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Population Dynamics and Dispersion of *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae) on Lettuce under Hydroponic Cultivation in Greenhouse

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ABSTRACT

Studies were conducted on the population dynamics of *Frankliniella schultzei* (Trybom) on Iceberg, Red Salad Bowl and Red Rapid lettuce cultivars grown hydroponically at Pathum Thani province, Thailand. In addition, studies were carried out on the dispersion patterns of *F. schultzei* on hydroponically grown Green Oak Leaf, Red Oak Leaf and Butterhead in Nakhon Pathom province, Thailand. The population of *F. schultzei* was not detectable in January and February 2012. However, the population clearly increased to its peak in the March planting and then sharply declined in the April planting. The temperature and the relative humidity did not have any effect on the population dynamics of *F. schultzei*. The dispersion of *F. schultzei* on the upper side and lower side of lettuce leaves was found to be most abundant at Sampling Point 3 on the upper side of the leaves of all three lettuce cultivars. On the lower side of the leaves of the three cultivars of lettuce, it was most abundant at Sampling Point 5 on Green Oak Leaf and Red Oak Leaf and at Sampling Point 3 on Butterhead only. The populations of *F. schultzei*, showed a uniform dispersion pattern on Green Oak Leaf and Red Oak Leaf and a clumped dispersion pattern on Butterhead.

Keywords: lettuce, hydroponics, *Frankliniella schultzei* (Trybom), population dynamics, dispersion

INTRODUCTION

Consumption of vegetables has recently increased in Thailand, resulting in greater popularity of hydroponically grown vegetables among consumers (Thongket, 2007). Hydroponics is a technique for growing plants including vegetables in water containing dissolved nutrients without using soil (Ernst and Busby, 2009). Growing vegetables using hydroponics offers the advantage of producing large quantities of vegetables in a relatively small area. Lettuce, pakchoi, tomato, sweet pepper and cantaloupe can all be grown using hydroponics (Arancon *et al*., 2005; Thongket, 2007).

Although growing plants hydroponically has many advantages, it creates a suitable environment for pests such as thrips, aphid and whitefly to thrive (Van *et al*., 2008). Thrips can cause direct damage to vegetables, for example, tipburn on lettuces and silver leaf on tomatoes (Thompson, 1926 Jones, 2005;). The thrips species commonly found in hydroponics lettuces include *Frankliniella occidentalis* (Pergande) (Liu, 2011), *F. fusca* (Hinds) (Natwick *et al*., 2007; Wilson, 1998), *F. schultzei* (Trybom), and *Thrips tabaci*

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Linderman (Burfield, 2009; Diffie and Riley, 2009). In addition, the aphid species found on lettuces include *Nasonovia ribis-nigri* (Mosley) (Australian Vegetable Grower's Association, 2002; Cole and Horne, 2004; Palumbo, 2006), *Macrosiphum euphorbiae* (Thomas), *Uroleucon ambrosiae* (Thomas) (De Conti *et al.*, 2008) and *Myzus persicae* (Sulzer) (Rekika *et al.*, 2009).

In Thailand, *F. schultzei* was found on sacred lotus, chrysanthemum, bean, cotton, pepper, onion and cucumber (Poonchaisri and Sengsim, 1993). Elsewhere *F. schultzei* has been reported, on the leaves of French bean, Irish potato and baby corn (Nyasani *et al.*, 2009) and also on the flowers of eight plant species—namely, *Malvaviscus arboreus* Cav., *Hibiscus rosasinensis* L., *Vigna caracalla* L., *Erythrina crista-galli* L., *Bauhinia galpinii* N.E. Brown, *Bauhinia variegat*a L., *Ipomoea cairica* Sweet and *Jacaranda mimosifolia* D. Don (Milne and Walter, 2000). In addition, *F. schultzei* was also reported on flowers of tomato, chili pepper, onion (Adkins *et al.*, 2009) and sunflower (Nyasani *et al.,* 2009).

