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Influence of distance between plants and pruning of axillary buds on morphological and productive characteristics of tomato plants

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This research was carried out for 120 days in the horticulture area of the Universidad Nacional de Concepción, Facultad de Ciencias Agrarias to evaluate how morphological and productive characteristics of tomato plants were influenced by the distance between plants and the pruning of axillary buds. The design used in the experiment was the randomized block method with factorial arrangement (3x3); factor A was the pruning of axillary buds (no pruning, pruning between 1 and 5 cm, pruning between 6 to 10 cm of sucker length) and factor B was the distance between plants (40, 59 and 60 cm). Three repetitions were carried out. Plant height, fruits per bunch, polar and equatorial fruit diameters, and fruit yield per plant were determined. The results indicated significant differences of pruning of axillary buds for all determinations carried out. Only fruit yield per plant showed a significant difference by planting density. Pruning of axillary buds (6 to 10 cm sucker length) gave the best morphological and productive results. It is shown here that pruning of axillary buds has a significant influence on tomato production.

Key words: *Lycopersicum esculentum,* sucker length, fruit yield.

INTRODUCTION

Sowing density is a key factor in the crops' level of exposure to sunlight. This affects the level of transformation of solar energy into biomass, which is essential for increasing crop productivity (Castilla, 2001).

The importance of pruning lies in the fact that a rapidly growing plant organ can compete with leaves for easily translocated nutrients, causing leaf senescence and a reduction in photosynthetic capacity. The growth resulting from branch pruning is quite fast, temporarily altering the ratio between the root and above-ground part of the plant. Likewise, the removal of foliage and branches reduces the amount of accumulated carbohydrates and, even more importantly, reduces the leaf area available for carbohydrate production (Salisbury and Ross, 1994).

Pruning is an important practice in tomato cultivation that can improve fruit quality and yield. Given this, pruning

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is a necessary practice for the planting of tomato varieties of indeterminate growth. Pruning is carried out when the first side stems appear, which are removed as well as on the oldest leaves, thus improving the ventilation of the root collar and making it easier to mound soil around the base of plants (Vera et al., 2015).

Machado et al. (2007) evaluated different planting densities and types of pruning of tomato plants. Total and commercial production was best with spacing of 20 cm between plants and average fruit weight was best with 50 cm spacing. Increasing the population density of plants increased fruit production but, in contrast, reduced the average weight of fruits.

Ponce et al. (2011) determined the effect of four levels of branch pruning on tomato cultivation, concluding that none of these levels produced a positive effect on fruit yield or quality. However, there was a positive effect observed between different varieties. The highest yield (963.5 g/plant) was obtained with the variety CHF1. Equatorial and polar fruit diameters of 54.44 and 34.1 mm were obtained respectively, with fruit weight of 26.4 g.

The objective of this research was to evaluate the influence of distance between plants and different levels of pruning of axillary buds on morphological and productive characteristics of tomato plants.

MATERIALS AND METHODS

The experiment was carried out in the experimental terrain of the Facutad de Ciencias Agrarias, Universidad Nacional de Concepción, Concepción, Paraguay, at coordinates 230° 40'13" latitude, 570°41'85" longitude, and 160 meters above sea level (mamsl).

The area's climate is characterized by annual average temperatures of 14 and 26°C, with maximum temperatures reaching 45°C in the summer months and minimum temperatures of 4°C in winter with light levels of frost (DMH, 2018).

According to the soil analysis, the soil in the experimental area has the following physical and chemical characteristics at a depth of 0 - 0.20 cm: sandy loam texture, pH (H_2O) 5.67; organic matter (Walkley Black, modified): 1.67%; $Ca^{+2}_{(KCl\ extraction)}$, $Mg^{+2}_{(KCl\ extraction)}$ and $K^{+}_{(Mehlich)}$: 5.06, 1.27 and 0.19 cmol/LS(liter of soil), respectively; P(Mehlich) and $S_{(Acetic\ acid)}$: 28.94 and 11.73 mg/LS respectively; Al^{+3}: 0.05; cation exchange capacity (CEC): 9.71 cmol/LS, and base saturation (V): 67.21%.

The design used in the experiment was the randomized blocks method with factorial arrangement (3x3). Factor A was pruning of axillary buds (no pruning, pruning between 1 to 5 cm of sucker length, pruning between 6 to 10 cm of sucker length) and Factor B was the distance between plants (40; 50 and 60 cm). Three repetitions were carried out, giving a total of 27 experimental units (EU). The total plot size was 240 m^2.

The soil was prepared with ridges of 20 cm in height. The ridges were 1 m apart from each other and contained 1 row of tomatoes sowed using the distances between plants already mentioned. During the preparation of the ridges, cattle manure was added uniformly in doses of 4 kg m^{-2} in all the experimental units.

Subsequently, photoselective netting with 50% light retention and a drip irrigation system were installed. Afterwards, the soil's surface was covered using white plastic sheeting.

