INFLUENCE OF THREE ROOTSTOCKS ON YIELD AND COMMERCIAL QUALITY OF "ITALIAN SWEET" PEPPER

Influência de três porta-enxertos na produção comercial e qualidade da pimenta "italiano doce"

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ABSTRACT

Pepper crops (*Capsicum annuum* L.) represent a very important production sector in the Southeast of Spain. Specifically, in the province of Almería, approximately 7000 hectares are grown every year. Due to the economic importance that this crop has for the region and the withdrawal of soil fumigants from the market, agronomic techniques have been adopted with the aim of controlling some soil pathogens and increasing the yield and quality parameters of the fruits obtained. The use of grafted pepper plants is not, as yet, very well established in this region, due mainly to the lack of commercial rootstocks that satisfy the producers of this vegetable. In this experiment three pepper rootstocks were assessed. An experiment was designed with four treatments and three replications of each one (12 experimental plots), which were distributed in randomised blocks. Three of the treatments corresponded to grafted plants of the "Palermo" cultivar onto: "Oscos", "AR40" and "Tresor", using non-grafted "Palermo" cultivar as the control test. The average yield expressed in kg/plant, showed significant differences between grafted and non-grafted plants. The highest fruit weight was obtained in Palermo onto Tresor. The presence of Blossom end rot (BER) in the assessed fruits also showed significant differences between the different treatments, with the fruits from plants grafted onto Tresor showing a higher proportion of BER and the fruits coming from plants grafted onto AR40 showing the lowest proportion.

Index terms: Grafting, *Capsicum annuum* L., blossom-end rot.

RESUMO

O cultivo de pimenta (*Capsicum annuum* L.) é muito importante para o setor produtivo do sudeste da Espanha. Especificamente, na província de Almería, são cultivados 7000 ha cada ano. Em razão da importância econômica da cultura para a região e a retirada de fumigantes do solo, técnicas agronômicas foram adotadas, a fim de controlar alguns patógenos de solo e melhorar os parâmetros e qualidade dos frutos. O uso de plantas de pimenta enxertadas, até agora, não é bem estabelecido na região, principalmente em decorrência da falta de porta-enxertos comerciais para atender aos produtores. Nesse experimento, foram avaliadas três porta-enxertos de pimenta. Um experimento com quatro tratamentos e três repetições de cada (12 parcelas) que foram distribuídos em blocos ao acaso. Três dos tratamentos corresponderam à variedade enxertada " Palermo" em " Oscos ", " AR40 " e " Tresor " usando cultivar " Palermo", sem enxertia, como plantas controle. O rendimento médio em kg/planta mostrou diferenças significativas entre plantas enxertadas e não enxertadas. O maior peso do fruto foi obtido em Palermo no Tresor. A presença de podridão fim flor (BER) nos frutos avaliados, também mostrou diferenças significativas entre os diferentes tratamentos com os frutos das plantas enxertadas sobre Tresor apresentando uma maior proporção de BER e frutos de plantas enxertadas sobre AR40, a menor proporção.

Termos para indexação: Enxerto, *Capsicum annuum* L., podridão apical da flor.

INTRODUCTION

Fruit and vegetable demand has increased significantly in the last few years, and the sweet pepper is one of the vegetables in this privileged situation. Southeast Spain is amongst the main production areas of sweet pepper in Europe (López-Marín et al., 2013), where 7000 ha of sweet pepper are grown under greenhouse in the province of Almería, and 1900 ha in the province of Murcia and southern Alicante (López-Marín et al., 2009). Spain is considered as the sixth pepper producing country, with 898,000 t in 2011, and the third exporting country behind Mexico and Holland. Turkey, due to the concurrent production calendars, is Spain's main competitor (Marm, 2014). The value of the total pepper production in this region during the 2010-2011 season was approximately 370 million Euros (M€). This production has remained stable during the last 5 years.

As a result of the intensification of crop systems and the lack of rotation, different phytosanitary problems have arisen. It is known that monocropping results in various soil fatigue problems and the presence of disease,

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the effects of which directly influence crop yield and growth (Guerrero et al., 2014). Soil fatigue has become a serious problem in pepper growing fields, resulting in drastic losses if appropriate precautions are not taken. The main root pathogen associated with pepper crops is *Meloidogyne incognita* and the main fungal disease is *Phytophthora capsici*, which is the foremost cause of disease of peppers worldwide; only some commercial pepper cultivars are partially resistant to these problems (Gisbert et al., 2010).

