



Macro- and micro-nutrient uptake pattern and their use efficiencies for maize (*Zea mays*) in maize-wheat (*Triticum aestivum*) cropping system under nutrient omissions

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ABSTRACT

A 2-year (2012 and 2013) field experiment was conducted at ICAR-Indian Agricultural Research Institute, New Delhi to assess the effect of omitted nutrients on nutrient concentration and uptake and (nutrient use efficiency) NUE for maize (*Zea mays* L.) in maize-wheat (*Triticum aestivum* L.) cropping system. The STCR-based application of nutrients was more rewarding in terms of improved concentrations, uptakes and better NUE of macro (N, P, K) and micro-nutrients (Zn) in maize. This treatment increased the total uptake of N, P and K by 14.9, 12.5 and 9.3 %, respectively, over recommended rates of NPKZn application. The continuous omission of P resulted in 13.7, 11.5 and 4.7 % reduction in total uptake of N, P and K, respectively. Similar to P, omitting K to both crops continuously also resulted in reduction of total uptake of N, P, K, Zn by 22.1, 13.6, 23.4, 1.9, respectively. Omitting Zn to both maize and wheat crop during 2012 and 2013 did not influence total nutrient uptake significantly. Omitting P and K also exhibited reduced agronomic efficiency and apparent recovery. Balanced application of NPK to preceding wheat crop resulted in higher uptake of N, P and K by maize compared to absolute control and imbalanced application of N, NP or NKZn directly to maize crop during experimentation. Omitting N, P or K to maize resulted in reduction in NUE and uptake in maize during second study year.

Key words: Nutrient omissions, Nutrient uptake, Nutrient use efficiency, Maize

In order to sustain continuous crop production, it is important to maintain nutrient status of soil at a desired level by applying optimum dose of fertilizers. However, in irrigated agro-ecologies, because of losses due to leaching, run-off, gaseous emission, and owing to slow mobility and fixation by soil, positive effects of applied fertilizer N, P, K and Zn on subsequent crops in the rotation are expected to last for variable periods (Kumar *et al.* 2016; Rana *et al.* 2018). Thus, the need to improve nutrient use efficiency (NUE) is therefore, of paramount importance, both for economical as well as environmental reasons (Bai *et al.*

2015; Mozafari *et al.* 2018). Several environmental, cultural and genetic factors influence maize (*Zea mays* L.) yield and quality (Suri and Choudhary 2012; Yadav *et al.* 2015). In this context, a balanced nutrition on the basis of soil test and crop response (STCR) studies is recently gaining importance (Suri *et al.* 2011, 2013; Suri and Choudhary 2012; Dass *et al.* 2015; Joshi *et al.* 2016). Since, many farmers apply even less fertilizers than that of the general recommended rates as explained above to maize crop (Yadav *et al.* 2015). Thus, it is imperative to study the direct, residual and cumulative effects of N, P, K & Zn applied to maize on the succeeding wheat (*Triticum aestivum* L.), so that necessary fertilizer N, P, K & Zn recommendations could be made for this cropping system.

In the era of precision agriculture, soil test-based fertilizer recommendation coupled with determining real-time demand of crop and matching supply of nutrients is important (Suri and Choudhary 2012; Dass *et al.* 2015; Joshi *et al.* 2018; Ghosh and Dass 2019). The quantification of indigenous nutrient supply (INS) of soil for major nutrients like N, P, K and the most deficient micro-nutrient, Zn is a prerequisite to increase NUE and yield levels of maize and wheat crops. Hence, the current study was made to determine the effect of omitted nutrients on nutrient uptake

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capacity of maize crop and applied nutrients-use efficiencies in maize–wheat cropping system.

MATERIALS AND METHODS

The field experiment was carried out during rainy seasons (July–October) of 2012 and 2013 at ICAR-Indian Agricultural Research Institute, New Delhi India. The total amount of rainfall received was 471 mm in *kharif* 2012 and 1090 mm in *kharif* 2013. The mean maximum temperature in June ranges from 40 to 45°C, while the mean minimum temperature in January is as low as 1.9°C. The distribution of rainfall during 2013 was uneven and resulted in water-logging in maize plots. Soil was medium in organic C, high in Zn, low in N and medium in P and K contents.

