

EFFECTS OF DIFFERENT ROOTSTOCKS ON YIELD OF GRAFTED PEPPER (*Capsicum annuum* L.) IN GREENHOUSE CONDITIONS

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ABSTRACT

A field study was carried out in the region of Shtime, the central part of Kosovo, in 2021 to investigate the rootstock effect on the number of fruits per plant, fruit mass per plant, and the obtained yield of grafted pepper in greenhouse conditions. For that purpose, the following cultivars were used as scions, "Vedrana", "Kaptur", "Ariadni" and "Gelby", while "SM Tant", "Vital Paprika" and "6210" as rootstocks. Non-grafted cultivars of "Vedrana", "Ariadni", "Kaptur" and "Gelby" were used as control treatments. The trial was designed in a randomized block system with four replications or 64 experimental plots in total. Each experimental plot contained 20 plants. The plants were transplanted in a plant density of 0.60m x 0.40m x 1.0m, or 4 plants/m². In addition, regular cultural practices were applied regarding irrigation, fertilization, and plant protection. According to the obtained results, differences were observed in terms of the average number of fruits per plant, average fruit mass(g), and the total yield (kg ha⁻¹), depending on the rootstock-scion combination and the different ripening stages. The largest number of fruits per plant was observed in the grafted combination "Ariadni/Sm Tant" (15.41) and in the "Gelby/Sm Tant" combination (14.31), while the lowest number of fruits was recorded in the plants from the cultivar "Vedrana" non-grafted (8.33) and the combination "Kaptur/6210" (7.99). The highest fruit mass was observed with the combination "Vedrana/Sm Tant", while the highest total yield was observed in the combination "Ariadni/Sm Tant", followed by "Vedrana/Sm Tant". The lowest yield was recorded in the combination "Kaptur/Sm Tant" and the combination "Kaptur/6210".

Key words: cultivars, fruit mass, grafting, number of fruits, rootstocks, yield.

INTRODUCTION

Pepper (*Capsicum annuum* L.) is one of the most important and widespread vegetables in Kosovo, both for local consumption and for export (Kaçiu, 2011). The most common production technology is open-field cultivation. Pepper is cultivated on a total area of 3134 ha, out of which 170 ha in greenhouses (ASK, 2021). Pepper production is mainly located in the Dukagjini Plain, which is characterized by more favorable climatic and soil conditions (Kaçiu, 2009).

Kosovo's climate provides relatively good conditions for pepper cultivation. However, the pepper plant faces several challenges in Kosovo such as specific pathogens, weeds, and insects. Due to that, in recent years, the production of pepper by grafting has become more common, whereas the advantages of grafting are attributed principally to the resistance of rootstocks to soil-borne diseases (fungus, bacterial wilt, and nematodes), but also to increased vigor and stress tolerance.

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 shooting 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 (Ulas et al., 2020). Although grafting is an age-old practice, it became a common practice in herbaceous vegetables during the 20th century (Lee, 1994; Lee et al., 2010). Worldwide, the main vegetable crops that benefit from grafting are tomato, cucumber, eggplant, melon, pepper, and watermelon (Yassin, 2015). These vegetables are usually grafted with a splice or tube, tongue, and cleft method (Khankahdani et al., 2012).

Grafting is an environment-friendly alternative method for disease control (Oka et al., 2004; Rivard and Louws, 2008). Usually, in vegetables, grafting is used to stop soil-borne diseases like *Fusarium* wilt in cucumber, and melon, and bacterial wilt in tomato, pepper, and other fruit crops (Pardeep et al., 2015).

Many authors have concluded that grafted plants produce higher single-fruit weight, total fruit yield, and better quality than non-grafted plants (Bogoescu et al., 2019; Kombo & Sari, 2019; Maršič et al., 2016; Ozmen et al., 2015). It can be singled out that for the pepper crop which is subject to our research a higher yield was reported by Gisbert et al., (2010), Donas-Ucles et al., (2014), and other authors. In general, the main reason for pepper grafting is the resistance to soil-borne pathogens and nematodes as well as to abiotic stresses (Penella et al., 2016; Schwarz et al., 2010), although in our experiment there was no infection from soil pathogens observed. According to Rico et al. (2004), the use of this technique with commercial varieties of bell pepper could significantly reduce the losses caused by *P. capsici* by up to 100%.

