Bulgarian Journal of Agricultural Science, 32 (No 2) 2026, 286–291

Influence of different irrigation scheduling and mineral fertilization on tomato determinant sort "Nikolina" F_1

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Abstract

Petrova-Branicheva, V., Dimitrov, E., Gigova, A., & Ivanova, M. (2026). Influence of different irrigation scheduling and mineral fertilization on tomato determinant sort "Nikolina" F_1. *Bulg. J. Agric. Sci., 32*(2), 286–291

Field experiments were conducted in 2020 – 2021 with a medium-early sort of tomato „Nikolina" F1, grown on Cinnamon Forest soils (Chromic Luvisols, FAO) in the Sofia experimental field of the Institute of Soil Science, Agrotechnologies and Plant Protection "Nikola Poushkarov". Different irrigation and fertilization regimes were applied to the determinant tomato "Nikolina" F_1, grown in an open field. In the experiment, two levels of irrigation scheduling and three fertilization regimes were performed with four replications. The vegetable crops were irrigated using drip irrigation technology, and fertilizers were applied using an injector with the drip irrigation system. The evaluated factors in the study were 100% and 50% irrigation rate, and increasing mineral fertilization rates: $N_{15}P_8K_{15}$; $N_{20}P_{12}K_{20}$ and $N_{25}P_{16}K_{25}$. In the control treatments, 100% irrigation rate and 50% irrigation without fertilization were applied. The influence of drip irrigation and fertilization with different fertilizer norms has been found on crop yields.

Keywords: drip irrigation; fertilization; irrigation scheduling; tomato

Introduction

In contemporary vegetable production, the problem of obtaining maximum yields from a unit of area is widespread. In order to obtain sustainable yields with high quality, it is necessary to satisfy the plants optimally not only with water, but also with the necessary nutrients with the right combination of the two factors: fertilization and irrigation (Nikolov et al., 2019; Moteva et al., 2016).

The tomato is one of the symbols of Bulgarian vegetable production and its demand is high throughout the whole year. According to the Ministry of Agriculture, the production of tomatoes for 2020 is 115.790 tons. Over 60% of tomato production in Bulgaria is for fresh consumption, and it is important to note that only 1/3 of them are from outdoor production.

Growing vegetables outdoors in Bulgaria is impossible without irrigation, due to the uneven distribution or lack of rainfall in July and August (Petrova, 2020; Petrova and Hristova, 2021; Bazitov and Bazitov, 2010; Mitova et al., 2021). The most efficient and precise water-saving technology for supplying the necessary amounts of water to plants is drip irrigation. This irrigation technology allows regulating irrigation norms, limiting the irrigated area and reducing the evaporation from the soil surface. (Patanè et al., 2011; Howell, 2006; Wang et al., 2017).

Drip or trickle irrigation has become into favor, because it meets the requirements to solve the recent problems of water shortage and water pollution. China is one of the countries facing serious shortage of water resources. About 60% of China's irrigation water is being wasted by poor facilities such as furrow and basin irrigation, which cause much water loss through evaporation and percolation into the ground. Even in the production of such vegetable crop as tomato, furrow and basin irrigation still remain dominant, which cause inefficient water use and low fruit yield. (Zhai et al., 2010). The same problems are a priority for the government in Republic of Bulgaria.

In many scientific papers, results on the interaction of water and fertilizer factors, and their complex influence on the quality indicators of tomatoes and plant samples tested by traditional laboratory methods, have been published. (Boteva and Chobakov, 2011; Vasileva et al., 2013; Li et al., 2014). The study of these dependencies provides opportunities to reduce the amount of fertilizers applied by optimizing irrigation and nutrition, in order to obtain environmentally friendly products.

The purpose of the study is to determine the influence of different irrigation and fertilization rates on the productivity (yield) of the determinate tomato variety „Nikolina F1" in the Sofia Field region and to provide recommendations for their application.

Material and Methods

Field experiments were conducted on the territory of ISSAPP „N. Poushkarov" experimental field in Chelopechene near town of Sofia, Bulgaria during 2020 and 2021. The experimental field, with geographical coordinates: 42°44′22.8″ N, 23°28′3.7″ E is a part of the South-West Sofia field, located at 550 m above sea level. This area has continental climate characterized by cold winter and hot summer. The soil is slightly humus (1.63%) Chromic luvisoil, which can be defined as moderate to strong water-permeable with an average filtration capacity. It was found that mechanical compositions of these soils were medium to heavy. The average water-physical properties of this subtype soil for the layer 0–0.50 m depth are the following: field capacity FC – 22.0% relative to the weight of the absolutely dry soil; soil volumetric weight – 1.47 g cm^{-3}.

