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Population Abundance of *Thrips tabaci* Lindeman and its Associated Predators on Some Crops at Shendi, River Nile State, Sudan

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Abstract* - Onion thrips (Thrips tabaci) (Thysanoptera: Thripidae) is a serious pest of onion and other crops in Sudan. Nevertheless, information about T. tabaci pertinent to different habitats in the country is incomplete, especially with regard to agro-ecological aspects. This research aimed to investigate the seasonality of T. tabaci and its main associated predators at Shendi area. These were fulfilled through field surveys on three major host plants (onion, rocket and tomato) during 2011/12 season at three locations, besides a field experiment on onion crop during 2012/13 season to validate surveys results. Moreover, the populations of T. tabaci adult and nymphs recorded from the field experiment were compared at monthly and seasonal levels. Accordingly, T. tabaci showed its peak levels on all crops (54-80% infested plants) during March, coinciding with an increase in temperature and a decrease in relative humidity at the end of winter season. Onion and rocket crops showed significantly higher percentages of infested plants than tomato. Adult thrips were significantly higher than nymphs equally at the first month (November) and through the second half (February-April) of the season. This proved that the peak reproduction period of the pest is highly confined to the succulent early stage of onion growth between November and January. Concerning predators, the green lacewing (Chrysoperla carnea) was the most abundant species, followed by the 11-spotted ladybird (Coccinella undecimpunctata). They peaked late in winter season (March-April), synchronizing with that of onion thrips. Further studies are needed on cultural practices to escape T. tabaci attack, particularly during the first half of crop growth, and to enhance natural control of thrips.

***Keywords:* Onion thrips, seasonality, host plants, natural enemies.**

I. INTRODUCTION

Onion thrips or cotton thrips (*Thrips tabaci* L.) is a polyphagous pest of various hosts among different plant families including, Amaryllidaceae, Malvaceae, Cucurbitaceae, Solanaceae and others. It particularly represents a major constrain to onion (*Allium cepa* L.) production as preferable host. The species is of cosmopolitan importance, which occurs in many parts of the tropics and subtropics in the Old and New Worlds, and even in temperate regions [10, 25, 33, 42, 47]. However, in colder climates, it often occurs in greenhouses [47]. In the Sudan, the onion thrips is abundant in most regions, including e.g., Kordofan, Khartoum, Kassala, Blue Nile, Sennar, Gezira, Darfur, Northern and River Nile States [2, 6, 25, 32].

Thrips tabaci prefers to feed on young plants and young leaves of its hosts, depletes plant nutrients, causes oviposition scars on leaves and fruits, and acts as a vector of plant diseases such as the Iris yellow spot virus in the family Bunyaviridae and genus Tospovirus [47]. Moreover, the short developmental period of *T. tabaci* coupled with ability to give numerous generations on multiple host plants [32] may indicate why this pest receives world attention. Available literature shows that several climatic and ecological aspects contribute to pest status of *T. tabaci* [12, 18, 26, 31], which can be exploited in its management based on research findings. Accordingly, *T. tabaci* may leads to variable yield losses on onion or other crops depending on different factors [6, 26, 42]. However, an average yield loss of more than 39% is reported for onion from central Sudan [26].

Reforms of certain cultural practices as well as employment of biological control through natural enemies seem to be potent in alleviating pest problems without adverse effects on the environment and non-target organisms in agricultural fields. Sowing (or transplanting) date, spacing, irrigation frequency, intercropping, mulching, fertilizers and soil tillage are among prominent examples of cultural means that can be adapted in ways to pose negative effects on thrips buildup [17, 19, 24, 26, 50]. Such measures still lacking complete appraisal in different habitats of the country. Similarly, natural enemies including predatory insects are important elements in combating thrips damage [30, 41]. Several predators are known to be associated with *T. tabaci* and other pests in Sudan and elsewhere. These may include, *Chrysoperla carnea* (Stephens), *Coccinella undecimpunctata* L., *Hippodamia variegata* Goeze, *Aelothrips* spp., *Orius* spp., and others [21, 31, 32, 40]. However, meager research is found regarding indigenous bio-agents, and even no data is encountered regarding the study area. Therefore, research gaps are found as with respect to evaluation of the aforementioned agronomical and environmental factors, which should be carefully addressed as perquisite steps for thrips management.

