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SEASONAL DIVERSITY OF ENTOMOFAUNA, THEIR IMPACT AND MANAGEMENT PRACTICES IN TOMATO FIELDS IN MERU DISTRICT, TANZANIA

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ABSTRACT

Tomato is a highly cultivated vegetable in Tanzania. The intensive tomato cultivation and production in Tanzania has resulted in high pests and diseases build-up. A survey to identify and quantify entomofauna diversity in different seasons and pest management practices in Meru District was conducted. In addition, a laboratory experiment was done to assess the effectiveness of commonly used pesticides SnowBecco (Thiamethoxam) and Belt (Flubendiamide) against two dominating insect pests, white flies (*Bemisia tabaci* (Gennadius, 1889)) and leaf miner (*Tuta absoluta* (Meyrick, 1917)), respectively. The results obtained revealed that, tomato fields in Meru District had significantly higher entomofauna build up during dry season than the rainy season ($U_{0.05}$ (df, 24) = 45, p = 0.0441). More than 70% of all collected entomofauna were dominated by the whiteflies (*Bemisia tabaci)* and tomato leaf miners (*Tuta absoluta*) belonging to orders Hemiptera and Lepidoptera, respectively. It was also observed that, the common pesticides management practices were the use of pesticidal cocktail, broad spectrum insecticides, use of botanical pesticides, frequent application of pesticide and insecticides over dosage. Moreover, yield reduction due to whiteflies and tomato leaf miners infestation were observed in terms of reduced fruits number per plant (38 and 18.4%), fruit size (22.4 and 14.2%), and fruits weight per plant by 43.6 and 26.2%, for *Bemisia tabaci* and *Tuta absoluta*, respectively. The study showed that the recommended doses in both tested insecticides caused significant pest mortality ($F_{0.05}$ (df, 19) = 4.367, p = 0.0199) and ($F_{0.05}$ (df, 19) = 4.761, p = 0.0147) for *B. tabaci* and *T. absoluta,* respectively, within a specified period of time. The results suggest that high insect pest infestations could be caused by factors other than development of insecticidal tolerance including inappropriate identification of insect pests due to lack of training, and inappropriate selection and application of insecticides. Consequently, frequent application of broad spectra insecticides not only increases production expenses but also disrupts agroecosystem by killing beneficial entomofauna and disrupting soil organisms that are susceptible to insecticide toxicity.

Key words: Pesticide tolerance, entomofauna diversity, control malpractices, pesticide susceptibility, farmers' knowledge

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INTRODUCTION

Vegetable crops are in high demand worldwide due to their important nutritional content, medicinal value and commercial significance. In Tanzania, for example, a total of 129,578 tons of tomatoes (*Solanum lycopersicon*) are produced annually, representing 51% of the total vegetable production [1]. They contribute to food and nutritional security as they contain vitamins, minerals, and antioxidants [2]; they form sources of income and poverty reduction at household level in regions where they are most cultivated including Morogoro, Iringa, Mbeya, Kigoma, Tanga, Arusha, Kilimanjaro and Zanzibar.

In Arusha, particularly Meru district, tomatoes are cultivated throughout the year due to the availability of irrigation water and farmers' access to high yielding tomato varieties. This intensive tomato cultivation, coupled with the use of tomato varieties that are highly susceptible to pests and diseases have resulted in increased incidences of pests and diseases in tomato fields [3]. The average tomato yields in Tanzania range from 2.2 to 3.3 t/ha, which is only 12% of the world average productivity of 27.5 t/ha [4]. To reduce the yield losses, farmers in Meru District have resorted to use of pesticides to manage the pest population not to exceed economic threshold on such a desirable crop [5].

Though high pesticide input has been associated with health risks and environmental pollution elsewhere, farmers in Meru District have adopted pesticidal malpractices such as the use of pesticides over-dose, cocktails and broad activity-pesticides, to deal with the tomato pest problem in the field. These inappropriate applications of pesticides are being suspected to have caused pesticide tolerance in targeted pests as farmers still experience high pest infestation, diversity and incidences of diseases. Some studies have been conducted on the control of local vegetable pests, quantification of tomato productivity and farming of tomatoes in Tanzania [4].

However, limited information exists on the status of entomofauna seasonal diversity in tomato agro-ecological fields, local farmers' knowledge in identifying and utilizing effective pest management practices, efficacy of commonly used pesticides to control dominant pests, and extent of reduction in tomato yields caused by the dominant pests in the fields.

