Plant Protection, 08 (03) 2024. 411-422 DOI:10.33804/pp.008.03.5253

Available Online at EScience Press
Plant Protection
ISSN: 2617-1287 (Online), 2617-1279 (Print)
http://esciencepress.net/journals/PP

Research Article

IMPACT OF LEAF TRICHOMES AND STOMATAL DENSITY ON THE RESPONSE OF THREE SOYBEAN VARIETIES TO SUCKING PEST INFESTATION

Nourelhoda Mohammed Rasmey Abdelhamid, Nihal Magdy Mohammed Khalil Bagy, Hanaa Fadl Hashem
Piercing and Sucking Insects Department, Plant Protection Research Institute, Agriculture Research Center, Giza, Egypt.

ARTICLE INFO

Article history
Received: 20th June, 2024
Revised: 1st August, 2024
Accepted: 1st September, 2024

Keywords
Pest management
Resistance
Soybean varieties
Morphological patterns
Trichomes
Stomata

ABSTRACT

Chemical pesticides disrupt local ecosystems, reduce populations of natural predators, and contribute to the evolution of pest resistance. Therefore, developing pest-resistant crop varieties is one of the most promising and environmentally friendly alternatives for pest control today. In the present study field experiments were conducted over two consecutive growing seasons in 2022 and 2023 to explore pest resistance among three soybean varieties viz. Crawford, Giza 111, and Giza 22. The research aimed to assess pest infestation resistance among these varieties, considering various leaf morphological factors. Four key pests were evaluated in the study viz. whiteflies (*Bemisia tabaci* Genn), spider mites (*Tetranychus urticae* Koc), aphids (*Aphis gossypii* Glover), and thrips (*Thrips tabaci* Lind)). The soybean varieties exhibited differences in susceptibility, and pest density varied across the two growing seasons. Crawford and Giza 111 demonstrated lower resistance, characterized by reduced leaf hair density and an increased number of stomata per leaflet. In contrast, Giza 22 was the most susceptible, featuring a higher density of trichomes and lower stomata density. In terms of field yield, Crawford produced the highest yield, followed by Giza 111, while Giza 22 yielded the least. The results of this study underscore the importance of selecting resistant plant varieties in future pest resistance improvement programs.

Corresponding Author: Nourelhoda Mohammed Rasmey Abdelhamid
Email: norelhodarasmey@ymail.com

INTRODUCTION

Soybeans (*Glycine max* (L.)) are considered a major grain legume crop in Egypt and worldwide. Low in fat and high in protein, soybeans have gained global prominence, surpassing other bean crops. They are an important protein supplement not only for direct human consumption but also as livestock and poultry feed. Additionally, soybean oil is used in the production of various industrial products, including antibodies, paints, varnishes, adhesives, lubricants, and more (Abou-Attia and Youssef, 2007; Netam et al., 2013). Soybean plants are attacked by various insect pests, primarily piercing-sucking pests such as aphids (*Aphis* spp.), leafhoppers (*Empoasca* spp.), thrips (*Thrips tabaci* (Lind)), two-spotted spider mites (*Tetranychus urticae* Koch) and whiteflies (*Bemisia tabaci* (Genn.)). Pest infestations reduce photosynthesis and adversely affect soybean yields both qualitatively and quantitatively (El-Samahy and Saad, 2010; Abd-El-Samad et al., 2011; Khattab et al., 2012; Salem, 2016; Muniappan and Heinrichs, 2018; Mesbah et al., 2019).

Utilizing resistant cultivars as part of Integrated Pest Management (IPM) programs is the most effective way to reduce pest damage and minimize the need for chemical treatments (Dent, 1991; Dick, 1974; Kassi et al., 2018, 2019a; Muhammad 2021a,b). Various soybean varieties resistant to pests provide a significant means to reduce, delay, or even prevent pest attacks, thereby enhancing both yield and quality (Kumar, 1984).

Certain plants possess morphological characteristics, such as trichomes and stomata, which play a crucial role in water regulation and herbivory prevention (Cipollini and Bergelson, 2002; Molina-Montenegro et al., 2006; Gonzales et al., 2008). These morphological traits significantly impact the interactions between pests, natural enemies, and the plant itself, resulting in positive, negative, or neutral effects (Dalin et al., 2008; Javed et al., 2017; Aslam et al., 2019; Kassi et al., 2019b). Consequently, trichomes and stomata influence the attraction and deterrence of various insects with distinct behaviors toward host plants (Chalwe et al., 2015; Pastório et al., 2023). Therefore, soybean traits such as trichome and stomata characteristics are essential in developing new integrated pest management strategies.

Many authors have studied the impact of resistant soybean varieties on preventing pest infestation (Hegab, 2001; Salman et al., 2002; Abd El-Samad et al., 2011; Al-Habshy et al., 2011; Khattab et al., 2012; El-Sarand, 2013; Abdallah et al., 2015; Salem, 2016). The prevailing seasonal soybean cultivars in Egypt are Crawford, Giza 111, and Giza 22. However, there is a lack of comprehensive studies on their response to pests in Upper Egypt. To address this gap, the present study aimed to examine the impact of various sucking pests on soybean plants over two growing seasons in Assiut Governorate, Upper Egypt. Additionally, this research sought to determine and compare the pest tolerance of different soybean varieties. Few studies have explored the effect of leaf morphological traits on pest population density, so this aspect was also investigated to enhance pest resistance through breeding soybean varieties with favorable morphological characteristics.

MATERIALS AND METHODS

Design and field experimentation

The experiment was conducted at the experimental farm of Assiut University, Faculty of Agriculture, over two consecutive agricultural seasons (2022 and 2023). The study focused on three popular soybean varieties in northern Egypt viz. Crawford, Giza 111, and Giza 22. While there have been few studies on these varieties in Upper Egypt, they were selected for this investigation. Seeds of the studied varieties were obtained from the Agricultural Research Center.

The experimental design used was a randomized complete block design (RCBD) with five replicates per treatment, resulting in a total of 15 plots. The experimental field, characterized by clay soil, was prepared under a flood irrigation system. The soil was plowed twice perpendicularly and leveled. The field was divided into 15 plots, each measuring 3m × 3.5m ($10.5m^2$); with each plot containing five ridges 3.5 m long and 60 cm wide.

