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INFLUENCE OF PLANT MANAGEMENT SYSTEMS ON GROWTH AND FRUCTIFICATION OF TOMATO PLANTS IN PROTECTED CULTURE

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Abstract

Tomatoes have a high capacity to form shoots on the stem which is why plants can be managed with multiple stems, thus influencing the increase in production and decrease in the number of plants per hectare. Research was conducted in the teaching field of the Faculty of Horticulture in Bucharest, within a prolonged cycle in solarium, during 2016-2017. Two varieties were used, Belmonte and Canestrino, and two hybrids, Cinto F1 and Clarabella F1, managed with one and a double stem. Stem management was performed through eliminating the portion of the plant from above the cotyledonal leaves, during the seedling phase, after the formation of the first pair of leaves, the percentage of stem formation being over 90 %. The planting was made at a distance of 0.8 m/0.4 m for the plants with one stem, resulting in 3.1 plants/m^2, and at 1 m/0.4 m for the plants with a double stem, resulting in 2.5 plants/m^2. The reduction in the number of plants was of 20% for the ones with double stem. The largest production of fruit per plant was obtained for the tomatoes with a double stem: 7.2 kg for the Belmonte variety and 7.2 kg for Canestrino, 6.9 kg for the hybrid Clarabella F1 and 6.4 kg for Cinto F1. The plants with one stem recorded a production of 2.6-2.9 kg/plant. The production per square meter was directly influenced by the production obtained per plant; thus, the plants with double stem recorded values of 16-18 kg, while the tomatoes with one stem produced 8.06-8.70 kg.

Key words: *double stems, pinching off, production, seedling.*

INTRODUCTION

Tomatoes (*Lycopersicon esculentum* Mill) have their origins in South America and, compared to other vegetable species, have the largest cultivation area in the world, being very appreciated by consumers. The fruits are rich in vitamins, minerals, amino acids and pigments (Dinu et al., 2017; Soare et al., 2015) and poor in calories, being considered very healthy for the human body. The biochemical composition of the tomato fruit is influenced, amongst other factors, by the position of the fruit within the inflorescence. The fruit in the middle has the highest content of polyphenols. The sugar content increases simultaneously for the fruits ranging from the base to the top of the inflorescence while fruit size decreases (Coyago-Cruz, 2017). Researches performed on tomatoes are diverse and attention is currently on improving the culture technology. From a biological point of view, tomatoes are herbaceous annual plants, with a very good capacity to form shoots, which has led to numerous researches regarding the increase of the production per plant and per unit of area, without affecting the production quality. In a culture tomatoes are usually managed with one stem; however numerous researches have been performed in which plants have been managed with 2, 3 and 4 stems, using only cultivars with undetermined growth. Obtaining several stems can be achieved through pinching off the plant above the cotyledonal leaves (Hoza and Stanciu, 2012; Mouaro et al., 2014), pinching off above the first pair of real leaves (Mouaro et al., 2014), pinching off above the second inflorescence (Franco et al., 2009) or through removing the growth peak of the seedling at planting and using the first 2 shoots at the base

of the plant (Hoza et al., 2011; Hoza, 2013). The research conducted by Mouaro et al. (2014) proved that plants managed with 2 stems generate larger productions (26.5 kg m^{-2}) compared to plants managed with 3 and 4 stems, for which the production was smaller (19.5 kg m^{-2}). Comparing the production for the double stem of the same plant, the differences were not significant. According to Rahmatian et al., 2014, grafted tomatoes managed with 2 stems in a hydroponic system formed more fruits per plant (46.04) than the ones with only one stem (27.43); the production per plant was larger (4.45 kg) compared to plants with one stem (3 kg), the fruits were firmer and of a higher quality, but the average fruit weight was lower by 12 %. In addition, grafted plants with a double stem accumulated a larger quantity of dry substance in various plant organs. Tomatoes with 2 and 3 stems formed from shoots led to an increase in the number of fruits (Hoza and Stanciu, 2012) and in the commercial production compared to plants with one stem. However their fruits were slightly smaller and the plants did not registered significant differences regarding quality and number of stems; plants conducted with 3 stems also extend the harvesting period (Mbonihankuye et al., 2013). For cherry tomatoes, plant management with 2 stems is a current practice in southern Spain, stem planning being made after the second inflorescence forms. According to Franco et al., 2009, for cherry tomatoes cultivated in greenhouse, managed with 2 stems on which are kept 2 side-shoots with 2 inflorescences on each, the production and number of fruits increase per unit of area, without significantly affecting the average fruit weight. By analyzing the correlation between the number of stems and the tomato production, it has been observed that plants managed with 2 stems have had a higher production and number of fruits, but the average fruit weight and the commercial production have been slightly lower for the plants with 2 stems compared to the ones with on stem (Ece and Darakci, 2007). Plant management with more stems in association with different doses of nitrogen demonstrated that the largest production has been registered at plants with 2 stems and 256 kg N ha^{-1} (Hossain, 2007).

