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Effect of irrigation regime and level of fertilization on morphological indicators and precocity of tomato greenhouse production

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Abstract

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The main aims of this study is to analyze the effects of different irrigation regimes and norms of fertilization on morphological indicators and precocity of tomatoes, greenhouse production. The study of the influence of the irrigation regime was carried out against the background of different levels of fertilization. The experiment is derived by the block method on a flat surface according to scheme 110 + 50 + 35 with the size of the plot of 10 m^2. The irrigation water was realized using a drip irrigation system with built-in droplets of 0.10 cm. In the first experimental year, 33 irrigations with an irrigation rate of 4950 m^3/ha were delivered. The irrigation rate in the second year is 4050 m^3/ha, realized through 27 irrigations. The size is dependent on the length of the growing season and on the need to irrigate in the optimum variant. The power of influence of the interaction of the factors irrigation and fertilization is established on the indicator plant height – it was 77.9%, average for the study period. Factors in relation to other morphological indicators are with less force of impact. It was found that a strong influence on the variation of the trait has a factor fertilization, the force of impact by 81% for the 1st harvest. Established role of the factor irrigation average for the period, with a high degree of reliability, is 91.8% on the 2nd harvest. The high degree of influence of the irrigation factor on the 3rd harvest indicator is established, which is 86.9%, average for the period. According to the one-factor dispersion analysis, the influence of both factors (irrigation and fertilization) separately, as well as their interaction, statistically proved with a very high degree of significance ($p \leq 0.001$) is the impact on the "total yield" indicator. The fertilization has the strongest influence on the variation of the trait, with the force of impact 99% for the indicator "total yield".

Keywords: greenhouse tomatoes, irrigation, fertilization, power of influence

Introduction

The production of vegetables is traditional for our country. Climate conditions determine the seasonality of vegetable production and the main purpose and importance of greenhouse production is to solve the problem of the year-round supply of fresh vegetables. The more favorable conditions for cultivating the crop have a direct impact on the amount of the costs, as well as on the yields and the quality of production. Regardless of the numerous studies in Bulgaria and abroad, related to the growth and productive manifestations of tomatoes, as well as to the various norms, forms and methods of fertilization, there is still no algorithm for precise and correct determination of fertilizer norms (Hartz, 2007; Javaria et al., 2012; Vasileva et al., 2016). Tomatoes are a crop of great productive potential, making them one of the most important vegetables. Tomatoes have specific requirements for the easy absorption of potassium from the soil. This could be achieved by fractional fertilization, which would provide the prolonged acceptance of quantities available in the vegetation (Vassileva, 2015).

Potassium fertilization has been shown to have a positive influence on the vegetative mass and the productivity of tomatoes (Boteva & Kostova, 2009), and the yield of fruit and vegetative mass mainly influences the export of macroelements (Mitova, 2014). On the basis of the amounts of nutrients exported from the soil with the biological yield, the optimal fertilization norms (Belichki et al., 1982) are determined. A team of scientists (Vasileva et al., 2013) finds that the export of macroelements follows the high yields. Application of different strategies, including irrigation in regulated water deficit, increase the efficiency of irrigation water, thus minimizing losses and maintaining the quality of the fruit (Patanè & Cosentino, 2010; Patanè et al., 2011; Kuşçu et al., 2014; Nangare et al., 2016). The efficiency of fertilizer and irrigation water use is also investigated by Du et al. (2017). Studying the impact of irrigation and fertilization with different levels of nitrogen, they establish the optimal irrigation regime (75% air) and fertilization norms (250 kg N ha^{-1}) and recommend the best strategy for water and nitrogen management for greenhouse tomato production , grown under drip irrigation conditions.

Particularly topical is the issue of efficient use of water resources. Therefore, in different parts of the world studies continue related to crop tolerance to water deficit stress in different phases of development (Ngouajio et al., 2007; Favati et al., 2009; Jensen et al., 2010; Yang et al., 2017; Zhang et al., 2017).