At the beginning of the growing season, soil samples were collected from Rhodic-Chromic luvisols from the surface layer (0–20 cm). The soil was characterised by the following agrochemical parameters: humus – 1.61%; mineral nitrogen – 8.6 mg/kg; mobile phosphorus (P_2O_5) – 13.5 mg/100 g; mobile potassium (K_2O) – 23.0 mg/100 g. Based on these and the export of nutrients, the optimum fertilizer rates were established.

The object of the study are to define optimal irrigation and nutrition for the medium-early determinant sort tomato „Nikolina F_1". Two levels of irrigation scheduling and three fertilization regimes with four replications were performed in the experiment. The vegetable crops were irrigated using drip irrigation technology, and fertilizers were applied using an injector with the drip irrigation system. The factors evaluated in the study were 100% full irrigation and 50% deficit irrigation and increasing rates of mineral fertilization: $N_{15}P_8K_{15}$; $N_{20}P_{12}K_{20}$ and $N_{25}P_{16}K_{25}$. In the control treatments, 100% full irrigation rate and 50% deficit irrigation without fertilization were applied.

To determine the influence of irrigation and fertilizer regimes on the development and productivity of the tested tomato variety, a two-factor experiment was set up with the following variants Table 1. in four repetitions. The size of the experimental area of one variant is 28.80 m^2, and of one repetition is 7.5 m^2.

Table 1. Experience options

Variants	Irrigation norm %	Fertilization %
T_1	100 % m	0
T_2	100 % m	$N_{15}P_8K_{15}$
T_3	100 % m	$N_{20}P_{12}K_{20}$
T_4	100 % m	$N_{25}P_{16}K_{25}$
T_5	50 % m	0
T_6	50 % m	$N_{15}P_8K_{15}$
T_7	50 % m	$N_{20}P_{12}K_{20}$
T_8	50 % m	$N_{25}P_{16}K_{25}$

Source: Authors' own elaboration

During the growing season, all agrotechnical measures related to the cultivation of the crop were observed in conventional production, including the control of weeds, diseases and pests.

Seedling cultivation: Unpicked seedlings were produced in an unheated steel-glass greenhouse on the territory of ISSAPP „N. Poushkarov" with a fertilizer-soil substrate. The sowing of tomato seeds of the „Nikolina F1" variety was carried out in the first ten days of March. Transplanting of plants: Planting of the crop in a permanent place was carried out in the third decade of May according to the scheme 120/50/50 cm.

Soil cultivation: In the autumn, the soil was cultivated to a depth of 0.25 m, with the introduction of phosphorus fertilizers. In the spring, before planting the tomatoes, shallow soil cultivation and milling were carried out.

Fertilization: Nitrogen (ammonium nitrate) and potassium (potassium chloride) fertilizers in all fertilization options were applied three times with the irrigation system (fertigation = irrigation rate + fertilizers). The fertilizer rates were divided equally and applied until the mass formation of the ties. The phosphorus rate, in the form of double superphosphate, was applied in the fall with deep plowing.

The plants were planted on a flat bed in a two-row strip according to the 90 + 50 × 50 cm scheme. They were grown without a tiller. The irrigation of the experimental plots was carried out using a drip system, with the irrigation wings consisting of two irrigation hoses (one in each row in the bed) with built-in drippers, diameter of 16 mm, distance between the water-distributing elements 0.50 m and flow rate of each of them – 2 l/h. The amount of water supplied to each of the beds was measured with a water meter. In order to equalize the initial conditions in all variants and test the constructed drip system, irrigation was carried out 5 days before transplanting, with the norm calculated for the layer 0–1.00 m. When planting the tomatoes in the field, in all variants, an irrigation of 5 mm was applied, after which catch-up irrigations with a total volume of 20 mm were applied every 5–7 days.

Determination of irrigation rates

Soil moisture dynamics were monitored by taking soil samples every 3 to 5 days at a depth of 0.50 m to 0.10 m in three repetitions, and processed by the classic thermostatic weight method. The results obtained on the basis of soil moisture were used to determine the necessary irrigation rates according to the formula (1).

