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Tomato cultivation under different spacing and different levels of defoliation of basal leaves

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Abstract

This work aimed to study the influence of plant spacing and level of basal leaf defoliation on yield traits of tomato. The experimental design was a randomized complete block design in a 2x4 factorial arrangement with five replications. We evaluated two spacings (0.30 and 0.50 m) and four levels of defoliation (0, 50% and 100% of basal leaves removed after fruiting the first cluster and 100% of basal leaves removed after harvest of the first cluster). We evaluated the number of normal, defective and total fruit per cluster, mass of normal, defective and total fruit per cluster, longitudinal and transverse diameter of normal fruit; and yield of normal and total fruit per cluster. Removing the basal leaves is favorable for production, when there is a higher plant density, and must be performed before the fruiting of the first cluster. For more widely spaced plants, basal leaves influenced the productive characteristics, and it is not favorable their removal during the formation of the first cluster, but rather after its harvest. Defoliation can be used to increase aeration, improving the use of solar radiation and reducing pest problems.

Key words: *Solanum lycopersicum* L., planting density, basal defoliation, crop management, leaf removal.

Cultivo do tomateiro sob diferentes espaçamentos entre plantas e diferentes níveis de desfolha das folhas basais

Resumo

Este trabalho teve como objetivo estudar a influência do espaçamento entre plantas e o nível de desfolha das folhas baixeiras nas características produtivas de tomate. O delineamento experimental utilizado foi de blocos casualizados, em esquema fatorial de 2x4, com cinco repetições. Foram avaliados dois espaçamentos entre plantas (0,30 e 0,50 m) e quatro níveis de desfolhas (0, 50% e 100% das folhas baixeiras, retiradas após a frutificação do primeiro cacho e 100% das folhas baixeiras, retiradas após a colheita do primeiro cacho). Foi avaliado o número de frutos normais, com defeito e total por cacho; massa dos frutos normais, com defeito e total por cacho; diâmetro longitudinal e transversal dos frutos normais; e a produtividade de frutos normais e total por cacho. A remoção das folhas baixeiras é favorável para as características produtivas, quando há uma maior densidade de plantas, e deve ser realizada antes da formação dos frutos do primeiro cacho. Para plantas mais espaçadas as folhas baixeiras exercem influência nessas características, não sendo favorável sua remoção durante a formação do primeiro cacho, mas sim após a colheita deste. A desfolha é uma prática que pode ser utilizada visando aumentar a aeração, melhorar o aproveitamento da radiação solar e diminuir problemas fitossanitários.

Palavras-chave: *Solanum lycopersicum L.,* densidade de plantio, desfolha basal, manejo da cultura, retirada de folhas.

1. INTRODUCTION

The importance of vegetables in the human diet is because they are not only a source of carbohydrates and protein, but also an excellent source of vitamin and mineral. Tomato (*Solanum lycopersicum* L.) is the main vegetable crop in terms of volume consumed fresh worldwide, one of the major sources of natural lycopene, an important antioxidant and anticancer compound, and acids (acetic, lactic and malic acids), vitamin C and traces of potassium, phosphorus and iron (Monteiro et al., 2008).

In the segment of table tomato, fruit quality and off season supply are factors that can ensure the production success (Guimarães et al., 2007). An option to improve the quality and appearance of the tomato is the adoption of appropriate crop management techniques (Marim et al., 2005).

The cultivation in protected environment provides an increased yield as well as better quality products (Carvalho and Tessaroli Neto, 2005). This type of cultivation allows to minimize the effects of seasonality of production, besides allowing partial control of factors responsible for the growth and development of plants (Darezzo et al., 2004).

This type of cultivation must use most of available area, due to high costs of the infrastructure and the high level of technology applied. One way to increase the use of the cultivation area is increasing planting density. According to Resende and Costa (2003), with an increased plant density per unit area, plants compete for essential growth factors such as nutrients, light and water, with direct influence on yield and fruit quality.

The effect of plant spacing can be verified in terms of exposure to light; with narrower plant spacing there is greater overlap and shading of leaves, reduced penetration of solar radiation to basal leaves and hence higher competition for light, reducing photosynthetic efficiency of the plant. The competition for light promotes increased energy expenditure in processes of cell growth and reduced translocation of sugars for fruit (Mueller and Wamser, 2009).

