

Productivity and profitability of Bt cotton (*Gossypium hirsutum*)–wheat (*Triticum aestivum*) cropping system as affected by nutrient omissions

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ABSTRACT

A field experiment on nutrient omission plot technique (NOPT) in Bt cotton (*Gossypium hirsutum* L.)-wheat (*Triticum aestivum* (L.) emend. Fiori & Paol) cropping system was conducted at New Delhi during 2010-11 and 2011-12. The experiment had 20 treatments, laid out in randomized block design with three replications in fixed plots. Treatments comprised omission of N, P, K, S and Zn, 50% 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). Each of the 10 treatments was duplicated and randomized so that there were 20 plots within each replication for cotton. Same nutrient omission treatments were tested on wheat in 50% of plots and uniform N was applied in the remaining 50% of the plots. Yield in cotton was estimated in terms of seed cotton, and stalk yield. Nitrogen proved to be most limiting nutrient and there was a reduction in the seed cotton yield to the tune of 28%, 6.5% and 14.5% due to N, P and K omissions during the year 2010. N continued to be the most limiting nutrient followed by P and K during the year 2011. The corresponding figures for the year 2011 were 26.5 %, 15.5% and 12.4 % respectively. The yield reduction in seed cotton yield due to S and Zn omission ranged from 2.0-5.0%, which was statistically at par with optimum nutrition treatment during both the years. The reduction in the grain yield of wheat due to N, P and K omission was 35%, 9.5% and 2%, respectively during the year 2010-2011 and the corresponding figures for the year 2011-12 were 48.5%, 11.1% and 7.7%, respectively. The reduction in grain yield due to S and Zn omission was marginal and ranged from 2.0-2.5% during both the years. Highest net profit of ₹1,33,340 and ₹1,58,340 was earned from cotton-wheat cropping system during the years 2010-11 and 2011-12, respectively, in the optimum nutrition plots.

Key words : Bt cotton, Nitrogen, Nutrient omission, Phosphorous, Potassium, Wheat

Cotton popularly known as ‘White Gold’ is grown mainly for fibre. In addition to this, cotton seed is second important source of the edible oils. India has been a traditional home of cottons and cotton textiles. The introduction of Bt cotton with inherent resistance to American bollworm (*Helicoverpa armigera* Hubner), in 2002 (bollgard I) and American bollworm and tobacco caterpillar (*Spodoptera litura* Fabricius) in 2006 (bollgard II) in India led to tremendous progress in cotton production. Subsequently the country became the second largest producer and third largest consumer of cotton in the world by 2010. By 2011-12, more than 90 percent of cotton area

was covered under Bt cotton and hence the production has more than doubled (compared to 2002-03), yields have gone up by almost 70%, and export potential for more than ₹10,000 crore worth of raw cotton per year has been created (agricoop.nic.in).

Cotton-wheat cropping system is certainly the next dominant cropping system after rice-wheat in north-western India and cotton growing areas of Pakistan. In India, cotton-wheat cropping system is followed on 1.40 m ha and on 2.62 m ha in Pakistan. The total area under cotton-wheat cropping system comes to about 4.0 m ha in the north-western plains of India and Pakistan (Mayee *et al.*, 2008). Cotton and wheat are exhaustive crops as is evident from the fact that they remove 43.2-29.3-53.3-24.0 and 25.0-9.0-33.0-4.7 kg of N-P-K-S/t of economic product, respectively (Tandon, 2004). To cater to the uptake needs of these crops, soil reserves alone are not sufficient making it necessary to supply them through chemical fertilizers. However, the fertilizers applied are either insufficient

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or imbalanced and not based on soil supply capacity. Initiatives are made in recent years through nutrient omission approaches to arrive at the soil and fertilizer contributions to the crops performance and finally arrive at site specific nutrient management recommendations for targeted and sustainable yield. Yield in the plot balanced fertilization with relatively good crop management can be used to estimate an attainable yield target. Nutrient-limited yields are determined from plots in which the nutrient of interest is not added. For example, the N-limited yield is determined in an N omission plot receiving no N fertilizer but sufficient P and K to ensure that they do not limit yield. The P/K-limited yield is determined in a P/K omission plot receiving no P/K fertilizer but a sufficient supply of other nutrients (www.irri.org/irrc/ssnm). Keeping the above facts in view a field experiment was conducted to assess the contribution of various nutrients towards yield and profitability of cotton, wheat and the cotton-wheat system *vis-a-vis* optimum fertilization schedules using nutrient omission plot technique.

