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Evaluation of Grafting onto Different Rootstocks on Yield and Disease Incidence of Eggplant (*Solanum melongena* L.) Under Verticillium and Fusarium Wilt Stress

Emine Polat[1,a], Naif Geboloğlu[1,b,*]

[1]*Tokat Gaziosmanpasa University, Faculty of Agriculture, Department of Horticulture, Tokat-Türkiye*
[*]*Corresponding author*

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ABSTRACT

Grafting is an effective strategy for enhancing disease resistance and improving eggplant (*Solanum melongena* L.) yield under pathogen stress. This study examined the effects of grafting onto different rootstocks in a soilless culture system contaminated with *Fusarium oxysporum* f. sp. *melongenae* and *Verticillium dahliae*. A split-plot experimental design with three replicates was employed to assess disease severity, yield components, and marketable fruit production. Results indicated that grafting onto specific rootstocks significantly increased marketable yield and reduced disease severity. In *Verticillium*-infected plants, the KingKong F_1 exhibited the highest early yield (2.75 kg plant^{-1}) and marketable yield (5.01 kg plant^{-1}), whereas self-grafted plants had the lowest yield (3.51 kg plant^{-1}). In *Fusarium*-infected plants, the Hawk rootstock achieved the highest marketable yield (5.20 kg plant^{-1}), representing a 68.28% increase over non-grafted control plants. Disease severity was significantly lower in grafted plants, with Hawk and KingKong F_1 showed complete resistance to *Verticillium* wilt, while Hawk, KingKong F_1, Anafor F_1, and Hikyaku F_1 exhibited complete resistance to *Fusarium* wilt. These findings underscore the efficacy of grafting as a sustainable disease management strategy, enhancing eggplant productivity in pathogen-stressed cultivation systems.

[a] *emine.polat5219@gop.edu.tr* *https://orcid.org/0000-0001-5839-9921* | [b] *naif.gebologlu@gop.edu.tr* *https://orcid.org/ 0000-0003-2495-7088*

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Introduction

Eggplant (*Solanum melongena L.*) is an economically and nutritionally important vegetable crop cultivated extensively in tropical and temperate regions worldwide (Chapman, 2020). However, its production is often hindered by a range of biotic and abiotic stress factors, among which soil-borne diseases pose a significant challenge. Two of the most severe soil-borne pathogens affecting eggplant production are *Verticillium dahliae* Kleb., the causal agent of *Verticillium* wilt, and *Fusarium oxysporum* f. sp. *melongenae*, responsible for *Fusarium* wilt. These pathogens are widespread and lead to substantial reductions in both yield and fruit quality, posing a major constraint on commercial eggplant cultivation (Pegg and Brady, 2002; Altınok, 2005; 2014; Rotino et al., 2014; Kaniyassery et al., 2023).

Eggplant cultivars generally exhibit high susceptibility to *V. dahliae*, and currently available commercial cultivars offer little to no genetic resistance to *Verticillium* wilt (Bletsos et al., 2004; Dervis et al., 2009; Pang et al., 2021). Similarly, susceptibility to *Fusarium* wilt is widespread among commercial cultivars, as demonstrated in screening studies (Altınok et al., 2014; Kumar et al., 2024). Due to the persistent nature of these soil-borne pathogens, traditional disease management strategies such as soil solarization have been explored as environmentally sustainable alternatives. However, solarization is often ineffective, particularly in open-field conditions, due to limitations in maintaining adequate soil temperatures over an extended period. Chemical fungicides have been employed to control these diseases, but their continuous use presents serious environmental and human health risks, in addition to promoting the development of fungicide-resistant pathogen strains.

Given the lack of resistant cultivars and the limitations of chemical and physical control methods, grafting has emerged as a viable alternative for managing soil-borne diseases in eggplant. Grafting onto resistant rootstocks is a well-established practice in horticultural production, widely employed in vegetable crops, particularly in the *Cucurbitaceae* and *Solanaceae* families, to mitigate the impact of soil-borne pathogens and root-knot nematodes (Bogoescu, 2012; Keatinge et al., 2014; Suansia and

Samal,2021). This technique was initially introduced in the early 20th century as a control method for soil-borne diseases and has since been adapted to enhance tolerance against abiotic stress factors such as salinity, drought, and alkalinity (Lee et al., 1998; Fernández-García et al., 2002; Sakata et al., 2005).