In connection with the constantly improving technologies and the fast growing production varieties, the fertilization and irrigation parameters of each tomato variety are of interest. The main aims of this study is to analyze the effects of different irrigation regimes and norms of fertilization on morphological indicators and precocity of tomatoes, greenhouse production.

Material and Methods

In order to meet the target in 2016-2017 in the experimental field of the Maritza Vegetable Crops Institute, Plovdiv had experience in an unheated polythene greenhouse. The subject of the study was a hybrid variety of tomato Vitelio. The study of the influence of the irrigation regime was carried out against the background of different levels of fertilization. The experiment is derived by the block method on a flat surface according to scheme 110+50+35 with the size of the plot of 10 m^2 (Barov, 1982). The variants of the study were based on the following scheme:

Experience has been conducted with four fertilization and feeding schemes. Basic fertilization where P_{23} (in the form of P_2O_5) and K_{25} (as K_2SO_4) are introduced. The remaining 3 fertilization schemes include basic fertilization plus 50%, 75% and 100% feeding with N_{50} (as NH_4NO_3) and K_{66} (as KNO_3).

Irrigation is done in an optimal and broken irrigation regimes. The regulated water deficit is carried out by realizing 50% and 75% irrigation rate. During the two years there were irrigations with regulated size of irrigation rate and different number. The irrigation time is determined by taking soil samples to determine moisture in the soil horizon of the option with 100% irrigation rate.

The irrigation water was realized using a drip irrigation system with built-in droplets of 0.10 m. In the first experimental year, 33 irrigations with an irrigation rate of 4950 m^3/ha were delivered. The irrigation rate in the second year is 4050 m^3/ha, realized through 27 irrigations. The size is dependent on the length of the growing season and on the need to irrigate in the optimum variant.

In order to investigate the effects of the irrigation regime and the feeding of tomatoes during vegetation, as well as their interactions, the morphological indicators of the tomatoes, the height of the plant, the number of leaves, the inflorescences, the wounds, as well as the single-factor variance analysis, R version 3.4.4 (2018-03-15) were used.

Results and Discussion

During the growing season of tomatoes, greenhouse production, the morphological features and phenological features of the plants under different feeding and irrigation options, the following indicators were studied: stem height, number of leaves formed, number of inflorescences, number of wounds. The duration of the planting period to the 1st harvest and the period from the 1st to the last harvest was determined. In the first year, the duration of the planting period to the 1st harvest is 84 days, and the period from the first harvest to the last is 70 days.

For the second year, the planting period up to the 1st harvest was established for 80 days, with a difference of 4 days compared to the first year. The second period, covering the period from 1st to last harvest, has a duration of 60 days. The size of the vegetation period also determines the size of the irrigation rate, which is 18% lower with a 140 days vegetation.

The parameters of tomato harvesting in greenhouse production, cultivated under conditions of irrigated irrigation regime and different fertilization norms have been established. The development of vegetable crops in a short period of time necessitates the application of high, in many cases unjustified, fertilization standards. The absorption capacity of nutrients as well as the interaction between irrigation and fertilization is not sufficiently clear.

In each variant, the influence of the fertilizer norm and the irrigation regime on the vegetative manifestations of the plants is monitored. It is important to note the role of vegetative mass of plants to feed more fruit. The high yield and the early age of culture depend on the balanced ratio between the leaf-berry mass and the number of colors. The results show an excess of 6 to 21% of the fed variants compared to the untreated control.

Using the statistical program, an analysis of each indicator was performed. The independent influence and the interaction of the two studied factors were investigated on the morphological indicators and the early tomatoes.

The influence on the indicator plant height for 2017 was statistically proven with a very high degree of significance ($p \leq 0.001$), according to the one-factor dispersion analysis, the influence of both factors (irrigation and fertilization) separately, and their interaction (Table 1). The fertilizer factor (91.5%) was most affected by the variation in the indicator in 2017.

