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Growth, yield and quality of *Bt* cotton (*Gossypium hirsutum* L.) as affected by nutrient omissions in irrigated cotton wheat cropping systems

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ABSTRACT: The experiment was conducted to assess the response of cotton to nutrient omissions and estimate yield losses due to sustained nutrient omissions in cotton-wheat cropping system. Treatments comprised omission of N, P, K, S and Zn , 50 per cent omission of N, P, and K, absolute control (no nutrient applied) and optimum plane of nutrition (150-26.4-50-15-3 kg ha^{-1} N-P-K-S-Zn). There was a significant reduction in the growth attributes such as plant height, leaf area index, dry matter accumulation due to N and K omission during the year 2010 and due to N, P and K omission during the year 2011. Omission of N and K during the year 2010 and N, P and K during the year 2011 also significantly reduced the yield attributes such as sympodials/plant, bolls/plant and boll weight. The results indicated that N is the most limiting nutrient followed by K and P because their omission resulted in a significant reduction in the growth and yield of cotton. The reduction in seed cotton yield (SCY) during the year 2010 was 28, 6.7 and 14.5 per cent due to N, P and K omission, respectively. The corresponding figures for the year 2011 were 26, 15 and 12 per cent, respectively. The effect of S and Zn omission on seed cotton yield was statistically non significant. The effect of nutrient omissions on fiber quality paramerts was non significant during both the years.

Keywords **:***Bt* cotton, cotton quality, nitrogen, nutrient omission, phosphorus, potassium, seed cotton yield

Cotton, the most important commercial crop of India, often referred to as the 'White Gold' provides employment to about 60 million people. It is cultivated on an area of 11.0 m ha out of which more than 90 per cent is occupied by *Bt* cotton. In India, cotton- wheat cropping system is followed on 1.6 million ha and on 2.62 million ha in Pakistan. It has been reported that 90 per cent of soils in India are low to medium in nitrogen (N), 80 per cent in phosphorus (P) and 50 per cent in potassium (K) (Anonymous, 2010). The S (41%) and Zn (49%) deficiency is also widespread in Indian soils (Singh, 2004). Application of all three nutrients had some effect on lint yield, although most of the response was attributed to N (all cultivars) and to some extent P (some cultivars) and the results for fibre length indicate that K fertilization is the key to long fibres, while N rates greater than 90 kg ha^{-1} significantly reduce lint quality variables (Girma *et al.,* 2007). Several factors, including soil type, affect cotton response to P. Potassium deficiency adversely affects the lint quality and decreases the fruit biomass (Pettigrew *et al.,* 2005). In the intensively cultivated North zone, S is becoming a major yield limiting factor and in recent years response to its application has been commonly observed. On alluvial soils, there was a response to direct application of 30 kg S/ha in cotton wheat/mustard (Singh *et al.*,, 2004) and cotton sunflower (Singh and Kairon, 2001) cropping system. Positive responses to soil application of 15-25 kg $ZnSO_4$ or foliar spray of $ZnSO_4$ (0.5%) was reported from Hisar in Haryana, Faridkot and Ferozpur in Punjab and Delhi.

Cotton, particularly hybrids being exhaustive, draw plenty of soil nutrients and thus under continuous cropping pattern, nutrient management assumes importance. To cater to the uptake needs of these crops, soil reserves alone are not sufficient making it is necessary to supply them through fertilizers. Hence, initiatives have been taken in recent years through nutrient omission approaches to arrive at the soil and fertilizer contributions to the crop performance and finally arrive at site-specific nutrient management recommendations for targeted and sustainable yield (Dobermann *et al.*, 2003). Though, such studies are being carried out in rice/maize wheat cropping systems only in India and abroad to generate useful information but, missing in cotton wheat cropping system. Therefore, keeping the above facts in view a field an experiment was conducted to assess the impact of nutrient omissions on growth, yield and quality of *Bt* cotton grown in cotton-wheat cropping system.

