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RESPONSE OF COTTON TO FERTILIZING LEVELS IN THE CONDITIONS OF SOUTHERN BULGARIA

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Abstract

The aim of this study was to evaluate the effects of different application rates of nitrogen and phosphorus on seed-cotton yield and total biomass of cotton (*G. hirsutum* L.), grown during the period 2012-2014 in Chirpan, Bulgaria, in crop-rotation with durum wheat under non-irrigated conditions. The soil type was Leached vertisols. The experimental design was a randomized complete block with four replications. Single and combined nitrogen as NH_4NO_3 in rates 0; 80; 120 and 160 $kg.ha^{-1}$ and phosphorus in rates 0; 80 and 120 $kg.ha^{-1}$ were tested. The year conditions had greatest share in the total variation of the factors – 67.4 %. The N influence on seed-cotton yield was 13.0 % and of phosphorus - 0.45 % of total variation. No significant differences in the total seed-cotton yield occurred as a function of the NP interaction. The nitrogen and phosphorus fertilizers used in cotton production remain important, as N has a decisive influence, while phosphorus has less effect. Under the influence of N fertilization, the total seed-cotton yield significantly increased by 26.6-32.9 % compared to the check (1.32 $t.ha^{-1}$), and under fertilization P_{120}– by 2.9 %. An alone phosphorous fertilization was not cost-effective agronomic activity. Application of increasing NP rates in different rates showed good economic results regarding the yield. The maximum effective yield and net return from cotton cultiar Darmi can be secured by application of $N_{120-160}P_{80-120}$ to cotton crop at Central South Bulgaria - 26.6-37.8 % more than the unfertilized. Total average dry biomass at maturity was 5.51 $t.ha^{-1}$. The total dry matter was more than the unfertilized by 24.0; 40.8 and 62.8 % at N_{80}, N_{120} and N_{160} respectively. The phosphorous fertilization increased the yield of biomass by 7.6 % at P_{80} and by 3.4 % at P_{120}. The year conditions had strong effect on seed-cotton yield and total biomass. The main reason for the high yields in 2014 for all tested rates, as well as the control, was the very good combination of temperature and rainfall during the vegetation period.

Keywords: Cotton, fertilization, nitrogen, phosphorus, seed-cotton yield, dry matter.

1. Introduction

Recommendations for cotton fertilization range from relatively low to very high rates (Clawson et al., 2008; McConell et al., 1993) but all authors agree that the maximum potential of yield cannot be attained without sufficient amount of nutrients at each developmental stage (Kirchmann & Thorvaldsson, 2000). The nitrogen level is one of the determinants of cotton productivity. In case of nitrogen deficit the cotton plants develop with suppressed vegetative and reproductive growth, have early maturity and low yield (Stewart et al., 2010). In contrast, excessive N can have negative impact on yield and can result in economic loss.

According to Clawson et al. (2006), Munir et al. (2015) and other authors N 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. According to Girma et al. (2007) the nitrogen, phosphorus and potassium fertilizers used in cotton production remain important, as N has a decisive influence, while phosphorus has less effect.

Sawan et al. (2008) and other authors reported that P fertilizer was generally not effective, and significant differences were not observed for cotton yield. Saleem et al. (2010) reported that phosphorus levels significantly affected almost all the characters related to earliness and yield. According to Cahill et al. (2008) phosphorus deficiency violates the nitrogen nutrition.

The critical level of phosphorus 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). The nitrogen uptake is reduced in plants with phosphorus deficiency (Breitenbeck and Boquet, 1993). According to Gill et al. (2000) 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 and to some extent P (Girma et al., 2007).

Weather conditions and fertilizers have a great effect on 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 have late maturity and fail to manifest their yield and quality potential. 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.

2. Material 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 during the period 2012-2014. The cotton (*G. 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 2.40-m rows spaced 0.60 m apart with a net plot size of 10 m^2. Single and combined N and P_2O_5 fertilizers were tested. The rates of nitrogen were 0; 80; 120 and 160 $kg.ha^{-1}$ and of phosphorus – 0; 80 and 120 $kg.ha^{-1}$. The source of 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 by 20-30 April. The plant population reached as much as 160 000 $plants.ha^{-1}$, approximately. Weeds were controlled by preplant and preemergence herbicides, inter-row cultivation and hand chipping. Defoliants were not applied. The crops were harvested by hand. Cultivar Darmi was established in Bulgaria in 2007 with improved quality of the fibre. It was created by crossing breeding line N 268 (with geneplasm from species *G. barbadense* L.) x C-9070 (Uzbek variety). The total seed-cotton yield ($t.ha^{-1}$) and yield of the total biomass ($t.ha^{-1}$) were determined. Analysis of variance (ANOVA) was performed to evaluate differences and interaction among the nitrogen rates, phosphorus rates and years.

