Effect of Grafting on Growth, Yield, and Verticillium Wilt of Eggplant

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Abstract. Eggplant (Solanum melongena L.) seedlings (‘Tsakoniki’) were grafted by hand on the Verticillium dahliae Kleb. resistant wild species Solanum torvum Sw. (GST) and Solanum sisymbriifolium Lam. (GSS). Grafted and nongrafted eggplants were transplanted to a fumigated soil with methyl bromide and to infested soil with microsclerotia of V. dahliae. Grafted plants were more vigorous, as measured by plant height, main stem diameter, and root system weight, than the nongrafted ‘Tsakoniki’. This resulted in an increased early production (GST, 45.5%; GSS, 18.4%) and late production (GST, 69.3%; GSS, 59.2%) as compared to the noninfected controls. The mean yield reduction (over years) in early production caused by the disease, as compared to the controls grown in fumigated soil, was 29.4%, 36.6%, and 77.9% for eggplant grafted on S. torvum, S. sisymbriifolium, and nongrafted plants, respectively. This yield reduction in total production was 6.9%, 20.5%, and 56.8%, respectively. The disease incidence in ungrafted plants was 96% and 100% during early and late harvest periods. In contrast, the disease incidence in grafted plants was significantly lower, averaging 28.1% (GST) and 52.6% (GSS) in early production, and 37.6% and 79.3%, respectively, in late production. Solanum torvum was found more resistant than S. sisymbriifolium, because grafted infected plants developed mild symptoms, as indicated by significantly lower leaf symptom index (average value 1.2 and 2.22) and disease index (average value 1.55 and 3.38), respectively. In conclusion, grafting of eggplant on either wild species had positive effects on growth, production, and verticillium wilt control.

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Materials and Methods

The experiments were carried out during 1998 and 1999 at the Agricultural Research Centre of Macedonia and Thrace, Greece. The soil was a sandy loam and had a pH of 7.25, free CaCO3 = 2.65%, organic matter 1.75%, electric conductivity 3.12 mmhos/cm, Olsen’s phosphorus > 200 ppm, and exchangeable potassium 895 ppm.

The Greek eggplant ‘Tsakoniki’ was planted in soil artificially infested with V. dahliae. Iso-lates of V. dahliae from tomato, potato, and eggplant were grown on potato dextrose agar and were used in a mixture (1:1:1) throughout. Inoculum was prepared by growing each isolate for 8 d at 20 ± 2 °C in plastic petri dishes, 5.5 cm in diameter. A quantity of ≤5 mL of sterile distilled water was added per dish and the colonies were scarped with a sterilized needle. The contents of each dish were filtered through cheesecloth; the filtrates were combined; and the inoculum suspension consisted of microc symbiosis adjusted to 106 spores/mL. Five milliliters of the above inoculum suspension was used to inoculate a 1-L glass jar containing 200 g growth medium made of 1 cornmeal : 1 perlite : 1 water (by weight). The jars were kept at 20 ± 2 °C and the fungus grew during the first 7 d at daylight; then they were covered with black plastic during the following 23 d in order to...
Table 1. Mode of calculation of verticillium wilt index

| LSI | VDF | LSI × VDI | DF |
|-----|-----|-----------|----|
| 1   | 1   | 1         | 1  |
| 2   | 2   | 2         | 2  |
| 3   | 3   | 3, 4, 5   | 3  |
| 4   | 4   | 6, 8, 9   | 4  |
| 5   | 5   | 10, 12, 15| 5  |
| 6   | 6   | 16, 18, 20, 24 | 6 |

1LSI = Leaf symptom index.
2VDF = Vascular discoloration index.
3DI = Disease index.

The numbers 7, 11, 13, 14, 17, 19, 21, 22, and 23 cannot be used as products of columns 1 and 2.

