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EFFECT OF USING ORGANIC FERTILIZERS ON THE PRODUCTIVE PARAMETERS OF TOMATOES UNDER FIELD METEOROLOGICAL CONDITIONS

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Abstract

In times of climate changes and increased demand for food purity a significant part of scientific research is directly addressed organic agriculture. The producers are increasingly orienting themselves to bio-production due to its long-run positive consequences both for human and environmental health. The role of organic production is clearly outlined in a number of papers and documents, related to the fight against climatic changes and soil and water contamination. This paper aims at answering the question of whether the biologically grown tomato variety Rugby presents a good alternative to the conventionally produced varieties with respect to their yield. The meteorological conditions during the vegetation period in 2021 have been analyzed in detail and basic productive parameters of the experimentally grown plants (number of standards and non-standard fruits; total weight in kg/da) have been compared for the two methods and three planting dates. At the first harvest in early summer, plants fertilized with mineral fertilizers NPK give better yields than unfertilized and fertilized with Arkobaleno. However, with the intensification of the unfavourable hydrothermal conditions by the end of the summer, the final total yield from the bio-fertilized plants for all the three planting dates already has better parameters not only compared to the unfertilized plants but also compared to the these grown after mineral fertilization. Biologically fertilized tomato plants show better productivity under conditions of over-wetting. Mineral fertilizers have a slight advantage in case of heat stress but the yields are comparable with those, from the plants, fed with the organic fertilizer Arkobaleno.

Key words: *yield, tomatoes, organic and mineral fertilizers, meteorological conditions.*

INTRODUCTION

In recent years, climate change has put serious pressure on all economic sectors, including agriculture. Global models predict temperature increase in Southeast Europe and Bulgaria by more than 2.0 degrees Celsius and an increase in the frequency of meteorological extremes (Alexandrov, 2010; 2011; Svetozarevic et al. 2021). Faced with this real threat, people are getting united by the idea of reducing the anthropogenic causes of the global warming. Soils and their health are identified as a key element in the fight against climate change. Their balanced management is one of the mechanisms for climate regulation and a path for biodiversity protection and conservation (Revised World Soil Charter, 2015). Adopted in Rio de Janeiro, Brazil, the 2012 document "The future we want" recognizes the economic and social importance of good governance for the land, including soil, and in particular its contribution to climate change reduction and water conservation. Plant organisms, in particular vegetable crops, extract trace elements and nutrients necessary for their growth and development, which are most often replenished by applying chemical fertilizers. In recent years, the quality of life and health status of people and nature requires more widespread use of organic nutrition and reduced utilization of chemical ones. The researches indicated that organic fertilization did not cause deficiencies in the nutrient content and yield of vegetables when compared with conventional fertilization, showing that ecological management can be used effectively (Herencia & Maqueda, 2016). Important advantages of organic fertilizers are the gradual release of micronutrients and maintaining a good soil balance. With their help optimal conditions are maintained for soil microorganisms, responsible for fertility and soil structure. Tomato (*Solanum lycopersicum*) is an important horticultural crop that also functions as a research model for the plant family of Solanaceae (Xu et al., 2017). Tomatoes are a major product for Bulgaria (Todorovska et al, 2013) and in particular for the dry region of the Upper Thracian lowlands and the Plovdiv field. Bulgarian tomato varieties are a symbol of our country and are recognizable around the world due to their excellent taste. Tomatoes are very sensitive to extreme phenomena of meteorological origin such as drought and overhumidification - a common phenomenon in the conditions of climate change in our country. These abiotic factors affect almost every stage of their life cycle. Depending on the phase of the plant and the duration of the stress period, abiotic stress can cause up to 70% loss of yield (Krishna et al, 2019; Adams et al, 2001). Extreme variations during the hot summer can damage the intermolecular interactions, necessary for proper growth, thus disrupting plant development and fruit set (Bita & Gerats, 2013). Are organic fertilizers a good alternative to the mineral ones in terms of final production amounts? Do they show good resistance to various weather conditions and are they able to reduce the abiotic pressure on tomatoes? This paper aims to analyze the impact of *mineral* and organic nutrition on early and total yield of Rugby tomatoes during a three-year period of outdoor cultivation for three planting dates.

