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SEED COTTON YIELD AND YIELD COMPONENTS AFFECTED BY THE MINERAL FERTILIZATION AND THE WEATHER CONDITIONS

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Abstract

The aim of the study was to determine the reaction of cotton to different fertilizer rates and combinations under the influence of different weather conditions. In 1966 a long-term stationary fertilizer experience was established at the Field Crop Institute in Chirpan, Bulgaria. The results represent 2019 and 2020 crop years. The experiment was based on two-field crop rotation. Cotton variety Philipopolis was grown with durum wheat, without irrigation. The following doses of nitrogen and phosphorus were applied: 40, 80, 120 and 160 kg ha^{-1}. Potassium fertilizer was used at a rate of 80 kg ha. $N_0P_0K_0$ was adopted as a control. $N_{160}P_{40}$ had the greatest effect on seed cotton yield and boll weight; $N_{160}P_{80}$ - lint yield and ginning; $N_{160}P_{120}$ - plant height; $N_{120}P_{120}$ - number of boll per plant and $N_{40}P_{80}$ - fiber length. The strongest correlation was observed between lint yield and ginning ($P = 0.902^{***}$), and fiber length was negatively related to all traits. Yield and yield components can be strongly influenced by different weather conditions.

***Key words**: phosphorus, potassium, nitrogen fertilization, weather conditions.*

INTRODUCTION

The foundations for working with cotton in Bulgaria were laid in 1901 in Sadovo. In 1925 the research institute was founded in Chirpan, where the main activity with cotton began. Bulgaria is located on the northernmost border for growing crops. However, there are good conditions for its cultivation.

More than 100 countries of the world produce cotton over an area of 33.2 million hectare with an average annual cotton production of 18.9 million tons (Hussain et al., 2020). In the EU, only three countries grow this crop on an area of 320 000 ha. Greece is the main producer with 80% of the total area, followed by Spain with 20%. EC Regulation 73/2009 changed the quota and reduced the area for cotton in Bulgaria to 3 342 ha. This area is extremely insufficient, given that in the recent past (1950s) the area was 200 000 ha.

The problem of productivity remains acute worldwide. According to estimates by the International Cotton Committee, world average yields have not increased since 1992/1993, with an average yield of 80 kg ha or 2% per year over the last 50 years (Stoylova et al., 2016). In recent years, with the emergence of global environmental issues, rising awareness of global warming and the increased coast of nitrogen have spurred an interest in the investigation of nitrogen fertilization (Chen et al., 2019). This is because application levels in a given year are based on their application rates from the previous year (Dhakal et al., 2019). This fact has led to an increase in studies of agricultural practices that reduce the amount of N lost (Allanov et al., 2019). Cotton yield can be restricted by the amount of available nutrients in the soil, especially if the supply does not meet the requirements of the plant (Echer et al., 2019). Therefore during its production process, a great amount of chemical fertilizers are used (Cevheri and Yilmaz, 2018). High rates of nitrogen fertilization frequently lead to a decrease in boll production as a result of excessive development and maturation of yield later in the growing season (Chen et al., 2019). Thus, it is necessary to optimize N fertilizer input boot to meet crop requirement and to reduce environmental pollution (Geng et al., 2016). Chen et al. (2018) reported that in Xinjiang (China) the nitrogen rate for the highest yield is 300 kg ha^{-1}, while the norm in the Yangtze River Valley is 240 kg ha^{-1}. Gomaa et al. (2019) report that in Egypt the highest agronomic efficiency was reported at 140 kg N ha^{-1}. In Turkey, Calakoglu (1980) recommended an optimal dose of 80-120 kg N ha^{-1}, 60-90 kg P ha^{-1} and 100-200 kg K ha^{-1}. In

Uzbekistan, the official recommended application rate of N for cotton is 160-180 kg ha^{-1} (Devkota et al., 2013).
The aim of the study was to determine the reaction of cotton to different fertilizer rates and combinations under the influence of different weather conditions.

