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Original scientific article

EFFECTS OF GRAFTING ON FRUIT YIELD AND LEAF NUTRIENT CONTENTS OF PEPPER (*Capsicum annuum* L.) INBRED LINES

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A field experiment was conducted to investigate the rootstock effects on the fruit and seed yield and leaf nutrient contents of pepper, four pepper inbred lines (ERÜ 1227 and ERÜ 462: Long fruited green pepper type; 21 H-1-2 and 33 H-3-1: Bell shaped pepper type) were grafted onto two pepper rootstock genotypes (46 KB F1 and Scarface F1). The non-grafted scion genotypes were used as control plants. Between grafted and non-grafted plants significant ($p<0.001$) differences were found in fruit yield, dry matter, diameter, length and fruit number, seed yield, thousand seed weight and leaf P, K, Ca, Mg, Mn and Zn contents. Among the graft combinations, significantly higher fruit yield, dry matter, length of long fruited green pepper genotypes, leaf K content was observed when 'ERÜ 1227' grafted onto 'Scarface' rootstock; significantly higher Ca and Mn contents were recorded when 'ERÜ 462' grafted onto 'Scarface' rootstocks. Whereas, significantly highest fruit number and diameter of long fruited green pepper genotypes was recorded at the non-grafted plants of 'ERÜ 1227'. Overall, the pepper rootstock genotype 'Scarface' showed a better performance for fruit yield, dry matter, length of long fruited green pepper genotypes, fruit diameter of bell shaped pepper genotypes, K, Ca, Mg and Mn contents in leaf tissue, thousand seed weight in different graft combinations as compared to non-grafted pepper plants. All these suggest that the powerful rootstocks, which might be characterized by an efficient nutrient uptake, play a major role in improvement of plant growth performance, fruit, and seed yield.

Keywords: fruit diameter, rootstock, scion, seed yield, thousand seed weight.

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INTRODUCTION

Pepper (*Capsicum annuum*) belongs to the Solanaceae family which also include tomato, eggplant, potato, tobacco, and petunia (TINDALL, 1983). According to BOSLAND and VOTAVA (2000), sweet pepper and hot pepper are rich in Vitamins A and C and also good source of Vitamin B_2, potassium, phosphorus and calcium. Capsicum fruits are used in the food industry as a colouring and flavouring agent in sauces, soups, processed meat, snacks, candies, soft drinks and alcoholic beverages either in the ground form or as an oleoresin (concentrated extract). In addition to their use as food or condiments, peppers are also used as medicine and have ornamental values (NAGLE *et al*., 1979).

Grafting involves joining together two living plant parts- a rootstock and a scion- to produce a single, living plant. The term scion refers to the shoot piece that comes from a donor plant and which will be the canopy of the grafted plant. The term rootstock refers to the plant that receives and fuses with the scion and functions as the root system of the grafted plant. Although grafting is an age old practice, it did not become common practice in herbaceous vegetables and ornamentals until the 20th century (LEE, 1994; LEE *et al*., 2010). The cultivation of grafted vegetable plants began in Korea and Japan at the end of 1920, with the grafting of watermelon plants to squash rootstocks (YAMAKAWA, 1982). Use of grafted vegetables (tomatoes, bean, eggplant, cucumber, melon, and watermelon) became a widespread agricultural practice in many parts of the world such as Japan, Korea, the Mediterranean basin, and several European countries (POGONYI *et al*, 2005).

The advantages of vegetable grafting are attributed principally to resistance of rootstocks to soil-borne diseases (fungus, bacterial wilt and nematodes), but also to increased vigour and stress tolerance. The problems associated with banning methylbromide for soil fumigation have increased vegetable grafting in Europe and the United States in the last decade. However, the use of grafting in pepper plants is not as common as in the rest of horticultural species mainly due to the lack of commercial rootstocks that perform satisfactorily (LEE *et al*, 2010), in spite of the fact that the use of appropriate rootstocks can be an alternative strategy to avoid or reduce yield losses caused by environmental stresses (SINGH *et al.*, 2017). So far, slight attention has been paid to the effect of grafting and rootstocks on grafted pepper vegetative growth, fruiting characteristics and yield has been investigated in few studies and with only a limited number of rootstocks (TSABALLA *et al*., 2013; DONAS-UCLES *et al.*, 2014; SOLTAN *et al.*, 2017). For all these reasons, the use of pepper grafted plants is not yet widely implemented in Turkey. Inbreeding effect due to selfing causes depression in plant growth and development in pepper inbred lines. Therefore, this study was investigated related to the pepper (*Capsicum annuum* L.) inbred lines were grafted onto different pepper rootstock genotypes in order to assess the fruit and seed yield and leaf nutrient contents of pepper plants based on the physiological and morphological response mechanisms.

