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First report and population dynamics of the Tobacco Thrips, *Thrips parvispinus* (Karny) (Thysanoptera: Thripidae) on ridged gourd, *Luffa acutangula* (L.) Roxy in selected export fields in southern Ghana

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Abstract

Thrips attack several crops causing considerable economic damage. To prevent this damage, sticky traps can be used to monitor their population for the timely execution of management interventions. Ridged gourd or turia (*Luffa acutangula* (L.) Roxy) is an important Asian vegetable exported regularly to the European Union market from Ghana. However, this vegetable has been intercepted severally at the point of entry because of thrips infestation. The current study is aimed at identifying and monitoring thrips population on turia using blue and yellow sticky traps in six export vegetable production sites in Ghana for two consecutive seasons and three trapping periods. The results showed that *Thrips parvispinus* (Karny) (Thysanoptera: Thripidae) was the commonest and only species of thrips found attacking turia. The highest and lowest mean number of thrips were recorded from the blue and yellow sticky traps during the dry and the late part of the major rainy seasons, respectively. Thrips population build-up was observed to reach its peak at the flowering stage of the crop. This is the first report of *T. parvispinus* in Ghana. The implications of this finding on the export of turia to the EU market has been discussed.

Keywords: DNA barcoding, export, intensification, seasonal pest fluctuations, sticky traps

1 Introduction

Thrips belong to the order Thysanoptera and family Thripidae and are small, slender, soft-bodied insects with fringed wings just visible to the naked eye (Reynaud, 2010). They feed on a wide range of plants by perforating them and sucking up the contents of the plants' cells (Reynaud, 2010). Many thrips species are pests of commercial crops. They feed on developing flowers, causing discolouration and physical damage resulting in reduced crop marketability (Nault, 1997). According to Mound & Teulon (1995), thrips damage includes direct feeding on leaves, flowers or fruits, transmission of viruses and contamination during or after feeding. Therefore, monitoring the population dynamics of thrips is important for the timely execution of control measures. The data obtained could be useful in identifying areas of low and high pest prevalence (Fening *et al*., 2017; Fening & Billah, 2019). Gillespie & Quiring (1987) reported that effective monitoring of thrips population is crucial for successful implementation of insect and vector control programmes. The population of thrips increases when there are high temperatures and prolonged drought, whilst high relative humidity and rainfall reduce thrips population (Hamdy & Salem, 1994). Traps are one of the most effective tools for monitoring and controlling insect pests in crop ecosystems. Traps that exploit the response of insects to colour are used in integrated pest management (IPM) programmes in diverse agricultural cropping systems (Gerling & Horowitz, 1984). Notably, blue colour sticky traps are much more attractive to

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thrips (Tian-Ye *et al.*, 2004; Muvea *et al.*, 2014; Maimom & Kusal, 2017).

Luffa acutangula (L.) Roxy is generally known as ridged gourd or turia. Taxonomically, it belongs to the family Cucurbitaceae, and it has varied names depending on the community. Some examples include turia, angulate, sinkwa towel sponge, vegetable sponge, ridged gourd, Chinese okra, luffa, dish-cloth gourd, ribbed luffa, rilk gourd, sinqua melon, etc, (Manikandaselvi *et al*, 2016). Ridged gourd is a dark green, ridged vegetable having white pulp with white seeds embedded in spongy flesh. This vegetable, believed to have originated within the Arabic deserts, is consumed widely in Asian countries, and exported into the European market. All species of the ridged gourd are edible, although they must be consumed before they mature (Shaun DMello, 2022). Gourds are consumed in varied forms, i.e., soup (cucumber, gherkins, long melon), sweet (ash gourd, pointed gourd), pickles (gherkins) and desserts (melons) (Rathore *et al.*, 2017).

The European and Mediterranean Plant Protection Organization (EPPO) listed *Thrips palmi* (Karny) (Thysanoptera: Thripidae) as an A1 pest recommended for regulation as a quarantine pest. A1 pests are absent from the EPPO region and member countries regulate the entry of the pest by putting restrictions on trade (EPPO, 2017). From October 2015 to December 2017, the European Commission decided to prohibit the introduction of five (5) plant commodities; *Capsicum* (peppers), *Lagenaria* (bottle gourd), *Luffa* (ridged gourd), *Momordica* (bitter gourd) and *Solanum* (mainly eggplant) from Ghana into the European Union (EU) market due to detection of harmful organisms (thrips, whiteflies, fruit flies and false codling moth) in vegetable shipments. As a result of the ban, the contribution of vegetable exports to Ghana's gross domestic product (GDP) decreased by USD 5 million (Yeray *et al.*, 2016). Following the reinstatement of exports to the EU, growers and exporters of turia have adopted sustainable pest management strategies. These strategies include field monitoring of thrips species, a thorough understanding of their crop population dynamics, and sustainable management to prevent the high interceptions that contributed to the earlier ban.

