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Impact of irrigation methods and two cotton varieties on sucking pest populations in Şanlıurfa, Türkiye

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Abstract
Cotton is a major industrial crop with high economic value, and the Southeastern Anatolia Region is the leading cotton producer in Turkiye. However, excessive irrigation and pest infestations during the growing period cause significant crop damage, especially from sucking pests affecting cotton's vegetative and generative organs. This study investigated the effects of three irrigation methods (drip, sprinkler, and furrow irrigation) and two cotton varieties (May-455, a hairy and Fiona, a hairless variety) on the population densities of major sucking pests in Şanlıurfa, Türkiye in 2022. Weekly sampling monitored the populations of *Thrips tabaci*, *Aphis gossypii*, *Lygus* spp., *Empoasca decipiens*, *Bemisia tabaci* and *Tetranychus urticae*. The results indicated that drip irrigation led to significantly lower populations of *T. tabaci*, *B. tabaci*, and *T. urticae*, with population densities of 14.4, 16.2, and 18.4 individuals, respectively, under furrow irrigation, compared to 13.6 for May-455 and 11.9 for Fiona cotton. The data also showed that the hairy May-455 variety supported significantly fewer *T. tabaci* individuals than Fiona, with May-455 averaging 13.6 individuals compared to 11.9 for Fiona. *A. gossypii* and *Lygus* spp. were not significantly influenced by irrigation methods or cotton variety. The findings suggest that drip irrigation creates conditions less favorable for pest populations due to reduced surface moisture and humidity, whereas furrow irrigation supports higher densities due to increased moisture availability. These results highlight the potential of using drip irrigation and hairy cotton varieties as effective pest management strategies, promoting sustainable cotton production while reducing reliance on chemical pesticides.

Keywords: Cotton, sucking pest, damage, population, pest management

Introduction

Cotton (*Gossypium hirsutum* L.) is a crucial industrial crop with high economic value, driven by factors such as population growth, improved living standards, and the increasing demand for environmentally friendly products (Çopur, 2018) [12]. In Turkey, cotton production covers 573,000 hectares, with the Southeastern Anatolia Region, particularly Şanlıurfa, being the dominant area, accounting for 63% and 32% of the national production, respectively (TUIK, 2022) [45]. This makes Turkey one of the top producers globally, ranking 7th after countries like India, China, and the USA (ICAC, 2022) [22]. Despite Turkey's significant position in global cotton production, there has been a noticeable decline, particularly in the Mediterranean and Aegean regions, driven by factors such as high input costs, excessive chemical use, and monoculture farming (ICAC, 2022) [22]. However, areas involved in the Southeastern Anatolia region have seen increased cotton planting and production (Çopur, 2018; Basal *et al*., 2019) [12], [8]. As in other countries, one of the primary factors limiting cotton production in Türkiye is the presence of harmful insect pests.

The primary pests are lepidopteran species, with the most significant being the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), and spiny cotton bollworm, *Earias insulana* (Boisd.) (Lepidoptera: Noctuidae) in cotton production, Türkiye (ZMMT, 2008) [50]. In addition to, several sucking insect species cause significant crop losses throughout the growth stages of cotton, from its basic developmental stages to harvest. Among these pests are the tobacco thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae), cotton aphid, *Aphis gossypii* Glov. (Hemiptera: Aphididae), cotton leafhoppers, *Empoasca decipiens* (Paoli) (Hemiptera: Cicadellidae), tarnished plant bugs, *Lygus* spp. (Hemiptera: Miridae), and whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae), two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) which are key pests during the vegetative (growth), generative (flower, boll), and maturation stages (boll) of cotton (ZMMT, 2008; Gençsoylu *et al*., 2003; Atakan *et al*., 2004; Aydın and Şekeroğlu, 2008) [50], [18], [6], [7]. Sucking insect pests cause direct damage to cotton by extracting sap, which leads to leaf curling, discoloration, and stunted growth, ultimately resulting in yield losses and these pests serve as vectors for viruses and diseases, worsening the impact. (ZMMT, 2008) [50].

The relationship between crop plants and sucking insects is central to integrated pest management. Cultural practices such as planting density, irrigation, and fertilization can significantly influence pest populations (Naveed *et al*. 2012) [35]. Excessive irrigation and nitrogen fertilization can create favorable conditions for sucking insects (ZMMT, 2008) [50] by promoting softer, juicier plant tissues and higher humidity, which attracts pests like *A. gossypii* (Juhász, *et al*., 2022) [24]. Irregular irrigation can stress plants, reducing their resistance to pests, while balanced practices strengthen the plant's defenses, enhancing its resistance to these insects (Abd-Rabou and Simmons, 2012; Juhász *et al*., 2022) [1], [24].

The morphological characteristics and earliness of cotton plants are critical in determining their susceptibility or resistance to pests (Naveed *et al*., 2011) [35]. Features such as leaf structure, pubescence, bract shape, and nectar-producing glands significantly influence the behavior of pests with piercing-sucking mouthparts, like aphids, thrips, and mites (Oğlakçı and Çopur, 1995; Naveed *et al*., 2011) [36], [35]. By understanding these cotton plant characteristics, it is possible to select varieties that reduce the need for chemical pesticides, supporting environmentally friendly production methods. This approach helps maintain ecological balance and promotes sustainable agriculture practices, reducing the negative impact on the environment while ensuring crop health.

Irrigation methods play a critical role in increasing cotton yield and quality in Turkey (Basal *et al*., 2019) [8]. The most commonly used irrigation methods include furrow irrigation, sprinkler irrigation, and drip irrigation (Çetin and Bilgel, 2002) [8]. Furrow irrigation, although traditionally preferred in the Southeastern Anatolia region, is disadvantageous due to inefficient water use and the risk of increasing soil salinity (Ünlü *et al*.,2007) [46]. However, sprinkler irrigation ensures a more even distribution of water, but it is susceptible to wind and evaporation losses (King *et al*., 2012) [28]. In recent years, drip irrigation has become more popular, as it delivers water directly to the plant roots, conserving water and supporting environmental sustainability (Yang *et al*., 2023) [49]. Drip irrigation generally creates a lower moisture level (Guo and Li, 2024) [19] compared to surface irrigation, which can reduce the population of sucking pests such as whitefly.