MATERIALS AND METHODS

Study site and pests sampling

The study was conducted in Meru District Council located between 36°58′ and 37°00′E, 03°37′ and 03°58′ S at 1290 m above sea level. Field surveys were conducted to establish the magnitude of pest and disease problems and the effectiveness of pesticides commonly used by farmers against dominant insect pests *Bemisia tabaci* and *Tuta absoluta.* The surveys covered a total of 4800 tomato plants from 240 farms conducted during the dry season (August –November, 2018) and rainy season (February –April, 2019). The farms were located in six different villages, namely

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Akheri and Patandi in Akheri Ward, Sing'isi and Seela in Seelasing'isi Ward and Maweni and Karangai in Kikwe Ward.

Each village consisted of four sites each with five different tomato fields. Each field was sub-divided into four equal plots in which five tomato plants were selected randomly for physical assessment and identification of entomofauna. The entomofauna were collected from randomly selected tomato plants by cover bags, hand picking and using vacuum machines. The number and kind of entomofauna collected were recorded and identified according to the descriptions reported by James *et al.* [6]. Both qualitative and quantitative data were collected through field observations, semi structure interviews of farmers visited and laboratory analysis of insect samples collected.

Various diversity indices were calculated to establish pests' diversity, richness, evenness and dominance. Pest diversity in terms of number and kind of insect pests collected during different seasons were calculated and compared using Shannon-Weaver index of diversity (H') and Simpson index of diversity (1-D). Shannon-Weaver index of diversity (H') was calculated using the formula $H' = -\sum Pi \log Pi$. $Pi = \frac{ni}{N}$ where, *Pi* is the proportion of individuals in the i^{th} species, *ni* is the number of individuals observed for each species and N is the total number of individuals in each study area.

The Simpson reciprocal index (1/D) was calculated by the formula =1-D, $D=N(N-1)/\sum n(n-1)$. Pests' richness was calculated using Margalef index (d) with the formula $d = \frac{(S-1)}{Ln(N)}$. Pests' evenness was performed using Pielou's index (J') with the formula $J' = H'/H'_{max}$ but $H'_{max} = \ln S$. [7].

Assessment of farmers' knowledge and skills on insect pests and control methods

Semi-structured interviews using semi-structured questionnaires were conducted on 240 farmers with age ranging between 17-58 years, selected randomly in surveyed sites. The key issue was to assess their skills on insect pest identification. The interviews involved asking local farmers to identify insect pests collected from their tomato fields by matching the pests with the pests' local Swahili names provided. Also, the farmers' knowledge on methods used in management of insect pests and the frequency by which the method was applied was assessed as described by James *et al.* [6]. All the qualitative information with regard to the frequency of application were summarized and documented as shown in table 2.

Assessment of yield losses due to insect pest infestation and diseases

To assess tomato yield losses due to dominant insect pests, late seedling stage tomato plants were subjected to two dominant insect pest treatments (infestations), *viz:* tomato leaf miners larvae and white flies. The first treatment consisted of 10 tomato plants infested with 50 larvae of tomato leaf miners. The second treatment consisted of 10 plants infested with 50 white flies against control treatment consisting of 10 tomato plants that were free from insect infestation as performed by Litsinger *et al.* [8].

The experiment was arranged in a completely randomized block design in which tomato plants make the main blocks and the treatments make the plots. The treatment blocks and plots were separated using agro-nets, to avoid cross infections and multiple infestations from unintended pests. The whole experiment was replicated three times as per the method described by Vieira *et al.* [9]. The white flies and larvae of tomato leaf miners were sourced from Tengeru Horticulture Research Training fields. Data on marketable fruit size, fruit number and fruit weight from each field plot were collected at maturity for the yield analyses in response to insect pest infestations.

Determination of the insecticidal toxicity against insect pests

Two commonly used insecticides, SnowBecco (Thiamethoxam 250g/kg) and Belt®SC 480 (Flubendiamide), were used to evaluate whether their recommended dosages had fatal effect on selected insect pests. The two pesticides were chosen based on recommendations from agro-pesticide dealers, as among the most used pesticides by local farmers to control white flies and tomato leaf miner larvae (*T. absoluta*), respectively, as described by Dougoud *et al.* [10].