MATERIALS AND METHODS

Plant material, treatments and experimental design

The experiment was conducted in the 2017-18 growing seasons at the vegetable research field in the campus of Faculty of Agriculture, University of Erciyes, Kayseri, in Turkey (38° 43' 56" N, 35° 29' 7" E). Four pepper inbred lines (21 H-1-2, 33 H-3-1, ERÜ 1227 and ERÜ 462)

were used as scion varieties and two different pepper cultivars (46 KB F1 and Scarface F1) were used as rootstock materials. The scion varieties of ERÜ 1227 and ERÜ 462 are long fruited green pepper type of inbred line genotypes. The scion varieties of 21 H-1-2 and 33 H-3-1 are bell shaped pepper type of inbred line genotypes. The rootstock variety of 46 KB F1 is bristle pepper genotypes. 21 H-1-2, 33 H-3-1 and 46 KB F1 were obtained from Ministry of Agriculture and Forestry, Black Sea Agricultural Research Institute, Turkey. The rootstock variety of Scarface F1 (Enza Zaden) is a hybrid rootstock commercial pepper genotype. It performs best when grafted to generative scions and will increase yields by extending the production season longer than is possible with non-grafted plants.

The seeds were sown in multi-pots in a mixture of peat (pH: 6.0-6.5) and perlite (2v:1v). When the seedlings developed five or six true leaves, scions were grafted onto rootstocks by "tube grafting" described by LEE, (1994) on May 9th, 2017. Non-grafted scion varieties were used as control plants. The grafted and non-grafted plants were transplanted into the field on June 5th, 2017. 0.5-meter spacing between plants and 1.0-meter spacing between the rows were used during transplanting in a randomized completely block design containing three replications. Four plants were selected randomly and tagged from each treatment of the experimental units and measurement was made on these plants for yield and other morphological traits. Measurements were made on the same plants throughout the growing season. Harvesting was done on September 19th, 2017. At the end of the harvest, plants were pulled up from the soil and bought to the Plant Physiology Laboratory, Erciyes University.

Harvest, fruit fresh -dry weight and fruit diameter-length determination

At the end of the experiment, plants were harvested by separating them into shoot, fruit and roots. Fruit diameter and length were measured from the five randomly selected fruits at the vegetative maturity stage with the help of calipers with the diameter and length were expressed in millimeters. The diameter and length of bell shaped peppers and long fruited green peppers were measured separately in two different groups. Number of fruits per plant was recorded by counting the number of fruits at each harvest and the total number of fruits from each harvest was recorded and expressed as a number. Total fruit fresh weight was recorded by taking the weight of five fruits from each tagged plant in successive harvests and the mean weight of the fruits was recorded and expressed in kilograms. The fruit yield per plant was measured by taking a weight of pepper fruits from five tagged pepper plants from each plot at each harvest. The total fresh weight of fruit of all harvests was summed up and expressed in kilograms. The fruits were harvested at the fully ripe stage. For the total dry fruit weight determination, fruits were dried in a forced-air oven for 72 h at 70°C.

Mineral analysis

0.5 g of the dried plant tissues (leaf) were analyzed for K, Ca, Na. Their concentrations were determined by dry ashing at 400°C for 4.5 h, dissolving the ash in 5 ml of HCl with 20% concentration was added to the ashed samples and filtered. The filtered solutions were then diluted with distilled water to a volume 50 ml. Out of which 10 ml was taken for Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) analysis. The ICP-AES results were converted into percentages (%) and parts per million (ppm).