Before sowing, superphosphate (15% P_2O_5) was broadcast at a rate of 358 kg/ha on the surface of the ridges and mixed well with the soil. Just prior to sowing, soybean seeds from each variety were placed in separate containers, and all seeds were inoculated with Okadeen inoculum, which contains specialized rhizobia for nitrogen fixation. This inoculum was purchased from the Biofertilizers Production Unit, Agricultural Microbiology Department, Institute of Soils, Water and Environment Research, ARC, Giza, Egypt.

Inoculated soybean seeds were planted by drilling them into holes 3-4 cm deep and 10 cm apart on one side of the ridge. Planting occurred at the beginning of June in both experimental seasons. Two weeks after germination, seedlings were thinned to two plants per hill. An activation dose of nitrogen fertilizer (48 kg N/ha as ammonium nitrate, 33.5% N) was applied with the second irrigation (25 days after sowing). Potassium sulfate (48% K_2O) was added at a rate of 119 kg/ha in two equal doses, 25 and 40 days after sowing. The plots were irrigated every 12-15 days. As per Egyptian Agriculture Ministry recommendations, standard agricultural practices were followed, excluding pesticide use.

Procedures for sampling

To estimate insect pest populations, ten plants were randomly selected from each plot every week, early in the morning. In the field, the number of pests (nymphs and adults) was directly counted and recorded. For aphids and thrips, a weekly sample of ten soybean leaves was randomly chosen from each plot. To count the immature stages of whiteflies and two-spotted spider mites, ten leaves were collected from each plot and brought to the laboratory in paper bags for examination under a binocular microscope. Sampling was conducted weekly for ten weeks, starting one month after planting and continuing through the end of the season.

Assessment of soybean variety susceptibility levels

The susceptibility of each soybean cultivar was assessed based on the mean (X) and standard deviation (sd) of the total number of pests, following the criteria suggested by Chiang and Talekar (1980). Cultivars were categorized as follows:

Highly susceptible

Mean number of pests exceeding X + 2 sd

Susceptible

Mean number of pests between X + 2 sd and X

Low resistance

Mean number of pests between X and X - 1 sd

Moderately resistant

Mean number of pests between X - 1 sd and X - 2 sd

Highly resistant

Mean number of pests less than X - 2 sd

Scanning of surface characteristics on leaflets

Five soybean leaflets from each variety were excised and examined using an analytical scanning electron microscope (SEM) in the Assiut University lab. Following Bakr (2005), the number and dimensions of stomata and trichomes were measured to distinguish between soybean varieties. The relationship between leaflet trichomes, stomata, and insect infestation was analyzed using the correlation coefficient.

Statistical analysis

Data were analyzed using SPSS version 16.0. Analysis of variance (ANOVA) was performed, and Duncan's multiple range test was used to compare means among all data, with a significance level set at 0.05 (Duncan, 1955).

RESULTS AND DISCUSSION

Seasonal population density of pests infesting soybean varieties

Three soybean varieties viz. Crawford, Giza 111, and Giza 22 were examined under field conditions to assess their susceptibility to insect pest infestation. Infestation levels were quantified each season as the number of insects per ten soybean leaves over two separate seasons. Figure 1 illustrates the seasonal mean numbers of whitefly, two-spotted spider mite, aphid, and thrips on the tested soybean varieties during the 2022 and 2023 growing seasons.

Differences between the soybean varieties were analyzed in relation to previous data and across the two seasons of the current study (Salem, 2016). It was confirmed that significant differences in infestation levels existed among the varieties during each of the two testing seasons. Specifically, pest populations were notably higher in 2022 compared to 2023, as reported by Mesbah et al. (2019). Conversely, Khattab et al. (2012) observed the opposite trend: whitefly populations were lower in the first season, while aphid populations were lower in the second season.

Giza 111 was the most infested by whiteflies, followed by Giza 22, with Crawford being the least infested. This finding aligns with the observations of Magouz et al. (2006) and Khattab et al. (2012). Abdallah et al. (2015) also reported significant variations in whitefly infestation among different soybean varieties over two years. In contrast, the two-spotted spider mite showed higher population densities on Giza 22 and Crawford compared to Giza 111 in both growing seasons (Figure 1).

Aphid populations were higher on Crawford during the first season and on Giza 111 during the second season (Figure 1), differing from Khattab et al. (2012), who found Giza 111 to be more susceptible to aphids. For thrips, Crawford exhibited higher population densities in the first season, whereas Giza 22 had higher densities in the second season (Figure 1). These findings are consistent with those of Raupach et al. (2002), Abd El-Samad et al. (2011), and Al-Habshy et al. (2011).

Table 1 summarizes the average number of soybean pests based on samples of ten leaves per variety during 2022 and 2023. Statistical analysis revealed highly significant differences between the two seasons in terms of populations of sucking pests: whitefly, two-spotted spider mite, aphid, and thrips (F-values of 14.21, 17.12, 43.05, and 16.83, respectively; P-value ≤ 0.05). The variations in insect population densities between the two seasons may be attributed to factors such as natural enemies, environmental conditions, climatic changes, and seasonal pest abundance (Raupach et al., 2002; Abd El-Samad et al., 2011; Al-Habshy et al., 2011; Salem, 2016).