The spatial distribution of different species of thrips was studied using six methods to determine their population dispersions—Taylor's power law (Taylor, 1961), Lloyd's mean crowding (Lloyd, 1967), Iwao's patchiness regression (Iwao and Kuno, 1968), the index of dispersion (Patil and Stiteler, 1974) and Morisita's coefficient of dispersion (Morisita, 1962). In general, insect populations are known to follow three distinct dispersion patterns—clumped, random or uniform (Southwood, 1978). Among these dispersion patterns, clumped or aggregated distributions have been reported: for *F. occidentalis* (Pergande) on greenhouse cucumber (Cho *et al.*, 2001); for *Aeolothrips intermedius* Bagnall, *F. intonsa* Trybom, *F. occidentalis*, *T. angusticeps* Uzel and *T. tabaci* on cotton (Deligeorgidis *et al*., 2002); and for *Scirtotrips dorsalis* Hood on pepper (Seal *et al*., 2006).

Fluctuations of insect populations are affected by density dependent (or biotic) factors and by density independent (or abiotic) factors, with the latter including temperature, humidity, rainfall, soil pH and food quality (Pongprasert, 2005). The relationship between an insect species and abiotic factors can be determined by estimating insect population fluctuations (Roy *et al*., 2002). The effect of abiotic factors on insect population fluctuations has been reported for thrips species (Panicker and Patel, 2001), cotton leafhopper, *Amrasca biguttula biguttula* (Ishida) (Gogoi and Dutta, 2000) and whitefly, *Bemisia tabaci* (Gennadius) (Murugan and Uthamasamy, 2001; Umar *et al*., 2003).

The objectives of this paper were to **study the** population fluctuations and dispersion patterns of *F. schultzei* and the influences of temperature and humidity on thrips populations under hydroponic conditions.

MATERIALS AND METHODS

The study was carried out in two separate greenhouses covered with fine mesh nets (206.40 mesh.cm^2) in Thailand; one in Mueang district, Pathum Thani province and the other in Kamphaeng Saen district, Nakhon Pathom province. At each test site, a hydroponics system was installed to sustain the growth of the tested plants and Iceberg, Red Salad Bowl, Red Rapid, Green Oak Leaf, Red Oak Leaf and Butterhead were grown according to the Nutrient Film Technique (Fa Fresh Farm. Co. Ltd., 2012).

Design of hydroponics systems and growing test plants

System A-The hydroponics system installed in Mueang district was constructed using six A-frames (6.25 × 0.85 × 1.33 m) with a total of 12 hydroponic troughs on both sides of the A-frames. For each trough covered in System A, 24 holes (5 cm in diameter) were drilled to provide openings for transplanting the seedlings and also to insert physical support for the growth of test plants. Three cultivars of lettuce (Iceberg, Red Salad Bowl and Red Rapid) were used with eight tested plants per cultivar grown in each of the six troughs. Thus, there were 24 plants per trough resulting in a total of 144 plants grown on each side of the A-frame and a total of 288 plants for system A.

System B-The hydroponics system installed in Kamphaeng Saen district had a different design from that of System A. System B consisted of five basket-like, pre-fabricated units. Each unit was composed of five plastic hydroponic troughs (2.0 × 0.80 × 0.85 m), which were evenly spaced from the top to the bottom of each unit to allow each tested plant to receive maximum light during growth. On each of the covered plastic troughs in System B, nine holes (5 cm in diameter) were drilled to provide openings for transplanting of seedlings and also to insert support for the growth of the tested plants. Three different cultivars of lettuce (Green Oak Leaf, Red Oak Leaf and Butterhead) were used as the test plants. There were three tested plants per cultivar grown in each of the five troughs in a unit. Thus, there were 15 plants per cultivar grown in each unit with a total of 45 plants per cultivar grown in the 5 units.

Population fluctuation of *F. schultzei* in lettuce grown in a screen house

This study was conducted in Mueang district during January to August 2012, using the System A procedure as described above. The three lettuce cultivars used in this study were Iceberg, Red Salad Bowl and Red Rapid. A sample of 100 leaves per cultivar was randomly sampled on a weekly basis. Since it required 35 d for a lettuce to reach maturation from a seedling, seven crops were sampled from January to August 2012 except in May, when the three lettuce cultivars were not grown and thus were not sampled. The first leaf sample was taken 1 d after transplanting when the lettuce was aged about 16 d until the lettuce was harvested at 51 days after planting (DAP). The number of thrips present on the leaves sampled was counted and recorded. The temperature, relative humidity and conditions of the lettuce leaves sampled were recorded.

