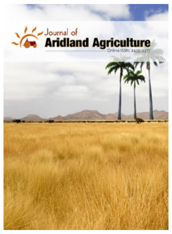
Journal of Aridland Agriculture 2023, 9: 39-43
doi: 10.25081/jaa.2023.v9.7676
https://updatepublishing.com/journal/index.php/jaa

Research Article



ISSN: 2455-9377

Estimating the infection severity and infection percentage by aphids on eggplant varieties

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Received: May 04, 2022
Revised: July 03, 2023
Accepted: July 04, 2023
Published: July 15, 2023

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ABSTRACT

Finding a new source of resistance is important to reduce the use of synthetic pesticides, which can meet the global need of suppressing pollution. In this study, the resistance of eight eggplant cultivars to *Aphis gossypii* was evaluated. Results of the current study highlighted that the cultivar Long-Green has a very strong resistance after 14 days post infestation whereas Pearl-Round and White-Casper cultivars were susceptible. The rest of the tested cultivars (Green-oblong, Purple-panter, Paris, Ashbilia, and Barcelona) had mild resistance. Also, the study found significant differences between the infested and non-infested plants among the tested cultivars in the plant's height, fresh-, and dry-weight. The susceptible cultivars lost about 30% of their height, fresh- and dry-weight after the infestation compared with the cultivars that had mild resistance. Pearl-Round and White-Casper showed a very strong susceptibility among the evaluated cultivars which may be used as an element in the pest control program against *A. gossypii*.

KEYWORDS: Eggplant, *Aphis gossypii*, Arthropod-plant interaction, Resistance

INTRODUCTION

Arthropod pests are very important in affecting the world economy (Aguirre-Rojas *et al.*, 2019; Zhao *et al.*, 2019; Kern *et al.*, 2022; Khalaf *et al.*, 2023). The family of Aphididae is one of the arthropod families which plays an essential role in reducing many crops' yields worldwide due to causing direct damage to many hosts, and indirect damage by transmitting many agriculturally important plant viruses (Adhab, 2010, 2021; Al-Ani *et al.*, 2011a; Adhab & Schoelz, 2015; Adhab *et al.*, 2019). A very good example of this family is the cotton aphid, *Aphis gossypii* (Glover), (Kocourek et al., 1994; Shrestha & Parajulee, 2013). Two important viruses transmitted by *A. gossypii* to the cotton, cotton bunchy top virus (Genus: Polerovirus, Family: Luteoviridae), recorded in Australia, and the other, CLRDV found in India, Africa, South America, and the US (Michelotto & Busoli, 2007; Mukherjee *et al.*, 2016; Avelar *et al.*, 2019).

The cotton aphid, has a very wide host range, such as cotton, melon cucumber, watermelon zucchini, tomato, chili, and eggplant (Blackman & Eastop, 2000). The eggplant is an economically important vegetable crop, due to its large number of fruit varieties that differ in color, shape, and size; also, it does have a positive impact on the human health in terms of providing biologically active compounds, minerals, and vitamins (Docimo *et al.*, 2016). Many chemical compositions reported that eggplant has a different biological role, like cardioprotective, antioxidant, anti-inflammatory, anti-obesity, anti-diabetic, antibacterial, and anti-carcinogenic probably due to its phenolic composition (Gürbüz *et al.*, 2018). India is the origin place of eggplant, Japan and China are considered the secondary centers of this vegetable origin and the cultivation gradually introduce to be spread to the Europe, America, the Mediterranean, and Africa (FAOSTAT, 2021). Recently, eggplants have obtained scientists' attention and consumers as well because of its nutritional and biological value (Gürbüz *et al.*, 2018; Mauro *et al.*, 2020).

Agricultural System Management can be influenced based on farm conditions (Al-Aani *et al.*, 2018). *A. gossypii* attacks eggplant, *Solanum melongena*, in the early stage of the plant development by sap-sucking (Dixon, 1997). This aphid excretes honeydew which creates a good microenvironment to develop *Capnodium* spp. which can slow down the plant photosynthetic rate, consequently, plant weakening (Blackman & Eastop, 2000; Slosser *et al.*, 2002; Fontes *et al.*, 2006). Estimation of yield loss by *A. gossypii* on eggplant when an outbreak occurs could reach 56% (Ghosh, 2012).