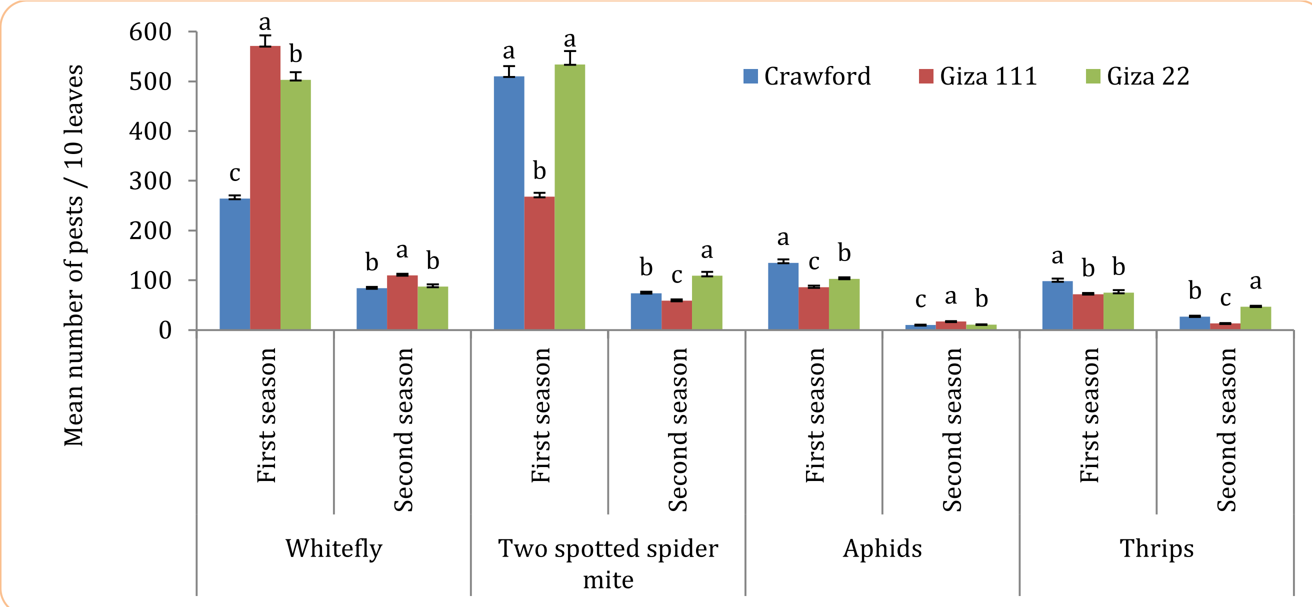

Figure 1. Seasonal mean numbers of pests on three soybean varieties during 2022and 2023 seasons at Assiut governorate.

Table 1. Population density of sucking pests of soybean plant during two growing seasons 2022 and 2023.

Season	Whitefly	Two spotted spider mite	Aphids	Thrips
2022	446 ± 93.20[a]	437.33 ± 85.05[a]	108 ± 14.38[a]	81.67 ± 8.22[a]
2023	93.67 ± 8.22[b]	80.67 ± 14.83[b]	12.67 ± 2.19[b]	29 ± 9.88[b]
F-value	14.21	17.12	43.05	16.83
P-value	0.0196	0.0144	0.0027	0.0148

Relative susceptibility of soybean varieties to pest infestation

An extensive study by Hegab (2001), Salman et al. (2002), Al-Habshy et al. (2011), Abd El-Samad et al. (2011), Khattab et al. (2012), El-Sarand (2013), Abdallah et al. (2015), and Salem (2016) explored the susceptibility of different soybean cultivars to pest infestation under Egyptian field conditions. These studies have highlighted variations in pest susceptibility among soybean cultivars and across different years.

Data presented in Table 2 indicate the resistance status of the tested soybean varieties to pest incidence, evaluated based on their susceptibility levels. Crawford showed moderate resistance to whiteflies, whereas Giza 111 and Giza 22 were found to be susceptible. A significant difference was observed among the screened varieties (F=29.055, P=0.0057), consistent with findings by Khattab et al. (2012), Salem (2016), and Mesbah et al. (2019). However, Salman et al. (2002) reported that Crawford was susceptible to *B. tabaci*, with Giza 111 displaying lower resistance. This is in agreement with Abdallah et al. (2015), who identified Giza 111 as the most susceptible cultivar.

For two-spotted spider mites, Crawford and Giza 22 were susceptible, while Giza 111 exhibited moderate resistance, with a highly significant effect among the treatments (F=28.07; P=0.0060). Crawford was also susceptible to aphids, with Giza 111 and Giza 22 showing lower resistance, and significant differences observed between the varieties (F=85.36, P=0.0007). This finding aligns with that of Mesbah et al. (2019) but contrasts with that of Khattab et al. (2012), who reported Giza 111 as susceptible to aphids.

Crawford and Giza 22 were susceptible to thrips, but Giza 111 exhibited lower resistance. The observed differences in resistance to thrips infestation among the three soybean varieties were consistent with Salem (2016), who also reported significant differences in susceptibility to thrips.

Overall, Giza 22 experienced the highest pest infestation and was classified as susceptible, followed by Crawford and Giza 111, which showed lower resistance. This was indicated by the total infestation scores, which showed highly significant differences between the varieties (F=203.74, P=0.0001).

According to Van Emden (1987), differences in varietal sensitivity to insect pest infestation may be attributed to antixenosis and/or antibiosis phenomena. Dent (1991) defines antixenosis (non-preference) as a resistance strategy that prevents insect colonization by potentially altering the plant's morphology and/or biochemistry. Antixenotic-resistant plants are predicted to have a higher rate of pest emigration and/or a lower initial infestation rate compared to susceptible plants. Conversely, antibiosis negatively affects the growth, reproduction and survival of insects.

The highest yield was recorded in the Crawford variety, which had the lowest infestation. This was followed by Giza 111 and Giza 22, which produced the lowest yield due to higher pest attack (Figure 2). This result suggests that pest infestation may impact yield production.

Table 2. Susceptibility degrees (SD) of three soybean varieties to pest infestation at Assiut governorate.

Varieties	Whitefly		Two spotted spider mite		Aphids		Thrips		Total pests	
	Mean number/10 leaves	SD	Mean number/10 leaves	SD	Mean number/ 10 leaves	SD	Mean number/10 leaves	SD	Mean number/ 10 leaves	SD
Crawford	174 ± 3.53 [c]	MR	292 ± 11.42 [b]	S	72.5 ± 3.55 [a]	S	62.5 ± 2.59 [a]	S	601 ± 17.51 [b]	LR
Giza111	340.5 ± 11.05 [a]	S	163.5 ± 4.67 [c]	MR	51.5 ± 1.74 [c]	LR	42.5 ± 1.22 [b]	LR	598 ± 15.36 [b]	LR
Giza22	295 ± 8.58 [b]	S	321.5 ± 13.85 [a]	S	57 ± 1.65 [b]	LR	61 ± 3.05 [a]	S	734.5 ± 21.74 [a]	S
Mean	269.83 ± 7.2		259 ± 9.7		60.33 ± 1.94		55.33 ± 2.05		644.5 ± 17.88	
F-value	29.05578		28.07112		85.36585		68.22119		203.7459	
P-value	0.005729		0.006095		0.000763		0.001172		0.00014	

Data are presented as mean± SE. values in columns followed by different letters are significantly different at P≤0.05 (Duncan multiple range test). SD: susceptibility degrees, MR: moderate resistant, LR: low resistant, S: Susceptible.

Effect of leaf morphological features of soybean varieties on population density of pest infestation

The interaction between insect pest infestation and the morphological characteristics of soybean leaflets was assessed using a scanning electron microscope. The shape and density of trichomes and stomata on soybean leaves are shown in Figure 3. The morphological features of a host plant can significantly influence pest interactions. The epidermal tissues of leaves, modified by the presence of stomata and trichomes, play a crucial role in protecting plants from insect infestations and aiding in photosynthesis (Kariyat et al., 2018).

