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Professional paper

THE EFFECT OF GRAFTING ON THE PLANT GROWTH IN TWO BELL PEPPER VARIETIES

Albina KIKA[1]*, Skender KACIU[1], Rukie AGIC[2], Gordana POPSIMONOVA[2], Biljana DRVOSHANOVA[3]

[1]Department of Plant Production, Faculty of Faculty of Agriculture and Veterinary, University of Prishtina "Hasan Prishtina"*
[2] Department of Vegetable and Flower Production, Faculty of Agricultural Sciences and Food – Skopje, Ss. Cyril and Methodius University in Skopje
3 Department of Vegetable Production, Institute of Agriculture – Skopje, Ss. Cyril and Methodius University in Skopje
[*]Corresponding Author: e-mail: albinaakika@gmail.com

Abstract

The aim of this study was to evaluate the growth dynamics of two bell pepper hybrids grafted onto three commercial rootstocks, in open field and greenhouses. The experiment was conducted in Kosovo on Gelby F1 and Vedrana F1 as rootstocks and Sm Tant, Vital Paprika and '6210' as scions in randomized block design over a period of three years. The plant growth dynamics were measured, starting 15 days after transplanting and every 10 days until the beginning of full harvest, as well as the stem diameter that was measured below the first bifurcation. A two-way ANOVA with repeated measures was performed to analyze the effect of Grafting status and Environment in five consecutive growth stages. The analyses revealed that there were statistically significant differences within subjects and between subjects regarding the Grafting status and Environment. Grafting significantly and consistently improved plant growth dynamics, although final plant height showed divergence. This variability was evident across different growth stages and was not solely attributed to grafting or production conditions.

Keywords: grafting, bell peppers, plant growth, stem diameter.

1. Introduction

Many experiments demonstrated that grafting can promote vegetative growth in pepper plants at different levels, especially plant height. Such improvements are often explained by a more efficient supply of water and nutrients by the rootstock's vigorous root system compared to the scion roots, as well as by the supply of endogenous hormones to the shoots, resulting in enhanced scion vigor and ultimately improved productivity.

However, the analysis of the literature data referring to the impact of various rootstocks on the height of the grafted plants showed variable findings. For example, Ergun and Aktas (2018) did not find significant differences between the non-grafted pepper cultivar Efil F1 and the grafted plants onto Guclu F1 grown under open field conditions. In very few experiments all grafted plants were significantly taller compared to non-grafted ones, such as the plants of sweet pepper cultivar Hongxing No. 2 grafted on five pepper lines (Shu et al., 2016), plants of Somborka grafted on Rocal and Fortama F1 (Rizani et al., 2021), or the plants of Herminio F1 grafted onto Creonte which were higher in all shading treatments (López-Marín et al., 2012). Similarly, Colla et al. (2008), find out that bell pepper hybrid cultivars Edo and Lux were 29% and 28% taller, respectively, when grafted on five commercial rootstocks (Snooker, Tresor, RX360, DRO8801, and 97.9001). In some experiments, the effect on this trait varied between the combinations, environments, applied conditions, or in different measurements. For example, Doñas-Uclés et al. (2015), found that non-grafted plants were the highest in the first measurement, while only the combination Palermo/Jalapeno had significantly higher plants at the end of the crop, compared to non-grafted plants. The plant vigor in the chili pepper cultivar Rebelde grafted on wild-type chili rootstock SCM334 resistant to P. capsici was reduced in the