MATERIALS AND METHODS

Meteorological measurements. The experimental work was carried out in the period 2019-2021 in UEEB (training and experimental base) of the Department of Horticulture at the Faculty of Viticulture and Horticulture at the Agricultural University - Plovdiv. The meteorological parameters were reported for each day of the vegetation period and for this purpose a meteorological station was installed with sensors for: air temperature (average, maximum, minimum in °C; relative humidity in %; precipitation in mm; solar radiation w/m^2). The measurements were compared with the norms proposed by the NIMH for the respective period.

Methodoloical formulation of the experiment. For the purposes of the study, the Bulgarian determinant variety Rugby, selectively adapted to the climatic conditions of our country, was used. For the needs of the experimental work, 40-45 day seedlings were produced, which were then planted in the field in phase 5-6 leaves on three dates, as follows: April 27; May 7; May 17. Three variants of fertilization were set for each planting date: 1st - unfertilized = control; 2nd - mineral fertilization; 3rd - organic fertilization. The experiment was based on three repetitions with 20 plants per repetition. The variant with mineral fertilization was set in a separate experimental plot. The mineral fertilization was carried out with the recommended norms for early field production with superphosphate (50% P_2O_5), potassium sulfate (35% K_2O), ammonium nitrate (33.5% N). For the organic fertilization Arkobaleno fertilizer in a dose of 100 kg ha-1was used. Prior to planting, the beds were mulched with silver black foil. Drip irrigation was applied by placing one drip hose per bed with drippers at a distance of 30 cm and a flow rate of 1.6 mm/h. The irrigation norm was keyed to the meteorological conditions and in particular to the amount of precipitation in the region in mm. Planting was done according to the scheme 160/50 cm with one row in the middle of the bed. Biometric readings were made periodically and at the same time for the batches, planted on the three different planting dates, starting from the moment of initial ripening of the batch, planted on the third one. Early and total standard yields were determined. The early yield was calculated in total in kg/ha from the first three harvests. Anova regression statistical method and two-factor analysis with significance levels $p \leq 0.05$ were used for evaluation of the two methods – biological fertilization and conventional fertilization – at the measured weather conditions in the open air.

RESULTS AND DISCUSSIONS

The planting, growth and development of tomatoes during the three experimental years took place under different weather conditions. The monthly averages and extremes of the main meteorological elements of the period are visualized in Table 1.

Table 1. Hydrothermal conditions during the tomatoes growing seasons 2019-2021

	Temperature in ° C						Precipitation, mm				Number of days	
Month	average T	δ T (°C)	max (°C)	date	min (°C)	date	Σ	Q/Qn	max	date	≥1	≥10
						2019						
May	18.4	1.3	32.4	28	2	9	22	34	6	31	6	0
June	23.4	2.5	34.2	8	10.6	4	197	364	79	3	11	5
July	23.5	0.6	36.4	3	13.2	19	68	135	27	11	8	2
August	24.7	2.7	36.4	22	12.4	7	31	81	20	3	5	1
						2020						
May	17.6	0.5	32	8	5.4	8	71	108	13	1	11	3
June	21.5	0.6	34.7	30	11.3	4	54	101	14	16	6	3
July	24.4	1.5	38	31	12	15	20	40	9	8	4	0
August	24.7	2.7	37	31	13.3	18	18	47	7	9	4	0
						2021						
May	18.5	1.4	31	24	4.6	10	35	54	14	31	6	2
June	21.9	1	38	25	10.1	5	58	108	23	11	11	1
July	26.3	3.4	39.4	30	14	26	36	73	10	9	4	1
August	25.7	3.7	41.6	2	12.9	31	25	66	13	19	3	1

The deviation from the climatic norm of the average air temperature by months varied widely - between 0.5°C in May 2020 and 3.7°C in August 2021. In the first summer month, during which the rooting and initial growth and development of the tomatoes took place, the deviation was 1.3°C in 2019 and 1.4°C in 2021, respectively. July was the hottest month with lowest temperature in 2019 - 23.5°C, and highest - in 2021 - 26.3°C, and deviation of 3.4°C from the climatic norm. In August both in 2019 and 2020 the average temperature was 24.7°C, while in the warmest 2021 year it was 25.7°C with a deviation of 3.7°C from the climatic norm for this month. The precipitation measurements showed conditions of over-wetting in 2019, when in July 79 mm for 24 hours were reported. All minimum temperature values were positive and frost damage conditions after planting the seedlings were not observed. Studies, related to heat stress in tomatoes, report decreased PSII electron transport under the influence of 43.0°C for 6 hours (Heckathorn et al., 1998).

