AgroLife Scientific Journal - Volume 6, Number 1, 2017
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

PRODUCTIVITY OF COTTON CULTIVAR DARMI UNDER THE INFLUENCE OF FERTILIZATION AT LONG-TERM FIELD TRIAL

Galia PANAYOTOVA[1], Svetla KOSTADINOVA[2], Neli VALKOVA[3], Lubov PLESKUTA[1]

[1]Trakia University, Faculty of Agriculture, 6000 Stara Zagora, Bulgaria
[2]Agricultural University, Faculty of Agronomy, Mendeleev 12, 4000 Plovdiv, Bulgaria
[3]Field Crops Institute, 6200 Chirpan, G. Dimitrov 2, Bulgaria

Corresponding author email: galia_panayotova@abv.bg

Abstract

The aim of this study was to evaluate the effects of different application rates of nitrogen and phosphorus on growth, yield, earliness and quality of cotton (Gossypium hirsutum L.) cultivar Darmi, grown in Chirpan, Bulgaria. The cotton was grown during 2007-2010 in crop-rotation with durum wheat under non-irrigated conditions. The experimental design was a randomized complete block with four replications. Single and combined nitrogen and phosphorus fertilizers in rates 0; 40; 80; 120 and 160 kg.ha^{-1} were tested. Values were established for the September and total seed-cotton yield, earliness, lint percentage, number of bolls per plant, boll size, plant height, 1000 seeds weight, fibre length. Under the influence of N fertilization the total yield increased with 10.0- 23.1% compared to the control and under phosphorous fertilization - with 1.4- 6.6% (P_{120}). Productivity increased most under combined fertilization $N_{120-160}$ P_{40-80} - 27.7-36.3% more than the unfertilised with a very good share of the September yield. The increase of nitrogen rates decreased earliness with 4.2% (N_{120}) to the check. Average for the 20-year period a high effective yield was formed under moderate N rates combined with low to moderate P levels, whereat the cotton yield increased with 17.8-24.4%. The fertilization significantly increased the height of the plant, boll number (55.6% over control) and boll weight (21.8% more). There was a tendency for decrease in lint percentage with the increase of fertilization rate. No significant changes were found in terms of fiber length and it ranged within 23.76-25.05 mm.

Key words: *cotton, fertilization, nitrogen, phosphorus, yield.*

INTRODUCTION

The cotton productivity and quality varies to a wide range depending on weather, cultivar, soil fertility, agrotechnology. Without adequate amount at each growth stage, the maximum yield potential of cotton can not be achieved (Gushevilov and Karev, 2000; Karthikeyan and Jayakumar, 2001; Zhao and Oosterhuis, 2000). Fertilizers are essential component of modern cotton production that affects plant growth, fruiting and yield (Sawan et al., 2006). The application of such agrotechnical methods that would guarantee high levels and stability of the economic parameters under different conditions is of importance for the production (Coker et al., 2009).
Without adequate amount of nutrient elements at each growth stage, the maximum potential of cotton cannot be achieved (Kirchmann & Thorvaldsson, 2000). Recommendations for cotton fertilization range from relatively low to very high rates (Clawson et al., 2008; McConell et al., 1993). The nitrogen level is one of the determinants of cotton productivity (Ali at al., 2003; Christidis, 1985; Geric et al., 1998). N-deficient cotton plants are likely to have suppressed vegetative and reproductive growth, prematurely senesce (Stewart et al., 2010) and low yields (Radin and Mauney, 1986). In contrast, excessive N can have negative impacts on yield and can result in economic loss. At the early boll filling stage, excessive N may inhibit fruit production due to the promotion of vegetative growth (Gerik et al., 1998).
According to Clawson et al. (2006), Munir et al. (2015) and other authors nitrogen increased lint yield, plant height, main stem nodes, and both whole-plant and subset individual boll weight, but lint percentage was not affected by nitrogen. Pettigrew and Adamczyk (2006) reported that N treatments had no effect on lint yield or any dry matter partitioning components. Nitrogen influenced both vegetative and reproductive growth (Surya et al., 2010) as its deficiency decreased yield by accelerating premature leaf senescence (Fageria

and Baligar, 2005) and early cut-out (Read et al., 2006), while, N in excess can delay crop maturity and promote boll shedding, diseases and insect damages (Howard et al., 2001; Oosterhuis, 2001). Diagnosing and correction of nitrogen deficiency is not difficult while excess of N is more difficult to detect and rectify. The cotton cultivars evolved in different agroclimatic regions behave differentially to application of mineral fertilizers (Prasad and Siddique, 2004).

According to Girma et al. (2007) the nitrogen, phosphorus and potassium fertilizer use in cotton production remains important, as N has a decisive influence, while phosphorus has less effect.

Cahill et al. (2008), Sawan et al. (2008), Mitchell (2000) and other authors reported that P fertilizer generally was not effective, and significant differences were not observed for cotton yield. Saleem et al. (2010) reported that phosphorus levels (30, 60 and 90 $kg.ha^{-1}$) significantly affected almost all the characters related to earliness and yield. According to Cahill et al. (2008) phosphorus deficiency violates the nitrogen nutrition.

Several factors including soil type affect cotton response to phosphorus. The critical level of P is a function of actual concentration of the labile pool that in turn determines the available P during the growth of cotton (Crozier et al., 2004). Bronson et al. (2003) founded that several variables including early P accumulation, biomass, and lint yields positively responded to P fertilization in calcareous soils. The nitrogen uptake is reduced in plants with phosphorus deficiency (Breitenbeck and Boquet, 1993). The phosphorus requirements of cotton are considered very low because of its deep root system and indeterminate growth habit (Malik et al., 1996). According to Gill et al. (2000) and Cope (1984) there are cases where cotton response to phosphorus has been positive and economical. Application of NPK nutrients had some effect on lint yield, although most of the response was attributed to N (all cultivars) and to some extent P (Girma et al., 2007). The use of only starter-N is more cost effective than using both N and P starter fertilizer (Cahill et al., 2008).