Irrigation scheduling

The irrigation norm was calculated using the formula:

$$m = [10H.\alpha.(\delta\ FC - \delta\ 80\%FC)].K, \quad (1)$$

where: m – irrigation norm in mm; α – soil density in g cm^{-3}; H – depth of the active soil layer in m (H = 0.50 m); δ of FC – marginal land moisture in % relative to absolute dry weight of soil, % of soil moisture content in % relative to absolute dry weight of soil; K – reduction coefficient of irrigation rate by plants occupied area in 1 ha.

The yield was determined in four repetitions for each variant in t.ha^{-1}. The statistical processing of the yields was performed on the ANOVA (Analysis of variance) dispersion analysis for each experimental year.

Meteorological characterization of the experimental years 2020/2021. Results of the study

The statistical evaluation of the experimental year in terms of temperature sum and rainfall totals was done for the period April – September. A 60-year series of outdoor air temperature and rainfall data for the period 1958–2021 was examined and the probability of exceedance curves was determined. In terms of air temperature, both the years 2020 and 2021 are characterized as very warm with a 7.78% and 9.13% probability of exceedance. In terms of rainfall, both years are very dry with a 95.67% (2020) and 94.07% (2021) probability of exceedance (Figure 1).

The distributions of monthly mean daily temperatures and rainfall total for the growing season are presented in Table 2 and Table 3.

As can be seen from Table 3, the highest mean daily temperatures are observed during the months of July and August, which coincides with the vegetation phase of flowering initiation and crop formation. For the tomatoes, this period is critical for flowering tassel and yield. Average temperatures measured at 14 hours reach 30–35°C, which adversely affects the development of crops and requires irrigation.

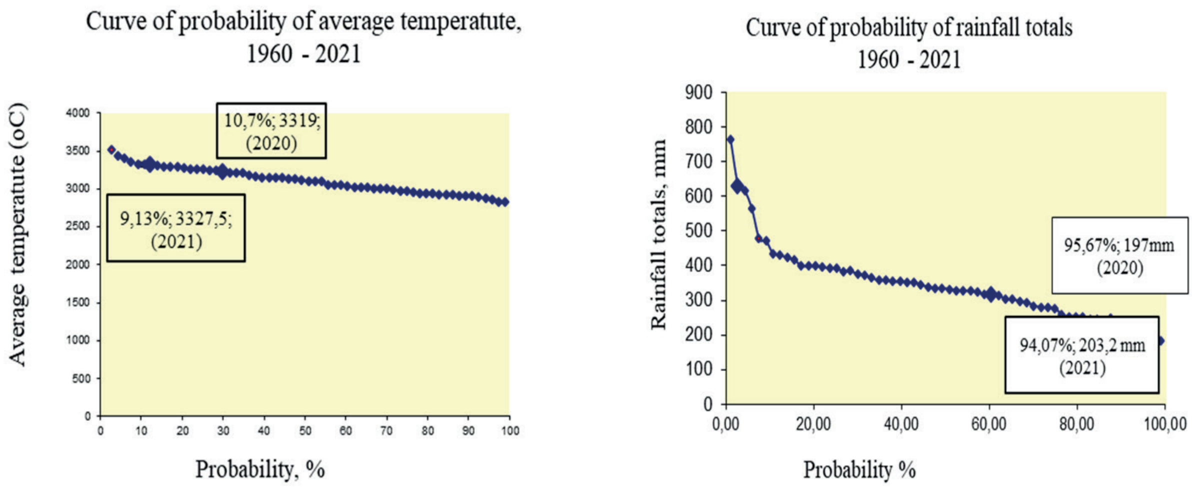

Fig. 1. Probability of exceedance curves of mean daily temperature and rainfall total for the period 1960-2021

Source: Authors' own elaboration

Table 2. Monthly sums of daily mean air temperatures in oC in the experimental field Chelopechene for the period April – September 2020/2021

Month/year	IV	V	VI	VII	VIII	IX	Total:
2020	322.75	500.50	581.00	670.25	652.50	592.25	3319.00
2021	282.00	495.00	594.00	754.00	711.00	489.00	3327.00
1960–2021	–	–	–	–	–	–	3219.45

Source: Authors' own elaboration

Table 3. Monthly rainfall totals (mm) in the experimental field in Chelopechene for the period April – September 2020/2021

Month/year	IV	V	VI	VII	VIII	IX	Total
2020	11.9	20.0	19.3	55.0	56.8	34.0	196.9
2021	17.6	31.3	51.4	29.0	57.8	16.4	203.2
1960–2021	–	–	–	–	–	–	354.68

Source: Authors' own elaboration

The rainfall during the crop growing season is unevenly distributed, which necessitates the implementation of irrigation to replenish the soil stock within the range of 80% of the Field Capacity (FC) to 100% FC.