Table 2. Effect of grafting eggplant on verticillium wilt resistant rootstocks (S. torvum and S. sisymbriifolium) compared with nongrafted eggplant, on scion plant height and several fruit and yield parameters, during the early production period of 1998 and 1999, when grown on both soil fumigated with methyl bromide and soil infested with Verticillium.

| Grafting on/Year | Characteristics |
|------------------|-----------------|
|                  | Total early yield (g) | Marketable yield (g) | No. of fruit | No. of marketable fruit | Mean wt of marketable fruit wt (g) | Mean fruit wt (g) | Plant ht (cm) |
|                  | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 | 1998 | 1999 |
| Fumigated soil   |
| S. torvum        | 2867 a | 993 bc | 2294 a | 894 b | 20.3 a | 6.0 bc | 14.0 a | 4.5 b | 159.7 a | 182.3 a | 137.7 ab | 226.5 a | 124 a | 116 ab |
| S. sisymbriifolium| 2217 b | 1240 b | 1516 b | 1080 b | 18.3 a | 9.4 a | 10.3 b | 7.5 a | 142.7 a | 162.1 ab | 119.7 ab | 158.7 b | 103 ab | 124 a |
| Not grafted      | 914 cd | 1599 a | 722 c | 1469 a | 6.7 b | 10.5 a | 4.3 cd | 9.3 a | 136.0 b | 139.8 bc | 118.3 ab | 130.6 bc | 92 b | 115 b |

Infested soil

| S. torvum        | 2491 ab | 452 d | 1848 ab | 404 c | 18.0 a | 2.8 d | 11.3 ab | 2.0 c | 160.0 a | 110.7 cd | 140.7 a | 106.1 bc | 115 b | 99 c |
| S. sisymbriifolium| 1283 c | 879 c | 863 c | 782 b | 10.0 b | 6.3 b | 6.3 b | 5.3 c | 125.0 ab | 121.4 cd | 108.0 b | 130.0 bc | 86 bc | 99 c |
| Not grafted      | 534 d | 413 d | 175 d | 310 c | 6.3 b | 3.9 cd | 1.3 d | 8.3 b | 96.6 d | 76.5 c | 90.0 c | 64 d | 67 d |

Means in the same column followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan’s multiple range test.
infested and noninfested soil. Total and marketable yield in 1998 decreased significantly on nongrafted as compared to GST when the plants were grown in fumigated or infested soil. Furthermore, root biomass and stem diameter decreased significantly in the control compared to GST. A significant decrease was also observed during the late production period for all parameters studied (except number of marketable fruit and marketable yield in 1999) on the plants grown in infested soil (Table 3). Finally, nongrafted and noninfected plants had marketable yield and plant height significantly higher than nongrafted and infected ones in the early production period, while all values were significantly higher (except number of marketable fruit in both years, marketable yield in 1998, and weight of marketable fruit in 1999) in the late production period (Table 3).

Differences in performance between S. torvum and S. sisybriifolium. In fumigated soil, during the early production period, the total early yield, marketable yield, and number of marketable fruit in 1998 had significantly higher values for plants grafted on S. torvum than on S. sisybriifolium. In 1999, however, significantly higher values for GST were observed for mean fruit weight and for GSS for number of fruit and number of marketable fruit (Table 2). In the late production period, only stem diameter in 1998 and biomass and root biomass in 1999 were significantly higher for plants grafted on S. torvum when compared to GSS. In infested soil and during the early production period, GST gave significantly higher total early yield, marketable yield, number of fruit, and mean fruit weight in 1998 when compared to GSS, while in 1999 the results were reversed for total early yield, marketable yield, and number of fruit. In the late production period, plants grafted on S. torvum produced significantly higher values for biomass and aerial biomass in 1998 and root biomass and height in 1999 when compared to GSS. Root biomass in 1998, however, was significantly higher for plants grafted on S. sisybriifolium. Over the 2 years in early production, plants grafted on S. torvum outyielded the ones grafted on S. sisybriifolium by 22.8% and 37.0% in fumigated and infested soil, respectively, and in late production by 6.3% and 24.5%, respectively.

Isolations from all plants showed positive results only on the susceptible eggplant scion, whereas the resistant Solaum rootstocks apparently remained free of infection, as evidenced by lack of vascular discoloration and the failure to isolate the pathogen from rootstock vascular tissue. The pathogen occurred at epidemic levels in nongrafted (control) plants, with essentially 96% and 100% disease incidence in the early and late production periods, respectively. In addition, the average value of LSI during early production and DI during late production were 3.78 and 5.23, respectively. Grafted plants that were infected by the pathogen generally developed mild symptoms, as indicated by a very low LSI (over years 1.2 and 2.22) and DI (over years 1.55 and 3.38) for GST and GSS, respectively.

