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INFLUENCE OF NITROGEN FERTILIZATION ON BULGARIAN COTTON CULTIVARS

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Abstract

The field experiment was conducted from 2011 through 2014, at the Field Crops Institute, Chirpan, to evaluate the influence of nitrogen rates of 0, 60, 120 and 180 kg.ha^{-1}. The response of four Bulgarian cultivars - Chirpan 539 and Boyana (G. hirsutum L.), Darmi (G. hirsutum x G. barbadense) and Helius (developed by experimental mutagenesis) was studied. Various indices were determined: the total seedcotton yield (t.ha^{-1}), number of bolls per plant, boll weight (g), 1000 seeds weight (g), plant height in maturity (cm), fibre length (mm). The soil type was Pellic Vertisols, with neutral soil reaction, with poor to middle nitrogen supply, low content of mobile phosphates and well provided with available potassium. The results demonstrated that the N rates affected greatly all the studied indices except fibre length, and caused largest differences to plant height, boll weight, and 1000 seeds weight. The cultivar led to the greatest significant differences in fibre length, lint percentage, 1000 seeds weight, September and lint yield, while they were not significantly different in boll weight and plant height. The total seedcotton yield ranged from 1.18 t.ha^{-1} in 2011 to 2.50 t.ha^{-1} in 2013. The N rates increased the yield with 21.7- 28.8% in comparison with the unfertilized. The optimal effective N rate for yield was 120 kg.ha^{-1}. The agronomic efficiency of N was 3.87 kg seedcotton at 80 kg N.ha^{-1} and decreased to 3.33 and 2.56 kg at 120 and 160 kg N.ha^{-1}, respectively. The studied cultivars had similar demands to the levels of N treatment. N fertilization at different rates had a positive impact on the cotton yield components. After 120 kg N.ha^{-1}, boll weight increased with 3.5% compared to the unfertilized, harvested bolls per plant - with 15.0%, plant height- with 32.5%. Seeds per boll and fibre length were variable and we could observe no consistent trends.

***Key words**: cotton, nitrogen, cultivar, yield.*

INTRODUCTION

Nitrogen is an essential nutrient for cotton that affects plant growth, fruiting and yield. Without adequate amounts of this element at each growth stage, the maximum potential of cotton cannot be achieved. Nitrogen plays a major role in defining the expression of a wide range of plant variables including plant size, fruiting intensity, boll retention rate, boll size and total boll number per plant (Gerik et al, 1998). Optimizing yield and earliness of cotton varieties with nitrogen fertilization is an ongoing concern of cotton producers. Nitrogen fertilization rate was the only factor that affected seedcotton yield (Alagudurai et al., 2006; Ansari and Mahey, 2003; Anwar and Afzal, 2003; Clawson et al., 2006; Khan et al., 2005; Panayotova and Kostadinova, 2003; Prasad, 2000; Stavrinos et al., 2002). Optimal nitrogen rate is determined by many environmental variables, including weather, soil type, residual fertility, insect pressure etc. (Stoilova and Nicolov, 2002).

Seilsepour and Rashidi (2011) reported that N application significantly increased boll number, boll weight, seed cotton weight of boll, seed cotton yield and lint yield. Results of study also showed that the highest seed cotton yield was obtained in case of 200 kg N.ha^{-1} rate and this application rate resulted in 19.6% increased seed cotton yield.

The foreign cultivars in Bulgaria have late maturity and fail to manifest their yield and quality potential. Highly actual are the results on the reaction of the Bulgarian cotton varieties to applied nitrogen fertilization. According to some authors cotton varieties manifest specific requirements to fertilization (Fritschi et al., 2003; Karamanidis et al., 2004; Clement-Bailey et al., 2007), but according to others (Kostadinova and Panayotova, 2003; McConnell et al., 2003; Panayotova and Videva, 2006; Pettigrew et al., 1996) cotton varieties with similar origin have similar N fertilizer requirements.

Sustainable cotton production requires new effective technologies and new cotton varieties, new and innovative solutions to cotton problems.