To study the effect of different nutrient omissions in maize–wheat cropping sequence and to find out their need of application in the cropping system either only to maize, only to wheat or to both the crops, four nutrient omission treatments as application of N (-PKZn), NP (-KZn), NPK (-Zn) and NPZn (-K) were taken. These four treatments were imposed in fixed plots as only to maize crop (no application in wheat crop), only to wheat crop (no application in maize crop) and application to both the crops, thereby making 12 treatment plots. One absolute control (no nutrient application), recommended rate of nutrients (RDF: 120-60-

40-5.5 kg/ha N-P-K-Zn) and STCR based application of nutrients (200-100-55-4 kg/ha N-P-K-Zn) were also taken, making the total number of treatments 15. This fixed-plot experiment was designed in a randomized complete block design (RCBD) replicated thrice. The experiment was started with maize (PEEHM 5) crop during rainy season of 2012. The experiment had a total of 45 plots of size 4.2 × 4.5 m each. Based on initial soil-test value of N, P and K, the fertilizer recommendation for maize variety PEEHM 5 for a targeted yield of 5 t/ha was calculated using STCR equation at the beginning of the experiment and computed values were 200, 100, 55 and 4 kg/ha of NPK and Zn. The STCR equations used in computing N, P and K dose for the experimental field are given as below:

$$FN = 6.61 T - 0.52 SN; FP_2O_5 = 4.77 T - 5.13 SP \text{ and } FK_2O = 2.75 T - 0.24 SK$$

As the Zn content of soil was in high range, its dose was reduced by 25% of the recommended dose (5 kg/ha) and thus applied @ 4 kg/ha. The fertilizers used for applying N, P, K and Zn were urea, diammonium phosphate (adjusted for its N content) and muriate of potash and zinc sulphate ($ZnSO_4 \cdot 7H_2O$), respectively. One-third dose of N and full dose of all other nutrients were applied basally to maize. Remaining N was top-dressed at 30 and 60 days

Table 1 Effect of nutrient omission treatments on nitrogen (N) and phosphorus (P) concentration at tasseling stage, grain and stover in maize

Treatment	N - concentration (%)						P - concentration (%)					
	Tasseling stage		Grain		Stover		Tasseling stage		Grain		Stover	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
NPKZn (Based on STCR)	1.9	2.0	1.7	1.8	0.6	0.6	0.36	0.38	0.25	0.25	0.14	0.15
NPKZn (RDF)	1.8	1.9	1.6	1.6	0.5	0.5	0.33	0.35	0.22	0.23	0.13	0.14
N (-PKZn) in both maize and wheat	1.7	1.8	1.3	1.4	0.4	0.4	0.31	0.32	0.20	0.19	0.12	0.12
NP (-KZn) in both maize and wheat	1.7	1.8	1.4	1.4	0.4	0.4	0.33	0.34	0.22	0.22	0.13	0.13
NPK (-Zn) in both maize and wheat	1.7	1.8	1.5	1.6	0.5	0.5	0.33	0.35	0.22	0.22	0.13	0.13
NPZn (-K) in both maize and wheat	1.7	1.8	1.5	1.5	0.5	0.5	0.33	0.34	0.22	0.22	0.13	0.13
N (-PKZn) only in maize	1.6	1.7	1.3	1.3	0.4	0.4	0.31	0.32	0.20	0.19	0.12	0.12
NP (-KZn) only in maize	1.7	1.8	1.4	1.4	0.4	0.4	0.32	0.33	0.22	0.22	0.12	0.12
NPK (-Zn) only in maize	1.7	1.8	1.5	1.5	0.5	0.5	0.33	0.34	0.22	0.22	0.13	0.13
NPZn (-K) only in maize	1.7	1.8	1.4	1.4	0.4	0.4	0.32	0.34	0.22	0.22	0.13	0.12
N (-PKZn) only in wheat	1.4	1.4	1.2	1.1	0.3	0.3	0.29	0.30	0.17	0.18	0.10	0.11
NP (-KZn) only in wheat	1.4	1.4	1.2	1.1	0.3	0.3	0.29	0.31	0.17	0.18	0.11	0.11
NPK (-Zn) only in wheat	1.4	1.5	1.2	1.2	0.3	0.3	0.29	0.31	0.18	0.18	0.11	0.11
NPZn (-K) only in wheat	1.4	1.5	1.2	1.1	0.3	0.3	0.29	0.31	0.18	0.18	0.11	0.11
Absolute control (No fertilizer)	1.4	1.4	1.1	1.0	0.3	0.2	0.29	0.28	0.17	0.17	0.10	0.10
LSD ($P = 0.05$)	0.11	0.12	0.13	0.11	0.02	0.04	0.016	0.017	0.007	0.015	0.004	0.010
Control v/s others												
LSD ($P = 0.05$)	0.07	0.09	0.08	0.08	0.01	0.03	0.010	0.013	0.004	0.011	0.003	0.008