P significantly enhanced crop growth, N and K uptake, total chlorophyll concentration and dry matter yield of cotton plant (Sawan et al., 2008). Deshpande and Lakhdive (1994) reported that P application increased P uptake and content in leaf, stem and reproductive part like seed. P is essential for cell division and has a stimulating effect on a number of flower buds and bolls per plant. Kaynak (1995) reported that positive correlation exists between seed cotton weight per boll and seed cotton yield per plant.

Dorahy et al. (2008) reported that phosphorus fertilizer application only increased P concentration in the plants during leaf expansion, but had no effect on biomass production, P uptake at later growth stages sampled, or lint yield. Acording to Leffler (1986) and Bassett et al. (1970) the phosphorus fertilization increased dry matter production and nutrient uptake.

Bronson et al. (2003) reported that phosphorus fertilizer did not affect lint yields at Lamesa.

Reiter and Kreig (2000) established some positive and notable P effects on lint fiber quality factors although both lint yield and lint quality were driven more by moisture availability than phosphorus.

According to some authors the cotton varieties manifest specific nutrient requirements (Karamanidis et al., 2004; Fritschi et al., 2003; Clement-Bailey and Gwathmey, 2008; Javaid et al., 2001; McConnell et al., 2003), while according to others (Kostadinova & Panayotova, 2003; Mullins and Burmester, 1990; Panayotova et al., 2007) the differences in the level of mineral nutrition of genotypes with close origin are insignificant.

Weather conditions and fertilizers exert great influence on the cotton yield. Cotton yield under different conditions is a desirable characteristic because Bulgaria is located on the northern cotton-cultivating boundary. In Bulgaria there are suitable soil and climatic conditions, tradition, experience and advanced research for cotton growing. The foreign cultivars in Bulgaria realise late maturity and fail to manifest their yield and quality potential. According to Christidis (1985) the NPK content in the cotton correlated significantly with the environmental conditions.

The nutrient requirements of the new varieties are often questioned by producers.

Optimizing fertilization for cotton cultivars is one possible way of tailoring production practices to achieve optimal economic returns.

The aim of this study was to evaluate the effects of different application rates of nitrogen and phosphorus on growth, yield, earliness and quality of cotton (*Gossypium hirsutum* L.) cultivar Darmi, grown in the region of Central-South Bulgaria.

MATERIALS AND METHODS

The experiment was carried out on the field of the Field Crops Institute, Chirpan, situated in a major cotton-growing region of Bulgaria. Data from a long-term experiment initiated in 1967 was used. The cotton (*Gossypium hirsutum* L.) cultivar Darmi was grown in double crop-rotation with durum wheat under non-irrigated conditions. The experimental design was a randomized complete block with 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. Twenty-five treatments containing different rates of N-P were evaluated. Single and combination of N and P_2O_5 fertilizers in rates of 0; 40; 80; 120 and 160 $kg.ha^{-1}$ were tested. The source of the N was ammonium nitrate, of P_2O_5 - triple superphosphate.

The applied agrotechnical practices were complied with the technology established for the region. Cotton seeds were sown within 20-30 April. The plant population reached as much as 160,000 $plants.ha^{-1}$, approximately. Weeds were controlled by preplant and preemergence herbicides, interrow cultivation and hand chipping. Defoliants were not applied. There were two harvests made by hand from four middle rows (20 m^2). At maturity the seedcotton yield from each plot was weighed and ginned on a rollergin.

The cultivar Darmi was established in Bulgaria in 2007 with improved quality of the fiber. It was created by crossing the breeding line № 268 (with genplasm of species G. barbadense L.) x C-9070 (Uzbek variety). The cultivar staking high fruiting bolls.

There were determined the September yield and total seed-cotton yield (kg. ha^{-1}); index of earliness as correlation between two harvests; lint percentage (%); the structural elements of yield: number of bolls per plant by accurate count; boll size (g), which was determined as seed cotton weight/ number of bolls; plant height (cm); 1000 seeds weight (g); fibre length measured handily by "butterfly" method (mm).

Analysis of variance (ANOVA) was performed to evaluate differences and interaction among the nitrogen and phosphorus fertilization and years.

The studied years were with different meteorological conditions during the vegetation period (May-October) (Table 1). With regard to temperature and rainfall supply 2007 was warm and moderately wet; 2008 was warm and moderately dry; 2009 - moderately warm and dry, without precipitation in the august and insufficient rainfall during flowering and boll formation; 2010 - moderately warm and wet, with sufficient rainfall during critical stage of the cotton development (Table 1).

The soil type at the Institute region was Pellic Vertisols (FAO), defined by the sandy-clay composition, with high humidity capacity and small water-permeability. The soil in the field was with neutral soil reaction in the 0-60 cm soil layer, medium supplied with organic matter, moderately N provided, with low content of mobile P_2O_5 and well supplied with available K_2O (Table 2).

RESULTS AND DISCUSSIONS

The results for cotton yield showed good effectiveness of the applied fertilization despite unfavorable weather conditions during the cotton vegetation. Additionally yield was realized as a result of direct fertilization and of soil fertility created by long-term fertilization.