To determine the insecticidal toxicity on white flies and tomato leaf miner larvae, various lethal concentrations of the insecticides including control, low dosage, recommended and over dosage were used by direct spraying on the insect pests and foliar application. To remove the effect of mortality other than those caused by insecticides, the corrected mortality was calculated by the formula % cor. mortality $(mc) = (\frac{(mi-m0)}{(mo-mc)}) \times 100$. Where, *mc* is corrected mortality rate, *me* is mortality rate of control and *mo* is observed mortality rate of treated insect pests. The formula works by integrating re-zero factor of control to all other treatments and left the probable effect of insecticide treated to be the affecting factor. Two methods of spray were used. *Direct spray on pests:* Belt insecticide was used directly on larvae of tomato leaf miner at different concentrations to determine the minimum lethal concentration. The recommended concentration of Belt insecticide that is 200 µ/l (4 ml/20ltr) was used as reference, while distilled water was used as control. A series of concentrations were used in the diluted dosage and an overdose to form the following concentrations: 0 µl/l, 100 µl/l, 200 µl/l and 300 µl/l. From each of the concentrations, 10 mls were applied by direct spraying on twenty (20) *T. absoluta* larvae placed in two petri dishes (Plate 1) containing tomato leaves. The experiment was observed every three hours for a duration of 12 hours. Time and number of dead larvae were re-coded for further analysis.

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Plate 1: Testing lethal dosage of Belt insecticide on tomato leaf miner larvae A) Covered petri dish sprayed with Belt B) Dead larvae of tomato leaf minor on tomato leaf

Foliar spray method: SnowBecco was used at different concentrations to determine the minimum lethal concentration for effective control of white flies. The recommended concentration of SnowBecco insecticide, that is 400 mg/l (8 g/20 liters), was used as reference while distilled water was used as control. A series of concentrations were used in the diluted dosage and an overdose to form the following concentrations: 0 mg/l, 200 mg/l, 400 mg/l and 600 mg/l. Ten (10) ml of each concentration was sprayed on two tomato plants kept in separate cage (Plate 2), and allowed to dry for one hour prior to infestation with twenty (20) white flies. The experiment was observed after 12 hours for 24 hours period.

Plate 2: Testing for minimum lethal dosage of SnowBecco on white flies A) Sprayed un-infested tomato seedlings (uncovered pots), and B) Sprayed and infested tomato seedling (covered pots)

Data analysis
Insect species diversity was examined using Shannon-Winner diversity index and Simpson reciprocal index (1/D). Species richness and evenness was explored using Margalef index (d) and Pielou's index (J'), respectively. Analysis of insect identification and management skills was performed based on descriptive statistics as percentage of farmers who could correctly identify the insect pest and apply appropriate management methods.

The analysis of variation of number of pests between different seasons and the lethal levels of tested insecticides was done using unpaired Mann Whitney U test and t- test, respectively. One way analysis of variance was used to compare yield variations between treatments. Tukey-Kramer Multiple Comparisons test was used as post-test for mean comparison.

RESULTS AND DISCUSSION

Identification of entomofauna in tomato fields during wet and dry seasons
A total of 738,590 entomofauna were collected in both dry and rain seasons in 2018/2019. The data showed a high number of entomofauna of 528,388 individuals during the dry season compared to 210,202 individuals during the rainy season representing nine orders namely, Hemiptera, Lepidoptera, Diptera, Trombidiformes, Hymenoptera, Coleoptera, Thysanoptera, Araneae and Neuroptera (Table 1). A total of 13 different kinds of insect pests (genera) were identified in dry season and twelve (12) different kinds of insect pests (genera) in rainy season. The analysis of number of entomofauna collected between two seasons using Mann-Whitney U test were significantly different ($U_{0.05}$ (df, 24) = 45, p = 0.0441) showing higher number of entomofauna in dry season than in rainy season.

Other studies showed that weather conditions of a region such as environmental temperature, moisture, carbon dioxide and precipitations could be the main determinants for thriving of particular insect pests [11]. It has been estimated that increase in temperature by only 2^{o}C might increase lifecycles of insect pests, from one life cycle to five life cycles per year, and accelerate development of most insect pests [12]. Lewis [13] showed that increase in temperature can change the gender ratios of some insect pests like thrips, hence affect reproduction rates and cause a greater number of thrips in dry season than in rain season. These might be the justifications for the high insect pests collected in dry than in rainy season.

Precipitation also has been listed as another influencing factor that impacts insect pest population and infestations on cultivated crops. Some research showed that some insects like white flies are sensitive to heavy rainfall [11]. Mutayoba and Ngaruko describe heavy rainfall as an important factor that can cause reduction of number of some insect pest infestation on cultivated crops by direct killing, removed from crops or for insect pest pupate in soil, flooding the soil may be effective control [6]. Other insect pests are not tolerant of drought, such as pea aphids (*Acyrthosiphon pisum*), hence their number increased in rainy season and decreased in dry season [14]. This concurred with the result obtained from this study (Table 1).