Seed yield and thousand seed weight

Seed extracted from fruits were weighed using sensitive balance and mean values were calculated. Thousand seed weight was carried out according to the ISTA rules (ISTA, 1996).

Statistical analysis

Analysis of variance (ANOVA) was performed using the SAS program (SAS 9.0, SAS Institute Inc., Cary, NC, USA). If ANOVA determined that the effects of the treatments were significant (*P < 0.05, **P < 0.01, ***P < 0.001, and ns means not significant for F-Test), then the treatment means were separated by Duncan's Multiple Range Test (P < 0.05). Pearson correlation coefficients were calculated using the PROC CORR procedure of SAS.

RESULTS AND DISCUSSION

Number of fruits per plant, fruit yield, fruit dry matter, seed yield and thousand seed weight

The results obtained from this experiment indicated that highly significant differences (P<0.001) were found among the graft combinations in number of fruits per plant, fruit yield, fruit dry matter, seed yield and thousand seed weight (Table 1). The number of the fruits per plant is related to the higher fruit yield. The non-grafted plant 'ERÜ 1227' (20.38) recorded highest number of fruits per plant followed by 'ERÜ 1227' grafted onto 'Scarface F1' rootstock (18.95). TURHAN *et al.* (2011) stated that the grafted tomato plants had significantly higher fruit number per truss than non-grafted plants. Similar results were observed by IBRAHIM *et al.* (2001). The significantly lowest number of the fruits per plant was produced by '33 H-3-1' grafted onto 'Scarface F1' rootstock (11.67). The reason might be graft combination of '33 H-3-1/Scarface F1' increased its fruit diameter and therefore it had the bigger fruits, so it has the minimum number of fruits (Table 2).

The average number of fruits ranged from 20.38-11.67. Regarding total fruit yield, 'ERÜ 1227' grafted onto 'Scarface' rootstock recorded highest total fruit yield and was followed by '21 H-1-2' grafted onto '46 KB F1' rootstocks. It is clearly evident that grafting has a positive effect on total fruit yield, since it increased the total fruit yield of non-grafted plant of 'ERÜ 1227' from 1483.63 g to 2039.81 g/plant which was an increase by almost 37.49% with 'Scarface' rootstock. Furthermore, non-grafted genotype 'ERÜ 462' (567.73 g/plant) increased its total fruit yield when it was grafted with the rootstock genotype of '46 KB F1' (781.71 g/plant) by almost 42.17%. Non-grafted genotype '21 H-1-2' increased its total fruit yield in different ratios when it was grafted with the rootstock genotype of '46 KB F1' (99.13%) and 'Scarface' (52.55%). On the other hand, conflicting results in our study were also found when the non-grafted control plant '33 H-3-1' was grafted onto 'Scarface' rootstock and consequently total fruit yield reduced from 1401.96 g to 733.86 g/plant which demonstrated a decline by almost 47% and it was grafted onto '46 KB F1' rootstock and consequently total fruit yield reduced from 1401.96 g to 1230.43 g/plant which demonstrated a decline by almost 12%. The reason might be '33 H-3-1/ Scarface' and '33 H-3-1/ 46 KB F1' had the minimum number of fruits per plant (Table 1). The lowest total fruit yield was produced in 'ERÜ 462' grafted onto 'Scarface' and non-grafted control plants of 'ERÜ 462'.

Table 1. Effect of graft combination on number of fruits per plant, fruit yield, fruit dry matter, seed yield and thousand seed weight of pepper plants