Table 1. Meteorological data recorded at the region of Chirpan, Bulgaria during the vegetative period of cotton, 2007-2010

Year	Months						Σ IV-IX	Σ VI-VIII	Σ V-IX
	IV	V	VI	VII	VIII	IX			
Temperature sum, Σ t °C									
1928/2010	343	519	622	720	711	561	3476	2053	3133
2007	351	579	693	825	753	527	3728	2271	3377
2008	386	522	636	717	792	555	3608	2145	3222
2009	357	569	648	751	725	571	3621	2124	3264
2010	364	554	625	706	798	582	3629	2129	3265
Rainfall, Σ W mm									
1928/2010	45	63	65	52	41	34	300	158	255
2007	19	53	39	0	62	128	301	101	282
2008	66	36	95	36	3	91	327	134	261
2009	17	16	14	89	35	58	229	138	212
2010	63	27	82	114	22	48	356	218	293
Hydrothermal coefficient (by Selyaninov)									
1928/2010	1.31	1.21	1.05	0.72	0.58	0.61	0.86	0.77	0.81
2007	0.54	0.92	0.56	0	0.82	2.43	0.81	0.45	0.84
2008	1.71	0.69	1.49	0.50	0.04	1.64	0.91	0.63	0.81
2009	0.48	0.28	0.22	1.19	0.48	1.02	0.63	0.65	0.67
2010	1.73	0.48	1.31	1.62	0.28	0.83	0.98	1.,02	0,90

Table 2. Content of humus, mineral nitrogen and mobile phosphorus and potassium in the Pellic Vertisols, Chirpan

Treatment	Depth, cm	N_{min}, kg.ha^{-1}			P_2O_5, mg/100 g	K_2O, mg/100 g	Humus, %
		N-NH_4	N-NO_3	Total			
$N_0P_0K_0$	0–30	20	14	34	2.4	17.4	2.28
	30–60	13	10	23	1.6	16.5	2.24
P_{160}	0–30	17	21	38	19.3	18.2	2.32
	30–60	21	15	36	18.7	16.9	2.28
N_{80}	0–30	44	30	74	3.2	16.6	2.39
	30–60	60	37	97	2.4	16.5	2.33
N_{160}	0–30	64	43	107	3.7	16.7	2.58
	30–60	57	23	80	3.3	16.2	2.42
$N_{120}P_{120}$	0–30	63	39	102	16.7	28.0	2.56
	30–60	61	26	87	15.0	22.5	2.47

The total seed-cotton yield was significantly influenced by the environmental conditions of the year, type of fertilizer and fertilization level (Table 3). The uncontrolled year conditions had greatest share in the total variation of the factors - 87.0%. The fertilization level led to significant differences - 8.31%. The influence of nitrogen was 6.92% and of phosphorus - 0.85% of total variation. No significant differences in the total seed-cotton yield were occurred as a function of the interaction between nitrogen and phosphorus rate. The variance of factors for the September yield was similar.

The total seed-cotton yield without fertilization was 1.52 t.ha^{-1} average for 4-year period (Table 4). Under the influence of alone N fertilization the yield increased by 10.0 (N_{40}) to 23.1% (N_{160}) compared to the control, and at phosphorous fertilization - by 1.4 (P_{160}) to 6.6% (P_{120}). Productivity increased the utmost at combined fertilization $N_{120\text{-}160}P_{40\text{-}80}$ - by 27.7-36.3% in more than unfertilised.

The total seed-cotton yield without fertilization was 1.52 t.ha^{-1} average for 4-years period (Table 4).

Table 3. Analysis of variance for total seed cotton yield, 2007-2010.

Source of variation	df.	Sum of squares, SQ	Sum of squares SQ, %	Mean squares MS	F
Total	99	312553.8	100.00	-	-
Years	3	271927.0	87.00	90642***	444.8
Fertilization	24	25953.2	8.31	1081***	5.3
N	4	21620.0	6.92	5405***	26.5
P	4	2647.2	0.85	661 *	3.2
N x P	16	1686.0	0.54	105 n.s.	0.5
Error	72	14673.5	4.69	203	

F-ratio amonhg the variables

Table 4. Effect of NP fertilization on the total seed-cotton yield, average for 2007-2010, $t.ha^{-1}$

Fertilization	2007	2008	2009	2010	Average $t.ha^{-1}$	Average %	Average Agronomic efficiency, kg cotton
$N_0P_0K_0$	1.40	1.53	1.04	2.09	1.52	100.0	-
N_{40}	1.48	1.62	1.09	2.48	1.67	110.0	3.80
N_{80}	1.67	1.71	1.17	2.49	1.76	116.0	3.02
N_{120}	1.81	1.71	1.28	2.64	1.86	122.5	2.84
N_{160}	1.75	1.68	1.28	2.80	1.87	123.1	2.19
P_{40}	1.48	1.61	1.05	2.10	1.56	102.9	1.10
$N_{40}P_{40}$	1.61	1.73	1.07	2.88	1.82	120.2	-
$N_{80}P_{40}$	1.84	1.84	1.16	3.01	1.96	129.3	-
$N_{120}P_{40}$	1.94	1.90	1.21	3.22	2.07	136.3	-
$N_{160}P_{40}$	1.79	1.89	1.22	3.22	2.03	134.0	-
P_{80}	1.58	1.52	1.10	2.18	1.59	105.1	0.96
$N_{40}P_{80}$	1.58	1.70	1.14	2.65	1.77	116.5	-
$N_{80}P_{80}$	1.66	1.71	1.22	2.75	1.83	120.8	-
$N_{120}P_{80}$	1.82	1.76	1.26	2.91	1.94	127.7	-
$N_{160}P_{80}$	1.94	1.79	1.34	2.95	2.00	132.1	-
P_{120}	1.62	1.58	1.12	2.13	1.61	106.6	0.81
$N_{40}P_{120}$	1.74	1.80	1.14	2.71	1.85	121.8	-
$N_{80}P_{120}$	1.83	1.88	1.33	2.78	1.96	128.9	-
$N_{120}P_{120}$	1.96	1.83	1.52	2.71	2.00	132.0	-
$N_{160}P_{120}$	1.43	1.77	1.45	2.74	1.85	121.8	-
P_{160}	1.48	1.48	1.09	2.10	1.54	101.4	0.14
$N_{40}P_{160}$	1.64	1.80	1.13	2.53	1.77	116.9	-
$N_{80}P_{160}$	1.70	1.81	1.40	2.69	1.90	125.2	-
$N_{120}P_{160}$	1.92	1.85	1.34	2.98	2.02	133.3	-
$N_{160}P_{160}$	1.78	1.75	1.38	2.75	1.91	126.2	-
Average	1.70	1.73	1.22	2.66	1.83	-	-
GD 5 %	0.352	0.459	0.263	0.566	0.201	13.26	-
GD 1 %	0.466	0.603	0.347	0.751	0.267	17.61	-
GD 0.1%	0.604	0.761	0.475	0.973	0.346	22.83	-