However, Sorenson's Coefficient between two seasons was 0.92, which means the two seasons had much overlap species. The closeness of entomofauna diversity reflects the communities being very similar and this is supported by fairly close similarity of diversity index values of Shannon winner diversity indices (H') that ranged from 3.57 to 3.25 and Simpson reciprocal indices (1/D) that ranged from 1.28 to 2.94 with exception of *Araneus sp.* The community comparison of species diversity and relative species abundance can be used to describe the state of succession and stability of individual species in the community.

The results of this study showed that the surveyed tomato fields in Meru District were dominated by a high number of entomofauna that constitute a crucial part of the agroecosystem. The abundance of Hemipteras and Lepidopterans was approximately 50% and 20%, respectively, of all collected entomofauna. The species in these two orders are tomato pests of economic importance. The rest of the orders had only one species contributing 10.3% (Diptera), 8.4% (Trombidiformes) and the remaining orders contributing 8.7% altogether.

The intensive farming and other field management malpractices are associated with increase in pests' abundance in agroecosystem in tomato fields at Meru District than natural enemies and other beneficial entomofauna that are more susceptible to broad spectra insecticides [15] (Table 1). The intensive farming is thought to enhance food availability of insect pests throughout the year by maintaining conducive microhabitats and hence, cause pests' build-up. Some researchers believe that the impact of affecting micro-habitat in the fields disrupts the whole agroecosystem in that particular field.

The disruption of agroecosystems can be observed in terms of insect behavior, distribution, development, survival, reproduction and population size [16]. The Margalef's diversity index (d) that ranged from 0.97 to 1.07 indicated little difference in the species richness of the entomofauna collected in three Wards of Meru District. The variation obtained between pests and their predators could be attributed to differences in the level of pollution or anthropogenic activities that occur in the agroecosystem in the fields under study [15]. Hence, any ecological imbalance arising from any anthropogenic activities could lead to severe alterations of some factors in agroecosystem and thus, may affect the environment and hence, richness of some species especially invasive species [17].

The Pielou's index (J) which measures evenness range from 1.73 to 0.17 with exception of two species *Chrysopa sp. and Araneus sp* suggests small value and differences of species evenness, which can be interpreted as low evenness of collected entomofauna. The results of this study showed that high single-order dominance may be imposed by land- based pollutants, caused by high pesticides utilization and from frequent anthropogenic activities like burning of plant wastes and use of broadspectrum pesticides. Similar observations were made by Belamkar and Jadesh about the impact of human activities on diversity of entomofauna [15].

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Farmers' knowledge in identifying entomofauna in tomato fields

The survey of local tomato farmers showed that most farmers could not correctly identify the pests that infested their tomato fields, as shown in table 2. Only 44.6% of all visited local tomato farmers were able to identify the insect pests in their fields. The percentage of local farmers who could correctly identify the collected insect pests based on the Ward was as follows: in Seelasing'isi Ward only 23.3% local farmers, in Akheri only 12.3% and only 8.6% of farmers in Kikwe Ward.

Out of all collected entomofauna, only 4 were commonly known by more than 50% of local farmers and included white flies, caterpillars, leaf hoppers and spiders as seen in table 2.

The cause of being unable to identify the insect pests was associated with low level of education that led to lack of interest in participating in trainings, search for consultation from agricultural extensionists and time for field survey as seen in fig. 1.