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presence of a pathogen, while in its absence grafted plants were significantly higher compared to non-grafted ones (García-Rodríguez et al., 2010). Under full irrigation, only the Creonte rootstock increased the plant height of Herminio F1, while the rootstocks Atlante and Terrano had no influence, but under 50% irrigation, only plants grafted on Atlante were significantly taller, although the height was also increased in plants grafted on Creonte, while Herminio/Terrano plants were shorter than the non-grafted control and shorter than the plants grafted on Atlante for 50% (López-Marín et al., 2017). The grafting effect was also variable in the results of Soltan et al. (2017), in this case, dependent on the combination and the experimental year. Five different rootstocks strongly and significantly influenced the plant height and number of branches of four sweet pepper cultivars (Toronto, Zedinca, Kurtovska Kapya, and Eigman) with the highest increase in the plants grafted onto Tan Tan and 52-03 RZ. In some cases, grafting had a negative effect on plant height. Orosco-Alcalá et al. (2021) found out that the average values for plant height of bell pepper Viper did not significantly differ from the values of non-grafted control when grafted on E21R10144, while plants grafted on E21R10197 had significantly lower height in both control and salt-stress treatments. López-Marín et al. (2009) concluded that the sweet pepper cultivar Almuden had significantly shorter plants when grafted on C29, while when grafted on Atlante had higher but not statistically different from the plants of the non-grafted cultivar. Similarly, Allagui et al., (2013) found differences in the height of two chili cultivars (Beldi and Baker) grown in soil infested with Phytophthora nicotianae. SCM334 rootstock reduced the height by 11% in Beldi scions, while Baker-grafted plants did not differ from the non-grafted control. The same rootstock reduced the height and number of nodes in the sweet pepper cultivar Triple Star, the other seven rootstocks used did not induce significant difference (Leal-Fernández et al., 2013), while the weekly growth was significantly higher only in the plants grafted on AR29 and AR30. Similarly, Fisk (2017) found that the average growth rate was higher in the non-grafted bell pepper cultivar Aristotle than in the combinations grafted onto pepper cultivars Black Pearl, Ghost Pepper, and Carolina Wonder.

Pepper stem diameter was evaluated in fewer experiments, in which predominantly all grafted combinations had thinner stem diameters in normal growing conditions (Ergun & Aktas, 2018; Shu et al., 2016) or in soil infested with P. capsici (García-Rodríguez et al., 2010). In some experiments, the stem diameter of grafted plants equaled that of non-grafted controls (Allagui et al., 2013; García-Rodríguez et al., 2010). However, there are findings that specific rootstocks increased (Leal-Fernández et al., 2013) or decreased (Orosco-Alcalá et al., 2021) the diameter in grafted plants, while the other rootstocks used in these two experiments did not have a significant effect on this trait.

Taking these literature data into consideration, the aim of this study was to evaluate the growth dynamics of two bell pepper hybrids grafted onto three commercial rootstocks, in open field and greenhouses in local production conditions.

2. Materials and methods

The subject of this study is to evaluate the growth dynamics of two bell pepper hybrids grafted onto three commercial rootstocks, in open field and in greenhouses. Non-grafted plants were used as control. The pepper hybrids used as scions were Gelby F1, produced by Semo company with creamy green (early maturity) to yellow (full maturity) fruits, and Vedrana F1 product of Enza Zaden company with fruits in greenish-white (technological maturity) to bright red or red color (full maturity). The rootstocks used in the experiment were: Sm Tant (*Capsicum annuum* x C. *chinense*), Vital Paprika (*Capsicum annuum* x *C. chinense*), and '6210' (a cross between two pepper genotypes). The experiment was set up in the village of Godanz, Municipality of Stime, Republic of Kosovo (at latitude 42° 27'30.68' S and longitude 21° 02 '09.56' 'E or

coordinates MGRS/USNG 34T EN 02959 00688, at an altitude of 583 m). The experiment was laid into a randomized block system with four replications, both in a greenhouse (GH) and in an open field (OF) for three consecutive years. Each replication represented a single experimental block consisting of 20 plants (5 m2). Plant growth dynamics was measured, starting 15 days after transplanting (middle of June), and every 10 days until the beginning of full harvest. The measurements were performed on 5 plants from each replication, starting from the soil to the apex, with measuring tape. The rate of growth was expressed as a percentage of deference subtracted from the final plant height that was recorded at the end of the harvest at the beginning of October. The stem diameter was measured below the first bifurcation with a digital caliper (NEIKO 01409A 12" Electronic Digital Caliper, Measurement Range 0 - 300mm; accuracy: 0.02mm).

Grafting combinations and growing environment (OF and GH) were the factors of the analyses that were subjected to a two-way ANOVA, For the measurements that were carried out over time such as the case of five-time intervals for growth dynamics and repeated measurement ANOVA was used to determine the differences among treatments. Tukey's Honest Significant Difference post-hoc test was used to test the difference between stages. After verifying the significance of the interaction for each variable, a one-way ANOVA was performed. Means were compared by the Fisher's least significance difference (LSD) test and Duncan's multiple range test at $P < 0.05$. All statistical analyses are performed in SPSS version 23.0.0.0 (SPSS, 2015).