Crop management is very important for yield gains and high fruit quality, always seeking to reduce production costs. In this context, along with the vertical staking, a recommended cultural practice for cultivation in protected environment is the removal of basal leaves to improve the use of sunlight, increase aeration between plants, and consequently decrease incidence and transmission of diseases and pests (Alvarenga, 2004). In contact with the ground, these leaves tend to be gateway for pathogens, and form a favorable humid environment for their development.

In accordance with Silva et al. (2011), the upper third of tomato plants, despite having only 23% of the total leaf area of the plant, intercepts 73% of the total solar radiation and is responsible for 66% of the production of photoassimilates. Thus, basal leaves are not very important for the net photosynthesis of plants, and its contribution to photosynthesis gradually decreases as the tomato leaf gets older (Silva et al., 2011).

Studies on tomato yield with respect to the relationship between removal of basal leaves and planting density are scarce. Therefore, this study aimed to determine the level of defoliation associated with the planting density that does not damage the production of tomato fruit.

2. MATERIAL AND METHODS

The experiment was conducted in a protected environment at the Center for Biological Control and Protected Cultivation, State University of West Paraná (UNIOESTE) in the municipality of Marechal Cândido Rondon (Paraná State).

The culture was installed under galvanized iron structure in arch format with 7x30 m and 3.5 m in height. The ceiling was covered with low density polyethylene (LDPE) and anti-UV 150 μ thick. The sides were closed with 30% black shading screen.

The experimental design was a randomized complete block design in a 2x4 factorial arrangement with five replications. The first factor consisted of two spacings between rows and the second, of four defoliation systems. The spacings used were 0.30 and 0.50 m between plants and 1 m between rows. The defoliation treatments were performed by removal of 0%, 50% and 100% of basal leaves after fruiting the first cluster (early fruit formation), and removal of 100% of basal leaves after harvesting the first cluster, accounting for a total of three and seven leaves in the 50% and 100% removal treatments, respectively. Basal leaves were all those below the first cluster.

Leaves were removed with garden shears, and disinfected with 10% sodium hypochlorite solution. On the injuries we applied a layer of cupric paste to prevent the entry of pathogens.

The genetic material used was the hybrid Andrea, Italian cultivar, with long structural life. Seedlings were grown in polystyrene trays of 128 cells containing commercial substrate. Plots consisted of seven plants, the five central plants were evaluated.

Planting fertilization was held according to soil analysis. The chemical analysis of soil resulted in: pH = 4.85; Al^{3+} = 0.0; K = 0.48; Ca^{2+} = 9.03 and Mg^{2+} = 1.28 in cmol dm^{-3}; P = 305.50 mg dm^{-3}. Topdressing by fertigation was performed three times a week, according to Trani et al. (2004). Drip irrigation was used with emitters at 1.3 L h^{-1}, at each planting line, and the amount of water applied varied depending on the weather conditions and the crop stage.

After transplanting, when the plants were 10-15 cm tall, they were vertically staked with narrow ribbon and conducted in single stem, removing the lateral branches. Apical bud pruning was performed above the third leaf emerged after the sixth cluster.

Weed control was done manually when needed and pest management, especially tomato leafminer (*Tuta absoluta*), was carried out preventively through the weekly release of *Thrichograma galloi*. The preventive disease management was done by weekly application of Bordeaux mixture (2.5 g L^{-1}).

Fruit were harvested when in uniform maturity stage (completely red) and classified according to the Classification Standards of CEAGESP (2000), into normal and defective fruit.

The number of normal and defective fruit, total mass of normal and defective fruit, average weight of normal fruit, longitudinal and transverse diameter of normal fruit, total fruit yield and normal fruit yield were analyzed, these last two variables were assessed per cluster and per plant.

Data were subjected to analysis of variance and means were compared by Tukey's test at 5% significance, using the Genes software (Cruz, 2013).

3. RESULTS AND DISCUSSION

Interaction occurred between spacing, level of defoliation and cluster for total fruit mass and normal fruit mass (Table 1), and total fruit yield per cluster and normal fruit yield per cluster (Table 2).