MATERIALS AND METHODS

A field experiment on Bt cotton-wheat cropping system was conducted during the of year 2010-11 and 2011-12, 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 and 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 20 treatments, laid out in randomized block design with three replications in fixed plots. In cotton treatments comprised omission of N, P, K, S and Zn, 50% 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). Each of the 10 treatments was duplicated and randomized so that there were 20 plots within each replication for cotton. Same nutrient omission treatments were tested on wheat in 50% of plots and uniform N was applied in the remaining 50% of the plots. All the 20 treatments differed from each other when taken on a system basis. 150-26.4 -50- 15-3 kg/ha N-P-K-S-Zn was applied as optimum fertilizer dose. The fertilizers used were urea (46% N), triple superphosphate (46% P₂O₅), 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. Half of N and full dose of all other nutrients was applied as basal application to cotton. Re-

maining N was applied at squaring and flowering in two equal splits. Similarly in wheat half N was applied as basal dose and the remaining half at first and second irrigation in two equal splits.

Bt cotton 'Rasi 134 BG II' with stacked genes, *cry I ac* and *cry I ab* for resistance against American bollworm and tobacco caterpillar (*Spodoptera litura* Fabricius), is medium tall with bushy growth habit having a ginning percentage of 37 and staple length of 27-28 mm. Wheat 'HD 2851' (Pusa Vishesh), a dwarf variety of 126-134 days duration having a yield potential 4-4.5 t/ha was used in the experiment. The cost of cultivation and relative economics of each crop was calculated on the basis of minimum support price of the inputs and the produce.

RESULTS AND DISCUSSION

The mean weekly minimum and maximum temperature during *khari*f season varied between 14.2°C to 28.9°C and 23.2°C to 41.5°C, respectively, during the year 2010 and 10.7°C to 27.2°C and 26.8°C to 39.2°C, respectively, during the year 2011. The total rainfall was 926.60 mm from 1st June 2010 to 31st December, 2010 and 574.30 mm for the corresponding period during 2011. Over all 2010 weather parameters particularly rainfall and temperature, were more favorable for cotton growth and yield. For wheat the weather conditions were more or less the same during the year 2010-11 and 2011-12.

Cotton

Yield attributes, stalk, and seed cotton yield

Nutrient omissions significantly influenced the yield components of cotton during both the years of experimentation (Table 1). Although, N omission resulted in severe reduction in opened bolls/plant, P and K omission had also significant effect on the opened bolls/plant an important yield attributes. The unopened bolls/plant were significantly lower in control and N omission treatments. Boll weight was also significantly reduced due to N, P and K omissions. Lowest boll weight was recorded in control and N omission plots followed P and K omission. Lower number of bolls plant⁻¹ and boll weight were recorded during second year in the respective omission treatments. The effect of S and Zn omission on yield attributes was not as pronounced as that of macro nutrients.

The seed cotton yield (SCY) was significantly affected by nutrient omission treatments. 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%, 6.7%, 14.5% due to N, P and K omission, respectively. The cor-

responding figures for the year 2011 were 26%, 15%, and 12 %, respectively. The reduction in SCY in 50% N omission and control plots ranged from 12 and 13% with respect to optimum nutrition treatments. The corresponding figures for control plots were 32 and 33% during the year 2010 and 2011, respectively. The reduction in SCY due to N and K omission was almost similar in the consecutive years. The reduction in the SCY due to P omission was much higher during the year 2011. Similarly the reduction in SCY in the treatments that received only N in the preceding wheat crop was almost similar to their corresponding omission treatments during the year 2010. However, during the year 2011 the SCY yields were slightly lower in the P and S omission treatments. N omission resulted in drastic reduction in the growth, yield components and yield, highlighting the importance of N in cotton production in N deficient soils. These findings corroborate the results of Biradar *et al.* (2011). P omission resulted in a yield reduction of 6.7% and 15.5% in the first and the second crop highlighting the fast depletion of soil P resources in cotton-wheat cropping system. Charles *et al.* (2005) from Cullars long term field experiment reported that yield losses when P was not applied during the preceding 10 years amounted to 57% compared to standard fertilization (N, P, K, S with micronutrients).