MATERIALS AND METHODS

A field experiments on *Bt* cotton was conducted during the rainy seasons of years 2010 and 2011 following cotton-wheat cropping system, at the research farm of the Indian Agricultural Research Institute, New Delhi (India). New Delhi is situated at 28°35'N latitude and 77°12'E longitude at an altitude of about 228.61 m above mean sea level. It has a semi arid and sub tropical climate with hot dry summers and severe cold winters. The soil of the experimental field was sandy loam in texture, low in available nitrogen (196.4 kg/ha), medium in available P (12.5 kg/ha) and K (286.6 kg/ha). The soil available sulphur and zinc amounted to 34.3 kg/ ha and 0.88 mg/kg of soil, respectively.

The experiment had 10 treatments laid out in randomized block design with three replications in fixed plots. Treatments comprised omission of N, P, K, S and Zn, 50 per cent omission of N, P, and K, absolute control (no nutrient applied) and optimum plane of nutrition (150-26.4-50-15-3 kg/ha N-P-K-S-Zn). Same treatments were repeated in wheat in fixed plots. The fertilizers used were urea (46% N), triple superphosphate (46% P_2O_5), muriate of potash (60% K2O), gypsum (15% S) and zinc oxide (81% Zn) so that each fertilizer shall supply only a single nutrient under investigation. The nutrient doses given to cotton are summarized in Table 2. The cotton variety used was transgenic 'Rasi 134 BG II' with stacked genes, *cry1ac* and *cry1ab* for resistance against American bollworm and tobacco caterpillar (*Spodoptera litura* Fabricius).

RESULTS AND DISCUSSION

Growth attributes : Tallest plants were recorded in the optimum nutrition plots and shortest in the control plots at all the growth stages during both the years (Table 1). Control and N omission plots showed significantly lesser plant height than other treatments. N being an integral part of plant proteins, nucleic acids and

Table 1. Effect on nutrient omissions on growth parameters of *Bt* cotton

Treatment	Plant height at harvest (cm)		LAI (120 DAS)		Dry matter partitioning (150 DAS)				Crop growth rate (g/m/day) (90-120 DAS)		Main stem nodes/ plant		Mono- pods/ plant		Sym- podials/ plant	
	2010	2011	2010	2011	Leaves	Stems	Reproductive	**Total**	2010	2011	2010	2011	2010	2011	2010	2011
NPKSZn	181.5	144.4	5.40	4.97	53.9	157.6	117.1	**328.6**	8.95	10.49	24.4	22.9	4.27	4.21	34.4	34.3
PKSZn(N)	146.0	114.4	4.00	3.21	34.5	107.1	75.4	**217.0**	5.76	4.07	16.4	14.4	2.76	2.73	23.0	21.7
NKSZn(P)	174.0	136.2	4.87	4.50	50.8	151.3	107.5	**309.5**	8.15	8.62	23.4	20.9	4.02	3.71	33.0	31.4
NPSZn(K)	173.0	143.0	4.91	4.61	50.8	151.2	107.5	**309.4**	8.73	9.04	23.7	21.4	3.77	3.75	32.4	32.1
NPKZn(S)	181.7	144.0	5.09	4.79	50.8	148.9	110.0	**309.6**	9.63	10.37	24.4	22.9	4.27	4.21	34.4	34.3
NPKS(Zn)	179.0	146.8	5.28	4.87	52.7	155.5	113.7	**321.9**	8.84	9.67	24.8	22.2	4.27	4.21	35.0	33.3
Control	141.9	107.9	3.49	3.15	30.9	95.8	67.3	**193.9**	4.37	4.31	16.0	14.1	2.76	2.73	22.5	21.1
(50%N)	168.5	146.9	4.59	4.14	42.6	126.7	90.2	**259.4**	5.81	9.16	21.6	19.9	3.52	3.47	30.4	29.8
(50%P)	173.0	141.2	5.00	4.53	49.5	146.9	104.6	**300.9**	7.95	8.27	24.4	22.4	4.27	4.21	34.4	33.7
(50%K)	170.8	122.5	5.01	4.72	51.9	154.5	109.7	**316.1**	9.54	7.53	24.5	21.7	4.27	4.21	34.6	32.6
SE (m)+	6.67	5.98	0.19	0.14	2.11	7.43	4.3	**8.45**	0.73	0.73	0.54	0.54	0.06	0.06	0.85	0.66
CD (p=0.05)	19.09	17.12	0.54	0.40	6.04	21.27	12.25	**24.15**	2.08	2.09	1.54	1.55	0.16	0.18	2.42	1.89