In this study, observations of trichomes and stomata were used to determine the characteristics of different soybean cultivars using a scanning electron microscope (Figure 3). The results showed that trichomes on soybean leaves act primarily as mechanical barriers, impeding the movement of herbivores and preventing feeding damage (Peiffer et al., 2009; Mithofer and Boland, 2012; Escobar-Bravo et al., 2016; Kariyat et al., 2017). As shown in Figure 3, stomata are tiny pores that plants use to exchange gases and control water loss (Ren et al., 2003).

Leaf trichomes are involved in defense against herbivores, as reported by Kariyat et al. (2018). The current study investigated the impact of trichomes on insect population and plant resistance. The variation in trichome density on the leaves of soybean varieties affected the size of insect pest populations (Table 3).

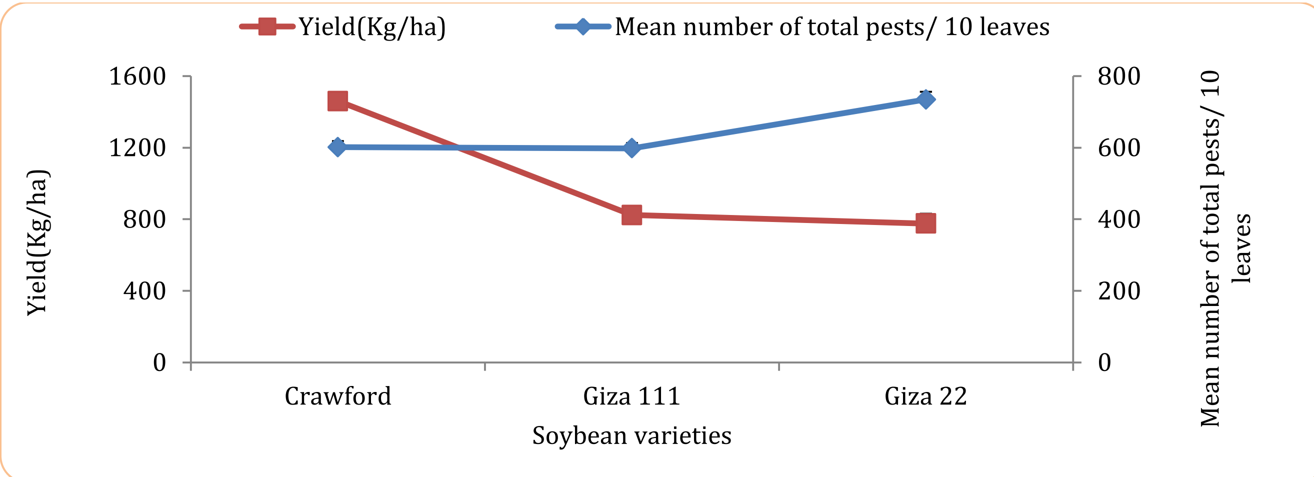

Figure 2. Effect of pest infestation on yield of soybean varieties.

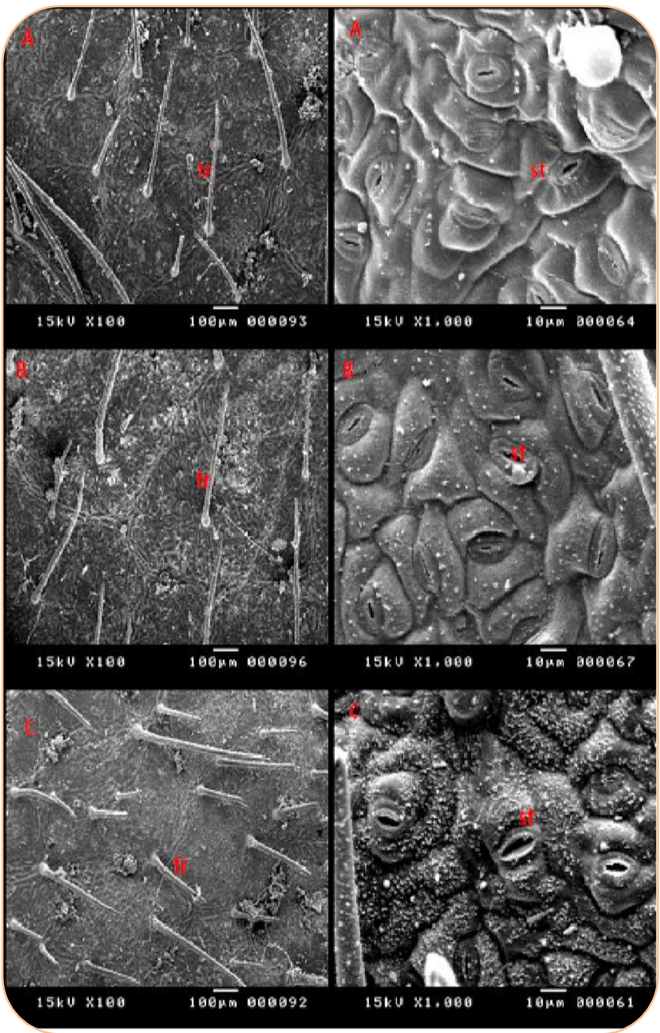
Figure 3. Scanning electron micrograph showing trichomes and stomata on leaflets of three soybean varieties (A = Crawford, B = Giza111, and C = Giza22); tr: trichomes and st: stomata.

Giza 22, with the highest number of trichomes, was the most heavily infested cultivar and considered susceptible. In contrast, trichome densities on Crawford and Giza 111 (38.33±1.45 and 24±2.08, respectively) were lower than those on Giza 22 (58.33±1.77) and classified as low resistant. Similarly, El-Samahy and Saad (2010) indicated that leaf hair density significantly affected pest populations. Increased trichome density may therefore boost resistance against herbivores. Trichome density also influences tolerance to abiotic stress and the number and efficiency of predators and parasitoids feeding on herbivores, as noted by Dalin et al. (2008).

