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Abundance and composition of cotton insect species in the western cotton growing area (WCGA) in Tanzania

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Abstract
Insect abundance and composition in the Western Cotton Growing area (WCGA) were investigated from November 2018 to April 2019. The aim was to investigate the cotton insect pest abundance in relation to crop phenological stages. The experiment was laid out as factorial in Randomized Completely Block Design with three replications in three locations. Data on abundance of insect was collected by counting insects on 36 randomly selected plants per location. The collected data were subjected to two-way Analysis of Variance and mean separated using Least Significant Difference ($LSD_{0.05}$) procedure. Results show that there were significant variations among locations and phenological phases. The location, Shanwa had higher number of aphids than other insect species during phase one while in later growing stages; Binza had highest number of insect. It is concluded that in all phenological phases of cotton, aphids and ants were the most dominant insect.

Keywords: cotton, insect pests, abundance, aphids, ants and beneficial insect

Introduction

Cotton (*Gossypium hirsutum* L.) is the most important natural fiber crop grown in the tropical and sub-tropical regions of the world [1]. The plant belongs to the genus Gossypium in the family Malvaceae [2]. It is cultivated as an annual shrub with broad three-lobed leaves and seeds in capsules or cotton bolls. Each seed is surrounded with white downy fibre, which is easily spun [3]. Before cotton's fluffy bolls emerge, the plant produces large white flowers, which attract a wide range of insects, including bees, flies, butterflies and beetles, which visit the flowers to collect nectar and pollen as food and act as pollinators, moving pollen between flowers. While other beneficial insects such as ladybird beetles, ants, ground beetles, syrphids, praying mantis, tinichid flies, spiders and fungal pathogen which are predators. Plants make its seeds by fertilization after union of pollen grains and ovaries. Some plants are self-pollinating but others need pollinators to help the process of pollination. This leads to increase (12%) in cross pollinated cotton production and 17% increase in number and weight of seeds, compared with self-pollinated cotton in both conventional and organic farming conditions [4, 5].

The major cotton pests, particularly in the WCGA, include *Helicoverpa armigera* (Hubner), *Aphis gossypii* (Glover) and *Dysdercus spp* (Herrich-Schaeffer) [6]. There are other pests but of minor significance such as stink bugs, thrips, whiteflies, spider mites and jassids. All these are insect pests of cotton, which cause seed cotton yield losses by up to 30-50% [3, 7, 9]. The incidence of cotton insect pests was on the increase regardless of increased insecticide doses. The abundance of insect pests is attributed to failure of farmers to follow manufacturer's guidance on the right dosage to use, in ability to diagnose the type and stage of the insect pests, stage of crop development and mixing insecticides [10, 11]. The current study provided information on cotton insect pests and their composition in Maswa district in Tanzania. A thorough understanding of cotton insect pest's abundance and species composition in relation with crop losses is fundamental for successful management.

Materials and Methods

Location and Duration

This study was conducted in Maswa District, which lies between 2^o 45′ and 3^o 15′S and 33^o 0′ and 34^o 1′ E and 1200 and 1300 m a, s. l... The experiment was conducted from November, 2018 to April, 2019.

Weather and soil patterns

Maswa district has a semi-arid climate with bimodal rainfall pattern of between 450 and 1000 mm, with an average of 750 mm. The average rainfall decreases from north to south and from west to east. The short rains start in mid-November and end in mid-January and the long rains start early in March and end in May. The average temperature is 26˚C. The topography of the district is characterized by flat, gently undulating plains covered with low sparse vegetation. The area is dominated by heavy black clay soils with areas of red loam and sandy soil. Large part of the district has hardly any vegetative cover and the soils fertility in the district range from medium to poor.