Table 2. Effect nutrient omissions on yield attributes and relative economics of Bt cotton

Treatment	Bolls/ plant		Unop- ened bolls/ plant		Boll weight (g)		Stalk yield (t/ha)		Seed cotton yield (t/ha)		Ginning outturn (%)		Net returns Rs×10^3		B.C ratio	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
NPKSZn	46.7	43.9	16	15.5	4.70	4.74	7.68	7.21	3.42	3.24	35.91	35.81	92.90	107.08	3.35	3.25
PKSZn (N)	35.7	31.4	11.6	9.7	3.15	3.17	5.06	4.11	2.45	2.39	33.71	32.15	60.20	70.49	2.33	2.29
NKSZn (P)	43.4	38.6	16.8	15.2	4.59	4.62	7.55	6.75	3.18	2.73	35.22	34.13	86.87	87.87	3.31	2.79
NPSZn (K)	41.4	37.6	13.9	14.4	4.34	4.36	6.93	6.36	2.91	2.83	33.48	33.61	77.28	91.59	2.94	2.94
NPKZn(S)	44.5	35.7	14.5	14.7	4.42	4.36	7.29	6.87	3.21	3.09	34.87	35.59	86.12	101.17	3.13	3.09
NPKS(Zn)	47.8	37.2	17.2	14.5	4.56	4.61	7.72	6.95	3.34	3.05	36.14	35.58	91.02	98.95	3.32	3.03
Control	28.4	29.2	8.9	9.0	2.94	2.98	4.56	3.80	2.27	2.17	32.69	31.88	57.04	65.95	2.54	2.44
(-50%N)	40.0	33.1	13.1	11.8	3.69	3.82	7.05	5.85	2.98	2.83	34.61	34.64	79.43	89.70	2.96	2.81
(-50%P)	41.2	36.6	11.6	13.1	4.45	4.49	7.44	6.71	3.34	2.97	35.37	34.13	91.00	96.26	3.37	2.99
(-50%K)	47.6	37.6	13.0	13.8	4.48	4.52	7.58	7.00	3.13	3.05	35.26	34.51	84.54	100.45	3.13	3.13
SE (m)+	1.76	1.66	0.72	0.65	0.10	0.09	0.23	0.33	0.14	0.12	0.59	0.53	-	-	-	-
CD (p=0.05)	5.03	4.76	2.06	1.87	0.30	0.27	0.67	0.94	0.40	0.33	1.68	1.52	-	-	-	-