Therefore, the objectives of this research were to determine the (i) variability of productivity among cotton cultivars and (ii) response of cotton cultivars to nitrogen rates in years with different meteorological conditions.

MATERIALS AND METHODS

The experiments were carried out on the testing field of the Field Crops Institute, Chirpan, situated in a major cotton-growing region of Bulgaria. From 2011 through 2014, under non-irrigated conditions was investigated the influence of four nitrogen rates - 0, 60,120 and 180 kg.ha^{-1} on cotton yield, yield components and some growth and quality indices. Nitrogen as ammonium nitrate was applied preplant on background of 60 kg P_2O_5.ha^{-1} for all plots. The cotton was planted in crop rotation with durum wheat.

The response of four Bulgarian cotton cultivars to N was studied. Chirpan 539 and Boyana which originated from *G. hirsutum* were early, high yielding cultivars (Bojinov et al., 1996; Valkova and Bozhinov, 2010). Cultivar Darmi was with longer fibre, created by interspecies hybridization (*G. hirsutum x G. barbadense*) (Stoilova and Saldzhiev, 2008). Helius was developed by experimental mutagenesis method (Valkova, 2009). The Chirpan 539 cultivar grown without N fertilization was accepted as a standard in the trial.

The experimental design was a randomised split plot design with cultivars as main plots, and N levels as sub plots, in four replications. Individual plots consisted of six 8.33-m rows spaced 0.60 m apart with a net plot size of 50 m^2. There were two harvests made by hand from four middle rows (20 m^2). The plant population reached as much as 160,000 plants.ha^{-1}, approximately. Cotton seeds were sown within 20-30 April. Weeds were controlled by preplant and preemergence herbicides, interrow cultivation and hand chipping. Defoliants were not applied. The applied agrotechnical practices were complied with the technology established for the region (Saldzhiev et al., 2005; Saldzhiev et al., 2006).

At maturity the seedcotton yield from each plot was weighed and ginned on a rollergin. The following were determined: total seedcotton yield (t.ha^{-1}); number of bolls per plant by accurate count; boll weight (g), which was determined as seed cotton weight per plant/number of bolls per plant; 100 seeds weight (g); plant height in maturity (cm); fibre length (mm) measured by hand by the "butterfly" method. Ten plants from each replication were analyzed.

Analysis of variance (ANOVA) was applied to determine differences and interaction among N rates, cultivars and years.

The soil type was classified as *Pellic Vertisols* (FAO), defined by the sandy-clay composition, with high humidity capacity and small water-permeability. The soil has a high-powered humus horizon (70-100 cm), it has a compact zone of the profile (united horizon). Soil analysis of the experimental field indicated bulk weight of the plough soil layer 1.0-1.2 g.cm^{-3}, specific gravity – 2.6-2.7. The cation exchange capacity ($T_{8.2}$) was 41.0-46.1 meq/100 g soil, total acidity (exchangeable $H_{8.2}$) was 3.6 meq/100 g soil, no damage soil acidity and exchangeable aluminum were established. Despite the long-term use of physiologically acid mineral fertilizers the degree of the bases saturation was very high – 93.4-98.8 %.

The soil had neutral soil reaction in the 0-60 cm soil layer, medium supplied with organic matter, with poor to middle nitrogen supply, with low content of phosphates and well provided with available potassium (Table 1).

The experimental field of the Field Crops Institute, Chirpan, is located at Latitude N 42°12'58", Longitude E 25°17'00" and Altitude 175 m. For the region are typical low winter temperatures and warm summers. The average annual temperature sum is 4317°C. The coldest month is January with daily average temperature of -0.3°C and the warmest is July with an average temperature of 23.2°C. The annual average rainfall is 567 L/m^2, with a maximum in June - an average of 70.0 L/m^2. The annual minimum precipitation is in September.