MATERIALS AND METHODS

In 1966 a long-term stationary fertilizer experience was established at the Field Crop Institute in Chirpan, Bulgaria. The results from 2019 and 2020 were used to assess the impact of N, P and K fertilization on yield and its components. The soil type is Pelic Vertisol. The humus stock in the 0-20 cm layer is 1386 kg ha^{-1} and decreases in depth. The total N content was 0.20% and decreased to 0.13% to 40 cm. $CaCO_3$ is 0.00% for 0-20 cm and 0.25% for 40 cm.
The experiment was set in 4 replications with a plot size of 10 m^2, in two-field crop rotation, cotton Philippopolis variety was grown with durum wheat, without irrigation. The degrees of the tested factor were a randomized complete block design. Enter row-space was 95 cm. Ammonium nitrate was chosen as nitrogen (NH_4NO_3). The commercial product has a nitrogen content of 34.4%. The following doses were applied: 40, 80, 120 and 160 kg N ha^{-1}. Phosphorus was incorporated in the form of triple superphosphate with a content of 46% and the following norms: 40, 80, 120 and 160 kg P ha^{-1}. Potassium sulphate (K_20) with a content of 50%, in the norm of 80 kg K ha was used as potassium fertilizer. NPK fertilizers were incorporated before sowing cotton with the last cultivation. $N_0P_0K_0$ was adopted as a control. The cotton was harvested by hand.
The following traits were examined: seed cotton yield (kg ha^{-1}); lint yield (kg ha^{-1}); ginning (%); plant height (cm); harvested bolls per plant (number); boll weight (g); fibre length (mm).
The effective effect of fertilization on yield, yield components and plant height were statistically analyzed by analysis of dispersion (ANOVA). The main effects were compared using Fisher's LSD with the least significant difference P = 0.1%. The correlation analysis was performed using the software statistics 13.0 (TIBCO, Software, 2018), with the least significant difference P = 0.01%.

RESULTS AND DISCUSSIONS

From the meteorological data presented in Table 1 it can be seen that the vegetation period in the two studied years had similar sums of temperatures. However, compared to the multi-year period, both years were warmer.
Regarding the amount of precipitation, 2019

Table 1. Meteorological data during the vegetative period of cotton, 2019, 2020 and 1928-2020

year	months						Σ IV-IX	Σ VI-VIII	Σ V-IX
	IV	V	VI	VII	VIII	IX			
Temperature sum, Σ t °C									
1928-2020	351	502	624	724	719	566	3186	2067	2835
2019	335	533	681	727	771	623	3670	2179	3335
2020	314	515	614	764	788	661	3656	2166	3342
Rainfall, Σ mm									
1928-2020	44	60	65	53	39	37	298	157	254
2019	51	21	123	77	53	15	340	253	289
2020	62	50	62	12	2	3	191	76	129

was close to the amount of the multiannual period. The difference was 35 mm. The amount of precipitation for 2020 was much lower than the previous year and the multiannual period. The least precipitation was reported in the critical phases for cotton.
Table 2 presents the mean squares of the studied traits. In order to facilitate comparison, the absolute values of square sums of the different sources were presented with their share in the total variance (100 x SQI / SQT).
The studied parameters were significantly influenced by fertilization. An exception is boll weight, where there was no significant difference. Most of the total dispersion was taken from harvested bolls per plant (84.04%).

Also a large share was observed in seed cotton yield (58.17%) and plant height (46.03%).
The coefficient of variation showed that fiber length (2.07%) and ginning (3.56%) were the most stable indices studied. Harvested bolls per plant (8.77%), plant height (7.07%) and lint yield (6.58%) were the most variable. Seed cotton yield remained relatively stable (4.71%).

Table 2. Effect of the fertilization on cotton yield and yield components (mean squares - % of total)

Source of variance	df	Seed cotton yield, kg ha	Lint yield, kg ha	Ginning, %	Plant height, cm	Harvested bolls per plant, number	Boll weight, g	Fibre length, mm
Replicate	2	33.41***	74.39***	90.56***	45.77***	1.84-02***	2.71	75.81***
Fertilization	17	58.17***	20.68**	5.11	46.03***	84.04***	47.14	16.94***
Error	34	8.42	4.93	4.33	8.20	15.95	50.15	7.26
VC, %		4.71	6.58	3.56	7.07	8.77	5.03	2.07