The studied years had different meteorological conditions during the vegetation period (May-October) (**Figures 1 and 2**). Regarding temperature and rainfall during cotton vegetation, the studied years were characterized as follows: 2012 was very warm and dry, with insufficient precipitation during the critical stages of cotton development – flowering and bolls formation; 2013 was characterized as moderately warm and moderately dry; and 2014 was moderately warm and very wet.

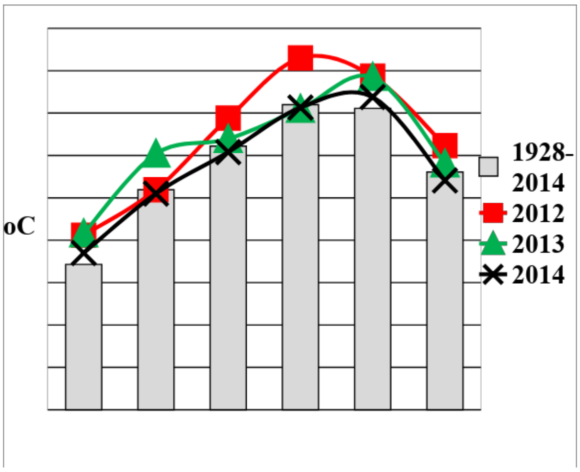

Figure 1. Temperature Sum, (°C) During Cotton Vegetation Period (IV–IX), 2012-2014

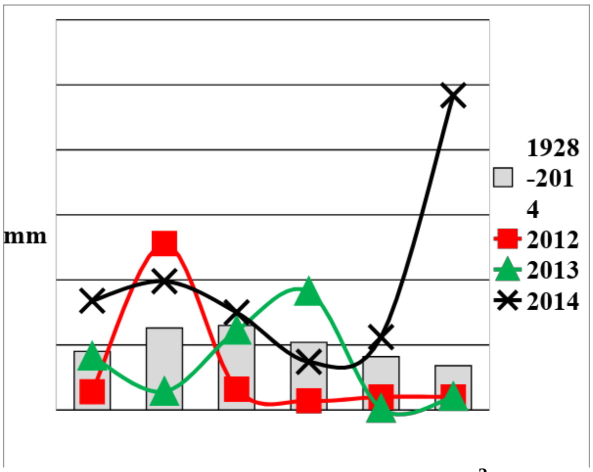

Figure 2. Rainfall Sum (mm/m^2) During Cotton Vegetation Period (IV–IX), 2012-2014

The soil type at the region was Pellic Vertisols (FAO), defined by its sandy-clay composition, with high humidity capacity and small water-permeability. The soil in the field had 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 1**).

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
Total Nmin, kg.ha^{-1}	97	83
Mobile P_2O_5, mg.kg^{-1}	51	39
Available K_2O, mg.kg^{-1}	230	160

3. Results and Discussion

Cotton productivity widely varied depending on the environmental conditions and agrotechnical activities, including applied fertilization and type of crop rotation (Coker et al., 2009). The effect of meteorological conditions on cotton yield was of great significance as Bulgaria is located on the northern border of the crop distribution.

The obtained results showed that fertilization had a good effect on seed-cotton yield with an average yield of 1.62 t.ha^{-1} (**Table 2**). The average formed seed-cotton yield without fertilization was 1.32 t.ha^{-1}. The shortage of nutrients held back the development of cotton plants and reduced cotton yield. There were significant differences in the yields of the tested N levels over the period. The studied single N fertilization showed an increase in the seed-cotton yield up to N_{120} – an average 1.76 t.ha^{-1}, which was 32.9 % above the unfertilized control. The high rate N_{160} decreased the yield by 2.4 % compared to the yield obtained from the moderate level of N_{120}.

