat province

Cropping systems	Number of thrips/trap (Mean±SE[1/])										Throughout study (Mean±SE[2/])
	Apr. 05	May 05	Jun.05	Jul.05	Aug.05	Sep.05	Oct.05	Nov.05	Dec.05	Jan.06	
Single-cropping	1,437.7 ±139.2	331.5 ±35.4	39.1 ±3.8	49.6 ±6.0	88.6 ±21.1	61.7 ±120.3	41.9 ±5.7	38.4 ±7.2	10.4 ±2.8	4.9 ±0.5	223.5 ±23.4
Mixed-cropping	342.1 ±54.9	176.8 ±32.2	23.8 ±3.8	73.6 ±20.5	17.0 ±2.6	14.8 ±2.7	98.7 ±47.6	3.2 ±0.5	9.9 ±5.2	3.1 ±0.4	69.1 ±8.3
T-test	6.9**	3.3**	2.5*	ns	3.4**	3.8**	ns	4.9**	ns	2.8**	6.9**

[1/] means from 40 traps, [2/] means from 400 traps, ** significant at 99% level, * significant at 95% level, ns = not significant

Table 2. Average percentages of scars on mangosteen fruit surfaces caused by thrips in two different cropping systems in May and June 2005 at Promkeeree District, Nakhon Sri Thammarat province

Cropping systems	% scarring on fruit surface (Mean±SE[1/])			Throughout study (Mean±SE[2/])
	May 21, 2005	June 4, 2005	June 18, 2005	
Single-cropping	35.1±2.0	25.4±1.7	36.0±2.1	32.2±1.2
Mixed-cropping	16.2±1.5	18.3±1.6	24.8±1.8	19.8±1.0
T-test	7.3**	3.0**	4.1**	8.1**

[1/] means from 200 fruits, [2/] means from 600 fruits, * significant at 95% level, ** significant at 99% level, ns = not significant

Table 3. Light intensity at yellow sticky trap positions in mangosteen canopy of two different cropping systems between April 2005 and January 2006 at Promkeeree District, Nakhon Sri Thammarat province

Cropping systems	Number of thrips/trap (Mean±SE[1/])										Throughout study (Mean±SE[2/])
	Apr. 05	May 05	Jun.05	Jul.05	Aug.05	Sep.05	Oct.05	Nov.05	Dec.05	Jan.06	
Single-cropping	839.9 ±94.8	732.9 ±27.6	359.7 ±76.7	430.0 ±75.7	733.0 ±95.8	845.8 ±39.1	1,134.9 ±55.4	244.9 ±37.6	430.2 ±85.7	496.8 ±71.6	615.5 ±33.3
Mixed-cropping	42.7 ±8.3	41.1 ±6.2	35.9 ±5.9	61.4 ±5.7	48.7 ±10.2	43.4 ±9.4	98.5 ±17.9	70.7 ±17. 7	73.4 ±11.5	29.2 ±4.8	54.8 ±3.7
T-test	7.9**	22.5**	4.3*	4.7**	7.2**	19.5**	25.4**	4.2*	4.4*	6.5**	17.0**

[1/] means from 10 replications, [2/] means from 100 replications,** significant at 99% level, * significant at 95% level

Table 4. Pearson's correlation of thrip numbers caught by yellow sticky traps in single- and mixed cropping systems of mangosteen with light intensity

	Correlation	Sig. (2-tailed)	n
Single cropping	0.321	0.5	10
Mixed cropping	-0.101	0.8	10

mixed-cropping systems in this study are similar to those found by Ampong-Nyarko *et al.* (1994), Theunissen and Schelling (1998), Kyamanywa *et al.* (1993), den Belder *et al.* (2000) and Pearsall and Myers (2000).

