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Effect of root pruning on yield and fruit quality of mirasol chili peppers

Abstract

In pepper crop it is hypothesized that when the transplants are transplanted to bare roots are lost roots and reserves (nutrients and carbohydrates) at the time of transplantation,causing stress, poor survival, and delayed harvest and low fruit yield. Bare-root transplanting of chile is a common practice in the Zacatecas and Aguascalientes region. Therefore, set out to determine the effect of washing and root pruning on survival, growth, yield and quality in 'Mirasol' pepper plants. In order to test this objective were established three treatments at transplant moment for two years (2010 and 2011): 1), transplants with root intact; 2), transplants with root washed and intact; and 3), transplants with root pruned to 50%. It was found that the year and the root management at transplanting affected (P≤0.05) independently the growth, yield and quality of the fruit. So, in year 2010 was obtained more yield (18%) than in year 2011, because there were better weather conditions for crop growth. Furthermore, washed transplants or transplants pruned to 50% were able to adapt and grow similarly to those transplants with root intact, since both types of the transplants showed the same survival, diameter and plant height, number and fruit weight. Also, pruned transplants to50% increased significantly (P≤0.05) yield (13.6%) and quality of fruit (22.5%). Finally, theseresults suggest that the transplants of pepper "Mirasol" can be transplanted to bare root without risk of loss in yield or in quality.

Keywords: *Capsicum*, "guajillo" pepper, root pruning, fruit quality

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Introduction

The transplanting technique in intensive horticultural systems, such as chili (*Capsicum annum* L.), allows better planning of planting, uniformity in growth, efficient use of seed, early harvest, etc.[1] The production of quality chili depends on variousenvironmental factors, crop type, cultural practices, among others.[2] A chiliseedling is considered of good quality if it has a vigorous stem, free of pests and diseases, dark green leaves, good root development, height of 0.10 to 0.15 m and six to eight true leaves.[3] In chili, the success of transplanting depends onthe seedlings being resistant to stress caused by handling, packaging and transport, adapting quickly, growing rapidly after transplanting and achieving high yields.[4,5] The constant search for alternatives that help to improve the establishment of chili peppers and increase the quantity and quality of fruits is a topic that entertains a large number of researchers. Recently, it was observed that pruning from half to three-quarters of the chile root significantly reduces fruit rot at the end of flowering, affects the size of the plants, but the number and weight of chile fruits remain stable.[6] Inhydroponics, root pruning in sweet chili (*Capsicum annumm*) is performed to minimize excessive root growth; it is also reported to improve the weight of the aerial part and fruit quality.[7] The effect of root pruning is a phenomenon that is not yet fully understood and results are contradictory. Studies on root pruning indicate that this practice, carried out at the time of transplanting, has negative effects on yield, quantity and quality of fruit, as well as affecting other physiological parameters.[6] In this sense, Bar-Tal et al.,[8] evaluated the combination of root pruning and N-NO3 concentration in irrigation water on fruit yield in tomato plants (*Solanum lycopersicum* L.), and determined that root pruning decreased shoot growth, average fruit weight and yield; in addition, the concentration of N-NO3 failed to replace the lack of roots in the plants, since yield and quality remained unchanged. Mulyati and Huang[9] established a greenhouse experiment where they evaluated the application of zinc levels in the soil, direct sowing and transplanting without pruning and with pruning of 50% of the roots in canola (*Brassica napus* L.), concluded that transplanted plants and especially pruned plants showed higher zinc requirements than those of direct sowing; in addition, root pruning and Zn fertilization in canola, presents an additive effect.[10] On the contrary, Larson[11] established intact, slightly severely pruned strawberry plants (*Fragaria* x *ananassa* Duch.) and found that pruning did not affect stem diameter or yield, a situation that has already been observed in chili.[6,7] There are few reports on root pruning and its effect on growth and yield in Mirasol chili. In this regard, Cabañas and Galindo[12] indicate that most pepper producers in the state of Zacatecas use bare root seedlings from criollo seeds and only between 1 and 3% transplant seedlings with root ball from hybrid seed.

