



Nutrient omissions effects on growth, yield, water productivity and profitability of wheat (*Triticum aestivum*) in maize (*Zea mays*)-wheat cropping system

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ABSTRACT

A field experiment was conducted at IARI, New Delhi, India to assess the effect of omitted nutrients on growth, yield and profitability of wheat (*Triticum aestivum* L.) crop, and to validate the STCR based fertilizer application for targeted yield (5.0 t/ha) of wheat (HD 2967) in maize (*Zea mays* L.)–wheat cropping system. The experiment comprised 15 treatments involving application of N (-PKZn), NP (-KZn), NPK (-Zn) and NPZn (-K) to both maize and wheat crops, to maize and to wheat crop only, absolute control (no nutrient applied), recommended rate of nutrients (150-60-40-5.5 kg/ha N-P-K-Zn) and STCR based application of nutrients (200-75-65-4 kg/ha N-P-K-Zn). The fixed plots experiment was carried out in a three-time replicated randomized complete block design. Growth and yield attributes were influenced by nutrient omission treatments significantly and their values were higher when nutrients were applied based on STCR approach. The STCR-based nutrient application significantly increased dry matter production at harvest and grain yield by 4.2 and 8.4% respectively, over recommended doses of NPKZn. Omission of P and K resulted in 12.4 and 17.5% reduction in grain yield, respectively. The yield reduction was slightly lower with Zn omission (2–5%). The STCR-based NPKZn application resulted in consistently higher gross returns of ₹71 658 and ₹66 720 and also enhanced water productivity by 9.7 and 7.1% during the year 2012-13 and 2013-14, respectively, compared to balanced fertilization with recommended doses of nutrients. Overall, the results revealed that omitting P and K leads to significant yield penalty and application of nutrients using STCR approach should be adopted for achieving higher yield, water productivity and profitability of wheat.

Key words: Nutrient omission, Profitability, STCR, Water Productivity, Wheat

In India, maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) system ranks first in rainfed ecologies and contributes about 3% to the national food basket. The productivity of this cropping system is limited by low fertilizer efficiency, inadequacy of current fertilizer recommendations, and the exclusion of nutrients other than N, P and K from the recommended/balanced nutrient dose and continuously deteriorating soil quality.

Amongst various agricultural inputs, fertilizers contribute about 30–50% towards yield performance (Stewart 2002). Nutrients available in soil are rarely present in adequate amount and in balanced proportion to meet the nutrient requirement of the crops. However, growing awareness about impaired soil health, declining or stagnating productivity growth and decreasing nutrient-use efficiency (NUE) are compelling the farmers to use higher

levels of fertilizers, mostly N and P fertilizers, particularly during last two decades leading to over mining of other major, secondary and micro-nutrients (Dass *et al.* 2014a). Eventually, the recovery efficiency of fertilizer nutrients is about 20–40%, 15–20% and 40–50% for N, P and K, respectively while for secondary and micro-nutrients, it is very low ranging between 5–12% (Rao 2014).

Applying fertilizers without considering information of crop requirement causes adverse effect on soil and crop owing to over use or inadequate use (Ray *et al.* 2000). Therefore, the fertilizer recommendations based on qualitative/semi-quantitative approaches do not show expected yield responses. Since soil reserves alone are not sufficient to meet the nutrient uptake needs of these crops, a balanced nutrient supply has to be ensured keeping in view the soil's inherent nutrient supplying capacity to achieve desired crop yield levels (Dass *et al.* 2014). Thus, the most appropriate method to determine the optimum doses of fertilizer is to apply fertilizer on basis of soil test and crop response (STCR) studies. Soil test provides the actual information about the amounts of nutrients available in the soil, while fertilizer recommendation aims at correcting the imbalances of nutrients according to crop requirement. Currently recorded average wheat yields compared with

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the yield potential for a given variety and climate indicate significant scope to further increase its productivity through site-specific, integrated nutrient and crop management based on crop requirements, soil test values and yield targets (Xu *et al.* 2009). Hence, the current study was made to recognize the flaws of blanket recommendations and to determine the effect of omitted nutrients on growth, productivity and profitability of wheat crop, in maize-wheat cropping system.

