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Within-plant distribution and seasonal population dynamics of flower thrips (Thysanoptera: Thripidae) infesting French beans (*Phaseolus vulgaris* L.) in Kenya

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Abstract

The aim of this research was to study spatial distribution of flower thrips on French beans (*Phaseolus vulgaris* L.) in Kenya. Their build up and seasonal population dynamics was monitored using sticky blue colour traps and sampling of leaves and flowers in two seasons in 2002. Thrips infested French beans from the second week after crop emergence. Their population peaked at peak flowering. The sticky trap catches were linearly related to the actual presence of thrips on the crop and could estimate population build up of adult thrips on leaves and flowers. On the plants, most adults were on flowers. Larvae mainly inhabited leaves, buds and pods. The two thrips species, *Frankliniella occidentalis* (Pergande) and *Megalurothrips sjostedti* Trybom were spatially separated. The former colonized lower-canopy leaves and early flowers while the latter inhabited middle-canopy leaves and mature flowers. Overall, *M. sjostedti* was less than 5% of the total thrips population, implying that *F. occidentalis* was the main thrips pest of French beans. This study suggests that French bean growers should monitor thrips population before initiating any control measure. In addition, they should commence thrips control early, at pre-flowering, using larvicides to reduce the thrips pool and their migration to flowers. A combination of monitoring with sticky traps and proper sampling would contribute to sustainable thrips management.

Additional key words: *Frankliniella*, *Megalurothrips,* monitoring, sampling.

Resumen

Distribución y fluctuación estacional del trips de la flor (Thysanoptera: Thripidae) en la judía (*Phaseolus vulgaris* L.) en Kenia

El presente estudio trató de determinar los patrones de alimentación del trips de la flor como plaga de la judía (*Phaseolus vulgaris* L.) en Kenia. El incremento de la población y grado de infestación de trips se evaluó usando trampas de adherencia azules en hojas y flores durante dos estaciones en el 2002. Los trips infestaron a la judía desde la segunda semana después de la emergencia del cultivo, y alcanzaron una población máxima durante la floración. Conteos en las trampas de adherencia mostraron una correlación lineal con la presencia de trips en el cultivo y pueden servir de referencia del crecimiento de las poblaciones de trips adultos en hojas y flores. En la planta, la mayoría de adultos se encontraron en las flores, mientras que las larvas se concentraron en las hojas, brotes y vainas. Las especies de trips *Frankliniella occidentalis* (Pergande) y *Megalurothrips sjostedti* Trybom se mantuvieron separadas en el espacio: mientras que la primera prefiere las hojas inferiores del dosel y las flores jóvenes, la segunda suele optar por las hojas de en medio del dosel y flores maduras. *M. sjostedti* representa menos del 5% de la población total de trips, lo que hace de *F occidentalis* la principal peste de la judía. El estudio sugiere que los agricultores deben monitorizar la dinámica poblacional de los trips antes de efectuar medidas de control, y complementariamente, deberían usar larvicidas antes de la floración previendo su posterior migración a las flores. Una adecuada combinación entre vigilancia y adecuada toma de muestras contribuiría al control sostenible de las poblaciones de trips.

Palabras clave adicionales: *Frankliniella*, *Megalurothrips*, monitoreo, muestreo.

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Introduction

Thrips currently rank as primary pests of French beans (*Phaseolus vulgaris* L.) in Kenya (MOA, 2006). *Frankliniella occidentalis* (Pergande) and *Megalurothrips sjostedti* Trybom are known as the main thrips species that cause 40-60% yield losses at farm level, mainly through abscission of buds, flower abortion and pod malformation making them unfit for the export market (Seif *et al.,* 2001). Their punching and sucking feeding behaviour also blemishes and causes silvery lesions on pods, resulting in a further 20% loss at harvest sites (Kibata and Anyango, 1996; Lohr, 1996). French beans are the most important horticultural crop in Kenya and they are grown mainly for export. They contribute more than 55% of the value of vegetable exports and rank second, after cut flowers, in volume and value among export crops (MOA, 2006). The French bean industry supports the livelihood of many small-scale farmers, who contribute more than 80% of bean production, with an average gross margin of US $2,250 ha^{-1} season^{-1} (Minot and Ngigi, 2003).