The reduction in the seed cotton yield due to K omis-

sion ranged from 12-14%, signifying the importance of K nutrition in cotton production. Yield losses to the tune of 20% due to K omission have been reported by Biradar *et al.* (2011). It appears that K soil supplies remained more or less constant during the three cropping seasons. It might also be due to the fact that cotton being a deep rooted plant, absorbed more K from the deeper soil layers (Gulick *et al.*, 1989). Seed cotton yield reduction due to S and Zn omission ranged between 2.0-5.0% but was statistically at par with optimum fertilization. Several workers have reported a non-significant response of cotton to S (Prasad, 2000) and Zn (Yin *et al.*, 2011) application. Similarly seed cotton yield reduced to the extent of 33.4% and 32.8% for the corresponding years in plots where no nutrient was applied over the optimum fertilization schedule. The reduction in the seed cotton was mainly attributed to the lesser number of bolls/plant and reduced boll weight.

Growth and biomass production were strongly affected by the limited indigenous nutrient supply and the nutrients supplied through fertilizers. This was reflected in the reduction in 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 (Table 1). The stalk yield was strongly related to the N supply, omission of which resulted in 36.3% and 47.3% reduction in stalk yield during the years 2010 and 2011, respectively. The reduction in the

Table 1. Effect of nutrient omissions on yield attributes and stalk and seed cotton yields of cotton

Treatment	Bolls/plant		Boll weight (g)		Seed cotton yield (t/ha)		Stalk yield (t/ha)		
	2010	2011	2010	2011	2010	2011	2010	2011	
Cotton	Wheat								
NPKSZn	NPKSZn								
PKSZn(-N)	PKSZn(-N)								
NKSZn(-P)	NKSZn(-P)								
NPSZn(-K)	NPSZn(-K)								
NPKZn(-S)	NPKZn(-S)								
NPKS(-Zn)	NPKS(-Zn)								
Control	Control								
(-50%N)	(-50%N)								
(- 50%P)	(- 50%P)								
(- 50%K)	(- 50%K)								
NPKSZn	(+N)								
PKSZn(-N)	(+N)								
NKSZn(-P)	(+N)								
NPSZn(-K)	(+N)								
NPKZn(-S)	(+N)								
NPKS(-Zn)	(+N)								
Control	(+N)								
(-50%N)	(+N)								
(- 50%P)	(+N)								
(- 50%K)	(+N)								
SEm±	1.76	1.66	0.10	0.09	0.14	0.12	0.23	0.33	
CD (P=0.05)	5.03	4.76	0.30	0.27	0.40	0.33	0.67	0.94	

stalk yield was 1.7 and 9 % for 2010 and 6.5% and 13.46% for 2011 due to P and K omission, respectively. The higher above ground biomass yield during the 2010 might be due to the excessive rainfall (926 mm) received during 2010 which was 61% higher than 2011 (574 mm). Under the conditions of excessive rain or irrigation, before fruit set, plant height and vegetative growth in cotton becomes excessive (Kerby *et al.*, 1996).

Nutrient uptake

Total N uptake varied from 46.6 to 125.1 kg/ha during the year 2010 and 43.7 to 110.0 kg/ha during the year 2011 at the harvest stage. Control and N omission treatments had significantly lower N uptake at harvest. P and K omissions also significantly reduced the N uptake at harvest. The N uptake, during the years 2010 and 2011, in treatments where only N was applied to the previous wheat crop did not differ significantly from their corresponding continuous omission treatments. N stimulates growth and dry matter production and thus results in its higher uptake. These results are in agreement with Bhalerao *et al.* (2011). P uptake decreased significantly in control, N omission, P omission and 50% P omission plots as compared to the rest of treatments. N omission also reduced the P uptake significantly during both the years. K omission reduced the P uptake significantly during the year 2011. Improved N, P and K uptake has been reported

under ample P supplies (Naiem, 2007). The total K uptake ranged from 62.5 to 137.5 kg/ha during the year 2010 and the corresponding figures for the year 2011 were 58.5 to 118.5 kg/ha. Significantly lower K uptake was observed in control, N omission and K omission treatments. P omission also reduced the K uptake especially during the year 2011. Generally higher K uptake was recorded during the year 2010 than the year 2011. N omission had more severe impact on K uptake than the K omission itself. Higher K accumulation in different plant parts of cotton and K uptake have also been reported in K applied treatments (Aladakatti *et al.*, 2011). K uptake in S and Zn omission plots was at par with optimum fertilization plots.