For 0.30 m plant spacing, the defoliation treatments, regardless of the level, when performed before harvesting the first cluster (B and C) showed higher total fruit and normal fruit mass, but not different from the treatment without defoliation. For 0.50 m spacing, treatments of defoliation after harvesting the first cluster (D) and without defoliation (A) were more satisfactory, since the total fruit mass and the normal fruit mass were greater. This result reinforces the hypothesis that basal leaves, under higher competition between plants for light, can act as a sink of photoassimilates. It is noteworthy that the total fruit mass per cluster also includes defective fruit. However, the largest mass in this case was achieved with unmarketable fruits, which is not of economic interest.

Still in Table 1, the first clusters showed greater total fruit mass and normal fruit mass when basal leaves were removed before harvesting the first cluster (treatment B and C) in the 0.30 m plant spacing. In the 0.50 spacing, although not statistically different, there was a reduction in the total fruit mass of the first clusters compared with subsequent clusters. Only in the last cluster, there was an increase in total fruit mass, which is probably due to an increased number of fruit in these final clusters (Table 1). According to Streck et al. (1998), the potential size of tomato fruit depends on their position in the inflorescence and the cultivar, but the size they reach also depends on the total of assimilates produced by photosynthetic tissues and the number of fruit that compete for these assimilates.

Considering plant spacing, 0.50 m between plants resulted in greater increases in both total fruit mass and normal fruit mass. Plant density management influences the balance between vegetative and reproductive growth of the tomato plant, as it affects the penetration of solar radiation inside the canopy and thus photosynthesis. Changes in the

Table 1. Total fruit mass (TFM) and normal fruit mass (NFM) according to plant spacing (SPAC), defoliation level (DEFL) and cluster

SPAC	DEFL	TFM -----g----- Cluster					
		1st	2nd	3rd	4th	5th	6th
0.30	A	544.9 abAβ	475.0 aAα	284.6 aAβ	295.7 aAβ	254.3 aAβ	291.1 aAα
	B	769.4 aAα	460.6 aBα	360.0 aBα	400.4 aBα	392.5 aBα	329.3 aBα
	C	595.5 abAα	598.7 aAα	342.9 aABα	276.2 aBα	317.2 aABα	428.6 aABα
	D	376.7 bAβ	418.2 aAβ	322.6 aAβ	331.2 aAα	367.5 aAα	393.6 aAα
SPAC	DEFL	Cluster					
		1st	2nd	3rd	4th	5th	6th
0.50	A	809.8 abAα	654.1 aABα	530.4 aABα	688.5 aABα	539.3 aABα	449.7 aBα
	B	731.3 bAα	542.4 aABα	397.7 aBα	330.6 bBα	419.8 aBα	450.8 aABα
	C	738.7 bAα	508.1 aABα	357.8 aBα	416.0 bBα	478.6 aABα	370.1 aBα
	D	1020.6 aAα	773.5 aABα	551.4 aBCα	366.2 bCα	491.4 aBCα	582.7 aBCα
CV (%)		34.57					
SPAC	DEFL	NFM -----g----- Cluster					
		1st	2nd	3rd	4th	5th	6th
0.30	A	510.2 abAβ*	390.9 baAβ	262.4 aABα	215.0 aBβ	170.2 aBβ	174.0 aBα
	B	765.0 aAα	433.4 aBα	346.4 aBα	340.4 aBα	303.7 aBα	223.0 aBα
	C	590.3 aAα	588.8 aAα	317.7 aABα	221.3 aBα	225.2 aBα	314.8 aABα
	D	357.8 bAβ	398.1 aAβ	284.3 aAβ	264.1 aAα	273.8 aAα	306.9 aAα
SPAC	DEFL	Cluster					
		1st	2nd	3rd	4th	5th	6th
0.50	A	783.1 abAα	630.2 aABα	440.9 aBCα	586.6 aABCα	405.3 aBCα	311.4 aCα
	B	718.5 bAα	519.0 aABα	372.3 aBCα	248.2 bBCα	258.2 aBCα	234.6 aCα
	C	731.9 bAα	484.2 aABα	327.8 aBα	348.1 abBα	386.3 aBα	255.9 aBα
	D	987.3 aAα	719.2 aABα	504.6 aBCα	244.8 bCα	354.9 aCα	398.8 aCα
CV (%)		38.59					