MATERIALS AND METHODS

A field experiment was carried out at ICAR-Indian Agricultural Research Institute, New Delhi during winter seasons (November–March) of 2012-13 and 2013-14. The site of the experimental field belongs to order Inceptisol, Mehruli series having non-calcareous alkaline sandy clay loam texture (sand 64.5%, silt 13.4% and clay 18.5%) with the pH of 7.9, cation-exchange capacity 10.7 cmol/kg and electrical conductivity 0.32 dS/m in the top 15 cm of soil. Soil had low initial N (124 kg/ha), medium P (17.37 kg/ha) and K (224 kg/ha) and high Zn (0.8 ppm) contents. The recommended dose of NPK Zn for wheat was 150-60-40-5.5 kg/ha. The experiment had 15 treatments, set in a randomized complete-block design (RCBD) with three replications in fixed plots. Treatments comprised application of N (-PKZn), NP (-KZn), NPK (-Zn) and NPZn (-K) to both maize and wheat crop, to maize and to wheat crop only, absolute control (no nutrient applied), recommended rate of nutrients (150-60-40-5.5 kg/ha N-P-K-Zn) and STCR based application of nutrients (200-75-65-4 kg/ha N-P-K-Zn). Based on initial soil test value of N, P and K, the fertilizer recommendation for wheat variety HD 2967 for a targeted yield of 5 t/ha was calculated using STCR equation at the beginning of an experiment and further justified with help of ready reckoners (Sharma and Singh 2007). The STCR equations for computation of N, P and K dose are given below:

$$F_N = 5.31 T - 0.51 SN$$

$$F_{P_{2O_5}} = 3.45 T - 5.55 SP$$

$$F_{K_{2O}} = 2.75 T - 0.32 SK$$

The fertilizers used for applying N, P, K and Zn were urea, di-ammonium phosphate (adjusted for its N content) and muriate of potash and zinc sulphate ($ZnSO_4 \cdot 7H_2O$), respectively. Half of the N was applied as basal and remaining half top-dressed in two equal splits, at first irrigation applied 21 days after sowing (DAS) and second irrigation applied 45 DAS. The full doses of P, K and Zn fertilizers were applied basally. Wheat was sown in line 22.5 cm apart in the third week of November and harvested in the first week of April. The total rainfall received during crop period was 164.4 and 152.4 mm in 2012-13 and 2013-14, respectively. The average monthly air temperature, relative humidity and bright sunshine hours were almost similar during both study years. Four irrigations were provided to wheat during 2012-13 and three irrigations during 2013-14. Two hand weedings were done at 25 and 60 DAS to control the weeds. Five plants in each plot were selected randomly and tagged for taking various biometric observations. For dry

matter accumulation at different growth stages all plants in 0.5 m row length, randomly chosen at two spots in sampling rows for each plot were cut close to the ground and kept in paper bags for sun drying. Sun dried samples were dried at 65°C temperature for 36 to 48 hr to obtain a constant dry weight. Leaf area meter was used for measuring leaf area. The leaf area index (LAI) was worked out as leaf area of plants divided by ground area covered by the plants. The produce was threshed with power operated plot-thresher, winnowed, cleaned, weighed separately and expressed in terms of grain and straw yield (t/ha). Statistical analysis of the data was carried out using analysis of variance technique as applicable to RCBD (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Growth parameters

The STCR approach based N, P, K and Zn application resulted in significantly higher dry matter accumulation (DMA) at flag-leaf stage and at harvest compared to rest of the treatments during both study years. The higher growth under STCR approach based fertilization might be due to balanced and faster availability of nutrients to plant during the crop growth and development period. The dry matter accumulation increased by 5.3% and 4.1 % at flag-leaf stage and at harvest respectively, compared to application of recommended dose of NPKZn (Table 1). The greatest plant height at harvest and LAI values at different growth stages (Table 1) and mean CGR for 0–30 days interval (Table 2) were obtained under STCR nutrient application. Similarly, the highest values of mean CGR for 30–60, 60–90 days intervals during both years of experimentation were obtained under the STCR approach based nutrient application (Table 2). However, this treatment was at par with recommended dose of NPKZn for all measurement intervals. The adequate and easy availability of nutrients under STCR approach to wheat crop might have increased the number of functional leaves which, in turn, enhanced the LAI and dry matter accumulation/m² and other growth indices of wheat. The specific leaf area (SLA) at flag-leaf stage was also significantly higher under STCR approach based fertilization. It was slightly greater during year 2013-14 compared to climatically less favorable year 2012-13 (Table 2).

