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Research Paper

Productivity, nutrient uptake and economics of wheat (*Triticum aestivum*) under potassium and zinc nutrition

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2010–11 and 2011–12 at Bichpuri, Agra , Uttar Pradesh on sandy-loam soil, to assess the effect of potassium and zinc nutrition on wheat [*Triticum aestivum* (L.) emend. Fiori & Paol]. Treatments comprising 4 levels each of K (0, 30, 60 and 90 kg K_2O/ha) and Zn (0, 3, 6 and 9 kg/ha) were evaluated in randomized complete-block design with 3 replications. Growth and yield parameters of wheat increased significantly with the increasing levels of K up to 60 kg K_2O/ha which were statistically at par with 90 kg K_2O/ha. The mean grain (5.31 t/ha) and straw yields (9.80 t/ha) with 60 kg K_2O/ha were 15.4 and 13.7% higher than the control, respectively. Application of 60 kg K_2O/ha resulted in significantly highest net returns (₹48.1 × 10^3/ha) and benefit: cost ratio (1.90). Increasing zinc levels up to 6 kg Zn/ha showed significant improvement in plant height, effective tillers, grains/spike and 1,000-grain weight over the control. Similarly, application of 6 kg Zn /ha resulted in 8.8% higher grain yield (5.22 t/ha) than the yield obtained in the control (4.80 t/ha). Significantly highest net returns (₹47.8 × 10^3/ha) and benefit: cost ratios (1.95) were recorded at 6 kg Zn/ha. Uptake of N, P, K, S and Zn in wheat crop increased significantly with increasing levels of potassium. Protein content and yield in wheat grain increased significantly with the addition of K_2O up to 90 kg/ha and Zn up to 9 kg/ha. The nutrient uptake (N, K and Zn) in wheat, except those of P and S, increased significantly up to 6 kg Zn/ha. The efficiency indices decreased at higher doses of K and Zn and the maximum values were recorded at 60 kg K_2O/ha and 6 kg Zn/ha.

Key words : Economics, Nutrient uptake, Potassium, Wheat, Yield, Zinc

Wheat is the most important staple foodgrain in Indian diet and main source of protein and calories for large section of population. By 2020, India will have a population of about 1.3 billion and there will be a substantial pressure on land to produce more food. Stagnation in wheat production, lower productivity and inferior quality of the produce is due to various constraints including inadequate and imbalanced nutrient application (Prasad, 2012). Potassium and zinc play important role in the production phenology of wheat and this crop responds well to applied K (Yadav *et al.*, 2012). Zinc, also an important micronutrient is reported to be deficient in the soils of Agra region (Singh, 2010) and plays an important role as a metal component in various enzymes or as a functional, structural or regulator cofactor of large number of enzymes. The depletion of soil Zn leads low productivity and low concentration in edible grains, which causes Zn deficiency in humans, particularly in semiarid tropics (Shivay *et al*., 2008). Losses of yield of 40% or more in many Zn-deficient soils have a major economic impact on the farmers due to the reduced income as a result of less yield. A suitable combination of K and Zn is, by and large, the most important single factor that affects the yield and quality of the crops. Since inadequate and scanty information on potassium and Zn nutrition of wheat is available, particularly on soils of Agra region, the present investigation was carried out to study the effect of potassium and Zn fertilization on yield, quality, economics, and nutrient uptake in wheat.

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MATERIALS AND METHODS

The field experiment was conducted during the winter season of 2010–11 and 2011–12 at research farm, Raja Balwant Singh College, Bichpuri, Agra, Uttar Pradesh. (27˚2' N, 77˚9' E 163.4 m above mean sea-level). The experimental site is characterized by semi-arid climate with extreme temperature during summer (45˚ to 48˚C) and very low temperature (as low as 2˚C). The average rainfall is about 650 mm, most of which is received during June-September. The soil was sandy loam having pH (7.8), electrical conductivity (EC) (0.29 dS/m), organic carbon (0.36%), low available N (160 kg/ha) and P (9.7 kg/ha), medium K (110 kg /ha) and low DTPA-extractable Zn (0.51 ppm). The field trial consisting of 4 levels of K_2O (0, 30, 60 and 90 kg/ha) and 4 levels of Zn (0, 3.0, 6.0 and 9.0 kg/ha) was a factorial experiment laid out in randomized complete-block design with 3 replications. A common dose of N and phosphorus @ 120 and 60 kg/ha was applied through diammonium phosphate and urea, respectively, at the time of sowing. Half of N and full dose of P were applied as basal dressing at sowing and rest half of N was top-dressed at the time of first irrigation at the crown-root-initiation stage of crop. Potassium and Zn were applied through zinc sulphate and muriate of potash, respectively, as per treatments. The amount of sulphur applied through Zn sulphate was equated with elemental sulphur. Wheat 'PBW 343' was sown in rows, 20.0 cm apart using 100 kg seeds/ha in the first week of November during both the years. Other agronomic management practices were followed as per the standard recommendation. The crop was harvested at maturity and grain and straw yields were recorded. Grain and straw samples were digested with di-acid mixture of HNO_3 and $HClO_4$ in 9:1 ratio. Phosphorus in the digest was determined by vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973), K by flame photometer, sulphur by turbidimetric method (Chesnin and Yien, 1951), Zn by atomic absorption spectrophotometer. Nitrogen in grain and straw was determined by modified micro Kjeldahl method (Jackson, 1973). The nutrient removal by crop was calculated by multiplying the concentration values with their respective grain and straw yield values. The economics of wheat production was worked out on the basis of prevailing market price of different inputs and final produce. Since trend of results was similar during both the years data were subjected to sample of mean of 2 years indices for results and discussion.