The seeds were sown in expanded-polystyrene germination trays with 105 cells. One hybrid Hs 1188 seed was planted in each cell. Plants were transplanted 30 days after sowing. Additionally, galvanized wire was installed so that the plants could be tied for support. 25 days after transplanting, pruning of axillary buds began. This was done according to a planned schedule: twice a week during the vegetative phase and once a week once flowering had begun.

To control diseases and pests, a contact fungicide (copper oxychloride, 3 g L^{-1} of water) was used preventively at 15-day intervals and a systemic fungicide was used (Tricur, 15 mL in 5 L of water). A systemic insecticide was also used (Imidacloprid, 8 mL in 5 L of water). In addition, a bactericide was used to control an outbreak of bacterial diseases.

Harvesting began 120 days after transplanting and was carried out daily until the fruits reached commercial maturity. Determinations were made by selecting 5 plants from each experimental unit and evaluating the following variables: 1) Plant height (the length of the main stem after the formation of the 9th floral bunch was measured using a tape measure); 2) number of fruits per bunch (fruits $bunch^{-1}$): the number of fruits in each bunch from the selected plants was counted and averaged; 3) Polar diameter (PD) and equatorial diameter (ED) of fruit (mm $fruit^{-1}$): These measurements were taken using a vernier caliper; 10 fruits were selected from each experimental unit for measurement; 4) mean fruit weight (g): 10 fruits were selected from each experimental unit; these were weighed, and a mean was obtained and 5) Fruit yield per plant (kg pl^{-1}): This was measured by weighing all the commercial fruits from the selected plants using precision scales; an average was calculated.

The data were subjected to variance analysis (ANOVA) using the Fisher test for each of the variables, and the averages from each treatment were compared using the Tukey test at 5% probability level.

RESULTS AND DISCUSSION

Plant height and number of fruits per bunch

Table 1 shows the average results for plant height and number of fruits per bunch obtained when varying the factors mentioned above. Significant differences were observed between the recorded means for the factor of pruning axillary buds. However, no statistical differences were observed for the factor of distance between plants. No significant effects were found for any of the variables studied in this experiment with regards to interaction between the two factors (Tables 1 to 3).

Analysis of the effect of pruning axillary buds on plant height shows that pruning between 6 and 10 cm SL produced plants with the greatest height, with an average of 177 cm. This does not statistically differ from pruning axillary buds between 1 and 5 cm in length, which produced an average height of 169 cm. However, it differed from no pruning, which produced the lowest value of 155 cm.

An analysis of the results in Table 1 for the number of fruits per bunch shows that the most favorable values were observed in plants pruned at 6 to 10 cm SL, with 4.53 fruits per bunch. These results were lower than those obtained by Max et al. (2016).

Monge (2016) investigated the effects of different types of pruning and planting density on the agronomic

Table 1. Plant height (PH) (cm) and number of fruits per bunch (NFB) (mm) as a function of pruning of axillary buds and plant density.

Factor	PH (cm)	NFB (mm)
Test F		
Pruning of axillary buds (A)	5.35*	35.97**
Distance between plants (B)	3.47^{ns}	1.68 ^{ns}
Interaction A x B	0.69^{ns}	1.18 ^{ns}
Pruning of axillary buds		
Pruning between 6 to 10 cm SL	177.07^{a}	4.53^{a}
Pruning between 1 to 5 cm SL	169.00^{ab}	3.16^{b}
No pruning	154.64^{b}	2.22^{c}
Distance between plants (cm)		
40	177.03	3.02
50	164.44	3.47
60	159.23	3.42
MSD	17.92	0.71
OA	166.90	3.31
CV	8.83	17.61

ns, *, **, F tests not significant and significant at 5 and 1%, respectively; for each column and each variable, means with different letters are significantly different at 5% probability by Fisher's test; CV, Coefficient of variation; MSD, Minimum significant difference; OA, Overall Average; SL, Sucker length.

Table 2. Polar (PD) (mm) and equatorial (ED) (mm) diameters in tomato fruits as a function of pruning of axillary buds and plant density.

Factor	PD (mm)	ED (mm)
Test F		
Pruning of axillary buds (A)	64.01**	99.39**
Distance between plants (B)	0.32 ns	1.93 ns
Interaction A x B	0.72 ns	1.61 ns
Pruning of axillary buds		
Pruning between 6 to 10 cm SL	86.36^{a}	66.42^{a}
Pruning between 1 to 5 cm SL	76.59^{b}	58.56^{b}
No pruning	69.43^{c}	51.04^{c}
Distance between plants (cm)		
60	77.84	59.89
50	77.77	58.23
40	76.77	57.89
MSD	3.88	2.82
OA	77.46	58.67
CV	4.11	3.94

ns, *, **, F tests not significant and significant at 5 and 1%, respectively; for each column and each variable, means with different letters are significantly different at 5% probability by Fisher's test; CV, Coefficient of variation; MSD, Minimum significant difference; OA, Overall Average; SL, Sucker length.

characteristics of pepper plants. In contrast to the present study, characteristics were not affected by these factors. Jovicich et al. (2004) examined the same factors and found that plant height was higher in plants with pruning

Table 3. Mean fruit weight (MFW) (g) and fruit yield per tomato plant (kg plant^{-1}) as a function of pruning of axillary buds and plant density.

