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Role of Different Rootstocks on Yield and Resistance for *Fusarium oxysporium*, *Verticillium dahliae* and *Meloidogyne incognita* in Grafted Peppers

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Summary

The aim of this study was to determine the effects of different rootstocks on yield characteristics and resistance capability against to *Fusarium wilt*, *Verticillium wilt* and *Meloidogyne incognita* in pepper cultivation. 'California Wonder' and 'Kandil' bell pepper varieties were grafted on 'Snooker F_1', 'Dro F_1', NGS and NGC rootstocks in the experiment. Nongrafted and selfgrafted plants were used as control. Grafted plants were cultivated in open field conditions with sterilized growth media. The experiment was conducted in randomized split plots design with three replications. Yield was increased significantly by rootstocks in infected plots and it was higher than control plants in uninfected plots. The highest yield was obtained from 'Kandil' × 'Dro F_1' combination in *Fusarium oxysporium* experiment, 'Kandil' × 'NGS' combination in *Verticillium dahlia* experiment and 'California Wonder' × 'Snooker F_1' combination in *Meloidogyne incognita* experiment.

Study showed that using of grafted plants was more effective than nongrafted and selfgrafted plants for obtaining resistance against to *Fusarium oxysporium* and *Meloidogyne incognita* by depending on rootstocks but, not against to *Verticillium dahliea*.

Key words. Pepper – grafting – rootstock – yield – *Fusarium* wilt – *Verticillium* wilt – root knot nematode.

Introduction

Pepper is one of the most popular vegetables in Turkey, and annual production is 1.81 million tonnes (Anonymous 2008). Soil-borne fungal diseases and root-knot nematodes are major problems that limit pepper production in Turkey and the whole world as well. Yield and quality are decreased significantly by *Fusarium oxysporium*, *Verticillium dahliae*, *Phytophthora capsici* and *Meloidogyne spp* (root-knot nematodes) of pepper cultivation in protected and open field.

Soil sterilization, solarisation and use of chemical fungicides and nematocides are common and traditional methods for fighting against to these diseases and pests. Although soil solarisation is effective method in protected cultivation, it is not suitable for in open field cultivation. Until recently, fumigant biocides such as methyl bromide and nematocides has been using commonly for getting rid of the root-knot nematodes and soil borne diseases in vegetable cultivation all around the world. Yet these chemicals were prohibited in European countries including Turkey and most of the world because of their hazardous effects on human health, environment, ozone layer and residues in soil and water. Consequently, scientists started to develop alternative control methods, which are more effective and environment-friendly for controlling the soil-borne plant diseases and nematodes.

Grafting is taken into considered one of the most important alternative methods for controlling the soil-borne diseases in pepper cultivation. Efficiency of this method depends on resistance level of rootstocks for diseases. Recently, using of grafted seedlings has been increased in some *Solanaceae* vegetables such as tomato, eggplant and pepper and some *Cucurbitaceae* vegetables like cucumber, pumpkin, watermelon and melon. Grafting on resistant rootstocks can provide positive effects against to *Fusarium* wilt, *Verticillium* wilt, *Bacterial* wilt, *P. capsici* and root-knot nematodes in these vegetables (Lee 1994; Oda 1999; Traka-Mavrona et al. 2000; Leonardi and Romano 2004; Rivard and Louws 2008). Rootstocks can also supply great advantages in vegetable production with strong growing performance and tolerance or resistance for abiotic stress factors such as salinity, drought, high and low temperatures (Ahn et al. 1999; Ioannous 2001; Bletsos et al. 2003; Rivero et al. 2003; Oka et al. 2004; Hibar et al. 2006; Leonardi and Giuffrida 2006; King et al. 2008). As a result, grafting may increase the yield and quality depending on the rootstocks (Davis et al. 2008).

The aim of this study was to determine the effect of grafted plants on control of *Fusarium* and *Verticillium* wilts and root knot nematodes in bell peppers. In addition, the effects of rootstocks on yield of grafted peppers grown in sterile soil conditions were also investigated.

