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Original Article

# Pattern and shape effects of orchid flower traps on attractiveness of *Thrips palmi* (Thysanoptera: Thripidae) in an orchid farm

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ABSTRACT

*Thrips palmi* Karny is widely distributed and causes damage to orchid flowers. Orchid varieties in the genera *Dendrobium* and *Mokara* are different in shape. This study determined if different trap patterns which reflect flower shape may affect the attractiveness to thrips. The shapes of *Dendrobium* and *Mokara* orchid flowers were characterized and the numbers of flowers per raceme were counted in inflorescences in order to design realistic trap patterns. Four patterns (A, B, C and D) of flower traps were made by increasing the petal area. The mean number of *T. palmi* in flower pattern A was significantly lower than for flower patterns B, C and D ($p < 0.05$). The numbers of *T. palmi* in flower traps increased with flower petal area ($r = 0.63$, $p < 0.05$), but decreased with increasing length of flower contour ($r = -0.56$, $p < 0.05$). Six patterns (B1, B2, B3, B4, B5 and B6) of inflorescence traps were created by increasing the number of flowers per raceme. The numbers of *T. palmi* increased with increased numbers of flowers per raceme, pattern area and length of contour ($r = 0.74$, $p < 0.05$). Thus, inflorescence patterns and sizes affected the numbers of *T. palmi* attracted. The results of this research indicated that not only the patterns but also the sizes of traps were important factors for attractiveness to thrips. This information may be useful in designing and monitoring control programs for *T. palmi*.



## Introduction

Thrips are very small insects commonly found in many crops and ornamental plants (Lewis, 1997). Agricultural crops provide opportunities for quick colonization and establishment of large populations of thrips, and some species become economically important pests (Funderburk, 2002). They damage a large number of crops by colonizing their flowers and as a result, flowers become deformed, then turn brown and become streaked and discolored (Lewis, 1973; Childers, 1997). Most thrips are pests of commercial plants; for example, *Frankliniella occidentalis* (Pergande) causes damage to greenhouse crops throughout the world (Mainali and Lim, 2010). *Scirtothrips perseae* Nakahara has been recorded as an economic pest of avocados (Hoddle et al., 2002). *Thrips tabaci* Lindeman is an economic pest that can reduce onion yields.

*Thrips palmi* Karny is a polyphagous insect found to damage economic crops and ornamental plants in Asia, Europe and the USA and to date has been reported to infest more than 50 plant species in various families such as the Cucurbitaceae, Solanaceae, Fabaceae and Orchidaceae (Dentener et al., 2002), and is a serious pest of flowers of several orchid types in many countries including the USA (Hata et al., 1991), Japan (Kawai, 1995; Murai, 2002) and Thailand (Kajita et al., 1996). *T. palmi* feeds inside newly expanding leaves and developing young inflorescence (Piluek and Wongpiyasatid, 2010) and is also found in open blooms deep inside the flower and petal folds (Hata et al., 1991). As a result of the infestation, orchid flowers become deformed and heavily scarred. Damage caused by *T. palmi* is an important problem in the flower trade industry, especially with orchid cut flowers from Thailand (Vierbergen, 2001). *T. palmi* has become a global quarantine pest in European countries, the USA and Japan and most detection has been related to imported ornamentals with 79% in Europe and 85% in the USA (European and Mediterranean Plant Protection Organization, 2006).

Substantial differences among orchid varieties in thrips densities have been associated with large differences in flower/inflorescence shape and structure (Hata et al., 1991). In Thailand, where orchid flowers are exportable products, *T. palmi* has been found infesting many *Dendrobium* varieties including *Dendrobium* Sonia, *Dendrobium* Sensational Purple and *Dendrobium* Lervia (Maketon et al., 2014). However, *T. palmi* infestation of other Thai commercial orchid varieties has not been reported, even when heavily

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infested *Dendrobium* Sonia is grown nearby (second author personal observation). The patterns and shapes of flowers have been investigated as attractive visual cues for thrips (Moreno et al., 1984; de Jager et al., 1995). Differences in the flowers and inflorescences of chrysanthemums affected the preferences of *F. occidentalis* (de Jager et al., 1995). Therefore, flower/inflorescence characteristics are considered to be important visual cues for attracting thrips. *Dendrobium* Sonia inflorescences comprise flowers with wide overlapping sepals and petals giving the inflorescences a compact, dense appearance. In contrast, *Mokara* inflorescences contain flowers with comparatively narrower sepals/petals and therefore have a more spindly, sparse appearance.