The influence of grafting and rootstocks on grafted pepper survival, vegetative growth, fruiting characteristics, and yield were investigated in a few studies and with only a limited number of rootstocks (Soltan et al., 2017).

Consistent with the results so far, the aim of our research was to investigate the effect of different rootstocks on the yield of grafted pepper under greenhouse conditions in Kosovo.

MATERIALS AND METHODS

The field experiment was conducted from May to October 2021 in the Shtime municipality of Kosovo (latitude:42°27'30.68''N and longitude: 21°02'09.56''E and an altitude of 583 meters above sea level). The soil type in the experimental greenhouse and the trial field is pseudogley. The pepper cultivars 'Vedrana' F1 and 'Gelby' F1 (bell pepper), 'Ariadni' and 'Kaptur' (long pepper) were used as scions grafted on three rootstocks 'SM Tant', 'Vital Paprika' and '6210'. Non-grafted plants of 'Vedrana', 'Gelby', 'Ariadni', and 'Kaptur' were used as control treatments. The cultivars used as scions are the most widely grown pepper cultivars in Kosovo which was the reason that they were selected for the experiment.

The scions and rootstocks were sown in March at a professional nursery in Albania and the grafting procedure was carried out during April with the application of the "cleft and tube" method as recommended by Lee et al., (2010). During the acclimatization period, young plants were kept at 28°C, with more than 95% relative humidity.

The grafted plants were then transplanted in Kosovo in May 2021. They were placed in an unheated plastic greenhouse. The trial was set in a randomized block design with four groups composed of a control cultivar and its grafting (each is made by four experimental plots) in 4 replications with 20 plants per experimental plot, or 64 experimental plots in total. The size of an individual experimental plot was 4.8 m². The plants were transplanted at a regular distance for pepper cultivation - 0.60 m x 0.40 m x 1.0 m, or 4 plants/m².

During the cultivation of pepper plants, all common agro-technical measures have been applied (Kaçi, 2011). The yield of pepper plants was recorded with each harvest, every 10

days, starting from the beginning of August. The yield and fruit traits were measured from all 20 plants in each replication.

Statistical analysis

The data were analyzed following Analysis of Variance (ANOVA). To test the significance of differences in the average pepper yield, the mean values were calculated and significant differences were tested using the Tukey HSD test and statistical computer program (JMB, 2010).

RESULTS AND DISCUSSION

Investigated parameters – the number of fruits per plant, fruit mass, and total yield were significantly influenced by the grafting combination for some of the cultivars, which is shown in the table below.

Regarding the number of fruits per plant, most of the grafted combinations were observed to have a larger number of fruits per plant compared to the plants that were non-grafted. The exception was the variety Kaptur non-grafted. The largest number of fruits per plant was achieved in the grafted combination Ariadni/Sm Tant (15.41) and Gelby/Sm Tant (14.31), while the lowest number of fruits per plant was counted with the combination Kaptur/6210 (7.99) and Vedrana non-grafted (8.33) (Tab. 1).

Table 1. Number of fruits per plant pepper, fruit mass (g), and total yields (kg ha⁻¹) depending on different rootstock