Controlling volunteer grasses to manage *A. gossypii* population outbreaks is complicated by many factors. Many species of range of grasses serve as hosts to aphids. Insecticide application is a good option to control A. *gossypii* (Liang *et al*., 2019). However, insecticides are used at frequencies and doses above the recommended most often, which could increase the possibility of emerging resistance of arthropod populations that may have resistant to many active ingredients (Nauen & Elbert, 2003).

Therefore, after more than a century, the plant resistance remains the most economically viable and environmentally safe approach to reduce yield losses from pest arthropod infestations (Smith, 1999); hence, using the plant resistance tactic to maintain the pest populations below the economic injury level, consequently reducing production costs (Smith, 2005).

Searching for new sources of resistance to arthropods is a key factor to reduce the yield loss (Chuang *et al*., 2017; Aguirre-Rojas *et al*., 2019; Khalaf *et al*., 2019), due to a few studies have evaluated the behavior of eggplant genotypes under the stress of A. *gossypii*, this study amid to assess the resistance of 10 eggplant genotypes to A. *gossypii* to develop a sustainable agricultural and thus, improve the cotton aphid management.

MATERIALS AND METHODS

Plant and Insect Material

The experiment was conducted under field conditions from the middle of March to the end of July in Al-Yusufiyah area in southern Baghdad (33°4'30″N 44°14'42″E).

A*phis gossypii* individuals were maintained on the susceptible eggplant cultivar White-Casper. Seeds from eight varieties: Paris, Ashbilia, Barcelona, Pearl-Round, White-Casper, Long-Green, Green-Oblong, Purple-Panter were kept in a soaked paper towel for 14 h before planting. All seeds were grown in 18 x 15 cm (diameter/height) plastic pots with peat moss potting mix. The pots were kept in the greenhouse at 25 ± 5 °C, 60 ± 10% RH, and a natural photoperiod. A. *gossypii* originated from a field collection in Baghdad province collected in 2020 and 2021. The cotton aphid colony was kept and maintained at 24:20 °C day/night and a 14:10 [L: D] h photoperiod. A cytochrome oxidase I (COI) polymorphisms marker (AlShabar *et al*., 2021), following (Khalaf *et al*., 2020) was used to verify the aphids are A. *gossypii*.

Thirty plants of each of the 8 eggplant genotypes were evaluated whether they have resistance (antibiosis) against cotton aphids. One seed of each of the eight breeding lines was grown in 11 x 9.5 cm plastic pots. All pots were then placed inside a 5 x 6 x 1.8 m mash cage to prevent contamination.

Thirty seedlings at the six-leaf stage of each tested genotype (five replications) were then infested with 5 A. *gossypii* adults and caged for only 14 day after infestation. Then, the assessment of each plant was done by counting the number of aphids on each plant. For dry weight calculation, the seedlings were dried at 60 °C in an oven for seven days. Plant height calculation was done by measuring directly above the soil level till the plant tip. The fresh and dry weight of each cultivar were measured according to the formulas shown in Table 1.

Data Analyses

A. *gossypii* virulence response experiments were arranged in completely randomized designs and data were subject to ANOVA using PROC GLIMMIX SAS software v.9.4 (SAS, 2009). Each parameter was analyzed independently. Means were separated by Tukey's test at $P<0.05$.

RESULTS

To evaluate the susceptibility of each cultivar to A. *gossypii*, we counted the number of adults aphids on each eggplant variety at two, four, seven, and fourteen days after infestation (dai). Table 2 shows, significant differences in the mean number of A. *gossypii* adults produced in choice tests using Long-Green resistant control, White casper susceptible control, and eggplant varieties ($F = 7.9$; $df = 7$; $p < 0.0001$); ($F = 10.7$; $df = 7$; $p < 0.0001$); ($F = 24.5$; $df = 7$; $p < 0.0001$); ($F = 50.2$; $df = 7$; $p < 0.0001$) at 2-, 4-, 7-, and 14-days post infestation. There was no significant difference in the number of adult aphids between Pearl-Round and the susceptible cultivars in the entire experiment. At 14 dai, the rest of the testing cultivars showed a significant difference from the susceptible control; however, they showed significant differences from the resistant control. At 7 and 4 dai, the Green-oblong was the only cultivar did not differ significantly from the resistant control, whereas, the rest of the testing cultivars showed significant differences from the susceptible control. At 2 dai, the only Ashbilia and Barcelona were different than the susceptible and the resistant control.