The purpose of this study was to determine if the shape and structure of orchid flower and inflorescence traps affect attraction of a *T. palmi* population. Firstly, the shapes of *Dendrobium* and *Mokara* flowers were characterized along with the number of flowers per raceme of plants from an orchid farm. Secondly, these characteristics were used to construct *Dendrobium* and *Mokara* flower and inflorescence-mimicking traps. Finally, field experiments were conducted on an orchid farm to determine the responses of the *T. palmi* population to these traps.

## Materials and methods

### *Study site*

The study site was located in Nakhon Pathom Province, Thailand (13°46′N, 100°16′E). The experimental area was arranged in a 65 m width × 90 m length section in the orchid orchard. Orchid varieties in the genera *Dendrobium* and *Mokara* were chosen which are economically important as cut flowers for export. These consisted of *Dendrobium* Sonia (Den_pur), *Dendrobium* White Fairy (Den_whi), *Mokara* Calypso (Mok_pur), and *Mokara* Sayan Duangporn (Mok_yel).

### *Design of trap patterns and sizes*

For each orchid variety, 30 flowering plants were randomly selected from the orchid farms. The number of flowers per raceme of the inflorescence was counted and the flowers were photographed. The digital photographs were downloaded onto a computer and the shapes and sizes of the flowers were measured using the ImageJ 1.46r software package (Rasband, 2012). Both flower and inflorescence trap patterns and sizes were designed based on orchid characters to test the hypotheses that an increase in flower sizes and altered patterns can affect their attractiveness to thrips. Four flower trap patterns were designed and named A, B, C and D. To increase the flower area, the center of the flower was represented by a regular hexagon and circumscribed by a circle with a radius of 0.35 cm. Each side of the hexagon was 0.4 cm long (Fig. 1). The width of petals on both sides was placed in categories increasing by increments of 1.2 cm, from 0.4 cm, 1.6 cm, 2.8 cm and 4.0 cm (named A, B, C and D, respectively) as shown in Figs. 1 and 2. All petals of each pattern were located within a circle with a radius of 3.5 cm.

For the inflorescence traps, flower pattern B was considered to be closest to the patterns of the four orchid varieties (Table 1 and Table S1) with a median shape area range of 20.58–31.82 $cm^2$ and length of shape contour range of 28.44–41.75 cm. The number of flowers per raceme was determined from the modal numbers of the four orchid inflorescence varieties (Table S2). Thus, the number of flowers per raceme in traps varied, with 3, 5, 7, 9, 11 and 13 for patterns B1, B2, B3, B4, B5 and B6, respectively (Fig. 2). Then, trap pattern areas and lengths of contour were investigated as provided in Table 1.

The trap patterns and sizes were reproduced and printed on paper (21 cm × 29.70 cm) using the color of the flower/inflorescence (blue) and background (green) which proved to be the most attractive to *T. palmi* based on the experiments of Pinkesorn (2015). All printed traps were placed on 21 × 29.70 cm polyvinyl chloride boards. Orchid plants were grown on benches under shade cloth within farms; the benches were divided into 7 m × 10 m rectangular units of orchid plants. Then, all traps were coated with Tangle-Trap® (The Tanglefoot Company; Grand Rapids, MI, USA) insect trap coating and hung 1 m above the center of each unit. Traps were set in a completely randomized design among units. The experiments were conducted with four replications for 7 d in every other month for one year. For each experiment, thrips were removed and counted from flower and/or inflorescence and background areas of traps for analyses.