Methyl bromide (MeBr) was used in some plantations of this region until the end of 2007, but after its use was banned, grafting has gradually become the most common and effective technique for the control of soil-borne diseases, such as *Phytophthora* spp and *Meloidogyne* spp (López-Marín et al., 2009).

MeBr was declared as an ozone-depleting substance at the 4th Meeting of the Montreal Protocol in Copenhagen in November 1992. Other fumigants tested as alternatives to MeBr have also been banned or are on the way to being banned in the coming years, Now that chemical methods of controlling soil diseases have been banned, grafting pepper is a topic of great interest to growers of Almeria and Murcia and other world regions where pepper is often cultivated. The biofumigation carried out with residues of fresh vegetable material and hen and sheep manure has had good results in Spain (Bello et al., 2000), as has biosolarisation and grafting onto resistant rootstocks, which have proved effective when both techniques have been combined in the control of *P. capsici.* The use of grafting in long cycle pepper crops has been shown to be as effective as the biofumigation technique for the control of some fungi and nematodes (Bello et al., 2000).

Overall, it can be said that the reasons which have given rise to the increased use of the grafting technique in vegetables are: the increased density of pathogen's inoculum in the soil, due to the intensification of production practices and the disappearance of traditional varieties adapted to the crop conditions, which were also used to meet the demands of local and specific markets (Sakata; Ohara; Sugiyama, 2007), a greater global movement and/or local invasion of new pathogens, increased use of organic products, the rapid spread of production systems in tunnels of great height and the eradication of the use of (MeBr), (Louws, 2010). Furthermore, it has been shown that the use of grafted plants in other fruity vegetables such as melon, watermelon, cucumber and tomato increases the yield per hectare with lower planting density and with higher parameters for quality standards (Huitrón-Ramírez et al., 2009; Ricárdez-Salinas et al., 2010).

In spite of recent progress, the percentage of grafted plants within the context of vegetable production in the world is still relatively low. The use of grafting in sweet pepper plants is not as widespread as in the rest of horticultural species (Lee et al., 2010), in spite of the fact that the use of adequate rootstocks can be an alternative strategy to avoid or reduce yield losses caused by environmental stress, such as excessive radiation or temperature in late crop cycles (Schwarz et al., 2010), as well as providing other advantages such as resistance to soil-borne diseases (López-Marín et al., 2013). Until now, little attention has been paid to the effect of rootstocks on the fruit quality of grafted sweet pepper (Colla et al., 2008).

The choice of the rootstock to be used is considered to be a key factor. It is necessary to choose a rootstock with the adequate characteristics insofar as the appropriate vigour characteristics, tolerance to flooding and salinity, or resistance to certain soil diseases or pests. All these characteristics must be accompanied by a perfect compatibility between rootstock and variety. These circumstances have been widely studied in fruity vegetables such as tomato and watermelon, but not in sweet pepper, mainly due to the lack of commercial rootstocks that perform satisfactorily. For all these reasons, the use of pepper grafted plants is not yet widely implemented in the region Almería. The above mentioned arguments justify the undertaking of this experiment.

The use of grafted plants generates an added cost for farmers compared with the use of non-grafted plants. The high planting density for this crop justifies its reduction, much more so than for tomato, watermelon and melon, taking into account the resulting savings in the control of soil pathogens where disinfection can be avoided (Oka; Offenbach; Pivonia, 2004). The cost of the plant, on the one hand, and the vigour of the grafted plant, on the other, has resulted in a lower density in the grafted horticultural crops compared to those grown with non-grafted plants. Several experiments have been carried out to this effect, and equal or higher yields have been obtained and the harvest quality has been maintained when grown with densities which are 50% to 70% of the non-grafted plant density, and even in some cases of cucurbits (melon and watermelon), grafted plant densities which represent 30%-50% of non-grafted plant densities have been used (Ricárdez-Salinas et al., 2010). Although it is true that the rootstocks used for this crop were Cucurbita hybrids which provide strong vigour, something which is not the case for the capsicum crop, where the vigour of grafted plants is not much higher than that of non-grafted plants. Work carried out with other types of peppers with fruits destined for the industrial market as well as for the fresh market (Maniutiu et al., 2010) offer the possibility of toying with plant density whilst keeping the same yield and without affecting product quality for the market, something which is also practised by the region's farmers when using grafted plants. For this, they work with a plant density of 70% with respect to when they use non-grafted plants, because they consider this to be the right balance between fruit quality, yield and the higher cost of the grafted plants and the overall investment that they make to put into operation the grafted pepper crop.