Differences in stomatal density and size were also recorded among the tested soybean varieties (Table 3). This is consistent with findings by Hasanah et al. (2019) and Caglar et al. (2004). Varieties like Crawford and Giza 111 had the highest number of stomata (431.33±6.97 and 331±5.87, respectively), correlating with higher resistance, while Giza 22, with low stomatal density (160.33±3.53), was more susceptible. This supports previous studies by Boso et al. (2010, 2016), which demonstrated that resistant cultivars tend to have higher stomatal densities. Variations in stomatal density among varieties affect gas exchange and adaptation, impacting plant resistance as shown by Barry et al. (2005). The lower stomatal density in Giza 22 may limit photosynthesis, increasing susceptibility to pest attacks and leading to decreased yield compared to Crawford and Giza 111 (Figure 2).

Table 3. Density and Dimensions of morphological resistance factors of leaflets of soybean varieties

Variety	Trichomes		Stomata		
	Number/cm^2	Length (µm)	Number/cm^2	Length (µm)	Width (µm)
Crawford	38.33±1.45^b	430±10.01^b	431.33±6.97^a	16±0.57^b	10±0.58^a
Giza 111	24±2.08^c	451.33±24.70^{ab}	331±5.87^b	18±0.57^a	9±0.57^b
Giza 22	58.33±1.77^a	473.33±35.32^a	160.33±3.53^c	13±0.57^c	8.33±0.33^c

Data are presented as mean ± SE. Values in columns followed by different letters are significantly different at P≤0.05 (Duncan multiple range test).

The present study demonstrated that the population dynamics of important insect pests are influenced by soybean morphological traits and their interactions (Table 4). The negative correlation between trichome density and whitefly infestation found in this study indicates that trichomes hinder the whitefly's ability to forage, feed, ingest, digest, mate, and deposit eggs, thereby limiting its growth (Amin et al., 2017). This negative effect is attributed to antixenosis being positively associated with the density of leaf trichomes in resistant cultivars (Doryanizadeh et al., 2017). Moreover, the negative correlation suggests that higher trichome density leads to increased predation and parasitism of whitefly nymphs, as high trichome density appears to attract antagonists to whiteflies (Pastorio et al., 2023).

This result contrasts with findings by Lima and Lara (2004), Dalin et al. (2008), Lutfi et al. (2019), Faiz et al. (2021), and Pastório et al. (2023), who reported a positive relationship. Data from this study indicated that the amount of trichomes on soybean leaves had a weak positive impact on the aphid population. According to Van Haren et al. (1987) and El-Solimany and Mostafa (2019), the detrimental impact may also vary depending on the pest's age, developmental stage, and growth level. Furthermore, the trichome effect on aphid populations can vary depending on environmental factors and pest species biology (Amin et al., 2017; Saitta et al., 2022).

Trichomes positively impacted the populations of two-spotted spider mites and thrips. High trichome density may promote increased humidity, providing ideal conditions for nymphal development (Berlinger, 1986). Therefore, varieties with a low number of leaf hairs should be used as a safe and easy tool in integrated pest management programs to reduce soybean pest infestations (El-Samahy and Saad, 2010). Similar results were noted by Prado et al. (2016) and El-Solimany and Mostafa (2019). Conversely, Jayabal et al. (2017) observed a negative effect on spider mites in okra entries.

Khalil et al. (2017) and Arif et al. (2004) showed a positive relationship between trichome density and thrips population, while Arif et al. (2006), Irfan et al. (2008), and Naveed et al. (2011) noted that hair density negatively impacted thrips populations. In general, besides trichome density, other factors that may contribute to pest resistance in certain cultivars include leaf size and color as well as biotic and abiotic factors (Roy et al., 1999; Pastorio et al., 2023).

Stomatal density exhibited a negative impact on the population of the mentioned insects due to its effect on gas exchange and adaptation. However, leaves with fewer stomata may perform less photosynthesis and be more susceptible to pest attacks (Barry et al., 2005). In contrast, stomatal density had a neutral effect on aphid populations. This may be because aphids induce the host plant to enhance their feeding habits. Aphids can reduce leaf transpiration and maintain the host plant's water potential. By altering the host plant's stomata, aphids can better collect water from the xylem and balance the phloem osmotic pressure, leading to increased aphid performance (Sun et al., 2015). Faiz et al. (2021) noted a positive correlation between aphid population and stomatal density.

The dimensions of trichomes and stomata showed significant differences in their correlation with insect pest populations (Table 4). Trichome length had a positive effect on whitefly and two-spotted spider mite populations. Similar results were noted by Bashir et al. (2001), Irfan et al. (2008), Khalil et al. (2017), and Lutfi et al. (2019). The positive correlation suggests that longer trichomes might provide a suitable habitat for pest development (Lutfi et al., 2019). In contrast, Khan et al. (2010) and Zia et al. (2011) reported a negative correlation between hair length and whitefly populations. Moreover, trichome length had a negative effect on aphids and thrips, which aligns with the findings of Khalil et al. (2017) but contradicts results reported by Arif et al. (2004, 2006) and Irfan et al. (2008).

Stomatal length exhibited a highly negative correlation with two-spotted spider mites and thrips. A weak negative correlation was found between aphids and stomatal length, while a weak positive correlation was found between whiteflies and stomatal length. Stomatal width negatively affected whitefly and spider mite populations but positively correlated with aphid and thrips populations. The negative effect may be due to increased photosynthesis, while the positive effect might result from changes in feeding behavior (Barry et al., 2005). Overall, trichome density and dimensions positively affected total pest populations, whereas stomatal density and dimensions negatively affected pest populations (Table 4).

Table 4. Correlation between morphological resistance factors of leaflets of soybean varieties and pest population density.

Pests	Trichomes		Stomata		
	Number/cm^2	Length (µm)	Number/cm^2	Length (µm)	Width (µm)
Whitefly	-0.17	0.70	-0.59	0.15	-0.78
Two spotted spider mite	0.90	0.18	-0.32	-0.90	-0.06
Aphid	0.16	-0.71	0.60	-0.14	0.79
Thrips	0.77	-0.06	-0.08	-0.76	0.18
Total pests	0.92	0.86	-0.92	-0.93	-0.79

Data are presented as mean± SE. values in columns followed by different letters are significantly different at P≤0.05 (Duncan multiple range test).

Within the integrated pest management (IPM) program, utilizing resistant cultivars is a key strategy. For the successful use of resistant varieties, entomologists and breeders need to examine the following: the morphological features of plant varieties, the stage of pest growth, and the ideal environmental conditions required to prevent pest infestation. Effective crop protection, from biological, ecological, economic, and social standpoints, can be achieved by combining resistant cultivars with other IPM strategies.