Table 1. Agrochemical properties of the soil, Chirpan

Parameters	Depth, cm	
	0-30	30-60
pH_{KCl}	6.7	6.2
Humus, %	2.80	2.55
Total N, %	0.100	0.090
$N-NH_4^+$, $kg.ha^{-1}$	50	53
$N-NO_3^-$, $kg.ha^{-1}$	47	30
Total N_{min}, $kg.ha^{-1}$	97	83
Available P_2O_5, $mg.kg^{-1}$	51	39
Exchangable K_2O, $mg.kg^{-1}$	230	160

In meteorological aspect the studied years had higher temperatures and less precipitation during the cotton vegetation period (May-October) compared to the average values of the 85-year period (Table 2).

With regard to temperature, 2012 was hot, 2011 and 2013 – very warm, 2014 was moderately cool - the temperature sum was lower with 23°C. As for rainfall supply, 2011, 2012 and 2013 were very dry, and 2014 was very humid in comparison with the long 85-year period.

In 2011 and 2014 the cotton was harvested in adverse temperature and humidity conditions.

Table 2. Meteorological data during the vegetative period of cotton

Year	Temperature sum, Σ t°C			Rainfall sum, mm		
	IV-IX	V-VIII	V-X	IV-IX	VI-VIII	V-IX
2011	3791	2160	3256	255	113	209
±	+315	+107	+123	-45	-45	-46
2012	3859	2305	3447	185	33	171
±	+383	+252	+314	-115	-125	-84
2013	3735	2134	3319	218	153	177
±	+259	+81	+186	-82	-5	-78
2014	3480	2059	3110	593	168	509
±	+4	+6	-23	293	10	254
1928-2013	3476	2053	3133	300	158	255

RESULTS AND DISCUSSIONS

Table 3 shows the mean squares of differences for the studied parameters. For an easier comparison the absolute values of square sums for the different sources of variance were replaced with their share in the total variance.

It is obvious that all studied parameters showed significant differences. The greatest and most significant of all indices appeared to be the influence of the uncontrollable environment factors, summarised here as factor years. The year impact took the largest part of the total variance; forming both seedcotton yield (92.73%) and lint yield (90.77%).

The rates of N fertilization affected greatly and significantly ($p<0.001$) all studied indices except fibre length. It was statistically determined that N fertilization led to largest differences to plant height, boll weight, and 1000 seeds weight. Although it was proved at $p<0.001$, N fertilization had moderate influence on the total seedcotton and lint yield (2.55-2.65% from total variance), and minimum (0.58%) on lint percentage and earliness, manifested in September yield (0.61%).

Cultivar, the third factor, led to the largest significant differences at $p<0.001$ on fibre length, lint percentage, 1000 seeds cotton weight, September and lint yield. Its influence on bolls per plant was low but significant, while the studied cultivars were not significantly different in respect to boll weight and plant height.

The year-to-year differences in growing conditions led to effect variation of cultivar and N rate on the total cotton yield. However, N manifested greater influence across all years. The N x C interaction was not proven, which statistically showed that the created and grown Bulgarian cultivars had similar needs for N fertilization rates in respect to yield. The analysis identified the strongest significant influence of YR x C, YR x N, C x N and YR x C x N interactions to lint percentage.

As far as the degree of variance was concerned, received through the variation coefficient, lint percentage and 1000 seeds weight were the most stable studied indices, while number of bolls per plant, plant height and cotton yield were the most variable. The total cotton yield ranged less (VC = 5.77 %) in comparison with September harvest (VC = 7.94 %).

The differences between years affected the total seed cotton yield, which ranged from 1.18 $t.ha^{-1}$ in 2011 to 2.50 $t.ha^{-1}$ in 2013 (Table 4). The significant differences between yields were caused by the meteorological differences between years, especially the amount and distribution of precipitation. The higher yield values in 2013 were caused mainly by the favourable conditions in July and August altogether. In this year, which had adequate seasonal rainfall distribution, the plants grew faster, produced more vegetative and reproductive growth, they were higher and had more biomass.

The total yield in 2012 exceeded the yield of the most unfavourable year 2011 with 40.1 %, in 2014 - with 29.5 % and in 2013 - more than two times (112.0 %).