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

Seed cotton yield varied significantly between years, ranging from 1352 kg ha^{-1} in 2020 to 2415 kg ha^{-1} in 2019 (Table 3). These large differences between the years can be explained by the differences in meteorology (Table 1). In 2020 in the critical phases of flowering-budding the precipitation was a total of 14 mm, while for 2019 it was 68 mm. When growing cotton without irrigation, the environmental was a decisive influence on both the yield of cotton seeds and the lint yield. In both years studied, fertilization with $N_{160}P_{40}$ was the most productive for seed cotton yield. This led to the highest average seed cotton yield - 2336 kg ha^{-1}, exceeding the control by 53.0%. On average for the observed period, the analysis of variance showed a proven effect for all studied combinations of fertilization. McConnell et al. (1993) reported that fertilization with nitrogen above 112 kg ha^{-1} did not significantly increase seed cotton yield, which is inconsistent with our results.
In the first year of the study, the greatest effect on lint yield was observed under the action of fertilization with $N_{160}P_{80}$ (1169 kg ha^{-1}). In the second year, the yield of cotton lint also differs significantly. Record low yields were reported, the lowest being from the unfertilized variant - 432 kg ha^{-1}. With 83.6% more lint was the variant fertilized with $N_{80}P_{120}$ (793 kg ha^{-1}). On average from two years the trend continues and the analysis of variance confirms the effect of fertilization. The highest average lint yield was the variant $N_{160}P_{80}$ - 944 kg ha^{-1}, which is 61.6% higher than the variant without fertilization. The results obtained from our study contradict the report of Al-Assaf (2020). The author reports that the lint yield increases from 0 to 45 kg N ha^{-1}, then decreases at 60 kg N ha^{-1}, while in our study the highest lint yield was obtained from the highest rate of N. Luo et al. (2018) confirm the results obtained by us.
The ginning in both years moved within narrow limits, which showed that fertilization had no effect, which confirms the results of the total dispersion (Table 3). The highest ginning in 2019 showed fertilization with $N_{160}P_{80}$ (48.9%). In 2020, the ginning of fertilized variants was even narrower. An increase in the values to one degree of the fertilizer rate was reported. With an increase after this degree, the values decreased. The highest values were reported by $N_{80}P_{120}$ (36.6%). Clawson et al. (2006) also observed that nitrogen fertilization did not affect the values of the trait. Devkota et al. (2013) observed an inverse relationship between ginning and N rates. The authors report that as the norm increases, the values decrease, which coincides with our results. On average from the two years, the analysis of variance showed low reliability, although all variants exceeded the control. Only $N_{40}P_{120}$ (41.7%) and $N_{160}P_{80}$ (42.4%) remained with a confirmed impact.
Mineral fertilization had a positive effect on the components of the yield (Table 4). It is clear that the low rates did not have or had a weaker effect on plant height. Increasing the values with increasing dose was maintained up to fertilizer rates of 160:120 NP. From this variant, the highest plants were measured, exceeding the control by 57.9%. At the higher rate of 160:160 NP the plants height decreases. McConnell et al. (2000) confirm the results obtained by us. Panhwar et al. (2018) and Allanov et al. (2019), however, observed an

increase in plant height with increasing fertilizer rate.

The analysis of dispersion showed a proven effect of the fertilizer factor on harvested bolls per plant. Ahmad et al. (2021) confirm the positive effect of mineral fertilization on harvested bolls per plant. The results showed that fertilization with $N_{120}P_{120}$ was the most efficient, as this variant exceeded the non-fertilization by 95.2%.

Table 3. Seed cotton yield (kg ha^{-1}), lint yield (kg ha^{-1}) and ginning (%) for 2019, 2020 and average