These data were first transformed by taking Log N+1 and then subjecting the result to Tukey's range test to determine whether there was a significant difference in the relative abundance of *F. schultzei* on the three cultivars of lettuce in the greenhouse conditions. The data were also subjected to regression analysis to determine their relationship with such abiotic factors as the temperature and humidity recorded in the greenhouse.

Dispersion patterns of *F. schultzei* in lettuce grown hydroponically

This study was conducted in Kamphaeng Saen district with one crop sampled from January to March 2013 using System B as described above. The three lettuce cultivars used in this study were Green Oak Leaf, Red Oak Leaf and Butterhead. A sample of 50 leaves per cultivar was sampled at 7 d intervals, resulting in five samplings as it required 35 d for a lettuce to reach maturation from a seedling starting from 16 DAP until the lettuce was harvested at 51 DAP.

The dispersion patterns of *F. schultzei* on the three lettuce cultivars were determined by two methods. The first method involved counting the number of thrips present at each of the six pre-selected sampling points on the upper side of the third leaf of each cultivar at: 1) the mid rib at the leaf apex, 2) the mid rib at the middle of leaf, 3) the mid rib at the leaf base 4) the margin of the leaf apex, 5) the margin of the middle of leaf and 6) the margin of the leaf base (Figure 1a). The same sampling procedure was repeated on the lower side of the third leaf of each cultivar (Figure 1b). The second method involved counting the number of thrips present on seven leaves in two lettuce heads of Green Oak Leaf and Red Oak Leaf as shown in Figure 2a and for Butterhead in Figure 2b.

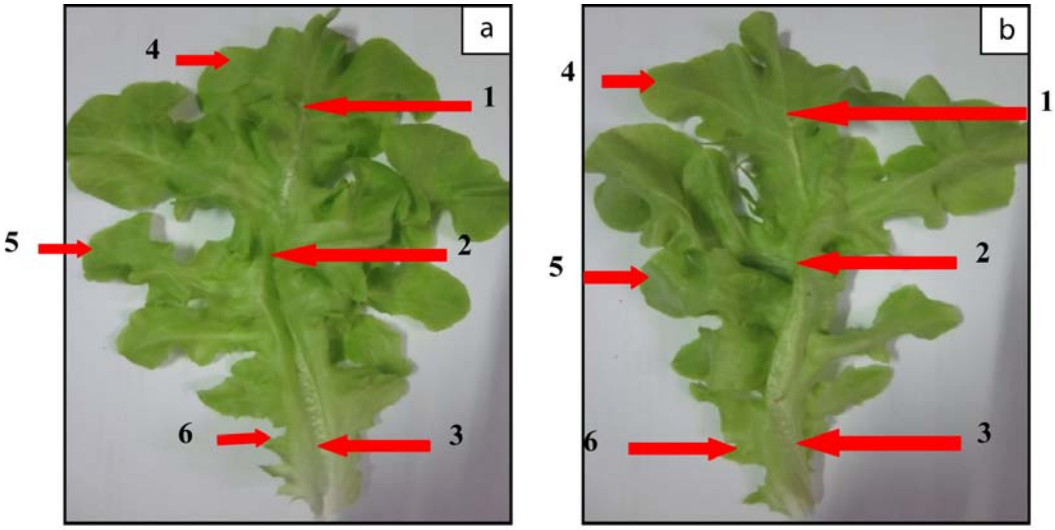

Figure 1 Sampling points on the three cultivars of lettuce: (a) Upper side of leaf; and (b) Lower side of leaf.