MATERIALS AND METHODS

The experiment was conducted in the teaching field of the Faculty of Horticulture Bucharest, in solarium, during 2016-2017. The main purpose of the experiment was to determine the influence of the number of stems and of the cultivar on plant growth and fructification, in the climatic conditions of the reference area, and the introduction of this particular plant management system into the tomato culture management. Two varieties were used, Canestrino and Belmonte, highly perishable, with superior characteristics regarding the taste and large fruits and two F1 hybrids, Clarabella and Cinto, very productive, with large, uniform, firm fruits with high resistance to various pathogens. Plants were managed with one and a double stem and 6 inflorescences were kept on each stem. Double stems were obtained through eliminating the portion of the plant from above the cotyledonal leaves when the tomato seedlings formed the first pair of real leaves. The buds at the base of the cotyledons formed 2 shoots that later became double stems. Specific maintenance works were applied for the tomato seedlings up to the planting moment.

Field preparation was made through soil loosening and crumbling works and fertilization with Orgevit 2 t/ha incorporated into the soil before planting.

The culture was established with seedling produced in warm greenhouse, of 55 days of age. During seedling production period, plants managed with one stem were kept in colder spaces (16-18°C) compared to the ones with a double stem, in order to reduce the growth difference and to ensure the planting could be made at the same time. This aspect is aimed be a subject to further research themes. Planting was made during the first decade of April for both experimental years, at a distance of 0.8 m/0.4 m for plants with one stem, resulting in 3.1 pl./mp, and at a distance of 1 m/0.4 m for plants with a double stem, resulting in 2.5 pl./mp and a reduction in the number of plants of 20%. Plants with a double stem were led as a V-shape towards the spaces between rows in order to allow light to penetrate through more efficiently. During the vegetation period, all lateral shoots were eliminated, plants were supported on

strings and optimal growth conditions were ensured: temperature, humidity and light according to the phenophase requirements. Phased foliar fertilizations were applied to ensure the nutrition necessary for the optimal growth and fructification of the tomato plants using: Codicevo at planting and Energevo at fruit formation. During growth and fruit maturation Finalevo and Rezistevo were applied. Fertilizer composition was as follows:

- Codicevo 19:19:19+ME 0.2%, with a content of NPK of 19:19:19, S 1.4%, MgO 1.8%, B 0.1%, Fe 0.07%, Mn 0.03%, Zn 0.03%, Cu 0.006% and Mo 0.002%, that favors a rapid and improved absorption of the soil nutrients;
- Energevo 9:53:9 0.2 %, with a content of N 9%, P_2O_5 53%, K_2O 9%, MgO 2.5%, Fe 0.1%, S 1.0%, B 0.1%, Mn 0.05%, Zn 0.1%, Cu 0.05% and Mo 0.005%, that increases plant resistance to various stress factors and accelerates the ongoing of vegetation phases;
- Finalevo 5:14:42 0.3 %, that contains N 5%, P_2O_5 14%, K_2O 42%, MgO 2.5%, S 6%, B 0.1%, Fe 0.1%, Mn 0.05%, Zn 0.1%, Cu 0.05% and Mo 0.005%, and improves the quantity and quality of the harvest;
- Rezistevo 0.3 %, that has N 14%, CaO 18%, K_2O 1.7%, MgO 4.2%, Mn 0.05%, B 0.2%, Zn 0.01% and Mo 0.005%, applied at an interval of 15 days to diminish the effects of calcium deficit and increase the fruit resistance to cracking, transport and storage.