According to Munir et al. (2015) the highest seed-cotton yield is obtained after application of 180 kg N.ha^{-1}, which, however, was not statistically proven for 120 kg N.ha^{-1}, and the authors drew the conclusion that cotton should be cultivated with fertilization of 120 kg N.ha^{-1}. These results also correspond to the realized yield in this study. A very good average yield was reported at low rates of nitrogen fertilization N_{80} – 1.67 t.ha^{-1}, and at this fertilization rate in 2014 cultivar Darmi had a very good yield - 2.46 t.ha^{-1}.

Table 2. Effect of Fertilization on the Total Seed-Cotton Yield, $t.ha^{-1}$

Treatment	Year			Average	
	2012	2013	2014	$t.ha^{-1}$	%
$N_0P_0K_0$	1.13	1.10	1.74	1.32	100
N_{80}	1.36	1.20	2.46	1.67	126.6
N_{120}	1.46	1.41	2.41	1.76	132.9
N_{160}	1.42	1.44	2.32	1.73	130.5
P_{80}	1.20	1.17	1.71	1.36	102.9
$N_{80}P_{80}$	1.38	1.32	2.45	1.72	129.9
$N_{120}P_{80}$	1.45	1.57	2.44	1.82	137.7
$N_{160}P_{80}$	1.48	1.38	2.36	1.74	131.6
P_{120}	1.22	1.11	1.6	1.32	99.9
$N_{80}P_{120}$	1.38	1.36	1.99	1.58	119.3
$N_{120}P_{120}$	1.48	1.54	2.23	1.75	132.3
$N_{160}P_{120}$	1.46	1.34	2.23	1.68	126.6
Average	**1.37**	**1.33**	**2.16**	**1.62**	
$GD_{5\ \%;\ 1\ \%;\ 0,1\%}$ = 0.28; 0.36; 0.47.					

Saleem et al. (2010) reported that phosphorus fertilization at different rates had a significant effect on almost all the traits related to cotton growth and yield. In this study, the effect of single phosphorus fertilization was low (**Table 2**). Average for the period, after fertilization at a moderate rate of 120 kg $P_2O_5.ha^{-1}$ the yield equaled the unfertilized variant, and varied significantly over the three years – an increase of yield in 2012 by 7.6 %, decrease by 5.9 % in 2014, and in 2013 it was close to the control. At a lower rate of P_{80} the average yield had an insignificant increase by 2.9 %. Cahill et al. (2008), Sawan et al. (2008) and other authors reported that single phosphorus fertilization as a whole was not effective and no significant differences were observed in cotton yields. Application of increasing NP rates in different ratios showed very good economic results regarding the yield. At combined $N_{120}P_{80}$ fertilization led to the highest average yield - 1.82 $t.ha^{-1}$. The low fertilization rate $N_{80}P_{80}$ had very good effectiveness when compared to the unfertilized, the yield was 29.9% more, and in 2014 the yield of seed cotton was 2.45 $t.ha^{-1}$. Fertilization at a moderate rate of $N_{120}P_{120}$ average for the period was 1.75 $t.ha^{-1}$, by 32.36 % more than the control. Compared to the unfertilized variant, the increase of yield at $N_{120}P_{120}$ in 2014 was 28.0 % above the control and a yield of 2.23 $t.ha^{-1}$was obtained.

The yield of seed cotton in 2014 was an average of 2.16 $t.ha^{-1}$, which was significantly higher than the ones obtained in 2012 (1.37 $t.ha^{-1}$) and 2013 (1.33 $t.ha^{-1}$). The highest result in 2014 was realized at fertilization with N_{80} – 2.46 $t.ha^{-1}$. One of the main reasons for the high yields in 2014 for all tested variants, including the control, was the very good combination of temperature and rainfall during the vegetation period. The rainfall in May and the summer months of 2014 contributed to emergence within the optimal terms, for the good density of the crops, stimulated the formation, holding and growth of a good number of bolls. In 2012 and 2013 the low yields were due to the higher temperatures during the vegetation period – 383 and 259^{o} C more than the average values, respectively, as well as due to the long spring-summer drought, which led to shedding of buds and blossoms and impeded the proper nourishment of the bolls.

The results from the analysis of variance for total seed-cotton yield as affected by the N rates, phosphorus rates and years factors are shown in **Table 3**.