Under the influence of alone N fertilization the yield increased by 10.0 (N_{40}) to 23.1% (N_{160}) compared to the control, and at phosphorous fertilization - by 1.4 (P_{160}) to 6.6% (P_{120}). Productivity increased the utmost at combined fertilization $N_{120-160}P_{40-80}$ - by 27.7-36.3% in more than unfertilised. The yield was significantly lower in 2009 - an average 1.22 $t.ha^{-1}$ under the influence of unfavorable weather conditions for cotton, while in other years the average yield was from 1.70 $t.ha^{-1}$ (2007) to 2.66 $t.ha^{-1}$ (2010). The results show that at NP fertilization combined with favorable weather conditions Bulgarian cotton varieties realize their potential for high productivity. The combine fertilization proved a much better influence on the cotton yield with very good share of the September yield (Table 5). The increase of nitrogen rates decreased earliness index by 4.2% (N_{120}) to the check. Dong et al. (2012) also showed that increasing N rate reduced earliness. Setatou and Simonis (1996) found that N fertilization caused a delay in the maturity of cotton plants, ranging from 0.2 to 2.5 days in comparison to the control in most of the experiments. Yang et al. (2011) reported that N ratio promoted an earlier squaring and flowering but delayed the opening stage, so prolonged the boll setting and filling period.

The efficiency of fertilization and the effect of 1 kg fertilizer were significantly higher for nitrogen (2.19-3.80 kg seed-cotton) as compared to phosphorus (0.14-0.96 kg) and the effect decreased at higher nutrient levels.

The cotton productivity increased as a result of long-term fertilization and soil fertility.

The average cotton yield for the last 20 years without fertilization was 1.56 $t.ha^{-1}$ (Table 6). Average for the period a high, economically effective and stable yield was formed under moderate N rates combined with low to moderate P levels, whereat the cotton yield increases with 17.8-24.4% to the unfertilized.

The high rates effect in most of the years was close to the one received by moderate fertilization caused by the extended vegetative period of cotton and failure of most of the formed bolls to ripe, especially in years with more rainfall and lower temperatures.

Table 5. September seed-cotton yield ($t.ha^{-1}$) at nitrogen-phosphorus fertilization, average for 2007-2010

Treatment	Year				Average		
	2007	2008	2009	2010	$kg.ha^{-1}$	%	Earliness, %
$N_0P_0K_0$	0.88	0.88	0.92	1.57	1.06	100.00	70.0
N_{40}	0.98	0.97	0.96	1.86	1.19	112.23	71.4
N_{80}	1.06	0.97	1.06	1.54	1.16	109.09	65.8
N_{120}	1.18	0.94	1.12	1.72	1.24	116.88	66.8
N_{160}	1.14	0.91	1.10	1.91	1.27	119.29	67.8
P_{40}	0.98	1.07	0.98	1.56	1.15	108.43	73.7
$N_{40}P_{40}$	1.06	1.02	0.99	1.96	1.26	118.45	69.0
$N_{80}P_{40}$	1.16	1.02	1.05	2.07	1.32	124.79	67.5
$N_{120}P_{40}$	1.18	1.06	1.10	2.14	1.37	129.04	66.2
$N_{160}P_{40}$	1.08	1.16	1.13	2.09	1.37	128.64	66.0
P_{80}	1.04	0.94	1.00	1.76	1.19	111.71	74.4
$N_{40}P_{80}$	1.03	1.06	1.04	1.83	1.24	116.95	70.3
$N_{80}P_{80}$	1.08	1.01	1.12	1.96	1.29	121.87	70.6
$N_{120}P_{80}$	1.19	1.05	1.16	1.98	1.34	126.57	69.4
$N_{160}P_{80}$	1.28	1.10	1.22	1.92	1.38	130.26	69.0
P_{120}	1.07	1.08	0.99	1.56	1.18	110.69	72.8
$N_{40}P_{120}$	1.11	1.24	1.03	1.85	1.31	123.09	70.7
$N_{80}P_{120}$	1.15	1.32	1.22	2.13	1.45	136.88	74.3
$N_{120}P_{120}$	1.20	1.19	1.37	1.94	1.42	134.22	71.1
$N_{160}P_{120}$	1.00	1.08	1.35	2.04	1.37	128.71	73.9
P_{1600}	0.96	0.93	0.97	1.60	1.11	105.02	72.4
$N_{40}P_{160}$	1.10	1.23	1.00	1.83	1.29	121.42	72.7
$N_{80}P_{160}$	1.12	1.22	1.26	1.86	1.36	128.42	71.8
$N_{120}P_{160}$	1.25	1.18	1.22	2.11	1.44	135.85	71.3
$N_{160}P_{160}$	1.18	1.10	1.24	1.88	1.35	127.35	70.6
Average	**1.10**	**1.07**	**1.10**	**1.87**	**1.28**	**-**	**70.38**
GD 5 %	0.247	0.306	0.348	0.632	0.348	32.83	
GD 1 %	0.327	0.464	0.489	0.838	0.489	46.13	
GD 0.1%	0.424	0.586	0.612	1.085	0.612	57.74	

Table 6. Effect of long-term fertilization on total seed-cotton yield for last 20 years (1991-2010)