*Similar lowercase letters are not significantly different as to the level of defoliation, similar uppercase letter are not significantly different as to cluster, similar Greek letters are not significantly different as to plant spacing, by Tukey's test (p>0.05); SPAC – spacing of 0.30 and 0.50 m between plants and 1.0 m between rows; DEFL – level of defoliation of basal leaves, where A – no defoliation (0%); B – removal of 50% of basal leaves before the formation of the first cluster; C – removal of 100% of basal leaves before the formation of the first cluster; D – removal of 100% of basal leaves after harvesting the first cluster.

Table 2. Total fruit yield (PFT) and normal fruit yield per cluster (NFYC) according to plant spacing, defoliation level and cluster

SPAC	DEFL	TFY ----- t ha^{-1} ----- Cluster 1st	2nd	3rd	4th	5th	6th
0.30	A	15.14 bcAα	13.19 aABα	7.91 aBα	7.07 aBα	7.06 aBα	8.08 aBα
	B	21.37 aAα	12.76 aBα	10.00 aBα	10.91 aBα	10.91 aBα	9.15 aBα
	C	16.54 abAα	16.63 aAα	9.53 aBα	8.81 aBα	8.81 aBα	11.91 aABα
	D	10.46 cAβ	11.62 aAα	9.20 aAα	10.21 aAα	10.21 aAα	10.94 aAα
SPAC	**DEFL**	**Cluster 1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
0.50	A	13.50 aAα	10.90 aAα	8.84 aAα	11.48 aAα	8.99 aAα	7.50 aAα
	B	12.19 aAβ	9.04 aABα	6.63 aABα	5.51 bBβ	6.99 aABα	7.51 aABα
	C	12.31 aAα	8.47 aABβ	5.96 aBα	6.93 abABα	7.98 aABα	6.17 aABβ
	D	17.01 aAα	12.89 aABα	9.20 aBCα	6.10 abCα	8.19 aBCα	9.71 aBCα
CV (%)				**34.11**			
SPAC	**DEFL**	**NFYC ------ t ha^{-1} ------ Cluster 1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
0.30	A	14.17 bcAα	10.86 bABα	7.29 aBCα	5.97 aBCα	4.73 aCα	4.83 aCα
	B	21.25 aAα	12.04 abBα	9.62 aBα	9.46 aBα	8.44 aBα	6.19 aBα
	C	16.39 abAα	16.36 aAα	8.83 aBα	6.15 aBα	6.25 aBα	8.78 aBα
	D	9.94 cAβ	11.06 abAα	7.89 aAα	7.34 aAα	7.61 aAα	8.53 aAα
SPAC	**DEFL**	**Cluster 1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
0.50	A	13.05 aAα	10.51 aABα	7.35 aABα	9.78 aABα	6.76 aBα	5.19 aBα
	B	11.98 aAβ	8.65 aABα	6.21 aABα	4.14 bBβ	4.31 aBβ	3.91 aBα
	C	12.20 aAβ	8.07 aABβ	5.47 aBα	5.80 abBα	6.44 aABα	4.27 aBβ
	D	16.46 aAα	11.99 aABα	8.41 aBCα	4.08 bCα	5.92 aCα	6.65 aBCα
CV (%)				**37.53**			

*Similar lowercase letters are not significantly different as to the level of defoliation, similar uppercase letter are not significantly different as to cluster, similar Greek letters are not significantly different as to plant spacing, by Tukey's test (p>0.05); SPAC – spacing of 0.30 and 0.50 m between plants and 1.0 m between rows; DEFL – level of defoliation of basal leaves, where A – no defoliation (0%); B – removal of 50% of basal leaves before the formation of the first cluster; C – removal of 100% of basal leaves before the formation of the first cluster; D – removal of 100% of basal leaves after harvesting the first cluster.

power of the sources, through a change in planting density or increasing the availability of radiation, indirectly affect the distribution of dry matter between plant organs (Duarte and Peil, 2010).