Several studies have been conducted in Turkey on the population density, damage rates, bioecology, and biology of sucking pest species identified in cotton fields (Efil *et al*., 1999; Gençsoylu, 2001; Gençsoylu *et al*., 2003; Kılıç and Gençsoylu, 2015; Tanyolaç, 2018) [13], [17], [18], [26], [44]. However, studies on the effects of different irrigation methods and cotton variety characteristics on sucking insects throughout the cotton phenology are quite limited. The selection and application of the correct irrigation method is a crucial part of integrated pest management and can contribute to insect control in cotton production. This study addresses this aspect, and the main hypothesis of the research is to investigate the effect of three different irrigation methods and the morphological characteristics of two cotton varieties on the population density of certain important sucking pest species in Şanlıurfa, Türkiye

Materials and methods

The main materials of this study consisted of the early-maturing cotton varieties May-455 and Fiona which are commonly cultivated in the Şanlıurfa region. The sucking pest species *T. tabaci*, *A. gossypii*, *Lygus* spp., *T. urticae*, *E. decipiens*., and *B. tabaci*. The cotton variety, May-455 used in the study is a high-yielding, early-maturing variety with a normal leaf structure, hairy leaves, gossypol, and nectar-producing glands. The Fiona cotton variety is a high-yielding, hairless variety with a normal leaf structure, medium-to-late growing season, and gossypol and nectar-producing glands.

This study was conducted in 2022 at the Harran University Osmanbey Campus, Faculty of Agriculture, Experimental Field (37.166764 N, 39.006926 E) in Şanlıurfa. The experiments were arranged in a randomized block design with split plots, and were set up in a completely randomized design with three replications. The planting process was carried out in the second week of May. Each plot was adjusted to 72 m² (12 × 6 m), and the cotton was planted with a row spacing of 75 cm and a plant spacing of 10 cm. A 3-meter safety strip was left between each experimental plot for each character. As in the producer's practices, fertilizers were applied (40 kg of 20-20-0 (NPK) and 25 kg of 46% urea per decare). Cultivation and weed control were carried out physically.

The irrigation of the experimental plots was based on farmer practices for the calculation of irrigation intervals and durations. In the furrow irrigation method, Ø75 pipes were used to deliver irrigation water. In the sprinkler irrigation method, Ø75 pipes were used as lateral pipes, with a sprinkler head installed at the end of each pipe. The sprinkler system was laid out according to a 12 × 12 m grid. In the drip irrigation system, Ø75 pipes were used as manifolds, with a lateral pipe laid for each row. The lateral pipes had a discharge rate of 2.4 l h^{-1} (1 atm) and a dripper spacing of 33 cm. After planting the cotton seeds, sprinkler irrigation was applied to all plots to ensure uniform seed emergence. Once the seedlings had emerged and the plants in the experimental field reached a uniform level, three different irrigation methods were applied according to the specific plots. In both furrow and sprinkler irrigation, the irrigation interval was set to 10 days (with 12 hours of irrigation per day), while in drip irrigation, the interval was 8 days (also with 12 hours of irrigation per day). Soil samples were collected before and after irrigation from the experimental plots to monitor soil moisture content. This approach ensured that the soil moisture content did not fall below critical levels throughout the experiment.

The population densities of sucking pests were monitored starting from the basic development stage when the cotton plants had three true leaves, and the sampling continued weekly until the harvest period. The counts of the target pests, including *T. tabaci*, *A. gossypii*, *Lygus* spp., *T. urticae*, *E. decipiens*, and *B. tabaci*, were conducted during the early morning hours when the pests were inactive on the plants. A twenty leaves were randomly selected from the upper, middle, and lower parts of 10 plants in the inner rows of each plot. The pests were counted on these leaves using a magnifying glass. For the counts of *A. gossypii* and *T. urticae*, twenty leaves were cut from the same plants and transported under cold storage to the laboratory. The individuals of both species were counted separately using a microscope and magnifying glass. The data obtained from each irrigation method were subjected to variance analysis (ANOVA) using the XLSTAT program, and the groups were classified according to the Least Significant Difference (LSD) test, a multiple grouping test.

Results and discussion

The variance analysis revealed that the main effects of irrigation methods and cotton varieties significantly influenced the population density of *T. tabaci*. The irrigation method showed a statistically significant effect ($F = 11.451$, $P = 0.002$), with differences observed among the three irrigation methods. Similarly, the effect of cotton variety was highly significant ($F = 20.936$, $P = 0.001$), indicating that the morphological traits of the cotton varieties had a notable impact on *T. tabaci* populations. In contrast, the interaction between irrigation method and cotton variety was not statistically significant ($F = 0.465$, $P = 0.639$). Data on the weekly *T. tabaci* density obtained from three different irrigation methods are presented in Table 1.'

Table 1: The population density of *Thrips tabaci* monitored weekly under three different irrigation methods

Irrigation methods	18 June	25 June	2 July	9 July	16 July	23 July	30 July	6 August	13 August	20 August	Total number of individuals
FI*	6.76 a	6.27 a	5.81 a	2.14 a	1.43 a	1.55 a	3.48 a	2.96 a	1.79 a	1.24 a	33.46 a
SI*	6.20 a	6.12 a	5.09 a	1.49ab	1.48 a	2.24 a	3.08 a	2.06 b	1.89 a	1.11 a	30.78 a
DI*	5.15 b	6.07 a	4.55 a	1.25 b	1.09 a	1.35 a	2.96 a	2.12 b	1.60 a	1.19 a	27.37 b
P value	0,005**	0,977	0,208	0,087	0,319	0,115	0,466	0,056	0,647	0,879	0,002**

* FI =Furrow irrigation SI =Sprinkler irrigation DI =Drip irrigation
**Significance at p<0:001

Total *T. tabaci* population density across different irrigation methods revealed that the drip irrigation resulted in the lowest population (27.37 individuals), significantly differing from furrow irrigation with 33.46 individuals. Sprinkler irrigation showed an moderate population density (30.78 individuals) but was not differ significantly from either FI or DI (Table 1). These results indicate that drip irrigation was more effective in reducing *T. tabaci* populations compared to furrow irrigation. *Thrips tabaci* adult population density in irrigation methods and cotton varieties parameters were given in Figure 1.

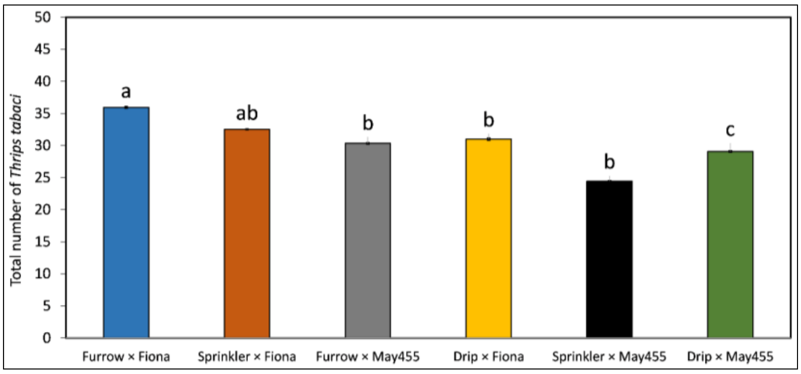

Fig 1: Population density of *Thrips tabaci* assessed under three different irrigation methods and two cotton cultivars (Fiona- May455)

The Fiona variety under furrow irrigation had the highest *T. tabaci* whereas, drip irrigation with the May-455 variety showed the lowest population density. However moderate population levels were observed for Fiona with drip and sprinkler irrigation, as well as for May-455 with furrow and sprinkler irrigation (Figure 1). The results suggest that both the irrigation method and the cotton variety significantly influence pest population dynamics, with the May-455 variety and drip irrigation offering better the pest control. *Thrips tabaci* populations varied under three irrigation methods and two cotton varieties, with the lowest densities observed under drip irrigation in the current study, this finding aligns with literature indicating that moisture availability influences thrips distribution and reproduction (Kirk, 1997) [29]. Juhász *et al*. (2022) [24] reported that drip irrigation reduced thrips densities on chili crops by minimizing surface humidity and water pooling. These results support the conclusion that drip irrigation can effectively manage *T. tabaci* populations compared to other irrigation methods.

