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Yield, nutrient uptake and soil nutrient balance in wheat (*Triticum aestivum*) as affected by nutrient omissions in cotton (*Gossypium* spp)-wheat cropping system

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ABSTRACT

Balanced fertilization is one of the key input for maintaining productivity and sustainability of the food production systems. For assessing the impact of nutrient omissions on grain yield, nutrient uptake pattern, soil nutrient balance and fertilizer requirement for targeted yield of wheat (*Triticum aestivum* L.), a field experiment on nutrient omission plot technique was conducted during 2010-11 and 2011-12. The treatments comprised omission of nitrogen, phosphorus, potassium and zinc, 50% omission of N, P, and K, absolute control (no nutrient applied) and optimum nutrition (150-26.4-50-15-3 kg/ha of N-P-K-S-Zn). The reduction in the grain yield due to N, P and K omission was 35.0%, 9.6% and 3.0% during the year 2010-11, which further increased to 49%, 11.5% and 7.4% during the year 2011-12, respectively. The reduction in N, P and K uptake was more drastic in the N omission treatment, mainly due to the reduced dry matter accumulation. The agronomic efficiency (AE) and apparent recovery (AR) of N, P and K was higher when applied at 50% of their recommended level. On the basis of the indigenous supply, nutrient uptake and apparent recovery efficiency (AR) of N, P and K estimated in this study, the N:P_2O_5:K_2O dose needed to attain a yield target of 4.5, 5.0 and 5.5 tonnes/ha wheat grain yield worked out at 155:37:45, 188:79:83 and 220:106:121 kg/ha, respectively. Omission of P and K resulted in a significant increase in the small grain screenings (<1.8 mm).

Key words: Grain screening, Nitrogen, Omission, Phosphorous, Potassium, Uptake, Wheat

In India, area coverage under wheat has shown an upward trend as it has increased from 26.38 million ha in 2004-05 to 31.18 m ha in 2013-14. Out of the total food grain production of 264.4 m t during the year 2013-14, wheat contributed about 95.91 m t and continues to be the second most important crop after rice in the national food security (GOI 2012). Wheat accounts for 28% of the fertilizer consumption in the country and ranks second to rice (Prasad 2012).

Replenishment of the nutrients is inevitable to make the food production systems more sustainable. The macronutrients N, P and K are in particular focus because of their wide spread deficiencies and their efficient use dominates considerations of fertilizer practice. The pervasive issue, however, is that to achieve and sustain the high yields in exhaustive cropping systems such as cotton-wheat, emphasis must be upon the nutrient requirements for targeted yields and their supply by integrated use of indigenous sources, soil organic matter, crop residues, and increasingly, inorganic fertilizers (Timsina and Connor 2001). Inappropriate nutrient management is one of the major factors causing such yield gaps (Majumdar *et al*. 2012).

Wheat is an exhaustive crop as is evident from the fact that it removes 25.0-9.0-33.0-4.7 kg of N-P-K-S/tonne of grain produced, respectively (Tandon 2004). An estimated 294.3 g of zinc are also removed by every tonne wheat grain produced (Mishra *et al.* 2008). A recent on farm study (Majumdar *et al.* 2012), using the omission plot studies in the Indo-Gangetic Plains, showed that wheat yield response ranged from 500-4 750 kg/ha, 67-2 806 kg/ha and 0–2 222 kg/ha for N, P and K respectively, which is related to the soil nutrient supplying capacity. To cater to the uptake needs of the crop, soil reserves alone are not sufficient making it necessary to supply them through chemical fertilizers. However, the fertilizers applied are either insufficient or imbalanced and not based on soil supplying capacity. Initiatives have been taken in recent years through nutrient omission approach to estimate the soil and fertilizer contributions to the crops performance and finally arrive at site-specific nutrient management recommendations for

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targeted and sustainable yield. Small wheat grains (screenings < 2 mm is one of the most important causes of price dockages of wheat in western countries, since grain size variation greatly affects flour yield and commercial value of grain/ seed. Screenings are known to be influenced by season, nutrient management and/or cultivar in wheat (Sharma and Anderson 2001). A field experiment was conducted to assess the impact of nutrient omissions on yield, nutrient uptake and grain screenings of wheat and estimate indigenous nutrient supplies to arrive at the fertilizer recommendations for targeted yield of wheat.