Two species of thrips of economic and quarantine importance that have recently spread around the world are the western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) and the melon thrips, *Thrips palmi* (Capinera, 2000). These two thrips species pose a high quarantine risk with the potential to affect world trade and crop production (Mound & Collins, 2000).

Other thrips species are important, such as the highly polyphagous tobacco thrips, *Thrips parvispinus* (Karny) (Thysanoptera: Thripidae)]. *T. parvispinus* is a major pest of *Capsicum* (Vos & Frinking, 1998) in Java and vegetable crops in Thailand (Bansiddhi & Poonchaisri, 1991). In Malaysia, it is a pest of papaya. The damage caused by its feeding on papaya is associated with secondary attacks by the saprophytic fungus *Cladosporium oxysporum*, causing bunchy and malformed tops of papaya (Lim, 1989). Extensive leaf damage attributed to *T. parvispinus* was observed on *Gardenia* plants in Greece (Mounds & Collins, 2000). Additionally, *T. parvispinus* is also reported as a vector of tobacco streak ilarvirus in transmission studies (Klose *et al.*, 1996). This pest was removed from the EPPO alert list in 2001 as doubts were expressed about the severity of damage in the EPPO region (EPPO, 2001b). However, *T. parvispinus* was intercepted on *Solanum aethiopicum* by the EU from Uganda in 2016 (EUROPHYT, 2016; EPPO, 2016).

The objective of this study was to identify thrips species present on luffa and monitor their population dynamics using blue and yellow sticky traps in six export vegetable production sites in southern Ghana to establish the levels of infestation. The baseline information obtained will be useful in ascertaining the effectiveness of pest management interventions undertaken by farmers and whether producers are strictly adhering to the guidelines outlined in the roadmap for pest reduction in vegetables for export by Ghana's Plant Protection Organisation (NPPO).

2 Materials and methods

2.1 Study sites

The study was conducted from December 2017 to August 2018 to monitor thrips population in ridged gourd farms using yellow and blue sticky traps. During the study period, the dry season spanned from the first week of December 2017 to the last week of February 2018, culminating in the onset of the major rainy season from March 2018 until the end of the season in July and part of the dry spell in August 2018. Therefore, we undertook three different trappings periods of approximately three months each. From 6^{th} December 2017 to 21^{st} February 2018 (dry season), 21^{st} March to 23^{rd} May 2018 (early part of the major rainy season) and 4^{th} June to 6^{th} August (late part of the major season into the early part of the dry spell in August). Six vegetable farms namely, AB Farms, AT Mahli Farms, My Farms, Dhillon Farms, Trosky Farms and Jeokopan Farms, were selected. The farms are in different localities in Greater Accra and Eastern regions of Ghana, coinciding with the semi-deciduous and Coastal Savanna agro-ecological zones of Ghana. AB Farms, My Farms, Trosky Farms, Dhilon Farms and Jeokopan Farms are located in the Nsawam area, a district in the Eastern Region of southern Ghana, a town situated on a main railway and highway to Kumasi. All these farms share the semi-deciduous forest agro ecological zone and the forest ochrosols soil type. AB Farms, My Farms and Trosky Farms are clustered around Nsawam town, while Dhillon Farms and Jeokopan Farms are located at Adeiso and Kyekyewere, respectively, a bit away from Nsawam town. AT Mahli Farms is in the west of Accra near the Weija dam. This area is made up of coastal savanna thicket and grassland vegetation where the soils are well drained, friable, porous loam savanna ochrosols.