According to Larcher (2000), the total of assimilates of a plant is directly proportional to photosynthesis, which is a function of the flux density of solar radiation, the atmospheric CO_2 concentration and leaf area. In this sense, increasing density causes a reduction in leaf area per plant and increased shading, and it is expected that the fresh fruit mass decreases with increasing plant density, which is observed in table 1.

With the increase in leaf area index, there is a greater availability of photosynthetically active area, an increased production rate correspondingly may occur (Larcher, 2000). However, when the plants are too close, there is an intense self-shading on the surfaces of assimilation and the radiation that passes through the foliage is no longer sufficient to maintain a positive carbon balance.

The values of total fruit mass (Table 1) indicate that the mass of clusters located at the top of the canopy was not affected, while the total fruit mass in the first cluster was directly influenced by plant spacing. It is observed the effect of increased spacing on the incidence of solar radiation only in the initial clusters, with no effect on the clusters located at the upper portion of the plant. The small difference observed for total fruit mass between clusters at the top of the plant and the first cluster demonstrates the benefits of vertical staking of plants, especially in relation to the better distribution of solar radiation over the canopy of the plants.

Our results are consistent with Wamser et al. (2007) who assumed that the penetration of solar radiation in the canopy of plants and, hence, their photosynthetic activity are relatively unaffected by reduced spacing, also contributing to a satisfactory amount of photoassimilates to the fruit growth. Larcher (2000) emphasized that the production of the plant is greater as the greater the amount of radiation intercepted and absorbed by assimilating surfaces.

In general, yield was higher in the narrower spacing. Mueller and Wamser (2009) reported that tomato yield per area increases with narrower spacing, up to a certain value, while the production per plant, number of fruit per plant and average fruit mass decrease.

Table 2 demonstrates that in the 0.30 m plant spacing, for most of the clusters, normal fruit yield was higher in treatments subjected to defoliation. This reinforces the argument that the leaves, at this time of the cycle, have no effect of source, but rather, sink. Radin et al. (2003) noted that all defoliation treatments led to an increase in the final yield of tomato crop of indeterminate growth habit.

On the other hand, the same result is not true for the 0.50 m plant spacing. In this treatment, basal leaves seem to have an influence until the fourth cluster, losing its power of source for the upper clusters. This is because these leaves are still photosynthetically active in this spacing, contributing to the fruit size, and hence to the yield.

For Kinet and Peet (2002), yield is positively related to the amount of solar radiation received by the tomato plant throughout its cycle. Furthermore, the shading reduces the fruit size. For these authors, greater fruit mass were obtained when light was applied at initial fruit formation until the onset of ripening, which is the period of rapid fruit growth. This is observed in table 2, where the wider spacing between plants, in which the light is better distributed throughout the crop canopy, showed higher yield increase.

The total fruit yield and normal fruit yield were also influenced by spacing, levels of defoliation and clusters. For both yield variables, the highest values were found in the narrower spacing (Table 2). These results agree with those obtained by several authors (Machado et al., 2007; Streck et al., 1998). The competition between plants at higher density seems to be compensated by the greater number of plants per area.

In the 0.30 m plant spacing, the total yield was not influenced by basal leaf removal. Instead, higher yields were obtained in the first cluster when removing basal leaves during the formation of the first cluster, regardless of the level (50% or 100%).

At the 0.50 m plant spacing, the removal of basal leaves before the formation of the first cluster provided a lower total yield, although not significantly different from the other treatments. This corroborates Peluzio et al. (1999), which reported that basal leaves tend to be important in the formation of the first cluster, and their removal can affect the final yield of the plant.

The yield of normal fruit had basically the same behavior of the total fruit yield. The largest difference was observed in the second cluster, in the narrower spacing (0.30 m). Under these conditions, the total fruit yield was not affected by defoliation treatments, although the yield of normal fruit was higher in treatments with defoliation, regardless of the level. This indicates that under these conditions, although without influence on the total yield, the defoliation treatments provided greater yield of marketable fruit that will effectively generate economic return to the farmer.

In general, in the initial clusters, mainly in the first one, there was an increase in yield, when removing the leaves, regardless of the level, before the formation of the first cluster. These leaves did not contribute photosynthetically to increases in yield when shaded.