Materials and Methods

'Kandil' and 'California Wonder' bell pepper varieties were used as commercial varieties, and 'Snooker F_1' (Syngenta Seed, Holland), 'Dro F_1' (Kanda Seeds Co., Japan) 'NGS' and 'NGC' (AVRDC, Taiwan) were used as rootstock. 'Snooker F_1' rootstock was chosen because it was commonly used as rootstock in pepper cultivation. 'Dro F_1' rootstock, which developed by Kanda Seed Company was chosen due to its strong growth performance. 'NGS' and 'NGC' rootstocks, which developed by AVRDC, were selected to evaluate their responses against to *Fusarium* and *Verticillium* wilt. Nongrafted and selfgrafted plants grown in sterile and infected plots were used as control. Seeds of rootstocks were sown about 4 to 6 days earlier than commercial varieties. When plants reached to the 4 to 5 true leaves, grafting was done by slunt-cut grafting technique. Grafted and nongrafted seedlings were planted with a distance of 0.70 m between rows and 0.30 m in rows. Growing media were prepared with mixing sterile soil, sand and composted farmyard manure at rates of 1:1:1. Growth media was sterilized with dry heat sterilization method after mixing. Black plastic mulch used to prevent contamination of sterilized growth media. The experiment was conducted in randomized split plots design with three replications. Ten plants were grown in each plot.

Fusarium oxysporium f. sp. *vasinfectum* and *Verticillium dahliae* were isolated from infected pepper plants that were grown previous season and then these isolates were used in the experiment. Seedlings were inoculated before planting (Koike et al. 1994; Ficcadenti et al. 2002). Inoculated plants were observed with five-day intervals. The number of dead and healthy plants was recorded for 21 days after the inoculation. Plants were classified as sensitive against to *Fusarium* or *Verticillium* wilt when they died. Plants were classified as resistant when they remained free of wilt symptoms.

Root knot nematode (*Meloidogyne incognita* (Kofoid & White)) was isolated from infected tomato roots and then it was used in the experiment. Grafted seedlings were inoculated with 1000 newly hatched second stage juveniles per plant after ten days from planting (Charu and Trivedi 1998). Plants were pulled up with their roots at the end of growing season. After that, roots were washed under tap water and a root galling index was determined by examining in ten plant root systems in each treatment according to galling index scale from 0 to 10 (Barker 1985), where 0 represents no galls on the roots, and 10 represents maximum galls on the roots (Kinloch 1990).

The effects of rootstocks and pathogens were analyzed by ANOVA using the SPSS software package (SPSS 10 for Windows 2001). Duncan's multiple range tests were performed at 5 % level.

Results

Fusarium oxsysporium experiment

Grafted plants were less affected from *Fusarium* wilt than nongrafted and selfgrafted pepper plants. Plants, which are control treatments, were killed around 75–80 %. However, wilt symptoms were no occurred in 'Kandil' and 'California Wonder' grafted on 'Snooker F_1' and 'California Wonder' grafted on 'Dro F_1'. Wilt rate was 25 % in 'Kandil' grafted on 'Dro F_1'. Wilt rate was changed between 25 and 50 % in all grafting combinations of 'NGS' and 'NGC' (Fig. 1). The highest yield was obtained from 'Kandil' (5.40 kg m^{-2}) and 'California Wonder' (5.25 kg m^{-2}) grafted on 'Dro F_1' and 'Kandil' (5.17 kg m^{-2}) grafted on 'Snooker F_1'. The lowest yield was obtained from nongrafted and selfgrafted plants (Table 1).