2.2 Land preparation, pest and crop management practices utilised by farmers

An acre size plot planted with turia was adopted in each farm for monitoring. The approved roadmap or farm management practices utilised by farmers involved a combination of crop and pest management strategies. These included good land preparation, certified hybrid seeds, improved soil fertility by applying organic manure and/ or inorganic fertilisers, and supplementary irrigation. Additionally, pests and diseases management involving the adoption of good farm sanitation practices (timely weeding and removal of crop residues), use of less toxic or low persistence synthetic insecticides and biopesticides, and trapping of thrips using sticky traps with or without lures were used (Fening *et al.*, 2017). Other agronomic practices for cultivating ridged gourd, such as staking, were done. The farmers utilised a planting distance of 150 cm x 150 cm for turia, with two seeds per hole.

2.3 Setting up of sticky traps for monitoring thrips population

Ridged gourd was grown in rows and staked as per the farmers' protocol. The traps were placed in between rows to the height of the staked plants two weeks after planting. Eight sticky traps, i.e., four yellow and four blue, were set randomly at equidistant positions in each field. The population dynamics of adult thrips were monitored at weekly intervals by recording the number of trap catches. Sticky traps were collected from the field weekly and brought to the laboratory to count and record the number of thrips. Monitoring was done for a period of 10-12 weeks. In addition, flowers were randomly selected from each plot/location to collect thrips for identification.

2.4 Pesticide treatments utilised by farmers

The farmers used a range of pesticides; synthetic insecticides, Protocol® (Lambda cyhalothrin 15 $g\,L^{-1}$ + Acetamiprid 20 $g\,L^{-1}$) @ 40 ml per 15 L of water, Cydim Super EC® (Dimethoate (400 $g\,L^{-1}$) + Cypermethrin (36 $g\,L^{-1}$) @ 35 ml per 15 L of water, Viper 46 EC® (Acetamiprid (16 $g\,L^{-1}$) + Indoxacarb (30 $g\,L^{-1}$)) @ 40 ml per 15 L of water. These were rotated biweekly until flowering stage of the crop. During flowering and fruiting stages, farmers applied either Eradicoat T GH® (Maltodextrin 282 $g\,L^{-1}$) @ 150 ml per 15 L of water, Aqueous Neem Kernel Extract (ANKE) @ 50 $g\,L^{-1}$ of water, neem oil (1 % Azadirachtin) @ 30 ml per 15 L of water, neem oil (0.3 % Azadirachtin) @ 60 ml per 15 L of water weekly to protect fruits against attack by thrips and others insect pests.

2.5 Molecular Identification of thrips

Collected thrips specimens were preserved in 95 % (v/ v) ethanol and sent to CABI Plantwise Diagnostic and Advisory Service laboratory, UK for molecular analysis and identification. Molecular assays were carried out on each sample using nucleic acid as a template. A proprietary formulation [microLYSIS®- PLUS (MLP), Microzone, UK] was subjected to the rapid heating and cooling of a thermal cycler, to lyse cells and release deoxyribonucleic acid (DNA). Following DNA extraction, Polymerase Chain Reaction (PCR) was employed to amplify copies of the DNA *in vitro*. The primers used in amplification were the universal primer pair HCO 2198 5'TAAACTTCAGGGTGCCAAAAAATCA-3' and LCO 1490 5'-GGTCAACAAATCATAAAGATATTGG-3' for the cytochrome c oxidase subunit 1 (COI) – mitochondrial gene (Former *et al.*, 1994). The quality of the PCR product was assessed by agarose gel electrophoresis. PCR purification was performed to remove unutilised dNTPs, primers, polymerase and other PCR mixture compounds and obtain a highly purified DNA template for sequencing. Semi-automated Sanger sequencing was done using previously described methods (Sanger *et al.*, 1977; Smith *et al.*, 1986). Following sequencing, identifications were undertaken by comparing the reverse compliment of the sequence obtained with those available from The Barcode of Life Data System (BOLD). Additionally, the sequence data was also compared to the database available from NCBI BLAST (Altschul *et al.*, 1990). https://blast.ncbi.nlm.nih.gov/Blast.cgi?CMD=Web&PAGE_TYPE=BlastHome.

2.6 Phylogenetic analysis

Relevant sequences for phylogenetic analyses were downloaded from GenBank in FASTA format. Multiple sequence alignments were done using MUSCLE (Edgar, 2004) in Molecular Evolutionary Genetics Analysis Version X. (MEGA X) (Tamura *et al.*, 2013). The evolutionary history was inferred by using the Maximum Likelihood method based on the Tamura-Nei model (Tamura and Nei, 1993). Pairwise sequence comparisons were made by aligning the sequences using MUSCLE in Species Demarcation Tool v 1.2 (SDT v. 1.2) (Muhire *et al.*, 2014).