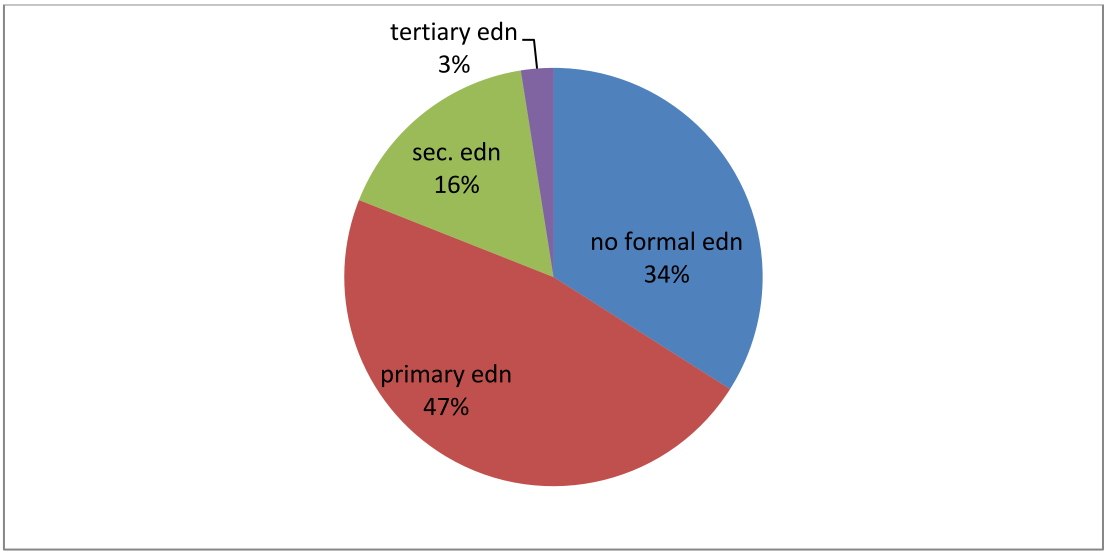

Figure 1: Education level of local tomato farmers in Meru District

The survey showed 34% of visited farmers did not obtain any formal education, 47% attended primary education, 16.5% attended secondary education and 2.5% obtained tertiary education. Out of 159 local farmers with formal education, 58% were from Seelasing'isi Ward, 28% from Akheri Ward and 14% from Kikwe Ward. Seelasing'isi Ward was leading with local farmers who were able to identify entomofauna in their fields, with high field management practice and high use of insecticides.

The survey showed that most local farmers with lower level of education did not attend any training in 2017/19 period, could not identify either the collected entomofauna is pests, beneficial insects or the natural enemies of pests. The low education farmers are mostly the ones who apply pest control malpractices, poor field management practices and mainly their decision for pest control and field management was inappropriate since it was based on experience, imitation and advice from others

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local farmers. The impact of inappropriate pest identification in the field was associated with poor establishment of pest management program, environmental pollution, disruption of the agroecosystem in the fields by killing beneficial and predator entomofauna [6].

The differences in ability to identify entomofauna varied significantly between these three Wards ($F_{0.05}$ (df, 31) = 5.501, p = 0.0094). Survey results (table 2) showed that the difference was due to the fact that most local farmers at Seelasing'isi are surrounded by different agriculture research institutes and have chances to participate in infield training and view demo-farms. Some local farmers can hire and cultivate in the research farm like Madira experimental farms 1, 2 and 3 where they get assistance from agricultural researchers and experts. These expose them to researchers, agricultural experts, demonstration farms and training programs compared to farmers in the other Wards. On the other hand, the survey showed that only 8.8 % of all visited farmers in Kikwe Ward, 23.8% in Akheri Ward and 40% in Seelasing'isi Ward did get exposure to extension service programs, demonstration farms and training programs at one of the institutions (HORTI-Tengeru, IITA, Rijkwan and AVRDC World Vegetable Centre) for the past 2 years (2017/18 and 2018/19).

One of the factors that restrict most farmers from participating in training and leading to inappropriate communication of instruction was found to be their level of education. The survey showed that the level of education of most local farmers was low (fig. 1), hence their decisions for pest control was based mostly on experience, imitation and advice from their peers, and other local farmers.

Farmers' knowledge on insect pest management methods

The survey revealed that farmers were able to identify several pest management methods including the use of chemical pesticides, botanical pesticides (as alternative to chemical pesticides), cultural practices such as crop rotation and field sanitation, use of tolerant and resistant accessions, use of biological control, physical barriers, pherohormones traps and Integrated Pest Management (IPM) as seen in the Table 3. In Seelasing'isi farmer use a variety of methods compared to other wards and had farmers who were well aware of pest management techniques. Participation of local farmers at Seelasing'isi to in-field trainings, consultation of experts in research institutions and demo-field was thought to justify the add up knowledge of local farmers in this ward than the others.

However, the assessment of farmer knowledge on pest management indicates that most farmers are conversant mainly with cultural practice and application of insecticides. These two methods were reported by all visited local farmers as the most frequently used methods for management of insect pests in the fields in all Wards. Although the field survey in Meru District revealed high insect pest infestation and disease build-up in some Wards more than others, the control methods observed in fields by all local farmers were mainly the same (Table 3). The analysis of control methods observed in fields among local tomato farmers in three Wards were not significantly different ($F_{0.05}$ (df, 29) =0.4703, p = 0.6209). The commonly used methods in all Wards include use of synthetic insecticides and cultural practices.