The analysis of weather conditions shows that the years studied are almost similar – warm and dry during the vegetation. This has a corresponding effect on the evapotranspiration of the tomato and on its productivity, especially on the need for irrigation.

Results and Discussion

Irrigation rates and irrigation norms

With the conducted experimental studies, the irrigation regime of tomato grown outdoors on Leached cinnamon forest soil in the area of Sofia field was established. The preirrigation moisture content of 80% of the FC under drip irrigation was assumed from literature sources. The distribution of irrigation in relation to the biological characteristics of the crop was established. The experimental data were the basis for developing an overall tomato irrigation scheduling for both the study area and similar areas.

During the vegetation period of the crop from May to September of 2020, depending on the indicators of soil moisture, 14 irrigations were realized with an average irrigation rate of 19.30 mm and an irrigation norm 275 mm at 100% full irrigation rate. Irrigation with an average irrigation rate of 18.80 mm and an irrigation norm 187.96 mm at 100% full irrigation rate was applied for 2021.

Depending on the type of soil and rainfall in the initial period, tomatoes development (from planting 23.05.2020 and 27.05.2021 to the beginning of flowering 30.06.2020 and 5.07.2021) need one irrigation per week. During the massive flowering (from 10.07.2020 to 15.08.2020), the need for water strongly increases and it is necessary to irrigate twice a week or eigth irrigations per month. In heavy soils, such as Leached Cinnamon forest soil, irrigation is usually done 1–2 times a week (during flowering). In July and August toma-

Table 4. Irrigation scheduling elements for 2020 and 2021

Variant	Regarding the irrigation rate in %	With regard to fertiliser feeding in %	Number irrig. rate 2020	Irrig. rate mm	Irrig. norm mm	Number irrig. rate 2021	Irrig. rate mm	Irrig. norm mm
T_1	100 % m	0	14	19.30	275	10	18.8	187.96
T_2	100 % m	$N_{15}P_8K_{15}$	14	19.30	275	10	18.8	187.96
T_3	100 % m	$N_{20}P_{12}K_{20}$	14	19.30	275	10	18.8	187.96
T_4	100 % m	$N_{25}P_{16}K_{25}$	14	19.30	275	10	18.8	187.96
T_5	50 % m	0	14	9.65	137.5	10	9.4	93.98
T_6	50 % m	$N_{15}P_8K_{15}$	14	9.65	137.5	10	9.4	93.98
T_7	50 % m	$N_{20}P_{12}K_{20}$	14	9.65	137.5	10	9.4	93.98
T_8	50 % m	$N_{25}P_{16}K_{25}$	14	9.65	137.5	10	9.4	93.98

Source: Authors' own elaboration

toes need one irrigation every 4 days 2020 and 2021, and in September due to reduced evapotranspiration of the crop and rainfall no irrigation is required. In 2020, five harvests were carried out until the first ten days of October. The first two harvests were on 25.08 and 30.08, every 5–7 days, and the next ones, due to a drop in average daily temperatures, every 10–15 days. The last harvest was carried out on 7.10.2020, because frost fell and the harvest was not fit for consumption. For 2021, 7 harvests were carried out, the first one started on 20.08.2021, and the last one on 25.10.2021. Petrevska (1999), in a three-year investigation of tomato crop, proved that the treatments with drip fertigation have the most economical effect. Tanaskovik (2005) also presented high positive effect of drip fertigation similar to our results.

The fresh tomato yield results are presented in Table 5.