after sowing (DAS) in 2 equal splits. The maize crop was sown using 25 kg seed/ha at spacing of 60×20 cm, in the second week of July and harvested in the second week of October. Crop was irrigated thrice (5 cm each) in 2012 and twice in 2013. The plant samples of maize collected at one month interval were dried in an electric oven at 65°C for 48 hr, ground and analyzed for N, P, K and Zn concentrations using standard procedures (Rana *et al.* 2014). Agronomic-use efficiency, recovery efficiency and physiological efficiency were computed using standard equations (Kumar *et al.* 2015). The data were analyzed by using ANOVA technique as applicable to a factorial RCBD as per the procedures described by Rana *et al.* (2014).

RESULTS AND DISCUSSION

Nitrogen concentration and uptake

The N concentration and uptake in maize plant material at tasseling stage, in grain and straw at harvest were highest under STCR-based nutrient application, which were significantly higher than that in all other treatments (Table 1, Fig. 1a). This might be due to the addition of considerable amounts of nutrients leading to better nutrient availability in soil and ultimately higher nutrient absorption by the crop (Paul *et al.* 2014, 2016). The application of N, NP, NPK and NPZn cumulatively to maize and wheat recorded statistically similar concentration of N as recorded under application of these nutrients to maize only except in the treatment of PKZn omission in maize. While, the application of nutrients to wheat crop only significantly reduced the N concentration in maize parts showing the insufficient residual effect of N and other nutrients to meet the N requirement of maize crop. Residual effect of NPK fertilization to preceding wheat was found insufficient for

better N accumulation by maize crop. Omission of P, K and Zn to both crops and only to maize significantly reduced the N concentration and its uptake in both grain and stover compared to recommended rate of nutrients application in both years of experimentation. It was because N, P and K bear synergistic interactions among them (Skowrońska and Filipek 2010). Omitting P to both crops decreased the N uptake at tasseling and harvest in both grain and stover by 4.3, 15.5 and 9.6, 13.5%, respectively. Similarly, omission of K decreased the N uptake at tasseling and harvest in both grain and stover by 25.3, 19.6 and 17.2, 18.7%, respectively. This is because K helps in better N uptake because it plays important role in N-metabolism (Kumar *et al.* 2016).

Phosphorous concentration and uptake

Application of NPKZn based on STCR-approach resulted in the highest P concentration and uptake at tasseling stage and at harvest compared to all other treatments (Table 1, Fig. 1b). Application of NPK and omitting Zn to both crops of maize-wheat cropping system and only to *kharif* crop, led to significantly higher P concentration and its uptake at tasseling stage and at harvest in both grain and stover compared to application of N alone and omitting PKZn. The residual effect of NPK application applied to preceding wheat on P content and respective uptake by maize was at par with N, NP and NPZn application during 2013. During both years, omission of P to both crops caused significant reduction in P uptake at tasseling stage (34.5%), and in grain (41.2%) and stover (24.2%) at harvest. This might be due to the fact that P initiates both first and second rootlets and develop extensive root system that helps in exploiting the maximum nutrients from the soil and its restricted availability reduces N, P and K uptake (Suri *et al.* 2011, 2013; Dass *et al.* 2008, 2013).