The results of the present study support the importance of both parameters in evaluating the resistance of soybean varieties to pests, specifically considering trichome and stomata density. This suggests a more nuanced interaction between plant morphological traits and pest infestation, possibly influenced by environmental conditions and the biology of the specific herbivorous species. Understanding these associations is crucial for developing integrated pest management practices for soybean.

Our results suggest that plant breeders and soybean farmers can select cultivars that are resistant or tolerant to insects, allowing them to thrive in Assiut's fields while reducing the need for insecticides in IPM programs. Based on the yield components of soybean varieties and their sensitivity to aphids, whiteflies, spider mites, and thrips, the current study recommends the Crawford variety. It demonstrated high yield, mild infestation by most pests, and favorable morphological features. This recommendation is based on data from two seasons of experiments conducted in Assiut Governorate, Upper Egypt.

CONCLUSION

The population density of pests on tested soybean varieties varies seasonally, as shown in the study. Sucking pest population densities were higher in season one compared to season two. Differences in susceptibility were also evident among the soybean varieties studied. The soybean variety Crawford produced the highest yield, followed by Giza 111, while Giza 22 had the lowest yield. The morphological characteristics of these varieties provide insight into the biological interactions between pests and their host plants.

Whitefly density was negatively correlated with trichome density, while other pest densities were positively correlated with trichomes, which were restricted only to whiteflies. Conversely, stomata density was neutrally associated with aphid abundance and negatively associated with other sucking pests. This knowledge can aid in the development of effective pest control strategies and enhance plant resistance.

Among all the varieties, Crawford emerged as the most resistant to pest attacks, with ideal morphological characteristics and the highest yield. These results suggest that Egyptian soybean farmers and plant breeders could select pest-tolerant or resistant varieties, which can help reduce the use of pesticides in integrated pest control strategies.

ACKNOWLEDGMENT

The authors express their gratitude to the members of the experimental farm at the Faculty of Agriculture, Assiut University, for their support in this work.

AUTHORS' CONTRIBUTIONS

NMRA, HFH and NMMKB conceived the idea, participated in the experimental design and practical work; NMRA performed data analysis, manuscript writing, and revision; all the authors proofread and approved the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abd El-Samad, A.A., Al-Habshy, A.Z.N., Ahmed, M.A., 2011. Survey and population density of some dominant homopterous insects attacking soybean plants. Journal of Plant Protection and Pathology, Mansoura University 2(7), 707-719.

Abdallah, F.E., Boraei, H.A., Mohamed, H.M., 2015. Susceptibility of some soybean varieties and effect of planting dates on infestation with whitefly in Kafr El-Sheikh region Egypt. Journal of Agriculture Research 93(4), 1093-1103.

Abou-Attia, F.A.M., Youssef, A.E., 2007. Field evaluation of some soybean cultivars for infestation with soybean stem fly, *Melanagromyza sojae* (Zehnter) and leaf miner, *Liriomyza trifolii* (Burgess) at Kafr El-Sheikh region. Journal of Agriculture Science, Mansoura University 32(3), 2301-2311.

Al-Habshy, A.Z.N., Abd El-Samad, A.A., Ahmed, M.A., 2011. Effects of certain agricultural practices on the infestation of soybean plants by some homopterous insect pests at Diarb Nigm district, Sharkia Governorate. Journal of Plant Protection and Pathology, Mansoura University 2(7), 721-729.

Amin, M.R., Afrin, R., Alam, M.Z., Hossain, M.M., Kwon, Y.J. 2017. Effect of leaf trichomes and meteorological parameters on population dynamics of aphid and jassid in cotton. Bangladesh Journal of Agriculture Research 42(1), 13-25.

Arif, M.J., Gogi, M.D., Ahmad, G., 2006. Role of morpho-physical plant factors imparting resistance in cotton against thrips, *Thrips tabaci* Lind. (Thripidae: Thysanoptera). Arab Journal of Plant Protection 24, 57-60.

Arif, M.J., Sial, I.A., Ullah, S., Gogi, M.D., Sial, M.A., 2004. Some morphological plant factors effecting resistance in cotton against thrips (*Thrips tabaci* L.). International Journal of Agriculture and Biology 6(3), 544-546.

Aslam, M.A., Javed, K., Javed, H., Mukhtar, T., Bashir, M.S., 2019. Infestation of *Helicoverpa armigera* Hübner (Noctuidae: Lepidoptera) on soybean cultivars in Pothwar region and relationship with physico-morphic characters. Pakistan Journal of Agricultural Sciences 56(2), 401-405.

Bakr, E.M., 2005. Anew software for measuring leaf area, and area damaged by *Tetranychus urticae* Koch. Journal of Applied Entomology 129(3), 173-175.

Barry, B.A., Hicks, C., De Rios, A., Jenson, D.L., 2005. Calcium ligation in photosystem II under inhibiting conditions. Biophysical Journal 89, 393-401.

Bashir, M.H., Afzal, M., Sabri, M.A., Raza, A.B.M., 2001. Relationship between sucking insect pests and physico-morphic plant characters towards resistance or susceptibility in some new genotypes of cotton. Pakistan. Entomologist 23 (1), 75-78.

Berlinger, M, 1986. Host plant resistance to *Bemisia tabaci*. Agriculture, Ecosystem and Environment 17, 69-82.

Boso, S., AlonSo -VillaVerde, V., Santiago, J. l., Gago, P., DürrenBerg-er, M., Düggelin, M., Kassemeyer, H.H., Martínez, M.C., 2010. Macro and microscopic leaf characteristics of six grapevine genotypes (*Vitis* spp.) with different susceptibilities to grapevine downy mildew. Vitis 49, 43-50.

Boso, S., Gago, P., AlonSo -VillaVerde, V., Santiago, J.l., Martinez, M.C., 2016. Density and size of stomata in the leaves of different hybrids (*Vitis* sp.) and *Vitis vinifera* varieties. Vitis 55, 17-22.

Caglar, S., Sütyemez, M., Beyazıt, S., 2004. Secilmis bazı ceviz (*Juglans regia*) tiplerinin stoma yogunlukları.(Stomatal density in some selected walnut (*Juglans regia*) types. Akdeniz Universitesi Ziraat Fakültesi Dergisi 17,169-174.

Chalwe, A., Melis, R., Shanahan, P., Chiona, M., 2015. Inheritance of resistance to cassava green mite and other useful agronomic traits in cassava grown in Zambia. Euphytica 205, 103-119.