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The use of synthetic insecticides was the most and commonly applied control method in all Wards although the frequencies of application differed significantly ($F_{0.05}$ (df, 29) =63.23, p = 0.0001) from Ward to Ward. The overall pesticide application showed the mean frequency of pesticide in Seelasing'isi Ward to be 12 times, in Kikwe 7.5 times and lastly, Akheri had pesticide application frequency of only 5 times from transplant to harvests (90 days) (Fig.2). As the common frequencies of pesticides of outdoor production range of 4-5 from transplant to harvest [18].

Frequency of pesticide applications can be depicted in terms of environmental pollution that enhances agroecosystem disruption, increase in health risks to applicators, consumers and increased production expenses. With such high frequencies of pesticide applications, the number of pest infestations had still become prominent and this suggests development of pesticidal tolerance of dominant species as shown in previous studies that high use of insecticides can lead into pesticide tolerance [5].

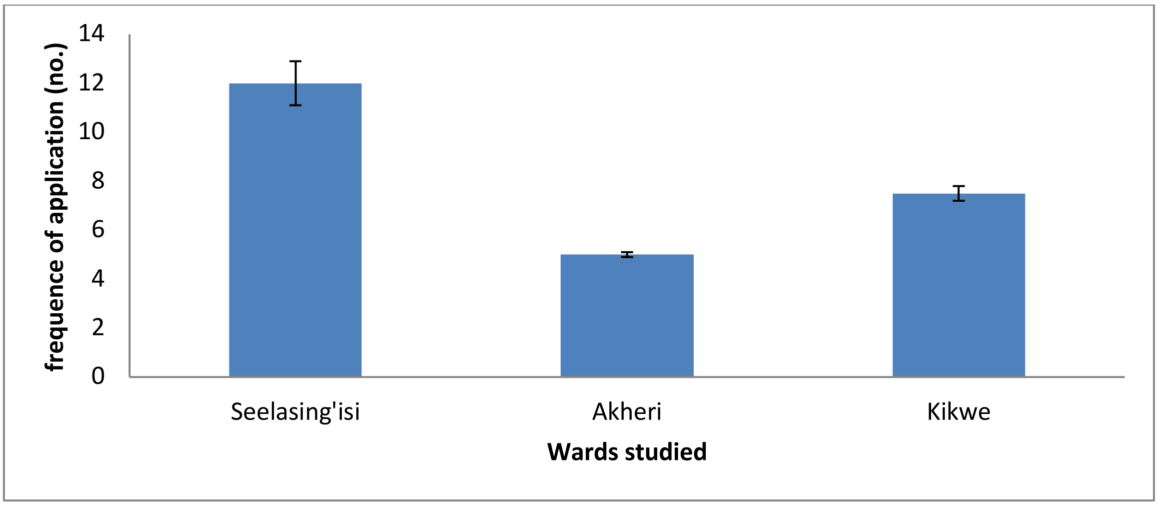

Figure 2: Frequency of pesticide application in local tomato fields across the wards over a period of 90 days

Effect of commonly utilized pesticides against dominant insect pests

The doubt for hypothesis that high pest infestation in tomato fields (Table 1) was a result of development of pesticidal tolerance by dominating insect pests was tested using commonly used insecticides (Tables 4, 5). Pesticides specific for management of whiteflies and tomato leaf miner were used at different dose concentrations to establish the minimum lethal effect on the pests. The results showed that, even the diluted concentrations of Snowbecco and Belt caused significant pest mortality ($t_{0.05}$ (df, 8) =3.23, p = 0.012; ($t_{0.05}$ (df, 8) =2.94, p = 0.0187)), respectively as summarized in Table 4.

The results show that Belt was 100% effective against tomato leaf miner larvae at recommended concentration of 200 µl/l and 68.5 % effective at dilute dosage of 100 µl/l. Whereas SnowBecco was 100% effective at recommended dosage of concentration of 400 µl/l and diluted dosage of 200 µl/l against whiteflies, hence may still be used according to the recommended dosage on labels as seen in Table 5. The problem of pests build-up within tomato fields may be associated with inappropriate application of synthetic insecticides, timing and selection of synthetic insecticides and reduction of natural enemies that are killed by most of broad spectrum insecticides as reported by Fernandez [19].