When bare-root transplanting is carried out, the seedlings are removed from the nursery and washed in running water. In this process, roots and possibly reserves (nutrients and carbohydrates) are lost, and it is assumed that these losses generate stress, poor survival, delayed harvest, reduced yield and fruit quality. For these reasons, the objective of thepresent study was to determine the effect of pruning and root washing on the survival, yield and quality of dry fruit in "Mirasol" chile plants grown under gravity irrigation conditions. We start from the hypothesis that root pruning does not affect the establishment capacity and quality parametersof the crop.

Materials and methods

The research was conducted in the ejido San Rafael de Ocampo, Asientos, Ags. during 2010 and 2011. This site is located at a northern latitude of 22° 06'; a western longitude of 102° 05'; and an altitude above sea level of 2010 meters. The climate is BS1 kw (e), which

corresponds to steppe, semi-dry, temperate, with rainfall in summer and extreme. With temperature and mean annual precipitation of 16.7 °C and 420.7 mm. Temperature oscillationof 9.1 °C, and percentage of winter rainfall of 7% of the annual total.[13] Duringthe experiment, the highest maximum temperatures were 31.6 (2010) and 32.3 °C (2011), both in the month of May; while the lowest minimum temperatures were 5.2 (2010) and 7.3°C (2011) and occurred in the month of March. The total accumulated precipitation per year was 510.0 mm in 2010 and 70.4 mm in 2011. (Figure 1)

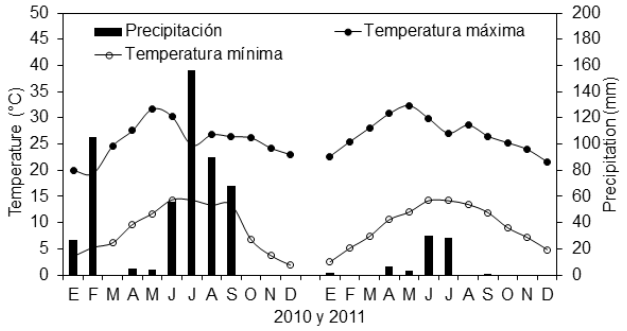

Figure 1 Maximum and minimum monthly temperatures and monthly precipitation during 2010 and 2011. San Rafael de Ocampo, Asientos, Aguascalientes.

The experiment was established during 2010 and 2011 and consisted of three treatments, using "Mirasol" creole guajillo chile seedlings with six true leaves and an average height of 0.1m, characteristics recommended by Montaño-Mata and Núñez.[3] The three treatments consisted of: one, transplanting seedling with root ball and intact root; two, transplanting seedling with bare root and intact root; and three, transplanting seedling with root ball and pruning 50% of the root ball volume. In the case of treatment two, the root was washed under running water to remove the substrate. In treatment three, the 50% of the root ball and root volume, to try to simulate the damage suffered by the seedling when the grower transplants bare root (Figure 2). The treatments were distributed in a 2x3 factorial arrangement (factor A = years, B = the three types of transplanting) in a randomized complete block design with four replications. The experimental plot consisted of three furrows,with a length of five meters, and the central furrow was considered as the useful plot. In this plot, the percentage of plant survival, stem diameter, plant height and number of fruits were measured. Subsequently, the fruits were dried in an oven at 60 °C until they reached constantweight. Once dried, they were classified and weighed to estimate the production per plant, quality and dry fruit yield. Data were analyzed by analysis of variance, Friedman's test and tests for separation of means (least significant difference) where appropriate ($P \leq 0.05$). Seedling survival data were expressed as percentages and arcsine transformed before analysis. All analyses were performed with the SAS statistical package.[14]

The experiments were established in a soil with a loam texture, with apparent density from 1.1 to 1.25, with organic matter content from 1.1 to 1.2, with pH from 7.6 to 7.8, electrical conductivity from 0.61 to 0.73 dS/m and with less than 5% of exchangeable sodium. The soil was prepared in the conventional way, with a fallow, two passes of harrow and furrows of 0.8 m wide and between 0.20 and 0.30 m high. The seedlings of the "Mirasol" type chile criollo were transplanted on March 21, 2010 and 2011, in furrows of 0.8 m wide and between 0.20 and 0.30 m high. 0.80 m wide, at a distance between plants of 0.30 m, at one row per furrow, which resulted in a population density of approximately 41,625 plants per hectare.

