ENTOMOLOGY

Diversity and abundance of thrips species on bananas from different ecological zones in Embu County, Kenya

Nicholas Ireri Njue,[1] Faith Jebet Toroitich,[2] John Wangai Kimenju[1]

[1]Department of Plant Science and Crop Protection, University of Nairobi; [2]Department of Biological Sciences, Egerton University, Njoro, Kenya

Abstract

Thrips are among the important pests infecting banana production systems because they have a direct effect on the banana fingers. A prerequisite to the development of any pest management strategy is the correct identification and determination of the pest species attacking crops. A field study was carried out to determine the diversity and abundance of thrips on banana plantations in Embu County, Kenya. The study was conducted in three agroecological zones, namely, Upper Highland UM1, Mid Highland UM2, and Lower Highland UM3 in two seasons in 2015. A total of 878 individual thrips belonging to two families (Thripidae, 12 species, and Phlaeothripidae, one species) were collected and identified. *Frankliniella schultzei* (Trybom) was the most abundant species, with 392 of the total individuals recorded (species dominance = 44.65%) followed by *Megalurothrips sjostedti* (Trybom) with 250 individuals (species dominance = 28.47%), while *Dendrothrips sp*. was the least abundant with only one individual recorded (0.11%). *F. schultzei, M. sjostedti, F. occidentalis* (Pergande), and *Haplothrips godweyi* (Franklin) were well distributed across the different zones during the two seasons. Overall species diversity was highest in the lower zone Shannon-Weiner (H'=1.654) and Simpson's diversity index (1-D=0.740) followed by the middle zone with H′=1.620 and 1-D=0.730 while the upper zone had the lowest diversity (H'=1.332) and (1-D=0.623). A high similarity of 0.8-0.82 and 0.67-0.69, according to Jaccard's and Sørensen's similarity index, respectively, was reported between all the sites, indicating that all the sites had the same level of similarity in the number of shared species. In conclusion, we report that bananas are infested by a wider array of thrips species than previously thought. *F. schultzei* and *M. sjostedti* are the major thrips species infesting bananas in the study area across all seasons and agroecological zones and should be the main targets for pest management interventions.

Correspondence: Faith Jebet Toroitich, Department of Biological Sciences, Egerton University, Njoro, Kenya.
E-mail: fjtoroitich@egerton.ac.ke

Key words: banana thrips, Thripidae, Phlaeothripidae, Frankliniella schultzei, Megalurothrips sjostedti

Contributions: all the authors made a substantial intellectual contribution, read and approved the final version of the manuscript, and agreed to be accountable for all aspects of the work.

Conflict of interest: the authors declare no potential conflict of interest.

Ethics approval and consent to participate: not applicable.

Availability of data and materials: data and materials are available from the corresponding upon request.

Funding: none.

Received: 15 April 2024.
Accepted: 20 February 2025.

Journal of Entomological and Acarological Research 2025; 57:12575
doi:10.4081/jear.2025.12575

Introduction

Thrips (order Thysanoptera) comprise 5500 species in 750 genera (Moritz *et al*., 2004). They are more common in warmer tropical parts of the world than in temperate regions. About 50% of them are fungal feeders, while 40% feed on living tissues of dicotyledonous plants and grasses, and 10% exploit primitive plants or are predatory (Morse & Hoddle, 2006). Thrips have emerged as a significant biotic constraint affecting banana production in Kenya (Wachira *et al*., 2013) as they cause silvery scarifications on fingers thus lowering their quality. Morse and Hoddle (2006) described thrips as small, opportunistic, and ubiquitous insects, often only a few millimeters in length and generally yellow, brown, or black in color. They are significant pests of virtually all crops, including fruiting vegetables, leafy vegetables, ornamentals, tree fruits, small fruits, and cotton (Lewis, 1997).

According to Salifu (1992), *Megalurothips sjostedti*, the bean flower thrips, development from egg to adult takes about 19 days at 29°C and 58% relative humidity and adults live for about 23 days. Rapid breeding, laying eggs on leaf petioles, peduncles, inflorescences, and pods was also reported in bean flower thrips by Tamò *et al*. (1993).