Experiment design and layout

A field experiment was planted in 15 November 2018 using UKM-08 seeds and laid out as factorial in Randomized completely block design (RCBD) with three replications as locations (i.e. Maswa Girls, Binza Secondary and Shanwa Primary school). In this study factor A was location while sub-factor was insect pest species. The sub-plots consisted of six rows each with 12 plants at spacing of 0.5 x 0.8 m, making it 3x6.8 m and while the main plot was 36 x 6.8 m resulting into a total of 244.8 m^2 area. The distance between sub-plots was 0.5 m equivalent to 36 plants within a total area of 246.84 m^2. All recommended agronomic practices for cotton were adhered to during the course of the experiment; such as farm yard manure (FYM) application at a rate of 10 t/ha during or just after land preparation in October, 125 kg NPK/ha applied six weeks after sowing. Four to five seeds were directly sown per hole at 2.5 cm depth, thinning and weeding were done manually three times during crop growth.

Data collected

Composition of insect pests

The number and type of all insects observed and collected were identified and counted using identification key, biology, and evidence of infestation and nature of damage by key of pests [12]. Scouting, observation and counting were done early in the morning starting from three weeks after cotton seedling growth. This was done based on the actual count of sucking insects from top, middle and bottom on three leaves of the selected plants [13]. During determination, six plants were selected at random in each sub-plot and labeled with plastic tags at weekly intervals. The mean and proportion of insect pest composition was calculated from different locations and phases.

Data analysis

Data collected were subjected to the ANOVA technique using SAS 9.3 software employing the following model:

$$Y_{ijk}=\mu+R_i+A_j+B_k+(AB)_{jk}+\dot{\varepsilon}_{ijk}$$

Where;

μ= the general mean, R_i= the effect of i^{th} level of factor (Replication), A_j = the effect of j^{th} level of factor (Main plot = location), B_k = effect of k^{th} level of factors B (Sub plot factor = insect pest), $(AB)_{jk}$= the interaction effect between factors A and B, and $\dot{\varepsilon}_{ijk}$= is the Experimental error (Residual error). Then, Least Significance Difference ($LSD_{0.05}$) was done as means separation.

Results

Various insect pest species of cotton at different cotton crop growth stages were observed (Table 1). It was clear that there were two categories of insects in the study locations, *viz*., insect pests and beneficial insects. During cotton seedling emergence to First Square, the crop was attacked by aphids, white flies, jassids and thrips while beneficial insects were ladybird beetles, ants, syrhpids, praying mantis and spiders. From First Square to Boll formation there were aphids, the American bollworm, cotton stainers, jassids, white flies and thrips as insect pests while beneficial insect species were ladybird beetles, ants, ground beetles, syrhpids, praying mantis, tinichid flies, spiders and fungal pathogen. From boll formation to boll splitting, insect pest species recorded were aphids, American bollworm, jassids, cotton stainers, and mealy bugs while ladybird beetles, ground beetles, ants, syrphids, praying mantis, tinichid flies, spiders, fungal pathogen, green lacewings and damsel bugs were beneficial insects.

In this study the dominant pest species were Aphids among locations and phases (Tables 2). Significant differences across locations at different phases were observed ($F_{2, 261}$ = 13.74, p < 0.0001) for phase one, ($F_{2, 362}$ = 10.65, p < 0.0001) for phase two and ($F_{2, 426}$ = 147.12, p < 0.0001) for three.

In phase one, Shanwa had higher number of species than Biza and Maswa (Table 3) while in phase two and three, Binza had the highest number of species compared to Maswa and Shanwa (Table 3). Significant differences between species in different phases were observed ($F_{7, 261}$ = 80.53, p < 0.0001), ($F_{10, 362}$ = 201.85, p < 0.0001) and ($F_{12, 426}$ = 232.04, p < 0.0001) for phases one, two and three, respectively. In all the three phases, Aphids were the most dominant insect pests followed by Ants. Other insect `species contributed less (Table 4).