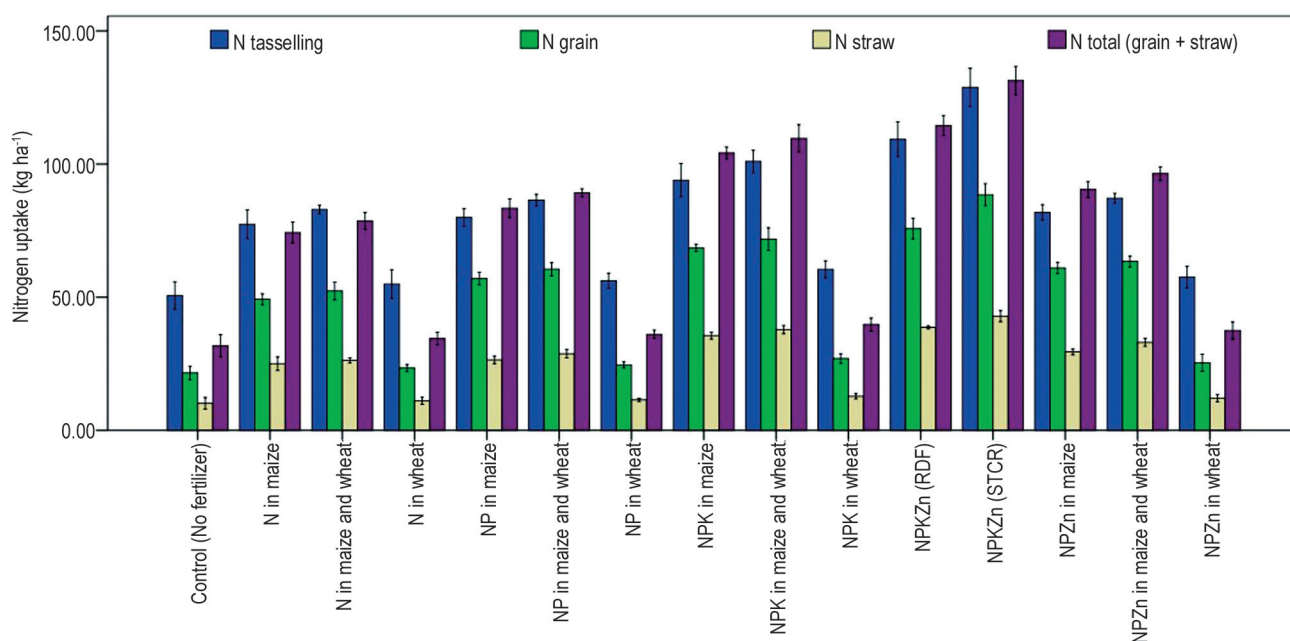


Fig 1 Effect of nutrient omission treatments on nitrogen (N) uptake at tasseling stage, in grain, stover and total uptake (pooled mean of 2 years) by maize. The error bars shows standard error of mean.

Similarly, omitting K to both crops resulted in decreased P uptake at tasseling (23.9%), in grain (12.1%) and stover (10.0%) at harvest during 2012 and 2013. Neglecting P or K fertilization resulted in much lower reduction of P and K accumulation in grain. Treatments where Zn was omitted to both crops and only to maize, showed slightly higher P concentration compared to treatments where Zn was applied. It might be due to the ample supplies of Zn in maize crop season during both study years; the experimental field soil was high in Zn (0.8 ppm). Similar to Zn, K omission also had non-significant effect on P concentration.

Potassium concentration and uptake

STCR based nutrient application resulted in the highest K concentration in maize grain and straw. Recommended dose of NPKZn resulted in higher K concentration, but was statistically at par with NPK (-Zn) application to both crops and application only to maize (Table 2). The cumulative effect of treatments where NPK was applied to both crops was reflected in significantly higher K concentration compared to N (-PKZn), NP (-KZn) and NPZn (-K) at tasseling and harvest. The similar trend was also observed for direct effect of NPK application on K concentration. Omitting P and Zn resulted in the reduced K concentration in maize at tasseling and harvest, but the reduction was not significant in either of the study years. It may happen because P helps in development of extensive root system that helps in exploiting the maximum nutrients from the soil and its restricted availability reduces K uptake (Dass *et al.* 2008). The residual effect of NPK applied to preceding wheat on maize K concentration was at par with N (-PKZn), NP (-KZn) and NPZn (-K) application. The K concentration in stover was nearly double the concentration of K in grain. Uptake of K was influenced significantly under different nutrient omission treatments during both years of study (Fig. 1c).

The STCR approach based nutrient application resulted in significantly higher K uptake at tasseling and at harvest. The cumulative and direct effect of application of NPK to both the crops and only to maize resulted in significantly higher K uptake at tasseling and at harvest in both grain and stover compared to N, NP and NPZn application during 2013. The treatment where K was omitted (NPZn applied) to both crops resulted in significant reductions in K uptakes. The decrease was to the tune of 30.3 and 33.4% at tasseling stage, 32 and 34.4% in grain, 18.2 and 14.8% in straw during 2012 and 2013, respectively. Similarly, omitting K to only maize decreased the K uptake at tasseling, K uptake by grain and straw by 43.8, 42.9 and 22.8% during 2013, respectively. Omission of Zn did not influence significantly the K at tasseling and harvest, but omission of P significantly reduced the K uptake in grain during 2012 and 2013. The residual effect of NPK (-Zn) application to preceding wheat resulted in significantly higher K uptake by maize grain compared to N, NP and NPZn during 2013.