Graft Combination	Number of fruits per plant	Fruit yield (g plant^{-1})	Fruit dry matter (g plant^{-1})	Seed yield (g plant^{-1})	Thousand seed weight (g plant^{-1})
ERÜ 1227	20.38 a	1483.63 c	144.92 b	20.67 c	5.29 bcd
ERÜ 1227/Scarface	18.95 b	2039.81 a	162.04 a	16.84 de	5.24 bcd
ERÜ 1227/46 KB F1	16.64 c	750.49 h	64.75 ı	7.74 g	4.06 fg
ERÜ 462	15.71 cde	549.96 ı	111.83 d	32.76 b	4.72 de
ERÜ 462/Scarface	12.81 hı	567.73 ı	70.43 h	33.06 b	5.54 ab
ERÜ 462/46 KB F1	13.71 fg	781.71 h	142.30 b	36.07 a	5.14 bcd
21H-1-2	14.90 ef	878.54 g	79.61 g	9.59 g	5.68 ab
21H-1-2/Scarface	13.47 gh	1340.13 e	102.62 e	18.39 d	5.96 a
21H-1-2/46 KB F1	14.92 de	1749.38 b	135.18 c	9.18 g	5.40 abc
33 H-3-1	16.14 cd	1401.96 d	95.65 f	17.98 d	4.79 cde
33 H-3-1/Scarface	11.67 ı	733.86 h	62.98 ı	13.24 f	4.44 ef
33 H-3-1/46 KB F1	13.33 gh	1230.43 f	93.01 f	15.14 ef	3.66 g
Minimum	**11.67**	**549.96**	**62.98**	**7.74**	**3.66**
Maximum	**20.38**	**2039.81**	**162.04**	**36.07**	**5.96**
Grafted+non-grafted mean	**15.22**	**1125.64**	**105.44**	**19.22**	**4.99**
Non-grafted mean	**32.49**	**1071.81**	**97.28**	**19.58**	**5.04**
Grafted mean	**38.19**	**1124.48**	**109.97**	**20.27**	**4.83**
F-Test	***	***	***	***	***

[1] Values denoted by different letters are significantly different between genotypes within columns at $P < 0.05$ (T-Test). ns, non-significant. *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$ (F-Test).

Our results are in accordance with the results of OZMEN *et al.* (2015), MARSIC *et al.* (2016) and KOMBO and SARI (2019) who concluded that grafted plants produce much more single fruit weight, total fruit yield and quality than non-grafted plants. The lowest yield in non-grafted plants was due to the decrease in fruit mean mass and number of fruits per plant (COLLA *et al.*, 2006). In the grafted plants more yield was reported in some vegetables such as pepper (GISBERT *et al.,* 2010; DONAS-UCLES *et al.,* 2014), melon (RICÁRDEZ-SALINAS *et al.,* 2010), tomato (IBRAHIM *et al.,* 2001) and watermelon (MIGUEL *et al.,* 2004; YETISIR and SARI, 2019).

Concerning fruit dry matter, significantly highest fruit dry matter was produced by 'ERÜ 1227' grafted onto 'Scarface' rootstock followed by non-grafted control plants of 'ERÜ 1227', while the lowest was shown by the 'ERÜ 1227' grafted onto '46 KB F1' rootstock and '33 H-3-1' grafted onto 'Scarface' rootstock (Table 1). There were different findings regarding effect of grafting on total fruit matter such as YARŞI *et al.* (2008) and TUĞ (2011) that grafted plants produced more fruit dry matter and fruit quality than non-grafted plants like tomato, pepper, eggplant, cucumber and watermelon. On the other hand, there were no significant differences observed between grafted and non-grafted plants such as pepper (OKA *et al*., 2004), in tomato (AYDIN, 2006), in tomato under greenhouse conditions (ULUKAPI and ONUS, 2005).

Table 2. Effect of graft combination on fruit diameter and fruit length of pepper plants

Graft Combination	Fruit diameter (mm fruit^{-1})	Fruit length (mm fruit^{-1})
Long fruited green pepper genotypes		
ERÜ 1227	41.73 a	134.00 a
ERÜ 1227/Scarface	40.30 b	133.15 a
ERÜ 1227/46 KB F1	37.20 c	115.08 b
ERÜ 462	31.42 e	77.13 d
ERÜ 462/Scarface	33.59 d	81.14 c
ERÜ 462/46 KB F1	32.61 de	84.18 c
Minimum	**31.42**	**77.13**
Maximum	**41.73**	**134.05**
Grafted+non-grafted mean	**36.14**	**104.11**
Non-grafted mean	**36.57**	**105.56**
Grafted mean	**35.92**	**103.38**
F-Test	***	***
Bell shaped pepper genotypes		
21H-1-2	59.42 bc	64.32 d
21H-1-2/Scarface	66.21 a	66.50 cd
21H-1-2/46 KB F1	58.40 c	55.23 e
33 H-3-1	57.49 c	68.47 bc
33 H-3-1/Scarface	68.20 a	70.89 b
33 H-3-1/46 KB F1	62.55 b	77.49 a
Minimum	**57.49**	**55.23**
Maximum	**68.20**	**77.49**
Grafted+non-grafted mean	**62.04**	**67.15**
Non-grafted mean	**58.45**	**66.39**
Grafted mean	**63.84**	**67.52**
F-Test	***	***

[1] Values denoted by different letters are significantly different between genotypes within columns at $P < 0.05$ (T-Test). ns, non-significant. *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$ (F-Test).