The experiment was bifactorial, organized in random blocks, with three repetitions. The following elements were used: four cultivars with large fruits and undetermined growth and two plant management systems - S1 with one stem and S2 with a double stem.

Measurements were made on five plants from each repetition, selected at the beginning of the experiment; average fruit weight was determined through harvesting fruit per variant, counting and weighting the fruits at each harvest and calculating the average weight.

Measurements were made also regarding plant growth, determined by the height at the end of the vegetation period, distance from the soil for the first inflorescence and average distance between inflorescences. During the fructification period, the number of fruits per plant, number of fruits per square meter, average fruit weight and the production per plant and per square meter were measured, according to the type of cultivar and plant management system used. The primary data was processed statistically by the variant analysis method.

RESULTS AND DISCUSSIONS

Regarding the vegetative growth of the tomato plants it was observed that between the plants with one stem and the ones with a double stem small differences were recorded, but the cultivar had a stronger influence on some indicators (Table 1). Regarding the distance from the soil for the first inflorescence, it had higher values for the varieties Camestrino and Belmonte, compared to the F1 hybrids Clarabella and Cinto. The average distance between inflorescences was slightly larger for the plants with two stems, except for the variety Canestrino, for which the average distance between inflorescences was smaller for the plants with double stem. Average plant height was smaller for the varieties Canestrino and Belmonte with a double stem, while Clarabella and Cinto had lower values for the plants with one stem; on average, plants with double stems slightly surpassed the average height of the ones with just one.

Table 1. Synthesis of the results regarding the growth of tomato plants with one and a double stem

Cultivar	Plant management system	Distance from soil for first inflorescence (cm)	Average distance between inflorescences (cm)	Plant height (cm)
Canestrino	S1	36.2	36.9	221.4
	S2	35.7	35.3	214.1
Belmonte	S1	32.6	26.5	175.0
	S2	34.2	28.9	173.6
Clarabella F1	S1	24.4	31.5	187.2
	S2	24.9	33.5	192.5
Cinto F1	S1	23.6	31.2	185.8
	S2	22.2	32.9	196.1
Average (mt)	S1	29.2	31.5	192.4
	S2	29.3	32.7	194.1

The interaction between the cultivar and number of stems was obvious in the potential of the fructification capacity, the plants with double stems producing more fruits than the ones with only one stem (Table 2).

The number of fruit per plant recorded an average increase amongst the studied varieties of 80%; for the variety Canestrino the increase was more than double compared to the other varieties, respectively 119 %, while for the two hybrids it was of 64%.

The number of fruits per plant with a double stem was between 40 and 45.5, being close to the data recorded in the professional literature (Ece and Darakci, 2007; Hoza and Stanciu, 2012; Rahmatian et al., 2014.).

The number of fruits obtained per square meter depended on the number of fruits per plant and the number of cultivated plants per square meter, the average increase of fruit varying between 32% for the hybrids and 77% for he varieties, having an average value of 45%. The number of fruits per square meter was between 100 fruits for Clarabella F1 and 113.8 for Belmonte, values slightly lower than the ones obtained by Mouaro et al., 2014, respectively 121.5 and 125 fruits per m^{-2}, dependant on the stem planning.

The cultivar's influence on the fruit production was poorly highlighted, both regarding the number of fruits per plant and the number of fruits per square meter.

The average fruit weight (Table 2) was lower for all cultivars with a double stem compared to the ones with one stem, fact proved by the professional literature (Ece and Darakci, 2007; Hoza and Stanciu, 2012; Rahmatian et al., 2014).