Factor	Mean fruit weight (g)	Yield (kg plant^{-1})
Test F		
Pruning of axillary buds (A)	480.85**	96.11**
Distance between plants (B)	3.26 ns	16.17**
Interaction A x B	2.33 ns	2.44 ns
Pruning of axillary buds		
Pruning between 6 to 10 cm SL	220.00^{a}	8.85^{a}
Pruning between 1 to 5 cm SL	126.44^{b}	6.89^{b}
No pruning	90.11^{c}	5.36^{c}
Distance between plants (cm**)**		
60	151.89	7.77^{a}
50	142.11	6.99^{b}
40	142.56	6.34^{b}
MSD	11.15	0.65
OA	145.52	7.03
CV	6.30	7.59

ns, *, **, F tests not significant and significant at 5 and 1%, respectively; for each column and each variable, means with different letters are significantly different at 5% probability by Fisher's test; CV, Coefficient of variation; MSD, Minimum significant difference; OA, Overall Average; SL, Sucker length.

of 2 stems/plant compared to plants with pruning of more than 2 stems/plant. Grijalva et al. (2008) did not observe significant differences for this variable.

Seifi et al. (2012) mentioned that plant height is occasionally greater when planting density increases. However, authors such as Aminifard et al. (2012) obtained opposing results or, just as has been seen in the present study, authors observed no statistical differences between different planting densities (Reséndiz et al., 2010).

In the research conducted by Arebalo et al. (2018) to evaluate the influence of different levels of early pruning on tomato plants, no statistical differences were detected for the variable of the number of fruits per bunch. These results differ from those reported by Sánchez and Ponce (1998) that investigated the density and pruning in tomato, and found significant differences for this determination. These results are similar to those achieved in this investigation, regarding pruning, but not for density.

Polar and equatorial diameters of fruits

Table 2 shows the mean values of the variables analyzed. The data indicate that there were significant differences regarding the pruning of axillary buds; however, no statistical differences were detected for distances between plants.

The highest polar diameter (PD) was recorded in plants with pruning of between 6 to 10 cm SL followed by pruning between 1 to 5 cm SL. The lowest value was found for no pruning. Between the best and worst-performing pruning techniques, there was a mean difference of 16.93 mm; this is a marked difference in fruit size.

The distance between plants did not significantly affect the polar and equatorial diameters of tomato fruits (Table 2). These data are similar to those obtained by Ponce et al. (2012). In contrast, Salguero and Curay (2016) reported that polar and equatorial diameters of tomato fruits were significantly affected by planting density: equatorial diameter of fruits varied between 79.8 and 104.5 mm with an OA of 94.7 cm. Those values were higher than values achieved in the present study probably due to the genetic material used.

Average fruits weight and yield per plant

As can be seen in Table 3, pruning of axillary buds and distance between plants produces significant differences in yield per plant. No significant differences are detected in fruit weight.

The best results for average fruit weight (Table 3) in relation to the pruning of axillary buds were observed for pruning between 6 and 10 cm SL, with 220 g fruit^{-1}. This was statistically superior to pruning axillary buds between 1 to 5 cm (126.44 g fruit^{-1}) and no pruning (90.11 g fruit^{-1}).

A yield of 8.85 kg plant^{-1} was obtained when pruning

axillary buds of 6 to 10 cm SL on average. This was statistically superior to pruning between 1 to 5 cm SL, and to no pruning, with values of 6.89 and 5.36 kg plant^{-1}, respectively. The distance of 60 cm between plants produced the highest value of 7.77 kg plant^{-1}. The data obtained in this work is slightly higher than that reported by Mendoza et al. (2018), who achieved a mean of 6.55 kg plant^{-1}.

For studies of population density and pruning of tomato plants, Machado et al. (2007), Sanchez et al. (2017) and Arébalo et al. (2018), in early pruning works in tomato, reported an increase in the average weight of the fruit with the lowest density. Likewise, Villegas et al. (2004), achieved an increase in fruit yield through the combination of higher population density and pruning pruning; the results of all these works coincide with those of the present investigation.

On the other hand, Sánchez and Ponce (1998) and Sánchez del et al. (2017) working with different levels of pruning and planting densities in tomato and Carrillo et al. (2003), investigating with different densities, found no significant effects for performance, in contrast to those found in this investigation.

Conclusions

The factor of pruning axillary buds proved to have a significant influence on tomato production: there was a notable difference observed in plants that were pruned for all determinations carried out. Pruning between 6 to 10 cm SL led to better performance, allowing for the assumption that pruning suckers within this length range is a good management alternative for tomato crops.

With regards to the factor of the distance between plants, a lower population density (60 cm apart) apparently contributed to more productive plants.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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