In eggplant, grafting onto resistant rootstocks has been proven to be an effective strategy for managing *V. dahliae* (Bletsos et al., 2003; Johnson et al., 2014) and *F. oxysporum* f. sp. melongenae (Bogoescu et al., 2014). Several rootstocks have been identified as highly resistant or tolerant to these pathogens, including *Solanum torvum* Sw. and interspecific hybrids (Boyaci and Ellialtioglu, 2018; Daunay, 2019; Boncukcu et al., 2023). The selection of appropriate rootstocks plays a crucial role in determining the success of grafting, as it directly influences the plant's resistance to pathogens, its ability to uptake nutrients, and overall growth performance.

This study aims to evaluate the impact of grafting onto different rootstocks in a soilless culture system contaminated with *F. oxysporum* f. sp. melongenae and *V. dahliae* on eggplant yield and disease progression. By assessing disease incidence, yield parameters, and overall plant performance, this research seeks to provide insights into the potential of grafting as a sustainable disease management strategy for eggplant production. Moreover, various eggplant rootstocks will be evaluated to identify differences in resistance among them.

Materials and Methods

Plant Materials and Cultural Conditions

The study was carried out under soilless culture in a screenhouse. A117 F_1 (Vilmorin), which is the most commonly grown as commercial variety in open field and greenhoses in Türkiye, was used as scion. Commercial eggplant variety was grafted on Hawk (Vilmorin), Hercules, Hikyaku F_1 (United Genetics), Köksal F_1, Boğaç F_1 (Yüksel Seed, Turkey), Conan F_1, KingKong F_1 (Rijk Zwaan) and Anafor F_1 (Enza Zaden) rootstocks. Nongrafted and self-grafted A117 F_1 plants were used as control. Seeds of scion and rootstocks were sown into sterilized medium consisting of peatmoss and perlite mixture (2:1). Grafting was carried out using the splice grafting method (also called slant-cut grafting) (Singh et al., 2017). Seedlings were produced in a commercial nursery (United Genetics, Türkiye). Rootstock seeds were sown 4 days before scion seeds. Grafted and nongrafted seedlings were grown under controlled polyethylene greenhouse. Seedlings were transplanted into pots with a volume of 25 liters and 75 cm length. Sterile peatmos and perlite mixture (2:1 ratio) as used for growing substrate. Seedlings transplanted in rows 0,5 m and between rows 1,20 m. Two plants were planted in each pot. Pots were placed on the ground where the ground covered with a white plastic mulch. Plants were watered with Hoagland nutrient solution 4 times a day, providing 500 ml of water per plant per day.

Preparation of Disease Isolates

The Fomg10 (*F.oxysporum* f.sp. melongenae) and Vd-14 (*V.dahliae* Kleb.) isolates used in pathogenicity tests. Isolates were supplied from the stocks of mycology laboratory of Phytopathology Department of Tokat Gaziosmanpaşa University Agricultural Faculty. *F. oxyspo*rum f.sp. melongenae and *V. dahliae* Kleb. suspensions were prepared from 4 weeks old cultures. Fungi were cultured on Potato Dextrose Agar (PDA) (from Sigma). Cultures were incubated at 25°C for 4 weeks. Spores were transfered into 250 mL Erlenmeyer flasks. Flasks were filled with 1000 mL of sterile distilled water containing 0.1% Tween 80. Suspensions were homogenized and filtered. The density of spores in the suspension was determined using a hemocytometer under a microscope. Spore concentration was adjusted to 1 x 10^6 conidia.ml^{-1}for *F. oxysporum f.sp.* melongenae and 3 × 10^6 conidia.ml^{-1} for *V. dahliae* (Narisawa et al., 2002; Altınok and Can, 2010).