Verticillium dahliae experiment

Verticillium wilt realized between 80 and 90 % during the growing season. The emergence time of *Verticillium* wilt was different between grafted and nongrafted treat-

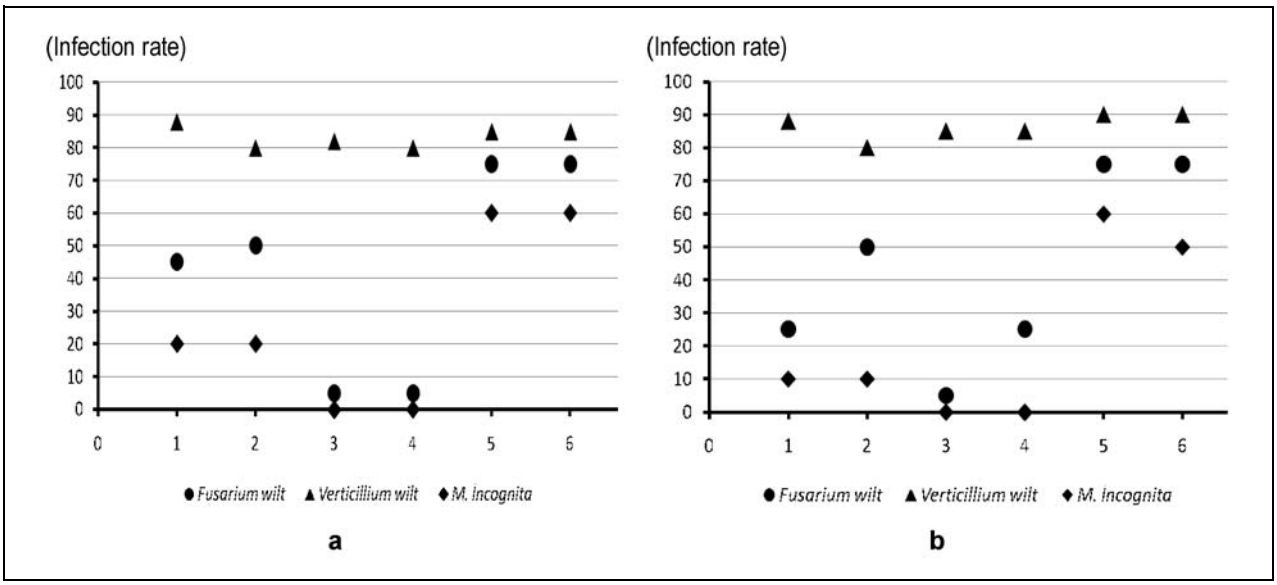


Fig. 1. Infection rates (%) of grafted and nongrafted plants a: 'California Wonder'; b: 'Kandil' (1: 'NGS', 2: 'NGC', 3: 'Snooker F_1', 4: 'Dro F_1', 5: Nongrafted plants, 6: Selfgrafted plants).

Table 1. Effects of rootstocks on marketable yield in contaminated with *Fusarium oxysporium, Verticillium dahliae* and *Meloidogyne incognita* (kg m^{-2}).

Varieties	Rootstocks	*Fusarium*	*Verticillium*	*M. incognita*	Control
'Kandil'	'NGS'	3.92 b[(1)]	2.36 a	2.94 b	4.15 b
	'NGC'	4.01 b	1.77 ab	3.66 a	4.52 a
	'Snooker F_1'	5.17 a	2.06 a	3.47 ab	4.09 b
	'Dro F_1'	5.40 a	1.35 b	3.12 ab	4.81 a
	Nongrafted	1.64 c	0.85 c	2.97 b	4.43 a
	Selfgrafted	1.28 c	0.88 c	2.75 b	3.85 b
'California Wonder'	'NGS'	3.78 c	2.07 a	2.23 b	3.76 bc
	'NGC'	4.52 b	1.03 b	2.81 b	4.14 bc
	'Snooker F_1'	4.26 bc	1.61 a	3.66 a	4.52 b
	'Dro F_1'	5.25 a	1.76 a	3.49 a	5.49 a
	Nongrafted	1.35 d	0.89 b	2.87 b	3.81 bc
	Selfgrafted	1.22 d	0.92 b	2.46 b	3.68 c

[(1)] Significant at 5 % level

ments. *Verticillium* wilt emerged at the begining of harvest in control treatments, but it emerged at about middle of the harvest period in all of the grafted treatments. On the other hand, emerging time of *Verticillium* wilt was delayed by grafting (Fig. 1). As a result, yield was significantly increased in grafted plants when they compared to the control plants. Increasing of yield indicates that all rootstocks had tolerance to *Verticillium* wilt. Also, there were significant differences among yields of all the grafted plants. The highest yield was obtained from 'Kandil' grafted on 'NGS' rootstock at infected with *V. dahliaee* (2.36 kg m^{-2}) (Table 1).