In an agroforestry system, the dynamics of insect pests and their natural enemies are governed by the complexity and composition of the agroforestry system. The pest situation in these systems will be influenced by the degree of interaction between the components, the type of agroforestry system and the composition of the plant communities in each component (Anonymous, 1999). Root (1973) proposed two hypotheses, the resource-concentration hypothesis and the enemies hypothesis, to explain the general reduction of pest densities in diverse plant combinations. The resource-concentration hypothesis suggests that in monoculture fields where the same plant species is cultivated over large areas the herbivores find a concentrated source of food in one place that supports uninterrupted population build up. The food plants in pure stands are easily detected and colonized. The pests, particularly the specialists, exhibit longer tenure periods and higher feeding and reproductive success. The resource-concentration and the enemies hypotheses would support this study. Since in the mixed-cropping system reflects less abundance of thrips than in the single-cropping system.

The interactions among plants in a mixed-cropping system create a micro-environment that is different from that of the single-cropping system. This micro-environment might suppress the thrip population in the mixed-cropping mangosteen system in this study. Shade is the most prominent consequence of tree–crop combinations and this shade may affect directly and indirectly on the activity of the insect pests and their natural enemies. Reduction in temperature and an increase in humidity are among the more important indirect effects (Anonymous, 1999). Shad from tree can interfere with the host-seeking and reproductive behavior of some insects (Risch, 1981; Yang *et al.*, 1988) Also, the more humid conditions in a mixed-cropping system may be favorable for the development of disease in insect pests. Coupled with the absence of direct sun, the effectiveness of entomopathogenic fungi may be increased by humidity (Jaques, 1983). The effective infective period of *Bacillus thuringiensis*, the most widely used entomopathogenic bacterial preparation, is greatly reduced in sunlight. Increased humidity has also been reported to favor parasitization of pest eggs by *Trichogramma* sp. (Pu, 1978). These reports would explain why the thrips were less abundant in the mixed-cropping system than in the single-cropping system in our study.

Many plants emit volatile chemicals or odours into the environment. These odours are perceived by herbivorous insects and utilized to orient themselves to the host fields (Anonymous, 1999). Onion flies, *Hylemya antigua*, for instance, have been found to fly directly towards the odor released by an onion bait (Dindonis and Miller, 1980). In monocultures, the odors released by the plants spread out in all directions and are perceived by potential pest herbivores without any interruption. But in mixed vegetation, the odors released by some plants may mask the effect of those released by other plants. Under these circumstances, the insects find it more difficult to locate the hosts on which to feed and reproduce (Altieri, 1986). It is possible that the volatile chemical from the mixed-cropping system of the mangosteen gives similar reactions to those reported before to the insect pests.

The barrier provided by non-host plants such as durian, longkong, rambutan and other plant trees occurring in the mangosteen mixed-cropping system probably contributed to reduced movement of thrips in this study. Anonymous (1999) postulated that the tall woody plants in an agroforestry system act as a physical barrier to the movement of insects to, from and within the system. The non-host plants of insect pests act as a biological barrier, restricting their movement towards the host plants. Non-host plants mixed in with host plants either act as a mechanical barrier to the dispersal of the insect pest (Kennedy *et al.*, 1959; Root, 1973) or physically repel the pests because of unpleasant morphological features such as hairy leaves (Levin, 1973). A wind flow in two different planting systems in our study might play a role in plant host finding. It is easier for wind-dispersed thrips to find their way to mangosteen orchards exposed to wind flow in the single-cropping than in the mixed-cropping systems. Pearsall and Myers (2000) revealed that exposure of orchards to a wind flow which carries dispersing thrips may play a role in thrip movement.

3.2 Thrips distribution in mangosteen canopy

The distribution of thrips based on visual assessment of scarring on the fruit surfaces showed that thrips were more abundantly distributed in the upper canopy than the lower one in both cropping systems. The mean percentage of the scarring in both cropping systems throughout the study period were 31.5±1.2% in the upper canopy, significantly ($P<0.01$) higher than the 20.4±1.0% found in the lower canopy (Table 5). These results are in agreement with several previous studies. Grant and Parker (1991) found more pear thrip adults in the upper maple canopy in two of three studies. Teulon *et al.* (1992) noted a significant effect of trap height on thrip captures and found more thrips on yellow sticky traps in upper canopy positions throughout the trapping period. Adults of the western flower thrips, *F. occidentalis* and *F. citrici* (Fitch), were significantly more abundant in tomato flowers in the upper canopy than in the lower canopy. In contrast, significantly more immature thrips occurred in the lower part of the plant canopy than in flowers in the upper part of the plant canopy (Reitz, 2002; Salguero-Navas *et al.*, 1991). Because thrips are thought to fly just above the plant canopy (BrØdsgaard, 1989; Gillespie and Vernon, 1990), it is reasonable to expect that most adults would be found in flowers in the upper part of the plant canopy (Reitz, 2002). McLaren and Fraser (n.d.) revealed that New Zealand thrips, *Thrips obscuratus* (Crawford), were found more in the tops