2.7 Data analysis

The prevalence of thrips was estimated using the indices used for fruit flies, F / T / W (ISPM 30, 2008; Billah & Fening, 2019; Fening & Billah, 2019). Where F = total number of thrips captured, T = number of inspected traps and W = number of weeks traps were exposed in the field. A student's t test of significance was used to compare catches from blue and yellow sticky traps ($P < 0.05$).

3 Results

3.1 Species of thrips identified on ridged gourd

The tobacco thrips, *Thrips parvispinus* was the only species identified on the ridged gourd (Table 1). The samples or specimens 1, 2, 5 and 6 for identification showed 100 % similarity to each other, marching with *T. parvispinus* in the GenBank, Accession number KF 144125.1 from Indonesia (Chang & Ramasamy 2013), among others (Figs. 1 and 2). Sequences generated from this study have been deposited in GenBank and assigned accession numbers (see Table 1). Samples 3 and 4 did not produce significant sequences that could be analysed, thus were not used in the analysis.

Table 1: *Summary of results of samples of thrips sent to CABI Plantwise Diagnostic and Advisory Service Laboratory, UK.*

SN	*MMS ref.*	*Accession number**	*Sample details*	*Summary key results*
1	E527001	OM761193	Thrips	*T. parvispinus*
2	E527002	OM761194	Thrips	*T. parvispinus*
5	E527005	OM761195	Thrips	*T. parvispinus*
6	E527006	OM761196	Thrips	*T. parvispinus*

Note: The samples or specimens 1, 2, 5 and 6 for identification showed 100 % similarity to each other, marching with *T. parvispinus* in the GenBank, Accession number KF 144125.1 from Indonesia (Chang & Ramasamy 2013), among others. SN: sample number; *Sequences have been deposited to the GenBank with their accession numbers indicated.

3.2 Thrips abundance in turia flowers

A total of 40 thrips were sampled in flowers during all cropping seasons in all farms and served as part of the specimens used for the molecular identification. Therefore, the data used in the population dynamics study were based on sticky traps catches only, as the number of thrips sampled in

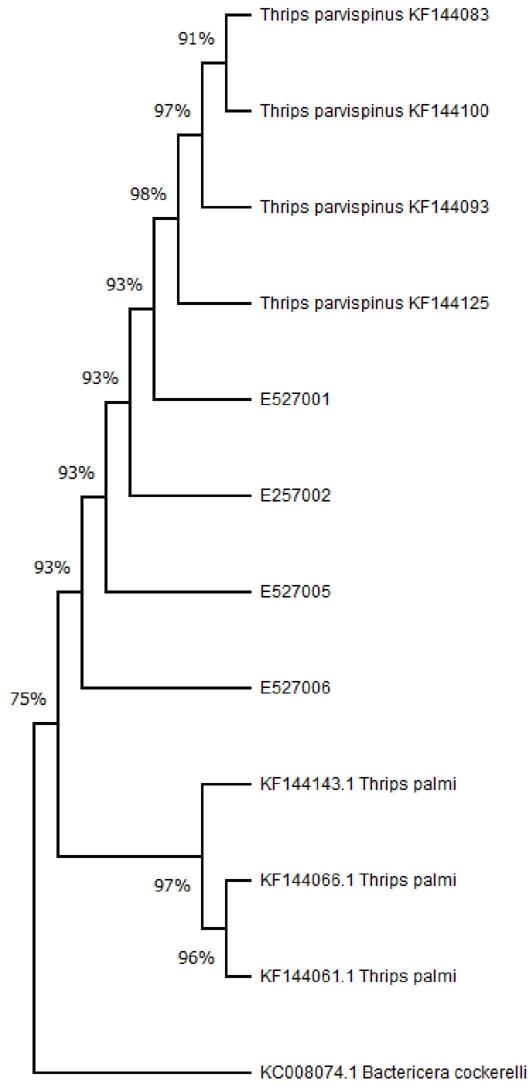

Fig. 1: *Molecular phylogenetic analysis by neighbour-joining method. The outgroup is the potato psyllid Bactericera cockerelli.*

flowers were very few. Six thrips specimen, three each from the flowers and trap catches were sent for molecular identification as they all appeared similar morphologically.