Root-knot nematode experiment

No root galls were observed in plants which grafted on 'Snooker F_1' and 'Dro F_1' although they were infected with *M. incognita*. Root galling rate was determined 10 % in the 'Kandil' grafted on 'NGS' and 'NGC'. It realized 20 % in the 'California Wonder' grafted on 'NGS' and 'NGC'. The highest root-galling rate occurred between 50 and 60 % in the control treatments (Fig. 1). The highest marketable yield was obtained from 'California Wonder' grafted on 'Snooker F_1'; 'Kandil' grafted on 'NGC'; 'California Wonder' grafted on 'Dro F_1' and 'Kandil' grafted on 'Snooker F_1' with 3.66, 3.66, 3.49 and 3.47 kg m^{-2} respectively in the inoculated plots. There were statistically significant differences among the treatments (Table 1).

Control experiment

The highest marketable yield was obtained from 'Kandil' and 'California Wonder' plants grafted on 'Dro F_1' in uninfected conditions. The marketable yield was similar both 'Kandil' and 'California Wonder' when they grafted on 'Snooker F_1', 'NGS' and 'NGC' rootstocks. However, it was lower than 'Kandil' and 'California Wonder' grafted on 'Dro F_1'. The lowest yield was obtained from selfgrafted plants of 'Kandil' and 'California Wonder' (Table 1).

Discussion

Fusarium wilt, *Verticillium* wilt and root knot nematodes (*M. incognita)* are known as important soil-borne pests for pepper in different parts of the world. (Bhat et al. 2003; Altinok 2005; Sogut and Elekcioglu 2007). Yield and quality are highly decreased by these soil pests and diseases in pepper cultivation. Recently, using of grafted plants has been increased the yield in commercial hybrids, which do not have adequate resistance against to soil-borne pests and diseases (Oka et al. 2004; Khah et al. 2006; Davis et al. 2008; Burelle et al. 2009). Using of grafted plants is not widespread in pepper cultivation. In our study, commercial varieties were grafted on different rootstocks and their responses were evaluated against *Fusarium* wilt, *Verticillium* wilt and root knot nematode (*M. incognita*). Both grafted and nongrafted plants were affected by *Fusarium* wilt, *Verticillium* wilt and root knot nematode (*M. incognita*), but they were affected considerably variable rate and different period of growing season. Especially, 'Snooker F_1' and 'Dro F_1' shown significantly lower disease rate than other rootstocks and control plants. Results showed that these rootstocks were more resistant than the others to the *Fusarium* wilt. Thus, 'Kandil' and 'California Wonder' grafted on 'Snooker F_1' and 'Dro F_1' rootstocks had higher marketable yield in infected plots. Our results agree with data presented by Attia et al. (2003) which reported that grafted pepper plants were less affected than ungrafted plants by wilting. Although not all the rootstocks, which are used in this study, showed resistance against to *Verticillium dahlea,* grafted plants were affected later than control treatments. Therefore, grafted plants had higher marketable yield than control treatments. It was concluded that, the delay of the *Verticillium* wilt on grafted plants due to strong root growth of the rootstocks. King et al. (2008) reported that resistance could be obtained against to *Verticillium dahlea* by grafting of sensitive varieties onto resistant rootstocks in vegetables, but there was no report on pepper.