Zinc concentration and uptake

Omission of P, K and Zn showed non-significant effect on Zn concentration and its uptake in maize plant at tasseling stage and in grain and stover at harvest. Application of recommended doses of NPKZn resulted in numerically higher Zn concentration at tasseling stage, its total uptake and uptake of Zn at different crop stages, was statistically at par with STCR approach based nutrients as NPKZn, N alone, NP, NPK and NPZn applied to both crops and only to maize at tasseling stage of maize (Table 2, Fig 2). But at harvest, recommended dose of NPKZn resulted in significantly higher Zn concentration in both grain and stover compared to STCR approach during 2013. The cumulative and direct effect of NPZn application on Zn concentration and Zn uptake at tasseling stage, at harvest in both grain

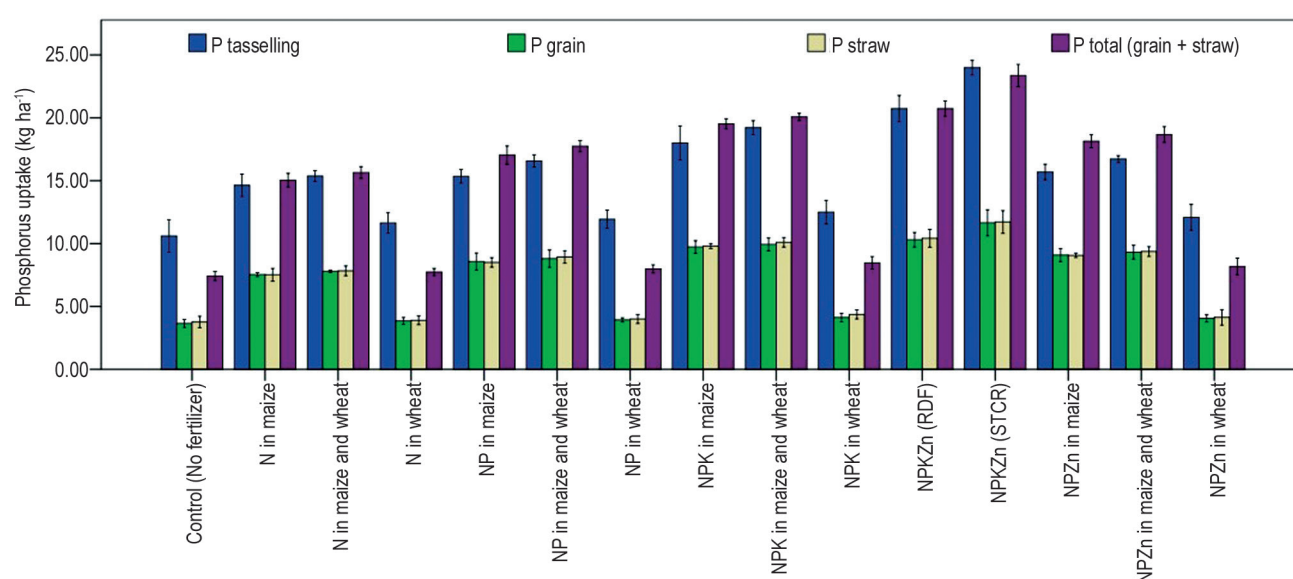


Fig 2 Effect of nutrient omission treatments on phosphorus (P) uptake at tasseling stage, in grain, stover and total uptake (pooled mean of 2 years) by maize. The error bars shows standard error of mean.

Table 2 Effect of nutrient omission treatments on potassium (K) and zinc (Zn) concentration at tasseling stage, grain and stover in maize