The maximum temperature in July and August had its lowest value in 2019 - 36.4°C, while in 2021 it exceeded 39°C, reaching up to 41.6°C in August.

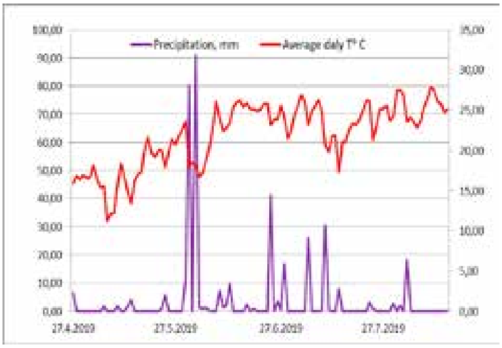

Figure 1. Average daily temperature and ∑ mm precipitation 27.04-27.08 2019

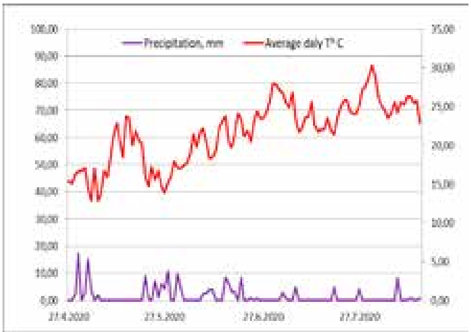

Figure 2. Average daily temperature and ∑ mm precipitation 27.04-27.07.2020

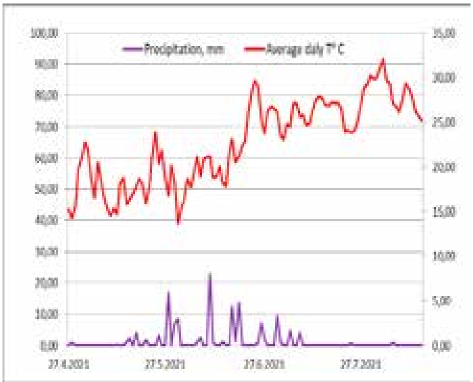

Figure 3. Average daily temperature and ∑ mm precipitation 27.04-27.07.2021

Solar radiation, daily rainfall and temperature values affect the development, productivity and taste of tomatoes. It is known that high maximum temperatures adversely affect the period of flowering and fertilization. Average temperatures of above 21.0°C and below 25.0°C are optimal for tomatoes (Geisenberg & Stewart 1986), with values above the optimum leading to lower seed and fruit yields (Peet et al. 1997). The most solar radiation was measured during the growing season of the plants, planted on 27.04, and the least - for the tomatoes with a period of development 17.05 - 29.08. During the period 27.04 - 15.08 (the earliest planting date) the most sunshine was registered in 2021 (16560.5 w/m^2).

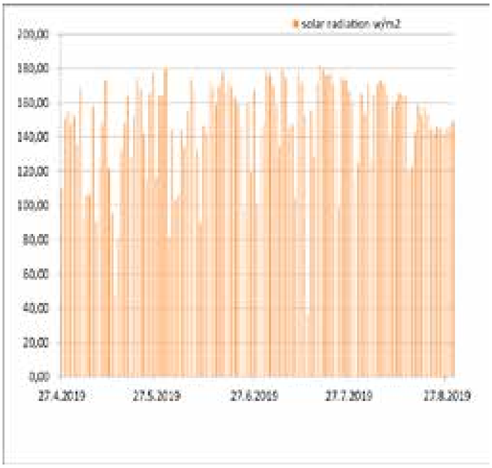

Figure 4. ∑ Solar radiation w/m^2 27.04-27.08 2019

In the second period 7.05-22.08 the solar energy is highest in 2020 (16188.5 w/m2), and in the third (17.05 - 29.08) - it is highest in 2019 (15843.95 w/m^2) (Table 2).