Chiang, H.S., Talekar, N.S., 1980. Identification of sources of resistance to the beanfly and two other agromyzid flies in soybean and mungbean. Journal of Economic Entomology 73(2), 197-199.

Cipollini, D.F., Bergelson, J., 2002. Plant density and nutrient availability constrain constitutive and wound-induced expression of trypsin inhibitors in *Brassica napus*. Journal of Chemical Ecology 27, 593-610.

Dalin, P., Agren, J., Bjorkman, C., Huttunen, P., Karkkainen, K., 2008. Leaf trichome formation and plant resistance to herbivory In: A. Schaller (Ed) Induced plant resistance to herbivory. Springer Science, p. 462.

Dent, D., 1991. Insect pest management. C.A.B. International, p. 213.

Dick, K.M., 1974. Insect resistance in crop plants. Economic Entomology 25(3), 441-450.

Doryanizadeh, N., Moharramipour, S., Hosseininaveh, V., Mehrabadi1, M., 2017. Antixenotic resistance of eight *Cucumis* genotypes to melon aphid *Aphis gossypii* (Hemiptera: Aphididae) and some associated plant traits. Journal of Crop Protection 6(2), 207-214.

Duncan, B.D., 1955. Multiple range and multiple F-test. Biometerics 11, 1-42.

El-Samahy, M.F.M., Saad, I.A.I., 2010. Population density of certain piercing sucking pests on three soybean varieties in relation to some leaf characteristic. Journal of Plant Protection and Pathology, Mansoura University 1(10), 767-773.

El-Sarand, E.A., 2013. Integrated management of certain piercing-sucking insects on soybean and faba bean plants at Kafr El-Sheikh Governorate. Ph.D. Thesis, Faculty of Agriculture, Tanta University, pp. 224.

El-Solimany, E.A., Mostafa, Y.A., 2019. Susceptibility of certain cantaloupe hybrids to major pests infestation in Sohag Governorate. Egyptian Journal of Plant Protection and Research Institute 2(2), 200-211.

Escobar-Bravo, R., Alba, J.M., Pons, C., Granell, A., Kant, M.R., Moriones, E., Fernández-Muñoz, R., 2016. A jasmonate-inducible defense trait transferred from wild into cultivated tomato establishes increased whitefly resistance and reduced viral disease incidence. Frontiers in Plant Science 7, 1732.

Faiz, M.F., Hidayat, P., Winasa, I.W., Guntoro, D., 2021. Effect of soybean leaf trichomes on the preference of various soybean pests on field. In IOP Conference Series: Earth and Environmental Science 694(1), p. 012046. IOP Publishing, doi: 10.1088/ 1755/694/0/2046.

Gonzales, W.L., Negritto, M.A., Suarez, L.H., Gianoli, E., 2008. Induction of glandular and non-glandular trichomes by damage in leaves of *Madia sativa* under contrasting water regimes. Acta Oecologica 33, 128-132.

Hasanah, Y., Hanum, H., Hidayat, A.S., 2019. Chlorophyll content and stomatal density of soybean varieties on technological packages application under dry land conditions. IOP Conf. series: Earth and Environmental Science 260: 012165. doi: 10.1088/1755-1315/260/1/012165.

Hegab, O.I.M., 2001. Studies on certain insect vectors of plant pathogenic agents. Ph.D. Thesis, Faculty of Agriculture at Moshtohour Zagazig University.

Irfan, M., Mumtaz, I., Raza, A.B.M., Ahmad, K., Khan, Z.I., Arif, N., 2008. Effect of leaf morphology on the incidence of sucking insect pests in some cotton genotypes. International Journal of Cell & Molecular Biology 1(3), 285-291.

Javed, H., Hussain, S.S., Javed, K., Mukhtar, T., Abbasi, N.A., 2017. Comparative infestation of brinjal stem borer (*Euzophera perticella*) on six aubergine cultivars and correlation with some morphological characters. Pakistan Journal of Agricultural Sciences, 54(4), 753-758.

Jayabal, T.D., Chinniah, C., Kalyanasundaram, M., 2017. Impact of trichomes on the incidence of two spotted spider mite *Tetranychus urticae* (Koch) on okra *Abelmoschus esculentus* L.(Moench). Journal of Entomology and Zoology *5*(6), 2540-2546.

Kariyat, R.R., Hardison, S.B., Ryan, A.B., Stephenson, A.G., De Moraes, C.M., Mescher, M.C., 2018. Leaf trichomes affect caterpillar feeding in an instar-specific manner. Communicative & Integrative Biology 11(3), 1-6.

Kariyat, R.R., Smith, J.D., Stephenson, A.G., De Moraes, C.M., Mescher, M.C., 2017. Non-glandular trichomes of *Solanum carolinense* deter feeding by *Manduca sexta* caterpillars and cause damage to the gut peritrophic matrix. Proceedings of the Royal Society B: Biological Sciences 284(1849), 20162323.

http://dx.doi.org/10.1098/rspb.2016.2323

Kassi, A.K., Javed, H., Mukhtar, T., 2018. Screening of okra cultivars for resistance against *Helicoverpa armigera*. Pakistan Journal of Zoology 50(1), 91-95.

Kassi, A.K., Javed, H., Mukhtar, T., 2019a. Screening of different aubergine cultivars against infestation of brinjal fruit and shoot borer (*Leucinodes orbonalis* Guenee). Pakistan Journal of Zoology 51(2), 603-609.

Kassi, A.K., Javed, H., Mukhtar, T., 2019b. Relationship of physico-morphic characters of okra cultivars with their resistance to *Helicoverpa armigera*. Pakistan Journal of Zoology 51(3), 835-841.

Khalil, H., Raza, A.B.M., Afzal, M., Aqueel, M.A., Khalil, M.S., Mansoor, M.M., 2017. Effects of plant morphology on the incidence of sucking insect pests complex in few genotypes of cotton. Journal of the Saudi Society of Agricultural Sciences 16(4), 344-349.

Khan, M.A., Akram, W., Khan, H.A.A., Asghar, J., Khan, T.M., 2010. Impact of Bt-cotton on whitefly, *Bemisia tabaci* (Genn.) population. Pakistan Journal of Agricultural Sciences 47 (4), 327-332.

Khattab, M.A.A., Nassef, A.M., Khalafalla, E.M.E., 2012. Relative susceptibility of some soybean varieties to the main piercing-sucking insects infestation in Kafr El-Sheikh Governorate. Journal of Plant Protection and Pathology, Mansoura University 3(7), 751-756.

