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PRODUCTIVITY OF COTTON VARIETIES AND EFFICIENCY OF IRRIGATION

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Abstract

The study was conducted in the period 2018-2020 in the Training and Experimental Base of the Department of Plant Breeding at the Faculty of Agriculture of the Trakia University - Stara Zagora on soil type typical meadow-cinnamon soil in fertilizer experience in non-irrigated and irrigated conditions. The field experience is by the method of fractional plots in four repetitions with the size of the harvest plot 15 m^2 (1.80 x 8.34 m). The research factors are: irrigation (A), variety (B), fertilization rates (C) and meteorological conditions during the marketing year (E). The study was conducted with three varieties of cotton - Helius, Darmi and Isabell, with three levels of nitrogen fertilization - 80, 160, 240 and 0. The effect of irrigation on cotton productivity has been established. As a result of the conducted Polish research, it was established that the total yield of unginned cotton realized on average for the research was very good – 1,945.2 kg/ha. The average yield under irrigated conditions exceeds the yield without irrigation by 34%. The Darmi variety stands out as the most productive and promising compared to Helius and Isabell. The optimal nitrogen rate of the tested is N_{160}. When fertilizing with N_{240}, the yield shows a downward trend compared to N_{160} and this fertilization is not effective. On average for the period, at the four levels of nutritional regime, the effect of 100 m^3 of irrigation water was established – 89.81 kg/ha. With the naturally coloured variety Isabel, the effect is the highest, on average for 4 levels of fertilization – 100.75 kg/ha.

Key words: *productivity, efficiency, cotton, irrigation, fertilization, yield*

INTRODUCTION

Cotton is a valuable crop, which in terms of cultivated area in the world occupies the sixth place after wheat, rice, corn, barley and sorghum (the group of the main crop for the nutrition of mankind). In terms of total and net income per unit of area, it ranks in one of the first places. Cotton productivity varies greatly with moisture conditions during the growing season.

Deficit or regulated deficit irrigation is one way to increase water use efficiency for higher yield per unit of irrigation. The goal of deficit irrigation is to increase the efficiency of irrigation water use by reducing the amount of irrigation water or by reducing the number of irrigation events (Wu et al., 2010) [18]. Under deficit irrigation, crops are deliberately exposed to water stress, resulting in reduced yield (Igbadun et al., 2008; Zhang et al., 2017) [6, 21].

According to Saldzhiev and Raykov (2010) [12], the reduction of the irrigation rate of 120 mm for cotton by 25% and 50% does not lead to adequate changes in yield - the decline in these cases is respectively 9.20% (26.1 kg/da) and 12.50% (35.5 kg/day). By reducing the irrigation rate to 60 mm, the cost of irrigation is reduced to 62%, the net income of 100 m^3 of irrigation water is the highest, and the effect of 1 m^3 of water is the greatest.

The degree of desiccation affects the content of chlorophyll a, chlorophyll b and carotenoids, which is explained by their biological role to protect chlorophyll from photooxidation under stress conditions (Koleva and Vasilev, 2012) [8].

Shareef et al. (2018) [14] also recorded a decrease in leaf area index. Fiber length was also shortened in response to water stress, while fiber strength index, fineness, and uniformity were not affected by irrigation levels. The efficiency of drip irrigation has been studied in a large range of crops (Saldzhiev and Nikolov, 2005; Mahan et al., 2018; Saldzhiev et al., 2014; Stoyanova and

Valchev, 2018; Stoyanova et al., 2019) [11, 10, 13, 16, 17].

Research on the influence of fertilization with nitrogen fertilizer applied with irrigation water found that a reduction of the rates by 18.75% did not reduce the quantity and quality of yields and increased the efficiency of use of supplied irrigation water (Zugui et al. 2003; Aujla et al. 2005; Li et al., 2017) [22, 1, 9].

Yang et al. (2015) [19] consider the impact of the limited supply of irrigation water and its efficient use, in the context of global trends towards gradual warming and drying.

Investigating the impact of drip irrigation fertigation on the efficiency and productivity of cotton, Jayakumar et al. (2015) [5] found the positive influence of drip fertilization on crop potential and soil fertility.

Aujla et al. (2005) [1] concluded that a reduction in the amount of water applied leads to a reduction in the agronomic efficiency of nitrogen. Drip irrigation increases the agronomic efficiency of nitrogen application compared to gravity irrigation.