Table 1: Observed cotton insect pests and beneficial insects

Cotton growth stage	Pest insects	Beneficial insects
Seedling emergence to first square	Aphids, Jassids Whiteflies and Thrips	Ladybird beetles, Ants, Syrphids, Praying mantis and Spiders
Square formation to bolls formation	Aphids, American bollworm, Jassids, Cotton stainer, Whiteflies and Thrips	Ladybird beetles, Ground beetles, Ants, Syrphids. Praying Mantis, Tinichid flies, Spiders and Fungal pathogen
Bolls formation to bolls splitting	American bollworm, Aphids, Mealy bugs, Cotton stainer and Jassids,	Ladybird beetles, Ground beetles, Ants, Syrphids (Hover flies), Praying matis, Tinichid flies, Spiders, Fungal pathogen, Green lacewings, Damsel bugs

Table 2: Mean insect pests abundance and composition per plant among locations in all three phases. Numbers in parentheses are percent contribution of each insect species in community

Species	Locations								
	Shanwa			Maswa girls			Binza Secondary School		
	Phase one	Phase two	Phase three	Phase one	Phase two	Phase three	Phase one	Phase two	Phase three
Aphids (*Aphis gossypii*)	1371(86.4)	1138(93.06)	197.4(76.10)	536(81.6)	1745(94.72)	218.9(80.80)	559.5(67.5)	1973(76.21)	1235(88.95)
Jassids (*Empoasca fascialis*)	98.5(6.2)	27.7(2.27)	3.3(1.27)	2 (0.3)	3.99(0.22)	0.33(0.12)	1 (0.1)	1.67(0.06)	0.33(0.03)
Whiteflies (*Bemisia tabaci*)	16.5 (1.1)	9.32(0.67)	0(0.0)	0 (0.0)	0.67(0.04)	0(0.0)	0 (0.0)	0(0.0)	0(0.0)

Ants (*Oecophylla* spp)	33 (2.1)	15.6(1.28)	1.4(40.56)	111 (16.9)	10.7(0.58)	0.33(0.12)	267(32.2)	595(22.98)	108(7.78)
Ladybird beetle (*Hippodamia* spp)	16 (1.0)	8.3(0.68)	5.3(2.04)	5 (0.8)	4.66(0.25)	5.74(2.12)	2 (0.24)	1.32(0.05)	2.64(0.19)
Syrphids/hover flies (*Eupeodes confrater*)	21 (1.32)	6.33(0.52)	10.63(4.10)	3 (0.45)	3.32(0.18)	13.66(5.04)	0 (0.0)	7.65(0.30)	18.9(1.36)
Praying mantis (*Sphodromantis viridis*)	26 (1.64)	0(0.0)	0(0.0)	0 (0.0)	0(0.0)	0.11(0.04)	0 (0.0)	1.65(0.06)	0.33(0.02)
Spider (*Chiracanthium inclusum*)	4 (0.26)	0(0.0)	0.11(0.04)	0 (0.0)	0(0.0)	0(0.0)	0 (0.0)	2(0.08)	0.33(0.02)
Thrips (*Thrips tabaci*)	0(0.0)	2.34(0.19)	0(0.0)	0(0.0)	2 (0.11)	0(0.0)	00.0	0(0.0)	0(0.0)
American bollworm (*H. armigera*)	0(0.0)	14.3(1.17)	5.41(2.09)	0(0.0)	25(1.36)	8.96(3.31)	0(0.0)	6.66(0.26)	4.08(0.29)
Cottonstainer (*Dysdercus sidae*)	0(0.0)	1(0.08)	5.98(2.28)	0(0.0)	3(0.16)	0.99(0.37)	0(0.0)	0(0.0)	0.11(0.01)
Mealy bugs (*Phenacoccus solenopsis*)	0(0.0)	0(0.0)	4.99(1.92)	0(0.0)	00.0	0(0.0)	0(0.0)	0(0.0)	9.34(0.67)
Fungal pathogen (*Neozygites fresenii)*	0(0.0)	0(0.0)	24.6(5.27)	0(0.0)	00.0	21.56(7.96)	0(0.0)	0(0.0)	8.98(0.65)
Green lacewing (*Chrysopa* spp.)	0(0.0)	0(0.0)	0.22(0.08)	0(0.0)	00.0	0(0.0)	0(0.0)	0(0.0)	0.33(0.02)
Damsel bugs (*Nabis* spp.)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	00.0	0.33(0.12)	0(0.0)	0(0.0)	0(0.0)
	1586	1222.89	259.38	657	1842.24	270.91	829.5	2588.95	1388.37