Wheat

Yield attributes, straw and grain yield

Spikes/m², grains/spike and 1,000-grain weight were significantly affected by the nutrient omissions during both the years. Maximum reduction in spike density/m² was caused due to N omission followed by P omission and the lowest was recorded in control plots. K, S and Zn had a non significant effect on spikes density/m². Spikes density/m² was also significantly reduced in the treatments where only N was applied and other nutrients were omitted. Similar trend was recorded during the year 2011-12. Spikes/m² further reduced under N omission and the treat-

Table 2. Effect of nutrient omissions on yield attributes and grain and straw yields of wheat

Treatment	Spikes/ m ²		Grains/spike		1000-grain wt. (g)		Grain yield (t/ha)		Straw yield (t/ha)		
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	
Cotton	Wheat										
NPKSZn	NPKSZn	403.9	404.4	35.4	34.5	43.1	41.4	4.70	4.68	6.07	6.02
PKSZn(-N)	PKSZn(-N)	278.2	226.3	22.2	26.1	39.6	36.7	3.05	2.40	3.99	3.51
NKSZn(-P)	NKSZn(-P)	348.9	349.2	32.1	32.0	42.1	37.2	4.25	4.16	5.86	5.38
NPSZn(-K)	NPSZn(-K)	405.2	386.1	33.4	32.4	40.4	39.1	4.56	4.33	5.74	5.61
NPKZn(-S)	NPKZn(-S)	392.1	390.5	32.8	32.9	41.9	40.8	4.59	4.55	5.74	5.81
NPKS(-Zn)	NPKS(-Zn)	422.9	409.6	31.8	33.3	44.0	40.6	4.60	4.57	5.91	5.76
Control	Control	229.6	179.9	15.9	23.2	39.3	35.7	1.65	1.54	2.72	2.22
(-50%N)	(-50%N)	329.8	297.6	30.6	32.0	40.4	38.7	3.89	3.77	5.04	4.94
(- 50%P)	(- 50%P)	389.8	397.8	34.3	33.0	41.4	37.6	4.55	4.23	5.90	5.54
(- 50%K)	(- 50%K)	371.4	406.3	33.1	34.2	41.7	38.2	4.62	4.58	5.71	5.62
NPKSZn	(+N)	383.6	358.3	31.2	32.7	41.4	40.0	3.96	3.78	5.67	5.14
PKSZn(-N)	(+N)	343.0	308.2	30.3	31.9	41.3	37.6	3.94	3.27	5.47	4.80
NKSZn(-P)	(+N)	367.9	351.7	28.8	29.6	41.2	38.0	4.03	3.42	5.76	4.89
NPSZn(-K)	(+N)	371.4	314.4	29.2	30.6	43.3	36.1	4.20	3.25	5.59	5.02
NPKZn(-S)	(+N)	366.9	319.9	28.7	30.7	39.7	36.9	4.14	3.50	5.57	5.18
NPKS(-Zn)	(+N)	367.7	334.4	31.8	30.5	41.5	36.1	4.25	3.41	5.59	5.25
Control	(+N)	338.1	282.2	26.8	30.7	40.9	36.8	3.96	3.11	5.08	4.47
(-50%N)	(+N)	339.3	312.2	28.9	28.9	40.9	39.4	4.39	3.56	5.69	4.78
(- 50%P)	(+N)	376.4	301.1	31.0	29.7	42.3	38.6	4.36	3.30	5.68	5.10
(- 50%K)	(+N)	383.5	329.6	30.8	29.9	41.3	36.7	4.38	3.47	5.45	5.03
SEm±		13.4	10.3	1.18	2.65	0.82	1.0	0.30	0.14	0.30	0.18
CD (P=0.05)		38.35	30.34	3.55	5.36	2.39	3.01	0.60	0.44	0.89	0.55

ments where only N was applied and all other nutrients were omitted. The effect of N omission was more prominent on grains spike⁻¹ followed by P omission. Lowest number of grains spike⁻¹ was recorded in control plots. Omission of all nutrients except N also reduced the grains spike⁻¹ considerably. Likewise 1000 grain weight was more affected under N omission treatments followed by P omission. It was more dramatically reduced in the treatments where only N was applied to wheat and all other nutrients were omitted. Improved yield attributes of wheat under higher N rates and balanced fertilization have also been reported by Zeng-Gen *et al.* (2007).