Stamatiadis et al. (2016) [15] found that reduced water supply causes a change in the distribution of N in plants, with seeds absorbing nitrogen to the highest extent under water stress conditions.

Optimizing fertilization and irrigation in agricultural crops is a feasible production practice for optimal economic results.

The main objective of the present study is to investigate the productivity of cotton varieties under drip irrigation conditions, as well as the efficient use of water resources.

MATERIALS AND METHODS

The field experience was brought to the experimental field of the Faculty of Agriculture at Trakia University, Stara Zagora. The soil is meadow-cinnamon soil, medium sandy-loamy. The power of the profile is 103-105 cm, with well-formed horizons. The humus horizon is clearly expressed with limits of 0-45 cm. For the root-inhabited layer 0-60 cm, the soil is characterized as having an average humus content of 2.08-3.00%.

The experiment was set up using the method of fractional plots in four repetitions with the size of the harvest plot 15 m^2 (1.80 x 8.34 m). The object of the study are three cotton varieties: two with white color (Hemus and Darmi) and one with natural brown colored fiber (Isabell).

The field study was carried out under irrigated and non-irrigated conditions at four fertilization levels. The volumetric mass for the surface soil layer is 1.07 g/m³ and reaches 1.34 g/m³ in the 60-80 cm layer. The relative density is 2.65-2.72. The average marginal field moisture content in the 0-40 cm layer is 31.6%. Irrigation was carried out with a drip irrigation system with built-in drippers at 0.15 m, with an irrigation rate of 150 mm when the soil moisture was below 75% of the RH for the layer 0-50 cm. Soil moisture dynamics were measured periodically with a soil moisture probe.

The rates of nitrogen fertilization for cotton are 0; 80; 160 and 240 kg/day. Nitrogen as NH_4NO_3 for cotton was applied once pre-sowing. The soil in the experimental area is characterized by a slightly alkaline to alkaline reaction with values for pH (H_2O) in the arable horizon of 7.7. In the arable layer 0-30 cm, the mineral nitrogen is in the range of 75.32 to 80.12 mg/1,000 g of soil, which corresponds to a good nitrogen supply of the soil. In terms of mobile phosphorus, the soil has low to medium reserves. In the 0-30 cm layer, its content is 4.01-5.12 mg/100 g of soil, and it slightly decreases in the lower soil layer. The content of mobile potassium in the layer 0-60 cm is 31.03-39.6 mg/100 g soil, which characterizes the soil as very well stocked with potassium.

RESULTS AND DISCUSSIONS

Agrometeorological characteristics in relation to the growth and development of cottonThe field experiment was conducted in the period 2018-2020 at a site with an altitude of 169 m and located at 42°41'51.75" N latitude, 23°19'18.722" E longitude. In terms of climate, the region falls into the European-continental region and the Transitional-continental subregion of it. The years of the

Polish study are meteorologically characterized by significant differences in measured mean diurnal temperatures by month compared to the multi-year period (1930-2020). The average annual temperature for the three-year period is 13.8°C (ranging from 13.6°C in 2018 to 13.9°C in 2020), which is 1.5°C above the multi-year average temperature values for the area (12.3ºC). For the period 1930-2020, an average of 565 mm of precipitation was recorded annually. Over the three years of the study, 672.0 were measured respectively; 477.0 and 574.6 mm. Rainfall is unevenly distributed over the cotton growing season (Fig. 1).

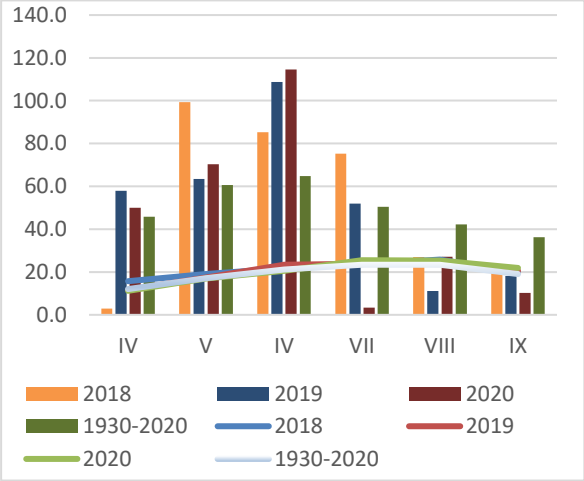

Fig. 1. Dynamics of precipitation and temperatures during the growing season
Source: Author's design.