Table 3: Effect of location and growth stage of cotton on insect species abundance

Location	Phase one	Phase two	Phase three
Shanwa	8.13^{a}	4.70^{b}	0.46^{b}
Binza	4.32^{b}	8.58^{a}	4.12^{a}
Maswa	2.49^{b}	5.28^{b}	0.59^{b}
$LSD_{0.05}$	2.16	1.78	0.48

*Means with same latter(s) within columns and rows are not significantly differently

Table 4: Mean number of insect species in different phases of cotton growth

Species	Phase one	Phase two	Phase three
Aphids (*Aphis gossypii* Glover)	32.8^{a}	58.25^{a}	19.76^{a}
Ants (*Oecophylla spp.)*	5.18^{b}	8.36^{b}	1.16^{b}
Jassids *Empoasca fascialis* (Dist.)	0.75^{c}	0.24^{c}	0.06^{c}
Praying mantis *Sphodromantis viridis* **(**Forskal)	0.50^{c}	0.02^{c}	0.01^{c}
Syrphids *Eupeodes confrater* (Wiedemann)	0.19^{c}	0.14^{c}	0.35^{bc}
Ladybird beetle *Coccinella septempunctata* (Linnaeus)	0.17^{c}	0.34^{c}	0.16^{c}
White flies Bemisia *tabaci* (Genn.)	0.14^{c}	0.12^{c}	0^{c}
Spider (*Chiracanthium inclusum*)	0.11^{c}	0.07^{c}	0.00^{c}
American bollworm *Helicoverpa armigera* (Hubner)	0^{c}	0.46^{c}	0.21^{bc}
Thrips *Thrips tabaci (*Lindeman**)**	0^{c}	0.05^{c}	0^{c}
Cotton stainer (*Dysdercus sidae* (Herrich-Schaeffer)	0^{c}	0.02^{c}	0.68^{c}
Fungal pathogen (*Neozygites fresenii* Nowakowski*)*	0^{c}	0^{c}	0.57^{bc}
Mealy bugs *Phenacoccus solenopsis* (Tinsley).	0^{c}	0^{c}	0.03^{c}
Damsel bugs (*Nabis spp*.)	0^{c}	0^{c}	0.01^{c}
Green lacewings *Chrysoperla carnea (*Stephens)	0^{c}	0^{c}	0.01^{c}
P-Value	<0.0001	<0.0001	<0.0001

*Means with same latter(s) within columns are not significantly differently

Discussion

The results showed significant variations among the three different locations in terms of abundance and composition in the three cotton growth phases. The difference could be attributed to variation in the start of seasonal rainfall, which led to differences in crop growth among these locations. Shanwa, for example, received more rainfall than the other locations, which enabled seedlings to emerge earlier than Binza and Maswa. The latter locations did not receive enough rainfall to allow commencement of seed germination [3, 14, 15]. During this period, cotton leaves were juicy and succulents, which offered maximum food and habitat for aphids and other sucking insect pests. This condition caused reproduction to be faster among aphids than the other insect pest species [16].

In later growing stages, Binza had higher insect pest species abundance, which could be attributed to the agricultural practices in this area being surrounded by trees, which create micro climate and provides shield effects leading to increase in relative humidity of the leaf [14, 15, 17, 19]. In addition, in Binza village, pesticides use has been reported to be more frequent, which can cause insect resistance. Pesticides resistance appears to correlate with cultivation period while using pyrethroid insecticides for insect pest management and causes to gene inherent of resistance to next generation [3, 20, 25].