Table 1 highlighted that A. *gossypii* infestation had significant effects on the eggplant plant's parameters, which decreases in plant height percentage ($F = 5.81$; $df = 7$; $p < 0.05$), the fresh weight percentage ($F = 16.12$; $df = 7$; $p < 0.05$), and the dry weight percentage ($F = 14.10$, $df = 7$; $p < 0.05$) by the end of the experiments. The biggest decrease percentages among the cultivars occurred on Pearl-Round and White-Casper (susceptible eggplant control) in all parameters were examined (height, fresh weight, and dry weight loss), while the lowest decrease percentages among the cultivars occurred on Long-Green (resistant eggplant control), Green-oblong, and Purple-panter. The full picture tends to be three groups of the six eggplant testing varieties in the entire experiment with all evaluated parameters. The cultivars Green-oblong and Purple-panter did not differ significantly from the resistant control. The cultivars Paris, Ashbilia, and Barcelona showed significant differences from the resistant and susceptible control. The cultivar Pearl-Round did not differ significantly from the susceptible control.

DISCUSSION

Farming practices have dramatically changed in the 21st Century (Al-Neami *et al*., 2011; Al-Aani *et al*., 2016), which enhanced many arthropods to rapidly overcome some plants' resistance traits; thus, it is very important to evaluate the A. *gossypii* on eggplant due to its economic impact in Iraq (Al-Ani *et al*.,

Table 1: Mean percentage proportional plant height change, percentage proportional plant weight change, and mean percent proportional plant dry weight change, in six eggplant varieties and two control eggplant varieties at 14 days post *A. gossypii* infestation in a non-choice experiment

Eggplant Cultivars	Mean (lower, upper CI) Percentage Proportional Change		
	Height Reduction %	Weight loss %	Dry weight loss %
Long-Green-R	10.91 (0.5, 6.01)a	12.71 (0.8, 17.91)a	9.97 (0.8, 16.77)a
Green-oblong	11.02 (0.5, 7.22)a	12.89 (0.9, 19.01)a	10.11 (0.8, 18.12)a
Purple-panter	13.01 (0.6, 8.91)a	13.04 (1.1, 19.99)a	12.01 (0.9, 19.19)a
Paris	18.82 (1.2, 16.71)b	29.16 (3.1, 21.07)b	26.17 (2.19, 22.20)b
Ashbilia	19.75 (2.2, 30.01)b	31.91 (4.6, 23.19)b	30.66 (3.96, 29.92)b
Barcelona	20.23 (3.0, 39.22)b	33.01 (5.89, 29.01)b	32.09 (4.51, 31.67)b
Pearl-Round	33.21 (6.01, 50.01)c	53.77 (12.19, 32.33)c	51.91 (8.14, 42.76)c
White casper-S	42.24 (7.29, 63.41)c	56.12 (14.01, 34.34)c	53.11 (9.19, 50.12)c

Means followed by different letters are significantly different based on Tukey–Kramer means separation tests ($P<0.05$). R - Resistant eggplant control; S - susceptible eggplant control; CI - confidence interval. Percentage proportional plant height change = ([plant height non-infested−plant height infested]/plant height non-infested) × 100. Percentage Proportional plant weight change = ([plant weight non-infested−plant weight infested]/plant weight non-infested) × 100. Percentage proportional plant dry weight change = ([dry weight non-infested−dry weight infested]/dry weight non-infested) × 100.