Variants	Cultivar/rootstock	Number of fruits per plant	Average fruit mass (g)	Yield (kg ha ⁻¹)
I	Vedrana/non-grafted	8.33ab	** 168.68 BC	58567.71 a
II	Vedrana/Sm Tant	**12.85 AE	** 176.27 DE	**92338.54 ADE
III	Vedrana/Vital Paprika	**11.25 B	*142.19 bd	*66656.25 dF
IV	Vedrana/6210	9.94 e	134.55 ce	**55286.46 ef
	LSD _{0.05; 0.01}	1.64 2.46	20.65 31.06	10215.16 15365.95
I	Gelby non-grafted	13.05	** 131.15 A	**70583.33 ABc
II	Gelby/Sm Tant	14.31	113.47 a	66385.42 ae
III	Gelby/Vital Paprika	13.51	120.27	* 67140.63 b
IV	Gelby/6210	14.50	121.54	* 73359.38 CE
	LSD _{0.05; 0.01}	2.22 3.33	11.14 16.76	2553.58 3841.18
I	Ariadni non-grafted	11.76 a	128.36 a	61010.42 a
II	Ariadni/ Sm tant	** 15.41 ADE	* 159.59 A	** 99166.67 ADE
III	Ariadni/Vital Paprika	10.16 d	150.33	63651.04 d
IV	Ariadni/6210	10.35 e	147.87	63187.50 e
	LSD _{0.05; 0.01}	1.90 2.86	23.99 36.84	9835.04 14794.22
I	Kaptur non-grafted	** 14.16 BC	**122.67 A	71229.17
II	Kaptur/Sm Tant	**12.16 De	90.95 ade	45614.58
III	Kaptur/ Vital Paprika	*9.33 bd	**133.14 D	52463.54
IV	Kaptur/6210	7.99 ce	* 125.74 E	40317.71
	LSD _{0.05; 0.01}	2.10 3.15	17.25 25.94	10358.49 15581.61

*significant difference at level <0.05; **significant difference at level <0.01; statistically the significant difference between I and II (Aa), I and III (Bb), I and IV (Cc), II and III (Dd), II and IV (Ee) , III and IV (Ff)

The highest average fruit mass is achieved with the combination of Vedrana/Sm Tant - 176.27 g, and a significantly higher fruit mass is achieved with Ariandi/Sm Tant 159.59 g compared with the non-grafted plants and the other combinations. The lowest fruit mass was observed with the combination Kaptur/Sm Tant from 90.95 g.

Consequently, at the fruit mass, the highest yield is achieved with the combinations Ariadni/Sm Tant (99166.67 kg ha⁻¹) and Vedrana/Sm Tant (92338.54 kg ha⁻¹), while the lowest yield is achieved by the grafted combination Kaptur/6210 (40317.71 kg ha⁻¹) (Tab. 1).

In relation to the average number of fruits per plant according to the obtained results, for the cultivar Vedrana, the best effect is achieved by grafting on Sm Tant, where the average number of fruits is increased by 35.18% compared to the non-grafted cultivar. Solid results have been also achieved with the combination of Vedrana/Vital Paprika where the average number has increased by 35.05% compared to the non-grafted cultivar.

There is a statistically significant difference between Vedrana/ Sm Tant with Vedrana non-grafted and Vedrana/6210 at the level of 0.05 and 0.01 and between Vedrana/Vital paprika and Vedrana non-grafted also at the level of 0.05 and 0.01.

The cultivar Gelby did not show a statistically significant difference in terms of the average number of fruits per plant between the variants. With the Ariadni cultivar, the highest number of fruits was achieved by grafting on a Sm Tant scion, which is the highest number of fruits per plant among all varieties in the study. There is a statistically significant difference on statistical levels 0.05 and 0.01 between Arinadi/Sm Tant and all three other variants.

Unlike the other cultivars, non-grafted Kaptur plants have the highest average number of fruits per plant. The statistically significant differences between the variants are shown in Table 1.

For the cultivar Vedrana, the highest average fruit mass (g) was observed in combination with Sm Tant as a rootstock, which is 4.5% higher than the average fruit mass of the non-grafted plants of this cultivar. Apart from the non-grafted variant, this combination shows a statistically significant difference with the other variants at both levels of significance (Tab. 1).

According to the increased fruit mass, the yield has also increased, so the combination Vedrana/Sm Tant has a total yield higher by 57.66% in relation to the non-grafted variant. A significant difference is also observed compared to other grafted combinations. Similar results in increased yield (by 20% in soil and 63% in soilless system) when Vedrana was used as scion and Rocal as rootstock have been reported by Maršić et al. (2019). Also, Gisbert-Mulloret et al., (2020) reported that grafting had a significant effect on total and marketable yield compared to the values recorded in the non-grafted plants.