Treatment	$t.ha^{-1}$	%	Agronomical efficiency, kg	Variation
$N_0P_0K_0$	1.56	100.0	-	0.76 – 2.09
N_{80}	1.75	112.0	2.34	0.89– 2.86
N_{120}	1.88	120.4	2.67	0.91 – 2.79
N_{160}	1.90	121.8	2.12	0.79 – 2.63
P_{80}	1.68	107.7	1.50	0.78 – 2.26
P_{120}	1.71	109.4	1.25	0.79 – 2.44
P_{160}	1.66	106.6	0.62	0.81 – 2.49
$N_{80}P_{80}$	1.91	122.2	-	0.99 – 3.16
$N_{120}P_{80}$	1.84	117.8	-	0.89 – 2.84
$N_{120}P_{120}$	1.94	124.4	-	1.01 –3.10
$N_{160}P_{80}$	1.81	116.0	-	0.92-3.08
$N_{160}P_{120}$	1.92	123.2	-	0.95 – 2.91
$N_{160}P_{160}$	1.92	122.8	-	0.99 – 3.05
GD 5%	0.167	10.70		
GD 1%	0.189	12.12		
GD 0.1%	0.196	12.56		

The fertilization efficiency was strongly dependent on the weather conditions, which was signified by the significant yield variance by years. The nitrogen fertilization exerted a decisive influence on the cotton productivity, signified by the significantly higher values for its effect (2.12-2.67 kg) compared to phosphorus (0.62-1.50 kg).

This showed that an alone phosphorus fertilization is not an effective agrotechnical measure.

Average for the studied four years the weight of 1 boll was 3.77 g, without fertilization - 3.40 g, and reached a maximum value of 4.14 g at $N_{80}P_{120}$ (Table 7).

At higher fertilizer rate the number of bolls per 1 plant increased and at fertilization with $N_{120}P_{120}$ the number of mature bolls per plant was 4.56, by 55.6% above unfertilized (2.93). The highest weight of 1 boll and number of bolls per 1 plant were formed in 2010 - an average of 4.25 g (in the range 3.76-4.66 g) and 5.43 (from 4.02 to 6.32) respectively.

Rashidi et al. (2011) reported that 200 $kg.ha^{-1}$ N application rate resulted significant increased in the boll number (19.8), and boll weight (6.26 g) compared to low rates.

Table 7. Structural elements of cotton yield, height in maturity, fiber length and output at fertilization, average for 2007-2010

Treatment	Weight of 1 boll		Bolls per 1 plant		Height at maturity		Fiber length		Lint percentage	
	g	%	number	%	cm	%	mm	%	%	% то check
$N_0P_0K_0$	3.40	100.0	2.93	100.0	44.6	100.0	24.29	100.0	38.1	100.0
N_4	3.46	101.8	3.58	122.2	50.2	112.6	24.36	100.3	37.9	99.5
N_8	3.58	105.3	3.67	125.3	53.4	119.7	24.38	100.4	37.8	99.2
N_{12}	3.62	106.5	4.40	150.2	60.5	135.6	24.64	101.4	37.4	98.2
N_{16}	3.76	110.6	4.30	146.8	60.9	136.6	24.70	101.7	37.3	97.9
P_4	3.46	101.8	3.47	118.4	47.7	106.9	24.63	101.4	38.0	99.7
N_4P_4	3.55	104.4	4.15	141.6	52.3	117.3	24.30	100.0	38.0	99.7
N_8P_4	3.81	112.1	4.21	143.7	56.1	125.8	24.83	102.2	37.9	99.5
$N_{12}P_4$	3.76	110.6	4.26	145.4	60.5	135.6	25.05	103.1	37.7	98.9
$N_{16}P_4$	3.69	108.5	4.15	141.6	62.6	140.4	24.63	101.4	37.6	98.7
P_8	3.64	107.1	3.69	125.9	47.3	106.0	23.89	98.4	38.0	99.7
N_4P_8	3.86	113.5	3.94	134.5	51.0	114.4	24.55	101.1	37.9	99.5
N_8P_8	3.82	112.4	4.19	143.0	56.9	127.6	24.83	102.2	37.7	98.9
$N_{12}P_8$	3.97	116.8	4.38	149.5	61.6	138.1	24.50	100.9	37.7	98.9
$N_{16}P_8$	3.96	116.5	4.05	138.2	64.1	143.7	24.36	100.3	37.5	98.4
P_{12}	3.64	107.1	3.16	107.8	48.1	107.8	24.00	98.8	37.9	99.5
N_4P_{12}	3.80	111.8	4.24	144.7	51.4	115.2	24.41	100.5	37.7	98.9
N_8P_{12}	4.14	121.8	4.17	142.3	56.7	127.1	24.08	99.1	37.6	98.7
$N_{12}P_{12}$	4.02	118.2	4.56	155.6	63.7	142.8	24.20	99.6	37.3	97.9
$N_{16}P_{12}$	4.00	117.6	4.29	146.4	63.7	142.8	24.14	99.4	37.1	97.4
P_{16}	3.59	105.6	3.81	130.0	47.6	106.7	24.61	101.3	37.9	99.5
N_4P_{16}	4.11	120.9	4.02	137.2	53.5	120.0	24.38	100.4	37.9	99.5
N_8P_{16}	3.88	114.1	4.47	152.6	56.2	126.0	23.96	98.6	37.6	98.7
$N_{12}P_{16}$	3.88	114.1	4.55	155.3	62.4	139.9	23.76	97.8	37.3	97.9
$N_{16}P_{16}$	3.86	113.5	4.29	146.4	64.3	144.2	24.01	98.8	37.3	97.9
Средно	**3.77**	**-**	**4.04**	**-**	**55.89**	**-**	**24.38**	**-**	**37.68**	**-**

Seilsepour and Rashidi (2011) and Rashidi and Gholami (2011) also reported that the seed-cotton yield, the fiber yield, weight of 1 boll, the number of bolls per 1 plant, the weight of seeds in 1 boll and N concentrations in the leaves significant increase at nitrogen fertilization. Several research findings reported that the yield advantages due to optimal N application were attributed to larger bolls at a greater number of fruiting sites (Boquet and Breitenbeck, 2000; McConnell et al., 1998; Moore, 1999).