Treatment	K - concentration (%)						Zn - concentration (mg kg ⁻¹)					
	Tasseling stage		Grain		Stover		Tasseling stage		Grain		Stover	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
NPKZn (Based on STCR)	1.60	1.61	0.54	0.55	1.35	1.38	60.3	61.4	50.3	51.1	21.3	21.1
NPKZn (RDF)	1.50	1.52	0.49	0.48	1.29	1.30	61.7	62.9	52.5	53.7	23.6	23.1
N (-PKZn) in both maize and wheat	1.37	1.36	0.38	0.37	1.12	1.13	60.5	61.6	50.6	46.8	20.7	20.2
NP (-KZn) in both maize and wheat	1.38	1.38	0.39	0.40	1.13	1.15	60.5	61.5	50.1	47.1	20.8	20.0
NPK (-Zn) in both maize and wheat	1.49	1.50	0.47	0.46	1.27	1.28	60.6	61.6	51.0	47.9	21.0	20.2
NPZn (-K) in both maize and wheat	1.39	1.40	0.40	0.40	1.13	1.18	60.8	61.9	51.9	52.7	22.9	22.1
N (-PKZn) only in maize	1.35	1.34	0.35	0.36	1.07	1.08	59.7	60.0	50.0	45.3	20.6	19.9
NP (-KZn) only in maize	1.36	1.35	0.36	0.37	1.09	1.10	59.5	60.0	50.0	45.4	20.6	19.8
NPK (-Zn) only in maize	1.46	1.48	0.46	0.45	1.25	1.24	59.8	61.0	50.5	48.1	21.0	20.1
NPZn (-K) only in maize	1.37	1.38	0.38	0.38	1.10	1.12	60.1	61.2	51.2	48.1	22.4	21.4
N (-PKZn) only in wheat	1.26	1.27	0.29	0.30	0.98	0.96	56.1	58.9	48.1	40.0	19.3	18.9
NP (-KZn) only in wheat	1.28	1.29	0.31	0.31	0.99	0.97	56.2	58.5	48.3	40.7	19.6	18.9
NPK (-Zn) only in wheat	1.30	1.31	0.31	0.32	1.02	1.00	56.1	58.6	48.6	40.9	20.0	19.0
NPZn (-K) only in wheat	1.29	1.30	0.30	0.31	1.01	0.99	56.7	58.8	48.9	42.7	20.0	19.3
Absolute control (No fertilizer)	1.26	1.23	0.29	0.26	0.96	0.94	56.0	58.2	48.0	38.0	19.1	18.1
LSD ($P = 0.05$)	0.07	0.082	0.033	0.033	0.042	0.069	2.00	2.46	2.39	2.04	1.30	1.47
Control v/s others												
LSD ($P = 0.05$)	0.045	0.06	0.021	0.024	0.027	0.051	1.28	1.80	1.53	1.49	0.83	1.08

and stover were significantly superior to application of N, NP and NPK during 2013. Similarly, the residual effect of NPZn application to wheat crop resulted in significantly higher Zn concentration and increased Zn uptake at tasseling stage and at harvest compared to absolute control. The drop in Zn concentrations in the grain and stalk in Zn omission plots was not so severe indicating more or less adequate supply of Zn over seasons.

Agronomic efficiency of nutrients

Highest agronomic efficiency (AE) of N during 2012 (22.9 kg maize grain kg⁻¹ of N) and 2013 (15 kg maize grain yield kg⁻¹ of N) was recorded where the recommended doses of NPKZn were applied to maize crop (Table 3, Fig 3). It is because of the fact that nutrient efficiencies are calculated from yield of crops, respective nutrient uptake by crops and amount of nutrient applied to crop (Adhikari *et al.* 2014). Under STCR approach where nutrients were applied in balanced proportion resulted in significant increase in grain yield compared to other treatments. But, the amount of respective nutrient applied were relatively higher than the corresponding increase in yield and resulted in lower AE compared to recommended dose of NPKZn during both years of experimentation. Omission of P, K and Zn to both the crops and to maize only decreased the AE of N during

both years of study. Likewise, AE of P was also highest under recommended doses of NPKZn. Omission of K and KZn together reduced the AE of P. AE of K was higher in recommended doses of NPKZn where lower dose of K was applied. Similarly, Zn exhibited higher AE in STCR approach based NPKZn application during both years of experimentation and omitting K to both crops and only to maize also reduced AE of Zn during 2013 (Table 3). The AE of N, P, K and Zn was relatively higher under cumulative effect of different treatments, *i.e.* application of N alone, NP, NPK and NPZn compared to their respective direct effects on maize crop.

Physiological efficiency of nutrients

Nutrient omission treatments differed significantly and considerably with regard to the physiological efficiency (PE). Highest PE of N was obtained under application of N alone to both crops and to maize crop only during 2012 and 2013. Omission of K or application of NPZn to both crops and to maize only resulted in highest PE of P during both study years. Similarly, application of NPK (-Zn) to both crops and to maize only resulted in the highest PE of K followed by application of recommended doses of NPKZn and STCR approach based nutrient application during both years of study. The STCR approach based

Table 3 Effect of nutrient omission treatments on apparent recovery, physiological efficiency and agronomic efficiency of Zn in maize