Nitrogen omission led to the maximum reduction of straw yield than any other nutrient and it reduced consistently with each season of N omission. The next most limiting nutrient was P as its omission resulted in significant reduction in straw yield especially during second year. The straw yield was also significantly reduced in the plots where only N was applied and this effect was more severe during the second year of the experiment due the progressive imbalance in the soil nutrient supply. The grain yield varied from 1.65 to 4.7 t/ha during the year 2010-11 and 2.40 to 4.68 t/ha during the year 2011-12. The reduction in the grain yield due to N, P and K omission was 35%, 9.6% and 3% during the year 2010-11 and 49%, 11.5 and 7.4% during the year 2011-12, respectively. N proved to be the most limiting nutrient from the very first season whereas,

P reduced the grain significantly during the second year due to the reduction in the indigenous P soil supplies under sustained omissions. These results corroborate findings of Dai *et al.* (2010). Omission of S and Zn resulted in grain yield reduction of 2.0-3.0% which was statistically non significant. Several workers have reported a non significant response of wheat to S (Orman and Ok, 2012) and Zn (Hussain *et al.*, 2011) applications. In the second set of treatments where specific nutrients were omitted in cotton and only N was applied to wheat, the grain yield reduced during the first year and more severely during the second year, because of imbalance in the nutrient supplies. Similar results have been reported by Laghari *et al.* (2010).

Nutrient uptake

The total N uptake varied from 37 to 129 kg/ha (2010-11) and 29 to 135 kg/ha (2011-12) in the control and optimum nutrition treatments, respectively. The optimum fertilization treatment had significantly higher N uptake over control and N omission and 50% N omission treatments at all the growth stages. Lowest N uptake was observed in control and N omission followed by 50% N omission treatments. The total P uptake ranged between 8.1 and 25.8 kg/ha in the control and optimum fertilization plots, respectively during the year 2010-11. The corresponding figures for the year 2011-12 were 6.7 and 21.3 kg/ha, respectively. The total P uptake in N omission treat-

Table 3. Effect of nutrient omissions on N, P and K uptake (kg/ha) in cotton and wheat