Thrips damage reduces household income and government and foreign exchange earnings. While *M. sjostedti* is an indigenous legume pest in Kenya, *F. occidentalis* has established itself as the main pest since its advent twenty years ago (Seif *et al.,* 2001). Records show that *M sjostedti* is manageable using insecticides to uneconomic levels but *F occidentalis* has posed management challenges due to resistance to most insecticides used by local farmers (Kasina *et al.,* 2006; Nderitu *et al.,* 2007). Another reason for difficulties of thrips management is because studies on their bionomics in Kenya are scanty. Data seems to show that thrips colonize the crop at pre-flowering, forming a pool that infests flowers once they form (Gitonga, 1999). The spatial distribution of thrips in French bean plants has not been studied world-wide. However, this has been done on other host crops such as cotton (Atakan *et al.,* 1996) and cucumber (Cho *et al.,* 2001). There are many reasons why thrips colonize different plant parts. These include preferred microhabitats in the plant, nutritional niches, or hide/seek behaviour with their natural enemies (Brodbeck *et al.,* 2001; Toapanta *et al.,* 2001; Reitz, 2002). Knowledge of thrips spatial distribution in a plant is critical in developing effective management strategies to curb their damage. Information generated can improve sampling protocols required for early warning of a possible build up of the pest population, as well as guiding the type and target of pesticide sprays. Most studies advocate sampling legume flowers to guide in the decision of when to apply pesticides (Chang, 1988; Fang, 1993; Tamo *et al.,* 1993; Matteson *et al.,* 1996), ignoring possible early build of pests before flowering. This explains why farmers only control thrips at flowering using many insecticide sprays (Nderitu *et al.,* 2001).

This study was conducted to determine the colonization and seasonal population dynamics of thrips and their spatial distribution in French bean plants in Kenya. This information would support integrated thrips management on French beans, and improve knowledge of their bionomics.

Material and methods

Crop establishment

The study was conducted at Mwea-Tebere, in Central Kenya, a major French bean growing area. In the area, French beans are grown during the dry seasons using furrow irrigation, to avoid flooding during periods of rain. The experiment was laid out in the first dry season of 2002 (28 January) and was repeated in the second dry season of the year (8 July). Seeds of Amy, the commonly grown bean variety, were hand sown in six replicates (plots) each plot was 3 x 10 m. Plants were spaced at 10 cm in the row with 60 cm between rows. They emerged one week after sowing. Plants were maintained using standard cultural practices recommended for the research area.

Crop colonization by thrips and seasonal population dynamics

Thrips populations on French beans were monitored using blue sticky trap cards (15 x 23 cm) on three replicates. The colour was reported to be a better attractant of thrips infesting French beans in Kenya (Gitonga, 1999). One trap was placed diagonally at the centre of each plot, at a height of about 13 cm above the canopy. A clear polythene sheet was wrapped around each trap and

Abbreviations used: ANOVA (analysis of variance) MOA (Ministry of Agriculture, Kenya), SE (standard error of means).

smeared with insect glue (Tangle foot®; Tangle foot Co., Grand Rapids, Michigan USA). In the first season, traps were placed from the third week of crop emergence, but this was adjusted to the second week (season 2). The polythene sheet was replaced every 7 days and was taken to the laboratory for counts of trapped thrips. In addition to sticky trap monitoring, thrips were sampled from 10 leaves and 20 flowers taken at random from plants in the inner rows of each replicate at 7 day intervals, coinciding with trap replacement. Leaf sampling started at the same time as sticky trap replacement while flowers were picked from the fourth week of plant emergence. Destructive sampling of thrips was used (the plant part was plucked and immediately immersed in a container with 70% ethanol to kill and preserve the thrips). This assured the acquisition of all adult thrips as they could not fly away. For data analysis, different plant structures (leaves, flowers) and sticky traps were used as treatment factors while thrips groups (*F. occidentalis, M. sjostedti* and larvae) were used as variables. In addition, linear regressions were performed to determine the relationship between thrips catches on the sticky traps and the thrips population on sampled leaves and flowers.