Figures 5 and 6. ∑ Solar radiation w/m^2 27.04-27.08. 2020; 27.04-27.08. 2021

The amounts of precipitation for the three-year period by days showed: over-wetting at the end of May 2019; need for irrigation in 2020 and 2021; and a well-defined drought in July 2021. According to the established irrigation norms (Zahariev et al, 1986), the water used for irrigation, required for optimal development of tomatoes in early and late cultivation, was 141.7 mm in 2020 and 178.2 mm in 2021. Since the the tomatoes, planted on the second date, grew at higher temperatures, the amount of water, required for irrigation increased to 303.1 mm in 2020 and 285.8 mm in 2021.

Air relative humidity (RH) between 55-60% is important for effective pollen production and pollination (OECD, 2017). In all three years, the average RH W % was within the favorable limits for the tomato plants. In 2019, the average relative humidity in % for the three periods batches of plants was between 64.7 and 66.9%. The values are lower in 2020 and 2021 due to the higher temperatures and the dry periods. In all three years, the average humidity in% was best for the development of the earliest planted tomatoes.

During the growing season of the tomatoes, planted on the second and third dates, the active temperature sums were higher than the ones, for the earliest planted pants, except for the year 2021, when the first period was the warmest with an active temperature sum of 2524°C.

Table 2. Agrometeorological conditions during the growing seasons 2019-2021

planting periods	Σ°C	Σp, mm	humidity %	w/m2
27.04.2019- 15.8.2019	2431,2	387,4	66,9	16292,9
7.05.2019- 22.8.2019	2438,5	384,8	66,3	16001,5
17.05.2019- 29.8.2019	2474,4	377,4	64,7	15843,9
27.04.2020- 15.8.2020	2398,4	168,3	65,7	16227,2
7.05.2020- 22.8.2020	2442,5	126,9	64,8	16188,5
17.05.2020- 29.8.2020	2395,2	125,7	64,2	15403,7
27.04.2021- 15.8.2021	2524,0	131,8	63,3	16560,5
7.05.2021 22.8.2021	2510,2	144,2	62,5	16164,1
17.05.2021- 29.8.2021	2506,0	152,4	63,0	15597,7

It can be noticed that the temperature sums for the three planting dates were very close within a year and with more than 100°C difference between the individual years. The average air temperatures were below the optimum in the initial stage of development in 2019 and 2020 and around the optimum in 2021. In all three years there was a decrease in temperature values at the end of May. The average values for the whole vegetation periods were lowest in 2019 - between 21.9°C and 22.7°C. They were above the upper optimal limit after July 27, except for 2019. In 2021, the average temperatures for the earliest and latest planting dates were higher than for the second one, with values of 23.6°C and 23.9°C, respectively. The most favorable in terms of temperature conditions with values around the optimal for tomatoes was 2019, and the most extreme – 2021, with an average temperature for July exceeding the optimal for growing the species (tomatoes). However, the combination of temperature and rainfall was most unfavorable in 2019, when the intense excessive rainfall created conditions for increase in diseases and pests and reduced quality and yields. Under conditions of irrigation, the most favorable for growing tomatoes were the thermal parameters of 2020.

Table 3. Early yield kg/da 2019-2021

2019				
factors	**1 date**	**2 date**	**3 date**	**means**
control	962.7	700.1	419.5	694.1
NPK	1427.9	947.8	566.9	980.9
Arkobaleno	1581.0	863.4	479.2	974.6
means	1323.9	837.1	488.5	
LSD	**p 0.05= 340.5**			
2020				
factors	**1 date**	**2 date**	**3 date**	**means**
control	1091.7	721.2	386.6	733.2
NPK	2046.2	834.5	557.2	1145.9
Arkobaleno	2176.8	963.8	569.2	1236.6
means	1771.6	839.8	504.3	
LSD	**p 0.05=541.3**			
2021				
factors	**1 date**	**2 date**	**3 date**	**means**
control	1703.6	838.5	379.9	974.0
NPK	2484.7	1598.3	823.8	1635.6
Arkobaleno	1916.9	1083.7	539.9	1180.1
means	2035.0	1173.5	581.2	
LSD	**p 0.05=227.3**			

As a result of the phenological stages, the best early yield in all three years was obtained from the first planted tomatoes, for which the yields after fertilizing with NPK and Arkobaleno were statistically significant compared to the control in 2021 - Table 3. Significant differences were found for the second and third batches of plants after using both mineral and organic fertilizers compared to the control plants. This shows that feeding at later dates and in extreme conditions affects the productivity of tomatoes in a positive direction.