3.3 Prevalence of thrips using sticky traps

The highest prevalence of thrips in the different farms across the seasons was recorded at Trosky Farms, followed by AB Farms with the blue sticky traps during the early part of the major rainy season (Table 2). However, during the late part of the major rainy season, the lowest prevalence of thrips per week was recorded from the yellow sticky traps at Trosky Farms and My Farms (Table 2). Generally, the dry season recorded high prevalence of thrips in all the farms during that period. Exceptionally, Jeokopan Farms recorded

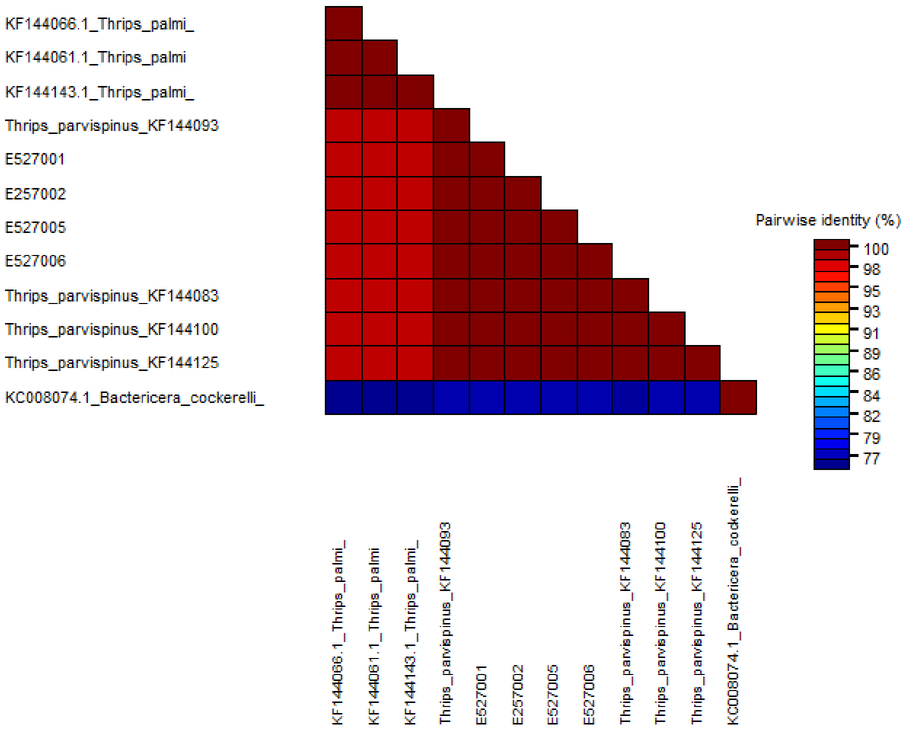

Fig. 2: *Pairwise comparison for thrips species using MUSCLE in Species Demarcation Tool v 1.2 (SDT v. 1.2), showing a cluster of identified thrips species (E527001-E527006) with Thrips parvispinus*

low prevalence of thrips during the early and late parts of the major rainy seasons when the traps were in place. Moreover, thrips relative density or prevalence in all the farms at the end of the study (third trapping period) was much lower compared to the beginning (first trapping period) and was always higher with the blue sticky traps compared to the yellow. Thus, the study revealed a significantly higher number of thrips catches in the blue sticky traps than the yellow traps during the dry season ($t_{3;4} = 12.58$; $P = 0.001$).

3.4 Population dynamics of thrips based on weekly trap catches

3.4.1 Yellow sticky traps

The dry season showed Dhillon and My farms having a high population of thrips, whereas AB farms and AT Mahli farms had low thrips population (Fig. 3). Thrips population then decreased in all the farms in week 2 and 3. From week 4 to 7 (coinciding with the beginning of fruit formation), the thrips population rose and peaked on week 6 for almost all the farms. After that, thrips population build-up reduced and remained constant with slight fluctuation from week 7 to 12 in all the farms.

Generally, during the late part of the major rainy season and early dry spell in August, AT Mahli and Dhilon farms had a higher population of thrips than the rest of the farms,

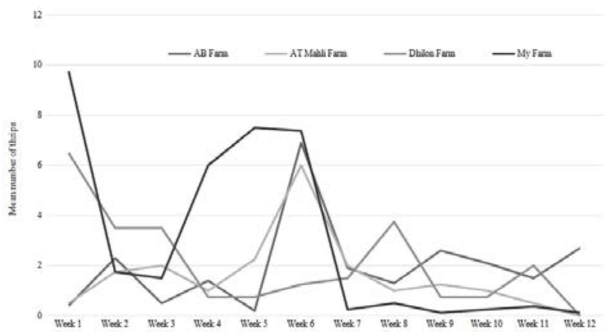

Fig. 3: *Mean number of catches of thrips by yellow sticky traps on weekly basis during the dry season at four exporters' turia farms.*

while Trosky farms had the least number of thrips (Fig. 5). Probably effective pest control ensured pest population is suppressed where the incidence of thrips population was initially high.