Thrips spatial distribution within French beans

The spatial distribution of thrips in French bean plants was done on three replicates. Samples of leaves, flower buds, flowers and pods were collected simultaneously at different levels (Table 1). Leaves were partitioned by their location in the plant canopy, buds, flowers and pods were partitioned based on their time of formation. Twenty units of each level were randomly sampled on different plants in a plot. This was done from fourth week after crop emergence at four-day intervals throughout crop development. Sampling was done randomly on plants from the inner rows of each plot. To reduce diurnal variation in sampling, samples were collected between 1200 h and 1500 h. Samples were collected destructively and were preserved in 70% ethanol. In the laboratory, thrips were extracted from different plant parts and counted under a dissecting microscope. Adult thrips were identified to species using criteria of Anonymous (1996) and Mound and Kibby (1998). This was reconfirmed using the guidelines of Palmer *et al.* (1992). Sex ratio was not determined. Larvae were not separated into species but were combined into a single group for analysis. For analyses different plant structures (Table 1) were used as treatment factors and their levels set the intensity of each factor while the thrips groups (the two species and larvae) were used as variables.

Data analysis

Data were analyzed using Genstat Statistical Software, version 7.1. Data for each variable were keyed-in on a spread sheet as they were collected. Thus there was no pooling of data before analysis. Analyses were carried out after a square-root transformation [*i.e.* $(x+0.5)^{0.5}$] of the data to normalize it, a requirement of ANOVA (Steel and Torrie, 1980). To evaluate statistical differences between groups, ANOVA was performed followed by a *post hoc* test using the Student-Neuman-Keuls test. Results with a $P < 0.05$ were considered to be statistically significant.

Results

Weather characteristics

The rainfall in the first season was 194 mm. It fell mainly March and April. In the second season it was 10 mm in August and September. The temperature in season 1 ranged from 16.7°C to 29.5°C compared with a range of 12.9°C to 26.4°C in season 2. Percent relative humidity was also variable, with season 1 recording a higher mean value (77.5%) compared with season 2 (67.8%). Average wind speed in season 1 was

Table 1. Description of French bean structures sampled to assess within plant thrips distribution

French bean part	Level sampled
Leaves	Bottom (lower) canopy, middle canopy and upper canopy
Flower buds	Early (immature buds; young) and mature (buds ready to open)
Flowers	Early (just opened; young), mature (2-3 days old) and late (forming pods)
Pods	Early (very young) and mature (ready to pick/ harvest)

higher than in season 2 (13.9 km h^{-1} and 9.7 km h^{-1} respectively).

Plant colonization and seasonal fluctuation

Frankliniella occidentalis was the dominant thrips species and accounted for 96% of the total thrips count, from sticky traps, in the two seasons (Fig. 1). The total number of thrips trapped in the second season was high compared with the first season. On leaves, larvae dominated the thrips population. Their number was significantly higher ($P < 0.05$) than the combined number of adults thrips (Fig. 2). They accounted for 90% and 77% of the total thrips population in the first and second seasons, respectively. Their population decreased from the third to the sixth week in the first season, coinciding with rain experienced at that period on. The number of *M. sjostedti* on leaves was negligible (1%) compared with larvae (86%) and *F. occidentalis* (13%). The number of *F. occidentalis* on leaves decreased from pre-flowering period as more flowers continued to form. Their number in flowers was significantly higher ($P<0.05$) than the number of *M sjostedti*, as well as the larvae (Fig. 3).

The larval population increased progressively and towards the end of flowering they became dominant.

Thrips in leaves

$$y = -0.13x + 36.96; (R^2 = 0.33, P > 0.05)$$

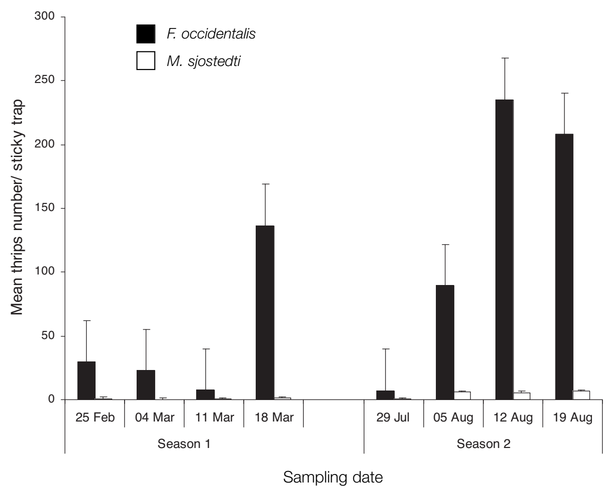

Figure 1. Mean (+ SE) number of *Frankliniella occidentalis* and *Megalurothrips sjostedti* trapped by sticky cards placed above French beans canopy at Mwea-Tebere, Central Kenya in 2002.