The relationship between insect pests, plant morphological traits, and irrigation methods has been a focal point of agricultural research due to their combined effects on pest populations and crop resilience (Naveed *et al*. 2012; Juhász *et al*., 2022) [35], [24]. Numerous studies indicated that morphological traits, such as leaf trichomes (density and length), play a crucial role in reducing pest densities, including *B. tabaci* and *T. tabaci* (Oğlakçı and Çopur, 1995; Xing *et al*., 2017) [36], [47]. *Thrips tabaci* population density on the May-455 cotton variety was lower than on Fiona in the current study, Leaf hairiness, including hair density and length, is known to contribute to resistance against sucking pests (Oğlakçı and Çopur, 1995) [36]. Several studies have reported reduced *T. tabaci* densities on hairy-leaf cotton varieties (Gawaad *et al*., 1982; Efil *et al*., 1999; Conzemius *et al*., 2023) [16], [13], [11]. Morphological traits like hair density, length, and positioning also correlate with thrips populations (Arif *et al*., 2004) [3]. Similarly, *T. tabaci* densities were significantly lower on the hairy Darab variety compared to the glabrous Acala variety and on the hairy BM13H and Roseum A256 varieties (Miyazaki *et al*., 2017) [33].

The data of *A. gossypii* density obtained weekly in three different irrigation methods were given in Table 2.

Table 2: The population density of *Aphis gossypii* monitored weekly under three different irrigation methods

Irrigation methods	18 June	25 June	2 July	9 July	16 July	23 July	30 July	6 August	13 August	20 August	Total number of individuals
FI*	-	6.93 a	16.81 a	3.83 a	3.73 a	3.42 a	4.73 a	2.87 a	4.07 a	2.25 a	48.66 a
SI*	-	6.06 ab	17.23 a	3.57 a	2.84 a	3.43 a	3.93 a	2.93 a	3.35 a	1.56 a	44.93 a
DI*	-	4.88 b	14.64 a	4.74 a	3.37 a	2.77 a	5.60 a	2.48 a	2.99 a	1.89 ab	4.3.40 a
P value	-	0,055	0,445	0,577	0,483	0,679	0,584	0,433	0,409	0,134	0,440

* FI =Furrow irrigation SI =Sprinkler irrigation DI =Drip irrigation
**Significance at p<0:001

Results for the analysis of variance on the effects of irrigation methods and cotton varieties on *A. gossypii* population density results indicate that neither the irrigation method (F = 0.879, P = 0.440) nor the cotton variety (F = 3.541, P = 0.084) had a statistically significant effect on the population density of *A. gossypii*. Additionally, the interaction between irrigation method and cotton variety was not significant (F = 0.187, P = 0.832). The weekly population densities of *A. gossypii* under three different irrigation methods showed no statistically significant differences throughout the observation period (*P* > 0.05 for all dates). The total number of individuals was slightly higher under FI (48.66), followed by SI (44.93), and DI (43.40), but these differences were not statistically significant (Table 2). These results suggest that the irrigation method did not have a substantial impact on the overall population density of *A. gossypii* under the conditions studied. *Aphis gossypii* adult population density in irrigation methods and cotton varieties data were given in Figure 2.

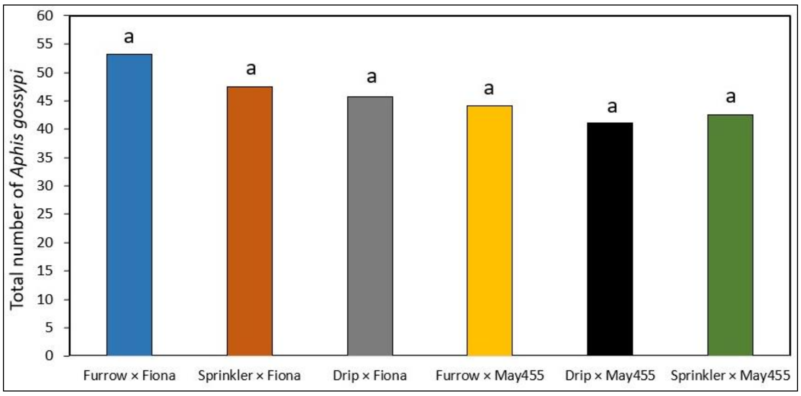

Fig 2: Population density of *Aphis gossypii* obtained under three different irrigation methods and two cotton cultivars (Fiona- May455)

The total number of *A. gossypii* individuals across various combinations of irrigation methods and cotton cultivars did not show any statistically significant changes. The Furrow × Fiona treatment exhibited the largest population; nonetheless, it was not significantly different from the other combinations (Figure 2). The findings indicate that neither the irrigation method nor the cotton type significantly influenced A. gossypii populations under the examined conditions.

The results showed that neither the irrigation methods nor the cotton varieties significantly influenced *A. gossypii* population density. This finding support with previous research, which indicates that while environmental factors like drought stress and irrigation can impact plant physiology, they may not always directly affect aphid populations in a statistically significant manner (Liu *et al*., 2023) [32]. Drought stress in cotton plants can reduce aphid fecundity by altering plant water content and nutrient availability (Liu *et al*., 2023) [32], while under adequate irrigation conditions aphid density often remains stable, unless extreme water stress occurs (Parajulee *et al*., 1997) [39]. Similarly, the lack of significant impact from cotton varieties might be due to the general adaptability of *A. gossypii* across different cultivars. Research shows that cotton aphids can exploit various cotton genotypes unless those varieties possess strong inherent resistance traits (Slosser *et al*., 1998) [43]. The results also showed that *Aphis gossypii* population density was unaffected by irrigation methods, cotton varieties, or their interaction. This suggests that neither water delivery systems nor cotton genetics significantly influenced aphid levels in this study. In contrast, Jiang *et al*. (2019) [23] found lower *A. gossypii* densities in drip-irrigated cotton compared to sprinkler irrigation in China. These findings highlight varying effects of irrigation on aphids, reflecting both support for and contradictions with our results. Such discrepancies may be due to differences in host plant species, aphid species, or aphid developmental stages. Consequently, while irrigation and variety selection are important for overall crop health, their effects on *A. gossypii* populations may be mediated by other factors, such as temperature, natural enemies, and plant chemical defenses.