MATERIALS AND METHODS

A field experiments on wheat were conducted during the year 2010-11 and 2011-12 at Indian Agricultural Research Institute, New Delhi (India) following irrigated cotton (*Gossypium* spp*)*- wheat cropping system. New Delhi is situated at 28°35'N latitude, 77°12'E longitude and an altitude of about 228.6 m above mean sea level. Delhi region experiences semi-arid and subtropical climate characterized by dry summers and 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 soil collected at the start of experiment and after harvest of each crop was mixed thoroughly to make composite representative sample, shade dried for two weeks, passed through 2 mm sieve and analyzed for soil physico-chemical properties.

The experiment had 10 treatments, laid out in randomized block design with three replications in fixed plots. In cotton, treatments comprised optimum (OPT) nutrition (150-26.4-50-15-3 kg/ha N-P-K-S-Zn), omission of N, P, K, S and Zn designated as OPT (-N), OPT (-P), OPT (-K), OPT (-S) and OPT (-Zn), respectively. The treatments also included 50% omission of N, P, and K, absolute control (no nutrient applied). Same nutrient omission treatments were tested on wheat in fixed plots. The fertilizers used were urea (46% N), triple superphosphate (46% P_2O_5), muriate of potash (60% K_2O), gypsum (15% S) and zinc oxide (81% Zn), so that each fertilizer shall supply only a single nutrient under investigation. In wheat, half N was applied as basal and the remaining half at first and second irrigation in two equal splits. Wheat HD 2851 (Pusa Vishesh), a dwarf variety of 126-134 days duration having a yield potential 4-4.5 tonnes/ha. The plant samples were analysed using standard procedures.

Fertilizer computations for targeted yield were made on the basis of uptake requirement while accounting for the indigenous nutrient supply and their limited recovery efficiency.

The nutrient uptake, agronomic efficiency (AE) and apparent recovery (AR) of the nutrients were calculated using standard methods (Fageria and Baligar 2003)

Uptake of N/P/K (kg/ha) = [% N/P/K in grain × grain yield (kg/ha) + % N/P/K in straw × straw yield (kg/ha)]/100

$$\text{AE (kg grain/kg nutrient applied)} = \frac{\text{Yf–Yc}}{\text{Na}}$$

$$\text{AR (\% of nutrient taken up by a crop)} = \frac{\text{NUf–NUc} \times 100}{\text{Na}}$$

In the above expressions, Yf and Yc are the yields (kg/ ha) in fertilized and nutrient omitted plots, respectively. NUf and NUc are the amounts of nutrients taken up by a crop in fertilized and nutrient omitted plots, respectively and Na refers to the amount of nutrient applied (kg/ha).

Fertilizer N/P/K (kg/ha) = ($U_{N/P/K}$ – $INS_{N/P/K}$)/AR(%), where $U_{N/P/K}$ is the plant N/P/K uptake requirement for the yield goal (kg/ha), $INS_{N/P/K}$ is the indigenous N/P/K supply measured as plant N/P/K uptake in a (-N), (-P) and (-K) plots, respectively. AR (%) is the apparent recovery efficiency of respective nutrients.

The three different fractions of wheat grain were obtained by using seed grader (Westrup, Japan). The protein content in wheat grain was estimated by multiplying the N concentration with a factor of 5.81 (Fujihara *et al.* 2008).

Protein yield (kg/ha) =% protein content × grain yield (kg/ha)

The statistical analysis of the data was performed using Microsoft Excel and MSTAT-C softwares. Statistical significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level.

RESULTS AND DISCUSSION

Dry matter accumulation, yield attributes and yield

Dry matter accumulation recorded at harvest was significantly affected by nutrient omission treatments (Table 1). Maximum reduction was observed in control plots and the same further declined during second year of experimentation. The reduction in dry matter accumulation due to N, P and K omission was to the extent of 38.3, 6.8 and 6.8% over optimum fertilization treatment during the year 2010-11, respectively. The corresponding figures during the year 2011-12 were 43.5, 10.3 and 6.5%, respectively.