Since broad-spectrum insecticides is the main tool adopted for thrips control [1], the search for sustainable environmentally sound management practices based on indigenous knowledge is urgently required. Hence, the current field works aimed to trace the seasonal abundance of *T. tabaci* and its main associated predators at Shendi area, River Nile State, as a step towards fulfilling such goals.

II. MATERIALS AND METHODS

Shendi is an agricultural area in the River Nile State, where pump irrigation is used to grow different field and horticultural crops. Uncultivated virgin and poor lands are also found at different locations, where some natural vegetation (trees, shrubs, weeds) are growing. This seems to enrich the biodiversity in the area, which ultimately interferes with abundances of agricultural pests and natural enemies.

The current study consisted of field surveys, and a field experiment dealt with seasonal abundances of onion thrips (*T. tabaci*) and its major predators on three host plants at Shendi area (latitude 16° 40`N: longitude 33° 33`E), River Nile State. The monthly mean temperatures, relative humidity and rainfalls during the study period (2011-2013), were obtained from the meteorological station of Shendi. Research activities to fulfill the stated objectives were conducted, as explained below.

1. Field surveys

Field surveys were conducted on farmer fields at three locations (viz., Al-shqalwa, Moyes and Al-misektab) in Shendi area, and repeated every 10 days during winter cropping period (November 2011-April 2012). Three crops known as hosts for *T. tabaci*, viz. onion (*Allium cepa* L.), rocket (*Eruca sativa* L.) and tomato (*Solanum lycopersicum* L.), were surveyed. From each location, three counting fields (replicates) untreated by chemical insecticides were chosen randomly for each crop, where three plots were investigated for thrips infestation and counts of predators. Hence, the percentage of infested plants/ 10 randomly selected plants/ plot were recorded for each crop. The numbers of associated predators (encountered stages) were concurrently counted.

Data of infested plants were statistically compared among the different hosts. Similarly, the numbers of different predators were statistically compared among the different hosts, and within each host. Analysis was based on a Randomized Complete Block (RCB) design, and means separation through an LSD test.

2. Onion field experiment

For validating surveys results, a field experiment was executed on onion crop where several parameters (included those treated in field surveys) were tackled. It was aimed to trace the seasonal infestation levels (% infested plants) by onion thrips, and to compare the populations of adult and nymphal stages of thrips on the crop at monthly and seasonal bases, as well as to study the seasonal trends of the detected predators. The experiment was conducted at Al-shqalwa area during winter season 2012/13. Onion was planted in the nursery on 21/9/2012 and transplanted to the field on 10/11/2012, where three replications were applied. The plot size was 4x5 m^2, which consisted of five rows. The spacing was 70 cm between rows, and 15 cm between plants. Three lines were planted per ridge. Irrigation and fertilization scheduling was done as recommended by the Agricultural Research Corporation. Stomp (pendimethalin) was sprayed at transplanting for weed control, and supported by hand weeding when necessary. For insects' counts, ten plants were randomly chosen and inspected per each plot. The counts of thrips damage (plus adults and nymphs counts) as well as numbers of predators were done at 10 days intervals. Data were analyzed based on an RCB design, followed by means separation via an LSD test, whereas Student T- test was used for adult-nymphs comparison.

III. RESULTS

1. Climatic conditions at Shendi area

Winter season (November-February) showed relatively lower temperatures (25.16±0.64°C) than summer (March-June) and autumn (July-October) seasons (32.38±0.39°C) in the study area. However, the latter season reflected relatively the highest humidity range (31-54% R.H.), while summer showed the lowest. Low rainfall (7 - 44 mm) was recorded during autumn 2012, which showed relatively higher humidity level. The lowest temperatures in winter seemed to conserve some relative humidity compared to the dry summer season (Fig. 1).

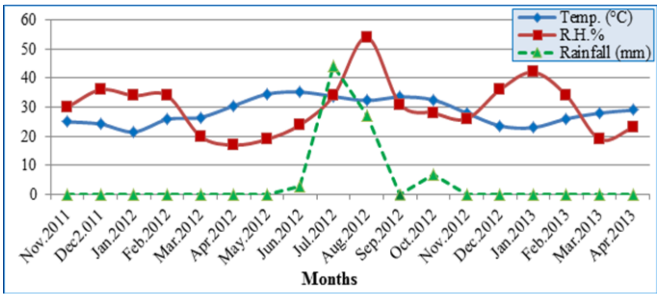

Figure 1. Mean monthly temperature (°C), relative humidity (R.H. %) and rainfall (mm), during the study period (2011-2013) at Shendi. (Data from meteorological station of Shendi)