Table 2: Mean number of *A. gossypii*, in six eggplant varieties and two control eggplant varieties at 14 days post *A. gossypii* infestation in a non-choice experiment

Eggplant Cultivars	Mean (lower, upper CI) # Adult Aphids			
	Days after infestation (dai)			
	2	4	7	14
Long-Green-R	3.6 (0.2, 25.1)a	6.1 (0.4, 26.3)a	9.1 (0.6, 50.9)a	41.3 (4.3, 212.0)a
Green-oblong	3.8 (0.3, 25.7)a	7.9 (0.8, 28.8)a	14.3 (0.9, 59.0)a	91.5 (12.1, 391.6)b
Purple-panter	4.0 (0.9, 40.9)a	18.6 (1.6, 27.7)b	38.6 (1.8, 71.6)b	125.1 (14.3, 500.1)bc
Paris	4.9 (1.0, 43.6)a	19.0 (2.1, 33.6)b	41.6 (2.4, 78.9)b	142.3 (16.0, 593.9)c
Ashbilia	12.8 (9.6, 101.6)b	29.9 (4.6, 54.1)c	60.3 (3.9, 83.3)b	144.1 (17.9, 601.8)c
Barcelona	12.9 (10.2, 120.1)b	27.3 (5.1, 79.2)c	85.7 (5.6, 91.3)c	148.3 (18.7, 613.6)c
Pearl-Round	20.9 (12.1, 130.2)c	38.1 (7.1, 90.1)d	139.8 (9.9, 120.3)d	279.5 (28.4, 1201.6)d
White casper-S	21.0 (14.9, 143.3)c	36.7 (11.3, 102.2)d	153.6 (12.6, 130.6)d	301.3 (30.1, 1291.0)d

Means followed by different letter are significantly different based on Tukey–Kramer mean separation tests ($P<0.05$). R, resistant eggplant control; S, susceptible eggplant control; CI, confidence interval.

2011a). This study provides eggplant growers with information about the most distractive aphid that reduces eggplant yield (Smith, 2005). On the other hand, the study would highlight some cultivars with some level of resistance against A. *gossypii*. All cultivars used in this study except Pearl-Round showed significantly fewer aphid numbers than the susceptible cultivar, White casper (Table 2 & Figure 1) which could indicate that the eggplant cultivars under investigation are promising to use to reduce the cost of eggplant production (Al-Ani *et al.*, 2011a). The cultivars that were used had different responses to A. *gossypii*, which may indicate the cultivars have some level of resistance to this aphis (Aguirre-Rojas *et al.*, 2019). Looking at Table 2 and Figure 2, 3, and 4 could indicate the level of resistance differs from low to high level which may claim to change in aphid population (Khalaf *et al.*, 2019).

The eggplant cultivars in this study except Pearl-Round achieved significantly fewer aphid numbers than the White casper, susceptible control at 2, 4, 7, and 14 days after infestation may suggest that the eggplant cultivars are a good source to suppress the A. *gossypii* population.

This study is the first document to highlight some plant resistant categories that might be available in eggplant cultivars under evaluation against A. *gossypii*: tolerance, antibiosis, and antixenosis (Aguirre-Rojas *et al.*, 2017). On the other hand, the significance of aphid-resistant eggplant also reduces aphid populations and that would decrease the survival of the aphid on the other hosts which can make secondary infestation. Finally, screening more eggplant cultivars that have some level of resistance toward arthropods is needed to improve

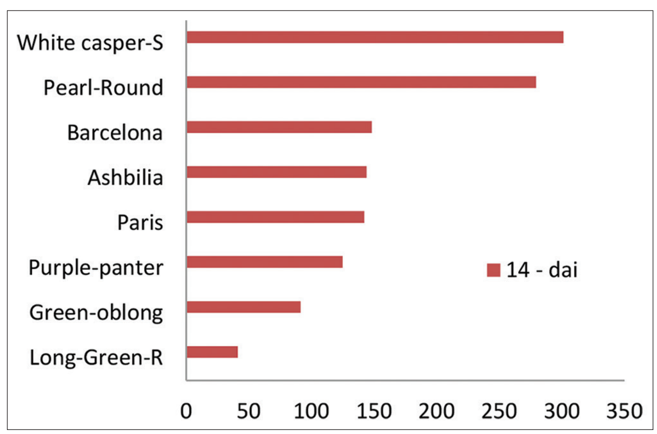

Figure 1: Mean number of *A. gossypii*, on eight eggplant varieties at 14 days post *A. gossypii* infestation in a non-choice experiment