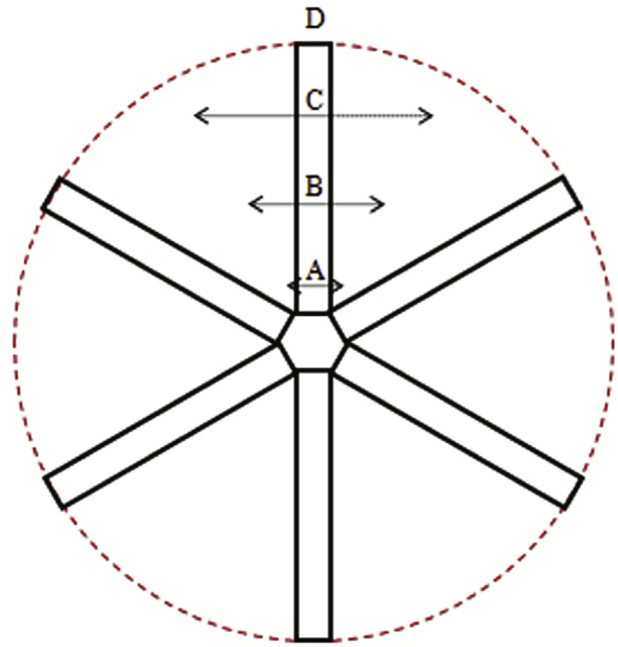


**Fig. 1.** Basic geometric 6-petal trap flower pattern with petal width of 0.4 cm (A), keeping the same center and radius 3.5 cm to create other flower patterns with petal width 1.6 cm (B), 2.8 cm (C) and 4 cm or circle (D).

### *Data analyses*

Shape parameters of the orchid flowers were compared among orchid varieties using the Kruskal-Wallis test. If significant differences were found, then pairwise comparison tests were used to test *post hoc* results as well. Differences between mean numbers of thrips captured from various trap patterns were compared using one-way analysis of variance. If significant differences were found, then the least significant difference (LSD) test was used to conduct *post hoc* comparisons. Data were transformed to normality using $\log_{10}(x+1)$. The correlations between the numbers of *T. palmi* and parameters of flower/inflorescence trap patterns/sizes were determined using Pearson's correlation. All analyses were conducted using the Statistix 9 software package (Analytical Software, 2013).

## Results

### *Design and measurement of flower and inflorescence-mimicking traps*

Flower trap pattern A represented a polypetalous flower with an area 19.72 $cm^2$ and length of contour of 38.40 cm. Patterns B, C, and