Direct crop damage by thrips results from both feeding and oviposition (Childers, 1997). Because of their thigmotactic behavior, feeding damage is often inflicted on developing tissues, which then goes undetected until flowers or fruit mature (Ghidiu *et al.*, 2006). The feeding damage can be confused with damage caused by other pests or diseases (Steiner & Goodwin, 2005).

Thrips feed by piercing and sucking resulting in scarification, thus reducing the photosynthetic capacity of leaves and causing blemishes on fruits. By feeding on pericarp, these thrips extract chlorophyll and cause a bronzing of the surface of the fruit, while the skin of severely damaged fruit may crack (Dennil & Erasmus, 1992). The direct injury results in the discoloration of fruits, which lowers the quality of the fruits.

The aim of this study was to determine the species composition, abundance, and diversity of thrips infesting bananas in Embu County. This information would support thrips management on bananas by identifying the damage-causing species and improving the knowledge of their bionomics.

Materials and Methods

Study area

The study was undertaken in the Runyenjes sub-county of Embu County on the Upper Eastern side of Kenya, which lies between 1200-2070 m above sea level. The area receives bimodal rainfall patterns from March to May and October to December that range between 1000-2000 mm. To study the area, stratification was done into three agroecological zones (AEZ), namely, Upper Highland (UM1), Mid Highland (UM2) and Lower Highland (UM3) (Jaetzold *et al*., 2006).

Sample collection

Thrips were collected from 30 farms, 10 each for the three AEZ of the sub-county, during two seasons in 2015. The first sampling was done in March, during the hot and dry season before the onset of long rains, and the sampling was repeated, as described above, during the cool and dry season (in June) after the long rains. In each farm, 10 male buds were randomly picked and opened to collect the thrips. The insects were swept with a bristle brush into a sample bottle and then quickly transferred into a universal bottle containing 70% ethanol. All the thrips collected from the 10 male buds were pooled together to make one composite sample, then labeled per farm and zone. A total of 60 samples were collected (30 for each season). Samples were then safely transported to the National Museums of Kenya for expert identification of thrips to species level.

Sample preparation

Specimens were carefully macerated to remove the body contents. They were then put in an AGA mixture (10 parts 60 % ethyl alcohol, 1 part glycerin, and 1 part acetic acid) and stored for 24 hours. 60% alcohol was then replaced with 5% sodium hydroxide (NaOH) and left for 30 minutes. The abdomens were then punctured between the coxae of the hind legs using a fine needle and gently squeezed to expel most of the body contents. Legs and antennae were then spread. NaOH was replaced with distilled water, and 50% alcohol was gradually added for 20 minutes. The mixture was then replaced with fresh 60 % alcohol and stored for 24 hours. 60% alcohol was replaced with 70% alcohol and stored for 1 hour. After an hour, 70% alcohol was replaced with 80% alcohol for 30 minutes. 80% alcohol was replaced with 95% alcohol for 10 minutes. 95% alcohol was replaced with absolute alcohol for 5 minutes. Absolute alcohol was then replaced with fresh absolute alcohol for 5 minutes and then replaced with clove oil and stored for 30 minutes.

The specimens were each mounted according to Mound and Kibby (1998) as follows: a drop of Canada balsam was put at the center of a glass microscope slide ensuring that the drop was sufficient to avoid crushing the thrips. A single thrip specimen was transferred in the drop, dorsal side up. Legs, wings and antennae were straightened by pressing on the basal segments with a fine needle. A clean 13 mm square cover slip was placed on the balsam drop, over the thrip, and gently pressed on so that the balsam spread over the whole cover slip surface. Each slide was labeled as per farmer, zone, date, and collector then dried in an oven at 40°C for 48 hours before identification. Identification was done according to Moritz *et al.* (2004), Mound and Marullo (1996), and Mound (1999), using morphological techniques for adult thrips.