Phosphorus and K omissions caused reduction in plant height, LAI and dry matter accumulation during both study years, the reduction was, however, more pronounced during 2013-14. Omission of P to both maize and wheat crops resulted in very small decrease in DMA at flag-leaf stage (1.8%) and at harvest (1.3%) during 2012-13 and 2.3 and 2.5% during 2013-14, respectively compared to application of N alone. Likewise, omission of P to both crops and only to wheat had no significant effect on plant height at harvest, LAI at 30, 60, 90 DAS, mean CGR at 30-60, 60-90, 90-120 days interval and SLA at flag-leaf stage of wheat crop compared to application of N alone. But contrary to P omission, K omission to both crops and only to wheat

Table 1 Effect of nutrient omission treatments on leaf area index, dry matter accumulation of wheat crop

Treatment	LAI at 30 DAS		LAI at 60 DAS		LAI at 90 DAS		Drymatter at flag leaf stage (g/m ²)		Drymatter at harvest (g/m ²)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
NPKZn (Based on STCR)	1.2	1.2	2.4	2.2	4.0	3.9	218.8	211	1079	1066.2
NPKZn (RDF)	1.2	1.1	2.3	2.1	4.0	3.7	208.0	204.5	1036.0	1023.4
N (-PKZn) in both maize and wheat	1.1	1.0	2.1	1.9	3.8	3.0	191.8	185.3	970.7	950.2
NP (-KZn) in both maize and wheat	1.1	1.1	2.2	1.9	3.8	3.5	195.2	189.6	983.7	971.0
NPK (-Zn) in both maize and wheat	1.1	1.1	2.3	2.0	3.9	3.7	205.8	199.3	1012.7	999.3
NPZn (-K) in both maize and wheat	1.1	1.1	2.2	1.9	3.9	3.6	198.5	191.9	995.3	983.0
N (-PKZn) only in maize	0.7	0.6	1.6	1.3	2.3	2.0	160.5	149.9	795.7	779.3
NP (-KZn) only in maize	0.7	0.6	1.6	1.3	2.4	2.0	161.8	151.3	800.0	783.6
NPK (-Zn) only in maize	0.7	0.7	1.6	1.4	2.4	2.0	165.5	153.9	815.3	800.0
NPZn (-K) only in maize	0.7	0.6	1.6	1.4	2.4	2.0	163.1	152.6	807.0	790.3
N (-PKZn) only in wheat	1.1	1.0	2.1	1.8	3.7	3.4	189.2	182.6	956.0	938.3
NP (-KZn) only in wheat	1.1	1.0	2.2	1.9	3.8	3.5	192.8	186.3	971.3	952.9
NPK (-Zn) only in wheat	1.1	1.1	2.2	2.0	3.9	3.6	202.7	196.1	1001.7	989.3
NPZn (-K) only in wheat	1.1	1.1	2.2	1.9	3.8	3.5	195.1	188.6	980.7	964.0
Absolute control (No fertilizer)	0.7	0.6	1.6	1.3	2.3	2.0	158.8	148.3	789.0	774.3
SEd±	0.03	0.04	0.04	0.07	0.03	0.06	4.06	3.09	18.87	18.03
CD (P = 0.05)	0.06	0.09	0.08	0.14	0.06	0.12	8.16	6.20	37.93	36.25
<i>Control v/s others</i>										
SEd±	0.02	0.03	0.03	0.05	0.02	0.04	2.97	2.26	13.81	13.20
CD (P = 0.05)	0.04	0.06	0.06	0.10	0.05	0.09	5.97	4.54	27.76	26.53

significantly reduced the plant height at harvest, LAI at 60 and 90 DAS, SLA at flag-leaf stage and DMA/m² at flag-leaf stage and at harvest in both years of study. Continuous omission of K in maize-wheat cropping system resulted in 4.8 and 4.1% reduction in DMA at flag-leaf stage and harvest during 2012-13 and 6.6 and 4.2% during 2013-14, respectively compared to recommended dose of NPKZn fertilization (Table 1). Omission of zinc did not significantly influenced wheat growth during 2012-13 but 2013-14. Kamrunnahar *et al.* (2017) also reported that omissions of N, P, K and S from complete treatment significantly shorten the plant by 12.73, 9.45, 8.08 and 2.9 cm, respectively. Nitrogen omission plot produced the shortest plant of 96.55 cm followed by P (99.83 cm), K (101.20 cm) and S (106.38 cm) omission. Similarly, the maximum plant height (87.80 cm) was found from fully fertilized plots while lowest was obtained from potassium missing plots followed by nitrogen missing plots (Rawal *et al.* 2017).