The data from Table 4 show that the highest yields at soil-meteorological conditions of 2020 in the Sofia field were obtained with the full irrigation with 100% realization of irrigation norms and fertilization rate $N_{20}P_{12}K_{20}$, – 66.01 t ha^{-1}**,** and the lowest yields were received in the unfertilized variants in both irrigation norms. The interaction of the tested factors – “water – fertilization” on the amount of yields is analyzed. The results show that the highest yields at both irrigation rates (100% and 50% M) are obtained from the fertilized variants, as the increase in yields is from 25% for the variants irrigated with 50% M to 31% for variants irrigated with 100% M compared to non-fertilized variants. From the used fertilizer rates, the yields are highest in the variant with fertilizer rate $N_{20}P_{12}K_{20}$ and 100% M, and the lowest in the non-fertilizer variant 45.81 t ha^{-1}.

The results from 2021 (Table 5) show that the highest yields at both irrigation rates (100% and 50% M) are obtained from the fertilizer variants. The increase in yields from the applied fertilization rates is from 44% for variants irrigated with 50% M to 53% for variants irrigated with 100% M compared to non-fertilized variants. The yields are the highest 63.04 t ha^{-1} from the variant with fertilizer norm $N_{20}P_{12}K_{20}$ and 100% M, and the lowest from the non-fertilized variant and 50% M – 24.36 t ha^{-1}.

The size of the irrigation norms (100% M and 50% M) has a significant impact on the obtained yields. The effect is highest during the 2021 in the without fertilization variants – about 30%, while in 2020 it is 9%, because of the fallen precipitation after the irrigations. The difference in yields according to irrigation norms for the highest fertilization rates leads to increase in yields by 18% during 2020 and 13% during 2021.

Conclusions

The results obtained from the production of the determinant tomato variety “Nikolina” F1 under different irrigation and fertilization regimes in 2020/2021 shows:

The statistical evaluation of the experimental years in terms of temperature and precipitation for the April–September period, based on 60 years of data (1958–2021), shows that both 2020 and 2021 are characterized as very warm, with probabilities of 7.78% and 9.13%, respectively. In terms of precipitation, both years are classified as very dry, with probabilities of 95.67% (2020) and 94.07% (2021).

During the vegetation period of the crop from May to September in 2020/2021, depending on soil moisture indicators, 14/10 irrigations were applied, with an average irrigation rate of 19.30/18.80 mm and an irrigation norm of 275/188 mm at 100% full irrigation.

The total tomato yield under full irrigation is 17% higher than the yield under deficit irrigation. It has been found that

Table 5. Yields from determinant sort tomato “Nikolina” F_1 for 2020/2021

Variants		Yield 2020			Yield 2021			
		t ha^{-1}	±Y	Proof	t ha^{-1}	±Y	Proof	
1	100%M, 0	45.81	St.	St.	33.48	St.	+++	1
2	100%M, $N_{15}P_8K_{15}$	61.31	16.50	+++	56.34	22.85	+++	2
3	100%M, $N_{20}P_{12}K_{20}$	66.01	20.19	+++	63.04	29.56	+++	3
4	100%M, $N_{25}P_{16}K_{25}$	58.26	12.45	+++	58.00	24.51	+++	4
5	50%M, 0	41.92	3.88	+++	24.36	- 9.12	+++	5
6	50%M, $N_{15}P_8K_{15}$	50.99	5.17	+++	43.65	10.16	++	6
7	50%M, $N_{20}P_{12}K_{20}$	54.77	8.96	++	55.03	21.54	++	7
8	50%M, $N_{25}P_{16}K_{25}$	55.37	9.56	++	47.89	14.41	+++	8
	2020 GD при P: 5% = 2.34 t.ha^{-1} 1% = 4.58 t.ha^{-1} 0,1% = 6.48 t.ha^{-1} *2021 GD при P: 5% = 4.05 t.ha^{-1} 1% = 5.58 t.ha^{-1} 0,1% = 7.53 t.ha^{-1}*							

Source: Authors’ own elaboration

combining irrigation levels with different fertilization rates significantly affects tomato yield. The results show that the treatments with the highest fertilization rate produce the highest yields under both full and deficit irrigation (66.01 and 54.77 t ha^{-1}, respectively).

Acknowledgement

The present work is based on researches that are funded from the Agricultural Academy, Sofia, Project: "Advanced technological approaches and technical means for obtaining sustainable and healthy agricultural products in modern meteorological conditions and measures for environmental protection.", 2020–2022.

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Received: **October, 08, 2024**; *Approved*: **December, 17, 2024**; *Published*: **April, 2026**