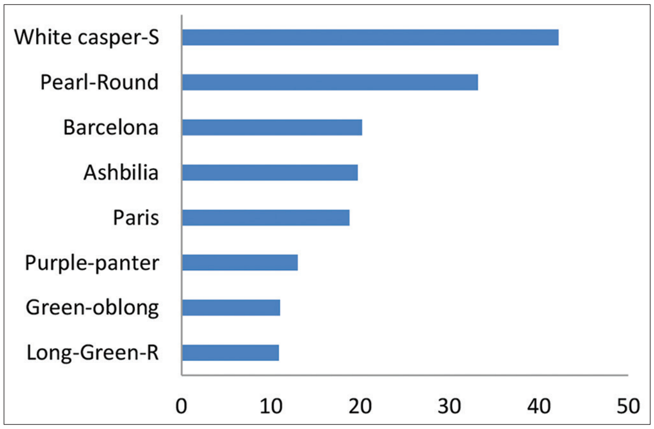

Figure 2: Plant height percentage change in eight eggplant varieties at 14 days post *A. gossypii* infestation in a non-choice experiment

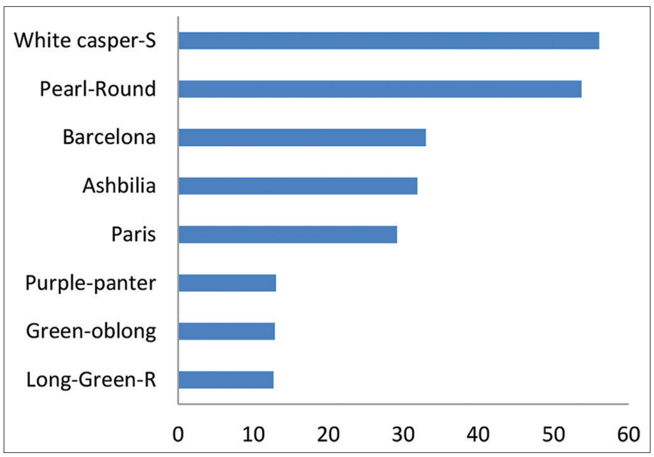

Figure 3: Plant weight percentage change in eight eggplant varieties at 14 days post *A. gossypii* infestation in a non-choice experiment

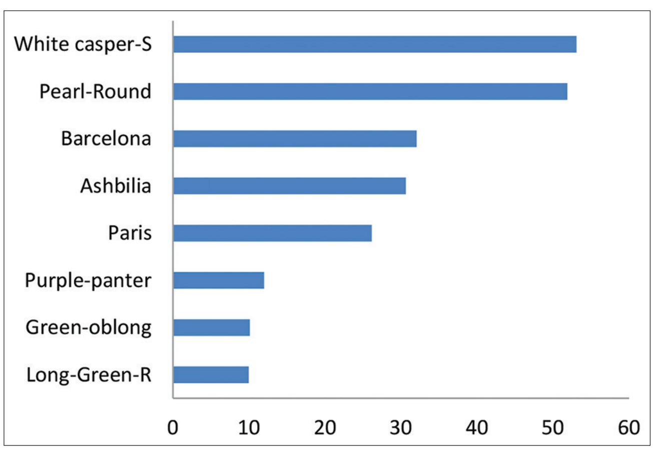

Figure 4: Plant dry weight percentage change, in eight eggplant varieties at 14 days post *A. gossypii* infestation in a non-choice experiment

eggplant cost-effectiveness (Khalaf *et al*., 2019). This study may contribute to the Iraqi endeavor of high food production as many other studies have already added to this effort (Al-Ani *et al*., 2009, 2011b, 2011c; Al-Ani, 2010; Abdul-Rassoul *et al*., 2012; Baazeem *et al*., 2022).

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