The results displayed no statistically significant differences among cotton varieties in the total population of *A. gossypii* in the current study. Zarpas *et al*. (2006) [48] reported that cotton hairiness reduced *A. gossypii* densities in their study in Greece and the study also suggested a negative correlation between plant hairiness and *A. gossypii* population density. However, in contrast to these findings, our study had not observed significant differences based on cotton leaf hairiness, indicating that additional factors beyond morphological traits may influence *A. gossypii* populations.

The data of *Lygus* spp. density obtained weekly in three different irrigation methods has shown in Table 3.

Table 3: The population density of *Lygus* spp. monitored weekly under three different irrigation methods

Irrigation methods	18 June	25 June	2 July	9 July	16 July	23 July	30 July	6 August	13 August	20 August	Total number of individuals
FI*	-	-	0.16 a	0.10 a	0.04 a	0.12 a	0.12 a	0.07 a	0.05 a	0.05 a	0.73 a
SI*	-	-	0.12 a	0.11 a	0.07 a	0.07 a	0.12 a	0.02 a	0.07 a	0.12 a	0.71 a
DI*	-	-	0.19 a	0.09 a	0.02 a	0.10 a	0.09 a	0.02 a	0.02 a	0.09 a	0.65 a
P value	-	-	0,178	0,910	0,460	0,509	0,850	0,363	0,679	0,462	0,894

* FI =Furrow irrigation SI =Sprinkler irrigation DI =Drip irrigation

**Significance at p<0:001

Three different irrigation methods were not any statistically significant effect on the population density of *Lygus* spp (F= 0.113, *P*= 0.894) in the current study. These results collectively suggest that neither irrigation methods, cotton varieties, nor their combination had a measurable impact on the population density of *Lygus* spp. The total number of *Lygus* spp. individuals were 0.73, 0.71, and 0.65 for FI, SI, and DI, respectively. The weekly data indicate that *Lygus* spp. densities were generally low, with minor variations among the irrigation methods. Overall, the total number of *Lygus* spp. did not differ significantly among the irrigation methods (Table 3). These results suggest that irrigation methods had not significantly influence the density of *Lygus* spp. in the current study. *Lygus* spp. adult population density in irrigation methods and cotton varieties data has been given Figure 3.

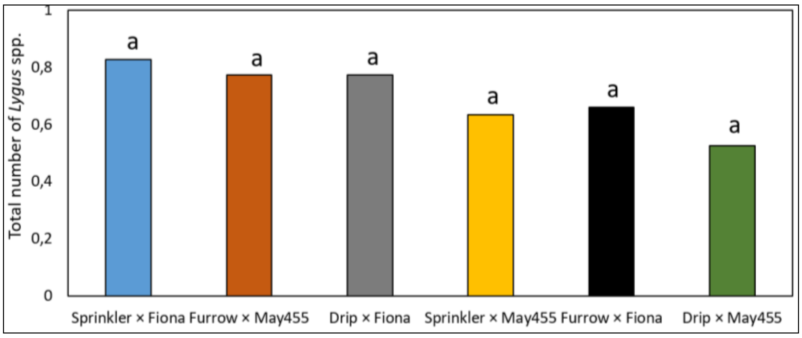

Fig 3: Population density of *Lygus* spp. obtained under three different irrigation methods and two cotton cultivars (Fiona- May455)

No significant differences were observed among the treatments (Figure 3). This suggests that neither the irrigation method nor the varieties significantly influenced the abundance of *Lygus* spp. in this study. The results of this study showed that different irrigation methods did not significantly affect *Lygus* spp. population density, which remained relatively low. Contrary our findings, Asiimwe *et al*. (2014) [5] observed increased *Lygus hesperus* Knight populations in furrow-irrigated plots and noted a 20% rise in pest density with increased irrigation levels. These studies suggest that drip irrigation tends to reduce *Lygus* spp. populations, supporting the findings of the current research. Furthermore, Armstrong *et al*. (2009) [4] observed that *Lygus* spp. deposited fewer eggs on okra-leaf, hairy cotton varieties. Consistent with their findings, this study also indicates that cotton varieties with leaf hairiness can have a suppressive effect on *Lygus* spp. populations, highlighting the role of plant morphology in pest management.

The data of *T. urticae* density obtained weekly in three different irrigation methods were given in Table 4.

Table 4: The population density of *Tetranychus urticae* determined weekly under three different irrigation methods

Irrigation methods	18 June	25 June	2 July	9 July	16 July	23 July	30 July	6 August	13 August	20 August	Total number of individuals
FI*	-	9.54 a	9.09 a	3.37 a	2.95 a	1.75 a	2.98 a	1.41 a	1.68 a	0.98 a	33.79 a
SI*	-	9.90 a	9.17 a	3.33 a	2.70 a	2.00 a	2.44 ab	1.05 ab	1.52 a	0.81 a	32.95 a
DI*	-	8.05 b	8.87 a	2.06 b	1.76 a	1.57 a	1.99 b	0.78 b	1.63 a	0.96 a	27.70 b
P value		0,007**	0,955	0,008**	0,339	0,600	0,060	0,131	0,893	0,841	0,028**

* FI =Furrow irrigation SI =Sprinkler irrigation DI =Drip irrigation
**Significance at p<0:001

The ANOVA results indicate that the *T. urticae* population density in cotton was significantly affected by the irrigation method (P = 0.028). However, the cotton varieties did not have a significant effect on the population density (P = 0.286). Additionally, the interaction between the irrigation method and the variety was not significant (P = 0.668). The weekly population densities and total population densities of *T. urticae* under three different irrigation methods showed notable variations. The highest total number of individual was observed under furrow irrigation at 33.79, followed by sprinkler irrigation with 32.95. The lowest total population was recorded under drip irrigation at 27.70 (Table 4). These results indicate that *T. urticae* populations are significantly lower under drip irrigation compared to furrow and sprinkler irrigation. *Tetranychus urticae* population density in irrigation methods and cotton varieties data were given in Figure 4.