Among the nutrients, nitrogen proved to be the most limiting in respect of the spikes/ m^2 and its omission resulted in 31% and 44% reduction during the year 2010-11 and 2011-12, respectively (Table 1). Number of spikes/ m^2 in S and Zn omission plots were at par with the optimum fertilization treatments during both the years. Grains/spike varied significantly among the treatments with a significant reduction in the control and N omission treatments. Omission of N, P and K significantly reduced the 1000 grain-weight during both the years. The grain yield varied between 1.65 to 4.70 tonnes/ha during the year 2010-11 and 2.40 to 4.68 tonnes/ ha during the year 2011-12 in the control and optimum fertilization plots, respectively. The reduction in the grain yield due to N, P and K omission was 35.0%, 9.6% and 3.0% during the year 2010-11 and 49%, 11.5% and 7.4% during the year 2011-12, respectively. N was the most limiting nutrient from the

Table 1 Effect of nutrient omissions on yield attributes, straw and grain yield of wheat

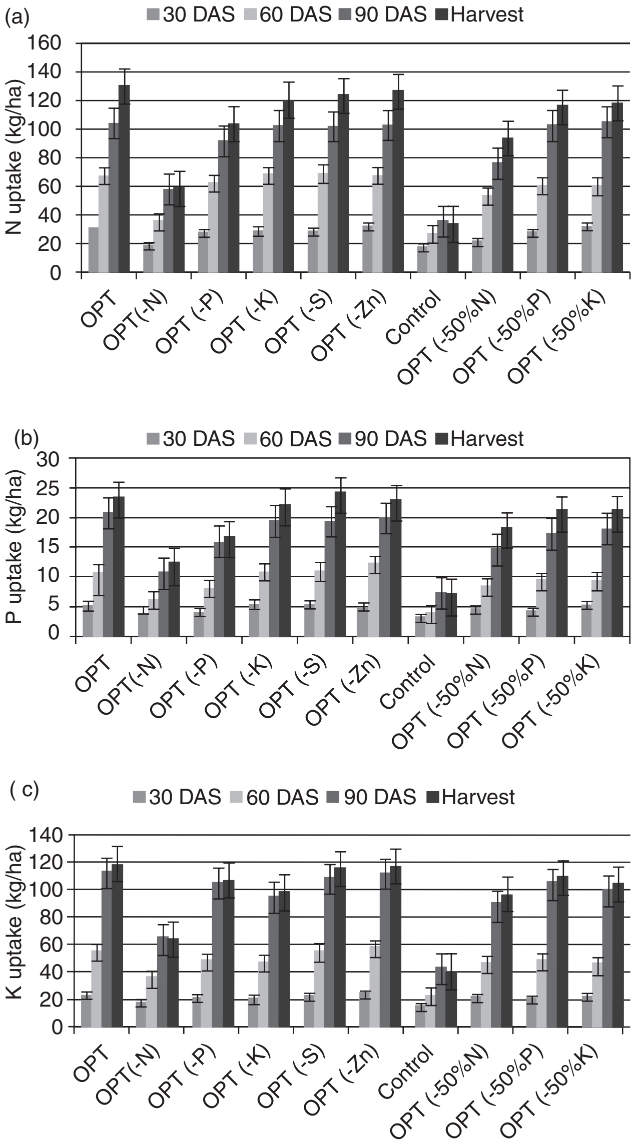
Treatment	Dry matter accumulation ($g\ m^{-2}$)		Number of spikes/ m^2		Number of grains/ spike		1000 grain weight (g)		Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Biological yield (tonnes/ha)	
	2010 -11	2011 -12	2010 -11	2011 -12	2010 -11	2011 -12	2010 -11	2011 -12	2010 -11	2011 -12	2010 -11	2011 -12	2010 -11	2011 -12
OPT	1038	1021	404	404	35.4	34.5	43.1	42.4	4.70	4.68	6.07	6.02	10.77	10.70
OPT (-N)	640	576	278	226	22.2	26.1	39.6	36.7	3.05	2.40	3.99	3.51	7.04	5.91
OPT (-P)	967	916	349	349	32.1	32.0	40.1	37.2	4.25	4.16	5.86	5.38	10.11	9.54
OPT (-K)	970	958	405	386	33.4	32.4	40.4	39.1	4.56	4.33	5.74	5.61	10.30	9.94
OPT (-S)	992	998	392	391	32.8	32.9	41.9	40.8	4.59	4.55	5.74	5.81	10.33	10.36
OPT (-Zn)	1010	993	423	410	31.8	33.3	44.0	40.6	4.60	4.57	5.91	5.76	10.51	10.33
Control	430	330	23	180	15.9	13.2	39.3	35.7	1.65	1.54	2.72	2.22	4.37	3.76
OPT (-50%N)	820	800	330	298	30.6	32.0	40.4	38.7	3.89	3.77	5.04	4.94	8.93	8.71
OPT (-50%P)	1010	940	390	398	34.3	33.0	41.4	37.6	4.55	4.23	5.9	5.54	10.45	9.77
OPT (-50%K)	1010	983	371	406	33.1	34.2	41.7	38.2	4.62	4.58	5.71	5.62	10.33	10.20
SEm±	16.40	15.50	13.29	10.49	1.24	1.87	0.84	1.05	0.21	0.15	0.31	0.19	0.43	0.28
CD (P=0.05)	47.00	44.40	38.00	30.00	3.55	5.36	2.39	3.01	0.60	0.44	0.89	0.55	1.24	0.81