Factors interactions in the second year have an impact strength of 83.3% with a very high degree of significance ($p \leq 0.001$). In the first experimental year, the power of influence was 72.5% at a significance level $p \leq 0.01$. On average, for the two years of experience, a slight influence of the irrigation factor on the plant height was found to be 20.6%.

It was found that fertilizing with 75% of the fertilizer rate, with a 50% reduction in irrigation regime, contributed to the best plant cellularity in the first experimental year. In the second year, the conditions for feeding and irrigation favor the formation of the largest vegetative mass in optimal fertilization and irrigation.

The statistical analysis of the results for the two experimental years shows the influence of the studied factors on the number of leaves (Table 2). The interaction of the factors, on average for the two years, is characterized by an influence force of 14.5%. Average for the period, the influence of fertilization is 32.0% and irrigation is 17.1%, respectively. As can be seen from the tables presented (Table 5 and 6), the influence of both factors is statistically unproven.

The balanced ratio between leaf-berry mass and the number of flowers, respectively the fruits in the flower, ensures the synthesis of enough plastic substances, providing a high yield at great economic prematurity. At the optimal irrigation rate, a reduction of the number of inflorescences was registered by 12.5% compared to the variant with a reduced (75%) irrigation rate. Knowledge of vegetative events is a prerequisite for accurately determining the size of the food area and proper regulation.

The analysis of the two-year results shows an increase in the number of inflorescences in increasing the moisture content (Table 3). The influence of irrigation and fertilization factors on the biometric count number of inflorescences was established for both years in tomatoes. The influence of the irrigation factor is 25% and 50%, respectively, for each year. For the fertilizing factor an influence force of 36.8% and 25% was established. The complex impact of both factors during the two year survey was found to be 20% and 25%, respectively. The influence of both factors on this indicator is not statistically proven.

Table 1. Statistical analysis of the irrigation factors and level of fertilization on the height of tomatoes for the period 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	11.48%	72.22	2	36.11	0.39	0.694
Residuals		556.67	6	92.78		
Fertilization	36.78%	128.00	2	64.00	1.75	0.253
Residuals		220.00	6	36.67		
Irrigation & Fertilization	72.48%	226.50	5	45.30	6.32	0.004**
Residuals		86.00	12	7.17		
2017						
Irrigation	29.60%	206.00	2	103.00	1.26	0.349
Residuals		490.00	6	81.67		
Fertilization	91.49%	2366.00	2	1183.00	32.26	0.0006***
Residuals		220.00	6	36.67		
Irrigation & Fertilization	83.28%	428.50	5	85.70	11.96	0.0003***
Residuals		86.00	12	7.17		

***, **, *, · – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

Table 2. Effect of irrigation and fertilization level on the number of leaves of tomatoes, 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	30.77%	24.00	2	12.00	1.33	0.332
Residuals		54.00	6	9.00		
Fertilization	33.23%	24.22	2	12.11	1.49	0.298
Residuals		48.67	6	8.11		
Irrigation & Fertilization	17.24%	22.50	5	4.50	0.50	0.771
Residuals		108.00	12	9.00		
2017						
Irrigation	3.57%	2.00	2	1.00	0.11	0.897
Residuals		54.00	6	9.00		
Fertilization	30.77%	24.00	2	12.00	1.33	0.332
Residuals		54.00	6	9.00		
Irrigation & Fertilization	11.84%	14.50	5	2.90	0.32	0.890
Residuals		108.00	12	9.00		