The direct and cumulative effect of NPK (-Zn) applied to wheat resulted in significantly higher DMA at flag-leaf stage and at harvest, mean CGR at 40 and 60 DAS compared to application of N alone and omitting all other nutrients during 2012-13 and 2013-14. But, the cumulative and direct effect of application of NPK on SLA at flag-leaf stage were

significantly superior to application of N (-PKZn), NP (-KZn) and NPZn (-K) during both years of experimentation. The residual effect of NPK application to preceding maize on plant height, dry matter accumulation at flag-leaf stage and at harvest, LAI at 60 and 90 DAS, mean CGR at 30-60, 60-90, 90-120 days interval and SLA at flag-leaf stage of wheat crop was at par with absolute control, N, NP and NPZn application 2012-13 and 2013-14.

Yield attributes and yield

The highest values of growth parameters with the application of NPKZn using STCR approach got translated into better yield attributes of wheat as reflected by the highest values of effective tillers/m², number of grains/ear and 1000-grain weight under this treatment. Probably due to more absorption and utilization of available nutrients leading to overall improvement of crop growth and source-sink relationship, which in turn enhanced the yield attributes and yield of wheat under STCR approach. Nutrient omissions significantly influenced the yield components of wheat during both years of experimentation (Table 3). Omitting P and Zn had resulted in numerically lower values of all yield traits, but consistent P omission and omitting P only in wheat significantly influenced and

Table 2 Effect of nutrient omission treatments on mean crop growth rate, plant height and specific leaf area (SLA) of wheat crop

Treatment	Mean CGR at 0-30 (g/m ² /day)		Mean CGR at 30-60 (g/m ² /day)		Mean CGR at 60-90 (g/m ² /day)		Mean CGR at 90-120 (g/m ² /day)		Plant height at harvest (cm)		Specific leaf area at silking stage (cm ² /g)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
	NPKZn (Based on STCR)	3.10	3.03	7.74	7.71	15.51	15.45	9.60	9.35	77.2	77.2	340.7
NPKZn (RDF)	2.87	2.76	7.19	7.20	15.47	15.36	9.00	8.79	75.3	75.3	330.0	321.0
N (-PKZn) in both maize and wheat	2.53	2.37	6.16	6.01	15.08	15.09	8.59	8.19	70.8	70.8	302.0	291.8
NP (-KZn) in both maize and wheat	2.61	2.44	6.47	6.42	15.06	15.10	8.65	8.40	71.3	71.3	310.0	300.5
NPK (-Zn) in both maize and wheat	2.82	2.68	6.99	6.92	15.17	15.04	8.78	8.67	74.1	74.1	326.3	316.2
NPZn (-K) in both maize and wheat	2.68	2.50	6.62	6.57	15.19	15.09	8.68	8.61	72.0	72.0	315.7	305.8
N (-PKZn) only in maize	1.66	1.35	4.80	4.73	12.50	12.20	7.57	7.69	43.0	43.0	227.3	206.2
NP (-KZn) only in maize	1.67	1.41	4.84	4.76	12.54	12.18	7.61	7.77	43.6	43.6	228.3	207.2
NPK (-Zn) only in maize	1.72	1.49	4.96	4.89	12.60	12.24	7.90	8.06	45.5	45.5	232.7	212.5
NPZn (-K) only in maize	1.71	1.43	4.89	4.84	12.50	12.16	7.80	7.91	44.0	44.0	230.7	209.5
N (-PKZn) only in wheat	2.48	2.27	5.90	5.87	15.17	14.84	8.32	8.30	69.0	69.0	296.0	280.8
NP (-KZn) only in wheat	2.53	2.37	6.23	6.16	15.21	14.84	8.40	8.39	70.2	70.2	305.0	292.0
NPK (-Zn) only in wheat	2.76	2.61	6.81	6.66	15.12	15.03	8.70	8.68	72.5	72.5	322.0	312.8
NPZn (-K) only in wheat	2.61	2.46	6.41	6.29	15.18	14.94	8.49	8.44	71.0	71.0	310.5	299.8
Absolute control (No fertilizer)	1.62	1.28	4.48	4.62	12.74	12.25	7.46	7.67	42.2	42.2	226.0	205.2
SEd±	0.101	0.123	0.362	0.384	0.497	0.475	0.677	0.796	1.42	1.42	4.89	5.13
CD (P = 0.05)	0.202	0.248	0.729	0.771	0.999	0.954	1.361	1.600	2.86	2.86	9.84	10.31
<i>Control v/s others</i>												
SEd±	0.074	0.090	0.265	0.281	0.364	0.347	0.496	0.583	1.04	1.04	3.58	3.75
CD (P = 0.05)	0.148	0.182	0.533	0.565	0.732	0.699	0.996	1.171	2.10	2.10	7.20	7.55