Inoculation and Pathogenicity Tests

Inoculation was performed when the seedlings had developed four true leaves. Seedlings were carefully removed from the trays, and their roots were thoroughly washed with sterile tap water to eliminate any residual growing medium. To facilitate pathogen entry, root tips were trimmed using a sterile lancet, creating small wounds that enhanced inoculum penetration. The trimmed and washed roots were then immersed in the inoculum solution for 15 minutes, ensuring adequate contact between the pathogen and the root system. In contrast, the roots of non-grafted and self-grafted control plants were dipped in sterile tap water for the same duration to maintain experimental consistency. Following inoculation, seedlings were transplanted into pots containing a sterile mixture of peat and perlite. The pots were subsequently placed inside the screenhouse under controlled environmental conditions. Throughout the growing period, daytime temperatures within the screenhouse ranged from 25°C to 30°C, while nighttime temperatures varied between 15°C and 20°C, providing optimal conditions for plant growth and disease development.

Evaluation of Verticillium Wilt Severity

During the experiment, disease severity was systematically assessed based on the degree of leaf yellowing caused by *V. dahliae*. Evaluations commenced four weeks after inoculation and continued until the conclusion of the fourth month. A standardized 0–5 scale was employed to quantify symptom severity. The classification of *Verticillium* wilt symptoms was conducted according to established grading criteria (0-5 scale) (Acciarri et al., 2001; Debode et al., 2005): (0) all leaves green (high resistant); (1) 30% of the leaves are yellow (resistant); (2) 50% of the leaves are yellow (moderately resistant); (3) 51–70% of the leaves are yellow (moderately sensitive); (4) 1–2 green leaves at the apex (sensitive); (5) all leaves are yellow (high sensitive).

Evaluation of Fusarium Wilt Severity

Fusarium wilt severity was evaluated using a 0–4 scale throughout the experiment. Assessments commenced two weeks post-inoculation, with the final evaluation conducted at four months. Observations were recorded biweekly, and disease severity was classified as follows (0-4 scale) (Altınok and Kamberoğlu, 2005): (0) no visible symptoms; (1) initial wilting and discoloration of thin veins in the lower leaves; (2) wilting, growth retardation,

chlorosis, and necrosis affecting 50% of the plant; (3) extensive wilting, leaf desiccation, abscission, and necrosis progressing from the leaf tips; (4) complete desiccation and plant mortality.

Trial Desing and Statistical Analysis

The experiment was conducted using a split-plot design with three replicates. Disease levels were assigned to the main plots, while grafting combinations were allocated to the subplots. Each experimental unit consisted of six plants. Data were analyzed using one-way analysis of variance (ANOVA) in IBM SPSS Statistics 20. Mean comparisons were performed using Duncan's multiple range test at a significance level of P = 0.05.

Results

Effect of Grafting on Yield Parameters in Verticillium Wilt-Infected Eggplant

The early yield of grafted eggplant grown in *Verticillium* wilt-infected environments was significantly influenced by the choice of rootstock. Notably, grafting onto *S. torvum* rootstocks resulted in a reduction in early yield. Among the tested rootstocks, plants grafted onto KingKong F_1 (2.75 kg plant^{-1}), Hercules (2.67 kg plant^{-1}), and Conan F_1 (2.63 kg plant^{-1}) exhibited the highest early yields. The number of early fruits per plant ranged from 8.62 to 17.43. Conversely, the lowest early yield was recorded in plants grafted onto the Hawk rootstock. Statistical analysis revealed a significant difference among the rootstocks, with $P < 0.001$ (Table 1).

One of the key concerns in grafting studies is the extent to which marketable yield is influenced in grafted plants subjected to *Verticillium* wilt stress. In the present study, marketable yield was assessed based on both the number of fruits per plant and the total yield per plant. The findings demonstrated that while *Verticillium* wilt stress led to a decline in marketable yield in both ungrafted and self-grafted control plants, grafting onto specific rootstocks resulted in a significant improvement in yield. The number of marketable fruits per plant ranged from 21.56 (self-grafted) to 31.67 (Hawk rootstock), whereas marketable yield per plant varied between 3.51 kg plant^{-1} (self-grafted) and 5.01 kg plant^{-1} (KingKong F_1 rootstock). Notably, all rootstocks, with the exception of Conan F_1, contributed to an increase in marketable yield under *Verticillium* wilt stress, while control plants exhibited a significant reduction in yield. Statistical analysis confirmed that the differences in marketable yield among the grafting treatments were significant, $P < 0.01$ (Table 1).