Irrigations were applied by gravity and were supplied according to crop needs. Fertilization was done with the formula 150-50-00 of N, P and K; applying half of the nitrogen and all of the phosphorus in the first weeding and the rest of the nitrogen at the beginning of flowering. For the first application, 275 kg of ammonium sulfate and 110 kg of diammonium phosphate (DAP) were used; and for the second application, 160 kg of urea were used. The hilling and weeding were done with the help of a tractor. In order to facilitate irrigation, the furrows were lifted at least twice. Once the rainy season was established, two to three manual weeding operations were carried out. The most common pests in the region, such as the flea flea (*Epitrix* spp.) and the green catarina (*Diabrotica* spp.) in the first two months of the cycle, Thiamethoxam was applied once at a rate of 300 grams per hectare.

Figure 2 Root treatments evaluated in seedlings of 'Mirasol' criollo chili bell pepper. Seedling with root ball and intact root (left), seedling with washed root (center) and seedling with root pruned to 50% of root ball volume (right).

For larvae control in the crop, Chlorfenapyr was applied one month after transplanting at a dose of 0.4 kg ha^{-1}. Finally, to prevent attack by the chile weevil (*Anthonomus eugenii* Cano),Thiamethoxam was applied during flowering at a dose of 400 grams per hectare.

Results and discussion

It is hypothesized that when seedlings are transplanted with bare roots, roots and reserves (nutrients and carbohydrates) are lost at the time of transplanting, which causes stress, poor survival, delayed harvest and reduced fruit yield.

Effect of root management

When considering the analysis of the two growing seasons evaluated root management only affected ($P \leq 0.05$) yield and some of its components.

Seedlings of "Mirasol" chile criollo type germinated in 338-cavity tray, pruned to 50% of root volume, subsequently transplanted, grown under field conditions and gravity irrigation were able to adapt and grow in a similar way to transplanted plants with intact root and with washed root, since both types of plants showed the same ($P > 0.05$) survival, diameter, height, fruits per plant and average fruit weight. (Tables 1&2)

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Table 1 Survival, diameter and plant height as a function of year and root managementin 'Mirasol' type chile criollo

Factor	Survival†	Stem diameter	Plant height
	%	cm	
Year (A)			
2010	91.67 b	0.91 a	68.72 b
2011	98.46 a 4.56	1.02 a 0.11	79.86 a 4.00
DMS	4.56	0.11	4
Root management (M)			
Root intact	94.12 a	0.96 a	75.25 a
Washed root	96.36 a	0.95 a	75.36 a
Root pruned to 50	95.83 a	1.00 a	74.12 a
DMS	5.56	0.13	4.87
Significance			
A	0.01	0.09	0
M	0.78	0.61	0.61
A*M	0.59	0.47	0.81

Different letters in each column indicate significant differences (LSD, P≤0.05). †Values expressed as percentages were arcsine transformed prior to analysis.

Table 2 Fruit and yield per plant and average dry fruit weight as a function of year and rootmanagement in 'Mirasol' type chile criollo

Factor	Fruits per plant	Average weight of fruit	Production per plant
Year (A)			
2010	15.30 a	4.65 a	70.45 a
2011	16.51 a	2.97 b	49.34 b
DMS	1.54	0.45	5.72
Root management (M)			
Root intact	15.05 a	3.71 a	54.77 a
Washed root	16.72 a	3.63 a	60.87 a
Root pruned to 50	16.15 a	3.81 a	60.53 a
DMS	1.88	0.55	6.96
Significance			
A	0.9	0	0
M	0.07	0.93	0.04
A*M	0.4	0.71	0.44

Different letters in each column indicate significant differences (LSD, P≤0.05).

In this research, the three root management treatments were established under gravity irrigation conditions for two years and survival ranged between 94 and 96% (Table 1). Comparable to what was reported by Serna-Pérez et al.,[15] who evaluated seedlings in "Mirasol" type chile bell pepper germinated in a tray, transplanted with root ball and grown under drip irrigation conditions during two growing seasons and found an average plant survival of 93%. Contrary to the opinion of Evans and Blazich,[16] it is demonstrated that the establishment of Mirasol chile plantations with bare-root seedlings does not favor plant death nor does it diminish the rooting of these seedlings under field conditions.

During the study time, production per plant, yield of first quality fruit and total yield of 'Mirasol' type chile criollo were modified (P≤0.05) by the effect of seedling root management (Tables 2&3). Thus, plants with the root washed or pruned improved quality by producing more than 245 kg ha^{-1} of first-quality dry chile compared to intact plants.