The resistance of the grafted plants was indicated by the increased percentage of the healthier plants observed in the grafted group as compared to the nongrafted ones (Table 4). The percentage of the severely diseased plants for GST, GSS, and nongrafted were 0.0%, 22.9%, and 79.0%, respectively. Healthy plants were observed among nongrafted plants only in the early production period.

Discussion

The high percentage of successful grafting observed for both Solaum species with no change in fruit quality indicated that both rootstocks are suitable for eggplant grafting. The yield advantage of the grafted plants was obvious when grown on infested soil (Tables 2 and 3). Yet, the advantage of the grafted plants was not justified in 1999 when the plants were grown in pathogen-free soil. The taller plants and the larger main stem diameter of the grafted plants were attributed to the vigorous root system (Table 3) of the rootstock. Similarly, the increased yield of grafted plants is believed to be due to enhanced water and mineral uptake (Lee, 1994). According to Young (1989), the rootstock’s vigorous root system is often capable of absorbing water and nutrients more efficiently than scion roots. Thus, the significantly higher marketable yield of the plants grafted on S. torvum and S. sisybriifolium were expected over the years 1.2 and 2.22 and DI (over years 1.55 and 3.38) for GST and GSS, respectively.

Table 3. Effect of grafting eggplant on verticillium wilt resistant rootstocks (S. torvum and S. sisybriifolium) compared with nongrafted eggplant on plant parameters and fruit yield quality, during the final harvest period in 1998 and 1999, when grown on both soil fumigated with methyl bomide and soil infested with Verticillium.

| Grafting on/Year | Marketable yield (g) | No. of marketable fruit | Wt of marketable fruit (g) | Biomass (g) | Aerial biomass (g) | Root biomass (g) | Stem diam (cm) | Ht (cm) |
|------------------|----------------------|-------------------------|--------------------------|-------------|-----------------|----------------|--------------|--------|
| 1998             | 1999                 | 1998                    | 1999                     | 1998        | 1999            | 1998           | 1999         | 1998   |
| Fumigated soil   |                      |                         |                          |             |                 |                 |              |        |
| S. torvum        | 4560 a               | 1912 a                  | 29.3 a 12.6 ab           | 158 a 161 a | 2090 ab 2514 a  | 1923 ab 2225 a | 167 ab 289 a  | 3.16 a 2.96 a 154 a 165 a |
| S. sisybriifolium| 3979 a               | 2108 a                  | 26.3 a 15.0 a            | 157 a 157 a | 1995 ab 1936 b  | 1798 b 1719 b  | 198 a 171 cd | 2.36 c 2.80 a 137 ab 156 ab |
| Not grafted      | 1601 b               | 7.97 b 13.0 ab          |                          | 153 a 143 ab | 1960 b 1693 b  | 1838 b 1543 b | 122 c 150 d  | 2.60 c 2.26 b 145 ab 136 bc |
| Infested soil    |                      |                         |                          |             |                 |                 |              |        |
| S. torvum        | 4719 a               | 1310 ab                 | 30.0 a 7.6 a            | 159 a 152 a | 2327 a 2144 a  | 1938 ab        | 134 bc 262 ab | 3.06 a 2.60 ab 129 b 156 ab |
| S. sisybriifolium| 3549 a               | 1291 ab                 | 23.0 a 8.6 ab           | 149 a 150 a | 1192 c 2357 a  | 1508 c 2095 a | 183 a 171 cd | 2.80 ab 2.30 b 137 ab 133 c  |
| Not grafted      | 882 b                | 678 b 6.7 b 6.3 b      |                          | 96 b 119 b  | 692 d 789 c 719 c | 79 d 70 e 1.47 c 1.76 c | 86 c 98 d |

Means in the same column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s multiple range test.

Table 4. Distribution of the eggplants in each grade of leaf symptom index and disease index during a) the early production period and b) at the final production period during the 2 years (1998 and 1999), when grafted on S. torvum and S. sisybriifolium or not grafted.

| Grafting on/Year | Percentage of plants in each grade of leaf symptom index | Percentage of plants in each grade of disease index |
|------------------|--------------------------------------------------------|-----------------------------------------------------|
| 1998             | 1999                                                   | 1999                                                |
| S. torvum        |                                          |                                                    |
| S. sisybriifolium|                                          |                                                    |
| Not grafted      |                                          |                                                    |

Means in the same column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s multiple range test.
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