Table 5. Average percentages of scarring on fruit surfaces of mangosteen occurring in the upper half and the lower half of the canopy of two different cropping systems in May and June 2005 at Promkeeree District, Nakhon Sri Thammarat province

Canopy area	% scarring on fruit surface (Means±SE)[1/]						Grand means[2/]
	Single-cropping			Mixed-cropping			
	May 21, 05	June 4, 05	June 18, 05	May 21, 05	June 4, 05	June 18, 05	
Upper canopy	38.73.0	30.3±2.4	46.6±3.1	17.8±2.2	22.2±2.6	33.4±2.9	31.5±1.2
Lower canopy	31.5±2.7	20.4±2.4	25.4±2.6	14.5±2.1	14.5±1.9	16.1±1.8	20.4±1.0
T-test	2.1*	3.5**	6.8**	ns	2.6*	5.8**	8.9**

[1/] means from 200 fruits; [2/] means from 600 fruits; *significant at the 95% level; **significant at the 99% level; ns = not significant

Table 6. Average percentages of scar on fruit surfaces of mangosteen occurring in four cardinal directions of two different cropping systems in May and June 2005 at Promkeeree District, Nakhon Sri Thammarat province

Cardinal directions	% scarring on fruit surface (Means±SE)[1/]					
	Single-cropping			Mixed-cropping		
	May 21, 05	June 4, 05	June 18, 05	May 21, 05	June 4, 05	June 18, 05
North	42.3±4.6	29.3ab[2/]±4.1	39.0±3.9	17.8±3.4	27.3a±4.1	23.2b±3.8
South	33.9±4.0	18.6ab±3.0	37.5±4.4	13.6±2.6	12.6b±2.0	19.5b±3.1
East	34.3±3.9	32.6a±3.7	38.9±4.6	20.6±3.9	18.7ab±3.4	35.4a±4.0
West	31.0±4.1	20.9ab±2.8	28.7±4.2	12.7±2.3	15.4b±3.4	20.6b±3.3
F-test	ns	**	ns	ns	*	**
CV (%)	47.4	52.6	49.5	67.1	64.9	56.9

[1/] means from 50 fruits; [2/] means with different letters in the same column are statistically significantly different (P<0.05) by DMRT; *significant at the 95% level; **significant at the 99% level; ns = not significant

of nectarine trees than in the lower branches. Within the tree, they moved around at different times of day.

The results of our study showed that the scarring on mangosteen fruit surfaces seemed to be higher in fruits on the north and east sides of the trees than on the south and west sides (Table 6), indicating that thrips were more abundant in the north and east sides than on the south and west. Sirising *et al*. (1992) reported that thrip distribution in a mangosteen canopy was more abundant in the south and east. In another study, no differences were found between the numbers of thrips sampled from nectarine branches facing north, south, east or west (McLaren and Fraser, n.d.).

The production of mangosteen in the south of Thailand currently seems to be conducted under conventional practices of thrip management, resulting in a high severity of fruit damage due to thrips, which then becomes a burden for export compared with mangosteens from the eastern part of the country. Finally, we conclude from our study two main points for thrip management strategy in mangosteen. Firstly, for those growers who are going to initiate new plantations, mixed-cropping system is one of the good alternatives. Secondly, for those growers who have mature fruiting trees, they should monitor and have a schedule of periodic pest surveillance on the flowers and young fruits which are located in the upper half of the canopy, mainly in the north and east cardinal directions since these plant organs are most sensitive to thrip infestation. Some control measures have to be established, if necessary.

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