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PLANTING TIME EFFECT ON THE GROWTH AND YIELD OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

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Abstract

The aim of the experiment was to investigate the effect of planting time on the growth and yield of tomatoes, grown in conditions of late field production. The experiments were carried out during the period 2020-2021 in the experimental field, Department of Horticulture at Agricultural University - Plovdiv, with cultivar Opal F_1. The opportunity of growing and fruiting of plants was evaluated by planting on three dates through 15 days (20th June, 5th, and 20th July). During the growing season, plant height (cm), leaf area (cm^2), first flowering and first fruiting, fruit set, and yield (kg/da), were recorded. The planting time has effects on the growth and yield of tomatoes. The better performance of tomato plants was observed planting on the 20th of June as the plants fall into climatic conditions near optimal for the crop, which affects the vegetative and generative growth of plants and increases the total yield.

Key words*: tomato, planting time, growth, yield.*

INTRODUCTION

The tomato (*Solanum lycopersicum* L.) is one of the economically significant vegetable crops, both globally and in Bulgaria (Meza et al., 2013; MZH, 2021). Tomato fruits contain macro- and micronutrients, antioxidants, vitamins A and C, which greatly support human health, which is why their consumption is increasing worldwide (Adalid et al., 2004; Luthria et al., 2006; Nour et al., 2013). In Bulgaria, suitable atmospheric conditions for tomato production are from April to October. Tomatoes are grown in three directions - early, mid-early, and late field production (Shaban et al., 2014). According to the adopting technology for growing late tomatoes, the seeds are sowed during the period June 1-5 and transplanted on 1-5 July (Cholakov, 2009). The production of late field tomatoes takes place in the period July - October, and part of the production is realized through post-harvest ripening of the fruits (Cholakov, 1987; Shopova & Cholakov 2013).

According to Cholakov (2009), the high requirements for the variety for the production of late-field tomatoes are determined by the climatic conditions during the growing season. The vegetative and generative development of plants takes place in the conditions of higher summer temperatures (July and August), and fruiting in September-October. In this period, the difference between day and night temperature increases, which negatively affects the plants, creates conditions for the development of diseases and the risk of fruit cracking. In this regard, air conditions during the growing season are particularly important for development and fruiting (Popov et al., 2003). As is known, tomatoes are grown in a wide range of climatic conditions but are sensitive to high temperatures (Alam et al., 2010).

The appropriate planting date is a major factor in vegetable production, directly related to the climatic conditions of the respective area (Rahman et al., 2020). Different planting days can affect the yield and quality of the production due to changing climatic conditions, and different stages of growth and development of the crop (Gent, 1992; Hossain, 2021). According to Emami (2014) determining a suitable date for transplanting tomatoes, is important to obtain early harvest and a high yield of tomatoes. According to Cebert et al. (1990), planting dates for one cultivar may not be suitable for another. For some plant species, different planting dates will affect only vegetative growth but will have no effect on reproductive growth.

The purpose of the conducted research was to determine the change in the growth and development of late tomatoes depending on the planting period.

MATERIALS AND METHODS

The experimental work was conducted in the period 2020-2021 in the Department of Horticulture, Agricultural University of Plovdiv, Bulgaria with tomatoes variety Opal F_1. Sowing of seeds was carried out during the period May 20, June 5, and June 20. The seedlings were grown in trays with 77 cells. The planting was carried out during the period - June 20 (first date), July 5 (second date), and July 20 (third date). Thirty-day seedlings were used for all three planting dates. The betting of the experiment was done in three repetitions in the high bed-furrow surface by a schema - 100 + 60/40 cm. The plants were grown under conditions of drip irrigation. The cultivation of the plants was carried out according to the adopted technology for late field production with the attachment of the plants to the structure, regular pruning, and single-stem formation, with the removal of the stem after the formation of 4th inflorescence (Cholakov, 2009). During the growing season, a biometric measurement was performed on the 40th day after planting on each study date.

Experiment 2020

Experiment 2021

The data on the phenological development of plants like days to first flowering, first fruiting, first fruit maturity, and days to the end of the harvest period were recorded. The numbers of flowers per plant, fruits per plant, and fruiting set (i.s. the percentage ratio between the number of flowers and fruits) were determined. The yield was determined by month and total for the period.