Trosky farms had the highest number of catches during the dry season and the least during the major rainy season, where thrips population remained zero after the first week. In the last three weeks of monitoring thrips population build up, the number of catches was zero on all farms. The late part of the major rainy season was also marked by a low

Table 2: *Comparison of relative density of thrips based on weekly trap catches.*

Season	*Trap colour*	*Relative density (F/T/W)*[*]					
		AB Farms	*AT Mahli Farms*	*Dhilon Farms*	*My Farms*	*Trosky Farms*	*Jeokopan Farms*
Dry season	Yellow	1.98	1.60	2.08	2.96	–	–
	Blue	6.63	7.75	6.81	7.35	–	–
Early part of the major rainy season	Yellow	1.75	1.38	0.48	0.80	4.14	0.16
	Blue	7.81	6.60	0.83	4.33	21.48	0.48
Late part of the major rainy season	Yellow	0.85	1.37	1.06	0.11	0.10	0.30
	Blue	0.55	0.20	0.57	0.14	0.27	0.12

*F = total number of thrips captured, T = number of inspected traps and W = number of weeks traps were exposed in the field;
– = Farm did not cultivate turia.

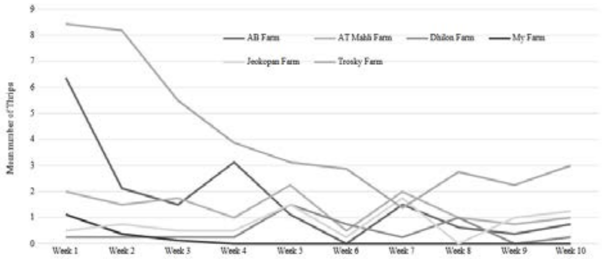

Fig. 4: *Mean number of catches of thrips by yellow sticky traps on weekly basis during the early part of the major rainy season at six exporters' turia farms.*

number of catches compared to the early part of the major rainy season and the dry season.

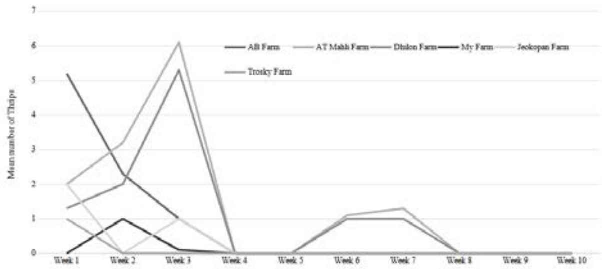

Fig. 5: *Mean number of catches of thrips by yellow sticky traps on weekly basis during the late part of the major rainy season at six turia exporters' farms.*

3.4.2 *Blue sticky traps*

During the cropping seasons, thrips population as depicted in catches from the blue sticky traps exhibited different peak periods. Unlike with the yellow sticky trap, the initial number of catches in all farms was lower, but between weeks 5 to 7, all the farms recorded their peak, followed by a general decline in the number of thrips. Week 1 to 4 corresponded to the vegetative period of turia plant. From week 5, flowering and fruiting started, and the thrips were probably more attracted to the plant, which resulted in the high number of catches during this period. As with the yellow sticky traps during the dry season, the highest number of thrips was recorded in My farms during week five (Fig. 6).

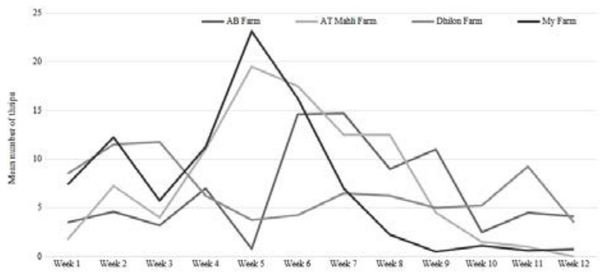

Fig. 6: *Mean number of thrips catches by blue sticky traps on weekly basis during the dry season at four exporters' turia farms*

Trosky farms recorded the highest number of catches, and My farms had the lowest, just like when the yellow sticky traps were used during the early part of the major rainy season (Fig. 7). The trend of thrips population build-up in all farms with the yellow or the blue sticky traps was very similar with the only difference was that the blue sticky traps had a higher number of catches than the yellow traps. The number of catches on the blue sticky trap during the dry season was the highest recorded in the study.