When the independent effect of the factors was reported, it was found that the year conditions were the strongest source of variation on cotton yield (67.37 % of the total effect), significant at P δ 0.001. The rate of N fertilization also had a strong impact (13.04 %). The effect of phosphorus rates at various rates - 0.45 % was low and not proven. The interaction N x P was insignificant, i.e. the applied phosphorus rates had one-way effect on nitrogen. The interaction N x Year was proven at P δ 0.01, whereas P x Year was significant to a low extent.

Table 3. Analysis of Variance for Cotton Yield with Fertilization, 2012-2014

Source of variation	Degree of freedom	Sum of squares	Sum of squares, %	Dispersion	F
Total	143	318628.5	100.00		
Blocks	3	3434.2	1.08*	1145	2.96
Variants	35	274627.8	86.19***	7846	20.31
A - N rate	3	41556.5	13.04***	13852	35.85
B - P rate	2	1425.5	0.45	713	1.84
C - Year	2	214654.5	67.37***	107327	277.8
A x B	6	516,8	0.16	86.12	0.22
A x C	6	9072	2.85**	1512	3.91
B x C	4	4174.8	1.31*	1044	2.70
A x B x C	12	3227.8	1.01	269	0.70
Error	105	40566.5	12.73	386	-

Regarding the independent effect of N, the analysis of variance showed that average for the study the tested rate of N_{120} led to forming the highest yield – 1.78 $t.ha^{-1}$, followed by the high rate of N_{160} – 1.66 $t.ha^{-1}$ (**Fig. 3**). Regarding the main effect of phosphorus, rate P_{80} had a greater effect on yield, but the differences with the effect of the other two tested phosphorus rates were insignificant (**Fig. 4**).

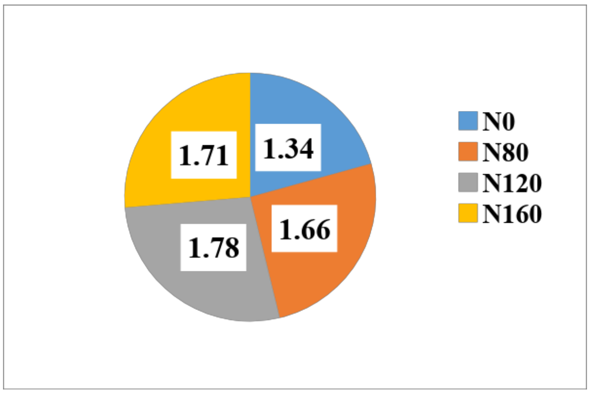

Figure 3. Main Effect of Nitrogen on the Total Seed-Cotton Yield, $t.ha^{-1}$

GD $_{5\,\%;\,1\,\%;\,0,1\%}$ = 0.92; 1.21; 1.57

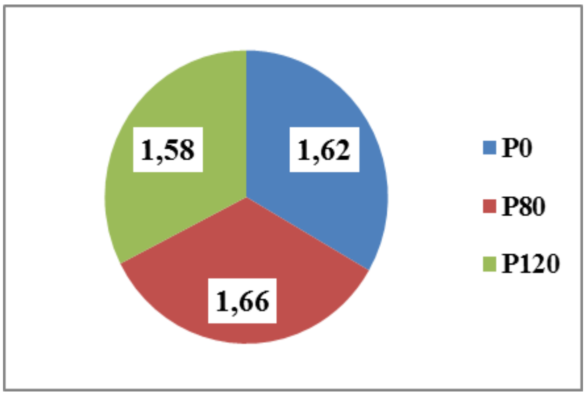

Figure 4. Main Effect of Phosphorus on the Total Seed-Cotton Yield, $t.ha^{-1}$

GD $_{5\,\%;\,1\,\%;\,0,1\%}$ = 0.79; 1.05; 1.39

The amount of dry matter including fiber and seed yield – i.e. the total yield of raw cotton, as well as formed leaves, stems and bolls under different nutritional management is shown in **Table 4.**

The total dry biomass in maturity average for the experimental period was 5.51 $t.ha^{-1}$. Average for the 3-year period, unfertilized cotton plants formed 4.07 $t.ha^{-1}$ of dry matter. At single fertilization with $N_{80}N_{120}$ and N_{160} the total average dry matter at the maturity stage exceeded the unfertilized by 24.0, 40.8 and 62.8 %, respectively. A number of authors analyzed the role of nitrogen in forming the total biomass. Surya et al. (2010) pointed out that nitrogen influenced both vegetative and reproductive growth as its deficiency decreased the yield of total biomass by accelerating the premature leaf senescence (Fageria and Baligar, 2005) and their early cut-out (Read et al., 2006), while nitrogen in excess can delay crop maturity and promote boll shedding, diseases and insect damages (Howard et al., 2001).