RESULTS AND DISCUSSIONS

The air temperature is the main meteorological factor affecting plant development (Kalbarczyk et al., 2011). The average daily temperatures (Table 1) for July, August, and September, during which most of the vegetation of plants takes place, were within the limits of the optimal range for the development of the plants. The optimum growth temperature of tomatoes is within a range of 18.3 and 32.2°C (Hochmuth & Hochmuth, 2012). The average daily temperature in June, when the plants from the first investigation date were planted, was also within the optimum range. The average maximum temperature for June, July, August, and September was close to the developmental maximum. According to Kittas et al., (2005), the growth of tomato plants stops below 10ºC and above 35ºC. The average minimum temperatures, except for the ones reported in October, were above the agro biological minimum (10ºC). In connection with the lowering of temperatures in October, it is worth noting that in both experimental years until the end of this month, no autumn frost was formed.
An important meteorological element that is directly related to the pollination and fertilization processes is relative humidity. The most favorable for plants is the moderate relative humidity between 60-70% (Huang et al., 2011). In July and August, when most of the fruits of late tomatoes are formed, the reported values were 62% in 2020 and 57-55% in 2021, respectively. The relative humidity in September is important for the third experimental date, which averages 57% for 2020 and 62% for 2021. In conclusion, it can be noted that the climatic conditions during the two experimental years were relatively favorable for growing late tomatoes.

Table 1. Climatic characteristics of the area

Meteorological parameters	June		July		August		September		October	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Average daily temperature	21,4	23,4	23,5	24,0	24,6	24,8	21,3	19,9	15,2	14,3
Average max. temperature	27,7	29,6	31,1	31,8	32,2	32,3	28,9	29,3	22,3	20,1
Average min. temperature	15,5	17,2	16,7	16,9	16,3	17,4	13,4	12,0	9,2	6,1
Absolute max. temperature	34,0	34,7	34,2	37,2	35,6	37,0	35,0	34,5	28,5	27,5
Absolute min. temperature	11,3	10,6	12,0	13,2	13,3	12,4	2,8	4,8	1,7	1,3
Relative humidity %	67,0	66,4	62,0	57,0	62,0	55,0	57,0	62,0	74,0	78,0
Rainfall, mm	55,4	45,4	20,0	10,6	17,8	49,7	1,3	9,2	62,3	110,4

Table 2. Phenological phenophases of development of the plant

Planting date on:	DURATION IN DAYS TO:							
	first flowering		first fruiting		first maturity/ first harvest		last harvest	
	2020	2021	2020	2021	2020	2021	2020	2021
20 June	40	41	47	48	85	86	138	136
5 July	40	41	48	49	87	88	145	144
20 July	44	45	52	54	94	95	131	135

The course of phenological phases has an important role in yield quantity and quality (Mozny et al, 2009; Tao et al, 2006; Vlahova, 2012; Panayotov et al., 2020). The occurrence of phenophases is weakly affected by the planting period (Table 2). On the first and second dates of planting, the flowering of the first inflorescence occurs on average 40-41 days after germination, while on the third date after 44-45 days. This delay is most likely due to that after the 2rd decade of July, the plants fall under conditions of higher temperatures. For all three planting dates, a longer period until the flowering was reported in 2021. A similar trend was observed for the phenophases of first fruiting and maturity. For all three dates, the period of reddening of the first fruit coincides with the first harvest. Traditionally, for late field tomato production, the last harvest is done before the first autumn frost (Cholakov, 1987). In the second planting time, the duration of the harvesting period is 58 days for 2020 and 56 days for 2021. The duration of the harvest period for the June planting was 53 days for 2020 and 50 days for 2021, and the last harvests were made in early October. At the third tested date, the harvest period is shortest - 37 days in 2020 and 40 days in 2021.

The results of the biometric measurements performed on the 40th day after planting (Table 3) showed a weak influence of the planting period on the main biometric parameters.

Despite the similar values of the reported biometric indicators, it should be noted that the plants with earlier planting have the largest stem-leaf mass, and the plants from the third date are the least. The differences between the investigated variants are most likely due to the different climatic conditions during the early stages after planting the plants. June planting coincides with moderately high average daily temperatures, allowing for faster plant establishment and more intense plant growth in the first few days after planting before the sustained increase in summer temperatures occurs in July. The plant's height is 110.7 cm, the number of leaves per plant was 24.2, the leaf area - was 4697.5 cm^2, and stem-leaf mass was the least developed.

Table 3. Biometric measurement per plant on the 40th day after planting

Planting date on:	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Stem-leaf mass (g)
2020				
20 June	116,1 a	23,8	4824 a	705
5 July	110,0 a	20,0	4588 ab	671
20 July	107,2 a	21,2	4080 b	619
2021				
20 June	105,3 a	24,6	4571 a	586
5 July	104,0 a	22,8	4178 b	521
20 July	98,2 a	22,0	4008 b	486
Average for the period				
20 June	110,7 a	24,2	4697,5 a	645,5
5 July	107,0 a	21,4	4383,0 ab	596,0
20 July	102,6 a	21,6	4044,0 b	552,5

Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$).