MATERIALS AND METHODS

The experiment was conducted in 2011 and 2012 during the spring-summer seasons, coinciding with the farmers' production calendar in the region. The facilities used were those of the Foundation's "Experimental Plot at the University of Almería, Anecoop", in the municipality of Almería – Spain. (36º 51´ 78" North latitude and 2º 17´ 08" West longitude). The experiment was carried out in a "multi-tunnel" greenhouse with a total area of 1800 m^2, the covering material was made of three-layer polyethylene of 200 microns thickness. The soil was covered with sand and the crop was grown according to the typical conditions of this technique, which coincide with those used by the majority of the region's farmers. Irrigation was carried out through a localised irrigation system with discharge drippers of 3 L h^{-1}. An experiment of randomised blocks was designed with four treatments and three replications, thus obtaining 12 experimental plots. The surface of each experimental plot was 100 m^2 with 230 plants in the control test treatment plot and with 160 plants in all the grafted treatments plots, the rest of the area into the greenhouse was used as border area between plots using non grafted "cv. Palermo". The planting date in both experiments was 8th of February.

The treatments have been designed using the non-grafted plant as the control test and, as the treatments, the grafted plants, at the densities used by the region's farmers. The cultivar "cv. Palermo" (Rijk Zwaan), which is Italian Sweet type with density of 2.3 plants/m^2. Palermo was grafted on three rootstocks "Oscos" and "AR40" (Ramiro Arnedo), 'Tresor' (Nunhems) and the planting density was 1.6 plants/m^2.

The description of the vegetal material which was used in this experiment is as follows:

Palermo: Italian pepper type which stands out by its high yield under low temperature conditions. It is a very hardy plant. Fruits have a conical shape and a medium-green colour, and they maintain a constant length throughout the production cycle. They have a very glossy and fairly smooth skin. This is a versatile pepper which can be harvested green and also red. It has an excellent taste, colour and firmness. It is recommended for planting in autumn and early spring in a greenhouse, and in the spring in the open fields or under mesh. High resistance to TMV: 0-2.

Oscos: This is a rootstock with good affinity to the different varieties of pepper. It has good root development, which provides great vigour to the crop and favours the good formation and structure of the plant, thus maintaining fruit quality. It has tolerance to problems of root asphyxia caused by flooding and to the most common soil diseases, such as *Phytophthora* and *Nematodes*. It is resistant to TMV: 0.

Tresor F1: This is a rootstock of high compatibility and affinity with the different types and varieties of pepper. It has a good root system, which enhances the plant development. It has also a good behaviour in soils infected with: Phytophthora (*P. capsici*), Nematodes (*Meloidogyne arenaria*, *M. incognita*, *M. javanica*). Intermediate resistance to PVY: 0,1 and high resistance to Tm: 0: BePMV/TMV/ToMV (L1).

AR40: Rootstock somewhat less vigorous than Oscos, it keeps its qualities with regard to resistances and enhances the fruit setting.

The grafting method used was splice grafting, which was described by Lee (1994). All these measurements were taken for each of the harvests (Table 1).

The productive parameters measured were: total and accumulated yield per square meter and also per plant, using EKS scales with a capacity of 40 kg (graduation $\pm$ 10 g) (Rue de Baldenheim 12, BP 10221, F-67820, Wittisheim France). The following quality parameters were measured: fruit weight, using EKS trademark scales with a 5 kg capacity (graduation $\pm$ 1 g) (Rue de Baldenheim 12, BP 10221, F-67820, Wittisheim France); fruit dimensions, length, fruit width in peduncle area and wall thickness, using a COX CB-500 graduated ruler. Lastly, the presence or absence of plant diseases such as blossom end rot (BER), the absence of seeds and presence of double ovaries were observed.

The data and statistical analysis was carried out using the computer program Statgraphics Centurión XVI, analysing variance ($p<0,05$) and carrying out the minimum significant difference test using Fisher´s LSD with a 95% confidence level.