2. Survey results

2.1. Infestation levels by onion thrips

Results of infestation levels by *T. tabaci*, among the three surveyed host plants (onion, rocket and tomato), are shown in table 1. The mean seasonal percentages of infested plants were significantly higher in onion (40.7±5.0% infested plants) and rocket (40.9±7.5%) crops than in tomato crop (31.9±4.8%). The pest showed relatively low infestation levels on all crops at the onset (November) of winter season, then progressively expanding its buildup distribution to attain peak infestations towards the end of the season in March, but a sharp drop occurred thereafter at the cropping end. The highest buildup of *T. tabaci* reported during March was coinciding with increasing temperature and declining relative humidity (Fig. 1), whereas the final drop of infestation levels in April came in correspondence with crops maturity and plant withering late in the season. However, rocket crop appeared to reflect rapid infestation rates compared to the other two crops, though, there were no significant differences between rocket and onion crops in most counts regarding infestation levels.

Table 1. Comparison of plants infested (%) by *Thrips tabaci* among the three surveyed crops at Shendi area, November 2011-April 2012.

Crops	Monthly mean (±S.E.) percentages of infested plants						Seasonal mean
	Nov.2011	Dec.2011	Jan.2012	Feb.2012	Mar.2012	Apr.2012	
Onion	10.0±1.9[a]	26.7±6.9[ab]	53.3±08.4[a]	62.2±6.8[b]	77.8±11.8[a]	14.4±4.8[a]	40.7±5.0[a]
Rocket	04.5±2.2[b]	22.2±4.9[b]	57.8±19.3[a]	75.6±9.9[a]	80.0±08.4[a]	05.5±4.0[a]	40.9±7.5[a]
Tomato	04.4±2.9[b]	31.1±4.9[a]	40.0±05.1[a]	48.9±4.9[c]	54.4±14.2[b]	12.2±2.9[a]	31.9±4.8[b]
C.V%	28.1	10.2	25.6	07.2	11.3	48.6	08.8
LSD (0.05)	04.0	06.2	29.2	10.2	18.1	11.8	07.6

* Means followed by the same letter(s), in each column, are not significantly different according to the LSD test.

2.2. Population trends of major predators

Four predatory insects were counted on the three surveyed crops during 2011/12 winter season, at Shendi area. They include, the green lacewing (*Chrysoperla carnea* Stephens) (Neuroptera: Chrysopidae), the eleven-spotted ladybird (*Coccinella undecimpunctata* L.) and the variegated ladybird (*Hippodamia variegata* Goeze) (Coleoptera: Coccinellidae), and the syrphid fly (*Xanthogramma aegyptium* Wied.) (Diptera: Syrphidae). The survey results for these predators were presented in table 2.

It is clear that the seasonal counts of *C. carnea* revealed significantly higher numbers (18.0±1.1) on onion than on the other two crops, while the lower being recorded on tomato (8.3±1.1). The peak populations of *C. carnea* on all crops were recorded during March, though it was extended up to the April on onion crop. Similarly, the seasonal numbers of *C. undecimpunctata* was significantly higher on onion crop (10.9±0.7 insects), than on rocket and tomato crops. However, the trend of this predator appeared to increase remarkably towards the end of the season (March – April), showing its peak on two crops in April, except for tomato in March (Table 2). The population densities of *X. aegyptium* larvae also appeared relatively late in the season, just from January onwards (Table 2). Contrarily, *C. carnea* was dominant since the first month (November) of the cropping season, while *C. undecimpunctata* appeared in December. However, the ranking of crops also put onion on the top as the most attractive host plant for syrphid larvae (5.7±0.2), but without significant differences from rocket and tomato. The peak populations of syrphid larvae on onion and tomato crops were recorded in March, whereas that for rocket occurred earlier in February. In general, syrphid populations were relatively lower than the other two predators on all crops (Table 2).