***, **, *, ˙ – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

Table 3. Effects of irrigation and fertilization levels on the number of inflorescences in greenhouse tomatoes, 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	25.00%	8	2	4.00	1.00	0.422
Residuals		24	6	4.00	–	–
Fertilization	36.84%	14	2	7.00	1.75	0.252
Residuals		24	6	4.00	–	–
Irrigation & Fertilization	25.00%	16	5	3.20	0.80	0.571
Residuals		48	12	4.00	–	–
2017						
Irrigation	50.00%	24	2	12.00	3.00	0.125
Residuals		24	6	4.00		
Fertilization	25.00%	8	2	4.00	1.00	0.422
Residuals		24	6	4.00		
Irrigation & Fertilization	20.00%	12	5	2.40	0.60	0.701
Residuals		48	12	4.00		

***, **, *, ˙ – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

The analysis of the results for early culture shows that the share of the second harvest is highest during the first experimental year (Tables 4, 5, 6). In the second year, the third harvest is the largest. Highest economic precocity is observed in the zero-fertilization option and half-irrigation rate. On average, for the high-rise period, the variant with half the irrigation and fertilizer rate stands out too. For all other options, economic precocity is lower than in the control.

Against the background of the same fertilizing norms in the variants with different irrigation norms there is a decrease in the early age with an increase of the irrigation norms. With the increase of the fertilizer rate in the same irrigation regime, the economic precocity decreases, the lowest in the maximum fertilizer and water regime.

When the indicator 1st harvest of tomatoes statistically proven at a very high level of significance ($p \leq 0.001$), the effect of irrigation and fertilization for 2016 is 65.9% and 85.3%, respectively. While 2017 though with a lower degree of proof is established a strong influence of the factor of irrigation (65.9%). The impact of fertilization is 76.4% for the second year of experiment (Table 4). According to the analysis, the influence of interaction between the two factors has been statistically proven with a very high degree of significance over both years. On average, the impact of fertilization is 80.9% and the impact of irrigation is 65.9%.

The influence of the two factors (irrigation, fertilization) on the indicator of 2nd harvest of tomatoes for two years, separately and their interaction, is statistically proven at a

Table 4. Effect of irrigation and fertilization level on the 1st harvest of tomatoes, 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	65.91%	14089.30	2	7044.60	70.34	6.844e-05***
Residuals		600.90	6	100.10		
Fertilization	85.31%	3485.90	2	1742.90	17.43	0.0032**
Residuals		600.00	6	100.00		
Irrigation & Fertilization	83.46%	6269.80	5	1253.95	12.11	0.0002***
Residuals		1242.60	12	103.55		
2017						
Irrigation	65.94%	1162.53	2	581.26	5.81	0.039*
Residuals		600.43	6	100.07		
Fertilization	76.40%	1943.06	2	971.53	9.71	0.013*
Residuals		600.17	6	100.03		
Irrigation & Fertilization	70.20%	3167.90	5	633.57	5.65	0.007**
Residuals		1344.60	12	112.05		

***, **, *, · – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

Table 5. Effect of irrigation and fertilization level on the 2nd harvest of tomatoes, 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	88.19%	4818.70	2	2409.33	22.40	0.002**
Residuals		645.30	6	107.56		
Fertilization	98.08%	43510	2	21755.10	153.45	7.051e-06***
Residuals		851	6	141.80		
Irrigation & Fertilization	98.35%	91995	5	18398.90	143.24	2.874e-10***
Residuals		1541	12	128.40		
2017						
Irrigation	95.33%	491.35	2	245.67	61.25	0.0001***
Residuals		24.07	6	4.011		
Fertilization	68.02%	1613.45	2	806.72	6.38	0.0327*
Residuals		758.67	6	126.45		
Irrigation & Fertilization	68.93%	2530.20	5	506.03	5.32	0.0083**
Residuals		1140.70	12	95.05		

***, **, *, · – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

very high degree of significance ($p \leq 0.001$) (Table 5). Strong influence on the variation of the trait appears for factor fertilization (98.1%) in 2016 and factor irrigation (95.3%) in 2017. Statistically proven with high reliability is the influence of interaction of the factors in the first year (98.4%), while in the second year the power of influence is 68.9%. The influence of the irrigation factor (91.8%) on the second grading indicator was determined on average over the period with a high degree of reliability.