Treatment	Apparent recovery (%)		Physiological efficiency (kg increase in grain yield/kg increase in nutrient uptake)		Agronomic efficiency (kg increase in grain yield/kg of nutrient applied)	
	2012	2013	2012	2013	2012	2013
NPKZn (Based on STCR)	0.8	1.0	12520.7	11412.6	161.6	163.7
NPKZn (RDF)	0.6	0.7	11506.3	9894.0	110.0	112.0
N (-PKZn) in both maize and wheat	-	-	-	-	-	-
NP (-KZn) in both maize and wheat	-	-	-	-	-	-
NPK (-Zn) in both maize and wheat	-	-	-	-	-	-
NPZn (-K) in both maize and wheat	0.5	0.6	11064.8	9707.1	95.6	92.8
N (-PKZn) only in maize	-	-	-	-	-	-
NP (-KZn) only in maize	-	-	-	-	-	-
NPK (-Zn) only in maize	-	-	-	-	-	-
NPZn (-K) only in maize	0.5	0.5	11142.9	10769.2	93.6	89.6
N (-PKZn) only in wheat	-	-	-	-	-	-
NP (-KZn) only in wheat	-	-	-	-	-	-
NPK (-Zn) only in wheat	-	-	-	-	-	-
NPZn (-K) only in wheat	-	-	-	-	-	-
Absolute control (No fertilizer)	0.00	0.00	0.00	0.00	0.00	0.00

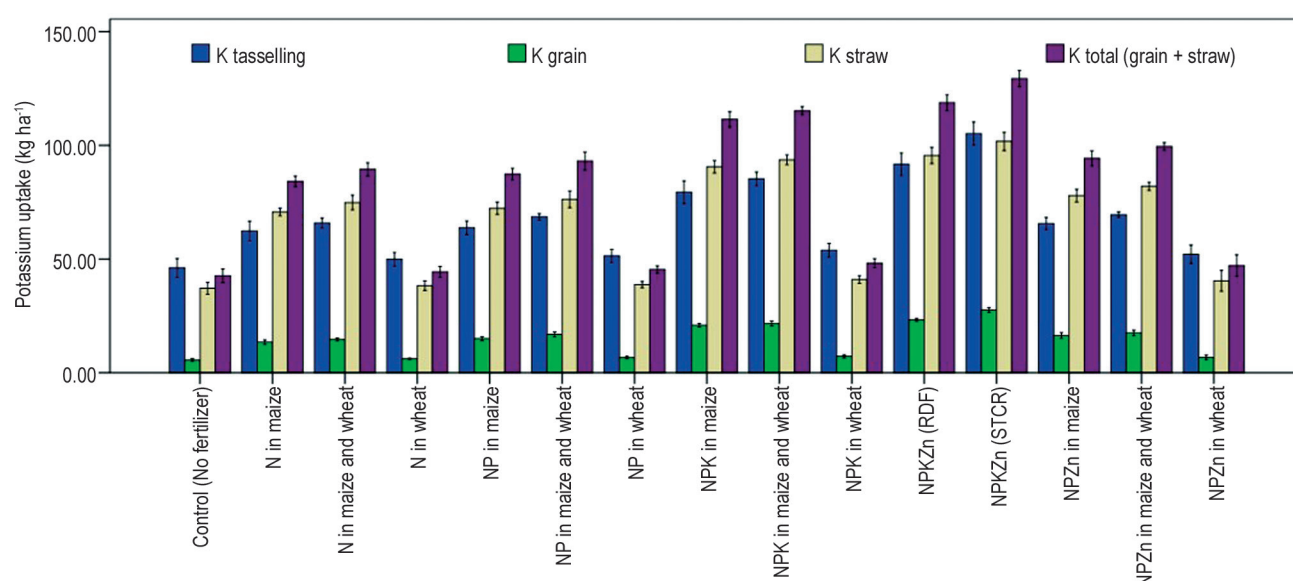


Fig 3 Effect of nutrient omission treatments on potassium (K) uptake at tasseling stage, in grain, stover and total uptake (pooled mean of 2 years) by maize. The error bars shows standard error of mean.

NPKZn application resulted in the highest PE of Zn (Table 3, Fig 3). Under STCR-approach, the increase in uptake of respective nutrients was relatively higher than increment in yield of crops, resulted in lower values of PE compared to recommended dose of NPKZn application during 2012-13 and 2013-14. The higher nutrient efficiencies could be achieved simply by sacrificing yield, but that would not be economically effective or viable for the farmers (Adhikari *et al.* 2014). Direct effect of N (-PKZn), NP (-KZn), NPK (-Zn) and NPZn (-K) application were relatively higher for PE of N, P, K and Zn in maize compared to cumulative

effect to respective nutrients application and their omission during 2013.