The comparison of population levels of the studied predators within each of the three crops (Table 3), confirmed the above mentioned results. Therefore, onion surveys showed that *C. carnea* was the highest predator throughout the season (18.0±1.1), followed by *C. undecimpunctata*, and lastly *X. aegyptium* (5.7±0.2). The two former predators revealed their peak densities in April, while *X. aegyptium* though appeared late in the season it peaked first (in March). More or less similar trends of the three predators were recognized on rocket, but relatively low counts were recorded in the latter crop (Table 3). Hence, *C. carnea* was the most abundant (10.4±0.7), followed by *C. undecimpunctata*, and lastly *X. aegyptium* (05.2±0.2). The first two predators revealed their peak levels in March and April, respectively, while *X. aegyptium* also peaked earlier (February) than the other species. On tomato, the ranking of the three predators put *C. carnea* in the top and *X. aegyptium* in the last as the lowest predator, with significant differences between them. All the species showed their peak populations in March (Table 3).

Table 2. Counts of three predators associated with *Thrips tabaci* and their comparison among the three surveyed crops at Shendi area, November 2011-April 2012.

Predator / Crops	**Monthly mean (±S.E.)/ 10 plants**						**Seasonal mean**
	Nov.2011	**Dec.2011**	**Jan.2012**	**Feb.2012**	**Mar.2012**	**Apr.2012**	
***Chrysoperla carnea*:**							
Onion	04.5±2.2^{a}	05.6±1.1^{a}	12.2±1.1^{a}	15.6±2.9^{a}	34.5±2.2^{a}	35.6±5.6^{a}	18.0±1.1^{a}
Rocket	01.1±1.1^{a}	04.4±1.1^{a}	10.0±3.3^{a}	13.3±1.9^{a}	21.1±1.1^{a}	12.2±4.0^{b}	10.4±0.7^{b}
Tomato	00.0±0.0^{a}	00.0±0.0^{b}	10.0±0.0^{a}	11.1±1.1^{a}	26.7±6.9^{a}	02.2±2.2^{b}	08.3±1.1^{b}
C.V%	120.1	41.6	30.1	27.0	26.1	48.3	12.9
LSD (0.05)	05.0	03.1	07.3	08.1	16.2	18.3	03.6
Coccinella undecimpunctata:							
Onion	00.0±0.0^{a}	04.4±2.9^{a}	06.7±0.0^{a}	07.8±1.1^{a}	14.4±1.1^{a}	32.2±2.2^{a}	10.9±0.7^{a}
Rocket	00.0±0.0^{a}	01.1±1.1^{a}	03.3±3.3^{a}	06.7±1.9^{a}	12.2±2.2^{a}	21.1±2.2^{b}	07.4±1.6^{b}
Tomato	00.0±0.0^{a}	04.5±2.2^{a}	08.9±1.1^{a}	03.3±0.0^{a}	13.3±5.1^{a}	10.0±1.9^{c}	06.7±0.8^{b}
C.V%	00.0	91.5	51.3	37.5	38.2	20.3	01.9
LSD (0.05)	00.0	06.9	07.3	05.0	11.5	09.7	02.1
Xanthogramma aegyptium:							
Onion	00.0±0.0^{a}	00.0±0.0^{a}	10.0±3.3^{a}	10.0±0.0^{a}	11.1±1.1^{a}	03.3±3.3^{a}	05.7±0.2^{a}
Rocket	00.0±0.0^{a}	00.0±0.0^{a}	04.4±2.9^{a}	12.2±1.1^{a}	10.0±1.9^{a}	04.5±2.2^{a}	05.2±0.2^{a}
Tomato	00.0±0.0^{a}	00.0±0.0^{a}	00.0±0.0^{a}	02.2±2.2^{b}	11.1±4.9^{a}	10.0±0.0^{a}	03.9±1.2^{a}
C.V%	00.0	00.0	112.3	27.4	45.2	81.8	24.7
LSD (0.05)	00.0	00.0	12.2	05.1	11.0	11.0	02.8

* Means followed by the same letter, in each column for each predator, are not significantly different according to the LSD test.

Table 3. Counts of predators associated with *Thrips tabaci* and their intra-crop comparison during field surveys at Shendi area, November 2011-April 2012.