Treatment		Cotton						Wheat					
		N		P		K		N		P		K	
Cotton	Wheat	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
NPKSZn	NPKSZn	125.1	110.0	23.1	20.4	137.5	118.1	129.8	130.8	23.5	24.2	118.2	119.4
PKSZn(-N)	PKSZn(-N)	59.7	49.9	14.6	11.2	76.2	64.0	62.4	55.6	14.8	10.6	67.9	61.0
NKSZn(-P)	NKSZn(-P)	114.2	101.6	17.0	13.5	125.2	102.9	102.4	104.9	17.6	16.5	107.7	105.8
NPSZn(-K)	NPSZn(-K)	108.8	100.6	19.6	17.3	109.6	83.6	123.6	117.6	23.2	21.8	97.9	99.7
NPkZn(-S)	NPkZn(-S)	116.0	107.3	21.4	18.6	130.6	108.2	124.7	123.4	23.8	25.0	115.4	116.3
NPkS(-Zn)	NPkS(-Zn)	122.3	103.5	24.1	18.3	141.3	114.4	128.6	124.6	22.9	23.5	115.7	118.2
Control	Control	47.6	45.5	11.6	10.4	68.0	61.1	37.1	30.5	8.1	6.7	43.0	38.4
(-50%N)	(-50%N)	92.3	82.0	18.4	14.9	115.7	95.3	94.6	93.4	19.5	17.6	95.7	97.2
(-50%P)	(-50%P)	113.9	97.2	18.9	16.9	128.2	106.3	121.6	109.9	23.0	19.8	110.5	108.1
(-50%K)	(-50%K)	113.7	104.0	21.2	17.0	121.6	97.7	118.9	117.7	21.6	21.2	104.5	104.5
NPkSZn	(+N)	126.0	109.3	21.8	19.5	137.9	114.3	112.5	105.8	20.1	18.3	110.1	101.9
PKSZn(-N)	(+N)	60.3	51.1	16.0	13.0	77.20	66.3	103.8	88.9	16.9	15.0	96.6	84.0
NKSZn(-P)	(+N)	116.4	97.0	14.6	13.2	123.8	99.7	103.0	89.8	20.0	14.9	102.6	92.0
NPSZn(-K)	(+N)	108.6	104.5	18.3	17.0	105.8	81.7	106.3	89.2	20.7	16.3	91.7	80.3
NPkZn(-S)	(+N)	117.9	103.0	20.3	17.8	127.9	111.7	116.2	97.4	21.4	18.0	103.8	102.6
NPkS(-Zn)	(+N)	123.7	111.3	21.0	18.5	141.3	114.9	108.8	95.6	19.5	17.7	105.5	104.7
Control	(+N)	46.6	43.7	10.5	9.4	62.5	58.5	100.6	82.7	16.9	14.1	85.1	76.4
(-50%N)	(+N)	92.1	82.9	16.2	14.5	110.9	100.0	113.6	94.8	20.0	17.5	105.0	100.5
(-50%P)	(+N)	115.1	103.8	16.6	14.5	129.7	107.4	111.4	92.3	20.2	15.8	102.9	94.6
(-50%K)	(+N)	114.4	104.9	19.3	17.1	115.6	97.3	109.3	93.0	20.1	17.4	97.3	91.4
SEm±		3.92	3.66	0.80	0.74	4.16	3.58	3.88	3.16	0.93	0.71	4.84	3.98
CD (P=0.05)		11.24	10.47	2.29	2.12	11.92	10.24	11.13	13.52	2.66	2.05	13.86	11.40

ment was lower than the P omission treatments. The treatments where only N was applied to wheat had also significantly lower P uptake than the optimum fertilization treatments. The total K uptake ranged between 43.2 to 118.2 kg/ha in control and optimum fertilization treatments during the year 2010-11, respectively. K uptake was significantly higher in optimum fertilization treatments over control, N omission and K omission treatments. N omissions had far greater impact on K uptake, rather than K omission itself. Marginal reduction in plant K uptake and dry matter accumulation due to K omission has been reported by Slaton *et al.* (2009). Omission of S and Zn had a non significant effect on K uptake at all the growth stage and total uptake at harvest.

Economics

Cotton profitability was considerably affected by nutrient omissions (Table 4). Cost of cultivation differed marginally on account nutrient omissions but resulted in large differences in the yield and net profit. Consistently higher net returns of ₹92,900 and ₹1,07,075 were realized during the year 2010 and 2011, respectively in balanced fertilization treatments. Highest B:C ratio (net returns per rupee invested) of 3.35 and 3.25 during the year 2010 and 2011, respectively was also realized in the optimum nutrition plots. Lowest net profit was realized in control plots.

Wheat crop profitability also responded to fertilizer

treatments with highest net returns of ₹40,407 and ₹51,269 realized in the balanced fertilization plots during the years 2010-11 and 2011-12, respectively (Table 5). P and K omission also reduced the net returns. The effect of S and Zn omission on net profit was only marginal. Highest B:C ratio of 2.43 and 2.78 during the years 2010-11 and 2011-12, respectively, was also recorded in the optimum nutrition plots.. Profits were also reduced in the treatments where only N to the exclusion of all other nutrients was applied to wheat especially during the second wheat season.

Maximum net returns of ₹1,33,307 and ₹1,58,344 were realized from the cropping system during the year 2010-11 and 2011-12, respectively, when balanced nutrition was applied to both the crops. Same treatments also recorded overall highest B:C ratio of 3 and 3.08 during the respective years. Among the nutrients, N omission reduced the net returns drastically and P proved to be the second most limiting nutrient in cotton wheat production.