lowered total tillers/m² and effective tillers/m² compared to application of N alone during both the years of study. The reduction due to different nutrient omission was severe during second year of experimentation. Omission of K to both crops also reduced all the yield traits significantly during both years of experimentation. The direct as well as cumulative effect of NPK application on total number of tillers/m², effective tillers/m² and number of grains/ear were significantly superior to application of N, NP and NPZn but was at par with NP and NPZn for 1000-grain weight during both the years of experimentation. The residual effect of NPK applied to preceding maize on all yield traits of wheat was at par with N, NP and NPZn during 2012-13 and 2013-14.

The effect of omitted nutrients on yield attributes was reflected directly in the grain and straw yields of wheat. Both grain and straw yields under STCR approach were significantly superior to all other treatments and were higher to the tune of 9.7, 4.4% in 2012-13 and 7.1, 5.9% in 2013-14, respectively compared to recommended dose of NPKZn (Table 4). Omission of P to both crops resulted in significant reduction in grain yield by 11.4 and 13.3%

during 2012-13 and 2013-14, respectively compared to the treatment where only N was applied and other all nutrients were omitted. Similarly, the sustained omission of K in the system significantly influenced the grain yield of wheat which was reduced by 14.9 and 20% during 2012-13 and 2013-14, respectively compared to recommended dose of NPKZn (Table 4). The yield reduction was slightly lower with Zn omission (2-5%). Stover yield is strongly correlated with K supply and was reduced significantly due to its omission to both crops by 7.9% during 2012-13 and 10.6% during 2013-14 in comparison to NPKZn. The reduction was higher during 2013-14 compared to preceding year. Omission of P and Zn had comparatively smaller effect on stover production. It might be due to progressive depletion of P and K in the respective omission plots could not meet the higher requirements of P and K for maize and wheat and therefore, resulted in reduction of yield attributes and yield of wheat. This result was in accordance with the findings of Rawal *et al.* (2017). They also reported that among all the treatments, the highest grain yield was obtained from fully fertilized plots (3001 kg/ha) followed by zinc missing

Table 3 Effect of nutrient omission treatments on yield attributes and harvest index of wheat