3. Results

The influence of grafting on the height and stem diameter of pepper plants varies according to different experiments and grafting combinations. Grafting has been shown to promote vegetative growth, including increased plant height (López-Marín et al., 2012; Pico et al., 2017; Rizani et al., 2021) in some cases. This increase is often attributed to the more efficient water and nutrient supply from the vigorous root system of the rootstock, as well as the supply of endogenous hormones to the shoots, leading to enhanced scion vigor and overall productivity.
In this study, the plant growth dynamic was monitored at regular intervals - every 10 days after transplanting when the height of all transplants was 13 cm, until the phase of massive ripening. This amounted to five distinct observation periods. Two parameters were observed, plant height and stem diameter. It was found that the grafting combinations developed at different rates after transplanting. This was based on the results from the two-way ANOVA with repeated measures that were performed to analyze the effect of Grafting status and Environment on the plant growth dynamics in five consecutive growth stages.

The analysis showed that the differences between growth stages induced by grafting and production conditions were statistically significant ($F(4,92) = 321.21$, $p < .001$) and ($F(4,48) = 328.16$, $p < .001$), respectively, for the analysis of the values in and between the separate stages of growth. The same procedure was carried out for the observation regarding the stem diameter and showed statistically significant values for all interactions within and between subjects regarding Grafting status and Environment ($F(4,92) = 247, 21$, $p <,001$) и ($F(4,48) = 279,14$, $p <,001$). The detailed analyses for both parameters (plant and stem growth dynamics) are presented in Table 1 and Table 2.

The observations for Gelby F1 and its grafting combinations are presented in Figure 1. It can be noticed that the non-grafted variant had a slower start in the first stage, in which the plants were significantly smaller compared to the grafted variants with a growth rate of only 13.2%. During the rest of the vegetation period, this difference was compensated, but there was no significant difference to be emphasized.

On the other hand, 'Vedrana' F1 continuously had more intense growth on open field compared to its grafted combinations. Under greenhouse conditions non grafted plants were taller than all grafted variants only in the first three decades, again without significantly different values (Figure 2).

Table 1. Effect of grafting on the growth dynamics of plant height in two bell pepper varieties (cm)

Grafting status		Environment	10 days after transplantation	20 days after transplantation	30 days after transplantation	40 days after transplantation	50 days after transplantation
Gelby F1	R0	OF	18.95 ± 0.13 **	28.80 ± 0.18 **	37.75 ± 0.50 **	41.60 ± 0.14 **	50.90 ± 0.26 **
		GH	19.88 ± 0.30 **	32.28 ± 0.57 **	46.95 ± 0.24 **	51.88 ± 0.82 **	57.50 ± 0.80 **
	R1	OF	24.65 ± 0.13 **	34.30 ± 0.18 **	36.28 ± 0.22 **	40.50 ± 0.36 **	43.15 ± 0.35 **
		GH	26.48 ± 0.37 **	37.10 ± 0.16 **	48.68 ± 0.40 **	55.63 ± 0.51 **	62.98 ± 0.40 **
	R2	OF	26.30 ± 0.22 **	28.83 ± 0.17 **	38.18 ± 0.13 **	42.43 ± 0.17 **	47.93 ± 0.22 **
		GH	27.48 ± 0.22 **	31.85 ± 0.21 **	49.13 ± 0.39 **	56.75 ± 0.21 **	64.10 ± 0.48 **
	R3	OF	26.83 ± 0.17 **	32.50 ± 0.08 **	40.23 ± 0.68 **	43.90 ± 1.56 **	45.20 ± 0.22 **
		GH	28.18 ± 0.10 **	34.28 ± 0.15 **	47.20 ± 0.43 **	55.60 ± 0.50 **	59.88 ± 0.99 **
Vedrana F1	R0	OF	20.73 ± 0.22 **	26.55 ± 0.13 **	33.63 ± 0.13 **	37.45 ± 0.13 **	39.48 ± 0.42 **
		GH	22.10 ± 0.53 **	29.08 ± 0.17 **	40.00 ± 1.19 **	42.45 ± 0.47 **	53.45 ± 0.47 **
	R1	OF	18.25 ± 0.21 **	23.23 ± 0.13 **	31.73 ± 0.25 **	34.63 ± 0.13 **	36.63 ± 0.21 **
		GH	19.60 ± 0.08 **	26.43 ± 0.10 **	34.53 ± 4.96 **	42.90 ± 0.85 **	56.83 ± 0.26 **
	R2	OF	20.98 ± 0.17 **	28.68 ± 0.17 **	30.75 ± 0.25 **	34.48 ± 0.19 **	37.68 ± 0.22 **
		GH	22.38 ± 0.31 **	30.90 ± 0.32 **	36.40 ± 0.56 **	42.35 ± 0.95 **	55.48 ± 0.62 **
	R3	OF	18.13 ± 0.10 **	26.05 ± 0.13 **	32.65 ± 0.24 **	36.30 ± 0.14 **	39.38 ± 0.40 **
		GH	20.25 ± 0.44 **	28.40 ± 0.29 **	38.45 ± 0.27 **	41.25 ± 0.66 **	52.65 ± 0.72 **