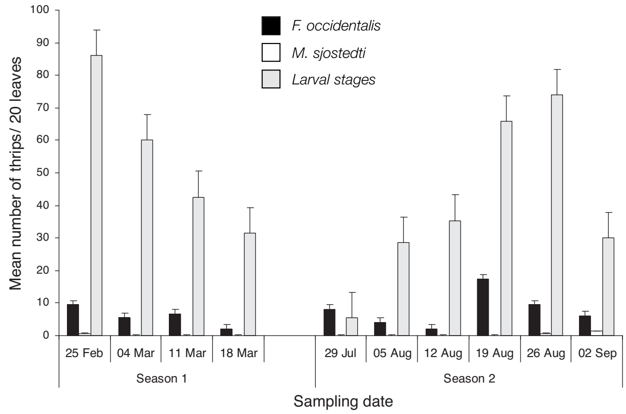

Figure 2. Mean (+ SE) number of *Frankliniella occidentalis*, *Megalurothrips sjostedti* and larval stages, collected from French bean leaves, in Mwea-Tebere, Central Kenya in 2002.

and flowers

$$y = 1.05x + 120.84; (R^2 = 0.99, P > 0.05)$$

had a negative and a positive relationship, respectively, with those trapped in the first season. In the second season, this was reversed. For leaves

$$y = 0.09x + 8.18; (R^2 = 0.49, P > 0.05)$$

and flowers

$$(y = -1.31x + 368.52; R^2 = 0.99, P > 0.05).$$

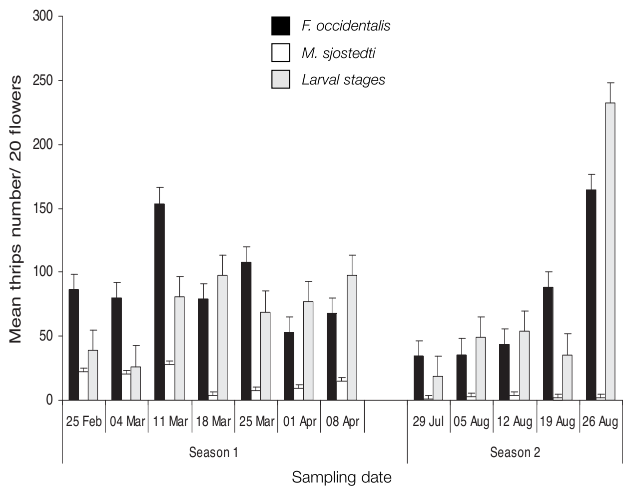

Figure 3. Mean (+ SE) number of *Frankliniella occidentalis, Megalurothrips sjostedti* and larval stages collected from flowers of French beans in Mwea-Tebere, Central Kenya in 2002.

Both leaf and flower models seemed to be reliable in understanding the trend in adult thrips populations, on the crop, using sticky traps. The positive and negative signs correspond with the numbers (trend) of adult thrips found on leaves and flowers in both seasons. The high thrips number in the first season, compared with the second season, could be due to higher temperatures and wind speed that might have played a role in enhancing their flight.

Within-plant distribution

Adult thrips and their larvae were spatially separated in plants. The number of *M. sjostedti* on leaves was low and most of them were located on the middle of the canopy (Fig. 4). The *F. occidentalis* population was significantly higher ($P < 0.05$) than the *M. sjostedti* population but lower than the larvae of both species combined. *Frankliniella occidentalis* adults mainly occupied the bottom of the canopy. The number of larvae on leaves was significantly higher ($P < 0.05$) than the number of adults. However, their number did not differ significantly ($P > 0.05$) among the three canopy levels (season 1). In season 2, their occurrence was significantly different ($P < 0.05$) at the three levels. Most larvae were in bottom canopy leaves.

As with leaves, larvae dominated the thrips population on flower buds where they occupied mainly mature buds (Fig. 5). Similarly, *F. occidentalis* adult numbers were higher in mature than in early buds (> 66%). Comparably, *M. sjostedti* populations in all buds were negligible (< 1%). Thrips infestation of flowers was different from that of leaves and buds. Most *F. occidentalis* were collected from early flowers (49%) compared with *M. sjostedti* (<3% at all flower levels) (Fig. 6). Most larvae (40%) were in mature flowers compared with early and late flowers. There were no seasonal differences in the number of thrips in pods, therefore the results were pooled (Fig. 7). Only larvae and *F. occidentalis* were found on pods. The latter were more prevalent on early pods (61%) while *F. occidentalis* (>99%) were found on mature pods.