OPT: Optimum dose, OPT (-N): N omission, OPT (-P): P omission, OPT (-K): K omission, OPT (-S): S omission, OPT (-Zn): Zn omission, control: no nutrient applied, OPT (-50%N): 50% N omission, OPT (-50%P): 50% P omission, OPT (-50%K): 50% K omission.

very first season, whereas P and K reduced the grain yield drastically during the second year. The reduction in grain yield due to S and Zn omission ranged between 2-3%, which was statistically at par with optimum fertilization treatment. The omission of N or P significantly reduced the yield attributes and yield of wheat, with the dominant effect of N whereas; K had a non-significant effect on grain yield of wheat (Mojid *et al.* 2012). Phosphorus fertilization was critical for grain yield since the NK treatment did not increase yield compared with no fertilizer treatment (Takahashi *et al*. 2007, Dai *et al*. 2010). Several workers have reported a non-significant response of wheat to S (Orman [a] and Ok 2012) and Zn (Hussain *et al.* 2011) applications. There are reports on the basis of modeling studies that by 2010 about 228.3 kilo tonnes of SO_2 would have been deposited annually in soil around Delhi (Guttikunda and Gurjar 2012). Zinc level in the soil did not fall below 0.80 mg/kg, which is considered normal for wheat growth. Balanced fertilization capitalizes on the positive interactions between the nutrients that result in higher straw and grain yield (Zeng-Gen *et al*. 2007).