In the first year, the total amount of rainfall for the months of June, July and August was 187.2 mm, with only 27 mm recorded in August. The average monthly temperatures for the city of April and May exceed the annual norm determined for a period of 90 years by 3.68 and 1.94 ºC respectively. Cotton vegetation occurs under favorable humidity and temperature conditions in the second year. The average monthly temperatures measured show an excess for all months compared to the average values, with the most significant differences in May (+1.94 °C), June (+2.27 °C), August (+1.83 °C) and September (+1.53 °C). The amount of precipitation in August was 11.2 mm, and due to the high temperatures, it was found that part of the ties were dripping. The last year is characterized as having the least amount of moisture and precipitation. This allowed to record the most significant differences in the growth and development of the plants during the phenological phases of the three tested cotton varieties in the irrigated and non-irrigated field. The high temperatures in July (25.5^0C) and the lack of precipitation caused a severe drop of buds and flowers.

A non-uniform distribution of precipitation was recorded for the growing season throughout the period of the field experiment. The water deficit coincides with the moisture critical flowering-early ripening period. This adversely affects the generative development and productivity of cotton, regardless of the fact that it is characterized as a relatively drought-tolerant crop.

Productivity of cotton varieties

Optimizing the nutritional and water regime is a prerequisite for the varieties to show their biological potential. On average for the period, the lowest yields were obtained in 2020, and the highest - in 2018, respectively by 16.8% and by 28.4% more than the yield in 2019 and 2020. The results establish a tendency towards increasing yields as fertilization levels increase. The lack of nutritional elements, according to Zeng et al. (2014) [20] arrested the development of cotton plants, reduced both the total raw cotton yield and the fiber yield.

Analyzes of the obtained yields show that the Darmi variety stands out with the highest yield of non-ginned cotton during the three experimental years (Figures 2 and 3). On average for the period, the yield of this variety was 1,790.2 kg/ha, exceeding the Helius variety by 8.5% and the Isabel variety by 5.05%. In 2018, 2019 and on average for the period, the Isabell variety showed a tendency to excel over the Helius variety with 4.9 respectively; 1.1 and 3.45%, and in 2020 its yield is lower at 3.84%.

On average for the period, N_{160}fertilization recorded the highest average yield in all combinations, except for the Isabel cultivar under non-irrigated conditions, where the yield was maximum when N_{240} fertilization. When fertilizing with moderate levels of N_{160}, on average for the period, yields were formed

from 1,440.8 kg/ha in the case of the Isabel variety without irrigation to 2,179.1 kg/ha in the case of Darmi with irrigation.

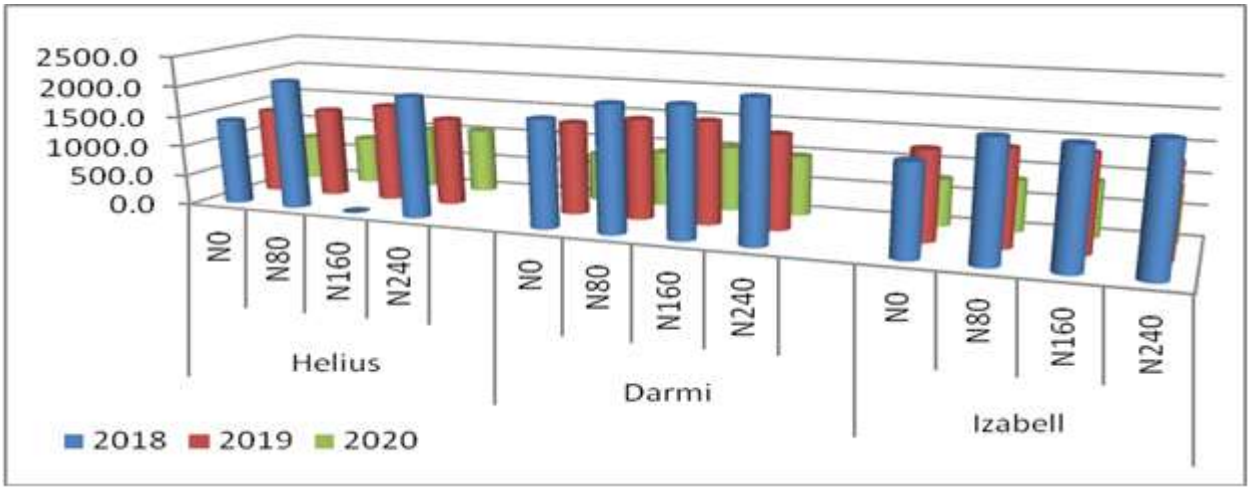

Fig. 2. Production under non-irrigated conditions
Source: Author's design and results.