In this research, seedlings pruned at 50% were able to produce a total dry chili yield of 2.6 t ha^{-1} as an average of two cycles (2010 and 2011) of evaluation and is comparable tothe yield (2.8 t ha^{-1}) average of three years (2008, 2009 and 2010) reported by Serna and Zegbe[17] in 'Mirasol' chili with seedlings transplanted with root ball and established under drip irrigation conditions. Also, the 50% pruned seedling treatment produced more 311 kg ha^{-1} of dry chile than intact seedlings (Table 3). These results differ from those reported by Bar-Tal, et al.[8] who evaluated intact, lightly and severely pruned tomato plants and reported thatroot pruning decreased plant growth and yield.

Table 3 Quality and yield (kg ha^{-1}) of dry fruit as a function of year and root management in 'Mirasol' type chile criollo

Factor	Quality distribution			Performance
	First	Second	Pintos	Total
Year (A)				
2010	1655.94 a	549.06 a	505.31 b	2710.31 a
2011	936.63 b	505.25 a	857.04 a	2298.92 b
DMS	155.73	133.42	106.24	255.98
Root management (M)				
Root intact	1075.19 b	515.01 a	697.42 a	2287.60 b
Washed root	1375.48 a	525.55 a	657.45 a	2558.50 ab
Root pruned to 50	1318.31 a	533.60 a	747.28 a	2599.20 a
DMS	189.46	162.40	129.31	310.67
Significance				
A	0.00	0.33	0.00	0.00
M	0.00	0.97	0.64	0.04
A*M	0.16	0.90	0.00	0.39

Different letters in each column indicate significant differences (LSD, P≤0.05).

In general, the practice of washing and 50% root pruning maintained seedling survival, vegetative growth, number of fruits per plant and average fruit weight of 'Mirasol' type chili during two years of evaluation. In addition, the practice of pruning the root to 50% significantly (P≤0.05) increased total yield and first quality of dry chili by 13.6 and 22.5%, respectively.[18] These results contrast with other research on other crops such as tomato, where it is noted that root pruning at the time of transplanting decreases shoot growth, average fruit weight and yield.[8] Also, in other research developed by Evans and Blazich[16] it was found that the use of containers protects the seedling root, reduces stress and increases rooting in the field.

Year x pruning treatment interaction effect

In this research it was found that the factor year (A) and the factor root management at transplanting (M) significantly (P≤0.05) independently affected growth, yield and quality of criollo "Mirasol" type chile bell pepper. The only interaction that was significant among the study factors was the variable pinto chile fruit yield (third-quality fruit); thus, seedlings with 50% root pruning in 2010 produced lower pinto fruit yield, but in 2011 the opposite occurred, this suggests that the plant with 50% root pruning is more stressed when there is less rainfall andhigher temperature (Figure 1). Because only this interaction was found, only the results due tothe simple effect of the factors are presented and discussed in more detail. (Tables 1-3)

Year effect

In this research, the year factor affected (P≤0.05) most of the response variables, except for stem diameter, number of fruits per plant and second quality yield (Tables 1-3). In general, during 2010

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there were better environmental conditions for the growth of the chile crop (Figure 1), so that in this year practically 18% more yield was obtained than in 2011 (Table 3), despite having a lower population (lower survival) of plants per hectare and smaller plants (Table 1). This behavior coincides with the results obtained by Serna-Pérez et al.,[15] who found more fruit per square meter and greater dry fruit weight in chile type."

Conclusions

The recurrent selection of materials for planting, carried out for hundreds of years, has allowed the adaptation of Mirasol chili to the hardiness conditions of the crop to which it is subjected in the Zacatecas and Aguascalientes regions. Therefore, it is not surprising that this practice gives statistically equal results to those obtained with plants from root ball, and inthe case of the variables quality and yield of dry fruit, which is the main variable of interest,the treatments of washed root and pruned to 50%, generate the best production (Table 3). Itis demonstrated that the practice of planting seedlings with native seeds of "Mirasol" chile andtransplanting with bare root is a viable, functional, economic and sustainable practice for low- income producers, which requires less expense and offers the same results as the transplanting of seedlings from root ball, where a greater investment is required.

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