Table 3. Effect of factors on cotton yield and yield components (mean squares - % of total)

Source of variance	df	September harvest, $kg.ha^{-1}$	Total seed cotton yield, $kg.ha^{-1}$	Lint yield, $kg.ha^{-1}$	Lint, %	Boll weight, g	Harvested bolls per plant, number	1000 seeds weight, g	Plant height, cm	Fibre length, mm
Replicate	3	0.02**	0.53***	0.53***	0.01	1.08	0.54	0.37	1.22	0.78
Year (Y)	3	97.05***	92.73***	90.77***	48.77***	32.24***	72.70***	71.42***	43.58***	16.59***
N rate (N)	3	0.61***	2.65***	2.55***	0.58***	5.09***	2.34***	4.47***	13.91***	0.47
Cultivar(C)	3	0.39***	0.24**	1.24***	28.18***	0.31	0.64*	8.21***	0.27	33.09***
Y x N	9	0.42***	0.63***	0.62***	1.48***	5.38***	2.32***	0.58	1.38	1.09
Y x C	9	0.33***	0.39**	1.13***	11.42***	7.84***	6.20***	3.82***	3.69*	8.73***
C x N	9	0.05	0.08	0.14	1.13***	2.01	0.31	0.39	1.31	1.32
Y x Cx N	27	0.09	0.12	0.28	6.26***	10.14**	1.52	1.19	2.36	1.45
Error	198	1.03	2.64	2.76	2.17	35.90	13.42	9.57	32.29	36.47
VC, %		7.94	5.77	5.75	0.66	4.69	9.86	1.92	8.88	4.43

*, **, *** - significant at p<0.05, p<0.01 and p<0.01, respectively

Table 4. Effect of nitrogen fertilization on the total seed-cotton yield, average of four Bulgarian cultivars

Fertilization	Year				Average		
	2011	2012	2013	2014	$t.ha^{-1}$	%	AE
$N_0P_0K_0$	1.04	1.53	2.09	1.08	1.44	100.0	-
N_{80}	1.17	1.71	2.49	1.62	1.75*	121.7	3.87
N_{120}	1.28	1.71	2.64	1.73	1.84**	127.9	3.33
N_{160}	1.24	1.68	2.80	1.69	1.85**	128.8	2.56
Average - kg/da	1.18	1.66	2.50	1.53	1.72	-	-
- %	100.0	140.1	212.0	129.5	-		

*, ** - significant at p<0.05 and p<0.01, respectively

The applied N rates - 80,120 and 160 $kg.ha^{-1}$ led to increase in yield with 21.7; 27.9 and 28.8 %, respectively, in comparison with the unfertilized. In all the years, the treatment exerted positive effect on cotton production. Results demonstrated that the difference between the yields at 120 and 180 $kg.ha^{-1}$ N rates was insignificant and the optimal effective N rate for yield was 120 $kg.ha^{-1}$. McConell et al. (1993) investigated the interaction of cotton genotypes with varying levels of N fertilization and reported that N rates above 112 $kgN.ha^{-1}$ did not significantly increase the seedcotton yield. The agronomic efficiency of nitrogen was 3.87 kg of seedcotton at 80 $kgN.ha^{-1}$ and decreased to 3.33 and 2.56 kg of seedcotton at 120 and 160 $kgN.ha^{-1}$, respectively.

Additional realised yield at N_{180} in comparison with N_{120} was insignificant and this treatment was ineffective. Data revealed that because of the late vegetative period and cotton growth at dry conditions the plant could form greater boll number and be higher, even at N_{180} application. In spite of this, cotton growth was sensitive to N supply. The delay in maturity due to excessive N and heavy rainfall was detected in 2014.

Discussing the response of the studied cultivars to levels of N treatment (Table 5), it was indicated that all cultivars had similar demands. This was also confirmed by the manifested insignificance of differences at N-by-C interaction (Table 2). A tendency was observed for Chirpan 539 and Boyana to increase their yield after N_{120} treatment and these cultivars were more effective. At this N rate, Chirpan 539 improved cotton yield with 26.0% in comparison with the unfertilized. The productivity of cultivars Darmi and Helius increased up to N_{160} and reached 1.92 $t.ha^{-1}$ for Darmi and 1.76 $t.ha^{-1}$ for Helius. Chirpan 539 and Darmi manifested high productivity at all N levels.