Plant height is a genetically controlled factor but nutritional disorder may also influence the height of plant (Ahmed et al., 2009). A field study showed that difference in plant height was due to the cultivars and number of monopodial branches per plant decreased while number of sympodial branches per plant increased with increasing P levels (Copur, 2006).

In our study alone and combined nitrogen fertilization significantly increased the height of cotton plants in maturity (from 44.6 cm without fertilization to 64.3 cm at $N_{160}P_{160}$). In 2010 under the influence of fertilization, combined with rainfall throughout the cotton vegetation, the growth rate of plants was the most intense and the height at the end of the vegetation from 53.8 cm without fertilization reached 91.5 cm at $N_{120}P_{120}$. Hallikeri et al. (2010) showed that cotton height was significantly affected by application of N levels, as taller plants were observed with N up to 120 kg·ha^{-1}.

Under the influence of various types of fertilizers and applied rates no significant changes were found in terms of the fiber length and it was in a range 23.76-25.05 mm. There was a tendency for a decrease of lint percentage with increasing the rate of fertilization, connected to the higher weight of 1000 seeds (108-113 g) (Figure 1). The conditions over the years proved to be a strong influence on the fiber length and lint percentage in comparisson with fertilization. Rashidi and Gholami (2011) and Sawan et al. (2006) also found that the effect of nitrogen on fiber properties were small and inconsistent. Fritschi et al. (2003) found that lint yield was increased linearly each year with N fertility levels, attaining a maximum yield at the 224 kg N ha^{-1} rate and they found that with increased N, gin turnout was decreased.

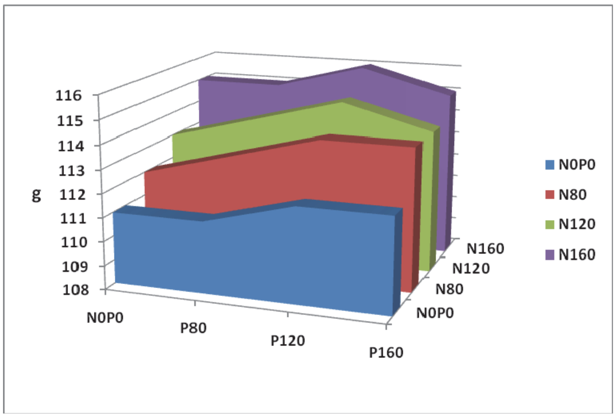

Figure 1. 1000 seeds weight at N-P fertilization, 2007-2010

CONCLUSIONS

The total seed-cotton yield without fertilization was 1.52 $t.ha^{-1}$ average for 4-year period. Under the influence of N fertilization the yield increased by 10.0 (N_{40}) to 23.1% (N_{160}) compared to the control and at phosphorous fertilization - by 1.4 (P_{160}) to 6.6% (P_{120}). Productivity increased the utmost at combined fertilization $N_{120\text{-}160}P_{40\text{-}80}$ - by 27.7-36.3% in more than unfertilised with very good share of the September yield.

The increase of nitrogen rates decreased earliness by 4.2% (N_{120}) to the check.

The agronomic efficiency was significantly higher for nitrogen (2.19-3.80 kg seed-cotton) as compared to phosphorus (0.14-0.96 kg) and the effect decreased at higher nutrient levels.

The average cotton yield for the last 20 years without fertilization was 1.56 $t.ha^{-1}$. Average for the long period a high effective yield was formed under moderate N rates combined with low to moderate P levels, whereat the cotton yield increases with 17.8-24.4% to the unfertilized.

The fertilization significantly increased the height of the cotton plant (44.2% over unfertilized), boll number (55.6% over control) and boll weight (with 21.8 % more).

There was a tendency for a decrease of lint percentage with increasing the rate of fertilization.

No significant changes were found in terms of the fiber length and it was in a range 23.76-25.05 mm.

REFERENCES

Ahmed H., Ali R., Zamir S. and Mahmood N., 2009, Growth, yield and quality performance of cotton cultivar BH-160 (*G. hirsutum* L.) as influenced by different plant spacing. JAPS, no. 19, p. 189-192.

Bang M., Milory S. and Roberts G., 2006. Managing for crop maturity. Aust. Cotton grower. 27 (7), p. 53-56.

Bassett D., Anderson W. and Werkoven C., 1970. Dry matter production and nutrient uptake in irrigated cotton (*Gossypium hirsutum*). Agron. J., 62, p. 299-303.

Breitenbeck G. and Boquet D., 1993. Effect of N fertilization on nutrient uptake by cotton. Proceedings of the Beltwide Cotton Conferences, Jan. 10-14 1993, New Orleans, LA., p. 1298-1300.

Bronson K.F., Keeling J.W., Booker J.D., Chua T.T., Wheeler T.A., Boman R.K. and Lascano R.J., 2003. Influence of Landscape position, soil series and phosphorus fertilizer on cotton lint yield. Agron. J., 95, p. 949-957.

Boquet D.J. and Breitenbeck G.A., 2000. Nitrogen rate effect on partitioning of nitrogen and dry matter by cotton. Crop Sci, 40, p. 1685-1693.

Cahill Sh., Johnson A., Osmond D.L, Hardy D.H., 2008. Response of Corn and Cotton to Starter Phosphorus on Soils Testing Very High in Phosphorus. Agronomy Journal, 100 (3), p. 537-542.