Table 3. Effect of nutrient omissions on quality parameters of Bt cotton

Treatment	Uni-formity ratio		2.5 per cent span length (mm)		50 per) cent span length (mm		Fibre strength (g/tex)		Fibre elongation (%)		Micronaire	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Cotton												
NPKSZn	52.76	46.86	27.61	26.45	14.38	12.08	23.32	20.91	5.81	6.43	3.97	3.48
PKSZn(N)	51.91	47.62	27.85	26.25	14.40	12.50	23.82	22.31	5.77	6.48	3.73	3.62
NKSZn(P)	51.09	49.14	28.27	26.56	14.53	13.13	24.59	22.13	5.71	6.61	3.82	3.53
NPSZn(K)	52.13	47.60	28.88	26.56	14.75	12.62	23.72	22.37	5.79	6.51	3.86	3.52
NPKZn(S)	52.83	47.17	28.57	26.48	15.29	12.62	24.42	22.90	5.69	6.50	4.06	3.25
NPKS(Zn)	52.26	48.66	28.71	25.96	15.21	12.63	24.30	21.12	5.76	6.74	3.97	3.54
Control	52.10	48.93	28.93	26.65	15.08	13.05	24.76	22.94	5.74	6.49	3.94	3.42
(50%N)	54.02	47.90	28.11	26.27	15.11	12.57	24.16	21.34	5.78	6.60	3.98	3.32
(50%P)	52.29	48.47	28.11	26.51	14.62	12.86	23.51	22.51	5.78	6.53	3.92	3.59
(50%K)	52.68	47.04	28.20	26.30	14.92	12.41	24.20	21.36	5.74	6.70	3.79	3.58
SE (m)+	0.84	0.78	0.39	0.46	0.72	0.37	0.90	0.70	0.02	0.01	0.14	0.16
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

chlorophyll, enhances photosynthesis rate and vegetative growth which is reflected in increased plant height. An increase in plant height of cotton due to increased N ferilization has been reported by several workers (Das *et al.*, 2008). Phosphorous and potassium omission slightly decreased the plant height but the same was at par with the optimum nutrition treatments. P omission significantly reduced the leaf area index during the year 2011. Srinivasan *et al.,* (2002) observed that phosphorus levels did not influence plant height, number of monopodial and sympodial branches, but resulted in higher number of bolls and boll weight at 100 per cent phosphorus level. Highest leaf area index was recorded in optimum nutrition plots and least in the control treatments at all the growth stages and in either years of the study. N omission, 50% N omission and control treatments significantly reduced LAI during both the years. During the year 2011 P omission had also resulted in significantly lower LAI than the optimum nutrition plots yield. The dry matter accumulation (averaged over two years) was considerably reduced in the N omission, 50 per cent N omission and control plots which affected the seed cotton and stalk yield. Perusal of the data at 150 DAS showed that N omission, 50 per cent N omission and P and K omission significantly reduced the dry matter partitioning into the reproductive parts which affected the seed cotton. S and Zn omission had a non significant effect on dry matter accumulation. Under optimum N supply in combination with other nutrients, higher dry matter was aportioned to leaves and reproductive parts which cotributed to the higher yield. Balanced supply of nutrients also maintained higher crop growth rates. Higher dry maater production under balanced fertilization has been reported by several other workers (Rui *et al.*,, 2008). The highest nodes/plant were recorded in the optimum nutrition plots and the lowest in control. N omission and 50 per cent N omission plots during both the years and P omission during the year 2011 also significantly reduced the number of main nodes/plant. Monopods/ plant were significantly reduced due to N, P, K and 50 per cent N omission during both the years. Sympodials/plant, the fruit bearing branches, were significantly reduced due to N omission and 50 per cent N omission during 2010 and N, P, K and 50 per cent N omission during the year 2011. P and K omission also resulted in the reduction of sympodials/plant by 8 per cent and 6 per cent, respectively during the year 2011. Partitioning of dry matter into monopodia and sympodia/plant were significantly influenced by the fertilization treatments particularly nitrogen. Taller plants with higher LAI, greater dry matter apportioning into leaves and repdroductive parts led to higher monopodials and sympodials/plant. Several other workers have also reported higher monopodials and sympodials at higher N doses (Bibi *et al.,* 2011) and balanced fertilization (Biradar *et al.,* 2011).