Table 2. Number of fruits per plant and per m^2 depending on the cultivar and number of stems

Cultivar	S1(one stem)			S2 (double stem)			Difference between S1 and S2, %	
	Average fruit weight, g	No of fruits $plant^{-1}$	No of fruits m^{-2}	Average fruit weight, g	No of $fruit/pl^{-1}$	No of $fruits/m^{-2}$	$plant^{-1}$	m^{-2}
Canestrino	133.7 ***	20.2 ^{o}	62.6^{ooo}	132.6***	44.3 *	110.8 N	+119	+77
Belmonte	111.2^{ooo}	25.0 N	77.5 **	109.9^{ooo}	45.5***	113.8 **	+82	+47
Clarabella F1	117.8^{oo}	24.4 N	75.6 N	116.6^{ooo}	40.0^{ooo}	100.0^{ooo}	+64	+32
Cinto F1	126.3 **	27.0 N	83.7 ***	124.7***	44.2 *	110.5 N	+64	+32
Media (mt)	122.5	24.2	74.9	121.0	43.5	108.8	+80	+45
DL 5%	2.20	3,41	1,83	1.13	0.73	2.45	-	-
DL 1%	3,33	5.16	2,77	1.72	1.11	3.72	-	-
DL 0.1%	5.31	8.23	4,41	2.74	1.77	5.92	-	-

The productive capacity of the tomato plants was influenced by the cultivar, but especially by the number of stems (Table 3). For the plants managed with a double stem, the production was superior compared to one stem plants as shown also by Hossain (2007) and Mouaro et al. (2014). For this experiment, the largest production per plant was recorded for the variety Canestrino with a double stem, 5.9 kg $plant^{-1}$, the production increase being of +3.2 kg $plant^{-1}$ compared to the one stem plants. Conversely, the smallest was obtained from the hybrid Clarabella, 4.6 kg $plant^{-1}$, the production increase being of +1.7 kg $plant^{-1}$ for two stem plants. Analyzing the average production per plant for the used cultivars, it was noted that plants with one stem formed 3 kg $plant^{-1}$, while the ones with double stems formed 5.3 kg $plant^{-1}$. Franco et al., 2009, showed that for cherry tomatoes cultivated in greenhouses, with a double stem and with two shoots on each stem, the production per unit of area increased.

The present experiment confirms this fact, the production for the plants with two stems being larger than for the tomatoes with one stem, with values varying from 11.6 kg m^{-2} for Cinto F1 and 14.7 kg m^{-2} for Canestrino. The average production of the cultivars with one stem was of 9.1 kg m^{-2}, while for the ones with double stems was of 13.2 kg m^{-2}.

Table 3. Tomato production per plant and m^2 depending on the cultivar and number of stems

Cultivar	S1 (one stem)		S2 (double stem)		Difference between S1 and S2	
	Production		Production			
	kg plant^{-1}	kg m^{-2}	kg plant^{-1}	kg m^{-2}	kg plant^{-1}	kg m^{-2}
Canestrino	2.7 N	8.4^{oo}	5.9 **	14.7 ***	+3.2	+6.3
Belmonte	2.8 N	8.6^{o}	5.0 N	12.5^{oo}	+2.2	+3.9
Clarabella F1	2.9 N	8.9 N	4.6^{oo}	11.6^{ooo}	+1.7	+2.7
Cinto F1	3.4 *	10.6 ***	5.5 N	13.8 **	+2.1	+3.2
Average (mt)	3.0	9.1	5.3	13.2	+2.3	+4.1
DL 5%	0.34	0.38	0.34	0.39	-	-
DL 1%	0.51	0.57	0.51	0.59	-	-
DL 0.1%	0.82	0.92	0.82	0.95	-	-

CONCLUSIONS

The research conducted with four tomato cultivars and two plant management systems, one with one stem and one with a double stem, showed that tomato plants react very well when they have multiple stems.

From a vegetative point of view, no significant differences were recorded between plants with one stem and plants with a double stem. However, on average, plants with a double stem had a slightly higher growth (194.1 cm) compared to plants with just one (192.4).

The fructification process was influenced by the plant management system, plants with double stems forming by 80% more fruits per plant and by 45% more fruits per square meter than the single stem plants.

The largest average production per plant (5.3 kg) and the largest production per square meter (13.2 kg) were obtained also from the double stem plants, result justified by the presence of a double locus of fructification on the plant.

Average fruit weight was slightly smaller for the double stem plants (121.0 g) compared to the plants with one stem (122.5 g), however this result cannot be used as an argument that plants with one stem ensure an obvious increment of larger fruits.

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