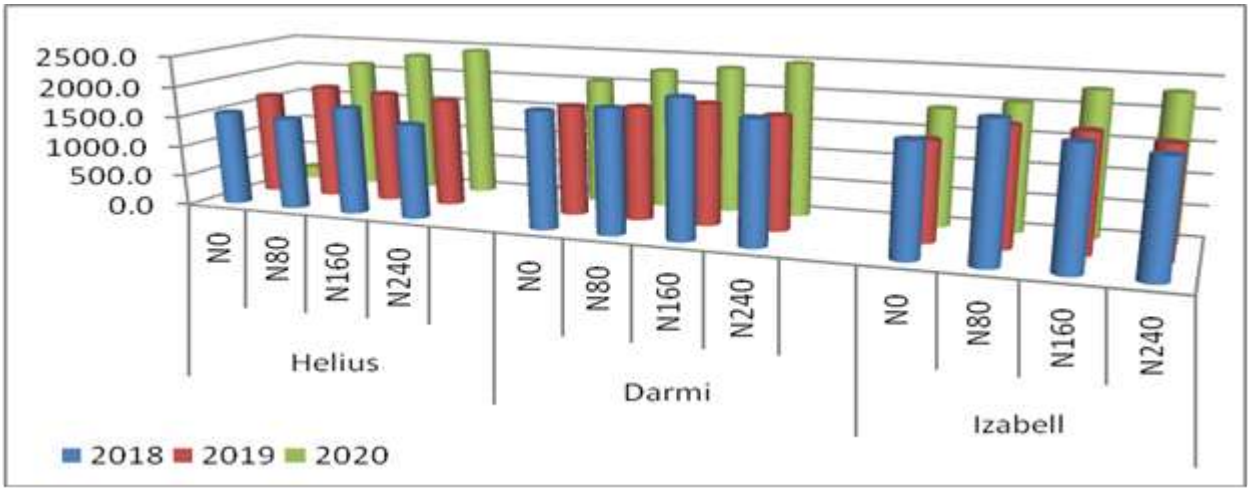

Fig. 3. Production under irrigated conditions
Source: Author's design and results.

Geng et al. (2015) [4] also reported that at the beginning of box filling, a high nitrogen rate may have a negative effect on raw cotton yield due to enhanced vegetative growth.

Over the three-year period, the lowest yields were obtained in 2020, and the highest in 2018, respectively 16.8% and 28.4% more than the yield in 2019 and 2020.

The large difference in yields in the three years confirms the strong influence of the environment - both temperature and humidity conditions.

Nitrogen fertilization of the cotton crop, especially under water deficit, is essential for recovery of growth and development from drought stress, according to Khan et al. (2017) [7].

Table 1 reflects the influence of the factors irrigation, variety and fertilization on the productivity of cotton.

The significant influence of the irrigation regime on the total yield of non-ginned cotton was established – 28.86% of the total influence of the factors, proven at $p \leq 0.1\%$.

Irrigation effect

Table 2 presents the parameters of the additional yield and the effect of 100 m^3 of irrigation water. The average irrigation rate over the three-year period is 7,500 mm.

Depending on the distribution of rainfall in the first year, two irrigations were

implemented, in 2019 – four irrigations, and in 2020 five irrigations were provided.

The parameters of the water used for irrigation in cotton (*Gossypium hirsutum* L.) are dependent on the climatic scenario, also confirm studies by Garcia-Vila et al. (2009) [3].