Data are means ± standard error (n = 4). Symbols indicate statistically significant differences within subjects; * $p < 0.05$; ** $p < 0.001$; Repeated Measures ANOVA; Tukey's Honest Significant Difference post-hoc test

Table 2. Effect of grafting on the growth dynamics of stem diameter in two bell pepper varieties (mm)

Grafting status		Environment	10 days after transplantation		20 days after transplantation		30 days after transplantation		40 days after transplantation		50 days after transplantation	
Gelby F1	R0	OF	6.53 ± 0.03	**	7.65 ± 0.02	**	8.50 ± 0.06	**	9.36 ± 0.02	**	13.95 ± 1.40	**
		GH	7.65 ± 0.07	**	9.94 ± 0.13	**	10.95 ± 0.12	**	14.77 ± 0.11	**	16.11 ± 0.57	**
	R1	OF	5.65 ± 0.03	**	8.74 ± 0.02	**	8.85 ± 0.02	**	9.63 ± 0.02	**	12.36 ± 0.09	**
		GH	7.11 ± 0.09	**	9.31 ± 0.14	**	12.45 ± 0.14	**	14.69 ± 0.05	**	19.98 ± 0.16	**
	R2	OF	5.51 ± 0.02	**	7.89 ± 0.02	**	7.52 ± 0.51	**	7.83 ± 0.03	**	12.59 ± 0.06	**
		GH	6.26 ± 0.06	**	8.62 ± 0.03	**	12.09 ± 0.04	**	13.39 ± 0.04	**	20.87 ± 0.25	**
	R3	OF	4.74 ± 0.06	**	6.85 ± 0.01	**	9.12 ± 0.02	**	9.84 ± 0.06	**	14.06 ± 0.05	**
		GH	5.31 ± 0.04	**	9.71 ± 0.07	**	10.39 ± 0.04	**	15.34 ± 0.04	**	18.04 ± 0.16	**
Vedrana F1	R0	OF	5.41 ± 0.02	**	7.74 ± 0.02	**	8.25 ± 0.02	**	8.94 ± 0.01	**	13.77 ± 0.05	**
		GH	5.80 ± 0.19	**	7.84 ± 0.04	**	9.65 ± 0.05	**	13.46 ± 0.14	**	15.32 ± 0.13	**
	R1	OF	6.82 ± 0.01	**	8.40 ± 0.02	**	8.23 ± 0.40	**	9.46 ± 0.04	**	10.35 ± 0.03	**
		GH	6.92 ± 0.03	**	7.78 ± 1.47	**	11.09 ± 0.08	**	14.01 ± 0.07	**	16.71 ± 0.14	**
	R2	OF	5.57 ± 0.02	**	7.65 ± 0.03	**	8.46 ± 0.49	**	9.43 ± 0.02	**	13.37 ± 0.04	**
		GH	5.70 ± 0.05	**	8.46 ± 0.03	**	10.50 ± 0.20	**	14.44 ± 0.08	**	16.15 ± 0.25	**
	R3	OF	6.15 ± 0.03	**	8.37 ± 0.02	**	9.47 ± 0.04	**	10.30 ± 0.07	**	13.98 ± 0.06	**
		GH	7.16 ± 0.05	**	8.84 ± 0.08	**	9.31 ± 0.03	**	11.26 ± 0.03	**	15.47 ± 0.11	**