In the present study, significant differences were observed in the average fruit weight of plants subjected to *Verticillium* wilt stress ($P < 0.01$). Among the evaluated rootstocks, plants grafted onto the KingKong F_1 rootstock exhibited the highest fruit weight, outperforming all other rootstocks. Notably, four of the tested rootstocks resulted in higher average fruit weights compared to the control treatments. Consistent with the findings on marketable yield, the KingKong F_1 rootstock demonstrated superior performance in terms of average fruit weight. The fruit weight ranged from 149.32 g (Hawk) to 187.73 g (KingKong F_1), highlighting the significant impact of rootstock selection on fruit development under *Verticillium* wilt stress (Table 1).

In this study, grafting generally led to a reduction in unmarketable yield in plants exposed to *Verticillium* wilt, although the extent of this effect varied depending on the rootstocks used. Notably, no unmarketable fruit production was observed in plants grafted onto the Hawk, Köksal F_1, and Boğaç F_1 rootstocks. In contrast, the highest unmarketable yield was recorded in self-grafted plants, reaching 0.77 kg per plant. A similar trend was observed in the number of unmarketable fruits, further supporting the role of rootstock selection in reducing fruit loss. Statistical analysis revealed significant differences in unmarketable yield among the grafting treatments ($P < 0.01$), emphasizing the influence of grafting on fruit marketability under disease pressure (Table 1).

Effect of Grafting on Yield Parameters in Fusarium Wilt-Infected Eggplant

The present study examined the influence of grafting on early yield performance under *Fusarium* wilt stress. While numerical variations were observed among the grafted and control plants, these differences were not statistically significant. Early yield ranged from 1.75 kg plant^{-1} (Boğaç F_1) to 2.38 kg plant^{-1} (KingKong F_1), with the KingKong F_1 rootstock exhibiting the highest early yield. The number of early fruits varied between 10.38 fruits plant^{-1} (Anafor F_1) and 14.10 fruits plant^{-1} (nongrafted). Notably, the highest early yield was recorded in nongrafted plants, although the differences in fruit number among treatments were not statistically significant (Table 2).

Table 1. Yield Parameters in *Verticillium*-Infested Conditions

Rootstocks	Early yield		Marketable yield		Mean fruit wt.	Unmarketable yield
	fruit plant^{-1}	kg plant^{-1}	fruit plant^{-1}	kg plant^{-1}	g	kg plant^{-1}
Hawk	08.62^{d}	1.24^{d}	31,67^{a}	4,72^{a}	149,32^{c}	0,00^{c}
Köksal F_1	12.53^{c}	1.87^{c}	24,44^{bc}	3,66^{c}	149,84^{c}	0,00^{c}
Boğaç F_1	14.10^{bc}	2.39^{ab}	25,51^{bc}	4,64^{a}	182,11$_{ab}$	0,00^{c}
Anafor F_1	13.51^{bc}	2.02^{b}	23,48^{c}	4,17^{b}	159,12$_{c}$	0,46^{ab}
Hikyaku F_1	12.93^{bc}	2.11^{b}	26,35^{b}	3,54^{c}	165,20^{bc}	0,56^{ab}
Hercules	17.43^{a}	2.67^{a}	27,31^{b}	4,18^{b}	153,25^{c}	0,34^{bc}
Kingkong F_1	15.28^{abc}	2.75^{a}	26,85^{b}	5,01^{a}	187,73^{a}	0,06^{c}
Conan F_1	15.86^{ab}	2.63^{a}	23,48^{bc}	3,96^{bc}	169,69$_{abc}$	0,33^{bc}
Selfgrafted	13.12^{bc}	1.87^{c}	21,56^{c}	3,51^{c}	154,11^{c}	0,77^{a}
Nongrafted	14.10^{bc}	2.12^{b}	22,76^{bc}	3,75^{bc}	160,44^{c}	0,29^{bc}
Significance	***	***	**	**	**	**

Means in the same column followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's multiple range test.
** and ***: Represents a statistically significant difference at P<0.01 and *P*<0.001, respectively (Duncan's multiple range test).