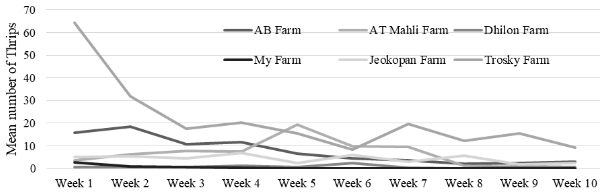

Fig. 7: *Mean number of thrips caught by blue sticky traps on weekly basis during the early part of the major rainy season at six exporters' turia farms.*

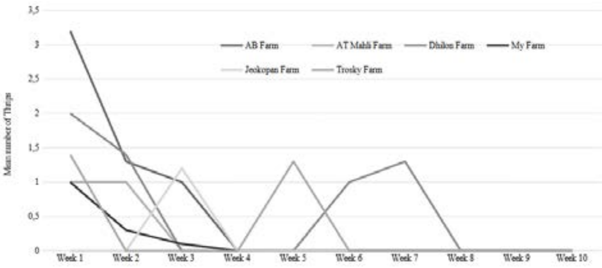

Fig. 8: *Mean number of thrips caught by blue sticky traps on weekly basis during late part of the major rainy season at six exporters' turia farms.*

4 Discussion

The study aimed to correctly identify and monitor the population dynamics of thrips species common on turia in Ghana. This was necessary as turia and other vegetables exported to the EU had been intercepted for the presence of thrips, mostly *T. palmi*, which is known to be of quarantine importance. This had led to export bans which were subsequently lifted. In the current study, the thrips species identified was the tobacco thrips, *T. parvispinus*. It is considered a polyphagous species and is reported as a major pest of *Capsicum* in Java and vegetable crops in Thailand (EPPO, 2001a). *Thrips parvispinus* was removed from the EPPO pest alert list in 2001 as doubts were expressed about the severity of damage in the EPPO region (EPPO, 2001b). However, *T. parvispinus* was intercepted on *Solanum aethiopicum* by the EU from Uganda in 2016 (EUROPHYT, 2016; EPPO, 2016). Although, *T. parvispinus* is not in the current EPPO Pest Alert List (EPPO, 2020), EPPO A1, or A2 Quarantine Pest Lists (EPPO, 2019), it still has implications on international trade as it was intercepted in 2016. In certain instances, the EU intercepts a commodity by identifying only to the genus level, e.g., *Thrips* sp. or the order and family only, e.g., order Thysanoptera, family Thripidae. For instance, turia or luffa from Ghana was intercepted recently for the presence of Thripidae as indicated in the Europhyt notifications (EUROPHYT, 2020). Thus, it can be inferred that the presence of thrips in an exported commodity poses a big threat to trade irrespective of the species identity.

Amin (1980) stated that ridged gourd, bottle gourd, bitter gourd, cucumber, pumpkin and soybean can be colonised by large populations of thrips. This confirmed the results in this study where the thrips population reached as high as 21 catches/ trap per week at Trosky Farms. As expected, the results from the current study concur with the fact that thrips prefer the blue sticky traps than the yellow traps. In a similar study, thrips were attracted to blue coloured sticky traps over the crop growth period than white, yellow and fluorescent green sticky traps (Soniya-Devi *et al.*, 2017). Winged adult thrips are usually monitored using coloured sticky traps, whereby the ability of a colour to attract thrips varies for different thrips species, but blue or white traps are known to be effective for trapping *T. palmi*, though yellow traps will also work (ISPM 27 Annex 1, 2010; 2016).

Within the same period of data collection, and with the same colour of sticky trap, there is a difference in the peak period throughout the farms. Therefore, the differences in the peak activity period of the pest observed in the present studies could be attributed to the variations in the flowering and fruiting period, and prevailing weather at different sites since they were planted at different times by the farmers for export. The findings of Pickett *et al.* (1988) are in line with the current study, as they found that thrips population build up reach their peak during the flower developmental stage of the cotton. Similarly, Gebretsadkan (2017) reported that thrips abundance fluctuated based on plant growth stage, months, locations (altitudes), and weather factors, mainly temperature and rainfall.