Christidis N, 1985. The cotton. Ed. Athens, p. 312-322 (Gr).

Clawson E.L., Cothren J.T. and Blouin D.C., 2006. Nitrogen fertilization and yield of cotton in ultra-narrow and conventional row spacings. Agron. Journal, 98, p. 72-79.

Clawson E., Cothren J.T., Blouin D.C. and Satterwhite J.L., 2008. Timing of Maturity in Ultra-Narrow and Conventional Row Cotton as Affected by Nitrogen Fertilizer Rate. Agronomy Journal, Vol. 100, Issue 2, p. 421–431.

Clement-Bailey J. and Gwathmey C., 2008. Earliness, partitioning and yield responses to potassium in cotton cultivars. Paper 1302, World Cotton Res. Conf.-4, 10-14 Sep 2007, Lubbock TX. ©2008 Omnipress [CD-ROM].

Coker D., Oosterhuis D. and Brown R., 2009. Cotton Yield Response to Soil- and Foliar-Applied Potassium as Influenced by Irrigation. The Journal of Cotton Science, 13, p. 1-10.

Cope J., 1984. Relationships among rates of N, P and K, soil test values, leaf analysis and yield of cotton at 6 locations. Commun. Soil Sci. Plant Anal., 15, p. 253-276.

Copur O., 2006. Determination of yield and yield components of some cotton cultivars in semi arid conditions. Pak. J. Biol. Sci., 9, p. 2572-2578.

Crozier C., Walls B., Hardy D. and Barnes J., 2004. Response of Cotton to P and K Soil Fertility Gradients in North Carolina. J. Cotton. Sci., 8, p. 130-141.

Dong H., Li W., Eneji A., Zhang D., 2012. Nitrogen rate and plant density effects on yield and late-season leaf senescence of cotton raised on a saline field. Field Crops Research, 126, p. 137-144.

Deshpande R. and Lakhdive B., 1994. Effect of plant growth substances and P levels on yield and P uptake by cotton. PKV Res. J., 18, p. 118-121.

Dorahy Ch., Rochester I., Blair Gr., Till A., 2008. Phosphorus Use-Efficiency by Cotton Grown in an Alkaline Soil as Determined Using ^{32}Phosphorus and ^{33}Phosphorus Radio-Isotopes. J. of Plant Nutrition, Vol. 31, Issue 11, p. 1877-1888.

Fageria N.K. and Baligar V.C., 2005. Enhancing nitrogen use efficiency in crop plants. Adv. Agron. 88, p. 97-185.

Fritschi F.B., Roberts B.A., Travis R.L., Rains D.W. and Hutmacher R.B., 2003. Response of irrigated Acala and Pima cotton to nitrogen fertilization: Growth, dry matter partitioning, and yield. Agron. J., 95, p. 133-146.

Javaid R., Ranjha A., Waheed T. and Ahmed I., 2001. Genotypic Differences Among Cotton Genotypes for Phosphorus Use Efficiency and Stress Factor. Intern. J. of Agriculture & Biology, 03-2, p. 186-187.

Gerik T.J., Jackson B.S., Stocckle C.O. and Rosenthal W.D., 1994. Plant nitrogen status and boll load of cotton. Agron. Journal, 86, p. 514-518.

Gerik T., Oosterhuis D. and Torbert H., 1998. Managing cotton nitrogen supply. Advances in Agronomy, 64, p. 115 -147.

Gill K., Sherazi S., Iqbal J., Ramzan M., Shaheen M. and Ali Z., 2000. Soil Fertility Investigations on Farmers Fields in Punjab. Soil Fertility Research Institute, Department of Agriculture, Govt. of Punjab, Lahore, Pakistan, p. 133-135.

Girma K., Teal R., Freeman K., Boman R., Raun W., 2007. Cotton Lint Yield and Quality as Affected by Cultivar and Long-Term Applications of N, P, and K Fertilizers. 15th annual 2017 NUE Conference, Baton Rouge, LA, p. 12-19.

Gushevilov J. and Karev K., 2000. Sustainable fertilizing influence on the yields and quality of cotton grown on leached cinnamonic forest soil. Plant Sci., 37, p. 150-156.

Hallikeri S.S., Halemani H.I., Patil V.C., Palled Y.B., Patil B.C. and Katageri I.S., 2010. Effect of nitrogen levels, split application of nitrogen and detopping on seed cotton yield and fibre quality in Bt-cotton. Karnataka J. Agric. Sci., 23 (3), p. 418-422.

Howard D.D., Gwathmey C.O., Essington M.E., Roberts R.K., and Mullen M.D., 2001. Nitrogen fertilization of no-till cotton on loess- derived soils. Agron. J., 93, p. 157-163.

Karamanidis G., Nechev Hr. and Stoilova A., 2004. Effect of fertilization and plant density on Bulgarian and Greece cotton cultivars growth in Orestiada district - Greece. Proc. Conference USB – St. Zagora, June 3-4 2004, p. 67-70.

Karthikeyan P. and Jayakumar R., 2001. Nitrogen and chlormequat chloride on cotton cultivar, p. 806-807. *In:* W.J. Horst et al. (ed.) Plant nutrition: food security and sustainability of agro-ecosystems through basic and applied research. Intl. Plant Nutr. Colloq., 14th, Hannover, Germany. 27 July-3 Aug. 2001. Kluwer Academic Publishers, Dordrecht, Netherlands.

Kaynak M., 1995. A research on the correlation and path coefficient analysis of the yield, yield components and fiber characteristics in cotton (*G. hirsutum* L.). J. Faculty Agric. Harran University, 1, p. 20-31.

Kirchmann H. and Thorvaldsson G., 2000. Challenging targets for future agriculture, European Journal of Agronomy, Vol. 12, Issues 3-4, p. 145-161.