Nutrient uptake

Nitrogen uptake, a function of N concentration and dry matter accumulation was significantly affected by the nutrient omission treatments (Fig 1). Maximum N uptake occurred between 60-90 DAS. The total N uptake at harvest averaged over two years ranged from 34 to 130 kg/ha among various treatments (Fig 1a). The optimum fertilization treatment had a significantly higher N uptake over control, N, P, and 50% N omission treatments at all the growth stages. The reduction in total N uptake at harvest, averaged over years, was to the extent of 54.7%, 20.4% and 7.4% due to N, P and K omission, respectively over the optimum nutrition treatment. S and Zn omission had a non-significant effect on N uptake at all the growth stages and the total N uptake at harvest. The omission of nitrogen resulted in the development of typical deficiency symptoms, viz small and yellow leaves, stunted growth, poor tillering, dry matter accumulation and reduced yield. Potassium uptake averaged over two years was significantly affected by various nutrient omission treatments (Fig 1c). Beyond 90 DAS there was a marginal increase in K uptake. K uptake was significantly higher in optimum fertilization treatments over control, N omission and K omission treatments. The extent of reduction in total K uptake was 45.8%, 10.1% and 16.8% due to N, P and K omission, respectively. N omissions had far greater impact on K uptake rather than K omission itself because N omission greatly depressed the biomass production. K uptake was significantly decreased due to P omission at all the growth stages during the year 2011-12. Omission of S and Zn had a non-significant effect on K uptake at all the growth stage and total uptake at harvest. Decrease in plant N concentration and reduced N uptake in wheat under limited N supply has been reported by several workers (Dai *et al*. 2010). The total P uptake in N omission was lower than the P omission treatments because of strong influence of N on biomass production. Combined application of fertilizer N and P resulted in higher nutrient uptake over 23-year cultivation period and interaction impact between P and N ranged from 71% to 109% (Takahashi *et al*. 2007). Marginal reduction in plant K concentration and dry matter accumulation due to K omission has been reported by Slaton *et al*. (2009). The positive influence of K on N and P uptake has been reported by Zuberi (2001)). Nitrogen interactions with P and K help to improve root system development, dry matter production, and other plant functions regulating crop yield and quality (Duan 2004).



The bars in the figures denote the critical difference between the treatments.

OPT: Optimum dose, OPT(-N): N omission, OPT (-P): P omission, OPT(-K): K omission,

OPT (-S): S omission, OPT (-Zn): Zn omission, control: no nutrient applied,

OPT (-50%N): 50% N omission, OPT (-50%P): 50% P omission, OPT (-50%K): 50%K omission

Fig 1 Effect of nutrient omissions on N (a), P (b) and K (c) uptake averaged over two years

Fertilizer requirement for targeted wheat grain yield

The apparent nutrient recovery (AR %), N, P and K uptake (U_{NPK}) in the optimum nutrition and respective omission plots were averaged over two years (Table 3). There was a significant reduction in the uptake of N, P and K in the respective omission plots. The uptake of the any nutrient in omission plot provides a reasonable estimate of its indigenous supply from the native sources. The values so computed were used for fertilizer dose calculations for targeted wheat grain yield. The N: P_2O_5: K_2O dose needed to attain a yield target of 4.5, 5.0 and 5.5 tonnes/ha wheat grain yield worked out at 155:37:45.4, 188:79:83 and 220:106:121 kg/ha, respectively (Table 2).

Nutrient use efficiencies

AE for N, P and K was higher at lower doses of respective nutrients (Table 3). The balanced fertilization treatment had also higher AE for N, P and K. The figures for AE (kg increase in grain/kg of nutrient applied) in balanced fertilization treatment were 11.0 and 15.1 for N, 17.2 and 19.7 for P and 2.9 and 7.2 for K during the years 2010-11 and 2011-12, respectively. N omission considerably decreased the AE of other nutrients. Similarly, the omission of P and K had a negative effect on the AE of N. The AR was enhanced to 44.9 % and 43.4% for N, 22.6% and 17.9% for P and 40.7% and 39.4% for K in balanced fertilization treatment as compared to the their respective nutrient omission treatments. The data shows that AR (%) for N, P and K was higher at 50% omission than balanced fertilization treatments. Reducing the dose of major nutrients to 50% of their recommended level for enhancing AE is not economically viable. Omission of P reduced the recovery of N and omission of N strongly reduced the recovery of P and K. Higher AE and AR (%) was recorded at lower doses of N, P and K. The balanced fertilization treatments also exhibited higher nutrient use efficiencies as compared to various nutrient omission treatments. Much higher nutrient efficiencies can be achieved simply by sacrificing yield, but that would not be economically viable for the farmers. The crop most effectively utilizes the nutrients when supplied at the lower doses (Mojid *et al.* 2012). Omission of P and K reduces the N use efficiency and the omission of N drastically reduced the use efficiency of P and K. The values for various efficiency indices of P and K became negative under N omission because it decreased the yield and nutrient uptake by much higher proportions than the P and K omissions. For example, data from a large number of multi-location on-farm field experiments conducted in India show the importance of balanced fertilization improving crop yield and N efficiency (Prasad 1996). Intensive cropping with only N input is an unsustainable practice; omission of a plant nutrient (be it macro or micro) leads to its progressive deficiency because of heavy removals. Sites initially well supplied with natural soil P, K or S become deficient when continuously cropped using N alone or S-free fertilizers. Fertilizer rates considered as optimum still resulted in nutrient depletion at high productivity levels and, if continued, become sub-optimal (Tiwari 2001). Under the optimal fixed rates of N and K fertilizer, recovery of N increased by 28% to 36% under optimal P. Similarly, optimal K application allows for higher N recovery. K application has been neglected in many developing countries, including India, which has resulted in soil K depletion in agricultural ecosystems and a decline in crop yields (Lal *et al*. 2007).