We found an interaction between defoliation systems and plant spacing, in which the plants were arranged for transverse and longitudinal diameter of fruit, normal fruit average mass, number of normal fruit and total number of fruit (Table 3).

For the transverse diameter of fruit, there was no difference between the levels of defoliation in the 0.30 m spacing. However, at 0.50 m spacing, treatments with defoliation, regardless of the level, showed higher values than in the treatment without removal of basal leaves, although the treatments of partial defoliation and complete defoliation before harvesting the first cluster (B and C) were not different from the treatment without defoliation.

When comparing the spacings within the defoliation treatments, we registered in the treatment with removal of

Table 3. Normal fruit transverse diameter (NTD), Normal fruit longitudinal diameter (NLD), normal fruit average mass (NFAM), normal fruit number (NFN) and total fruit number (TFN) per cluster according to plant spacing and defoliation level of basal leaves

DEFL	NTD		NLD		NFAM		NFN		TFN	
	------------mm------------				----------g----------					
	Spacing									
	0.30	0.50	0.30	0.50	0.30	0.50	0.30	0.50	0.30	0.50
A	45.0 aA	44.1 bA	54.8 aA	52.0 abA	61.5 abA	62.3 abA	4.64 bB	8.24 aA	7.35 aB	11.18 aA
B	44.9 aA	44.3 abA	54.4 aA	51.4 bA	64.3 aA	58.7 aB	6.29 aA	6.66 bA	8.37 aB	9.94 abA
C	44.5 aA	44.6 abA	52.5 abA	51.7 abA	58.9 abA	57.4 bA	6.36 aA	7.26 abA	8.42 aA	9.38 bA
D	43.5 aB	46.5 aA	49.0 bB	55.9 aA	50.2 bB	71.5 aA	6.15 aB	7.39 abA	8.92 aB	10.31 abA
CV (%)	7.48		12.63		29.90		30.69		26.72	

*Mean values followed by the same lowercase letter are not significantly different as to the level of defoliation and mean values followed by the same uppercase letter are not significantly different as to plant spacing, by Tukey's test (p>0.05); DEFL – level of defoliation, where A – no defoliation (0%); B – removal of 50% of basal leaves before the formation of the first cluster; C – removal of 100% of basal leaves before the formation of the first cluster; D – removal of 100% of basal leaves after harvesting the first cluster.

basal leaves after harvesting the first cluster (D) fruit with larger transverse diameter in the 0.50 m plant spacing. The same was observed for longitudinal fruit diameter. At higher densities, plants compete more for light and direct a greater expenditure of energy to the processes of cell growth and reduced translocation of sugars to fruit, resulting in a decrease in fruit diameter (Carvalho e Tessarioli Neto, 2005).

The longitudinal fruit diameter, under narrower plant spacing (0.30 m), was larger in treatments without defoliation and with 50% and 100% defoliation before harvesting the first cluster, although the latter was not different from treatment where defoliation was performed after the harvest of the first cluster. For wider spacing, treatments of total defoliation before and after harvesting the first cluster and the treatment without defoliation provided larger diameter.

This demonstrates that under higher density, competition for photoassimilates begins early in the development of plant and fruit. According to Larcher (2000), a closed vegetation cover works as an assimilation system, in which the leaf layers are overlapped and mutually shaded. At each depth of the vegetation cover, the radiation penetrating is intercepted and gradually used, being almost completely absorbed on the ground surface.

Moreover, the average mass of normal fruit was influenced by the defoliation. The treatment without defoliation (A) and with partial defoliation (B) had the highest average masses for normal fruit when under 0.30 m plant spacing (Table 3). Similar results were reported by Marcano (1996) who examined the effect of levels of defoliation on the number and weight of tomato fruit of determinate growth habit, noting that these variables were affected by the time when defoliation occurred and by its level.

For the 0.50 m spacing between plants, the treatment without defoliation (A) and treatment with defoliation after harvesting the first cluster (D) stood out as to the average mass of normal fruit. This result is in line with that obtained by Marcano (1996) that studied salad type tomato and verified lowest level of defoliation causing greater average fruit mass. For total defoliation after harvesting the first cluster (D), the leaves represented source for that cluster, while the plant did not self-shaded. From the moment in which the upper part of the plant shaded basal leaves, their removal is favorable, providing a mass 15% higher than without leaf removal.