Inappropriate application of synthetic insecticides that were observed in the field survey included to the use of cocktail insecticides, use of expired insecticides, poorly stored insecticides by local farmers, poor methods of chemical application and open spaced farms that are owned by different farmers and that had different application schemes (Table 2). Some studies have shown that not all pesticides can be mixed to produce the best results due to antagonistic effect, while some can work best synergistically [20]. The study discovered that there had been no previous study to guiding local farmers on which synthetic chemicals or with botanicals that were compatible to work synergistically so that they may adapt to use them or that work antagonistically so they may avoid them.

Therefore, local farmers just mixed the insecticides by assuming that they might work best. The ignorance of timing, poor application and differential pest control of vicinity farmers also could result in escape and hiding places of insect pests that recover and bring pests' outbreak. When recovery occurs, the pests reappear in subsequent higher population levels than those of the previous one, and this might be what was seen in the field survey (Table 1).

Effects of the dominant insect pests on tomato yields

The tomato yields, in response to selected entomofauna, were tested at Tengeru Horticulture Research Farm which is within the vicinity of the study site. The parameters measured in marketable tomato yields included mean fruits number per plant, mean fruit size, and mean fruit weight per plant in three replications. The results showed that the impact of the selected insect pests *T. absoluta* and *B. tabaci* on tomato yield on various parameters were significantly different ($F_{0.05}$ (df, 8) =28.84, p = 0.0008) from the controlled treatments. The differences were observed in terms of mean number of marketable yields, mean of fruit sizes ($F_{0.05}$ (df, 8) =20.31, p = 0.0026) and mean tomato weight per plant ($F_{0.05}$ (df, 8) =28.4, p = 0.0009).

Comparative study of effect on tomato yields due to leaf miner and whiteflies has shown reduction of fruit number by 37.7% and 18.7%, respectively, fruit size by 22.4% and 14.2% and that of total fruit weight by 43.6% and 26.6%, respectively. The Tukey-Kramer Multiple Comparisons test showed that yields from the control field plots had significantly higher values for mean number of tomato fruits, mean size of fruits (in cm) and mean weight of harvestable fruits per plants (in kg) compared to pests infested field plots (Table 6). Different studies which support these findings showed that insect pests may cause generally yield loss of up to 75% by directly damaging the crop plant in high infestations fields and if insect pests and pathogen infest the field highly, may cause complete loss [21,22]. This phenomenon directly affects farmers' production, income and market due poor quantity and quality of tomato fruits.

CONCLUSION

This work concludes that agricultural fields are dominated by entomofauna most of which are pests of economic importance. Out of all collected entomofauna, 70% were dominated by the whiteflies (*Bemisia tabaci)* and tomato leaf miners (*Tuta absoluta*). The diversity of agroecosystem is thought to be the result of anthropogenic activities and field management malpractices that affect beneficial insects, natural enemies to balance the pests that cover only 4% of all collected entomofauna, also affect good micro and macro organisms in soil that are responsible for maintaining soil health. It is obvious that reducing use of insecticides maintains soil health, balance of beneficial entomofauna with field insect pests that contribute much to the ecological wellbeing and sustainable crop production.

From field survey of Meru District, the agroecosystem is considered to have diverse and numerous insect pests of agricultural importance with very few beneficial and natural enemies of pests as expected. Hence, this study promotes establishment of organic farming, sustainable agriculture that reduce applications of synthetic agricultural pesticides so as to raise the number of beneficial and natural enemies and revive soil health. The study also recommended assessment of entomofauna in various fields so as to establish foundation of entomofauna data base for future references.

From this study we strongly recommend increase in extension services and intensive training of local farmers on how to identify insect pests, better selection of pesticides, timing and application techniques and integrated pest management (IPM) that promote reduce use of synthetic pesticides on cultivated vegetables to create good environment that support natural enemies for sustainable cultivation. Also local farmer networks could be established to enhance platforms where most of the local farmers could get information on proper handling/management of their tomato farms.

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Table 1: Characteristics of entomofauna collected in local tomato fields in Meru District in 2018/2019