Table 2 Fertilizer requirement for targeted grain yield of wheat on the basis of uptake in OPT plots and indigenous nutrient supply

Particular	Targeted grain yield (tonnes/ha)								
	4.5			5.0			5.5		
	N	P	K	N	P	K	N	P	K
Estimated plant nutrient requirement (kg/ha)	127.3	20.2	113.7	142.0	24.0	126.4	156.0	26.4	139.2
INS (kg/ha)	59.0	17.0	98.8	59.0	17.0	98.8	59.0	17.0	98.8
Net plant nutrient requirement	68.4	3.2	15.0	83.0	7.0	27.6	97.0	9.4	40.2
AR (%)	44.15	20.3	40.0	44.1	20.3	40.0	44.2	20.3	40.0
Actual nutrient requirement (kg/ha)	155.0	16.03	37.5	188.0	34.5	68.9	220.4	46.4	100.0
Oxide form (P_2O_5 and K_2O)	155.0	37.0	45.4	188.0	79.0	83.5	220.4	106.2	121.0

INS, Indigenous nutrient supply, AR, apparent recovery

Table 3 Effect of nutrient omissions on agronomic efficiency and apparent recovery of nutrients in wheat

Treatment	Agronomic efficiency (kg increase in grain/kg of nutrient applied)						Apparent recovery(%)					
	N		P		K		N		P		K	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
OPT	11.0	15.2	17.2	19.7	2.9	7.1	44.9	43.4	22.6	17.9	40.7	39.4
OPT (-N)			-45.5	-66.7	-30.2	-38.5			-10.6	-22.3	-60.0	-77.4
OPT (-P)	8.0	11.7			-6.2	-3.3	26.7	29.2			19.6	12.3
OPT (-K)	10.1	12.8	11.7	6.2			40.8	39.0	21.3	20.2		
OPT (-S)	10.3	14.3	13.0	14.6	0.7	4.5	41.6	41.6	23.6	32.3	35.0	33.2
OPT (-Zn)	10.4	14.4	13.5	15.3	0.9	4.8	44.2	33.9	20.3	26.3	35.7	37.0
Control												
OPT (-50%N)	11.2	18.3	-13.5	-14.8	-13.3	-11.1	42.9	44.9	7.2	4.3	-4.3	-5.0
OPT (-50%P)	10.0	12.2	23.0	5.3	-0.1	-1.9	39.5	33.7	40.9	24.7	25.2	16.9
OPT (-50%K)	10.5	14.5	14.0	15.7	2.4	10.0	37.7	36.4	15.1	17.9	26.6	9.7
SEm ±	0.29	0.30	0.26	0.31	0.22	0.24	1.12	1.07	0.85	0.96	1.09	1.16
CD P=(0.05)	0.82	0.85	0.76	0.89	0.63	0.68	3.21	3.08	2.45	2.76	3.12	3.34

OPT: Optimum dose, OPT (-N): N omission, OPT (-P): P omission, OPT (-K): K omission, OPT (-S): S omission, OPT (-Zn): Zn omission, control: no nutrient applied, OPT (-50%N): 50% N omission, OPT (-50%P): 50% P omission, OPT (-50%K): 50%K omission.