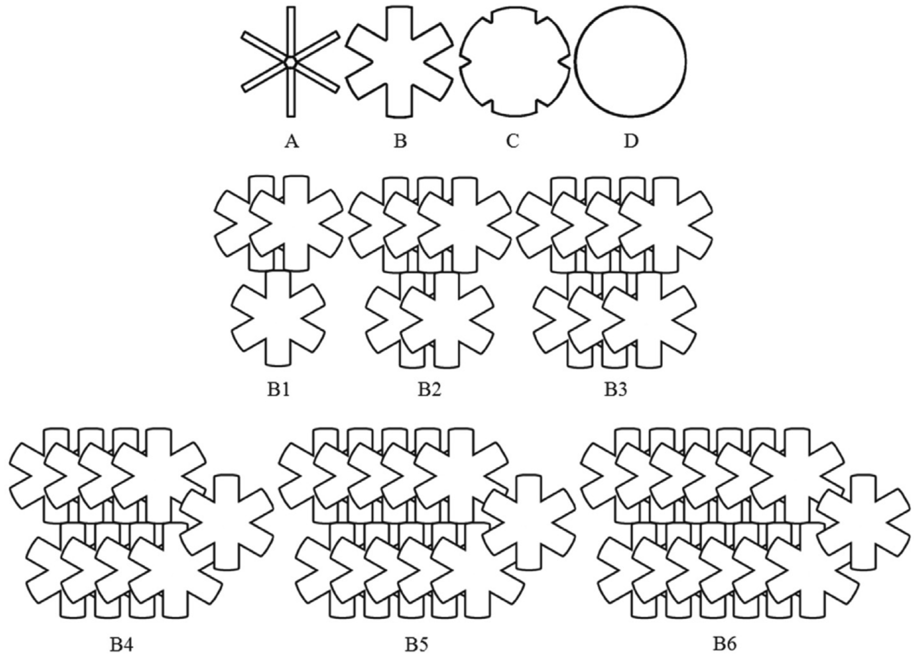


**Fig. 2.** Different patterns of designed trap flowers (A, B, C and D) and inflorescence (B1 to B6).

**Table 1**
Mean ± (SE) values of *Thrips palmi* abundance and parameters of flower and inflorescence trap patterns.

| Trap | Pattern | Area ($cm^2$) | Length of contour (cm) | Number of thrips (mean ± SE) |
|---|---|---|---|---|
| Flower | A | 19.72 | 38.40 | 0.50 ± 0.34 |
| | B | 27.28 | 33.60 | 11.17 ± 2.27 |
| | C | 35.44 | 25.20 | 13.33 ± 1.98 |
| | D | 38.50 | 21.13 | 10.17 ± 1.74 |
| Inflorescence | B1 | 65.95 | 76.10 | 10.83 ± 1.92 |
| | B2 | 93.14 | 96.70 | 16.00 ± 1.84 |
| | B3 | 119.92 | 116.60 | 19.33 ± 1.99 |
| | B4 | 156.97 | 146.00 | 22.50 ± 1.34 |
| | B5 | 183.72 | 164.60 | 23.00 ± 2.35 |
| | B6 | 211.51 | 184.70 | 26.33 ± 1.96 |

D represented different sympetalous patterns with increasing area and decreasing length of contour (Table 1). Numbers of *T. palmi* were positively correlated with flower pattern area ($r = 0.63$, $p < 0.05$), but were negatively correlated with length of contour ($r = -0.56$, $p < 0.05$). The numbers of thrips were positively correlated with numbers of thrips per inflorescence and inflorescence pattern area ($r = 0.74$, $p < 0.05$) as well as length of contour ($r = 0.74$, $p < 0.05$).

*Thrips numbers in flower and inflorescence-mimicking traps*

*T. palmi* individuals were counted from different flower and inflorescence trap patterns. A few *T. palmi* were trapped on the background area to enable comparisons with flower areas. The majority of *T. palmi* were trapped on flower and inflorescence areas. The mean numbers of *T. palmi* found in flower and inflorescence areas were not significantly different from those in overall areas (paired *t*-test, $t_9 = 1.59$, $p > 0.05$; Fig. 3). Thus, the results of trap experiments were described in terms of the mean numbers of *T. palmi* in the overall area of traps in order to explain the response to trap patterns.

When the mean numbers of *T. palmi* caught in flower and inflorescence traps were separated for analysis of variance, the number in flower trap pattern A was lower than that in other flower trap patterns ($F_{3,20} = 32.70$, $p < 0.05$) using the transformation $\log_{10}(x+1)$. No significant differences in numbers of *T. palmi* occurred among flower trap patterns B, C, and D (LSD test, $p > 0.05$; Fig. 4).

Differences in numbers of *T. palmi* caught in inflorescence trap patterns were also examined using one-way analysis of variance. The results of this analysis indicated statistically significant differences in the mean numbers of *T. palmi* caught per week in different trap patterns ($F_{5,30} = 8.37$, $p < 0.05$; Fig. 5). Thrips were trapped in higher numbers in inflorescence pattern B6 than in other patterns. However, there were not significant differences in numbers of *T. palmi* caught among trap patterns B3, B4, B5 and B6 (LSD test, $p > 0.05$). Significantly lower *T. palmi* were trapped on the inflorescence pattern B1 compared to other patterns (LSD test, $p < 0.05$) except for pattern B2 (LSD test, $p > 0.05$; Fig. 5).

## Discussion

The present study categorized the geometric patterns of orchid flowers and inflorescences and investigated the relationships between preferences of *T. palmi* with respect to flower and inflorescence-mimicking trap patterns and sizes. Four flower and six inflorescence trap categories were investigated.