Table 2. Yield Parameters in *Fusarium*-Infested Conditions

Rootstocks	Early yield		Marketable yield		Mean fruit wt.	Unmarketable yield
	fruit plant^{-1}	kg plant^{-1}	fruit plant^{-1}	kg plant^{-1}	g	kg plant^{-1}
Hawk	13.12	2.30	28.80^{ab}	5.20^{a}	180.60	0.00^{c}
Köksal F$_1$	12.73	1.99	25.40^{bcd}	4.13^{bcd}	163.26	0.00^{c}
Boğaç F$_1$	10.58	1.75	23.00^{cde}	3.88^{cd}	168.80	0.00^{c}
Anafor F$_1$	10.38	1.90	24.75^{b-e}	4.41^{b}	178.86	0.44^{ab}
Hikyaku F$_1$	12.54	2.07	26.59^{abc}	4.25^{bc}	159.94	0.60^{ab}
Hercules	12.73	2.10	21.08^{de}	3.59^{d}	170.26	0.57^{ab}
Kingkong F$_1$	13.52	2.38	30.87^{a}	4.40^{b}	157.19	0.00^{c}
Conan F$_1$	12.34	2.03	23.72^{b-e}	4.03^{bcd}	170.27	0.67^{a}
Selfgrafted	11.95	1.88	19.89^{e}	3.09^{e}	155.62	0.40^{b}
Nongrafted	14.10	2.23	19.61^{e}	3.08^{e}	147.47	0.54^{ab}
Significance	ns	ns	**	***	ns	***

Means in the same column followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's multiple range test; ns: Denotes a non-significant difference; **: Represents a statistically significant difference at p < 0.01; ***: Represents a statistically significant difference at p < 0.001 (Duncan's multiple range test).

Table 3. Response of grafting to *V. dahliae* in eggplant plants

Rootstocks	Disease severity scores		Disease Severity (%)	Degree of resistance
	4 weeks	4 months		
Hawk	0.00±0.00^{d}	0.00±0.00^{d}	0	HR
Köksal F$_1$	0.51±0.04^{c}	0.70±0.08^{c}	21	MR
Boğaç F$_1$	0.35±0.03^{c}	0.80±0.09^{c}	24	MR
Anafor F$_1$	0.52±0.04^{c}	0.72±0.09^{c}	22	MR
Hikyaku F$_1$	0.86±0.11^{b}	1.55±0.17^{b}	39	MR
Hercules	0.46±0.06^{c}	0.87±0.19^{c}	26	MR
Kingkong F$_1$	0.00±0.00^{d}	0.00±0.00^{d}	0	HR
Conan F$_1$	0.33±0.04^{cd}	1.70±0.43^{b}	43	SR
Selfgrafted	1.25±0.23^{a}	3.42±0.65^{a}	77	S
Nongrafted	1.12±0.22^{a}	3.20±0.68^{a}	72	S
Significance	**	**		

Disease severity (%) was calculated based on the evaluation made 4 months after inoculation. HR – highly resistant (disease severity 0–10%); MR – moderately resistant (disease severity 11–40%); SR – slight resistance (disease severity 41–70%); S –susceptible (disease severity 71–100%); the Kruskal-Wallis H test was used for statistical analysis of resistance to *V. dahliae* Kleb.; data followed by different lowercase letters show statistically significant differences at *P* < 0.05 according to Tamhane's T2 test; **: Represents a statistically significant difference at p < 0.01.

Fusarium wilt, a major soil-borne pathogen responsible for substantial reductions in eggplant yield and quality, significantly affected marketable yield in the study. The highest marketable yield was obtained from plants grafted onto the Hawk rootstock (5.20 kg plant^{-1}), whereas the lowest yield was recorded in nongrafted plants (3.08 kg plant^{-1}). Grafting resulted in a marketable yield increase of 16.18% to 68.28%, depending on the rootstock used. A similar trend was observed in marketable fruit number, with plants grafted onto the KingKong F$_1$ rootstock producing the highest number of marketable fruits (30.87 fruits plant^{-1}), while nongrafted plants exhibited the lowest count (19.61 fruits plant^{-1}). Statistical analysis confirmed that the differences among grafting treatments were highly significant for both marketable yield (P < 0.001) and marketable fruit number (P < 0.01) (Table 2).

Although variations in average fruit weight were recorded across grafting treatments, these differences were not statistically significant. Fruit weights ranged from 147.47 g (nongrafted) to 180.60 g (Hawk), with all grafted plants demonstrating an increase in fruit weight relative to the control treatments (Table 2).