Crops/ Predators	**Monthly mean (±S.E.)/ 10 plants**						**Seasonal mean**
	Nov.2011	**Dec.2011**	**Jan.2012**	**Feb.2012**	**Mar.2012**	**Apr.2012**	
On onion:							
Chrysoperla carnea	04.5±2.2^{a}	05.6±1.1^{a}	12.2±1.1^{a}	15.6±2.9^{a}	34.5±2.2^{a}	35.6±5.6^{a}	18.0±1.1^{a}
Coccinella undecimpunctata	00.0±0.0^{a}	04.4±2.9^{a}	06.7±0.0^{a}	07.8±1.1^{a}	14.4±1.1^{b}	32.2±2.2^{a}	10.9±0.7^{b}
Xanthogramma aegyptium	00.0±0.0^{a}	00.0±0.0^{a}	10.0±3.3^{a}	10.0±0.0^{a}	11.1±1.1^{b}	03.3±3.3^{b}	05.7±0.2^{c}
C.V%	150.0	81.8	39.1	32.3	09.7	29.1	09.7
LSD (0.05)	05.1	06.2	08.5	08.1	04.4	15.6	02.6
On rocket:							
Chrysoperla carnea	01.1±1.1^{a}	04.4±1.1^{a}	10.0±3.3^{a}	13.3±1.7^{a}	21.1±1.1^{a}	12.2±4.0^{ab}	10.4±0.7^{a}
Coccinella undecimpunctata	00.0±0.0^{a}	01.1±1.1^{b}	03.3±3.3^{a}	06.7±1.9^{a}	12.2±2.2^{b}	21.1±2.2^{a}	07.4±1.6^{ab}
Xanthogramma aegyptium	00.0±0.0^{a}	00.0±0.0^{b}	04.4±2.9^{a}	12.2±1.1^{a}	10.0±1.9^{b}	04.5±2.2^{b}	05.2±0.2^{b}
C.V%	300.0	60.6	99.0	32.8	24.8	49.0	24.6
LSD (0.05)	02.5	02.5	13.3	08.0	08.1	14.0	4.3
On tomato:							
Chrysoperla carnea	00.0±0.0^{a}	00.0±0.0^{a}	10.0±0.0^{a}	11.1±1.1^{a}	26.7±6.9^{a}	02.2±2.2^{b}	08.3±1.1^{a}
Coccinella undecimpunctata	00.0±0.0^{a}	04.5±2.2^{a}	08.9±1.1^{a}	03.3±0.0^{b}	13.3±5.1^{b}	10.0±1.9^{a}	06.7±0.8^{b}
Xanthogramma aegyptium	00.0±0.0^{a}	00.0±0.0^{a}	00.0±0.0^{b}	02.2±2.2^{b}	11.1±4.8^{b}	10.0±0.0^{a}	03.9±1.2^{c}
C.V%	00.0	150.0	17.5	34.9	20.6	30.0	06.3
LSD (0.05)	00.0	05.1	02.5	04.4	07.9	05.0	00.9

* Means followed by the same letter, in each column for each crop, are not significantly different according to the LSD test.

Table 4. Comparisons between numbers of adults and nymphs of *Thrips tabaci* in an onion field experiment at Shendi, November 2012-April 2013.

Pest stage	**Monthly mean (±S.E.)/ 10 plants**						**Seasonal mean**
	Nov.2012	**Dec.2012**	**Jan.2013**	**Feb.2013**	**Mar.2013**	**Apr.2013**	
Adults	9.7±0.8^{a}	22.7±3.7^{b}	69.3±0.3^{b}	152.2±7.8^{a}	176.0±3.5^{a}	35.3±0.9^{a}	103.1±25.2^{a}
Nymphs	4.7±0.7^{b}	37.3±5.9^{a}	104.5±2.4^{a}	136.3±5.8^{b}	171.0±4.0^{b}	18.7±8.3^{b}	78.8±01.3^{a}

* Means followed by the same letter, in each column, are not significantly different according to Student's T- test.

Table 5. Counts of predators associated with *Thrips tabaci* in an onion field experiment at Shendi, November 2012-April 2013.

Predator species	Monthly counts (mean ± S.E.)/ 10 plants						Seasonal mean
	Nov.2012	Dec.2012	Jan.2013	Feb.2013	Mar.2013	Apr.2013	
Chrysoperla carnea	2.3±0.3^{a}	2.6±0.3^{b}	3.7±0.2^{a}	5.0±0.3^{a}	6.0±0.0^{a}	6.0±0.3^{a}	4.3±0.2^{a}
Coccinella undecimpunctata	2.4±0.1^{a}	3.7±0.2^{a}	5.3±0.6^{a}	6.0±0.6^{a}	5.9±0.2^{a}	2.1±0.4^{b}	4.2±0.3^{a}
Xanthogramma aegyptium	3.0±0.4^{a}	4.5±0.2^{a}	4.1±0.6^{a}	4.5±0.8^{a}	4.9±1.0^{a}	1.9±0.3^{b}	3.8±0.4^{a}
C.V%	25.3	14.4	23.2	21.9	17.4	20.7	13.5
LSD (0.05)	01.5	01.2	02.3	02.6	02.2	01.6	01.7

* Means followed by the same letter, in each column, are not significantly different according to the LSD test.