Yield and yield attributes: Highest number of bolls/plant was recorded in the optimum nutrition plots and lowest in control plots (Table 2). N omission, 50 per cent N omission and K omission significantly reduced the number of opened bolls/plant during 2010. During 2011, P omission also led to significant reduction in the number of bolls/plant. Higher number of unopened bolls/plant was recorded in the optimum nutrition plots and lower in the treatments where no nutrient was given. P omission also resulted in increase in the number of unopened bolls plant. Generally higher number of bolls/plant was recorded during the year 2010 than the year 2011. S and Zn omission had a non significant effect on number of bolls when compared with optimum nutrition plots. Optimum nutrition plots produced heavier bolls and lowest boll weight was recorded in the control plots during both the years. N, 50 per cent N, P and K omission significantly reduced the boll weight during both the years. The reduction in the boll weight due to N, P and K omission was 30 per cent, 12 per cent, and 14 per cent, respectively during the year 2010. The corresponding figures for the year 2011 were 25 per cent, 10 per cent and 15 per cent, respectively. S and Zn resulted in the reduction of only 2-4 per cent in boll weight, which was statistically non significant during both the years. Growth and biomass production were strongly affected by the indigenous nutrient supply and the nutrients supplied through fertilizers. This was reflected in yield components, stalk and seed cotton yield. Stalk yield ranged from 4.5 to 7.5 t/ha and 4.1 to 7.2 t/ ha during the years 2010 and 2011, respectively. The reduction in stalk yield was strongly related to the N supply, omission of which resulted in 34.1 per cent and 43 per cent reduction during the years 2010 and 2011, respectively. The reduction in stalk yield due 50 per cent N omission was 9 per cent and 18 per cent over optimum fertilization treatment during the years 2010 and 2011, respectively. The reduction in the stalk yield was 1.7 and 9 per cent for 2010 and 6.5 per cent and 13.46 per cent for 2011 due to P and K omission, respectively. It was observed that N is the most limiting nutrient and P became progressively limiting under sustained omissions in cotton-wheat cropping system. Seed cotton yield ranged from 2.27-3.42 t/ha and 2.17-3.24 t/ha during the year

2010 and 2011, respectively. Overall the SCY was slightly lower during the year 2011 than the preceding year. The reduction in SCY during the year 2010 was 28 per cent, 6.7 per cent, 14.5 per cent due to N, P and K omission, respectively. The corresponding figures for the year 2011 were 26 per cent, 15 per cent, and 12 per cent, respectively. Higher vigour and dry matter accumulation resulted in taller plants, greater number of bolls and boll weight in the optimum nutrition plots. Continuous omission of P in the preceding cotton and wheat crops might have resulted in severe decline in the P supply, which had an adverse effect on yield attributes. Ginning turnout (GOT%) was significantly lower at higher levels of N. N omission and control treatments (no nutrient) resulted in higher ginning per centage and differences in other treatments were statistically non significant. Optimum plane of nutrition wherein N, P, K, S and Zn was applied at recommended rates maintained superiority in respect of yield components, stalk and seed cotton yield. Several workers have reported a significant response of yield attributes to applied N (Bibi *et al.,* 2011), P (Rajendran *et al.*, 2011), K (Kaur *et al.,* 2011) and balanced application of N, P and K (Birader *et al.,* 2011).

Fibre quality parameters: The data on the fibre quality parameters of cotton are given in Table 3. The nutrient omission treatments failed to produce any significant difference in the quality parameters of cotton *viz* uniformity ratio, 2.5per cent span length, 50per cent span length, fibre strength, fibre elongation and micronaire during both the years. Numerically though higher values of these were recorded during the year 2010 than 2011, except fibre elongation, which was higher during the year 2011.Potassium remains in an ionic form in the plant cells and tissues and plays an important role in osmoregulation. K plays an important role in fibre development and the turgor driven expansion of fibre cells which ultimately determines the fibre length (Dhindsa *et al.*,, 1975). It is generally believed the quality parameter was more controlled by genetic make up of the plant these results are conformity with Aruna and Reddy (2010).

CONCLUSION

N omission resulted in a significant reduction in growth and yield attributes and seed cotton yield and thus proved to be the most limiting and deficient nutrient in the soil. Balanced fertilization is very important for sustaining high cotton yields. However, nutrient application did not affect the cotton quality parameters.

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