Single phosphorus fertilization contributed to the increase of dry matter by 7.62 % at P_{80} and by 3.36 % at P_{120}. The results showed differences by years and greater biomass in 2014 stood out – 4.95 and 4.45 $t.ha^{-1}$ at P_{80} and P_{120}, respectively, whereas the quantity in 2012 and 2013 for the two high rates ranged from 3.90 to 4.26 $t.ha^{-1}$. According to some researchers (Dorahy et al., 2008) the application of phosphorus fertilizers has no effect on the quantity of biomass and fiber yield, whereas others (Bassett et al., 1970; Leffler, 1986) reported that phosphorus fertilization increased dry matter and assimilation of nutrients.

Table 4. Effect of Fertilization on the Total Dry Biomass of Cotton in Maturity, $t.ha^{-1}$

Treatment	Year			Average	
	2012	2013	2014	$t.ha^{-1}$	%
$N_0P_0K_0$	3.80	3.65	4.75	4.07	100.0
N_{80}	4.74	4.50	5.85	5.03*	123.7
N_{120}	5.12	4.96	7.10	5.73***	140.8
N_{160}	5.76	6.20	7.90	6.62***	162.8
P_{80}	4.20	3.96	4.95	4.38	107.5
$N_{80}P_{80}$	5.06	4.58	5.95	5.20**	127.8
$N_{120}P_{80}$	5.48	5.20	7.25	5.98***	147.0
$N_{160}P_{80}$	6.04	5.90	8.05	6.66***	163.8
P_{120}	3.90	4.26	4.45	4.20	103.4
$N_{80}P_{120}$	4.72	4.96	5.75	5.14**	126.5
$N_{120}P_{120}$	5.48	5.48	7.60	6.19***	152.1
$N_{160}P_{120}$	6.18	6.35	8.14	6.89***	169.4
Average	**5.04**	**5.00**	**6.48**	**5.51**	-
$GD_{5\%;\,1\%;\,0,1\%}$ = 0.63; 0.86; 1.16					

Combined NP fertilization had a proven effect on dry matter yield. After fertilization with $N_{80}P_{80}$ the total dry biomass increased and it was 5.197 $t.ha^{-1}$ average for the period, which was by 27.8% above the unfertilized. Increasing the combined fertilization rates also led to an increase of cotton dry matter. $N_{160}P_{80}$ formed 6.66 $t.ha^{-1}$ biomass, 63.85% more than the control. Average for the period, the highest result was reported for high combined fertilization at rate $N_{160}P_{120}$ – 69.4% above the unfertilized.

Table 5. Correlation of Fertilization and Cotton Productivity

Correlations	2012	2013	2014	2012-2014
Only N rates - Total cotton yield	0.923*	0.953*	0.776	0.921*
Only N rates - Total dry biomass	0.997**	0.960**	0.986*	0.988*
N rates combined with P - Total cotton yield	0.935**	0.652	0.712	0.805*
N rates combined with P - Total dry biomass	0.991*	0.973**	0.968**	0.989**
Only P rates - Total cotton yield	0.945	0.981	0.518	0.774
Only P rates - Total dry biomass	0.827	0.999*	0.882*	0.928*
P rates combined with N - Total cotton yield	0.836*	0.678	0.460	0.659
P rates combined with N - Total dry biomass	0.673	0.761*	0.622	0.685

The effect of fertilization on total biomass was strong – 61.58 % of the total effect of tested factors, and year conditions also had significant effect – 32.5 %. In 2014, the biomass yield was significantly higher compared to the other two years and at rate N_{160} biomass was 7.90 $t.ha^{-1}$ - 66.3 % more than the control, whereas at $N_{160}P_{120}$ dry biomass exceeded the unfertilized by 71.4 %. The average amount of biomass in 2014 was 6.48 $t.ha^{-1}$, and in 2012 and 2013 – 5.04 and 5.00 $t.ha^{-1}$, respectively. The increased biomass at different fertilization rates was mainly from vegetative mass – leaves, stems and bolls.