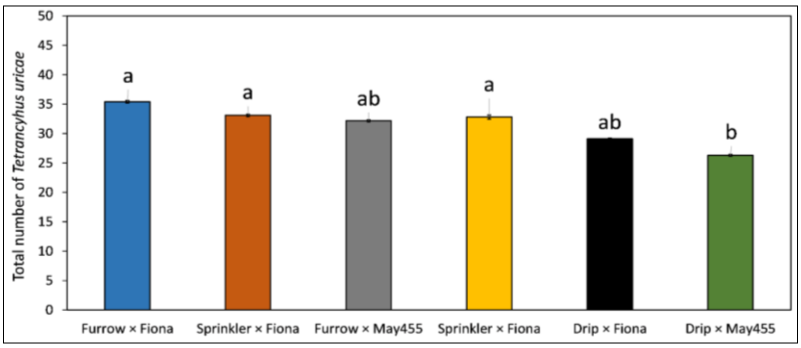

Fig 4: Population density of *Tetranychus urticae* monitored under three different irrigation methods and two cotton cultivars (Fiona- May455)

The results revealed that significant differences in *T. urticae* densities among different irrigation methods and cotton varieties. The highest *T. urticae* densities were observed in the combinations Furrow × Fiona, Sprinkler × Fiona, and Furrow × May455, which were not significantly different from each other. The lowest *T. urticae* densities were recorded for Drip × Fiona and Drip × May455 (Figure 4).

The findings suggested that irrigation methods influenced *T. urticae* population density, whereas cotton variety did not appear to have a notable impact. These results implied that environmental factors, such as soil moisture driven by different irrigation practices, played a more significant role in determining the mite population levels than plant genetics (Opit *et al*., 2001) [37]. Additionally, the lack of a combined effect between irrigation method and cotton variety indicated that their influence on *T. urticae* density operated independently. This underscored the importance of selecting appropriate irrigation strategies as a key factor in managing mite populations effectively. Opit *et al*. (2006) [38] found that *T. urticae* populations were four times lower in areas with sprinkler irrigation compared to drip irrigation. In contrast, He *et al*. (2018) observed lower *T. urticae* populations in drip-irrigated cotton fields. The findings from Opit *et al*. (2006) [38] indicated that sprinkler and furrow irrigation reduced *T. urticae* densities, whereas He *et al*. (2017) [21] showed a reduction under drip irrigation. The differences between these studies and the current research may be due to differences in plant species or varieties used.

There was no significant difference in *T. urticae* density between the two cotton varieties included in the current study. However, contrary to the findings of this study, other studies have reported that certain morphological traits of the leaves in different cotton varieties can influence the density of *T. urticae*. Reddall *et al*. (2010) [40] observed reduced *T. urticae* densities on hairy cotton varieties. Consistent with these findings, the current study also demonstrated that cotton varieties with leaf hairiness had a suppressive effect on *T. urticae* populations. This suggests that plant morphological traits, such as leaf hairiness, can play a crucial role in reducing pest densities and should be considered when developing pest management strategies.

The analysis of variance results for the effect of three different irrigation methods on *E. decipiens* population density in cotton indicated that none of the factors were statistically significant. The irrigation method showed a near-significant effect (*P*= 0.061, F= 3.559). Similarly, the cotton variety had a near-significant effect (*P*= 0.053, F= 4.619). The interaction between irrigation method and variety was not significant (*P* = 0.852). The data for *E. decipiens* density acquired weekly in three different irrigation methods were given in Table 5.

Table 5: The population density of *Empoasca decipiens* determined weekly under three different irrigation methods

Irrigation methods	18 June	25 June	2 July	9 July	16 July	23 July	30 July	6 August	13 August	20 August	Total number of individuals
FI*	1.59 a	1.86 a	1.93 a	0.89 a	0.19 a	0.32 a	2.16 a	1.87 a	1.78 a	1.52 a	14.13 a
SI*	1.38 a	1.93 a	1.55 a	0.82 a	0.20 a	0.39 a	1.83 a	1.63 a	1.64 a	0.92 a	12.31 ab
DI*	1.54 a	1.90 a	1.68 a	0.63 a	0.11 a	0.23 a	1.66 a	1.50 a	1.60 a	0.86 a	11.74 b
P value	0,602	0,972	0,327	0,347	0,738	0,464	0,490	0,509	0,860	0,154	0,061

* FI =Furrow irrigation SI =Sprinkler irrigation DI =Drip irrigation

**Significance at p<0:001

The highest total number of *E. decipiens* was observed in the FI (14.13 individuals), followed by SI (12.31 individuals) and DI (11.74 individuals). Although there was a trend of decreasing *E. decipiens* density under DI compared to FI, the difference among the irrigation methods was not statistically significant (P = 0.061, F = 3.40) (Table 5). The results suggest that irrigation method may influence *E. decipiens* density, with furrow irrigation potentially providing more favorable conditions for population growth compared to drip irrigation. *E. decipiens* population density in irrigation methods and cotton varieties data were given in Figure 4.

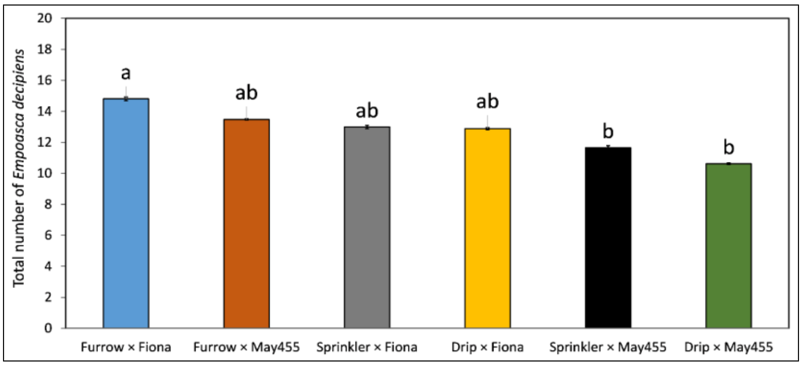

Fig 5: Population density of *Empoasca decipiens* monitored under three different irrigation methods and two cotton cultivars (Fiona-May455)

The total number of *E. decipiens* varied significantly across the irrigation systems and plant varieties examined. The highest number of individuals was observed in the combination of Furrow irrigation with the Fiona variety. The combinations of Sprinkler × Fiona, Drip × Fiona, and Furrow × May455 exhibited moderate levels of *E. decipiens* populations, with no significant differences among these treatments. The combinations of Drip × May455 and Sprinkler × May455 displayed the lowest numbers of *E. decipiens* in the current study (Figure 5). These findings suggest that the irrigation method and cotton cultivar interact to influence *E. decipiens* population density. Specifically, the Fiona cultivar combined with furrow irrigation creates more favorable conditions for *E. decipiens*, while the May455 cultivar under sprinkler and drip irrigation limits their population growth.