Kostadinova S. and Panayotova G., 2003. Agronomic Efficiency of Nitrogen Fertilization at Bulgarian Cotton Cultivars. Ecology and Future, vol. I, 1, p. 43-46.

Leffler H., 1986. Mineral compartmentation within the boll. Chapter 21, p. 301-309. *In* J.R. Mauney and J.McD. Stewart (eds.), Cotton Physiology. The Cotton Foundation. Memphis, TN.

Malik M., Chaudhry F. and Makhdum M., 1996. Investigation on phosphorus availability and seed cotton yield in silt loam soils, J. An. Plant Science, 6 (12), p. 21-23.

McConnell J.S., Baker W., Miller D., Frizzell BS. and Varvil J.J., 1993. Nitrogen Fertilization of Cotton Cultivars of Differing Maturity. Agronomy Journal, Vol. 85, No. 6, p. 1151-1156.

McConnell J.S., Baker W.H., and Kirst, R.C.Jr., 1998. Yield and petiole nitrate concentrations of cotton treated with soil-applied and foliar-applied nitrogen [Online]. J. Cotton Sci., 2, p. 143-152.

McConnell J., Meyers B. and Mozaffari M., 2003. Varietal Responses of Cotton to Nitrogen Fertilization. In: Wayne E. Sabbe, Arkansas Soil Fertility Studies, p. 32-33.

Mitchell C.C., 2000. Cotton response to P in Alabama's long-term experiments. In: Proceeding Beltwide Cotton Conference, Vol. 2, National Cotton Council of America, Memphis, TN, p. 1420-1425.

Moore S.H., 1999. Nitrogen effect on position of harvestable bolls in cotton. J. Plant Nutr., 22, p. 901-909.

Munir M., Tahir M., Saleem M. and Yaseen M., 2015. Growth, yield and earliness response of cotton to row spacing and nitrogen management. The Journal of Animal & Plant Sciences, 25(3), p. 729-738.

Oosterhuis D., 2001. Physiology and nutrition of high yielding cotton in the USA. Informações agronômicas, 95, p. 18-24.

Panayotova G., Stoilova A. and Valkova N., 2007. Response of New Cotton Varieties to Fertilizing Levels at Stationary Trial Condition. Field Crops Studies, vol. IV - 2, p. 327-332.

Pettigrew W.T. and Adamczyk J.J., 2006. Nitrogen Fertility and Planting Date Effects on Lint Yield and Cry1Ac (Bt) Endotoxin Production. Agron. J., 98, p. 691-697.

Prasad M. and Siddique M.R., 2004. Effect of nitrogen and mepiquat chloride on yield and quality of upland cotton (*Gossypium hirsutum*). Indian J. Agric. Sci., 74, p. 560-562.

Rashidi M., Gholami M., 2011. Nitrogen and boron effects on yield and quality of cotton (*Gossypium hirsutum* L.). International Res J. Agri. Sci. and Soil Sci, 1, p. 118-125.

Read J.J., Reddy K.R. and Jenkins J.N., 2006. Yield and fiber quality of Upland cotton as influenced by nitrogen and potassium nutrition. Europ. J. Agron., 24, p. 282-290.

Reiter J.S., and Kreig D.R., 2000. Texas research shows fertigation is a viable option to save cotton growers both time and money on fertilizer inputs. Fluid Journal, Issue 29, 8 (2), p. 20-22.

Rutto E., Arnall B., May J., Butchee K. and Raun W., 2013. Ability of cotton (*Gossypium hirsutum* L.) to recover from early season nitrogen deficiency. J. Cot. Sci., 17, p. 70-79.

Saleem M., Shakeel A., Bilal M., Shahid M. and Anjum S., 2010. Effect of different phosphorus levels on earliness and yield of cotton cultivars. Soil & Environ., 29 (2), p. 128-135.

Sawan Z., Mahmoud M. and El-Guibali A., 2006. Response of Yield, Yield Components, and Fiber Properties of Egyptian Cotton (*Gossypium barbadense* L.) to Nitrogen Fertilization and Foliar-applied Potassium and Mepiquat Chloride. The J. of Cotton Science, Vol. 10, Issue 3, p. 224-234.

Sawan Z., Mahmoud M. and El-Guibali A., 2008. Influence of K fertilization and foliar application of zinc and P on growth, yield and fiber properties of Egyptian cotton. J. Plant Ecol., no. 1, p. 259-270.

Seilsepour M. and Rashidi M., 2011. Effect of different application rates of nitrogen on yield and quality of cotton (*Gossypium hirsutum*). American-Eurasian J. Agric. & Environ. Sci., 10 (3), p. 366-370.

Setatou H.B. and Simonis A.D., 1996. Effect of Time and Rate of Nitrogen Application on Cotton. Fertilizer Research, 43, p. 49-53.

Stewart J.McD., 1986. Integrated Events in the Flower and Fruit. In: J.R. Mauney and J. Mcd. Stewart (Eds.). Cotton Physiology. Cotton Foundation, Memphis, Tenn., p. 261-297.

Stewart J., Oosterhuis D., Heitholt J. and Mauney J. Editors. 2010. Cotton Physiology, Springer Publishing Co., New York.

Surya K., Bi Y. and Rothstein S., 2010. Understanding plant response to nitrogen limitation for the improvement of crop nitrogen use efficiency. J. Exp. Bot., 62(4), p. 1499-1509.

Yang G., Tang H., Nie Y., Zhang X., 2011. Responses of cotton growth, yield, and biomass to nitrogen split application ratio. European Journal of Agronomy, Vol. 35, Issue 3, p. 164-170.

Zhao D. and Oosterhuis D., 2000. Nitrogen application effect on leaf photosynthesis, nonstructural carbohydrate concentrations and yield of field-grown cotton. Spec. Rep. 198. Arkansas Agric. Exp. Stn., Fayetteville, AR.