For the Gelby cultivar, significance in relation to the fruit mass was observed only between the non-grafted variant and the Gelby/Sm Tant combination, the average fruit mass of the non-grafted plants was 15.58% higher. Statistically, a significant difference was observed in the total yield between the combinations. In that direction, the combination Gelby/6210 stands out for almost 4% of the non-grafted variant, 10.5% of Gelby/Sm Tant, and 9.3% of the combination Gelby/Vital Paprika.

As mentioned earlier, fairly high average fruit mass compared to other combinations, as well as the highest yield is achieved with the combination Ariadni/Sm Tant, which is 62.5% higher than the yield of the non-grafted variant. This combination shows statistically significant differences compared to other grafted combinations, which is shown in Table 1. With this, the Sm Tant rootstock for now proved to be quite solid for grafting both types of pepper.

Kaptur cultivar is the only one in our research that showed better results without grafting, in terms of the average number of fruits per plant and total yield. In the combinations of Kaptur/Vital paprika and Kaptur/6210, a higher average fruit mass was achieved, but in these combinations, the average number of fruits per plant was significantly lower, which resulted in a lower total yield compared to the non-grafted variant.

Other researchers reported significantly higher average yields between grafted and non-grafted pepper plants (Gisbert et al., 2010; Ulas et al., 2020), but the yield obtained per square

meter in the different treatments of “Italian type” pepper does not depend on whether the plant is grafted or not grafted (Doñas-Uclés et al., 2014).

Ergun and Aktas (2018) in their research, concluded that total yield was influenced by rootstock, whereas fruit weight was not affected by grafting. The highest yield was obtained by the combination ‘Efil/Guclu’, while the lowest value was recorded on the control (non-grafted) and ‘Efil/Efil’ (grafted itself). Grafted rootstock (‘Efil/Guclu’) produced around 12% more yield than the control plant.

Nielsen and Kappel (1996) have also concluded that grafting directly affects plant yield. Its influence can be exerted by the interaction of some or all of the following processes: increase of water and nutrient uptake due to the rootstocks’ vigorous root system (Lee, 1994), enhanced production of endogenous hormones (Zijlstra et al., 1994), and enhancement of scion vigor (Leoni et al., 1990). The joint action of some or all of these processes could explain the higher pepper yield from grafted plants (Lee, 1994).

Camposeco-Montejo et al. (2018) in their study, have also demonstrated significantly increased yield from 19 to 30% in grafted variants compared to non-grafted.

López et al. (2012, 2014) reported an increment of over 25% in fruit yield, with the use of abiotic stress-tolerant rootstocks, making it a good adaptation strategy for abiotic stress conditions.

Sanchez et al. (2015) and Marquez et al. (2017), also indicate that the use of grafting increases yields by up to 50%, resulting in increased commercial yields.

Despite the positive results, several authors have not found a positive effect from the grafting combinations. For instance, Soltan et al. (2017), who studied a two-year yield of the pepper crop, reported that grafting did not significantly affect the total (seasonal) yield in the second year of the research.

In addition, Estañ et al. (2005), did not find significant yield differences between the grafted and the non-grafted tomato plants under normal cultivation conditions. Gisbert et al. (2010), reported a general trend for reduction of fruit weight in greenhouse experiments of the grafted pepper (cvs. Almuden and Coyote), but only on two hybrid rootstocks, ‘Charlot’ and ‘Foc.’

CONCLUSIONS

According to the obtained results, regarding the average number of fruits per plant, the average fruit mass, and total yield, we can notice that the rootstock Sm Tant has a significantly positive effect on improving these parameters for the cultivars used in our research. Thus, the use of grafted pepper plants in the greenhouse would denote a probable strategy for an increase in the fruit number and consequently an increase in the total pepper yield.

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