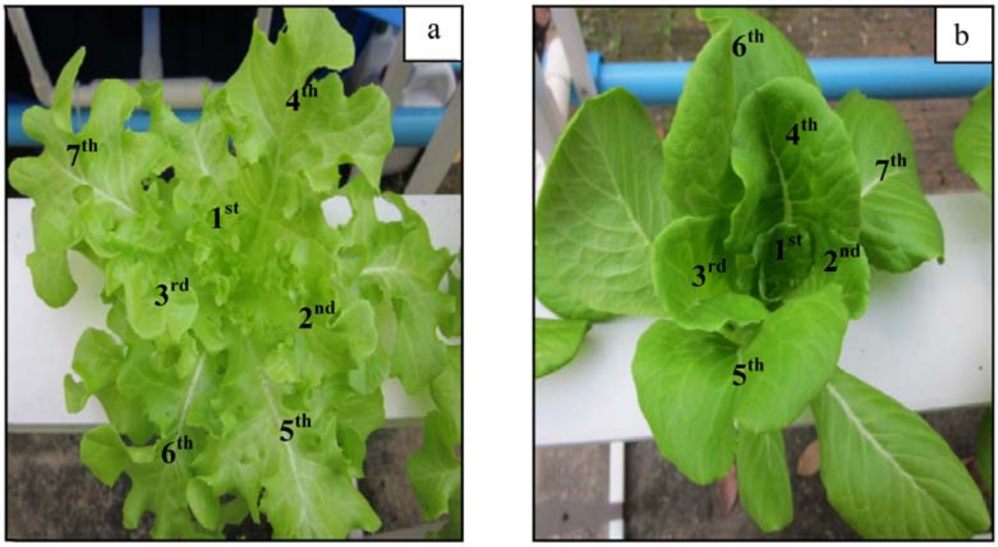

Figure 2 Positions of lettuce leaves sampled from lettuce cultivars; (a) Leaf number of Green Oak Leaf and Red Oak Leaf; (b) Leaf number of Butterhead.

The dispersion patterns of *F. schultzei* on the upper side and lower side of the third leaf of Green Oak Leaf were determined using Equation 1 (Southwood, 1978):

$$t = \frac{S^2 / \bar{x} - 1}{S_{\bar{x}}} \quad (1)$$

where S is the variance, $\bar{x}$ is the mean and $S_{\bar{x}}$ is the standard error.

The dispersion patterns of *F. schultzei* on plants of three lettuce cultivars were first transformed by taking log N+1 (N = Number of thrips) and then subjecting the result to Tukey's range test.

RESULTS AND DISCUSSION

Population fluctuation of *F. schultzei* in lettuce grown in screen house

In System A, lettuces were sampled during January to August 2012. Populations of *F. schultzei* in the three cultivars were first detected on lettuce leaves sampled in January. The populations reached their peak in March and then sharply declined in April and June to August, Populations of *F. schultzei* on Iceberg declined a little during June and July and then increased again in August. Populations of *F. schultzei* on Red Salad Bowl steadily increased from June to August, while in Red Rapid, populations of *F. schultzei* reached their peak in July and decreased in August (Figure 3).

No damage by thrips on the three cultivars of lettuce was observed in January and April as the mean numbers of thrips were 0. The mean numbers of thrips on the three cultivars were significantly ($P < 0.01$) different in February ($F = 49.94$), March ($F = 10.26$), June ($F = 481.46$), July ($F = 9.18$) and August ($F = 122.51$). Among the three cultivars, the highest numbers of thrips was recorded on Iceberg, followed by Red Salad Bowl and Red Rapid.

Figure 3 shows that except in April when no thrips were detected, the mean numbers of thrips per leaf on Iceberg were significantly ($P < 0.01$) higher in the dry season months of February

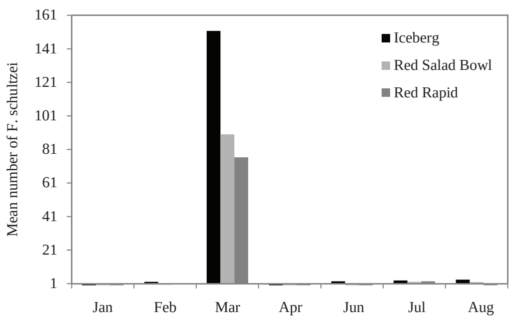

Figure 3 Mean numbers of *Frankliniella schultzei* per leaf caught on three lettuce cultivars grown hydroponically in a greenhouse.

and March than in the wet season months of June, July and August . However, a similar result was not observed on the other two cultivars (Figure 3). Figure 3 also shows that the mean numbers of thrips per leaf on Iceberg, Red Salad Bowl and Red Rapid were at their highest in March at 151.7, 90.0 and 76.3 thrips, respectively.

The mean temperature and the mean relative humidity recorded during the study are shown in Figure 4.

Correlation coefficient (R^2) analysis between the mean temperature and the populations of thrips on Iceberg, Red Salad Bowl and Red Rapid showed that there was no significant ($P < 0.05$) correlation, with R^2 values of 0.039, 0.037 and 0.042, respectively. Similarly, no significant ($P < 0.05$) correlations were observed between the humidity and the populations of thrips on Iceberg, Red Salad Bowl and Red Rapid, with R^2 values of 0.043, 0.043 and 0.046, respectively.