There were no or slightly root galling in all the grafting combinations than control treatments, and marketable yield was higher as well. Based on the results of the present study, 'NGS' and 'NGC' rootstocks showed tolerant reaction to the root galling. 'Kandil' × 'NGC' graft combination yielded more than 'California Wonder' × 'NGC' graft combination. It was concluded that, the yield increase in 'Kandil' × 'NGC' combination could be related with high graft compatibility or vigour of the rootstock. On the other hand, 'Snooker F_1' and 'Dro F_1' rootstocks showed resistant reaction against *Meloidogyne incognita* without forming any root galling. The results presented here on root-galling are in agreement with data reported by SOGUT and ELEKCIOGLU (2007). ROS et al. (2005) suggested that grafted pepper plants could be used as an alternative method instead of using methyl-bromide for getting rid of root knot nematodes such as *M. incognita* and *M. javanica*. Similarly, the results are in agreement with OKA et al. (2004) which reported that grafted of commercial varieties onto 'Snooker F_1' rootstock had lower root galling and higher marketable yield than control treatments when they were grown in *M. incognita* infected soil. Also, JANG et al. (2008) reported that rootstocks increase the yield of pepper plants in sterile conditions depending on rootstock vigour. Furthermore, COLLA et al. (2008) reported that marketable yield was increased between 22 and 49 % when pepper plants grafted on 'Snooker F_1', 'Dro 8801' and 'Dro F_1' rootstocks. The results, which obtained in this study, are in agreement with their results. Both commercial varieties, which are grafted on all the rootstocks, showed superior tolerance against to *Fusarium wilt* (*F. oxysporium* f. sp. *vasinfectum)* and root knot nematode (*M. incognita*) under controlled conditions.

As a conclusion, grafting could be an effective method for preventing the soil-borne diseases and pests, and it has a positive effect on yield and quality as well in open field conditions. However, ecological conditions, rootstocks, varieties and graft compatibility should be taken into considered in grafting applications.

References

AHN, S.J., Y.J. IM, G.C. CHING, B.H. CHO and S.R. SUH 1999: Physiological responses of grafted-cucumber leaves and rootstock roots affected by low temperature. Sci. Hort. **81**, 397–408.

ALTINOK, H.H. 2005: First Report of *Fusarium* wilt of eggplant caused by *Fusarium oxysporium* f. sp. *melongenae* in Turkey. Plant Path. **54**, 577p.

ANONYMOUS, 2008: Pepper production in Turkey. http://www.fao.org/corp/statistics/en.

ATTIA, M.F., A.M. ARAFAT, M.A. MOUSTAFA and M.A. MOHAMED 2003: Pepper grafting, a method of controlling soilborne diseases and enhancement of fruit yield: 1. Improvement of pepper resistance to *Fusarium* wilt. Egypt. J. Phytopathol. **31**, 151–165.

BARKER, K.R. 1985: Nematode extractions and bioassays. In: BARKER, K.R., C.C. CARTER and J.N. SASSER (eds.): An advanced treatise on *Meloidogyne*, methodology, Vol. II. North Carolina State University Graphics, Raleigh, pp. 19–35.

BHAT, R.G., R.F. SMITH, S.T. KOIKE, B.M. WU and K.V. SUBBARAO 2003: Characterization of *Verticillium dahliae* isolates and wilt epidemics of pepper. Plant Dis. **87**, 789–797.

BLETSOS, F., C.C. THANASSOULOPOULOS and D.G. ROUPAKIAS 2003: Effect of grafting on growth, yield and *Verticillium* wilt of eggplant. HortSci. **183**, 186–186.

BURELLE, N.K., E.N. ROSSKOPF and M.G. BAUSHER 2009: Grafting for control of *Meloidogyne* spp. in fruiting vegetables. Organiz. Nematologists Trop. Am. **39**, 121–123.

CHARU, J. and P.C. TRIVEDI 1998: Nematicidal activity of certain plants against root-knot nematode, *Meloidogyne incognita* infecting chickpea, *Cicer arietinum*. Ann. Plant Prot. Sci. **5**, 171–174.

COLLA, G., Y. ROUPHAEL, M. CARDARELLI, O. TEMPERINI, E. REA, A. SALERNO and F. PIERANDREI 2008: Influence of grafting on yield and fruit quality of pepper (*Capsicum annuum* L.) grown under greenhouse conditions. Acta Hort. **782**, 359–364.

DAVIS, A.R., P.M. PERKINS VEAZIE, R. HASSELL, A. LEVI, S.R. KING and X. ZHANG 2008: Grafting effects on vegetable quality. HortSci. **43**, 1670–1672.