The findings suggested that while cotton varieties were not produce statistically significant differences in *E. decipiens*. population density. However, the results of irrigation methods also indicated that while weekly population densities of *E. decipiens* did not significantly vary between irrigation methods, furrow irrigation ultimately supported higher total population densities compared to drip irrigation. These findings indicate that drip irrigation may be a more effective method for reducing *E. decipiens* populations, whereas furrow irrigation appears to create conditions that favor higher pest densities. Several studies corroborate the finding that irrigation methods significantly influence *E. decipiens* populations. In particular, furrow irrigation tends to support higher population densities compared to drip irrigation. Fornasiero *et al*. (2012) [15] observed higher densities of *Empoasca vitis* (Goethe) in vineyards with drip irrigation compared to non-irrigated plots where water stress was more severe. Additionally, Sabra (2012) [41] noted that *E. decipiens* populations were influenced by environmental factors, with increased humidity and optimal temperature ranges contributing to higher infestation rates, further suggesting that irrigation type can create favorable conditions for these pests. The relationship between plant stress and pest abundance under different irrigation regimes may explain why furrow irrigation supports higher *E. decipiens* populations by providing consistent moisture levels compared to the more controlled water delivery of drip irrigation. This emphasizes the influence of varying moisture levels on aphid population dynamics based on the selected irrigation strategy. This difference may be attributed to differences in the plant species used in the studies. Atakan *et al*. (2004) [6] observed significantly higher populations of *E. decipiens*. on cotton varieties with few or no hairs compared to hairy varieties. This finding aligns with studies showing that *E. decipiens* prefers hairless cotton varieties, resulting in lower densities on hairy ones (Hassan *et al*., 1999) [20]. However, some researches reported higher *Empoasca* spp. populations on hairy varieties (Butler *et al*., 1991; Ahmad *et al*., 2004; Singh *et al*., 2022) [9], [2], [42]. Similarly, Tanyolaç (2018) [44] found higher *Asymmetresca decedens* populations on hairless varieties like Gloria and Claudia, while lower densities occurred on hairy types such as Özbek105, PG2018, and GSN12. These variations suggested that plant traits and pest species interactions may influence results. Consistent with this, our study indicates that hairy cotton varieties reduce *E. decipiens* populations.

The data for *B. tabaci* density obtained weekly in three different irrigation methods were given in Table 6

Table 6: The population density of *Bemisia tabaci* determined weekly under three different irrigation methods

Irrigation methods	18 June	25 June	2 July	9 July	16 July	23 July	30 July	6 August	13 August	20 August	Total number of individuals
FI*	-	-	-	-	-	-	2.56 a	3.57 a	4.12 a	8.23 a	18.49 a
SI*	-	-	-	-	-	-	2.57 a	3.57 a	4.13 a	5.94 a	16.22ab
DI*							2.51 a	2.69 a	3.52 a	5.70 a	14.43 b
P value							0,974	0,133	0,650	0,140	0,010**

* FI =Furrow irrigation SI =Sprinkler irrigation DI =Drip irrigation
**Significance at p<0:001

The analysis of variance indicated that the irrigation method and cotton variety significantly affected the population density of *B. tabaci*. The effect of the irrigation method was statistically significant (*P* = 0.010, F = 7.019,), as was the effect of the cotton variety (P = 0.007, F = 10.451). However, the interaction between irrigation method and cotton variety was not significant (*P* = 0.500, F = 0.735,). The data of *B. tabaci* density obtained weekly in three different irrigation methods were given in Table 6.

The highest total number of individuals was observed under FI (18.49 individuals), followed by SI irrigation (16.22 individuals), and the lowest population was recorded for DI (14.43 individuals) (Table 6). The differences in total population densities were statistically significant (P = 0.010, F = 6.69), indicating that irrigation methods influence *B. tabaci* population growth. These findings suggested that FI creates more favorable conditions for *B. tabaci* populations, while DI helps reduce their density. *Bemisia tabaci* population density in irrigation methods and cotton varieties data were given in Figure 6.

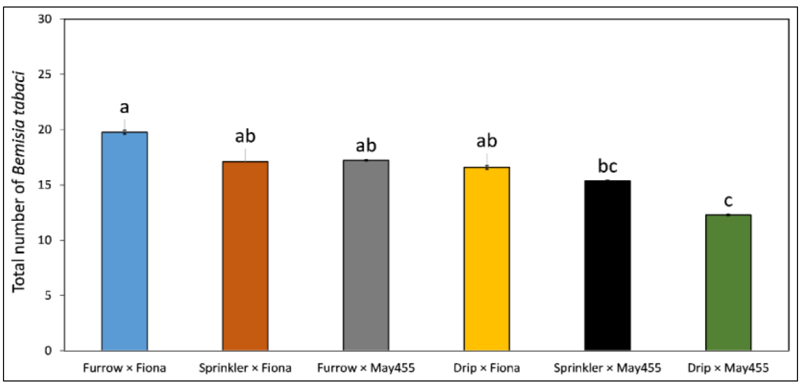

Fig 6: Population density of *Bemisia tabaci* determined under three different irrigation methods and two cotton cultivars (Fiona- May455)

The population of *B. tabaci* individuals showed significant variation depending on the irrigation methods and cotton varieties. The highest population was recorded in the Furrow × Fiona treatment, while the lowest was observed in the Drip × May455 treatment. Moderate number of *B. tabaci* were found in other combinations, with significant differences indicated by the statistical groupings (Figure 6). These results suggested that both irrigation methods and cotton varieties play a role in influencing *B. tabaci* populations.

The results indicated that the significant influence of both irrigation methods and cotton variety on *B. tabaci* population density. Furrow irrigation was the highest number of *B. tabaci*, followed by sprinkler irrigation, while the lowest population was observed under drip irrigation. These findings suggest that irrigation practices play a crucial role in shaping *B. tabaci* populations, potentially due to differences in humidity and microclimate created by each method. The findings of this study support with previous research indicating that *B. tabaci* populations were influenced by irrigation methods. Abd-Rabou and Simmons (2012) [1] reported higher *B. tabaci* densities under sprinkler irrigation compared to drip irrigation on various vegetable crops. Similarly, Gençsoylu *et al*. (2003) [18] and Flint *et al*. (1992) [14] stated that furrow irrigation supported higher *B. tabaci* densities than drip irrigation in cotton fields. Leggett (1993) [30] also observed the highest populations under furrow irrigation. These studies, consistent with the results of the current research, suggest that furrow irrigation generally favors *B. tabaci* increase, while drip irrigation was less conducive to population growth. Differences in plant type may account for the minor variations observed across studies.

Regarding leaf pubescence, some researchers have stated that an increase in pubescence in cotton was associated with an increase in *B. tabaci* density (Butler *et al*., 1991) [9]. The findings of this study indicated that *B. tabaci* populations were lower on cotton varieties with hairy leaves, which aligned with several previous studies. Researchers such as Hassan *et al*. (1999) [20] reported higher *B. tabaci* densities on hairy plants. Conversely, study by Nanov *et al*. (1991) [34] found fewer *B. tabaci* eggs on hairy cotton varieties compared to glabrous ones. Aydın and Şekeroğlu (2008) [7] observed significantly higher *B. tabaci* populations on glabrous cotton varieties grown in Çukurova. Tanyolaç (2018) [44] reported the highest *B. tabaci* densities on glabrous varieties like GSN12, while hairy varieties like Claudia and Gloria supported the lowest populations. These findings suggested that leaf hairiness generally reduced *B. tabaci* densities, though discrepancies between studies appeared to stem from differences in the cotton varieties examined.