Data analyses

An overall measure of thrips abundance at each site was estimated by summing the counts of the adults of all species. Species dominance (D) was determined according to a method by Buschini and Woiski (2008): D = (abundance of a species/total abundances recorded) × 100. If D>5%, the species was considered dominant, if 2.5%<D<5%, the species was considered an accessory species/species of intermediate abundance, and if D<2.5%, the species was considered an incidental species. Rare species were the ones that had less than 5 individual thrips and/or sampled from only one ecological zone. Shannon-Wiener Diversity Index (H′) and Simpson's Index of Diversity (1-D) were used to determine species diversity and were calculated using PAST software. The equations used are as follows [Eqs. 1 and 2]:

$$\text{Shannon Index } (H') = -\sum_{i=1}^{s} p_i * ln(p_i) \quad \text{[Eq. 1]}$$

where p_i is the proportion of individuals that belong to species i, and s is the number of species.

$$\text{Simpson's Index of Diversity } (1\text{-}D) = 1 - \sum(n_i/N)^2 \quad \text{[Eq. 2]}$$

where n_i = number of individuals of each species, N is the total number of individuals found and Σ is the sum of the calculations.

The Sørensen, Jaccard, and Gauch percentage similarity indices were used to compare similarities among the zones and were calculated according to Kiernan (2014) which was done using Microsoft excel, 2010. The equations of the similarity indices used are as follows [Eqs. 3 and 4]:

$$\text{Jaccard's Index} = c / (a + b + c) \quad \text{[Eq. 3]}$$

$$\text{Sørensen's Index} = 2c/ (a + b + 2c) \quad \text{[Eq. 4]}$$

Where c is the number of common species among the study sites; a and b are the unique species in each site (*i.e.*, the number of species present in site a but absent in site b and *vice versa*).

Gauch Percentage Similarity Index was calculated as follows [Eq. 5]:

$$PS_{ij} = \frac{200 \sum \min(y_{ki}, y_{kj})}{\sum y_{ki} + y_{kj}} \quad \text{[Eq. 5]}$$

Where y_{ki} and y_{kj} are the abundances of the kth species at sites I and j respectively (sites i and j are compared), i is site 1 while j is site 2. Σki and Σkj is the total abundance of the species in each study site (*e.g.*, total abundance in the upper zone plus lower zone).

For the diversity indices, the higher the value, the higher the species diversity in a given zone. Similarly, for the similarity indices, the higher the value, the more ecologically similar two sites are.

Results

Species composition of thrips communities on bananas in farmers' fields

A total of 13 thrips species were recorded on bananas belonging to two families (Table 1). A total of 12 species belong to the Thripidae family, while one species belongs to Phlaeothripidae. *M. sjostedti* was recorded with almost a uniform distribution across all the zones during both sampling seasons. Other thrip species that were well distributed across the zones during both seasons include: *Frankliniella schultzei, F. occidentalis* and *Haplothrips gowdeyi* (Table 1).

Dendrothrips spp. was found in the second season only, and in the upper zone only, while *Hydatothrips adolfifriderici* (Karny) was also found in the second season and in the lower zone only making these species the least distributed in the study area. *Microcephalothrips abdominalis* (Crawford) were found during the second season only, in the upper and lower zones. *Chirothrips frontalis* (Williams) was also poorly distributed in that, although it was collected during both seasons, they were found in one zone in each season: the middle zone in the first season and the lower zone in the second season.

Out of the 878 individuals examined, *F. schultzei* had the most members, with 392 of the total individuals recorded, and with the highest overall dominance of 44.65% while *Dendrothrips* spp. had the least members with only one out of the total individuals recorded, and the least dominant at 0.11% (Table 2).

Based on the pooled data, 5 dominant species were recorded which included *M. sjostedti* (D=28.47), *F. schultzei* (D=44.65), *F. occidentalis* (D=5.7), *Thrips* sp. (D=6.0) and *H. gowdeyi* (D=6.38). A total of 2 species categorized as accessory species with intermediate abundance are *Ceratothripoides brunneus* (Bagnall) and *Thrips florum* (Shmutz). Within the different AEZ, *F. shultzei* was dominant in the middle and upper zones, whereas in the lower zone, *M. sjostedti* was the most dominant. Furthermore, the number of dominant species varied across the AEZ, with the upper zone having 3 dominant species: *F. shultzei*, *M. sjostedti* and *Haplothrips godweyi* in that order. In the middle zone, there were 5 dominant species namely *F. schultzei, M. sjostedti*, *Thrips* sp., *F. occidentalis* and *H. gowdeyi* in that order, and

Table 1. Distribution of thrip species in different agroecological zones in two seasons.