Treatment	Total no. of tillers/m ²		Effective tillers/m ²		Grains/ear		1000-grain wt (g)		Harvest index	
	2012-13	2013-14	2012-13	2013-14	2013-14	2013-14	2012-13	2013-14	2012-13	2013-14
NPKZn (Based on STCR)	492	490	449	448	50.0	48.0	47.0	46.0	44	43
NPKZn (RDF)	474	471	433	432	46.7	44.7	44.3	43.3	42	43
N (-PKZn) in both maize and wheat	415	410	380	375	39.7	36.7	38.0	36.5	40	39
NP (-KZn) in both maize and wheat	435	432	402	399	41.7	39.0	40.3	39.0	41	40
NPK (-Zn) in both maize and wheat	460	458	423	421	46.0	43.7	43.7	42.3	42	43
NPZn (-K) in both maize and wheat	437	430	404	395	42.3	40.0	40.5	39.3	41	41
N (-PKZn) only in maize	333	323	323	312	23.0	21.0	26.7	23.7	36	33
NP (-KZn) only in maize	338	328	327	317	23.3	21.3	27.0	25.0	37	33
NPK (-Zn) only in maize	342	332	330	321	25.0	23.0	28.7	26.7	38	33
NPZn (-K) only in maize	341	330	330	219	23.7	21.7	27.5	25.1	38	33
N (-PKZn) only in wheat	405	400	390	385	37.0	35.5	37.0	35.5	41	38
NP (-KZn) only in wheat	426	421	401	396	40.0	38.0	39.0	37.7	42	40
NPK (-Zn) only in wheat	458	455	424	421	44.8	42.3	42.0	40.5	44	44
NPZn (-K) only in wheat	430	423	404	397	40.7	38.7	39.5	38.5	41	40
Absolute control (No fertilizer)	330	320	321	312	22.1	20.1	25.0	23.0	36	33
SEd±	8.8	8.1	7.5	7.0	1.79	1.90	1.86	1.84	1.1	1.1
CD (P = 0.05)	17.6	16.3	15.1	14.2	3.60	3.82	3.73	3.70	2.3	2.2
<i>Control v/s others</i>										
SEd±	6.4	5.9	5.5	5.2	1.31	1.39	1.36	1.35	0.8	0.8
CD (P = 0.05)	12.9	11.9	11.0	10.4	2.63	2.80	2.73	2.71	1.7	1.6

plots and the lowest grain yield was found from potassium missing plots (990 kg/ha) followed by nitrogen missing plots (1308 kg/ha). Similarly, the wheat and maize yields were highest in the NPK treatment, followed by those in the NP treatment. In the PK or NK treatments, the yields of wheat and maize were significantly lower than those in the NP and NPK treatments. Compared to those in the NPK treatment, the yields of wheat and maize decreased, respectively, by 77% with the N omission, 79% and 78% with the P omission, 2% and 26% with the K omission, and 81% and 84% with no fertilizer (Dia *et al.* 2017).

The direct and cumulative effect of NPK application resulted in significantly higher wheat grain and straw yield compared to N, NP and NPZn during both years of study. The residual effect of NPK applied to preceding maize on wheat grain and straw yields was also significantly superior to absolute control but statistically at par with application of N, NP and NPZn. The HI was higher under STCR approach based nutrient supply followed by recommended dose of NPKZn. Omission of P, K to both crops and directly to wheat had significantly reduced the HI during 2012-13 (Table 3). Omission of Zn did not influence the proportioning of dry matter towards grain significantly. Highly significant correlations between the effective tillers/m², number of

grains/ear and 1000-grain weight with grain yield suggest that they largely account for the differences in the grain yield among the treatments.

Economics

Omitted nutrients showed considerable effect on gross returns and net profit from wheat cultivation. Consistently higher gross and net returns were realized during the year 2012-13 and 2013-14, respectively in balanced application of NPKZn based on STCR approach, which was significantly superior to recommended dose of nutrients (Table 4). The highest B:C ratio (net returns per rupee invested) of 1.6 and 1.2 were realized from the treatment involving the application of nitrogen only, exclusion of P, K and Zn to both crops in a maize-wheat cropping system and recommended dose of NPKZn during 2012-13 and 2013-14, respectively. The cumulative effect of treatments where N alone, NP, NPK and NPZn were applied resulted in numerically higher gross and net returns of wheat compared to the direct effect of similar treatments applied to wheat. Omission of P reduced the gross and net returns significantly by 10.2 and 8.7% and 11.2 and 6.5% during 2012-13 and 2013-14, respectively compared to application of N only and excluding all other nutrients (Table 4). Omitting K to both maize and wheat

Table 4 Effect of nutrient omission treatments on grain yield, straw yield, water productivity and economics of wheat