Kumar, R., 1984. Insect pest control with special reference to African Agriculture. Edward Arnold, London. pp. 298.

Lima, A.C.S., Lara, F.M., 2004. Resistência de genótipos de soja à mosca branca *Bemisia tabaci* (Genn.) biótipo B (Hemiptera: Aleyrodidae). Neotropical Entomology 33, 71-75.

Lutfi, M., Hidayat, P., Maryana, N., 2019. Correlation between epidermis thickness, leaf trichome length and density with the whitefly *Bemisia tabaci* population on five local soybean cultivars. Jurnal Perlindungan Tanaman Indonesia 23(1), 23-31.

Magouz, R.I.E., Saadoon, S.E., Kassem, S.A.A., 2006. Population density of *tetranychus cucurbitacearum* (Sayed) and *Bemisia tabaci* (Genn.) on certain soybean varieties in relation to some weather factors and leaf chemical contents. Journal of Agricultural Research, Tanta University 32(1): 95-102.

Mesbah, I.I., Khalafallah, E.M.E., Eissa, G.M., Hegazy, F.H., Khattab, M.A., 2019. Susceptibility of some soybean varieties to certain piercing-sucking insects under the field conditions of north delta. Egyptian Journal of Agricultural Research 97(1), 159-166.

Mithöfer A, Boland W., 2012. Plant defense against herbivores: chemical aspects. Annual Review of Plant Biology 63(1), 431-450.

Molina-Montenegro, M.A., Vila, A´., Hurtado, P., 2006. Leaf trichome density may explain herbivory patterns of *Actinote* sp. (Lepidoptera: Acraeidae) on *Liabum mandonii* (Asteraceae) in a montane humid forest (Nor Yungas, Bolivia). Acta Oecologica 30: 147–150.

Muhammad, W., Javed, H., Ahmad, M., Mukhtar, T., 2021a. Optimizing transplanting dates for the management of brinjal shoot and fruit borer and better crop yield under field conditions. Pakistan Journal of Zoology 53(3), 967-973.

Muhammad, W., Javed, H., Ahmad, M., Mukhtar, T., 2021b. Economical impact of some selected cultural practices on population build-up of *Leucinodes orbonalis* in brinjal crop. Fresenius Environmental Bulletin 30(06B), 7346-7354.

Muniappan, R., Heinrichs, E.A., 2018. Building bridges between disciplines for sustainable crop protection. Arab Journal of Plant Protection 36(1), 32-36.

Naveed, M., Anjum, Z.I., Khan, J.A., Rafiq, M., Hamza, A., 2011.Cotton genotypes morpho-physical factors affect resistance against *Bemisia tabaci* in relation to other sucking pests and its associated predators and parasitoids. Pakistan Journal of Zoology 43 (2), 229-236.

Netam, H.K., Gupta, R., Soni, Sh., 2013. Seasonal incidence of insect pests and their biochemical agents on soybean. Journal of Agriculture and Veterinary Science 2(2), 7-11.

Pastório, M.A., Hoshino, A.T., Kitzberger, C.S.G., Bortolotto, O.C., de Oliveira, L.M., dos Santos, A.M., Lima, W.F., Menezes Junior, A.d.O., Androcioli, H.G., 2023. The leaf color and trichome density influence the whitefly infestation in different cassava cultivars. Insects, 14, 4.

Peiffer, M., Tooker, J.F., Luthe, D.S., Felton, G.W., 2009. Plants on early alert: glandular trichomes as sensors for insect herbivores. New Phytologist

184, 644-656.

Prado, J.C.D., Peñaflor, M.F.G.V., Cia, E., Vieira, S.S., Silva, K.I., Carlini-Garcia, L.A., Lourenção, A.L., 2016. Resistance of cotton genotypes with different leaf colour and trichome density to *Bemisia tabaci* biotype B. Journal of Applied Entomology 140, 405-413.

Raupach, K., Borgemeister, C., Hommes, M., Poehling, H.M., Stamou, M., 2002. Effect of temperature and host plants on the bionomics of *Empoasca decipiens* (Homoptera: Cicadelidae). Crop Protection 21, 113-119.

Ren, H., Pan, K.Y., Chen, Z.D., Wang, R.Q., 2003. Structural characters of leaf epidermis and their systematic significance in Vitaceae. Acta Phytotax 41, 531-544.

Roy, B.A., Stanton, M.L., Eppley, S.M., 1999. Effect of environmental stress on leaf hair density and consequences for selection. Journal of Evolutionary Biology 12, 1089-1103.

Saitta, V., Rebora, M., Piersanti, S., Gorb, E., Gorb, S., Salerno, G., 2022. Effect of leaf trichomes in different species of cucurbitaceae on attachment ability of the melon ladybird beetle *Chnootriba Elaterii*. Insects 13(12), 1123.

Salem, A.A.A., 2016. Resistance of some soybean varieties to *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) and *Thrips tabaci* L. (Thysanoptera: Thripidae) in Assiut. Assiut University Bulletin for Environmental Researches 19(2), 11-23.

Salman, F.A.A., Mohamed, A.M., Mohamed, H.A., Gad El-Rab, M.L.S., 2002. Evaluation of some soybean varieties to natural infestation with whitefly, *Bemisia tabaci* (Genn.) and spider mite, *Tetranychus urticae* (Koch.) in Upper Egypt. Egyptian Journal of Agricultural Research 80, 619-629.

Sun, Y., Guo, H., Yuan, L., Wei, J., Zhang, W., Ge, F., 2015. Plant stomatal closure improves aphid feeding under elevated CO_2. Global Change Biology 21(7), 2739-2748.

Van Emden, H.F., 1987. Cultural methods: the plant. In: Burn, A.J., T.H. Coaker and P.C. Jepson (Eds.) Integrated Pest Management, Academic Press, London, New York. pp. 27-67.

Van Haren, R.J.F., Steenhuis, M.M., Sabelis, M.W., Ponti, O.M.B., 1987. Tomato stems trichomes and dispersal success of *Phytoseiulus persimilis* relative to its prey *Tetranychus urticae*. Experimental and Applied Acarology 3, 115-121.

Zia, K., Ashfaq, M., Arif, M. J., Sahi, S.T., 2011. Effect of physicomorphic characters on population of whitefly, *Bemisia tabaci* in transgenic cotton. Pakistan Journal of Agricultural Sciences 48 (1), 63-69.