The average values for the influence of the fertilization factor (83.05%) and the interaction of the irrigation factors and fertilization levels (83.6%) are also characterized by high values. The interaction of both factors has been statistically proven over the two years with a high degree of significance.

In analyzing the impact of factors on the indicator 3rd harvest it is established high degree of influence of irrigation on the average for the period – 86.9% (Table 6). A strong influence is established in the first year (92.98%), with a high level of significance ($p \leq 0.001$). The impact of fertilization is also characterized by high values – 71.56% and 83.13%, respectively for the two years (Table 6). The complex influence of the factors is more pronounced in the first year, with an impact force of 96.13% and a high level of significance ($p \leq 0.001$).

Statistically significant effect of the test factors on overall yield is established over the two years of the experiment (Table 7). The influence of the irrigation factor is 66.7% and 99.3%, respectively. The power of influence of the factor fertilizer is 98.8% and 99.3% for every year, and the interac-

Table 6. Effect of irrigation and fertilization level on the 3rd harvest of tomatoes, 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	92.98%	8505.10	2	4252.50	39.71	0.0003***
Residuals		642.60	6	107.10		
Fertilization	71.56%	878.10	2	439.05	7.55	0.0230*
Residuals		348.99	6	58.17		
Irrigation & Fertilization	96.13%	29809.40	5	5961.90	59.56	4.71e-08***
Residuals		1201.30	12	100.10		
2017						
Irrigation	80.73%	2788.03	2	1394.01	12.57	0.007**
Residuals		665.57	6	110.93		
Fertilization	83.13%	2524.01	2	1262.00	14.78	0.005**
Residuals		512.19	6	85.37		
Irrigation & Fertilization	69.95%	1379.95	5	275.99	5.59	0.0070**
Residuals		592.85	12	49.40		

***, **, *, ˙ – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

Table 7. Effect of irrigation and fertilization on the level of total yield of tomatoes, 2016–2017

Source of variation	Power of influence	Sum Sq	Df	Mean Sq	F value	Pr (>F)
2016						
Irrigation	66.70%	1961678	2	980839	6.01	0.037*
Residuals		979522	6	163254		
Fertilization	98.75%	16673678	2	8336839	237.24	1.947e-06***
Residuals		210842	6	35140		
Irrigation & Fertilization	99.70%	50550674	5	10110135	790.83	1.12e-14***
Residuals		153410	12	12784		
2017						
Irrigation	99.26%	453102	2	226551	403.35	4.024e-07***
Residuals		3370	6	562		
Fertilization	99.25%	23605386	2	11802693	396.35	4.239e-07***
Residuals		178672	6	29779		
Irrigation & Fertilization	99.96%	76135242	5	15227048	6090.80	2.2e-16***
Residuals		30000	12	2500		

***, **, *, ˙ – proven in $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.1$

tion of the two factors has the effect of influence 99.7% and 99.96% at a high significance level ($p \leq 0.001$).

Conclusions

The power of influence of the interaction of the factors irrigation and fertilization is established on the indicator plant height – the average for the study period is 77.9%. With less force of impact are factors in relation to other morphological indicators.

It was found that a strong influence on the variation of the trait has the factor fertilization, with the force of impact by 81% for the 1st harvest.

Average for the period, the factor irrigation has high influence on the indicator 2nd harvest (91.8%), with a high degree of reliability.

The high degree of influence of the irrigation factor on the 3rd harvest indicator is established – 86.9%, average for the period.

According to the one-factor dispersion analysis, the influence of both factors (irrigation and fertilization) separately, as well as their interaction, statistically proved with a very high degree of significance ($p \leq 0.001$) is the impact on the "total yield" indicator. The strongest influence on the variation of the trait has fertilization factor, the force of impact from 99% for the indicator "total yield".

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