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Water productivity (kg/m ³)		Gross return (×10 ³ ₹/ha)		Net return (×10 ³ ₹/ha)		B:C ratio	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
NPKZn (Based on STCR)	4.98	4.50	6.42	5.97	1.67	1.51	71.7	66.7	42.6	35.9	1.30	1.16
NPKZn (RDF)	4.54	4.20	6.15	5.64	1.52	1.41	65.6	62.3	38.7	33.6	1.24	1.17
N (-PKZn) in both maize and wheat	3.50	3.00	5.35	4.73	1.17	1.00	51.2	45.2	29.4	21.7	1.51	0.92
NP (-KZn) in both maize and wheat	3.90	3.40	5.65	5.06	1.31	1.14	56.7	51.0	31.3	23.8	1.21	0.88
NPK (-Zn) in both maize and wheat	4.45	4.10	6.03	5.50	1.49	1.37	64.3	60.9	38.0	32.7	1.19	1.16
NPZn (-K) in both maize and wheat	3.95	3.50	5.70	5.10	1.32	1.17	57.4	52.4	31.4	24.6	1.15	0.89
N (-PKZn) only in maize	1.95	1.50	3.45	3.10	0.65	0.50	29.0	23.4	9.5	2.1	1.31	0.10
NP (-KZn) only in maize	2.10	1.52	3.50	3.15	0.70	0.51	31.0	23.7	11.5	2.4	1.58	0.12
NPK (-Zn) only in maize	2.20	1.60	3.63	3.24	0.74	0.54	32.5	24.8	13.0	3.6	1.64	0.17
NPZn (-K) only in maize	2.15	1.55	3.58	3.18	0.72	0.52	31.7	24.1	12.3	2.9	1.63	0.14
N (-PKZn) only in wheat	3.45	2.90	5.00	4.65	1.16	0.97	50.2	43.8	29.6	20.2	1.56	0.86
NP (-KZn) only in wheat	3.80	3.20	5.23	4.80	1.27	1.07	55.0	48.0	32.8	20.8	1.49	0.77
NPK (-Zn) only in wheat	4.40	4.00	5.62	5.11	1.47	1.34	63.3	59.1	40.5	31.0	1.53	1.10
NPZn (-K) only in wheat	3.85	3.30	5.58	5.04	1.29	1.11	56.0	49.6	33.2	21.8	1.44	0.79
Absolute control (No fertilizer)	1.90	1.45	3.40	2.96	0.64	0.49	28.3	22.5	8.8	1.5	0.94	0.07
SEd±	0.139	0.077	0.143	0.175	0.046	0.026	1.89	1.56	1.36	1.01	0.053	0.040
CD (P = 0.05)	0.279	0.155	0.287	0.351	0.093	0.052	3.80	3.13	2.74	2.04	0.106	0.080
<i>Control v/s others</i>												
SEd±	0.102	0.056	0.104	0.128	0.034	0.019	1.38	1.14	1.00	0.74	0.039	0.029
CD (P = 0.05)	0.204	0.113	0.210	0.257	0.068	0.038	2.78	2.29	2.01	1.49	0.078	0.058

crop resulted in 14.2 and 19.1% reduction in gross returns and 23.0 and 36.7% reduction in net returns from wheat during 2012-13 and 2013-14, respectively. Omission of Zn had decreased gross and net returns by 2-3% only. The NPK applied to preceding maize crop resulted in significant increase in gross returns and net returns of wheat compared to absolute control.

Water productivity

Water productivity of wheat was higher during 2012-13 than during 2013-14 owing to higher yield and higher amount as well as uniform distribution of rainfall in 2012-13. The lower amount of rainfall during 2013-14 resulted in lower water-use and did not increase grain yield proportionately; finally resulted in the lower water productivity of wheat. Application of nutrients on the basis of STCR resulted in significantly higher water productivity over all the other treatments. Application of NPK only to *kharif* crop resulted in significantly higher water productivity over application of N alone and absolute control during both the years of experimentation (Table 4). Omission of K resulted in greatest reduction in water productivity (16.8%) followed by P

(8.3%) and Zn (2.7%). The direct and cumulative effect of NPK applied on wheat, water productivity was significantly higher than N, NP and NPZn application during 2012-13 and 2013-14.

Conclusion

Overall, the STCR based nutrient management resulted in highest crop and water productivity, and profitability in wheat crop under maize-wheat cropping system over 100% RDF in the system. The maximum reduction in growth, productivity and profitability of wheat due to omission of K highlighted the significance of K application to wheat and proved be to be the most limiting nutrient for wheat over other nutrients. In nutshell, the STCR approach rationalized the optimum nutrient use over recommended fertilizer use to make maize-wheat cropping system more remunerative and sustainable.

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