Generally, the late part of the major rainy season of 2018 recorded the least number of thrips partly since it coincided with the peak period of the rainfall (June-July), which may have dislodged the thrips from the crop. But that period was also the third trapping occasion, so the continuous trapping involving many traps (mass trapping) may have also led to population suppression of thrips.

A very low number of thrips were found in the flowers of turia sampled from the fields. Some of the exporter farms seem to have fewer thrips catches in the traps, which suggests that the management interventions for thrips as proposed in the roadmap for pest reduction were better adhered to by some farmers than others (Fening *et al.*, 2017). The farmers are therefore encouraged to pay more attention to implementing the control measures for thrips strictly, especially during the dry and early part of the major rainy seasons, including the use of blue sticky traps for monitoring and mass trapping (by increasing the trap density) to suppress the thrips population. Post-harvest treatment, involving the removal of dried floral parts attached to the turia, sorting and washing of harvested turia gently in a diluted soapy detergent solution or mineral oil are likely to dislodge most of the thrips hidden in the ridges and the dried floral parts (KO Fening Per. Comm.).

Interestingly, *T. parvispinus* has concurrently been identified as the commonest and only species of thrips found on African eggplant, *S. aethiopicum* and okra, *Abelmoschus esculentus*, sampled during the same period in Ghana from the University of Ghana Research Farms, Kpong (K.O. Fening, Per. Comm.). Thus, it is recommended that a detailed study of *T. parvispinus* distribution on different host plants (crops and wild plants) in Ghana should be undertaken to inform management decisions. The current finding is the first report of *T. parvispinus* in Ghana.

Homology search using BLAST search option for the samples or specimens of thrips collected from turia in Ghana resulted in 100 % similarity to *T. parvispinus* sequences from Indonesia with the Accession number KF 144125.1 in the GenBank (Chang & Ramasamy, 2013). The potato psyllid, *Bactericera cockerelli* was used as the outgroup in the molecular phylogenetic analysis by Maximum Likelihood method. The *T. parvispinus* samples from Ghana (with accession numbers OM761193, OM761194 and OM761196) branched with some accessions from Indonesia with over 99 % similarity. The molecular evidence verify that the specimens of thrips collected from turia in Ghana represents *T. parvispinus*. Pairwise comparison for thrips species using MUSCLE in Species Demarcation Tool v 1.2 also revealed a similar trend of 100 % pairwise identity between *T. parvispinus* collected from turia in Ghana and those from Indonesia.

5 Conclusion

The population of thrips are very difficult to trace in the field due to their cryptic nature. The use of yellow and especially blue sticky traps in ridged gourd production could be a useful tool to monitor the build-up of thrips population in the field and help farmers to protect their crops against thrips infestation early enough by timely execution of management interventions to avert significant damage symptoms on their crop. The results from this study and earlier studies have confirmed the distribution and population of thrips under a sustainable pest management programme is always fluctuating according to different factors such as seasonality, agroecology, land use history and management interventions employed, among other reasons (Amin, 1980; Fening *et al.*, 2017; Soniya-Devi *et al.*, 2017).

The population of thrips decreased during the late part of the major rainy season (June and July which mostly receives more rainfall) as compared to the dry and early part of the major seasons (December to May, which receives less rainfall). The use of sticky traps in pest monitoring should be an integral part of tailor-made IPM programme, where detection and monitoring of thrips population becomes an integral part for decision making before pesticide applications and other control measures are employed in the field. According to the CABI Crop Protection Compendium and the European and Mediterranean Plant Protection Organisation, *T. parvispinus* has not previously been recorded in Ghana and is not of quarantine importance, unlike *T. palmi* which is an A1 pest species that have been recorded as the cause of many interceptions of commodities from Ghana to the EU market. Therefore, this study offers a baseline for further studies to ascertain if other *Thrips* spp., especially *T. palmi*, is present in Ghana, as it has been intercepted severally in exported vegetables (including turia) from Ghana into the EU market.

Authors' contribution statement

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by KA and EEF under the supervision of KOF, FOW and MKB. The first draft of the manuscript was written by KA and all authors commented on previous versions of the manuscript. Funding for the study was sought by WH. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that they have no conflict of interest.

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