Table 1 – Work calendar.

	Year 1		Year 2	
Planting date	W.6		W.6	
Measurements	Harvested red	Harvested green	Harvested red	Harvested green
	W.20	--	W.19	W.19
	W.21	--	W.26	--
	W.22	--	W.27	--
	W.23	--	W.28	--
	W.24	--	W.29	--
	W.25	--	W.30	--
	W.26	--	W.32	--
	W.27	--	W.34	--
	W.29	--	W.36	W.36
	W.30	--	--	--
	W.31	--	--	--
	W.33	--	--	--
Crop end	W.34		W.37	

W: Week.

RESULTS AND DISCUSSION

Yield. The yield behaviour within the two years that the experiment lasted was different, in the first year it did not show significant differences T0 (non-grafted plant) being the one which gave a higher yield (4.17 kg·m^{-2}) and T3 (Palermo onto Tresor) gave the lowest one 3.76 kg·m^{-2}. In the second year there were significant differences between T3, the most productive treatment with 3.70 kg·m^{-2}, and the rest of the treatments (Table 2).

Accumulated yield per plant. During the first crop year none of the treatments showed significant differences. In the second year, significant differences were observed between treatments: T0, T1 and T2 produced less than T3 (Palermo onto Tresor) which gave 2.31 kg/plant, (Table 2).

The spring crop cycle used in the experiment for this pepper type is not as productive as the autumn-winter long cycle, nevertheless the earning is usually better during the spring cycle.

The yield parameters analysed are not consistent with those found by Estañ et al. (2005), who did not find significant yield differences between the grafted and the non-grafted tomato plants under normal cultivation conditions. Miguel et al. (2004); Huitrón et al. (2007); Huitrón et al. (2008); Huitrón-Ramírez et al. (2009) did not find differences in their triploid watermelon trials, although their control test was always grafted watermelon, whereas in our experiment non-grafted plants were used for the control. Ricárdez-Salinas et al. (2010), did find significant differences in the treatments of grafted melon onto the interspecific rootstock (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) which showed the highest value in the yield parameters of total production expressed in kg m^{-2} compared with the non-grafted plant.

Fruit weight. The data showed significant differences between the two years. T0 (non-grafted plant) had the lowest fruit weight with values of 140.83 g and 110.76 g, respectively. The treatment which offered a higher fruit weight consistently in the two years was T3 (Palermo onto Tresor) with 148.89 g and 124.90 g respectively (Table 3).

Fruit length. In the first year, T1 (Palermo onto Oscos), showed significant differences, having the lowest fruit length, 216.64 mm. In the second year, T0 (non-grafted Palermo) gave the lowest values with 224.08 mm, thus grouping with T1 (Palermo onto Oscos). In both years, T3 (Palermo onto Tresor) offered the highest length values with 222.79 mm and 222.90 mm, respectively (Table 3).

Diameter of the peduncular end of the fruit. There were no significant differences in either of the two years. Even without said differences, T0 (non-grafted Palermo) gave the lowest values consistently and T3 (Palermo onto Tresor) the highest values (Table 3).

Table 2 – Ratios of total accumulated yield and marketable yield per square meter and per plant obtained in general in the different treatments and throughout the experiment and, specifically in each crop cycle.

Treatments	Total yield	
	Accumulated Yield (kg m^{-2})	Accumulated yield (kg/plant)
	2011	
T0	4.17 a	1.77 a
T1	3.89 a	2.41 a
T2	3.89 a	2.41 a
T3	3.76 a	2.34 a
Pvalue	0.91	0.17
	2012	
T0	3.26 ab	1.39 a
T1	2.57 a	1.59 a
T2	2.84 a	1.76 a
T3	3.70 b	2.31 b
Pvalue	0.02	0.00

Different letters mean significant differences, at P<0.05.

Table 3 – Data about fruit quality parameters: Weight, length, peduncular area diameter and wall thickness. The data shown represent the different treatments, in general, and throughout the experiment and, specifically in each crop cycle.