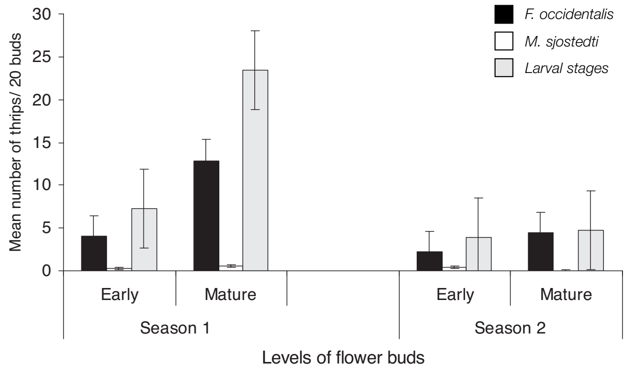

Figure 5. Mean (± SE) number of *Frankliniella occidentalis, Megalurothrips sjostedti* and larval stages collected in flower buds of French bean, in Mwea-Tebere, Central Kenya, 2002.

Discussion

This study suggests that thrips infestation of French beans starts before flowering. At this time in crop development the thrips can only forage on vegetative plant parts as the crop has not flowered. As adults are known to prefer flowers (Kirk, 1997), they probably lay their

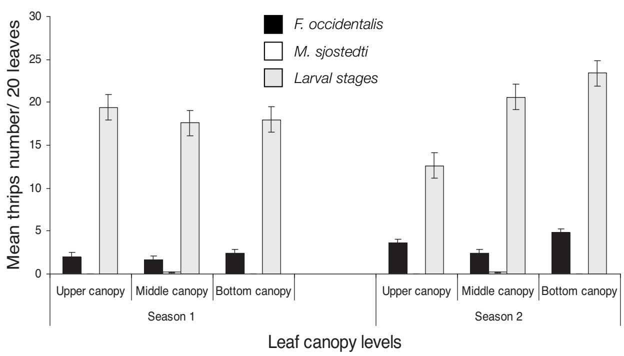

Figure 4. Mean (± SE) number of *Frankliniella occidentalis, Megalurothrips sjostedti* and larval stages collected on different levels of French bean leaves in Mwea-Tebere, Central Kenya in 2002.

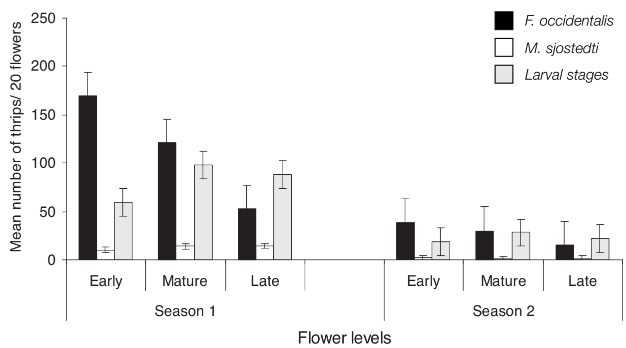

Figure 6. Mean (± SE) number of *Frankliniella occidentalis, Megalurothrips sjostedti* and larval stages on different aged French bean flowers at Mwea-Tebere, Central Kenya in 2002.

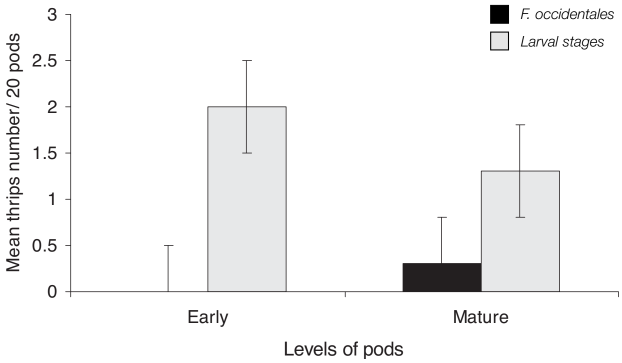

Figure 7. Mean (± SE) number of flower thrips collected from French bean pods in Mwea-Tebere, Central Kenya, 2002.

eggs and then fly to plants with flowers. This could be the reason why a large number of adult thrips were trapped pre-flowering, compared with their number and the number of larvae on leaves at the same time. The presence of thrips during the early stages of French bean growth confirms previous studies that speculated flower thrips infestations of host crop pre-flowering period (*e.g.,* Akingbohunge, 1982; Kyamanywa *et al.,* 1993; Gitonga, 1999). Peak thrips trapping coincided with peak flowering, when thrips are expected in large numbers. The high thrips number, on flowers, could be due to upward migration of thrips from lower in the canopy in addition to new infestations from nearby host plants (*e.g.,* Chellemi *et al.,* 1994; Reitz, 2002).