Conclusion

This study highlights the significant influence of plant leaf traits (hairy and hairless) and three irrigation methods on sucking pest populations in cotton cultivation. Morphological features such as leaf hairiness play a critical role in reducing the densities of pests like *T. tabaci*, *Lygus* spp., and *B. tabaci*. Hairy cotton varieties demonstrated a consistent ability to suppress these pests, likely by creating physical barriers that hinder feeding, oviposition, and movement. Additionally, the study found that drip irrigation reduced populations of *T. tabaci*, *E. decipiens*, and *B. tabaci* compared to furrow and sprinkler irrigation. It was concluded that this reduction was due to the lower humidity and controlled moisture conditions provided by drip irrigation, which created less favorable microenvironments for pest proliferation. In contrast, *A. gossypii* populations showed no significant response to either cotton variety or irrigation method, suggesting that factors beyond morphology and water management, such as temperature and natural predators, might be more influential in regulating aphid densities. Similarly, *T. urticae* populations were primarily influenced by irrigation methods rather than plant traits, indicating the importance of moisture levels in managing the mite infestations. These findings underscore the necessity of integrating both plant breeding for pest-resistant traits and optimized irrigation strategies to achieve sustainable pest management in cotton production.

Author’s contribution

The authors contributed equally for conceptualization and designing, collection of plant, collection of insect and data collection, analysis of data and interpretation and preparation of manuscript of this research paper.

Conflict of Interest

Authors have declared that no competing interests exist.

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References

1. Abd-Rabou S, Simmons AM. Effect of three irrigation methods on incidences of *Bemisia tabaci* (Hemiptera: Aleyrodidae) and some whitefly-transmitted viruses in four vegetable crops. Trends in Entomology, 2012, 8.
2. Ahmad S, Shah M, Farooq HMK, Ullah F. Resistance of cotton against *Amrasca devastans* (Dist.) (Jassidae: Homoptera) and relationship of the insect with leaf hair density and leaf hair length. Sarhad Journal of Agriculture,2004:20(2):265-268.
3. Arif MJ, Sial IA, Ullah S, Gogi MD, Sial MA. Some morphological plant factors affecting resistance in cotton against thrips (*Thrips tabaci* L.). *International Journal of Agriculture and Biology*,2004:6:544-546.
4. Armstrong JS, Coleman RJ, Sétamou M. Oviposition patterns of *Creontiades signatus* (Hemiptera: Miridae) on okra-leaf and normal-leaf cotton. *Annals of the Entomological Society of America*,2009:102(2):196-200.
5. Asiimwe P, Naranjo SE, Ellsworth PC. Effects of irrigation levels on interactions among *Lygus hesperus* (Hemiptera: Miridae), insecticides, and predators in cotton. *Environmental Entomology*,2014:43(2):263-273.
6. Atakan E, Boyacı K, Gençer O. Population development of leafhoppers [*Asymmetrasca decedens* Paoli and *Empoasca decipiens* Paoli (Homoptera: Cicadellidae)] on some cotton varieties in Çukurova. *Turkish Journal of Entomology*,2004:28(4):267-273.
7. Aydın L, Şekeroğlu N. Integrated management strategies for controlling *Bemisia tabaci* in cotton fields

of the Çukurova region, Turkey. *Journal of Pest Science*,2008:81(5):55-64.