The yield increase in all cultivars was caused by the higher number of bolls per plant and boll weight with the increasing of N rates. The advantage of Chirpan 539 was manifested in the highest lint percentage, the bigger number of harvested bolls per plant and boll weight. Good combination of fibre length and lint percentage was found for the varieties Darmi and Boyana.

Table 5. Effect of nitrogen fertilization on total seedcotton yield of four Bulgarian cotton cultivars, average for 2011-2014, $t.ha^{-1}$

Cultivar	Fertilization				Average for cultivars	
	N_0	N_{80}	N_{120}	N_{160}	t/ha	%
Chirpan 539	1,50	1,82	1,90	1,88	1,78	100,0
Darmi	1,47	1,77	1,87	1,92	1,76	98,87
Boyana	1,43	1,72	1,85	1,85	1,71	97,15
Helius	1,36	1,69	1,75	1,76	1,64	93,18

Nitrogen fertilization at different rates had a positive impact on the cotton yield components (Table 6). At an effective N rate for yield of 120 $kg.ha^{-1}$ the boll weight increased with 3.5% compared to the unfertilized, harvested bolls per plant - with 15.0%, plant height- with 32.5%, etc. Boll size and seeds weight were larger in the first September harvest. Seeds per boll and fibre length were variable and we could observe no consistent trends.

Table 6. Effect of nitrogen fertilization on cotton yield components, average for 2011-2014

Treat ment kgN/ha	Boll weight, g	Harvested bolls per plant, number	1000 seeds weigh t, g	Plant height, cm	Fibre length by "butterfly, mm
N_0	4.24	4.07	103.0	52.96	24.48
N_{80}	4.33	4.36	104.1	55.74	24.62
N_{120}	4.39	4.68	105.5	70.16	24.81
N_{160}	4.42	4.96	106.0	76.35	24.53
LSD 0.05	0.07	0.14	0.07	1.43	0.44
LSD 0.01	0.09	0.19	0.09	1.89	0.58
LSD 0.001	0.12	0.24	0.12	2.43	0.75

High N rates led to decrease in lint percentage. The differences in fibre length were found to be insignificant for all N rates. However, the effect of increased N rate treatment on fibre length was slightly negative at 180 kg $N.ha^{-1}$. Other authors (Nikolov, Stoilova, 1999; Seilsepour and Rashidi, 2011) also confirmed this.

CONCLUSIONS

Results demonstrated that on *Pellic vertisols* soil type the total seedcotton yield of studied cultivars ranged from 1.18 $t.ha^{-1}$ in 2011 to 2.50 $t.ha^{-1}$ in 2013 under typical production practices in Southern Bulgaria. The applied N rates - 80,120 and 160 $kg.ha^{-1}$ led to increase of yield with 21.7; 27.9 and 28.8 %, respectively, in comparison with the unfertilized. The difference between cotton yields at 120 and 180 kg $N.ha^{-1}$ was insignificant and the optimal effective N rate for yield was 120 $kg.ha^{-1}$.

The agronomic efficiency of nitrogen was 3.87 kg of seedcotton at 80 kg $N.ha^{-1}$ and decreased to 3.33 and 2.56 kg of seedcotton at 120 and 160 kg $N.ha^{-1}$, respectively.

The studied cultivars had similar demands to the levels of N treatment. A tendency was observed that Chirpan 539 and Boyana increased their yield after N_{120} treatment and these cultivars were more effective.

N fertilization at different rates had a positive impact on the cotton yield components. At 120 kg $N.ha^{-1}$ the boll weight increased with 3.5% compared to the unfertilized, harvested bolls per plant - with 15.0%, plant height- with 32.5%. Seeds per boll and fibre length were variable and we observed no consistent trends.

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