The difference in thrips population in the two seasons could have been due to the previous rainy season. The first season followed the short rainy season (November-December) while second season followed the long rainy season (April-May). The short season supports less vegetation and lowers the thrips host range. This might have increased thrips infestation of French beans in the first season. The recorded wind speed was within reported ranges that allow thrips to take off and control their own flight. Pearsall (2002) reported optimum flights of *F. occidentalis* at temperatures of 15 to 30°C and wind speed of 15 km h^{-1}, ranges recorded in this study.

It was possible to estimate crop thrips populations with sticky traps using linear regression models. Pearsall and Myer's (2000a) results also related the general trend of thrips population, trapped on cards, with their activity on the crop. However, growers should be careful in interpreting the relationship as it gives an idea of thrips population build up and not their density on the crop (Pearsall and Myers, 2000a). As early crop infestation may create a pool of thrips that can readily and quickly migrate to flowers, once formed, early thrips management would ensure flowers were less infested compared with crops where there was no intervention. This implies that thrips monitoring is important and should form a major component of thrips management.

In this study, most larvae were on upper-canopy leaves. A similar study that used three levels of leaf strata recorded most larvae of *Scirtothrips dorsalis* Hood on upper-canopy leaves of pepper plants (*Capsicum annuum* L.) (Seal *et al.*, 2006). Lower canopy usually have older leaves that may have longer trichomes than young leaves. Leaf hairiness is known to confer resistance to pest infestation through prevention of access to the leaf surface for feeding or oviposition, or trichomes may trap and/or injure the insect (Kirk, 1997). Larvae of *F. occidentalis* larvae are reported on other plants such as tomatoes, to be hindered or permanently trapped by trichomes (Kumar *et al.,* 1995).

The dominance of *F. occidentalis* shows that it outcompetes *M. sjostedti* which has been the main thrips species of legumes in Kenya on French beans. It is also reported to displace major thrips on other host crops, e.g., *Thrips tabaci* Lindeman on cotton (Yokoyama, 1978). *Frankliniella occidentalis* has been shown to infest fast growing parts of a host crop because they are high in nitrogen (Yokoyama, 1978). Ugine *et al.* (2006) related a high presence of adult *F. occidentalis* on young flowers of garden impatiens [*Impatiens wallerana* (Hook. f.)] to pollen compared with vegetative parts and older flowers that already have shed their pollen. This probably explains its preference for young flowers, leaving larvae and *M. sjostedti* in relatively older flowers, which have fewer resources. This spatial segregation of thrips could be a way of managing competition for resources or it may be that *F. occidentalis* fights the others, responding to increased population (Kirk, 1997). Other studies have reported that adult *F. occidentalis* prefer flowers as their main feeding sites (Atakan *et al.,* 1999; Cho *et al.,* 2001). This may be the reason for their large numbers. However, it is also possible that their presence on flowers would be a preferred site for taking off to other fields.

The presence of thrips on pods confirms their role in quality damage, of silvery patches and pod malformation (Pearsall and Myers, 2000b). Growers could reduce this damage by careful timing of their harvests to avoid high pod infestation. High numbers of larvae on plant parts abandoned by adults suggests that adults prefer to lay their eggs at those sites. The dominance of flowers by adults and larvae on leaves, flower buds and pods has been reported by Yadav *et al.* (1974) and Gupta and Singh (1990).

In conclusion, this study shows that *F. occidentalis,* an exotic pest, is a challenge to French bean growers in Kenya. Early infestations can be managed using larvicides to reduce the thrips pool and later attack on flowers. However, this should be guided by monitoring, using sticky traps, and sampling of different plant parts. This would reduce the injudicious use of pesticides, hence managing thrips insecticide resistance build up. Further, this will impact positively the environment and contribute to sustainable management of thrips in the agricultural lands of Kenya and other countries with similar ecological and climatic conditions.

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