Data are means ± standard error (n = 4). Symbols indicate statistically significant differences within subjects; * $p < 0.05$; ** $p < 0.001$; Repeated Measures ANOVA; Tukey's Honest Significant Difference post-hoc test

Figure 1. Actual growth dynamics of Gelby F1 non-grafted and grafted on different rootstocks (R) measured in five-time intervals after transplanting (DAT)

Figure 2. Actual (cm) growth dynamics of Vedrana F1 non-grafted and grafted on different rootstocks (R) measured in five-time intervals after transplanting (DAT)

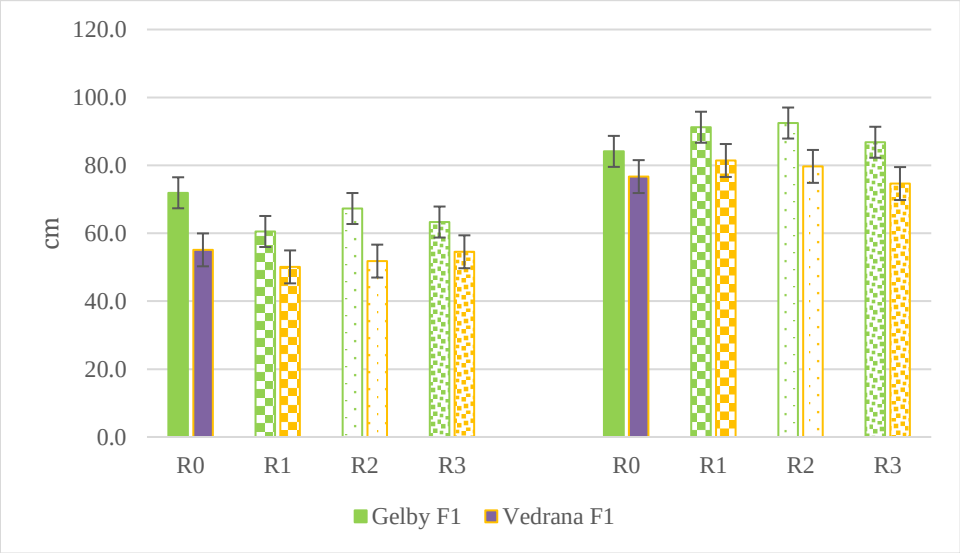

Figure 3. Final plant height (cm) in non-grafted (R0) and grafted hybrids on 'SM Tant' (R1), 'Vital Paprika' (R2) и '6210' (R3) rootstocks on open field (left) and greenhouse (right)

4. Discussion and conclusions

It is observed that the growth dynamics of pepper plants can be affected by many factors depending on the type of production (open field/greenhouse), environmental influences, as well as abiotic stresses. Aidoo et al. (2019) assessed the effect of low root zone temperature conditions on the growth and development of two grafted bell pepper plants Canon and Syngenta-S103. The findings revealed an adverse negative impact on the root and shoot biomass growth, with variations observed among different cultivars, treatments, and the control group. Although no significant differences were observed at 27°C after 2 and 6 weeks, Canon/S103 consistently displayed slightly superior shoot development compared to self-grafted Canon across all treatment levels. Additionally, it is found that different rootstocks in grafted plants give various responses in the growth dynamic. A limited number of studies reported significantly higher plants in grafted compared to non-grafted ones (Colla et al., 2008; López-Marín et al., 2013; Rizani et al., 2021).

The influence of grafting on the total plant height is presented in Figure 3. Several studies suggest variable even negative effects of the grafting on plant height (López-Marín et al., 2012, Doñas-Uclés et al., 2015; Fisk, 2017; Soltan et al., 2017; Orosco-Alcalá et al., 2021). One such example is the research of Gálvez et al. (2021) on the growth and yield responses in salinized pepper plants, where the hybrid "Gacela F1" was grafted on three commercial rootstocks and compared to a non-grafted plant. The study suggests that different growth rates are associated with changes in the hormonal balance induced by the rootstocks. Significant influence of the rootstock on the plant height was found in the study of Leal-Fernández et al. (2013) while evaluating morphological characteristics and yield of marketable fruit of the pepper cultivar Triple Star grafted onto eight rootstocks. The interaction with AR96029 rootstock had a positive effect on plant growth (weekly and total growth) and stem diameter. However, the use of CM334 rootstock negatively affected all of the agronomic and morphological characteristics. The Tresor rootstock induced an increase in leaf length without affecting the plant height. Therefore, the proper evaluation and selection of rootstock is very important before performing the graft.