The presence of *F. schultzei* on various Iceberg, Red Salad Bowl and Red Rapid cultivars used as the test plants in this study indicates that lettuce leaves serve as an important nutritional source for the development of thrips. It was reported that the nutritional quality of a plant is an important factor affecting the host selection of thrips (Brodbeck *et al*., 2002). Lettuce leaves are known to have a high nutritional content which provides high concentrations of amino acids that are then converted into proteins to sustain the rapid growth of immature thrips (Brodbeck *et al*., 2001). Among the nutrients required for the growth of thrips, carbohydrates were reported to stimulate feeding of thrips and to increase their food consumption (Scott Brown *et al*., 2002). The results of the population dynamics study of *F. schultzei* on the three cultivars of lettuce planted monthly in January to August 2012 showed that the thrips were not present on the lettuce in the January plantings; however, thrip populations quickly built up in the March planting and then declined rapidly in the April planting. The cause for the thrip population buildup in the March planting and the decline in the April planting is not exactly known. However, one possible cause is that as the growth of the lettuce leaves reduced with the increase in temperature, their leaf texture became more fibrous, thicker, and bitter in taste (Wolford and Banks, 2009); thus, they were less preferred for feeding by thrips. During the current study, the temperature in the greenhouse in March was in the range 24.2 to 37.7 °C, which appeared to be most suitable for the growth of thrips. However, the temperature rose in April and was in the range 32.8 to 47 °C, probably causing a sharp decline in the thrip populations on the lettuce due to the change in the leaf texture, which impacted on the survival of the thrips. The fact that the thrip populations on the three cultivars of lettuce reached their peaks in the March planting suggests that lettuce growers should not plant lettuce in March to avoid damage caused by thrips.

The relative humidity recorded at the study site in Pathum Thani meant that leaf texture was maintained relatively constant around 95% in the greenhouse. Therefore, it can be expected that the relative humidity had no effect on the population fluctuations of *F. schultzei* under the greenhouse conditions. The temperature increased from 37.7 to 47 °C in April and from 36.05 to 44 °C in August. However, this change in the temperature had no significant effect on the population fluctuations of *F. schultzei* in the greenhouse which was consistent with the finding that temperature has a minimal effect on the population fluctuations of *F. occidentalis* and *T. palmi* Karny on orchids under greenhouse conditions in Singapore (Liansheng *et al.*, 2013). Contrary to the findings in the greenhouse, the temperature was reported to be an important factor affecting the abundance of thrips, which caused