RESULTS AND DISCUSSION

Growth and yield attributes

All the growth and yield-attributing characters were affected significantly by different levels of potassium and zinc (Table 1). Significantly taller plants and higher number of effective tillers/m^{-2}, grains/spike and 1,000-grain weight were recorded at 90 kg K_2O/ha, followed by 60, 30 kg K_2O/ha and the control (Table 1). However, the higher levels (60 and 90 kg K_2O/ha) were statistically at par in respect of growth and yield attributes. Potassium plays a crucial role in meristematic growth through its effect on the synthesis of phyto-hormones. Among various plant hormones, cytokinin plays important role in growth of tillers and bud (Yadav *et al.,* 2012). Beneficial effects of K on growth and yield attributes have been reported by Jat *et al.* (2013). Application of Zn increased the plant height, effective tillers, grains/spike and 1,000-grain weight significantly over the control. However, there was no further increase in any character when the level of zinc was raised to 9 kg Zn/ha. This increase may be due to involvement of zinc in biosynthesis of Indole-3 acetic acid (Shivay and Prasad, 2013).

Yield

Grain and straw yield of wheat increased significantly with potassium application over the control. The mean yield of wheat grain increased by 7.6, 15.4, and 19.1% over the control owing to addition of 30, 60 and 90 kg K_2O/ha respectively. The corresponding increases in straw yield were 6.6, 13.7 and 16.7%. As K is essential for grain development, the favourable effect of high doses of K on growth and yield attributes of wheat was mainly responsible for higher grain and straw yields. The results confirm the findings of Jat *et al*. (2013) and Kumar *et al.* (2015). With successive increase in Zn levels, grain and straw yield of wheat increased significantly up to 6 kg Zn/ha and further increase in Zn level did not significantly enhance the yield over 6 kg Zn/ha. However, the highest grain and straw yields were recorded with 9 kg Zn/ha, which registered 11.2 and 12.7% higher grain and straw yield over the control. But increase in yield was statistically non-significant at higher level (9 kg Zn/ha) of Zn over 6 kg Zn/ha. The increase in yield owing to application of Zn may be ascribed to improved growth and yield attributes and yield is directly related to these attributes. Increase in yield with application of Zn is quite obvious, as the soil under study was deficient in available Zn (0.52 mg/kg). Jat *et al*. (2013) and Shivay and Prasad (2013) also reported such favourable effect of Zn on grain and straw yield. Harvest index is the indicator of grain yield per cent of the biological yield in the respective treatments. However, with K and Zn application there was no significant difference in harvest index of wheat. Profuse tillering owing to K application increased inter-plant competition leading to higher dry matter with the same amount of grain yield, ultimately results low harvest index (Jat *et al.*, 2013).

Quality

Increasing levels of K and Zn significantly increased the protein content in wheat grain from 11.1 to 12.2 and 11.3 to 12.0 % with 90 kg K_2O and 9 kg Zn/ha respectively. The increase in protein content owing to Zn addition might be attributed to its involvement in the N metabolism. Chauhan *et al.* (2014) reported an increase in protein content in wheat with Zn application. Corresponding application of potassium and Zn also increased the protein yield from 510.6 to 668.6 and 542.4 to 640.8 kg/ha, respectively. The increases in protein yield were significant up to 90 kg K_2O and 9 kg Zn/ha over the control. Protein yield is the function of protein content and grain yield. Since variation in protein content has genetic and bio-chemical limitation, the protein yield is more influenced by grain yield and thus followed almost trend similar to grain yield. Khare and Dixit (2011) also reported a positive response of K and Zn on protein content respectively.