3. Results of the onion field experiment

3.1. Infestation levels by onion thrips

Figure 2 shows the results of *T. tabaci* infestation on the onion winter experiment (2012/13) at Shendi area. The pest showed a high infestation level (35.6±1.1% infested plants) since the first month (November), and kept an increasing trend to attain its peak (72.2±4.0%) during March, and then decline thereafter. This is typically the same trend obtained from previous onion surveys, but the recorded mean seasonal infestation level (49.6±1.3%) was relatively higher than that of onion surveys (40.7±5.0%).

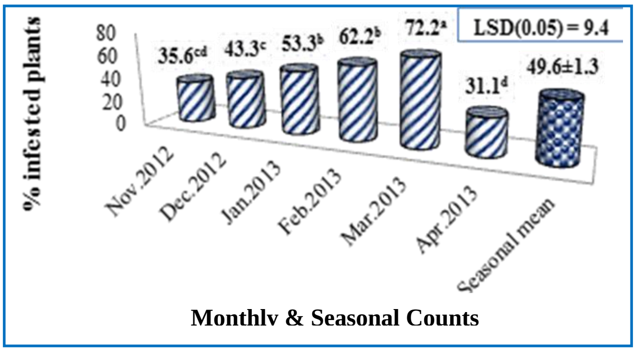

Figure 2. Monthly and seasonal mean onion plants (%) infested by *Thrips tabaci* in a field experiment at Shendi, Nov.-April 2012/13.
* Charts with same letter(s) are not significantly different based on LSD test.

Counts of adults and nymphs of *T. tabaci* compared at monthly and seasonal levels from this experiment were presented (Table 4). At the onset of season (November), adult population was significantly higher than that of nymphs. Soon thereafter, and due to high reproduction rates of the pest, the counts of nymphs significantly overpassed those of adults during two subsequent months (December-January). However, some sort of balance seemed to occur in mid-season, and both stages peaked during March to drop again in April. Meanwhile, nymphs showed declining trend between February and April with significantly low populations compared with adults. Nevertheless, the comparison of seasonal means showed no significant differences between adults and nymphs. The peak population counts of such stages (Table 4) were in consistency with their mean infestation level (Fig. 2), which appeared in March.

3.2. Population trends of major predators

The population trends of predators associated with onion thrips in the same previous experiment (winter 2012/13) were presented in table 5. Although *C. carnea* was the most abundant predator, no significant differences were noticed between population means of the three predatory species. The highest buildup of *C. carnea* occurred during March-April, meanwhile the other predators showed declining trends. In contrast to *T. tabaci*, it is obvious that the levels of all predators in this experiment were comparatively lower than those recorded from onion surveys. However, the peaks of total predators were more or less near to that of onion thrips.

IV. DISCUSSION

Based on the field surveys, the rocket and onion crops manifested significantly higher infestation percentages by *T. tabaci* than tomato crop. This attributed largely to host preference of *T. tabaci* towards the former two crops, which assumed to be guided by several ecological and morphological features pertained to these crops, and probably certain phytochemical effect. It is suggested that, since both crops grow in dense canopy, this seemed to facilitate movement and transference of the pest between plants and its ultimate distribution in the field. These thought to be possible since adults of *T. tabaci* are poor fliers, and that due to their feathery wings they are liable to wind current as a main factor of dispersal [30], though flight of thrips is documented [28]. Such drift of *T. tabaci* can also be boosted by the occurrence of more adults in the upper than basal sections of onion plants at all crop stages, as well as the distribution of larvae on the plant at late stages when crop matures and thrips density increases [34]. In this respect, the effect of onion planting density on population of *T. tabaci* has been reported [3]. Another point is that the two mentioned crops generally grow in short stands close to the ground and this might help in reproduction of *T. tabaci*, as soil is critical for pupation, besides providing open fields for wind movement and pest dispersion as described above. Dense and short stands of plants' canopy is supposed to provide good shading on the soil, which is critical in conserving humidity required for pupation and adult emergence, especially in heavy clay soils. In addition, the mentioned crops, particularly onion, generally grow in light soils, which believed to be advantageous for pupation and adult emergence compared to crops in heavy soils. Zereabruk (2017) proved that lowland areas (1386 m.a.s.l.) of sandy to loam soil and hot weather show the highest number of onion thrips compared to other areas in Tigray region of Ethiopia [51].