Family	Species	Season one (March)			Season two (June)		
		Upper zone	Middle zone	Lower zone	Upper zone	Middle zone	Lower zone
Thripidae	*Ceratothripoides brunneus*	5	11	4	3	0	0
	Chirothrips frontalis	0	2	0	0	0	2
	Dendrothrips sp.	0	0	0	1	0	0
	Frankliniella occidentalis	3	3	5	4	23	12
	Frankliniella schultzei	151	109	45	33	23	31
	Megalurothrips sjostedti	43	63	34	38	25	47
	Microcephalothrips abdominalis	0	0	0	1	0	2
	Hydatothrips adolfifriderici	0	0	0	0	0	4
	Stenchaetothrips sp.	3	1	0	0	2	4
	Thrips australis	3	0	3	0	0	3
	Thrips florum	9	1	1	0	11	1
	Thrips sp.	0	41	11	1	0	0
Phlaeothripidae	*Haplothrips gowdeyi*	23	6	8	5	12	2

Table 2. Dominance of thrip species in banana across different agroecological zones.

Family	Species	Total individuals				Dominance %			
		Overall	Upper	Mid	Lower	Overall	Upper	Mid	Lower
Thripidae	*Megalurothrips sjostedti*	250	81	88	81	28.47	24.40	26.91	37.0
	Frankliniella schultzei	392	184	132	76	44.65	55.42	40.37	34.7
	Thrips florum	23	9	12	2	2.62	2.71	3.67	0.9
	Stenchaetothrips sp	6	3	3	0	0.7	0.90	0.92	0.0
	Ceratothripoides brunneus	23	8	11	4	2.62	2.41	3.36	1.8
	Frankliniella occidentalis	50	13	20	17	5.7	3.92	6.12	7.8
	Thrips australis	9	3	0	6	1.03	0.90	0.00	2.7
	Chirothrips frontalis	4	0	2	2	0.46	0.00	0.61	0.9
	Thrips sp	53	1	41	11	6.0	0.30	12.54	5.0
	Microcephalothrips abdominalis	7	1	0	6	0.8	0.30	0.00	2.7
	Dendrothrips sp	1	1	0	0	0.11	0.30	0.00	0.0
	Hydatothrips adolfifriderici	4	0	0	4	0.46	0.00	0.00	1.8
Phlaeothripidae	*Haplothrips gowdeyi*	56	28	18	10	6.38	8.43	5.50	4.6
	Total	878	332	327	219	100	100.0	100.0	100.0

in the lower zone, there were 4 dorminant species namely *M. sjostedti*, *F. schultzei*, *F. occidentalis* and *Thrips* sp. A total of 6 species were recorded as incidental species, which included *Stenchaetothrips* sp., *Thrips australis* (Bagnall), *C. frontalis, M. abdominalis, Dendrothrips* sp. and *H. adolfifriderici*. Additionally, *Dendrothrips* sp., and *H. adolfifriderici* are further categorized as rare species.

Diversity of thrips species across the ecological zones and seasons

Overall, H' was found to be 1.593 while 1-D was 0.707. There was higher species diversity in the June (cool and dry) season at H'=1.664 and 1-D=0.741 and the lower zone had the highest overall diversity with H'=1.654, closely followed by the middle zone with H'=1.620 while the upper zone had the lowest diversity H'=1.332. (Table 3).

Diversity within the seasons varied between the March and June seasons (Table 4). During the March season, species diversity was highest in the lower zone at H'=1.546 and 1-D=0.723; whereas in the June season, diversity was highest in the middle zone at H'=1.624 and 1-D=0.789. Diversity was lowest in the upper zone in both seasons.

A total of 8 species were shared between upper and mid zones, 9 among upper and lower zones, and 8 species between lower and mid zones. Jaccard's Index was 0.67 between upper and mid zones; 0.69 between upper and lower zones and 0.67 between mid and lower zones. Sørensen's similarity index was 0.8 between upper and mid zones, 0.82 between upper and lower zones and 0.8 between mid and lower zones. The highest similarity is observed between the upper and the mid zones (80.42%), indicating that these two regions have more overlapping species whereas the lower had the lowest similarity scores; 69.33% with upper and 74.36% with mid (Table 5).