Significant differences (P < 0.001) were detected in unmarketable yield among the grafting treatments. The discard yield varied depending on the rootstock used, with grafting generally contributing to a reduction in unmarketable yield. However, certain rootstocks resulted in elevated unmarketable yield. Specifically, plants grafted onto Hikyaku F$_1$ (0.60 kg plan^{-1}), Hercules (0.57 kg plant^{-1}), and Conan F$_1$ (0.67 kg plant^{-1}) rootstocks exhibited higher unmarketable yields than the control. In contrast, no unmarketable fruits were observed in plants grafted onto Hawk, Köksal F$_1$, Boğaç F$_1$, or KingKong F$_1$ rootstocks, highlighting their potential efficacy in reducing fruit losses under *Fusarium* wilt stress conditions (Table 2).

Effect of Grafting on Disease Severity in Verticillium Wilt and Fusarium Wilt-Infected Plants

In the study, grafting significantly improved resistance to *Verticillium* wilt in eggplant. Among the tested rootstocks, Hawk and KingKong F$_1$ rootstocks exhibited complete resistance, with no detectable disease symptoms. The Conan F$_1$ rootstock displayed slight resistance, whereas the remaining rootstocks demonstrated moderate resistance. In contrast, ungrafted and self-grafted control plants were highly susceptible, exhibiting severe disease symptoms. Disease severity among the rootstocks ranged from 0% to 43%, with statistically significant differences observed among grafting treatments (P<0.05) (Table 3). These findings highlight the effectiveness of grafting onto resistant rootstocks as a viable strategy for mitigating *Verticillium* wilt in eggplant cultivation.

Table 4. Response of grafting to F. *oxysporum* f.sp. *melongenae* in eggplant plants

Rootstocks	Disease severity scores		Disease severity (%)	Degree of resistance
	4 weeks	4 months		
Hawk	0.00±0.00^{d}	0.00±0.00^{d}	0	HR
Köksal F_1	0.14±0.01^{c}	0.85±0.16^{c}	26	MR
Boğaç F_1	0.88±0.14^{a}	1.85±0.22^{b}	46	SR
Anafor F_1	0.00±0.00^{d}	0.00±0.00^{d}	0	HR
Hikyaku F_1	0.00±0.00^{d}	0.00±0.00^{d}	0	HR
Hercules	0.17±0.04^{c}	0.67±0.14^{c}	20	MR
Kingkong F_1	0.00±0.00^{d}	0.00±0.00^{d}	0	HR
Conan F_1	0.11±0.01^{cd}	0.85±0.15^{c}	26	MR
Selfgrafted	0.89±0.12^{a}	3.20±0.23^{a}	80	S
Nongrafted	0.67±0.10^{b}	3.38±0.26^{a}	85	S
Significance	**	**		

Disease severity (%) was calculated based on the evaluation made 4 months after inoculation. HR – highly resistant (disease severity 0–10%); MR – moderately resistant (disease severity 11–40%); SR – slight resistance (disease severity 41–70%); S –susceptible (disease severity 71–100%); the Kruskal-Wallis H test was used for statistical analysis of resistance to *F. oxysporum* f.sp. melongenae.; data followed by different lowercase letters show statistically significant differences at $P < 0.05$ according to Tamhane's T2 test.

In the present study, the tested rootstocks exhibited significantly greater resistance to *Fusarium* wilt in comparison to *Verticillium* wilt. Among the rootstocks tested, Hawk, King Kong F_1, Anafor F_1, and Hikyaku F_1 showed high resistance, showing no symptoms of *Fusarium* wilt. In contrast, both ungrafted and self-grafted control plants were highly susceptible to the disease. Disease severity in the remaining rootstocks ranged from 20% to 46%, indicating variation in resistance levels. Statistical analysis revealed that the differences between the various grafting treatments were significant ($P<0.01$), as shown in Table 4.

These findings underscore the importance of rootstock selection in enhancing resistance to *Fusarium wilt* and highlight the effectiveness of grafting with resistant rootstocks as a strategy for improved disease management.