The results were in consistence with those of several investigators who indicated that *T. tabaci* is a serious pest of onion crop in different parts of the world including the Sudan [16, 13, 36]. According to Doederlein and Sites (1993), *T. tabaci* exhibits a strong preference for *Allium cepa*. Regarding effects of soil environment, Wardle and Simpson (1927) stated that certain soil conditions exerted greater influences on thrips populations than heavy rains and flooding, as the more cohesive the soil after drying the fewer adults will emerged [49]. Therefore, an acceptable level of soil humidity is vital in the life cycle of *T. tabaci*, especially in heavy soils, though very high humidity is destructive to this pest. In this respect, heavy watering/rainfall and flooding are known to kill pupae in the soil [26, 27].

Considering morphological aspects of host plants, as onion generally characterized by closed apical leaves, they apparently served to protect nymphal stages of thrips from adverse environmental conditions (e.g., sun radiation, high humidity, winter cold, windstorms and some natural enemies). According to Mo *et al*. (2008), larvae of *T. tabaci* are found to congregate at the basal sections of onion especially during young plant stages and low thrips density [34]. On the other hand, rocket plants have broader leaves than those of onion and tomato, but the dense growth habits of rocket plants might be of credit for the pest, also from protection as well as dispersion point of views. The leaf structure of a plant is reported to affect the number of *T. tabaci* they can support [23, 46]. According to Priesner (1964), Middle East thripid species selected vertical leaves for oviposition sites to protect their eggs from heat [37].

The results obtained from surveys and the field experiment at Shendi area determined that *T. tabaci* is an all season pest in its occurrence, but normally considered a late season pest that aggravates crop damage during March. According to Edelson *et al*. (1986), *T. tabaci* shows progressive within-field population increases throughout the season to attain its peak level before harvesting [13]. Winter (November – February) is the main growing season of onion, tomato, legumes and various vegetables in the study area. Hence, March is an intermediate month between winter and summer seasons, coinciding with the rise of temperature and drop of relative humidity, as set by the meteorological data. Such results agree with several authors who indicate that dry and warm conditions are suitable for reproduction of *T. tabaci*, which found to correlate negatively with relative humidity and positively with temperature [12, 18, 51]. Accordingly, the lightly irrigated and late sown crop is found to be more liable to thrips attacks than heavily irrigated and early sown one [8, 26, 27, 31, 39]. In this context, Szostek and Schwartz (2015) stated that the activity of onion thrips seems to cease merely under very cool conditions below 0°C [47].

Putting in mind the variations in climatic conditions from one ecological zone to another, the current results of seasonality are comparable to some degrees with those obtained in different regions worldwide. For instances in India, *T. tabaci* used to breed on onion crop from November to May [4, 45], while in Pakistan it infests onion from March to May [25]. Likewise, the pest attacks onion crop from February to April/May (with a peak in early April) in USA [13], while shows its maximum numbers during March - April at Mansoura region in Egypt [5]. Also, at different altitudes (1350-2131 m.a.s.l.) in Tigray region of Ethiopia this species appears at low levels in early December and then progressively increases to attain its peak in March [51], whereas in Sokoto of Nigeria it breeds from January to May with peak equally in March [19]. Additionally, the results also indirectly agree with some earlier records in the country, which showed that late sown crops are exposed to more attack by *T. tabaci* than early sown ones [7, 26, 42]. In the Sudan Gezira scheme for example, early-transplanted onion in October can be established well before severe infestation by *T. tabaci* occurs and with significantly high yield without chemical control, but late transplanted onion crop suffers variable levels of thrips that leads to yield losses ranged between 39 – 57% [26].