In the total yield, the fed variants (NPK and Arkobaleno) are statistically significantly better, compared to the control, in the unfavorable in terms of humidity 2019 as well as in the warmer 2021 (Table 4) Later planted tomatoes had significantly higher yields in 2019 and 2020 compared to the control. In 2021, the best yield was observed from the tomatoes, planted on the second date.

Abiotic and biotic stress contributes 50% and 30% respectively to losses in agricultural productivity worldwide (Kumar & Verma, 2018). During the most unfavorable 2019 the yields from the control for the three growing periods were lower than the average as it follows: control - first date 26.9%; second date 24.9%; third date 29.9%. In 2020, the values were above the average for the period, namely: first date - 16.8%; second date 16.0% and third date 8.5%. In the extremely hot 2021 the deviation is positive, but less than in 2020: first date 10.5%; second date 8.9%; third date 21.4%.

Table 4. Yield kg/da 2019-2021

2019				
factors	**1 date**	**2 date**	**3 date**	**means**
control	3070.8	2116.1	2515.8	2567.5
NPK	3514.9	2757.1	4063.6	3445.2
Arkobaleno	3321.7	2429.6	3279.9	3010.4
means	3302.4	2434.2	3286.4	
LSD	**p 0.05= 410.0**			
	2020			
factors	**1 date**	**2 date**	**3 date**	**means**
control	4123.0	3103.2	3436.5	**3554.2**
NPK	5428.0	4421.6	5763.9	**5204.5**
Arkobaleno	4262.9	3617.8	4366.9	**4082.5**
means	**4604.6**	**3714.2**	**4522.4**	
LSD	**p 0.05=855.9**			
	2021			
factors	**1 date**	**2 date**	**3 date**	**means**
control	4632.2	4830.8	4099.0	**4520.6**
NPK	5104.1	5738.6	5743.9	**5528.8**
Arkobaleno	5754.6	5929.2	4605.5	**5429.8**
means	**5163.6**	**5499.5**	**4816.1**	
LSD	**p 0.05=756.5**			

In general, the productivity is highest for the third planting date in 2021, as well as for the first and second dates in 2020. When feeding with mineral fertilizers, the negative deviation in the unfavorable 2019 was the largest of all variants for all three dates: first date 43.2%; second date 37.4%; third date 45.4%. In 2020, the productivity was above average with values: first date 13.4%; second date 7.2% and third date 12.1%. Mineral fertilization gave the best yields in 2021: first date 29%; second date 30.2% and 33.3%. Regarding Arkobaleno feeding, the deviation below the average yield for 2019 was first date 32.7%; second date 21.7%; third date 24.9%. Better yields were found on all three dates in 2020: first date - 23%; second date 11% and third date 19.6%. In the unfavorable year 2021, the yields were above the average, but with a lower % than in 2020: first date 9.7%, second date 10.7% and third date 5.3%.

CONCLUSIONS

The main meteorological parameters during the vegetation period of development of Rugby tomatoes, planted on three different dates and grown in a conventional and organic way in three consecutive years from 2019 to 2021, were taken into account. Despite the trends of warming and increasing thermal potential, extreme phenomena resulting from climate change have a rather negative impact on tomato productivity. At the second and third planting date at higher air temperature values and insufficient rainfall, tomatoes need doubling water for irrigation. An analysis of the early and total yields during the experimental period was made and the best harvest in 2021 was established, except for the third planting date, which showed good productivity in 2020. For the three dates of planting a significant positive effect of feeding with mineral NPK fertilizer and with organic fertilizers was observed. The Rugby variety gave good yields in conditions of irrigation in the extremely warm 2021, which focuses interest in its use in the warmer climate of the Upper Thracian lowlands. In case of over-wetting, biological fertilization gives better yields than the conventional one. During vegetation in periods with excessive temperatures, the plants, fed with a mineral NPK fertilizer, show better productivity. Feeding with Arkobaleno can be used to mitigate adverse events of meteorological origin and, given the increased requirements for food and soil purity, this organic fertilizer can be more widely used in the Upper Thracian lowlands.

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