In a limited number of experiments that evaluated pepper stem diameter, most grafted combinations exhibited thinner stem diameters under normal growing conditions (Ergun & Aktas, 2018; Shu et al., 2016)or in soil infested with P. capsici (García-Rodríguez et al., 2010). However,

in some cases, the stem diameter of grafted plants was comparable to that of non-grafted controls (Allagui et al., 2013; García-Rodríguez et al., 2010). Nonetheless, certain findings indicated that specific rootstocks either increased (Leal-Fernández et al., 2013) or decreased (Orosco-Alcalá et al., 2021) the stem diameter in grafted plants, while other rootstocks employed in these experiments did not have a significant impact on this particular trait.

Overall, the impact of grafting on plant height and stem diameter in pepper plants is complex and depends on various factors, including the specific rootstock, scion combination, environmental conditions, and measurements conducted in different experiments.

Through the thorough three-year trial implemented in diverse environments, open-field and greenhouse settings, the following conclusions can be drawn:

Despite the range of grafted combinations under consideration, it was determined that their influence on plant growth dynamics remained largely consistent.

The statistical analysis revealed that the differences between growth stages induced by grafting and production conditions were statistically significant for plant height and stem diameter.

Our study confirmed that the impact of grafting on plant height and stem diameter in pepper plants is complex and depends on various factors, including the specific rootstock - scion combination and environmental conditions.

References

[1]. Aidoo, M. K., Sherman, T., Lazarovitch, N., Fait, A., & Rachmilevitch, S. 2019. Physiology and metabolism of grafted bell pepper in response to low root-zone temperature. *Functional Plant Biology*, 46(4), 339–349. https://doi.org/10.1071/FP18206

[2]. Allagui, M. B., Saadoun, M., & Bechir, M. 2013. Management of chili pepper root rot and wilt (caused by Phytophthora nicotianae) by grafting onto resistant rootstock. *Phytopathologia Mediterranea*, 52, 141–147. www.fupress.com/pm

[3]. Colla, G., Rouphael, Y., Cardarelli, M., Temperini, O., Rea, E., Salerno, A., & Pierandrei, F. 2008. Influence of Grafting on Yield and Fruit Quality of Pepper (Capsicum annuum L.) Grown under Greenhouse Conditions. In D. I. Leskovar (Ed.), *Proc. IVth IS on Seed, Transplant and Stand Establishment of Hort. Crops* (pp. 359–363). http://www.istat.it/agricoltura/datiagri/coltivazioni/ital2005.htm,

[4]. Doñas-Uclés, F., Pérez-Madrid, D., Amate-Llobregat, C., Rodríguez-García, E. M., & Camacho-Ferre, F. 2015. Production of pepper cultivar palermo grafted onto serrano de Morelos 2, Jalapeño, and three commercial rootstocks. *HortScience*, 50(7), 1018–1022. https://doi.org/10.21273/hortsci.50.7.1018

[5]. Ergun, V., & Aktas, H. 2018. Effect of grafting on yield and fruit quality of pepper (*Capsicum annuum* L.) grown under open field conditions. *Scientific Papers. Series B, Horticulture*, LXII (Online ISSN 2286-1580), 463–466.

[6]. Fisk, T. S. 2017. Quality Changes in Grafted Pepper (*Capsicum annuum* L.) Scion Fruit. (*Master Thesis)*. The Ohio State University, USA.

[7]. Gálvez, A., Albacete, A., Martínez-Andújar, C., Del Amor, F. M., & López-Marín, J. 2021. Contrasting rootstock-mediated growth and yield responses in salinized pepper plants (*Capsicum annuum* L.) are associated with changes in the hormonal balance. *International Journal of Molecular Sciences*, 22(7). https://doi.org/10.3390/ijms22073297

[8]. García-Rodríguez, R., Chiquito-Almanza, E., Damián Loeza-Lara, P., Godoy-Hernández, H., Pineda, E. V., Luis Pons-Hernández, J., Martín González-Chavira, M., & Luis Anaya-López, J. 2010. Producción de chile ancho injertado sobre criollo de morelos 334 para el control de Phytophthora capsici. *Agrociencia* [Online], 44(6), 701–709.