In terms of seed yield, the significantly highest seed yield was obtained by ‘ERÜ 462’ grafted onto ‘46 KB F1’ rootstock (Table 1). This obviously showed that grafting has a positive effect on seed yield, since it increased the seed yield of non-grafted plant of ‘ERÜ 462’ from 32.76 g to 36.07 g/plant which was an increase by almost 10% with ‘46 KB F1’ rootstock. It was followed by ‘ERÜ 462’ grafted onto ‘Scarface’ rootstocks and non-grafted plants of ‘ERÜ 462’. Furthermore, non-grafted genotype ‘21 H-1-2’ (9.59 g/plant) increased its seed yield when it was grafted with the rootstock genotype of ‘Scarface’ (18.39 g/plant) by almost 91%. The seed yield was ranged from 36.07-7.74 g. Though, the significantly lowest seed yield was obtained by both ‘21 H-1-2’ and ‘ERÜ 1227’ grafted onto ‘46 KB F1’ rootstock, and non-grafted control plants of ‘21 H-1-2’. Conversely, conflicting results in our study were also found when the non-grafted control plant 33 H-3-1 was grafted onto Scarface rootstock and consequently seed yield reduced from 17.98 g to 13.24 g/plant which demonstrated a decline by almost 26% and it was grafted

onto '46 KB F1' rootstock and consequently seed yield reduced from 17.98 g to 15.14 g/plant which demonstrated a decline by almost 15%. Furthermore, non-grafted genotype 'ERÜ 1227' (20.67 g/plant) decreased its seed yield when it was grafted with the rootstock genotype of '46 KB F1' (7.74 g/plant) by almost 62% and with the rootstock genotype of 'Scarface' (16.84 g/plant) by almost 18%. Similar results obtained by KOMBO and SARI (2019) who clearly stated that grafted plants produced more seed yield than non-grafted control plants. Enhanced seed yield in grafted plants may be the result of increased plant biomass and number and size of fruits, that were all caused by the consequences of a stronger and deeper root system that can absorb more water and nutrients. In a study conducted by NERSON and PARIS (2002) stated that increased seed yield is determined by many components, however the main one is the number of fruit per unit area.

Regarding thousand seed weight, significantly highest thousand seed weight was produced by '21 H-1-2' grafted onto 'Scarface' rootstock followed by 'ERÜ 462' grafted onto 'Scarface' rootstock and non-grafted control plants of '21 H-1-2' (Table 1). Grafting increased the thousand seed weight of non-grafted plant of '21 H-1-2' from 5.68 g to 5.96 g/plant which was an increase by almost 5% with 'Scarface' rootstock. Furthermore, non-grafted genotype 'ERÜ 462' (4.72 g/plant) increased its thousand seed weight when it was grafted with the rootstock genotype of 'Scarface' (5.54 g/plant) by almost 17% and '46 KB F1' (5.14 g/plant) by almost 9%. Non-grafted genotype '21 H-1-2' increased its thousand seed weight when it was grafted with the rootstock genotype of 'Scarface' rootstock (5%). However, the lowest thousand seed weight was produced by the '33 H-3-1' grafted onto '46 KB F1' rootstock (Table 1). On the other hand, contradictory results in our study were also found when the non-grafted control plant '33 H-3-1' was grafted onto '46 KB F1' rootstock and consequently thousand seed weight reduced from 4.79 g to 3.66 g/plant which demonstrated a decline by almost 24%. Besides, non-grafted control plant 'ERÜ 1227' was grafted onto '46 KB F1' rootstock and consequently thousand seed weight reduced from 5.29 g to 4.06 g/plant which demonstrated a decline by almost 23%. KOMBO and SARI (2019) explained that thousand seed weight was significantly highest when watermelon cultivar of Crimson sweet (CS) was grafted on to Cucurbita 'NUN-9075', *Lagenaria* 'Argentario', and also at non-grafted control plants, on the other hand the significantly lowest thousand seed weight was found when CS was grafted on to citron watermelon 'PI296341'.