For the studied period the share of seed cotton compared to the total above ground mass was an average of 29.4 %, and when grown without fertilization it was 32.5 %, 33.2 % at N_{80} and it decreased to 26.1% at N_{160} and up to 24.3 % at $N_{160}P_{120}$ (**Tables 2 and 4**). The differences can be explained with the role of nitrogen to stimulate growth of over ground plant parts, with the growing conditions and technology, with the difference in formed yields of cotton and vegetative mass. The variations by years under the influence of fertilization were better expressed regarding the vegetative mass compared to the fiber and seed yield.

Over the three years, the correlation between alone and combined nitrogen fertilization with biomass was better expressed (**Table 5**), while the phosphorous fertilization was significantly correlated only to total dry biomass.

4. Conclusions

On the basis of three years field experimentation, we can conclude that the nitrogen and phosphorus fertilizers used in cotton production remain important, as N has a decisive influence, while phosphorus has less effect.

Application of increasing NP rates in different rates showed good economic results regarding the yield. The maximum effective yield and net return from cotton cultiar Darmi can be secured by application of $N_{120}P_{80}$ per hectare to cotton crop at Central South Bulgaria in Leached vertisols soil type. At this combined fertilization the average seed cotton yield was 1.82 $t.ha^{-1}$, by 37.8 % above the unfertilized. Under the effect of nitrogen fertilization, yield increased by 26.6 (N_{80}) to 32.9 % (N_{120}) compared to the unfertilized (1.32 $t.ha^{-1}$), and phosphorus fertilization – up to 2.9 % at P_{80}. An alone phosphorous fertilization was not an efficient agronomic activity.

The total dry biomass in maturity was an average 5.51 $t.ha^{-1}$. Unfertilized cotton plants formed 4.07 $t.ha^{-1}$ of biomass. At single fertilization with N_{80}, N_{120} and N_{160}, the total dry matter in the maturity stage was more than the unfertilized by 24.0, 40.8 and 62.8 %, respectively. Single phosphorus fertilization increased the biomass yield by 7.6 % at P_{80} and by 3.4 % at P_{120}. The biomass was highest at combined fertilization $N_{160}P_{120}$ – 69.4 % above the unfertilized.

The share of seed cotton compared to the total above ground biomass was an average of 29.4 %, and when grown unfertilized it was 32.5 %, it was 33.2 % at N_{80} and decreased to 26.1 % at N_{160} and to 24.3 % at $N_{160}P_{120}$.

The year conditions had strong effect on seed-cotton yield and total biomass. The main reason for the high yields in 2014 for all tested rates, as well as the control, was the very good combination of temperature and rainfall during the vegetation period.

References

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

Breitenbeck, G. & 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.: 1298-1300.

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): 537-542.

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

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

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

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

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, 31 (11): 1877-1888.

Fageria, N.K. & Baligar, V.C. (2005). Enhancing nitrogen use efficiency in crop plants. Adv. Agron. 88: 97-185.

Gill, K., Sherazi, S., Iqbal, J., Ramzan, M., Shaheen M. & Ali, Z. (2000). Soil Fertility Investigations on Farmers Fields in Punjab. Soil Fertility Research Institute, Department of Agriculture, Govt. of Punjab, Lahore, Pakistan: 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: 12-19.

Howard, D.D., Gwathmey, C.O., Essington, M.E., Roberts, R.K., & Mullen, M.D. (2001). Nitrogen fertilization of no-till cotton on loess- derived soils. Agron. Journal, 93: 157-163.

Kirchmann, H. & Thorvaldsson, G. (2000). Challenging targets for future agriculture, European Journal of Agronomy, 12 (3-4): 145-161.

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

McConnell, J.S., Baker, W., Miller, D., Frizzell, B.S. & Varvil, J.J. (1993). Nitrogen Fertilization of Cotton Cultivars of Differing Maturity. Agronomy Journal, 85(6): 1151-1156.

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

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

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

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

Sawan, Z., Mahmoud, M. & 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., 1: 259-270.

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

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