Based on Jaccard's and Sørensen's similarity indices, all the zones have the same level of similarity in the numbers of shared species. The percent similarity index, however, suggests that similarity is highest between the upper and the middle zones and lowest between the upper and the lower zones.

Discussion and Conclusions

Studies conducted on various crops have established a combination of thrip species occurring on the same crop (Okwakpam, 1967; Higgins, 1992). The number of thrips species infesting a crop at a time varies according to the type of crop as reported by Higgins (1992) who found 2 species on tomatoes and 29 species infesting barley. In Kenya, 4 thrip species have been established to infest snap beans *M. sjostedti, F. schultzei, H. aldolfifriderici,* and *F. occidentalis* (Nyasani *et al.*, 2012; Moritz *et al.*, 2013) which is an indicator that several species infest the crops. Additionally, a study by Ssemwogerere *et al.* (2013) in Uganda reported 6 thrip species infesting tomatoes and 5 species infesting pepper in the same localities. The results of this study show that banana is infested by several species with a total of 13 species

Table 3. Overall bio-diversity indices for thrips in banana.

Statistic	Overall	Season		Zone		
		March	June	Upper	Middle	Lower
Taxa_S	13	10	13	11	9	11
Individuals	878	588	290	332	327	219
1-D	0.707	0.660	0.741	0.623	0.730	0.740
H'	1.593	1.437	1.664	1.332	1.620	1.654

1-D, Simpson's Index of Diversity; H', Shannon-Wiener Diversity Index.

Table 4. Diversity characteristics of thrips in different ecological zones within different seasons.

Statistic	Season one (March)			Season two (June)		
	Upper	Middle	Lower	Upper	Middle	Lower
Taxa_S	8	9	8	8	6	10
Individuals	240	237	111	86	96	108
1-D	0.561	0.685	0.723	0.65	0.789	0.711
H'	1.192	1.390	1.546	1.309	1.624	1.573

1-D, Simpson's Index of Diversity; H', Shannon-Wiener Diversity Index.

Table 5. Shared species, Jaccard's Index and Sørensen's Index and similarity percentage index.

Zones	Mid	Lower
Upper		
Shared species	8	9
Jaccard's Index	0.67	0.69
Sørensen's Index	0.8	0.82
% similarity index	80.42	69.33
Mid		
Shared species	-	8
Jaccard's Index	-	0.67
Sørensen's Index	-	0.8
% similarity index	-	74.36

being reported from three AEZ in Embu. There are limited studies on banana thrips in Kenya, and even then, none has documented thrips species found on bananas. A study by Wachira *et al.* (2013) indicated that the incidence of banana thrips in Embu ranged from 11% in the upper zone to 27% in the lower zone. This paper reported the overall incidence of thrips on bananas, without identifying the species found. A subsequent study by Muthee *et al.* (2019) only indicated that 24% of farmers in Embu mentioned thrips being among the factors constraining banana production. The major species identified in this study were *F. schultzei* (44.65 %), *M. sjostedti* (28.47 %), *H. gowdeyi (*6.38 %), *Thrips* sp. (6.0%) and *F. occidentalis* (5.7 %) which were distributed in all zones where banana is grown in Embu County. These species are known to be polyphagous and are widespread. *F. schultzei* is a polyphagous species known to infest more than 83 plant species belonging to 35 plant families (Milne & Walter, 2000) and has been reported in various crops in Kenya (Gikonyo *et al.*, 2017; Odanga *et al.*, 2017). *M. sjostedti* is a common, polyphagous, and widespread pest in Africa (Karungi *et al*., 2000; Alabi *et al*., 2004; Ngakou *et al*., 2008, Ssemwogerere *et al.,* 2013) and *F. occidentalis* which was reported for the first time in Kenya in 1989 (Kedera & Kuria, 2005) is also polyphagous, feeding and breeding on more than 240 host species belonging to 62 plant families. *H. godweyi* has previously been reported to be widespread in various tropical countries on a wide array of crops (Mound & Matsunaga, 2017; Hutasoit *et al*., 2019).