Fruit diameter and fruit length

The results obtained from this experiment indicated that highly significant differences ($P<0.001$) were found among the graft combinations in fruit diameter and fruit length (Table 2). Among bell shaped pepper genotypes, the significantly higher fruit diameter was observed in both '33 H-3-1' and '21 H-1-2' grafted onto 'Scarface' rootstock and was followed by in '33 H-3-1' grafted onto '46 KB F1' rootstock, while the lowest was observed in '21 H-1-2' grafted onto '46 KB F1' rootstock and non-grafted control plants of '33 H-3-1'. The diameter of the bell shaped pepper fruit was ranged from 68.20-57.49 mm. The significantly higher fruit length was observed by '33 H-3-1' grafted onto '46 KB F1' rootstock followed by '33 H-3-1' grafted onto 'Scarface' rootstock, while the lowest was found in '21 H-1-2/46 KB F1'. The length of the bell shaped pepper fruit was ranged from 77.49-55.23 mm (Table 2). TSABALLA *et al.* (2013) reported

that the fruit shape of the grafted pepper plants was changed in elongated fruits different from the normal round shape fruit in the scion when round shaped pepper was grafted on to long shaped pepper. DONAS-UCLES *et al.* (2014) examined the effect of grafting on pepper plants with different rootstocks and observed that the grafted plants had significantly higher fruit length than non-grafted plants; on the other hand, diameter of the peduncular end of the fruit was higher in the grafted plants but it was not significant.

Regarding long fruited green pepper genotypes, the significantly higher fruit diameter was observed by non-grafted control plants of 'ERÜ 1227' followed by 'ERÜ 1227' grafted onto 'Scarface' rootstock, while the lowest was shown by the non-grafted control plants of 'ERÜ 462' (Table 2). The diameter of the bell shaped pepper fruit was ranged from 41.73-31.42 mm. The significantly higher fruit length was observed in 'ERÜ 1227' grafted onto 'Scarface' rootstock and non-grafted control plants of 'ERÜ 1227' and was followed in 'ERÜ 1227' grafted onto '46 KB F1' rootstock, while the lowest was shown by the non-grafted control plants of 'ERÜ 462'. The length of the bell shaped pepper fruit was ranged from 134.0-77.13 mm (Table 2). KOMBO and SARI, (2019) studied in a grafting experiment by using watermelon cultivar of Crimson sweet (CS) was grafted on to three different rootstocks (*Cucurbita* 'NUN-9075', *Lagenaria* 'Argentario', and citron watermelon 'PI296341') to examine rootstock effects on seed yield and quality in watermelon on field conditions. The 'NUN-9075/CS' graft combination resulted significantly higher fruit diameter and fruit length, though non-grafted control plants had significantly lower fruit diameter and fruit length in field conditions. In some vegetable plants like pepper (GISBERT *et al.,* 2010) and watermelon (MIGUEL *et al*., 2004) larger fruits were observed when grafted on to rootstocks. Fruit quality might be different by grafting partly to different production environments (e.g. light intensity, air temperature, vapor pressure deficit) and methods (e.g. soilless vs. soil culture, irrigation, and fertilization), type of rootstock/scion combinations used, rootstock/scion incompatibility, and harvest time (LEE *et al*., 2010; ROUPHAEL *et al.*, 2010; ZHAO *et al*., 2011).