There was a significant reduction in the number of normal fruit and total number of fruit per plant with reduced plant spacing from 0.50 m to 0.30 m, for most of defoliation treatments. This decrease in the production of individual plants at larger populations is attributed to the distribution of assimilates, which is modified as a response to the existing competition (Machado et al., 2007).

As to defoliation levels in the spacing of 0.30 m, it was favorable for the number of normal fruit, regardless of the level and time. For the 0.50 m plant spacing, defoliation was not favorable, demonstrating that these basal leaves still have some influence when not shaded. This same result was obtained for the total number of fruit under these same conditions. For the spacing of 0.30 m between plants, no significant difference was detected between the levels of defoliation for this variable.

Also, there was no interaction between clusters and other treatments for the transverse and longitudinal diameter of normal fruit, average mass of normal fruit, defective fruit mass, number of defective fruit and number of normal fruit; thus this factor was analyzed separately (Table 4).

The fruit transverse diameter decreased in accordance with the position of the cluster on the plant, that is, fruit of the first clusters showed larger transverse diameter than those of from the third cluster.

In relation to the longitudinal diameter, a direct relationship between the diameter value and the position of the cluster on the plant was observed. According to Bertin (1995), this is due to the greater number of defective fruit in the upper clusters, directly affecting their development and fruit do not show a uniform growth among different clusters. Table 4 shows a decrease in the number of normal

Table 4. Normal fruit transverse diameter (NTD), Normal fruit longitudinal diameter (NLD), normal fruit average mass (NFAM), defective fruit mass (DFM) and defective fruit number (DFN) and normal fruit number (NFN) according to cluster

Cluster	NTD	NLD	NFAM	DFM	DFN	NFN
	-----------mm-----------		------------g------------			
1st	47.8 a	55.7 ab	81.9 a	17.8 d	0.82 c	8.21 a
2nd	46.3 ab	52.1 bcd	70.4 a	33.3 d	1.23 c	7.41 a
3rd	44.2 bc	48.6 d	48. 3 b	36.4 cd	1.51 bc	7.59 a
4th	43.5 c	50.2 cd	52.9 b	79.5 bc	2.90 b	5.97 b
5th	43.4 c	53.0 abc	52.1 b	110.3 ab	4.49 a	5.87 b
6th	42.9 c	56.7 a	58.1 b	134.5 a	5.19 a	4.71 b
CV (%)	**7.47**	**12.63**	**29.90**	**78.37**	**66.86**	**30.69**

*Means followed by the same letter in the column are not significantly different by Tukey's test (p>0.05). Cluster follows the order of emission in the plant, in which 1st is the first cluster to appear and 6th is the last cluster.

fruit according to the elevation in the cluster position in the plant. The results clearly show that the sink power of the fruit depends on the position of the cluster on the plant. This result is similar to that presented by Bertin (1995), which emphasizes that a greater number of defective fruit is present on the upper clusters.

Defective fruit mass was higher in clusters located at the top of the plant, being highest in the cluster 6 and lowest in the cluster 1 These data can be compared to the number of defective fruit; this number was higher for the cluster 6 and lower for the cluster 1, maintaining a trend of increase in the number of defective fruit the later the cluster is formed.

Higher values of average mass of normal fruit were obtained for the first clusters, decreasing as new clusters appear in the plant. According to Bertin (1995), initial clusters do not compete for photoassimilates as clusters formed later compete. In initially formed fruit, there is no decrease in the supply of assimilates, as they are the only sink to be supplied. There is a reduction in the supply of assimilates with increasing in number of fruits, so that there is a smaller contribution to the mass of fruit in the upper clusters.

4. CONCLUSION

The 0.30 m plant spacing is the most adequate for the production characteristics of tomato, when basal leaves are removed.

The removal of basal leaves is favorable for production traits, when there is higher plant density, and should be performed before the formation of the first clusters. For more widely spaced plants, basal leaves influence these characteristics, and their removal is not recommended during the formation of the first cluster, but after its harvest.

Defoliation can be used to increase aeration in the crop canopy without damaging the production of tomato plants in protected environments and can bring advantages as to the increased use of sunlight and lower incidence of disease.

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