There were fewer thrips in June compared to March and this could be attributed to weather conditions. In March, the weather was dry and hot whereas in June, the weather was cool and dry preceding the long rains. Temperature and relative humidity are known to have an effect on thrips activity, and they also influence the intrinsic rate of natural increase of the thrips (Murai, 2000). Studyies by Dobson *et al.* (2002) and Akemo *et al*. (1999), indicated that the drier the weather, the quicker the onset of thrips damage and the more severe the symptoms. This was in agreement with this study, as high thrips populations were observed in March, a season that was hot and dry. This was also in agreement with earlier findings by Lewis (1997) that the distribution of a thrips population is strongly influenced by climatic conditions. Stacey and Fellowes (2002) and Pearsall and Myers (2001) also showed that temperature affects the development rate of thrips, and consequently their population dynamics. Earlier research has shown that rainfall affects thrips populations both negatively and positively (Morsello *et al.,* 2010). It can suppress populations by killing larvae, and thrips populations so affected often recover slowly (Morsello & Kennedy, 2009).

Species diversity was high in the middle and lower zones and low in the upper zone. This can be attributed to the warmer temperatures in these zones which could be more favorable to a wider array of thrips species compared to the higher cooler zone. Although thrips diversity was lowest in the upper zone, the total thrip counts were almost similar between UM1 and UM2 and lowest in UM3. This observation can be attributed to the large numbers of *F. shultzei* collected in the two zones. Studies have reported that this species prefers mild temperatures (Palmer *et al*., 1992; Milne *et al.*, 1996; Kakkar *et al.*, 2012). Furthermore, recent studies show that the abundance of *F. shultzei* was greater in higher altitude areas than in lower altitude areas of Kenya and Tanzania (Odanga *et al.*, 2017). This could then point to *Frankliniella* sp. preferring milder temperatures hence the observation from this study. The implication of these findings is that management efforts should be targeted at *F. shultzei* in UM1 and UM2 with higher altitudes, and UM3, management should target *M. sjostedti* in addition to *F. shultzei* as these occur in almost identical numbers. The presence of few species in high abundance in the upper zone points to the possibility of pest outbreaks due to the absence of natural control as opposed to the middle and lower zones with higher species diversity and lower thrip populations.

We can conclude based on this study that there are various thrips species infesting bananas in all AEZ in Embu County. The most abundant and widely distributed species were *F. shultzei and Megalurothrips sjostedi* and the high-altitude zone and these two species should be the focus of pest management efforts.

References

AKEMO C.M., KYAMANYWA S., SSEKYEWA C., LUTHER G.E., WILSON H., ERBAUGH M., WARREN H., 1999 - Developing IPM systems for tomato diseases and pests in central Uganda. Available from: https://worldveg.tind.io/record/31512?v=pdf.

ALABI O.Y., ODEBIYI J.A., TAMÒ M., 2004 - Effect of host plant resistance in some cowpea (Vigna unguiculata {L.} Walp.) cultivars on growth and developmental parameters of the flower bud thrips, Megalurothrips sjostedti (Trybom). - Crop Prot. 23: 83-88.

BUSCHINI M.L.T, WOISKI T.D., 2008 – Alpha-beta diversity in trap-nesting wasps (Hymenoptera: Aculeata) in Southern Brazil. - Act. Zool. 89: 351-358.

CHILDERS C.C., 1997 - Feeding and oviposition injuries to plants. In: Lewis T., ed. Thrips as crop pests. - CAB International, Wallingford: 505-537.

DENNIL G.B., ERASMUS M.J., 1992 - The insect pests of avocado fruits. Increasing pest complex and changing pest status. - J. Ent. Soc. Sth. Afr. 55: 51-57.

DOBSON H., COOPER J., MANYANGARIRWA W., KARUMA J., CHIIMBA W., 2002 - Integrated vegetable pest management: safe and sustainable protection of small-scale brassicas and tomatoes, a handbook for extension staff and trainers in Zimbabwe. - NRI, Greenwich: 179 pp.

GHIDIU G.M, HITCHNER E.M, FUNDERBURK J.E., 2006 - Goldfleck damage to tomato fruit caused by feeding of Frankliniella occidentalis (Thysanoptera: Thripidae). - Florida Entomol. 89: 279-281.