FICCADENTI, N., S. SESTILI, S. ANNIBALI, G. CAMPANELLI, A. BELISARIO, M. MACCARONI and L. CORAZZA 2002: Resistance to *Fusarium oxysporium* f. sp. *melonis* race 1, 2 in muskmelon lines Nad-1 and Nad-2. Plant Dis. **86**, 897–900.

HIBAR, K., M. DAAMI-REMADI, M. JABNOUN-KHIAREDDINE and M. EL MAHJOUB 2006: Control of *Fusarium* crown and root rot of tomato, caused by *Fusarium oxysporium* f. sp. *radicis-lycopersici* by grafting onto resistant rootstocks. Plant Path. J. **5**, 161–165.

IOANNOUS, N. 2001: Integrating soil solarization with grafting on resistant rootstocks for management of soil-borne pathogens of eggplant. J. Hort. Sci. Biotech. **76**, 396–401.

JANG, Y., Y. CHO, H. RHEE and Y. UM 2008: Effects of rootstocks and night temperature on the growth and yield of grafted pepper (*Capsicum annuum* L.). Hort. Environ. Biotech. **49**, 63–71.

KHAH, E.M., E. KAKAVA, A. MAVROMATIS, D. CHACHALIS and C. GOULAS 2006: Effect of grafting on growth and yield of tomato (*Lycopersicon esculentum* Mill.) in greenhouse and open-field. J. Appl. Hort. **8**, 3–7.

KING, S.R., A.R. DAVIS, W. LIU and A. LEVI 2008: Grafting for disease resistance. HortSci. **43**, 1673–1675.

KINLOCH, R.A. 1990: Screening for resistance to root nematodes. In STAR, J.L. (ed.): Methods for evaluating plant species for resistance to plant-parasitic nematodes. Hyattsville, MD, USA, Society of Nematologists, 24–32.

KOIKE, S.T., K.V. SUBBARAO, R.M. DAVIS, T.R. GORDON and J.C. HUBBARD 1994: *Verticillium* wilt of cauliflower in California. Plant Dis. **78**, 1116–1121.

LEE, J.M. 1994: Cultivation of grafted vegetables I. Development of grafting robots in Japan. HortSci. **29**, 235–239.

LEONARDI, C. and D. ROMANO 2004: Recent issues on vegetable grafting. Acta Hort. **631**, 163–174.

LEONARDI, C. and F. GIUFFRIDA 2006: Variation of plant growth and macronutrient uptake in grafted tomatoes and eggplants on three different rootstocks. Eur. J. Hort. Sci., **71**, 97–101.

ODA, M. 1999: Grafting of vegetables to improve greenhouse production. Food and Fertilizer Technology Center. Extension Bulletin **480**, 1–11.

OKA, Y., R. OFFENBACH and S. PIVONIA 2004: Pepper rootstock graft compatibility and response to *Meloidogyne javanica* and *M. incognita*. J. Nematology **36**, 137–141.

RIVARD, C.L. and F.J. LOUWS 2008: Grafting to manage soilborne diseases in heirloom tomato production. HortSci. **43**, 2104–2111.

RIVERO, R.M., J.M. RUIZ and L. ROMERO 2003: Role of grafting in horticultural plants under stress conditions. J. Food Agric. Environment. **1**, 70–74.

ROS, C., M.M. GUERRERO, M.A. MARTINEZ, N. BARCELO, M.C. MARTINEZ, I. RODRIGUEZ, A. LACASA, P. GUIRAO and A. BELLO 2005: Resistant sweet pepper rootstocks integrated into the management of soilborne pathogens in greenhouse. Acta Hort. **698**, 305–310.

SOGUT, M. and I.H. ELEKCIOGLU 2007: Methyl bromide alternatives for controlling *Meloidogyne incognita* in pepper varieties in the Eastern Mediterranean region of Turkey. Turk. J. Agric. For., **31**, 31–40.

TRAKA-MAVRONA, E., M. KOUTSIKA-SOTIRIOU and T. PRITSA 2000: Response of squash (*Cucurbita* spp.) as rootstock for melon (*Cucumis melo* L.). Sci. Hort. **83**, 353–362.

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