Order	**Family**	**Species identified**	**Total number of individuals**	**Dominance (%)**	**Simpson Reci. index**	**ShanonWinner index**	**Mergalef index**	**Pielous's index**
Hemiptera	Aleyrodidae	*Bemisia sp.*	366947	49.68	2.94	3.56	1.17	1.73
	Aphidae	*Apis sp.*						
	Pentatominae	Acrosternum sp.						
	Ciccidillidae	*Amrasa sp.*						
Lepidoptera	Gelechidae	*Tuta sp.*	141398	19.14	2.94	3.57	1.27	1.72
	Noctuidae	*Helicoverpa sp.*						
Coleoptera	Coccinelidae	*Epilachna sp.*	29205	3.95	2.78	3.52	1.48	1.7
Diptera	Agromyzidae	*Liriomyza sp.*	75805	10.26	2.85	3.55	1.36	1.72
Trombidiformes	Tetramydidae	*Tetranychus sp.*	61970	8.39	2.94	3.54	1.39	1.71
Thysanoptera	Thripidae	*Frankliniella sp.*	28162	3.81	2.94	3.56	1.37	1.73
Hymenoptera	Braconidae	*Cotesia sp.*	31704	4.29	2.27	3.25	2.07	1.57
Neuroptera	Chrysopinae	*Chrysopa sp.*	151	0.02	1.28	0.38	1.4	0.17
Araneae	Araneidae	*Araneus sp.*	3248	0.44	4.55	1.64	0.89	0.75
		Total	**738590**					

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Table 2: Insect pests identified by tomato local farmers (%) in Meru District

Insect pest	Name in Kiswahili	Seelasing'isi Ward %	Akheri Ward%	Kikwe Ward%
1. Whiteflies (*Bemisia tabaci*)	Inzi weupe	100	100	100
2. Tomato leaf miner (*Tuta absoluta*)	Kantangaze	55	33	20
3. Tomato aphid (*Apis gossypii*)	kimambo/kidukari	70	48	30
4. Caterpillars (*Helicoverpa armigera*)	Viwavi	95	50	43
5. Beetle (*Epilachna dodecastigma*)	mende kibiongo/mbawakawa	68	20	0
6. Leaf miner (*Liriomyza sativae*)	Chorachora	53	5	0
7. Spider mites (*Tetranychus utricae*)	utitiri mwekundu	48	20	0
8. Stink bugs (*Acrosternum hilare*)	mende mnuko	58	0	0
9. Thrips (*Frankliniella occidentalis*)	visiripi	35	5	0
10. Leaf hopper (*Amrasa biguttula*)	vipanzi wa mazao	88	48	35
11. Spiders (*Araneus diadematus*)	Buibui	100	78	58

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Table 3: Pest control methods as utilized by tomato local farmers (%) in three wards in Meru District in 2017/19

Method	Seela sing'isi Ward %	AkheriWard %	Kikwe Ward%
Synthetic pesticides	100	100	100
Botanical pesticides	73	0	0
Biological control	15	0	0
Cultural practices (crop rotation)	100	97	100
Field sanitation	100	100	92
Use of tolerant and resistant accessions	25	0	0
Integrated pest management	25	0	0
Pheromones	8	0	0
Insect traps	12	0	0
Physical barriers	9	0	0

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Table 4: Time series mortality of *Tuta absoluta* larvae using different concentration of Belt insecticides in Meru District

		Concentration level (µl/l)		
Time (Hrs)	**Control**	**Diluted**	**Recommended**	**Overdosage**
	C1 (0)	**C2 (100)**	**C3 (200)**	**C4(300)**
0	40	40	40	40
3	40	29	17	6
6	40	20	8	0
9	38	14	1	0
12	35	11	0	0
% cor. mort.	0	68.57143	100	100

C – concentration, µl/l- microliters per liter, %cor. mot- correction mortality

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Table 5: Time series mortality of *Bamisia tabaci* using SnowBecco insecticide at different concentration Meru District

	Concentration (µl/l)			
Time (Hrs)	**Control**	**Diluted**	**Recommended**	**Overdosage**
	C1 (0)	**C2 (200)**	**C3 (400)**	**C4(600)**
0	40	40	40	40
12	40	19	0	0
24	37	7	0	0
36	37	0	0	0
48	35	0	0	0
% cor. mortality	0	100	100	100

C – concentration, µl/l- microliters per liter, %cor. mot- correction mortality

Table 6: Mean marketable yield reduction caused by *Tuta absoluta* and *Bemisia* tabaci insect pests in local tomato fields in Meru District

SN	Treatment	Fruit no./plant	Fruit size (cm)	wt. /fruit (gm)
1	Control	11.93±2.2 A	16.33±1.8 A	1.49±0.3 A
2	*B. tabaci*	9.73±2.2 B	14.00±1.8 B	1.10±0.3 B
3	*T. absoluta*	7.43±2.2 C	12.67±1.8 B	0.84±0.3 B

The replicates with same latter show no significant difference caused by treatment within the same parameter, while those with different letters indicate significant difference caused by treatment within the same parameter

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