Apparent recovery of nutrients

Apparent recovery (AR) of nutrients in maize, expressed as the % increase in uptake per unit of nutrient applied, for N, P, K and Zn was higher where lower doses of respective nutrients were applied (Table 3, Fig 3). Omission of P, K and Zn to both crops of the cropping system and to maize reduced the AR of N during both years of study. Similarly, omitting K to both crops and to maize also reduced the

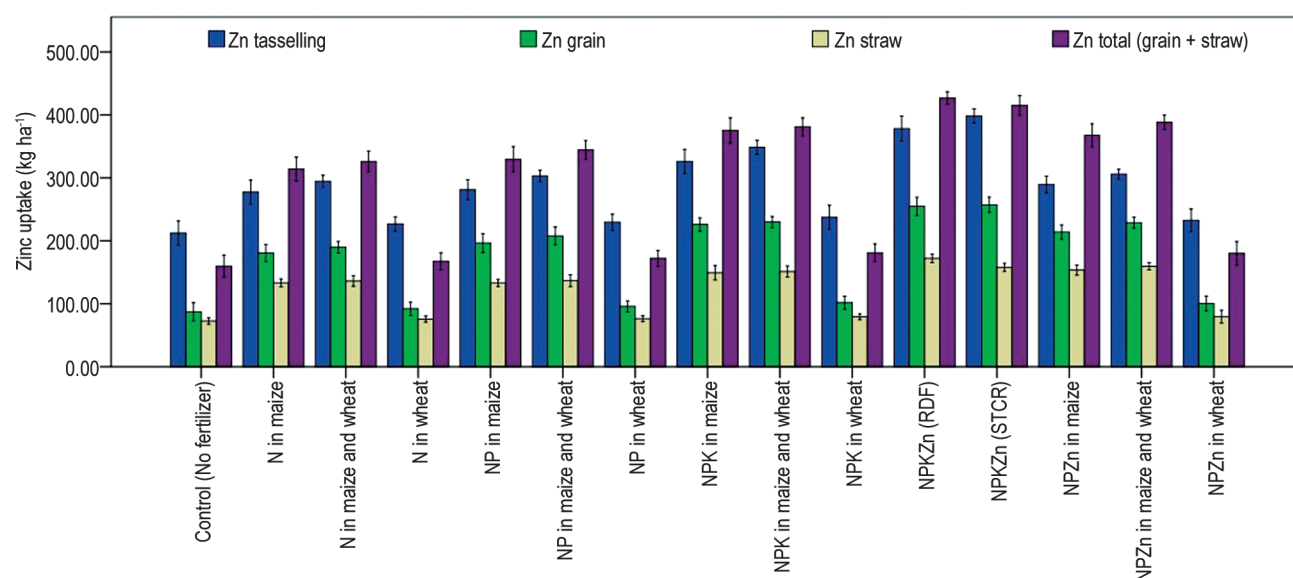


Fig 4 Effect of nutrient omission treatments on Zinc (Zn) uptake at tasseling stage, in grain, stover and total uptake (pooled mean of 2 years) by maize. The error bars shows standard error of mean.

AR of P. It might be due to the better recovery of N and P in presence of K was due to the involvement of K in N metabolism. Omission of P and K to both maize and wheat in a system-mode resulted in 24 and 18.5% reduction in AR of N and P respectively in maize. Cumulative effect of NPK application was higher compared to its direct effect. The AR of Zn was the highest under STCR approach based NPKZn application during both years. Omission of K resulted in decrease in AR of Zn. Omission of Zn resulted in higher AR of P and lower AR for N and K in maize compared to treatment where Zn was applied. It is because P and Zn have negative interaction and K and Zn have positive interaction with each other (Suri *et al.* 2011).

Conclusion

It is inferred that continuous omission of P resulted in 13.7, 11.5 and 4.7% reduction in total uptake of N, P and K by maize crop. Similar to P, omitting K to both crops continuously resulted in reduction of total uptake of N, P, K, and Zn by 22.1, 13.6, 23.4 and 1.9%, respectively. Thus, STCR approach based nutrient management to both maize and wheat in system-mode is significantly superior in terms of higher nutrient uptake and nutrient-use efficiencies over conventional recommended NPKZn dose; which strongly advocate that conventional recommended dose of plant nutrition in maize–wheat cropping system is still sub-optimal and the STCR based nutrient prescription is more precise. Omission of P, K and Zn in the cropping system highlighted the significance of P and K application to both the crops but the effect of K omission is more pronounced as compared to P omission in the system-mode.

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