Treatments	Fruit quality			
	Weight (g)	Length (mm)	Higher diameter (mm)	Pulp thickness (mm)
		2011		
T0	140.83 a	221.15 b	49.87 a	4.18 a
T1	141.14 a	216.64 a	50.19 a	4.13 a
T2	144.06 a	220.74 b	49.88 a	4.10 a
T3	148.89 b	222.79 b	50.64 a	4.67 a
Pvalue	0.00	0.00	0.20	0.22
		2012		
T0	110.76 a	224.08 a	43.53 a	3.83 a
T1	115.63 ab	225.21 a	44.04 a	3.87 ab
T2	118.72 b	226.34 ab	43.86 a	3.99 b
T3	124.90 c	229.90 b	44.36 a	3.91 ab
Pvalue	0.00	0.05	0.66	0.01

Different letters mean significant differences, at P<0.05.

Fruit pulp thickness. Significant differences were not shown the first year. In the second crop year, significant differences were obtained and T0 (non-grafted Palermo) with a value of 3.83 mm was the treatment with the lowest wall thickness, and T2 (Palermo onto AR40) the treatment with the highest value, 3.99 mm (Table 3).

Double fruits. Measurable data was also obtained with regard to the presence of double ovaries in the harvested production. This problem did not appear in any of the treatments during the first year. In the second year, the treatment with the lowest presence of double ovaries was T3 (Palermo onto Tresor, with an accumulated value of 1.82 fruits/100 m^2, and it showed significant differences compared to the rest of the treatments. T2 (Palermo onto AR40) gave the highest value with 2.75 fruits/100 m^2 (Table 4).

Seedless fruits. Significant differences were observed in the two years. T3 (Palermo onto Tresor) gave the highest value the first year with a 0.9 %, and also the same tendency was observed during the second year with a value of 3.94 % (Table 4).

Blossom-end rot (BER). Significant differences were observed in both years of the experiment. T3 (Palermo onto Tresor) showed the lowest values with 4.78 % and 2.32 %, respectively (Table 4).

The results obtained from the individual quality analysis of each fruit, showed that for the majority of the parameters analysed, the use of rootstocks under the experiment conditions equalled or improved the parameters obtained from the non-grafted control test treatment. This data is consistent with the findings of other trials carried out with mini-watermelon crops (Proietti et al., 2008), triploid grafted watermelon (Miguel et al., 2004; Huitron et al. 2007, 2008 and 2009), and grafted melon (Ricárdez-Salinas, et al., 2010). In our experiment, the pepper grafted onto the rootstock "Tresor" showed the best assessed quality parameters, which even showed differences with the product obtained from non-grafted plants. Tsaballa, et al., (2013), points out that the rootstocks cause changes in the fruit shape of sweet pepper.

Special mention must be made of the behaviour that some rootstocks show in the presence of fruit diseases. As the pepper fruits increase in weight, length, diameter in the peduncle area and wall thickness, there are fewer double ovaries and they are less affected by blossom-end rot (BER). The low incidence of fruits with BER symptoms in Palermo onto Tresor (T3) could be because this rootstock is better equipped to overcome water stress, as described by Johkan et al., (2009) in grafted sweet pepper plants. These results are consistent with Sánchez-Rodríguez et al., (2012) who suggested that grafting onto specific rootstocks more adapted to water stress conditions may be a tool to improve crop quality.

Table 4 – Data about fruit quality parameters in percentage. Accumulated data of presence of diseases: Silvering, Double fruits, Seedless fruits and Blossom-end Rot (BER) in the analysed fruits. The data shown represent the different treatments, in general, and throughout the experiment and, specifically in each crop cycle.

Treatments	Double fruits (%)	Seedless fruits (%)	Blossom end Rot (%)
2011			
T0	0.00	0.00 a	15.72 c
T1	0.00	0.00 a	8.18 b
T2	0.00	0.00 a	7.72 b
T3	0.00	0.09 b	4.78 a
Pvalue	---	0.00	0,00
2012			
T0	1.42 b	3.15 c	3.27 b
T1	1.50 b	1.49 a	2.48 a
T2	1.77 c	2.27 b	2.56 a
T3	1.17 a	3.94 d	2.32 a
Pvalue	0.00	0.00	0.00

Different letters mean significant differences, at P<0.05.

CONCLUSIONS

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.

Among the rootstocks used, the fruits coming from "Tresor", showed the best results in the quality parameters measured, such as fruit weight, length, bigger diameter at the peduncle end and greater pulp thickness.

The number of fruits coming from plants grafted onto "Tresor" showed the lowest incidence of double ovaries and the lowest amount of fruits with BER symptoms.

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