Field experiments comparing these trap patterns confirmed that different patterns and sizes affected their attractiveness to *T. palmi*.

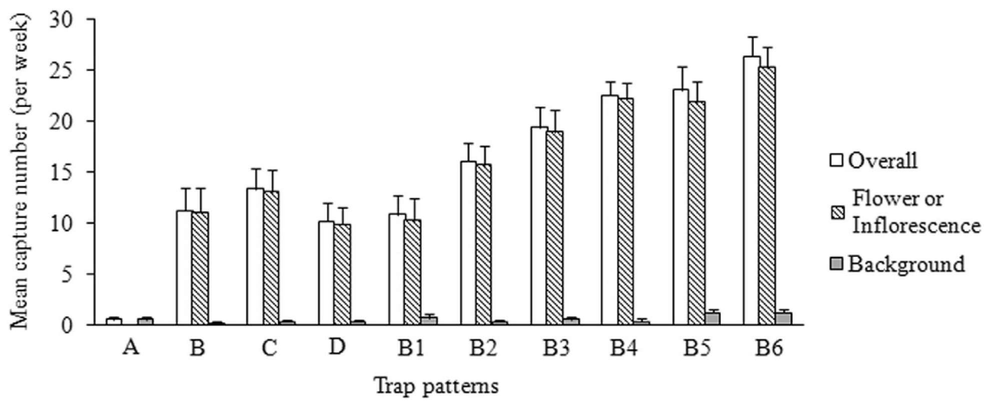


**Fig. 3.** Mean numbers (±SE) of *Thrips palmi* per week captured in each trap pattern (shown in Fig. 2) in overall, flower and background areas.

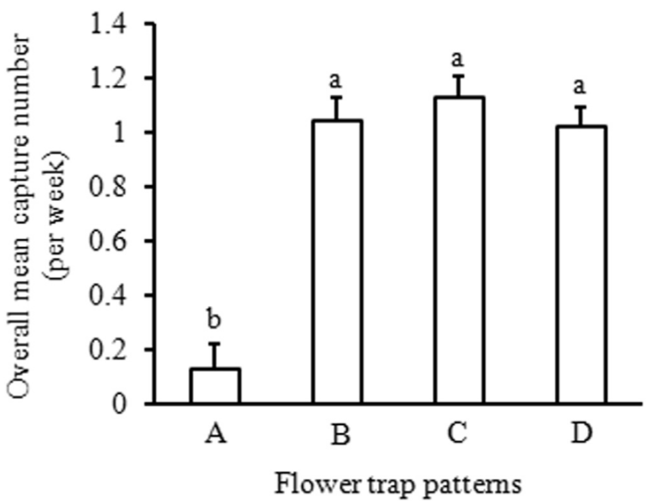


**Fig. 4.** Comparison of overall mean numbers (±SE) of *Thrips palmi* per week captured on all areas in flower trap patterns shown in Fig. 2 (different lowercase letters above columns indicate significant differences using the least significant difference test at $p < 0.05$).

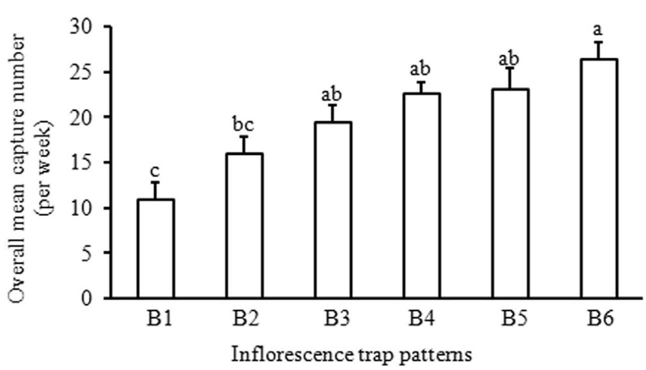


**Fig. 5.** Comparison of overall mean numbers (±SE) of *Thrips palmi* per week captured on all areas in inflorescence trap patterns shown in Fig. 2 (different lowercase letters above columns indicate significant differences using the least significant difference test at $p < 0.05$).