GIKONYO M.W., NIASSY S., MORITZ G.B., KHAMIS F.M., MAGIRI E, SUBRAMANIAN, S. 2017 - Resolving the taxonomic status of Frankliniella schultzei (Thysanoptera: Thripidae) colour forms in Kenya – a morphological-, biological-, molecular- and ecological-based approach. - Int. J. Trop. Ins. Sci. 37: 57-70.

HIGGINS C.J., 1992 - Western flower thrips (Thysanoptera: Thripidae) in greenhouses: population dynamics, distribution on plants, and associations with predators. - J. Econ. Entomol. 85: 1891-1903.

HUTASOIT R.T., TRIWIDODO H., AND ANWAR, R., 2019 - The abundance and diversity of thrips (Thysanoptera: Thripidae) on chilli (Capsicum annum L.) and cayenne (Capsicum frutescens L.) in Bogor. - J. HPT Tropika 19: 33-41.

JAETZOLD R., SCHMIDT H., HORNETZ B., SHISANYA C., 2006 - Farm management handbook of Kenya, vol. II. Natural conditions and farm management information. - Ministry of Agriculture, Nairobi.

KAKKAR G., SEAL D.R., KUMAR V., 2012 - Assessing abundance and distribution of an invasive thrips Frankliniella schultzei (Thysanoptera: Thripidae) in South Florida. - Bull. Entomol. Res. 102: 249-259.

KARUNGI J., ADIPALA E., OGENGA-LATIGO M.W., KYA-

MANYWA S., OYOBO N., 2000 - Pest management in cowpea. Part 1. Influence of planting time and plant density on cowpea field pests infestation in eastern Uganda. - Crop Prot. 19: 231-236.

KEDERA C., KURIA B., 2005 - Invasive alien species in Kenya: status and management. Available from: https://www.fao.org/4/y5968e/y5968e10.htm.

KIERNAN D., 2014 - Quantitative measures of diversity, site similarity, and habitat suitability. In: Natural resources biometrics. Open Suny Textbooks, New York.

LEWIS T., 1997 - Pest thrips in perspective. In: Lewis T., ed. Thrips as crop pests. - CAB International, Wallingford: 1-14.

MILNE J.R., JHUMLEKHASING M., WALTER G.H., 1996 - Understanding host plant relationships of polyphagous flower thrips, a case study of Frankliniella schultzei (Trybom). In: Goodwin S., Gillespie P., eds. Proceedings of the 1995 Australia and New Zealand thrips workshop: methods, biology, ecology and management. NSW Agriculture, Gosford: 8-14.

MILNE M., WALTER G.H., 2000 - Feeding and breeding across host plants within a locality by the widespread thrips Frankliniella schultzei, and the invasive potential of polyphagous herbivores. - Divers. Distr. 6: 243-257.

MORITZ G., MOUND L.A., MORRIS D.C., GOLDARAZENA A., 2004 - Pest thrips of the world, visual and molecular identification of pest thrips, Cd-rom. CBIT, Brisbane.

MORITZ G., BRANDT S., TRIAPITSYN S., SUBRAMANIAN S., 2013 - Identification and information tools for pest thrips in East Africa. - QBIT, QAAFI Biological Information Technology, The University of Queensland, Brisbane.

MORSE J.G., HODDLE M.S., 2006 - Invasion biology of thrips. - Ann. Rev. Entomol. 51: 67-89.

MORSELLO S.C., KENNEDY, G.G., 2009 - Spring temperature and precipitation affect tobacco thrips, Frankliniella fusca, population growth and tomato spotted wilt virus spread within patches of the winter annual weed Stellaria media. - Entomol. Exp. Appl. 130: 138-148.

MORSELLO S.C., BEAUDOIN A.L.P., GROVES R.L., NAULT B.A., KENNEDY G.G., 2010 - The influence of temperature and precipitation on spring dispersal of Frankliniella fusca changes as the season progresses. - Entomol. Exp. Appl. 134: 260-271.

MOUND L.A. 1999 - Saltatorial leaf-feeding Thysanoptera (Thripidae, Dendrothripinae) in Australia and New Caledonia, with newly recorded pests of ferns, figs, and mulberries. - Austr. J. Entomol. 38: 257-273.

MOUND L.A., KIBBY G. 1998 - Thysanoptera: an identification guide, (2nd edition). - CAB International, Wallingford and New York: 70 pp.