In all variants, the vegetative peak of the plants was removed after the formation of the fourth inflorescence. The total number of flowers and fruits per plant was obtained as the sum of the flowers and fruits formed in each inflorescence. This makes it possible to determine the fruit set per plant (Table 4). The number of flowers and the degree of fruit set was directly related to the size of the yield.

Depending on the date of planting in 2020 the number of flowers was 21.3-24.7 and the number of fruits per plant was 18.4-22.6 (a fruiting rate of 86.4-91.5%). In the second experimental year, the number of flowers was 20.2-23.8 per plant, and the number of fruits was 17.4-21.8. The reported fruit set in 2020 was higher, which shows that the conditions for pollination, fertilization, and fruiting were more favorable. As it knows, tomatoes are grown under a wide range of climatic conditions but are sensitive to hot and humid environments (Alam, 2010). High air temperature reduces the fertility rate of flowers, resulting in flower drop and fruit set. Tomato plants drop flowers when exposed to several days of daytime temperatures above 29°C and nighttime temperatures above 21°C (Ayankojo & Morgan, 2020). Values higher than 35°C will also reduce fruit set and delay the development of normal fruit colors (Jones, 2013).

Table 4. Number of flowers and fruits per plant, and fruit set (%)

Date of planting	2020			2021			Average		
	Flower per plant	Fruit pre plant	Fruit set %	Flower per plant	Fruit pre plant	Fruit set %	Flower per plant	Fruit pre plant	Fruit set %
20 June	24,7	22,6	91,5	23,8	21,8	91,6	24,3	22,2	91,5
5 July	22,4	20,0	89,3	21,8	19,4	89,0	22,1	19,7	89,1
20 July	21,3	18,4	86,4	20,2	17,4	86,1	20,8	17,9	86,3

On average for the two-year period, the generative potential of plants was 20.8-24.3 flowers, the number of fruits was 17.9-22.2, fruit set of 86.3-91.5%. The number of flowers and fruits per plant and the fruit set was highest in June planting.

The fruit yield shows most objectively the influence of the studied factor on plant productivity. In the three variants, the values of this indicator were higher in 2020 (Table 5). The difference in yield between the first and second date of planting was small - 258.3 kg in 2020 and 334.2 kg in 2021 and differences have not been proven.

A higher yield was reported in June planting, and it decreased with later planting. The higher yield corresponds to the results for the flowering and fruiting of plants in this variant. The yield from the third date was the lowest and the differences are statistically proven. The distribution of yield by months is important for the economic efficiency of production. In 2020, in August, 6.1% of the total yield is obtained in planting in early July and 45.2% in planting in June. In September, 64% of the total yield was harvested (5 July), and from 46.3% to 48.5% in the other two investigated planting dates.

Table 5. Effect of planting time on yield kg/da

Planting date on:	2020	2021	average	Distribution of yield by month, average for the period						
								October		
	kg/da	kg/da	kg/da	August kg/da	% to Total yield	September kg/da	% to Total yield	Total yield kg/da	The yield of green for post-harvest kg/da	% to Total yield
20June	5768,7 a	5656,2 a	5712,5 a	2582,0	45,2	2770,5	48,5	359,9	0,0	6,3
5 July	5510,4ab	5322,0 ab	5416,2 a	330,9	6,1	3466,4	64,0	1619,4	478	29,9
20 July	5056,2 b	4856,3 b	4956,3 b	0,0	0,0	2294,8	46,3	2661,5	1025,1	53,7

Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$).

The amount of harvested fruit was the highest in September.

In October, the yield was highest in late July planting (20 July). Warmer and longer autumn favors the ripening of most fruits. At the end of the harvesting period, 2661.5 kg/da was harvested, of which 1025.1 kg/da was for post-harvest ripening.

During early July planting, the yield was 1619.4 kg/da, of which 478 kg/da was for post-harvest ripening. At the June planting, the yield of 359,9 kg was formed only from ripe fruits, as the harvesting period ends in the first ten days of October.

CONCLUSIONS

The experiment showed that the vegetative and generative development of late tomatoes was influenced by the date of planting. Planting on June 20 increases the number of flowers and fruits, fruit set, and the total yield. Depending on the date of planting, in August was obtained from 6.1-45.2% of the total yield, from 48.5-64% - in September, and from 6.3-53.7% - in October. When the purpose of production is to extend the consumption period of fresh fruit by post-harvest ripening, July planting is appropriate.

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