From the two year study on Bt cotton-wheat cropping system it is concluded that N is the most limiting nutrient and its omission resulted in drastic reductions in yield and profitability of both cotton and wheat. P omission resulted in yield reductions which increased during the year 2011-12 for both cotton and wheat. K omissions resulted in significant yield reductions in cotton and only marginal yield responses were observed in wheat during year 2010-11

Table 4. Effect of nutrient omissions on net returns and benefit cost ratio of cotton, wheat and cotton-wheat cropping system

Treatment		Cotton				Wheat				Cotton-wheat cropping system			
		Net returns (× 10 ³ ₹/ha)		B:C ratio		Net returns (× 10 ³ ₹/ha)		B:C ratio		Net returns (× 10 ³ ₹/ha)		B:C ratio	
Cotton	Wheat	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
NPKSZn	NPKSZn	92.9	107.1	3.35	3.25	40.4	51.3	2.43	2.78	133.3	158.3	2.43	2.78
PKSZn(-N)	PKSZn(-N)	60.2	70.5	2.33	2.29	22.4	20.2	1.53	1.24	82.6	90.7	1.53	1.24
NKSZn(-P)	NKSZn(-P)	86.9	87.9	3.31	2.79	37.0	45.1	2.45	2.66	123.9	133.0	2.45	2.66
NPSZn(-K)	NPSZn(-K)	77.3	91.6	2.94	2.94	39.9	47.9	2.63	2.88	117.2	139.4	2.63	2.88
NPKZn(-S)	NPKZn(-S)	86.1	101.2	3.13	3.09	39.0	49.5	2.37	2.71	125.1	150.7	2.37	2.71
NPKS(-Zn)	NPKS(-Zn)	91.0	99.0	3.32	3.03	39.5	49.7	2.41	2.74	130.5	148.6	2.41	2.74
Control	Control	57.0	66.0	2.54	2.44	9.5	10.3	0.84	0.82	66.5	76.3	0.84	0.82
(-50%N)	(-50%N)	79.4	89.7	2.96	2.81	31.5	39.0	2.01	2.24	111.0	128.7	2.01	2.24
(- 50%P)	(- 50%P)	91.0	96.3	3.37	2.99	39.3	45.5	2.47	2.57	130.3	141.8	2.47	2.57
(- 50%K)	(- 50%K)	84.5	100.5	3.13	3.13	39.6	50.2	2.49	2.86	124.1	150.6	2.49	2.86
NPKSZn (+N)	NPKSZn (+N)	93.5	101.8	3.37	3.09	35.7	42.2	2.7	2.88	129.1	144.0	2.7	2.88
PKSZn(-N) (+N)	PKSZn(-N) (+N)	60.4	70.6	2.34	2.29	35.2	40.2	2.66	2.75	95.6	110.7	2.66	2.75
NKSZn(-P) (+N)	NKSZn(-P) (+N)	87.4	83.2	3.33	2.65	36.5	37.1	2.76	2.54	123.9	120.4	2.76	2.54
NPSZn(-K) (+N)	NPSZn(-K) (+N)	77.1	96.5	2.94	3.10	38.0	35.1	2.88	2.4	115.1	131.6	2.88	2.4
NPKZn(-S) (+N)	NPKZn(-S) (+N)	86.5	88.8	3.14	2.71	37.4	38.6	2.83	2.64	123.9	127.5	2.83	2.64
NPKS(-Zn) (+N)	NPKS(-Zn) (+N)	91.2	100.6	3.32	3.08	38.5	37.6	2.91	2.57	129.7	138.2	2.91	2.57
Control (+N)	Control (+N)	56.6	69.3	2.52	2.56	34.8	32.5	2.63	2.22	91.4	101.7	2.63	2.22
(-50%N) (+N)	(-50%N) (+N)	79.7	87.5	2.98	2.75	40.1	39.2	3.03	2.68	119.8	126.7	3.03	2.68
(- 50%P) (+N)	(- 50%P) (+N)	91.3	92.3	3.38	2.87	39.8	35.9	3.01	2.45	131.1	128.2	3.01	2.45
(- 50%K) (+N)	(- 50%K) (+N)	84.5	97.6	3.13	3.05	39.6	37.9	3.00	2.59	124.2	135.5	3.00	2.59

and significant reductions during the year 2011-12. Application of only N to wheat and omitting all other nutrients resulted in huge yield losses especially during the year 2011-12. S and Zn omission resulted in non significant yield reductions in both cotton and wheat. Thus balanced fertilization in both cotton and wheat is very important to maintain sustainability and profitability of cotton-wheat cropping system.

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