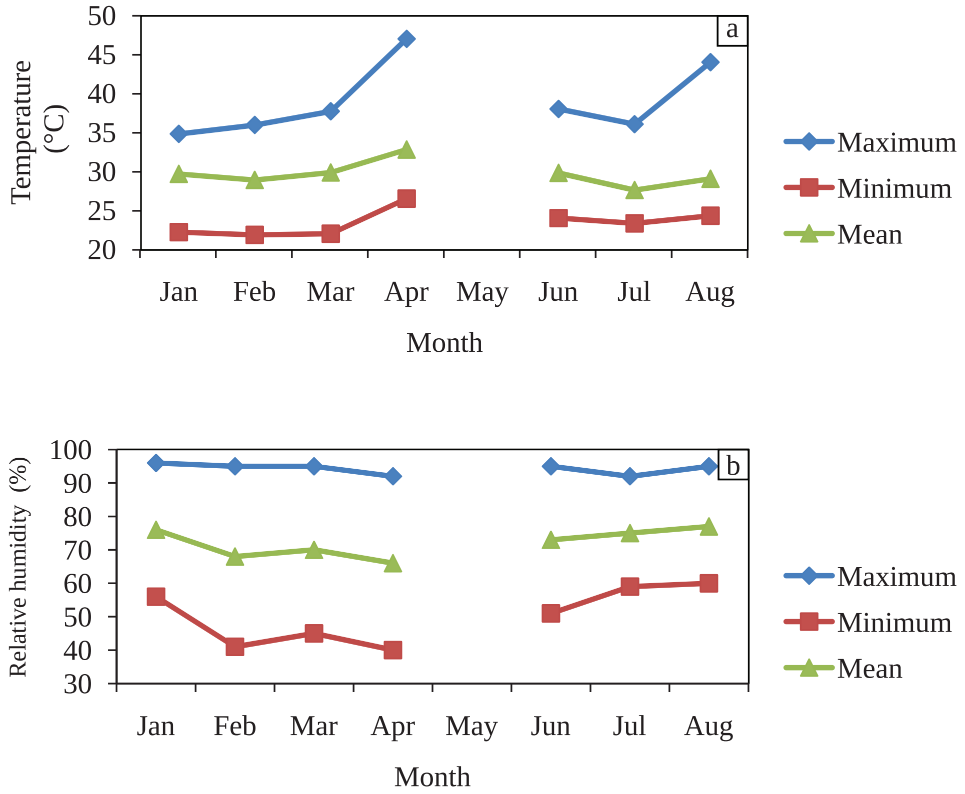

Figure 4 Climatic data recorded during the study period from January to August 2012: (a) Monthly mean temperature; (b) Relative humidity.

economic damage to nectarine crops in open field conditions in Turkey in March and April (Hazir and Ulusoy, 2012).

Among the three cultivars of lettuce tested, *F. schultzei* was found to be most abundant on Iceberg, followed by Red Salad Bowl and then Red Rapid. The highest population count found on Iceberg suggests that it has a mild flavor which appears to be preferred by thrips (Wolford and Banks, 2009). Based on this study, Red Rapid was the least preferred among the three cultivars as it was reported to be resistant to disease, insects and climate stress (Miles *et al.*, 2005).

Dispersion patterns of *F. schultzei* in lettuce grown hydroponically

There was no significant (F = 0.38, P > 0.05) difference in the total number of thrips on the upper- and lower sides of lettuce leaves. However, there were significant (F = 9.34, P < 0.01) differences in the number of thrips found among the three cultivars of Green Oak Leaf, Red Oak Leaf and Butterhead. The results showed that Green Oak Leaf appeared to be a preferred host over Butterhead and Red Oak Leaf. Similarly, there were significant (P < 0.01) differences found among the six sampling points on the upper side (Table 1) and lower side (Table 2) of leaves with F values of 5.65 and 4.21, respectively. On the upper side of lettuce leaves of all three lettuce cultivars, *F. schultzei* was most abundant at Sampling Point 3. On the lower side of the leaves of the three cultivars of lettuce, *F. schultzei* was most abundant at Sampling Point 5 on Green Oak Leaf and Red Oak Leaf and at Sampling Point 3 on Butterhead. The mean numbers of thrips on each of the seven leaves from Green Oak Leaf, Red Oak Leaf and Butterhead were counted and recorded from January to March 2013. The results showed that the mean numbers of the thrips on the first leaf were not significant (P > 0.05) on Green Oak Leaf, Red Oak Leaf and Butterhead at F = 2.81. However, the mean numbers were significantly different (P < 0.01) on the second through to the seventh leaf on Green Oak Leaf, Red Oak Leaf and Butterhead (Table 3). Among all the seven leaves sampled, the mean number of the thrips per leaf was the highest on the third leaf of Green Oak Leaf and Red Oak Leaf. The mean number of thrips per leaf on the first leaf of all three cultivars was lower than on the other leaves in the same lettuce head, except for the seventh leaf where there were no thrips found on the cultivars Red Oak Leaf and Butterhead (Table 4).

The dispersion patterns of thrips on the three cultivars were estimated using the

Table 1 Mean numbers of *Frankliniella schultzei* found at the six sampling points on the upper side of leaves of three lettuce cultivars grown hydroponically in a greenhouse in Kamphaeng Saen district, Nakhon Pathom province, during January to March 2013.