Among the 10 trap patterns tested, inflorescence pattern B6 was the most effective, followed by patterns B5, B4, B3, B2, C, B, B1, D, and A (Table 1). Similarly, other studies have found that various geometrical patterns affect their attractiveness for thrips (Hata et al., 1991; Maketon et al., 2014). Triangular and elliptical patterns, mimicking the shapes of tender leaves, captured *Scirtothrips citri* (Moulton) in greater numbers than did rectangular, circular or square patterns (Moreno et al., 1984). However, Mainali and Lim (2010) showed that *F. occidentalis* preferred circular patterns more than diamond, rectangular and inverted triangular patterns, whereas Cho et al. (1995) found that *Frankliniella tritici* (Fitch) preferred cylindrical and cup-pattern traps over flat traps. Other than pattern, size also affected the number of thrips captured (Davidson et al., 2011; Kirk, 1987; Parker and Skinner, 1993; Vernon and Gillespie, 1995).

*Flower trap patterns and sizes*

The present study found that *T. palmi* responded to flower trap pattern A significantly less than to other flower trap patterns. The petal area of pattern A (polypetalous flower) was the smallest and gaps between the petals were the largest. This result was consistent with the findings of Broadbent and Allen (1995) and de Jager et al. (1995) for chrysanthemum flowers, in which spider flower types captured fewer thrips than single, decorative/pompom or anemone flower types. Spider flower types had only ray florets (with a small area), which were difficult to feed on. Although increasing the flower area affected the attractiveness for thrips, the numbers of *T. palmi* in the larger flower areas of trap patterns B, C and D (sympetalous flower) were not significantly different. It is possible that the gaps between petals of flower trap patterns B, C and D were not sufficiently narrow. The flower patterns were flat two-dimensional traps and therefore without the petal folds of real flowers in which thrips are commonly found (Childers, 1997). Hata et al. (1991) found that *Dendrobium* orchids of a *Phalaenanthe* morphotype, which had overlapping wide petals with rounded shape and less space between them, attracted higher numbers of thrips than *Dendrobium* orchids of a *Ceratobium* morphotype, which had narrow petals (small area) and large spaces between petals.

The sympetalous patterns B, C and D had flower trap areas that were probably close to real orchid flowers (Table 1 and Table S1). These results were similar to those of Papadaki et al. (2008) who showed that the thrips *F. occidentalis* was found most abundantly in the sympetalous flowers of melon, followed by cucumber, tomato, sweet pepper, eggplant and beans.

*Inflorescence trap patterns and sizes*

The numbers of *T. palmi* in inflorescence trap pattern B6 were significantly greater than in inflorescence trap patterns B1 and B2. The numbers of *T. palmi* increased both with increasing number of flowers per raceme and increasing inflorescence area (both $r = 0.74$, $p < 0.05$). Similarly, de Jager et al. (1995) showed that chrysanthemums, which had more and larger flowers, had higher numbers of *F. occidentalis* than plants with fewer and smaller flowers. This same thrips was also found in the highest numbers in cherry, apple and nectarine trees with the highest numbers of flowers (Pearsall, 2000). *F. occidentalis* were most attracted to dense inflorescences with more flowers per raceme (Bailey, 1933). In addition, many reports have indicated that various other insects respond to large inflorescences more than to small inflorescences (Cole and Firmage, 1984; Cruzan et al., 1988; Schmid-Hempel and Speiser, 1988; Thomson, 1988; Pleasants and Zimmerman, 1990; Dafni et al., 1997), a pattern consistent with the current findings on *T. palmi*.

In conclusion, *T. palmi* was differentially attracted to different patterns and sizes of flower and inflorescence traps. Increasing the flower trap area helped thrips to detect and recognize the objects. Understanding how the flower trap pattern and shape affect the preferences of thrips is essential as it may enable more effective management.

## Conflict of interest statement

The authors declare that there are no conflicts of interest.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.anres.2017.11.006.

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