Leaf mineral composition and partitioning

The leaf macro- and microelements concentration and distribution in grafting combinations and pepper plants are displayed in Tables 3. Highly significant ($P<0.001$) differences were found in leaf macro- and microelements (P, K, Ca, Mg, Mn and Zn) concentration among graft combinations. The significantly highest values for the concentration of P in leaf recorded by '33 H-3-1' grafted onto '46 KB F1' rootstock and non-grafted control plants of '33 H-3-1' and followed by '33 H-3-1', 'ERÜ 462' and '21 H-1-2' grafted onto 'Scarface' rootstock. Regarding K concentration in leaf tissue, the significantly highest values were observed when 'ERÜ 1227' grafted onto 'Scarface' rootstock and followed by '21 H-1-2' grafted onto 'Scarface' rootstock and 'ERÜ 462' grafted onto '46 KB F1' rootstock. In a study by RUIZ *et al.* (1997) reported that K content of melon leaves was significantly different at grafted plants than non-grafted plants. Additionally, K uptake enhancement due to grafting has also been stated for eggplants by LEONARDI and GIUFFRIDA (2006) and for melon by QI *et al.* (2006), and for cucumber by ZHU *et al.* (2008). In terms of Ca concentration in leaf tissue, the significantly highest values were observed when 'ERÜ 462' grafted onto 'Scarface' rootstock and followed by both 'ERÜ 1227' and '21 H-1-2' grafted onto 'Scarface' rootstock. Concerning

Mg concentration in leaf tissue, the significantly highest values was found by both '21 H-1-2' and 'ERÜ 462' grafted onto 'Scarface' and '21 H-1-2' grafted onto '46 KB F1' rootstock and non-grafted control plants of 'ERÜ 462'. It was followed by '33 H-3-1' grafted onto 'Scarface' rootstock. Likewise, to the results in the present study, SUN *et al.* (2010) found that the K, Ca and Mg content of watermelon leaves was higher in grafted plants than in the non-grafted ones. Relating to Mn concentration in leaf tissue, the significantly highest values was found by 'ERÜ 462' grafted onto 'Scarface' rootstock and followed by '21 H-1-2' grafted onto 'Scarface' rootstock. In terms of Zn concentration in leaf tissue, the significantly highest values were observed at the non-grafted control plants of '21 H-1-2' and followed by both '33 H-3-1' and 'ERÜ 462' grafted onto '46 KB F1' rootstock. Plant growth and development are improved by grafting and leaf mineral content of sweet melons and watermelons were affected by grafting (RUIZ *et al.,* 1997; UYGUR and YETISIR, 2009). CEYLAN *et al.,* (2018) found that K, Mg, Ca, Fe, Cu, Zn and Mn content of leaves were significantly higher at the grafted watermelon plants as compared to the non-grafted plants. Up to now in many studies, it was reported that grafting with some rootstock genotypes were significantly more effective in absorbing and transporting nutrients to the shoot, for example phosphorus, nitrogen, potassium, magnesium, calcium, iron, or other micronutrients (SALEHI *et al.,* 2010).

Table 3. Effect of graft combination on leaf P, K, Ca, Mg, Mn and Zn concentration of pepper plants

Graft Combination	P (%)	K (%)	Ca (%)	Mg (%)	Mn (ppm)	Zn (ppm)
ERÜ 1227	0.39 d	4.32 d	1.64 fg	0.21 d	32.02 cd	42.82 e
ERÜ 1227/Scarface	0.41 cd	4.70 a	2.34 b	0.28 bc	30.48 cd	18.44 g
ERÜ 1227/46 KB F1	0.32 e	3.83 f	1.08 i	0.20 d	26.69 fg	55.99 c
ERÜ 462	0.37 de	3.94 e	1.60 g	0.32 a	26.38 g	53.75 cd
ERÜ 462/Scarface	0.49 ab	4.43 c	2.45 a	0.33 a	35.96 a	22.15 fg
ERÜ 462/46 KB F1	0.41 cd	4.60 ab	2.00 e	0.26 c	30.31 de	72.62 b
21H-1-2	0.45 bc	3.81 f	1.43 h	0.27 c	28.92 ef	79.14 a
21H-1-2/Scarface	0.50 ab	4.67 ab	2.38 b	0.33 a	33.40 ab	26.25 f
21H-1-2/46 KB F1	0.38 de	4.46 c	2.26 c	0.31 a	29.32 ef	45.56 e
33 H-3-1	0.55 a	4.27 d	1.44 h	0.26 c	32.65 bc	50.51 d
33 H-3-1/Scarface	0.52 ab	4.58 b	2.07 d	0.30 ab	30.72cd	26.10 f
33 H-3-1/46 KB F1	0.54 a	4.45 c	1.69 f	0.28 bc	32.40 bc	73.17 b
Minimum	**0.32**	**3.81**	**1.08**	**0.20**	**26.38**	**18.44**
Maximum	**0.55**	**4.70**	**2.45**	**0.33**	**35.96**	**79.14**
Grafted+non-grafted mean	**0.44**	**4.34**	**1.87**	**0.28**	**30.77**	**47.21**
Non-grafted mean	**0.44**	**4.08**	**1.52**	**0.28**	**29.99**	**56.56**
Grafted mean	**0.44**	**4.46**	**2.03**	**0.28**	**31.16**	**42.53**
F-Test	***	***	***	***	***	***