Discussion

Eggplant is highly susceptible to soilborne pathogens such as *V. dahliae* and *F. oxysporum* f.sp. *melongenae*. One of the primary strategies for mitigating the impact of these biotic stress factors is grafting onto resistant rootstocks. This approach not only enhances disease resistance but also contributes to improved tolerance to abiotic stress factors. In the present study, the effects of grafting onto various rootstocks in controlling *Verticillium* and *Fusarium* wilt diseases were investigated. The findings indicate that, although the degree of improvement varied among rootstocks, grafting generally led to significant increases in early yield, marketable yield, and marketable fruit weight in infected conditions. Among the rootstocks tested, tomato rootstock KingKong F_1 and *S. torvum* rootstocks Hawk F_1 and Hercules emerged as the most effective in enhancing both disease resistance and yield performance.

The existing body of literature on the impact of grafting on *Verticillium* and *Fusarium* wilts in eggplant is relatively limited. However, available studies suggest that in addition to controlling disease incidence, grafting significantly enhances eggplant yield under infected conditions, with effectiveness varying according to the selected rootstock. Notably, most prior studies have examined only a limited number of rootstocks, typically ranging between two and four. In contrast, the present study evaluated eight different rootstocks, allowing for a broader assessment of yield performance and disease resistance across different grafting combinations. Consistent with previous findings, the results reinforce the notion that grafting onto resistant rootstocks provides substantial protection against *Verticillium* and *Fusarium* wilt, though the extent of resistance and yield improvements varies depending on the rootstock used (Bletsos et al., 2003; Zhenyu et al., 2004; Çürük et al., 2009; Bogoescu, 2019).

Several studies have highlighted the efficacy of *S. torvum* as a rootstock in conferring resistance to *Verticillium* and *Fusarium* wilts in eggplant (Sebahattin et al., 2005; Bogoescu and Costache, 2014; Gabriela et al., 2019). In particular, Hawk, one of the most effective rootstocks in the present study, belongs to *S. torvum*, which is frequently cited as the most effective eggplant rootstock against these soilborne pathogens (Zhou et al., 2001; Bletsos et al., 2003; Lacasa et al., 2024). The findings of Bogoescu et al. (2014) further support this conclusion, reporting that eggplants grafted onto *S. torvum* rootstocks in *Verticillium*- and *Fusarium*-contaminated soils exhibited a 19% increase in yield alongside a significant reduction in disease symptoms.

In addition to *S. torvum*, resistant tomato rootstocks have shown significant efficacy in reducing the incidence of *Verticillium* and *Fusarium* wilt in eggplant cultivation in the present study. Studies by Wang et al. (2003) and Johnson et al. (2014) have shown that grafting eggplant onto tomato rootstocks can be an effective strategy for managing soil borne diseases management. Liu et al. (2009) reported that eggplants grafted onto *Verticillium*-resistant local tomato rootstocks exhibited significant improvements in both early and total yields compared to ungrafted controls in pathogen-infected conditions, while also displaying a marked reduction in disease severity. Similarly, Johnson et al. (2014) found that eggplants grafted onto the Beaufort F_1 tomato rootstock remained unaffected by *Verticillium* wilt in contaminated soils, leading to a substantial increase in overall yield. Consistent with these findings, was among the most effective rootstocks in our study.

Conclusion

This study, conducted under soilless culture, demonstrated that grafting onto rootstocks with moderate to high levels of resistance to *Verticillium* and *Fusarium* wilts significantly enhanced marketable yield compared to ungrafted and self-grafted plants in pathogen-infested conditions. The results indicate that grafted plants exhibited a substantial level of protection against soilborne pathogens, with the Hawk F_1 and KingKong F_1 rootstocks showing complete resistance. Conversely, ungrafted and self-grafted A117 F_1 eggplant plants were highly susceptible to *Verticillium* and *Fusarium* infections, highlighting the species' natural susceptibility to these pathogens. These findings align with previous research, emphasizing the role of resistant rootstocks in mitigating disease impact and improving overall crop productivity. Therefore, grafting onto resistant rootstocks presents a viable and sustainable approach for managing soilborne diseases in eggplant cultivation, minimizing dependence on chemical control methods while enhancing yield stability.

Declarations

Author Contribution Statement

E.P.: Data collection, investigation, formal analysis, and writing the original draft

N.G.: Project administration, supervision, conceptualization, methodology, review and editing

Conflict of Interest

The authors declare no conflict of interest.

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