[26] Reported that indiscriminate application of insecticides, instead of controlling cotton aphid populations, it increases their reproductive potential through influences cotton secondary metabolites and make the plant more attractive to aphid pests [27, 28] also can due to lower activity of Pathogenesis Related (PR) of cotton plants [28, 29, 30].

Female cotton aphids are able to reproduce both with and without mating. When environmental conditions are favorable, females that haven't mated will give birth to live nymphs [17, 21]. However, insects with high reproductive potential have higher chances of developing resistance to insecticides compared to those of low potential. As it applies to cotton aphid, their high reproductive potential complements their capacity for resurgence after application of insecticide [31, 24].

In the current study, ants were major insect although it is beneficial insect in a cotton cropping system. When cotton leaves were juicy and succulent, the predators' populations were low to consume aphids while number of ants was high to support aphids to reproduce fast [8, 32, 34, 8]. Populations were more severe due to low stand density of cotton plants, which was caused by late and unreliable rainfall in some study locations [25]. The low stand of cotton plants resulted from increased mortality of developing American boll worm and boll weevils by direct exposure to or of enhancing the effectiveness of indigenous natural enemies. Ants are important predators of the American bollworm by preying on caterpillars leads to low population densities when compare to Shanwa and Maswa girl where the number of ants was low [35, 36].

Similarly, Binza had higher number of ants than other beneficial insect species as compared to other locations, which attracted honeydew as a predictable, renewable food resource and, consequently, accompany honeydew-producing aphid species, p protecting them from predators and parasitoids [37, 40]. Aphids could alter their feeding behavior and the composition of their honeydew through increasing the concentrations of amino acids at the expense of their own growth and fecundity [38, 41]. Presence of tending ants and persistent honeydew removal by ants allows aphids to attain maximal feeding rates, improving nutrient uptake and assimilation, without the threat of host plant contamination. Ants can further benefit aphids by removing sticky honeydew and fungal-infected aphid cadavers, which would otherwise support fungal growth, leading to reduced aphid survival [40-42]. Therefore, ants had an impact on consuming large numbers of pest insects, instead of disturbing pests during feeding and oviposition, and increasing soil quality and nutrients [43].

Generally, at phase three of cotton crop growth stages, some of the insect pests disappeared; such as thrips and white flies while mealy bugs appeared on cotton crop. Disappearance of thrips and white flies was common due to early-season pests of cotton and its peak numbers usually occurs early in the season and during high humidity periods [12, 44]. This situation could be attributed by buildup of various beneficial insects in previous studies, which attack insect pest species and heavy rainfall that occurred during long rains season caused undesirable cool weather [8, 24, 36, 45, 49].

Mealy bugs as secondary pests appeared after application of pyrethroid insecticide at phase three, which killed most of the beneficial insects that parasitized on them [46-47, 49]. Previous studies have reported that use of pesticides to solve pest problems promised short-run economic benefit but instead led farmers onto path dependency that increases system complexity by inducing pest outbreaks that may cause crop losses and increase costs [50]. Heavy infestation of cotton mealy bugs may have resulted from the absence of natural enemies which may be caused by indiscriminate application of insecticides, high reproductive capacities and multiple generations per year, are potentially capable of becoming resistant to insecticides on consistent exposures [51]. Mealy bugs are known to bribe ants with their sugary secretion (honeydew) and in return ants help in spreading mealy bugs and provide protection from predator ladybird beetle, parasites and other natural enemies as adaptive features for survive. Ant facilitates population growth of mealy bugs, not only by reducing predation and parasitism from natural enemies, but also by reducing the risk of fungal infection [52-53].

Conclusion

In conclusion, the results from the present study showed that aphids was the most dominant insect pest in all growing stages of cotton, followed by ants, which were beneficial insects. It could be concluded that at later crop growth stages, Mealy burg abundance increased. It is therefore recommended from this study that rotation of insecticide application throughout the cotton growth stages would be important due to differences in insect pest species build up.

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