[1] Values denoted by different letters are significantly different between genotypes within columns at $P < 0.05$ (T-Test). ns, non-significant. *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$ (F-Test).

CONCLUSIONS

Different pepper inbred lines grafted onto different pepper rootstocks and non-grafted ones behaved significantly ($p<0.001$) different in number of fruits per plant, fruit yield, fruit dry matter, fruit diameter, fruit length, seed yield, thousand seed weight and leaf P, K, Ca, Mg, Mn and Zn composition. Among different grafting combinations, the significantly higher fruit yield, fruit dry matter, fruit length of long fruited green pepper genotypes, K composition in leaf tissue was observed when 'ERÜ 1227' grafted onto 'Scarface' rootstock. Significantly higher Ca and Mn compositions was recorded when 'ERÜ 462' grafted onto 'Scarface' rootstock. Overall, the pepper rootstock genotypes 'Scarface F1' showed a better performance in fruit yield, fruit dry matter, fruit length of long fruited green pepper genotypes, fruit diameter of bell shaped pepper genotypes, K, Ca, Mg and Mn compositions in leaf tissue, thousand seed weight in different graft combinations as compared to non-grafted pepper plants. The powerful rootstocks play a major role in improvement of plant growth performance, fruit and seed yield.

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EFEKTI KALEMLJENJA NA PRINOS PLODA I SADRŽAJ HRANLJIVIH SASTOJAKA U LISTU INBRED LINIJA PAPRIKE (*Capsicum annuum* L.)

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Izvod

Vrsta *Cannabis sativa* L. nedavno je svedočila ponovnom oživljavanju interesovanja širom sveta zbog svojih višenamenskih primena i naučne potvrde svojih farmakoloških svojstava. Genotipovi sa visokim sadržajem kanabinoida cenjeni su u farmaceutskoj i kozmetičkoj industriji zbog svog terapijskog potencijala. Ovi genotipovi, sa pretežno visokim sadržajem kanabidiola (CBD), predmet su istraživanja i oplemenjivanja u nekoliko programa, ali do danas je objavljeno malo podataka o *in vitro* kulturi tkiva kanabisa. Naša studija se fokusirala na uspostavljanje efikasne metode mikropropagacije za dve linije sa visokim sadržajem CBD (MKS-CBD-11 i MKS-CBD-707) kao osnovu za napredne biotehnološke pristupe oplemenjivanja. Rezultati su pokazali da se *in vitro* kultura medicinskog kanabisa može zasnovati na različitim medijima za uzgoj kulture, da se te biljke mogu uspešno aklimatizovati i da čvorni položaj, a posebno genotip, imaju značajan uticaj na uspeh uspostavljanja kulture izdanaka. Pokazali su da publikovani mediji za kulturu tkiva optimizovani za jedan soj meksičkog kanabisa sa visokim THC-om nisu toliko efikasni za druge genotipove (medicinske) kanabisa. Završili smo ovo istraživanje genetskom studijom 95 biljaka sa dve linije za oplemenjivanje sa 16 mikrosatelitskih (SSR) markera koji su grupisali biljke na osnovu linije za oplemenjivanje. Rezultati su pokazali da je za diskriminaciju svih analiziranih biljaka i njihovu upotrebljivost za klonsku identifikaciju potrebno samo 8 markera.

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