Sampling point on lettuce leaf	Mean number of *F. schultzei* on lettuce cultivar					
	Green Oak Leaf		Red Oak Leaf		Butterhead	
	Mean	SD	Mean	SD	Mean	SD
1. Mid rib of the apex of leaf	0.04^b	0.20	0^b	0	0.02^b	0.14
2. Mid rib of the middle of leaf	0.20^b	0.57	0.26^b	0.44	0.22^b	0.68
3. Mid rib of the base of leaf	0.70^a	0.89	0.60^a	0.64	0.64^a	0.83
4. Margin of the apex of leaf	0.08^b	0.27	0.06^b	0.24	0.04^b	0.20
5. Margin of the middle leaf	0.16^b	0.42	0^b	0	0.04^b	0.20
6. Margin of the base of leaf	0^b	0	0.06^b	0.24	0.01^b	0.36

^{a,b} = Means within column followed by different lowercase superscript letters are significantly different using Tukey's range test (P < 0.01).

coefficient of variation and the *t* statistic as shown in Equations 2 and 3, respectively:

$$S^2/\bar{x} \quad (2)$$

$$t = \frac{S^2/\bar{x} - 1}{S_{\bar{x}}} \quad (3)$$

where S is the variance, $\bar{x}$ is the mean and $S_{\bar{x}}$ is the standard error..

Any absolute value of t >1.96 for 49 degrees of freedom indicates a distribution that differs from being random with a certainty of 95%. The results of the study showed that the thrips had a uniform distribution on Green Oak Leaf and Red Oak Leaf and a clumped distribution on Butterhead (Table 5)

It is interesting that the results of the study showed no significant difference in the mean numbers of *F. schultzei* per leaf between the

Table 2 Mean numbers of *Frankliniella schultzei* found at the six sampling points on the lower side of leaves of three lettuce cultivars grown hydroponically in a greenhouse in Kamphaeng Saen district, Nakhon Pathom province, during January to March 2013.

Sampling point on lettuce leaf	Mean number of *F. schultzei* on lettuce cultivar					
	Green Oak Leaf		Red Oak Leaf		Butterhead	
	Mean	SD	Mean	SD	Mean	SD
1. Mid rib of the apex of leaf	0.18^{b}	0.56	0^{NS}	0	0.02^{b}	0.14
2. Mid rib of the middle of leaf	0.26^{b}	0.49	0.18	0.39	0.30^{b}	0.71
3. Mid rib of the base of leaf	0.22^{b}	0.46	0.06	0.24	0.46^{a}	0.86
4. Margin of the apex of leaf	0.16^{b}	0.42	0.06	0.24	0.10^{b}	0.30
5. Margin of the middle leaf	0.54^{a}	1.20	0.20	0.40	0.10^{b}	0.30
6. Margin of the base of leaf	0.14^{b}	0.40	0.06	0.24	0.08^{b}	0.34

a,b = Means within column followed by different lowercase superscript letters are significantly different using Tukey's range test (P < 0.01).

NS = Means within the column are not significantly different (P > 0.01).

Table 3 Mean numbers of *Frankliniella schultzei* found on leaves of three lettuce cultivars grown hydroponically in a greenhouse in Kamphaeng Saen district, Nakhon Pathom province, during January to March 2013.

Leaf number	Lettuce cultivar						CV	*F*
	Green Oak Leaf		Red Oak Leaf		Butterhead			
	Mean	SD	Mean	SD	Mean	SD		
1st leaf	0.16^{NS}	0.36	0.28	0.53	0.16	0.36	17.50	2.81
2nd leaf	0.74^{a}	1.15	0.72^{a}	0.78	0.30^{b}	0.46	12.06	12.49
3rd leaf	1.84^{a}	1.15	0.74^{bc}	1.40	0.46^{c}	0.75	11.68	5.87
4th leaf	1.12^{a}	1.28	0.18^{c}	0.38	0.58^{b}	0.72	10.46	11.71
5th leaf	0.08^{a}	1.24	0.22^{b}	0.50	0.28^{b}	0.53	13.46	11.71
6th leaf	0.70^{a}	1.01	0.06^{b}	0.23	0.16^{b}	0.50	18.70	5.92
7th leaf	0.42^{a}	0.36	0^{b}	0	0^{b}	0	25.21	3.54

CV = Coefficient of variation; *F* = *F* test statistic.

a, b, c = Means within a row followed by different lowercase superscript letters are significantly different using Tukey's range test (P < 0.01).