[9]. Leal-Fernández, C., Godoy-Hernández, H., Núñez-Colín, C. A., Anaya-López, J. L., Villalobos-Reyes, S., & Castellanos, J. Z. 2013. Morphological response and fruit yield of sweet pepper (*Capsicum annuum* L.) grafted onto different commercial rootstocks. *Biological Agriculture and Horticulture*, 29(1), 1–11. https://doi.org/10.1080/01448765.2012.746063

[10]. López-Marín, J., Gálvez, A., del Amor, F. M., Albacete, A., Fernández, J. A., Egea-Gilabert, C., & Pérez-Alfocea, F. 2017. Selecting vegetative/generative/dwarfing rootstocks for improving fruit

yield and quality in water stressed sweet peppers. *Scientia Horticulturae*, 214, 9–17. https://doi.org/10.1016/j.scienta.2016.11.012

[11]. López-Marín, J., Gálvez, A., González, A., & Fernández, J. A. (2009.). Agronomic Behavior of Grafted Sweet Pepper Grown in a Greenhouse in Mediterranean Area. *Acta horticulturae*, 807, 655-660 https://doi.org/10.17660/ACTAHORTIC.2009.807.98

[12]. López-Marín, J., González, A., Pérez-Alfocea, F., Egea-Gilabert, C., & Fernández, J. A. 2013. Grafting is an efficient alternative to shading screens to alleviate thermal stress in greenhouse-grown sweet pepper. *Scientia Horticulturae*, 149, 39–46. https://doi.org/10.1016/j.scienta.2012.02.034

[13]. López-Marín, J., Vidal, M. F., Gálvez, A., & González, A. 2012. Effect of shading and grafting technique on growth and fruit production of sweet pepper plants. *Acta Horticulturae*, 952, 125–130. https://doi.org/10.17660/ActaHortic.2012.952.14

[14]. Orosco-Alcalá, B. E., Núñez-Palenius, H. G., Díaz-Serrano, F., Pérez-Moreno, L., Valencia-Posadas, M., Trejo-Tellez, L. I., Cruz-Huerta, N., & Valiente-Banuet, J. I. 2021. Grafting improves salinity tolerance of bell pepper plants during greenhouse production. *Horticulture Environment and Biotechnology*, 62(6), 831–844. https://doi.org/10.1007/s13580-021-00362-x

[15]. Pico, M. B., Thompson, A. J., Gisbert, C., Yetis¸ir, H. Y., & Bebeli, P. J. 2017. Genetic Resources for Rootstock Breeding. *In Vegetable grafting: principles and practices* (pp. 22-69). Wallingford UK: CABI.https://cabidigitallibrary.org

[16]. Rizani, S., Babaj, I., Lluga -Rizani, K., & Durmishi, B. 2021. The impact of grafted seedlings on the yield and fruit quality of pepper somborka cultivar (*Capsicum annuum* L.) under common open field conditions. *Journal of Hygienic Engineering and Design*, 305–308. http://www.fao.org/faostat/es/#home.

[17]. Shu, C., Yang, R., Yin, L., Ai, X., Wang, S., & Zhao, W. 2016. Selection of rootstocks for better morphological characters and resistance to low-temperature stress in the sweet pepper cultivar 'Hongxing No. 2.' *Horticulture Environment and Biotechnology*, 57(4), 348–354. https://doi.org/10.1007/s13580-016-0065-1

[18]. Soltan, M., A ElAidy, F., C Scheerens, J., & D Kleinhenz, M. 2017. Grafting, Scion and Rootstock Effects on Survival Rate, Vegetative Growth and Fruit Yield of High Tunnel-grown Grafted Pepper (*Capsicum annuum* L.) Plants. *Advances in Crop Science and Technology*, 5(5), 1–12. https://doi.org/10.4172/2329-8863.1000312

[19]. SPSS. (2015). SPSS Statistics for Windows, version 23.0.0.0 (23). IBM Corp., Armonk, N.Y., USA.