The obtained results proved significant dominance of *T. tabaci* adults over those of nymphs, both at the onset (November) as well as at the end (April) of the season, but nymphs' densities progressively surpass adults during the early vegetative growth (December – January) of the cropping period. The reasons of adults' dominance under such cases are thought to be connected with two factors. Firstly, the adults of thrips that transfer from nearby hosts (weeds or other plants) to onion crop during the first month ultimately require some time before their establishment and reproduction. Secondly, at the end of the season the insect seems to seize breeding on senescent leaves waiting for migration to other fresh hosts. To prove, Shelton *et al*. (1987) suggested that *T. tabaci* may moves into the field from surrounding areas, and it distributes randomly within the field [44].

However, the high nymphal populations during the first stage of plant growth indicated that onion thrips prefers young plants as well as fresh leaves for feeding and reproduction. Some authors stated that young onion plants are more susceptible to *T. tabaci* [29], and this pest generally confines to younger tissues during its egg laying and feeding [48]. Therefore, a strategy of thrips management should be designed in a way based on research findings to avoid the peak infestation period, particularly during seedling and early growing stages of onion crop. Sing (1984) stated that in India thrips are active throughout the year and breed on onion from November to May [45]. Also, Jones (2005) stated that the adults and nymphs of thrips present from February to harvest (April or May) with peak abundance in early April, and given that the two stages (adults and nymphs) feed on young tissues [22]. Nevertheless, the comparison of seasonal populations of *T. tabaci* from the current research showed no significant differences between the numbers of adults and nymphs on onion leaves. This fact could be due to the population fluctuation during the season, between adults and nymphs, as appeared from the monthly data.

The last population drop of *T. tabaci* seemed to occur largely due to the leaf senescence and withering at crop maturity as mentioned earlier, a factor that believed to enforce adults' migration to other crops and probably mortality of some immature stages. However, the phenomenon of migration is likely to be triggered by a combination of some ideal factors including, weather conditions (particularly wind), crop maturity, and harvest activities. Lewis (1964) stated that several species of thrips prefer to fly when it is sunny, settled weather with slight convection and a maximum temperature of at least 20ºC [28]. Thus, directional mass flights of thrips can occur between plants under suitable conditions as already mentioned [9, 20, 35, 43]. For instances, Shelton and North (1986) showed that *T. tabaci* females move from weeds and cereal crops to infest adjacent crops, such as cabbage, that are growing more vigorously, and the results are well correlated with senescence and harvesting of the former crops [43].

As results show, among predators associated with onion thrips, *C. carnea* and *C. undecimpunctata* are the most prevalent. These species were already reported among predators of thrips from elsewhere [5, 14, 15, 38]. The results also proved that the occurrence, seasonal buildup and peak populations of the aforementioned predators on the studied host plants were closely associated and coincided with those of their prey hosts (*T. tabaci*). Nevertheless, the stated conclusion is not always the case as other factors including for instances ecological and morphological characteristics of different hosts besides the occurrence of other prey alternatives, all may interfere to affect the levels of such predators. On the other hand, the fact that the experimental field had attracted lower levels of predators than the farmer fields surveyed, as opposite to thrips, could be related to different reasons. Of these, doubtless the large cultivated areas of different crops with different growing stages in the latter case had provided some sort of floral diversity. This seemed to act as an intercropping system, which believed to encourage widespread buildups of such biological agents due to availability of various ecological and prey alternatives. Consequently, the low predatory level recorded in onion experiment is considered one of the factors reducing biotic stresses on thrips abundance, contrarily to what had been recognized in surveys. However, Lewis (1997) stated the possible role of mixed cropping in enhancing some predators of thrips [30]. In other way, Fok *et al*. (2014) reported that the seasonal population dynamics of various predators and that of *T. tabaci* depict similar trends, but that the predator abundance was nearly 2.5 to 13 times greater in small-scale onion fields surrounded by multiple vegetable crops than in large-scale monoculture onion cropping system surrounded by other onion fields [14].

V. CONCLUSION

The present study revealed that *T. tabaci* is a serious pest on onion and other different crops at Shendi area, which shows its highest buildup between March and April at the end of winter season. The pest reflects progressive multiplication rates during the early vegetative growth period (December-January) of onion crop to attain its peak levels in March, and then to drop sharply in April because of crop senescence and predatory actions. The recorded seasonality need to be validated under different cultural practices, such as sowing dates, intercropping and irrigation/fertilization scheduling etc., with emphasis on predatory-prey interactions. Thrips management programs are urgently required, pending that the research gaps are well addressed, for each ecological situation.

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