Nutrient uptake

The N uptake by wheat grain increased by 10.6, 20.7 and 26.3% over the control due to 30, 60 and 90 kg K_2O/ha respectively (Table 2). The corresponding increases in N uptake by straw were 10.3, 19.6 and 26.7%. This increase in N uptake by wheat grain and straw may be ascribed to higher grain and straw production of wheat due to K application. Khare and Dixit (2011) observed the same trend of results in wheat. The N uptake by wheat grain and straw increased significantly with zinc application which is apparently the result of favourable effect of this element on N absorption coupled with grater wheat grain and straw production. Singh (2010) also indicated an increase in N uptake by wheat grain and straw due to Zn application. Application of K resulted in 21.1, 33.8 and 52.1% increase in P uptake due to 30, 60 and 90 kg K_2O/ha over the control respectively. The corresponding increases in P uptake by straw were 32.2, 40.3 and 61.3%. Kumar *et al*. (2015) also reported an increase in P uptake with K application. The phosphorus uptake by wheat grain and straw tended to decrease significantly with higher levels of Zn compared with the control. The phosphorus uptake by wheat grain decreased from 9.6 to 8.3 kg/ha at 9 kg Zn /ha. The corresponding reduction in P uptake by

Table 1. Effect of potassium and zinc levels on growth, yield attributes and yield of wheat (mean data of 2 years)

Treatment	Plant height (cm)	Effective tillers/m^2	Grains/ spike	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Potassium (kg/ha)							
0	92.0	246	43.2	35.6	4.60	8.62	34.8
30	94.1	249	44.5	37.9	4.95	9.19	35.0
60	96.5	252	45.1	39.3	5.31	9.80	35.1
90	97.0	257	46.2	39.9	5.48	10.06	35.2
Zinc (kg/ha)							
0	94.0	234	41.7	35.9	4.80	8.87	35.0
3	94.6	249	44.3	38.2	4.97	9.15	35.2
6	95.4	259	46.1	39.1	5.22	9.65	35.1
9	95.6	263	46.8	39.4	5.34	10.0	34.8
SEm±	0.3	3.1	0.37	0.44	0.06	0.11	0.15
CD (P=0.05)	0.8	8.8	1.05	1.23	0.16	0.31	NS

Table 2. Effect of potassium and zinc levels on uptake of N, P, K, S and Zn in grain and straw of wheat crop (mean data of 2 years)

Treatment	Uptake (kg/ha)								Uptake (g/ha)	
	N		P		K		S		Zn	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Potassium (kg/ha)										
0	92.8	50.5	7.1	6.2	25.0	84.7	8.4	8.8	192.8	248.2
30	102.6	55.7	8.6	8.2	29.2	93.0	9.6	10.5	212.2	280.5
60	112.0	60.4	9.5	8.7	34.8	102.6	11.5	12.9	235.6	314.4
90	117.2	64.0	10.8	10.0	38.2	107.7	12.4	14.3	247.4	334.8
Zinc (kg/ha)										
0	97.1	51.6	9.6	9.1	29.0	90.5	10.4	12.3	174.6	198.6
3	102.9	55.2	9.2	9.0	30.9	93.9	10.5	12.0	205.3	254.5
6	110.1	59.9	8.8	8.0	33.1	99.7	10.5	11.2	242.8	329.0
9	114.4	63.8	8.3	7.0	34.2	103.8	10.5	11.1	265.3	395.7
SEm±	1.95	1.37	0.66	0.48	1.21	1.58	0.36	0.56	5.31	7.99
CD (P=0.05)	5.40	3.80	1.83	1.33	3.35	4.26	1.01	1.57	14.71	22.15