8. Basal H, Karademir E, Goren HK, Sezener V, Dogan MN, Gencsoylu I, *et al*. Cotton production in Turkey and Europe. In: *Cotton Production*, 2019, 297-321.
9. Butler GD, Wilson FD, Fishler G. Cotton leaf trichomes and populations of *Empoasca lybica* and *Bemisia tabaci*. *Crop Protection*,1991:10(6):461-464.
10. Çetin Ö, Bilgel L. Effects of different irrigation methods on cotton yield and water use efficiency in the Harran Plain, Turkey. *Agricultural Water Management*,2002:54(1):1-15.
11. Conzemius SR, Reay-Jones FP, Greene JK, Campbell BT, Reisig DD, Wang H, Bridges WC. Field screening of wild cotton, *Gossypium hirsutum*, landraces for resistance to thrips (Thysanoptera: Thripidae). *Crop Protection*, 2023, 163, Article 106113.
12. Çopur O. The impact of the GAP Project on cotton production in Turkey: Changes over the last decade. *Adıyaman University Journal of Agricultural Practices and Land Management Research Center*,2018:6(1):11-18.
13. Efil L, Özgür AF, İlkhan A. Harran Ovası'nda farklı pamuk çeşitlerinde *Thrips tabaci* Lind. (Thysanoptera: Thripidae) ve *Empoasca* spp. (Homoptera: Cicadellidae)'nin populasyon gelişmesinin belirlenmesi. *Harran Üniversitesi Ziraat Fakültesi Dergisi*,1999:3(3-4):97-106.
14. Flint HM, Parks NJ, Hendrix DL, Wilson ED, Radin JW. Whitefly population growth in cotton: A 3-year study in Maricopa, Arizona. *U.S. Department of Agriculture Research Service (ARS)*, 1992, 93.
15. Fornasiero D, Duso C, Pozzebon A, Tomasi D, Gaiotti F, Pavan F. Effects of irrigation on the seasonal abundance of *Empoasca vitis* in North-Italian vineyards. *Journal of Economic Entomology*,2012:105(1):176-185.
16. Gawaad AAA, El-Gayar FH, Soliman AS. Effect of cotton varieties on population density of *Thrips tabaci* Lind. and *Empoasca lybica* de Berg. *Assiut Journal of Agricultural Sciences*,1982:13(2):167-177.
17. Gençsoylu İ. A research on population dynamics of cotton pests, relationship with natural enemies and their effects on cotton quality and fibers in different management programs in the Great Menderes Valley. *Adnan Menderes University, Institute of Science, Department of Plant Protection*, 2001, 248.
18. Gençsoylu I, Horowitz AR, Sezgin F, Öncüer C. Effect of drip and furrow irrigation methods on *Bemisia tabaci* populations in cotton fields. *Phytoparasitica*,2003:31(2):139-143.
19. Guo H, Li S. A review of drip irrigation's effect on water, carbon fluxes, and crop growth in farmland. *Water*, 2024, 16(15), Article 2206.
20. Hassan M, Ahmad F, Mushtaq F. Role of physico-morphic characters imparting resistance in cotton against some insect pests. *Pakistan Entomologist*,1999:21(12):61-62.
21. He J, Zhou L, Yao Q, Liu B, Xu H, Huang J. Greenhouse and field-based studies on the distribution of dimethoate in cotton and its effect on *Tetranychus urticae* by drip irrigation. Pest Management Science,2018:74(1):225-233.
22. ICAC. Turkey's cotton industry: Challenges and future prospects. International Cotton Advisory Committee, 2022. https://www.icac.org
23. Jiang H, Wu H, Chen J, Tian Y, Zhang Z, Xu H. Sulfoxaflor applied via drip irrigation effectively controls cotton aphid (*Aphis gossypii* Glover). *Insects*, 2019, 10(10), Article 345.
24. Juhász E, Németh Z, Kovács J. Effects of irrigation methods on the dynamics of pest populations in agriculture. Journal of Applied Entomology,2022:146(8):940-949.
25. Khyali Ram, Kumar D, Kalkal D, Puneet. Seasonal abundance of sucking pests and natural enemies in Bt cotton ecosystem and their correlation with abiotic factors. *The Pharma Innovation Journal*,2021:10(10):2065-2067.
26. Kılıç S, Gençsoylu İ. Determination of Population Changes of Some Significant Cotton Pests and Natural Enemies in The Second-Crop Cotton (*Gossypium hirsutum* L.) Varieties of Aydin Province. *Journal of Adnan Menderes University Agricultural Faculty*,2015:12(1):109-117.
27. Kılıç S, Gençsoylu İ. Determinate the population dynamics of sucking-piercing pest in cotton planted as second crop in Aydın. Jornal of Central Research Institute for Field Crops,2016:25(2):118-124.
28. King BA, Dungan RS, Bjorneberg DL. Evaluation of center pivot sprinkler wind drift and evaporation loss. American Society of Agricultural and Biological Engineers, 2012.
29. Kirk WD. Distribution, abundance and population dynamics. In: Thrips as Crop Pests. CAB International, 1997, 217-257.
30. Leggett JE. Comparison of arthropods sampled from cultivars of upland and pima cotton with drip and furrow irrigation. Southwestern Entomologist,1993:18:37-43.
31. Liao H, Liu K, Hao H, Yong Y, Zhang W, Hou Z. Effects of irrigation amount and nitrogen rate on cotton yield, nitrogen use efficiency, and soil nitrogen balance under drip irrigation. *Agronomy*,2024:14(8):1671:1-22.
32. Liu J, Wang C, Li H, Gao Y, Yang Y, Lu Y. Bottom-up effects of drought-stressed cotton plants on performance and feeding behavior of *Aphis gossypii*. *Plants*,2023:12(15):2886.
33. Miyazaki J, Stiller WN, Wilson LJ. Sources of plant resistance to thrips: A potential core component in cotton IPM. *Entomologia Experimentalis et Applicata*,2017:162(1):30-40.
34. Nanov A, Melamed Madjer V, Zur M. Effects of a primitive cotton accession in feeding of *Spodoptera littoralis* and *Helicoverpa armigera* and on oviposition of *Bemisia tabaci* Genn. *Phytoparasitica*,1991:19(2):143-147.
35. Naveed M, Anjum ZI, Khan JA, Rafiq M, Hamza A. 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,2011:43(2):229-236.
36. Oğlakçı M, Çopur O. The relationship of the chemical and morphological traits of cotton for resistance to insects. In: Proceedings of the GAP Region Plant

Protection Problems and Solutions Symposium, Şanlıurfa, Turkey, 1995, 1-19.
37. Opit GP, Jonas VM, Williams KA, Margolies DC, Nechols JR. Effects of cultivar and irrigation management on population growth of the twospotted spider mite *Tetranychus urticae* on greenhouse ivy geranium. *Experimental & Applied Acarology*,2001:25:849-857.
38. Opit G, Greg KF, Margolies D, Nechols JR. Overhead and drip-tube irrigation affect twospotted spider mites and their biological control by a predatory mite on impatiens. *HortScience*,2006:41(3):691-694.
39. Parajulee MN, Montandon R, Slosser JE. Relay intercropping to enhance abundance of insect predators of cotton aphid in Texas cotton. *International Journal of Pest Management*,1997:43:227-232.
40. Reddall AA, Sadras VO, Wilson LJ, Gregg PC. Contradictions in host plant resistance to pests: spider mite (*Tetranychus urticae Koch*) behaviour undermines the potential resistance of smooth-leaved cotton (*Gossypium hirsutum* L.). Pest Management Science,2011:67(3):360-369.
41. Sabra IM. Infestation density of leafhoppers; *Empoasca decipiens* and *Orosius albicinctus*. *Fayoum Journal of Agricultural Research and Development*,2012:26(1):93-98.
42. Singh V, Mandhania S, Pal A, Kaur T, Banakar P, Sankaranarayanan K, Datten R. Morpho-physiological and biochemical responses of cotton (*Gossypium hirsutum* L.) genotypes upon sucking insect-pest infestations. *Physiology and Molecular Biology of Plants*,2022:28(11):2023-2039.
43. Slosser JE, Pinchak WE, Rummel DR. Biotic and abiotic regulation of *Aphis gossypii* in West Texas dryland cotton. *Southwestern Entomologist*,1998:23:31-36.
44. Tanyolaç S. Population Fluctuations of Sucking Pests and Their Effects in Terms of Yield and Quality on Some Cotton Varieties. Doctoral Thesis, Ege University Institute of Science, 2018, 164.
45. TUIK. Crop production statistics, 2022. https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=2
46. Ünlü M, Kanber R, Onder S, Sezen M, Diker K, Ozekici B, Oylu M. Cotton yields under different furrow irrigation management techniques in the Southeastern Anatolia Project (GAP) area, Turkey. *Irrigation Science*,2007:26:35-48.
47. Xing Z, Liu Y, Cai W, Huang X, Wu S, Lei Z. Efficiency of trichome-based plant defense in *Phaseolus vulgaris* depends on insect behavior, plant ontogeny, and structure. *Frontiers in Plant Science*,2017:8:2006.
48. Zarpas KD, Margaritopoulos JT, Stathi L, Tsitsipis JA. Performance of cotton aphid *Aphis gossypii* (Hemiptera: Aphididae) lineages on cotton varieties. International Journal of Pest Management,2006:52(3):225-232.
49. Yang P, Wu L, Cheng M, Fan J, Li S, Wang H, Qian L. Review on drip irrigation: impact on crop yield, quality, and water productivity in China. *Water*,2023:15(9):1733.
50. ZMMT. Technical Instructions for Plant Protection (Volume 2). Ministry of Agriculture, Forestry, and Rural Affairs, General Directorate of Agricultural Research Publications, Ankara, Türkiye, 2008.