Fertilization rates	2019			2020			average		
	Seed cotton yield, kg ha^{-1}	Lint yield, kg ha^{-1}	Ginning, %	Seed cotton yield, kg ha^{-1}	Lint yield, kg ha^{-1}	Ginning, %	Seed cotton yield, kg ha^{-1}	Lint yield, kg ha^{-1}	Ginning, %
$N_0P_0K_0$	1703	737	43.3	1352	432	32.0	1527	584	37.7
$N_{40}P_{40}$	2073	931	44.9	1724	572	35.8	1898^{**}	751^{**}	40.4^{NS}
$N_{40}P_{80}$	2043	823	45.2	1820	655	36.0	1913^{***}	789^{**}	40.6^{NS}
$N_{40}P_{120}$	2163	1017	47.0	1753	636	36.3	1958^{***}	826^{***}	41.7*
$N_{40}P_{160}$	2024	891	44.0	1880	669	35.6	1952^{***}	720^{*}	39.8^{NS}
$N_{80}P_{40}$	2345	1051	44.8	2003	713	35.5	2177^{***}	882^{***}	40.2^{NS}
$N_{80}P_{80}$	2194	957	43.6	2060	726	35.2	2127^{***}	841^{***}	39.4^{NS}
$N_{80}P_{120}$	2295	948	41.3	2167	793	36.6	2231^{***}	870^{***}	39.0^{NS}
$N_{80}P_{160}$	2293	1009	44.0	1903	678	35.6	2098^{***}	843^{***}	39.8^{NS}
$N_{120}P_{40}$	2310	993	43.0	2221	781	35.1	2265^{***}	887^{***}	39.1^{NS}
$N_{120}P_{80}$	2134	967	45.3	1993	699	35.1	2063^{***}	833^{***}	40.2^{NS}
$N_{120}P_{120}$	2325	1053	45.3	2020	707	35.0	2172^{***}	880^{***}	40.2^{NS}
$N_{120}P_{160}$	2048	889	43.4	2023	717	35.4	2035^{***}	803^{***}	39.4^{NS}
$N_{160}P_{40}$	2415	1077	44.6	2258	777	34.4	2336^{***}	927^{***}	39.5^{NS}
$N_{160}P_{80}$	2391	1169	48.9	2008	720	35.9	2199^{***}	944^{***}	42.4**
$N_{160}P_{120}$	2214	939	42.4	1915	691	36.1	2064^{***}	815^{***}	39.3^{NS}
$N_{160}P_{160}$	2377	987	41.5	1978	707	35.7	2147^{***}	847^{***}	38.6^{NS}
$N_{120}P_{120}K_{80}$	2259	983	43.5	1785	616	34.7	2022^{***}	799_{**}	39.1^{NS}
LSD 5%							205	114	3.0
LSD 1%							282	157	4.1
LSD 0.1%							386	216	5.6

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

Although with small differences, a decrease in harvested bolls per plant was observed with increasing rate. Chen et al. (2019) come to the conclusion that high rates of nitrogen fertilization frequently lead to a decrease in boll production as a result of excessive vegetation development and maturation of yield later in the growing season.

The analysis of variance by variants confirms the results of the total variance in Table 2 on the effect of fertilization on boll weight. $N_{160}P_{40}$ had the greatest impact. This treatment exceeded the control by 13.14%. When fertilizing with 80:40 NP a close increase was reported - 12.47%. The results of this study correspond to the results obtained by Niu et al. (2021). The authors report that fertilization has a positive effect on boll weight up to a certain threshold, after this threshold the values do not increase. That the two variants with the heaviest bolls were from the low P rate confirms the statement of o et al. (2020) that phosphorus fertilization has no effect.

Fiber length values moved in different directions and no specific trend was observed. This is confirmed by Hernández-Cruz et al. (2015), which conclude that that the different N rates applied did not affected the fibre-quality components of cotton. Fertilization with higher rates showed results that were close to or lower than the variants with low fertilizer rates. The longest lint and almost identical values were reported

when applying $N_{40}P_{80}$ and $N_{40}P_{40}$, 9.0% and 8.6% more than the control, respectively.
The correlation analysis presented in Table 5 shows strong and proven relationships between most of the studied traits. The strongest relationship was between lint yield and ginning (P = 0.902 ***). This result clearly shows that with increasing ginning lint yield also increases. A number of authors, such as Shao et al. (2016) and Zeng and Meredith (2009) confirm a similar strong relationship between the two traits.