Table 1. Analysis of dispersion for total unginned cotton yield, average for 2018-2020, for the Stara Zagora region, Bulgaria

Source of variation	Degree of freedom	Sum of squares	Effect of factor,%	Mean squares	Fisher's test	Probability level
Total	71	165,995.8	100.00	-	-	-
Blocks	2	12,209.2	7.35	6,104.6	3.1	n.s.
Variants	23	64,335.8	38.76	2,797.2	1.4	n.s.
Factor A-Irrigation	1	47,907.8	28.86	47,907.8	24.6	***
Factor B - Variety	2	2,387.2	1.44	1,193.6	0.6	n.s.
Factor C - Fertilization	3	10,252.2	6.18	3,417.4	1.8	n.s.
A x B	2	1,657.8	1.00	828.9	0.4	n.s.
A x C	3	190.2	0.11	63.4	3.3	n.s.
B x C	6	1,208.5	0.73	201.4	0.1	n.s.
A x B x C	6	732.0	0.44	122.0	6.3	n.s.
Error	46	89,450.8	53.89	-	-	-

*p ≤ 5% ** p ≤ 1% *** p ≤ 0.1%
Source: Author's results.

The results show that as a result of optimizing the humidity conditions, the yields increase by 25.4% on average.

The most responsive to irrigation on average for all levels of fertilization is the Isabell variety with 28.5%.

Darmi variety increased its productivity by 25.1%. The Helius variety is characterized by the highest environmental plasticity.

Under irrigated conditions, the production of unginned cotton increases by 21.6%. The highest additional yield under irrigation was registered with the naturally colored variety Isabell – 609.8 kg/ha.

The effect of 100 m^3 is calculated as the ratio between the additional yield and the amount of irrigation rate.

From the data, it can be seen that the effect of irrigation with 100 m^3 ranges from 52.78 to 110.87 kg/ha.

The Isabel variety (100.75 kg/ha) is distinguished by the highest effect. Irrigation, at a rate of nitrogen fertilization of 80, has contributed to obtaining an additional yield of 609.8 kg/ha at the size of the realized irrigation rate of 550 mm.

A high effect was also recorded with nitrogen 160. No trend was observed with the effect of irrigation water.

Cetin et al. (2002) [2] found that water logging resulted in lower overall cotton yield. The highest additional yield, as well as the highest effect of irrigation water at zero fertilization, was calculated for the Helius variety.

In the case of Darmi variety, the established additional yield at zero fertilization and with nitrogen 160 was 553.0 kg/ha and 565.6 kg/ha, respectively.

This also determines the close values of the effect per 100 m^3 – 100.55 and 102.84 kg/ha. In contrast, the Isabell variety has the greatest effect of irrigation water at nitrogen fertilization level 80.

Research by Li et al. (2017) [9] also found that reducing nitrogen rates did not reduce the quantity and quality of yields, but increased the efficiency of use of water supplied for irrigation.

Table 2. Irrigation parameters, productivity and effect of 100 m^3 of irrigation water for three varieties of cotton, 2018-2020

Variants		**Irrigation norm (M)**	**Yield (Y)**	**Additional yield (AY)**	**Effect of 100 m^3**
Variety	Fertilizer	mm	kg/ha	kg/ha	kg/ha
Helius	N_0	550	1,707.3	522.0	94.91
	N_{80}	550	1,833.2	373.9	67.98
	N_{160}	550	1,963.0	290.3	52.78
	N_{240}	550	1,915.1	417.3	75.87
		550	**1,854.7**	**400.9**	**72.89**
Darmi	N_0	550	1,908.6	553.0	100.55
	N_{80}	550	1,952.2	501.9	91.25
	N_{160}	550	2,179.1	565.6	102.84
	N_{240}	550	2,094.7	486.9	88.53
		550	**2,033.7**	**526.9**	**95.79**
Izabell	N_0	550	1,760.2	528.9	96.16
	N_{80}	550	2,037.5	609.8	110.87
	N_{160}	550	2,023.5	592.7	107.76
	N_{240}	550	1,959.6	485.2	88.22
Average		**550**	**1,945.2**	**554.2**	**100.75**
Average of the three varieties		**550**	**1,944.5**	**494.0**	**89.81**

Source: Author's results.

CONCLUSIONS

As a result of the conducted field research, it was established that the total yield of unginned cotton realized on average for the research was very good - 1,945.2 kg/ha.

The average yield under irrigated conditions exceeds the yield without irrigation by 34.0%. The Darmi variety stands out as the most productive and promising compared to Helius and Isabell. The optimal nitrogen rate of the tested is N_{160}. When fertilizing with N_{240}, the yield shows a downward trend compared to N_{160} and this fertilization is not effective.

On average for the period, at the 4 levels of nutritional regime, the effect of 100 m^3 of irrigation water was established - 89.81 kg/ha. With the naturally colored variety Isabell, the effect is the highest, on average for 4 levels of fertilization – 100.75 kg/ha.

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