NS = Mean within row not significantly different (P > 0.05).

upper side and lower sides of leaves. This seems to indicate that thrips may not have a preference in their feeding for the upper side or lower side of the leaf as was reported for adults of *Parthenothrips dracaenae* and *F. occidentalis* who mostly preferred the upper side of the leaf of ornamental plants; however, nymphs of *P. dracaenae and Echinothrips americanus* preferred the lower side of the leaf of ornamental plants and sweet pepper, respectively (Entocare, 2013). The density of trichomes on a leaf and the softness of leaf tissues can affect the spatial distribution of *T. tabaci* (Duchovskiene, 2006). The results of the study on the relative abundance of *F. schultzei* at the six sampling points each on the upper side and lower side of lettuce leaves provided no indication why there were differences in the relative abundance at different sampling points; however, *F. schultzei* appeared to prefer colonizing at the mid-rib of the base and the outer margin of the lettuce leaf.

The dispersion study illustrated that *F. schultzei* had a uniform distribution pattern on Green Oak Leaf and Red Oak Leaf, while it had a clumped or aggregated distribution pattern on Butterhead. In addition, several studies have described *F. schultzei* as having both types of dispersion pattern. Kakkar (2010) reported that *F. schultzei* possesses both aggregated and random-to-regular distribution patterns on cucumber. *F.*

Table 4 Mean numbers of *Frankliniella schultzei* found among all seven leaves sampled on three lettuce cultivars grown hydroponically in a greenhouse in Kamphaeng Saen district, Nakhon Pathom province, during January to March 2013.

Mean number of thrips	Lettuce cultivar					
	Green Oak		Red Oak		Butterhead	
	Mean	SD	Mean	SD	Mean	SD
1st leaf	0.16^{d}	0.36	0.28^{bc}	0.53	0.16^{cd}	0.36
2nd leaf	0.74^{bc}	1.15	0.72^{a}	0.78	0.30^{bc}	0.46
3rd leaf	1.84^{a}	1.15	0.74^{a}	1.40	0.46^{ab}	0.75
4th leaf	1.12^{b}	1.28	0.18^{bc}	0.38	0.58^{a}	0.72
5th leaf	0.08^{b}	1.24	0.22^{b}	0.50	0.28^{bc}	0.53
6th leaf	0.70^{c}	1.01	0.06^{bc}	0.23	0.16^{cd}	0.50
7th leaf	0.42^{cd}	0.36	0^{c}	0	0^{d}	0
CV	7.22		11.76		10.0	

CV = Coefficient of variation.
a, b, c, d = Means within column followed by different lowercase superscript letters are significantly different using Tukey's range test ($P < 0.01$).

Table 5 Dispersion patterns of *Frankliniella schultzei* on three cultivars of lettuce grown hydroponically in a greenhouse in Kamphaeng Saen district, Nakhon Pathom province, during January to March 2013.

Lettuce cultivar	$S^2/\bar{x}$	t	Dispersion pattern
Green Oak	0.98	-0.08	uniform
Red Oak	0.27	-8.10	uniform
Butter Head	1.28	1.23	clumped

S is the variance, $\bar{x}$ is the mean and $S_{\bar{x}}$ is the standard error.

schultzei was observed to have an aggregated distribution pattern on flowers of *Hibiscus rosasinensis* and *Gossypium hirsutum* (Milne *et al*., 2002) and on flowers of blueberry (Arevalo *et al*., 2009). Similarly, *F. occidentalis* was reported to have an aggregated distribution pattern on orchid (Liansheng *et al*., 2013) and on cucumber and green bean (Cho *et al*., 2001; Mateus *et al*., 2005).

CONCLUSION

Growing lettuce hydroponically in a greenhouse has become popular in Thailand. However, damage caused by *F. schultzei* remains a challenge to lettuce growers. Based on the investigation of the population dynamics and dispersion patterns of *F. schultzei*, lettuce growers are advised to grow Red Oak and Red Rapid instead of Iceberg and Green Oak Leaf. Unfortunately, Iceberg and Green Oak Leaf are two popular cultivars grown in Thailand. As such, to minimize the damage caused by *F. schultzei*, growers are advised not to plant Iceberg and Green Oak Leaf in March when the populations of thrips are most abundant. Rather, regardless of cultivar, lettuces should be planted in January and February when the population of *F. schultzei* is low. When there is an outbreak of *F. schultzei*, lettuce growers should intervene using direct control at the third leaf stage of lettuce development as this is the stage when the insects preferably aggregate. This may be useful in keeping the insect pest under control from a quantitative as well as a qualitative viewpoint.

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