Table 4. Plant height (cm) and yield components average for the test period

Fertilization rates		Plant height, cm	% of control	Harvested bolls per plant, number	% of control	Boll weight, g	% of control	Fibre length, mm	% of control
$N_0P_0K_0$		53.0	100.0	6.3	100.0	4.49	100.00	26.8	100.0
$N_{40}P_{40}$		60.1^{NS}	113.4	7.8*	123.8	4.73^{NS}	105.35	29.1***	108.6
$N_{40}P_{80}$		64.3*	121.3	8.9***	141.3	4.86^{NS}	108.24	29.2***	109.0
$N_{40}P_{120}$		68.6**	129.4	9.9***	157.1	4.62^{NS}	102.90	27.4^{NS}	102.2
$N_{40}P_{160}$		61.6^{NS}	116.2	9.1***	144.5	4.89*	108.91	27.4^{NS}	102.2
$N_{80}P_{40}$		68.4*	129.1	11.4***	181.0	5.05**	112.47	28.5***	106.3
$N_{80}P_{80}$		70.7**	133.4	11.2***	177.8	4.99*	111.14	27.4^{NS}	102.2
$N_{80}P_{120}$		67.8**	127.9	11.7***	185.7	4.63^{NS}	103.12	28.0*	104.5
$N_{80}P_{160}$		69.7**	131.5	10.8***	171.4	5.01*	111.58	27.6^{NS}	103.0
$N_{120}P_{40}$		80.7***	152.3	11.8***	187.3	4.54^{NS}	101.11	28.1**	104.9
$N_{120}P_{80}$		76.4***	144.2	11.0***	174.6	4.95*	110.25	28.1**	104.9
$N_{120}P_{120}$		78.2***	147.6	12.3***	195.2	4.88^{NS}	108.69	28.1**	104.9
$N_{120}P_{160}$		79.2***	149.4	9.8***	155.6	4.86^{NS}	108.24	27.3^{NS}	101.9
$N_{160}P_{40}$		76.5***	144.3	11.8***	187.3	5.08**	113.14	26.8^{NS}	100.0
$N_{160}P_{80}$		80.7***	152.3	12.2***	193.7	4.77^{NS}	106.24	28.8***	107.5
$N_{160}P_{120}$		83.7***	157.9	9.6***	152.4	4.47^{NS}	99.56	28.5***	106.3
$N_{160}P_{160}$		81.4***	153.6	10.9***	173.0	4.89*	108.91	27.7^{NS}	103.4
$N_{120}P_{120}K_{80}$		74.7***	140.9	8.5*	134.9	4.76^{NS}	106.01	28.5***	106.3
LSD	5%	10.7	20.2	1.5	23.8	0.40	8.91	1.0	3.7
	1%	14.7	27.7	2.0	31.8	0.54	12.03	1.3	4.9
	0.1%	20.2	38.1	2.6	41.3	0.71	15.81	1.7	6.3

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

It is impressive that boll weihgt did not correlate with any of the traits, and fiber length is in a negative relationship with all. The same negative correlation between fiber length and all studied traits was reported by Nawaz et al. (2019).

Table 5. Correlation coefficients between the studied traits

	seed cotton yield	*lint yield*	*ginning*	*plant height*	*harvested bolls per plant*	*boll weihgt*	*fibre length*
seed cotton yield	1						
lint yield	0.881***	1					
ginning	0.601***	0.902***	1				
plant height	0.772***	0.738***	0.544***	1			
harvested bolls/plant	0.705***	0.437***	0.099^{NS}	0.516***	1		
boll weihgt	0.278^{NS}	0.245^{NS}	0.162^{NS}	0.145^{NS}	0.227^{NS}	1	
fibre length	-0.521***	-0.772***	-0.841***	-0.480***	-0.071^{NS}	-0.148^{NS}	1

n=34; *** 0.01%; **0.05%; *0.1%

CONCLUSIONS

Mineral fertilization has a strong effect on yield and some of its components. Boll weight and ginning were not affected. Fertilization with $N_{160}P_{40}$ had the greatest effect on seed cotton yield and boll weihgt; $N_{160}P_{80}$ - lint yield and ginning; $N_{160}P_{120}$ - plant height; $N_{120}P_{120}$ - boll weight and $N_{40}P_{80}$ - fibre length. The strongest correlation was observed between lint yield and ginning (P = 0.902 ***), and fiber length was negatively related to all traits. Yield and yield components can be strongly influenced by weather conditions. These results can be helpful to breeders for production practices.

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