straw was from 9.1 to 7.0 kg/ha. Thus, minimum P uptake by wheat grain and straw was recorded with 9 kg Zn/ha owing to the antagonistic relationship of Zn with P (Chauhan *et al.,* 2014). The higher concentration of Zn created hindrance in absorption and translocation of P from the root to the above parts (Jain and Dahama, 2006). The K uptake by the wheat grain and straw increased from 25.0 to 38.2 and from 84.7 to 107.7 kg/ha, respectively as the dose of K was increased from 0 to 90 kg K_2O/ha. This increase in K uptake may be ascribed to higher grain and straw production and K content in wheat due to K application (Singh and Singh, 2009; Khare and Dixit, 2011). The addition of Zn also increased K uptake by grain and straw from 29.0 to 34.2 and from 90.5 to 103.8 kg/ha, as the dose of Zn was increased from 0 to 9 kg Zn/ha (Khare and Dixit 2011). Sulphur uptake increased significantly with the increasing levels of K up to 90 kg K_2O/ha over the control and increases were 16.8, 39.2 and 52.8% due to 30, 60 and 90 kg K_2O/ha, respectively. The corresponding increases in S uptake by straw were 25.0, 46.6 and 62.5%. The S uptake by grain and straw decreased with increasing levels of Zn which may be attributed to antagonistic relationship between them. The Zn uptake by grain and straw with 90 kg K_2O/ha increased from 192.8 to 247.4 and 248.2 to 334.8 g/ha respectively. The increases in Zn uptake by grain and straw were from 174.6 to 265.3 and 198.6 to 395.7 g/ha, respectively with 9 kg Zn/ha. This increase in Zn uptake may be ascribed to the higher grain and straw production of wheat as well as improvement in Zn content with its addition (Chauhan *et al.* 2014). Significant response of wheat to 9 kg Zn/ha could be directly attributed to enhanced availability of Zn in soil at a level below where the optimum requirement of crop fulfilled. This showed that enhancement in Zn levels not only increased the yields but also increased the nutrient concentration and ultimately their uptake. Higher yield recorded with zinc application led to higher zinc uptake by the crop (Jain and Dahama, 2006).

Economics

Each successive increment in K levels from 0 to 90 kg K_2O/ha increased the net returns and benefit: cost ratio significantly over the control. The significantly highest net returns and benefit: cost ratio were obtained with 60 kg K_2O/ha, which have proved more remunerative than the other levels of potassium. However, 90 kg K_2O/ha fetched higher net returns than 60 kg K_2O/ha but the increase in net returns was non-significant. From Zn application perspective, the maximum net returns and benefit: cost ratios were obtained with 9 kg Zn/ha. The difference in net returns fetched by 9 and 6 kg Zn/ha was statistically non-significant. No Zn treatment resulted in the lowest net returns and benefit: cost ratio due to lower grain and straw production. This means that the higher net quantity of inorganic fertilizers required for obtaining higher yield resulted in higher returns (Jat *at al.* 2013).

Efficiency indices

Agronomic use efficiency of potassium and Zn were the highest at 60 kg K_2O and 6 kg Zn/ha, respectively, and progressively decreased at higher level of potassium (90 kg K_2O/ha) and Zn (9 kg Zn/ha). Agronomic use efficiency of K and Zn in wheat declined from 11.8 to 9.7 and 71.6 to 61.1 kg grain increase/kg nutrient, respectively, when the levels of K and Zn increased from 60 to 90 kg K_2O and 6 to 9 kg Zn/ha (Table 1). The apparent recovery declined from 16.4 to 14.7 and 0.07 to 0.06%, respectively, when the level of K was increased from 30 to 60 kg

Table 3. Effect of potassium and zinc levels on agronomic efficiency of wheat crop (mean data of 2 years)

Treatment	Protein content in grain (%)	Protein yield (kg/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	Agronomic efficiency (kg grain increased/ kg nutrient applied)	K apparent recovery (%)	Zn apparent recovery (%)
Potassium (kg/ha)							
0	11.1	510.6	40.1	1.69	–	–	–
30	11.6	574.2	44.1	1.80	11.6	14.0	0.06
60	12.0	637.2	48.1	1.90	11.8	16.4	0.07
90	12.2	668.6	49.6	1.89	9.7	14.7	0.06
Zinc (kg/ha)							
0	11.3	542.4	42.7	1.80	–	–	–
3	11.6	576.5	44.7	1.85	60.0	63.3	1.02
6	11.8	616.0	47.8	1.95	71.6	38.3	1.14
9	12.0	640.8	49.1	1.97	61.1	57.8	1.00
SEm±	0.06	9.5	0.61	0.03	–	–	–
CD (P=0.05)	0.17	26.3	1.69	0.08	–		

K_2O/ha (Singh and Singh, 2009). Similarly, the apparent recovery of Zn decreased from 1.14 to 1.0%, when the level of Zn was increased from 6 to 9 kg Zn/ha (Chauhan *et al.,* 2014). The potassium recovery of wheat tended to decrease with increasing levels of Zn.

It may be concluded that, in light textured soils deficient in K and Zn potassium and Zn fertilization are required to harvest optimum crop yield, nutrient uptake and economic output. Application of 60 kg K_2O/ha and 6 kg Zn/ha was found optimum for maintaining higher wheat yield, net returns in sandy loam soil of Agra region of Uttar Pradesh.

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