Table 4 Effect of nutrient omissions on small grain screenings, grain protein content and protein yield of wheat

Treatment	Screenings (%)*						Protein content (%)		Protein yield(kg/ha)	
	2010-11			2011-12			2010-11	2011-12	2010-11	2011-12
	S_1	S_2	S_3	S_1	S_2	S_3				
OPT	92.3	3.2	4.5	92.1	3.0	4.9	12.3	12.6	580	591
OPT (-N)	93.0	3.6	3.4	92.4	3.6	4.0	9.5	10.0	291	240
OPT (-P)	89.8	3.3	6.9	88.6	3.5	7.9	10.7	11.2	453	465
OPT (-K)	91.3	2.9	5.8	90.9	3.0	6.1	12.1	11.8	552	509
OPT (-S)	92.6	3.1	4.3	92.9	3.0	4.1	12.4	12.1	569	548
OPT (-Zn)	93.2	3.5	3.3	92.2	3.2	4.6	12.5	12.0	576	548
Control	91.4	2.8	5.8	89.4	4.6	6.0	9.8	8.7	161	134
OPT (-50%N)	94.6	2.3	3.2	93.3	2.3	4.4	11.4	11.0	442	415
OPT (-50%P)	93.3	3.8	2.9	91.9	3.5	4.6	12.1	11.6	551	490
OPT (-50%K)	93.6	2.8	3.6.	91.4	3.8	4.8	11.8	11.5	543	528
SEm ±	1.34	0.19	0.37	1.42	0.25	0.41	0.30	0.24	26.06	19.78
CD (P=0.05)	3.86	0.54	1.05	4.08	0.71	1.18	0.86	0.69	74.78	56.78

OPT: Optimum dose, OPT (-N): N omission, OPT (-P): P omission, OPT (-K): K omission, OPT (-S): S omission, OPT (-Zn): Zn omission, control: no nutrient applied, OPT (-50% N): 50% N omission, OPT (-50% P): 50% P omission, OPT (-50% K): 50% K omission. S_1 , heavy bold grain > 1.8 mm size, S_2, light bold grain > 1.8 mm size and S_3, small grain <1.8 mm size

Small grain screenings and protein content

Interestingly, omission of N did not increase the small grain fraction, which in other words means that yield of good quality bold grain/seed decreased with the omission of P and K (Table 4). The proportion of bold grains (S_1) ranged between 88.2-92.3% and 84.6- 92.1% during the year 2010-11 and 2011-12, respectively. The fraction with bold light weight grains (S_2) ranged between 2.3 - 4.6% which was almost similar between the treatments during both the years. The small grain size fraction (S_3) varied significantly among the treatments. S_3 ranged from 2.9-6.9% during the year 2010-11, which further increased to 4.1 -7.9% in 2011-12 due to nutrient P and K omission. The impact of P and K omission resulted in a significant increase in the small grain size fraction, which further increased during the second year under sustained omissions. Grain filling is the deposition of polymeric product in cells and organelles formed during the grain enlargement phase. Undoubtedly, stress curtails assimilate supply during grain filling. P application is important for harnessing the benefits of N and other nutrients. N application tends to increase the small grain fraction, whereas P and K applications reduce the percentage of small grain screenings (Sharma and Anderson 2001, Malik and Paynter 2010). The impact of marginal potassium deficiency can be exacerbated by the use of high rates of nitrogen fertilizer in coarse-textured soils, which may reduce grain yield and hectolitre weight and increase the proportion of small grains (Curtis *et al*. 2002).

Control, N omission and P omission treatments had significantly lower protein content than the optimum fertilization treatments. The protein yield was significantly reduced in the control and N omission treatments over optimum fertilization treatments. N being an integral constituent of proteins and its application obviously increase the protein content (Perez *et al*. 1996). The values of protein content in grain wheat increased by 0.1-0.6% in proportion to the potassium rates applied (Gheorghe *et al*. 2011).

The experiment amply demonstrated that N is the most limiting nutrient in respect of grain and straw yield and protein content. P and K can become progressively limiting if omitted in the cropping system because of decline in the soil indigenous supplies. P and K improve the proportion of quality grain/seed thus are crucial in maintaining the quality of the grain/seed.

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