MOUND L.A., MARULLO R. 1996 - The thrips of central and south America: an introduction (Insecta: Thysanoptera). - Mem. Entomol. Int. 6: 1-487.

MOUND L.A., MATSUNAGA J.N., 2017 - The species of Haplothrips (Thysanoptera, Phlaeothripinae) and related genera recorded from the Hawaiian Islands. - ZooKeys, 662: 79-92.

MURAI T., 2000 - Effect of temperature on development and reproduction of the onion thrips, Thrips tabaci Lindeman (Thysanoptera: Thripidae), on pollen and honey solution. - Appl. Entomol. Zool. 35: 499-504.

MUTHEE A.I., GICHIMU B.M., NTHAKANIO P.N., 2019 - Analysis of banana production practices and constraints in Embu County, Kenya. - Asian J. Agric. Rural Dev. 9: 123-132.

NGAKOU A., TAMÒ M., PARH I.A., NWAGA D., NTONIFOR N., KORIE S., NEBANE C.L.N., 2008 - Management of cowpea flower thrips, Megalurothrips sjostedti (Thysanoptera: Thripidae) in Cameroon. - Crop Prot. 27: 481-488.

NYASANI J.O., MEYHÖFER R., SUBRAMANIAN S., POEHLING H.M., 2012 - Effect of intercrops on thrips species composition and population abundance on French beans in Kenya. - Entomol. Exp. Appl. 142: 236-246.

ODANGA J.J., MOHAMED S., OLUBAYO F., NYANKANGA R., OTIENO I.A., MWALUSEPO S., MWACHALA G., JOHANSSON T., 2017 - Spatial characterization of common blossom thrips (Frankliniella schultzei) in smallholder avocado orchards along slopes of Taita Hills and Mount Kilimanjaro. - Int. J. Env. Agric. Biotech. 2: 2675-2678.

OKWAKPAM B.A., 1967 - Three species of thrips (Thysanoptera) in cowpea flowers in the dry season at Badeggi, Nigeria. - Nigerian Entomol. Mag. 1-4: 45-46.

PALMER J.M., MOUND L.A., de HEAME G.J., 1992 - CIE guides to insects of importance to man. 2. Thysanoptera. - CABI Wallingford UK: 73.

PEARSALL I.A., MYERS J.H., 2001 - Spatial and temporal patterns of dispersal of western flower thrips (Thysanoptera: Thripidae) in nectarine orchards in British Columbia. - J. Econ. Entomol. 94: 831-843.

SALIFU A. B., 1992 - Some aspects of the biology of the bean flower thrips Megalurothrips sjostedti (Trybom) (Thysanoptera: Thripidae) with reference to economic injury levels on cowpea (Vigna unguiculata (L.) Walp). - Rev. Zool. Afric. 106: 451-459.

SSEMWOGERERE C., OCHWO-SSEMAKULA M.K.N., KOVACH J., KYAMANYWA S., KARUNGI J., 2013 - Species Composition and Occurrence of Thrips on Tomato and Pepper as Influenced by Farmers' Management Practices in Uganda. - J. Plant Prot. Res. 53: 158-164.

STACEY D.A., FELLOWES M.D.E., 2002 - Temperature and the development rates of thrips: evidence for a constraint on local adaptation? - Eur. J. Entomol. 99: 399-404.

STEINER M.Y., GOODWIN S., 2005 - Management of thrips (Thysanoptera: Thripidae) in Australian strawberry crops: within-plant distribution characteristics and action thresholds. - Austr. J. Entomol. 44: 175-185.

TAMÒ M., BAUMGÄRTNER J., DELUCCHI V., HERREN H.R., 1993. - Assessment of key factors responsible for the pest status of the bean flower thrips, Megalurothrips sjostedti (Thysanoptera: Thripidae) in West Africa. - Bull. Entomol. Res. 83: 251-258.

WACHIRA P., KIMENJU J., KIHURANI A., MWANIKI S.W., GATHAARA, V., NDIRITU M. 2013. - Incidence of pests and diseases affecting banana in a commercial banana production setting in Kenya. - 13th Workshop on Sustainable Horticultural Production in the Tropics, 3rd - 6th December 2013, Meru University of Science and Technology (MUST).