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Research Paper

Potassium and zinc fertilization of wheat (*Triticum aestivum*) in western arid zone of India

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ABSTRACT

A field experiment was conducted during *rabi* 2007-08 and 2008-09 at Jobner on loamy sand soil to assess the influence of different levels of K and Zn on wheat [*Triticum aestivum* (L.) emend Fiori & Paol]. Treatments comprised of four levels each of fertilizer K (0, 20, 40 and 60 kg K_2O/ha) and Zn (0, 3, 6 and 9 kg Zn/ha) in a randomized block design with four replications. Results revealed that the application of 40 kg K_2O/ha recorded the significantly highest dry matter accumulation (881 g/m^2), effective tillers (257/m^2), grains/spike (46.2), test weight (39.4 g), grain yield (3.20 t/ha) and biological yield (8.0 t/ha) of wheat. However, uptake of N, P, K, S and Zn in wheat was increased significantly up to 60 kg K_2O/ha. Application of 60 kg K_2O/ha also recorded the highest values of net returns (₹29,502), B:C ratio (1.55) and returns/rupee invested (₹2.51). Zn fertilization in wheat at 6 kg Zn/ha was found to be statistically best in terms of growth, yield attributes, and yield. The nutrient uptake (N, K, S and Zn) in wheat, except uptake of P was increased significantly up to 9 kg Zn/ha, which also recorded the highest net returns (₹29,425), B:C ratio (1.52) and returns/rupee invested (₹2.47). The values of efficiency indices were decreased with increasing doses of K and Zn.

Key words **:** Economics, Nutrient uptake, Potassium, Productivity, Wheat, Zinc

Wheat is the most important staple foodgrain crop in Indian diet and main source of protein and calories for a 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). The targeted production levels can only be achieved through balanced and efficient nutrient management. In India the prominent wheat growing areas are in arid and semi-arid regions having sandy and sandy loam soils which are low in organic carbon and prone to be K and Zn deficiency. A fall in wheat productivity in the absence of adequate K application has been proven by the data emanating from long-term experiment (Swarup, 2002). Potassium is the key nutrient in the plants and imparts tolerance to stresses such as temperature, drought and to the incidence of diseases.

The depletion of soil Zn leads to low productivity and low concentration in edible grains, which causes Zn deficiency in humans, particularly in semi arid tropics (Shivay *et al.*, 2008). Continuous intensive cropping of high yielding crop varieties has further aggravated the depletion of soil Zn leading to low Zn concentration in edible grains. Zn is essential for the normal healthy growth and reproduction of plants, animals and humans and when the supply of plant available Zn is inadequate, crop yields are reduced and the quality of crop products is frequently impaired. 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 lost yield. Although wheat is relatively tolerant to Zn deficiency but, the soils in which wheat is grown have very low concentrations of plant available Zn and cause wide spread Zn deficiency in grain and straw (Singh, 2009). The present investigation was carried out to study the effect of K and Zn fertilization on growth parameters, yield, quality and nutrient uptake by wheat and its economics.

MATERIALS AND METHODS

A field experiment was carried out during *rabi* seasons of 2007-08 and 2008-09 at the experimental farm (26°5' N latitude, 75°28' E longitude), S.K.N. College of Agricul-

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ture, Jobner, located at an altitude of 427 meters amsl in Jaipur district of Rajasthan, representing western arid zone of India. The experimental site is characterized by sub-tropical climate; with extreme temperature during summer (40° to 46°C) and very low temperatures during winter (as low as 3°C). The rainfall is low (400-500 mm) most of which is received from July to September. The soil was loamy sand, well drained, having pH (1: 2.5) 8.2, EC (0.17 dS/m), organic carbon (0.20%), potassium permanganate oxidizable available N (132 kg/ha), Olsen's available P (18 kg/ha), 1 M ammonium acetate exchangeable available K (186 kg/ha) and DTPA extractable Zn (0.4 ppm) at the commencement of the experiment. The experiment was conducted with four levels each of fertilizer K (0, 20, 40 and 60 kg K_2O/ha) and Zn (0, 3, 6 and 9 kg Zn/ha) in a randomized block design with four replications. Wheat 'Raj-3077' was planted on 26th/27th November and harvested on 18th/20th April during respective season. The crop received K and Zn application as per treatment through muriate of potash and Zinc sulphate, respectively with a basal dose of 60 kg N and 50 kg P_2O_5. The crop also received 40 kg N/ha at first irrigation.

Growth parameters were measured as per standard procedures at the harvest stage and the crop was harvested at maturity and grain and straw yields were recorded. Grain and straw samples were dried, grounded in a Willey mill and analysed. Nitrogen in ground grain and straw samples was determined by micro-Kjeldahl method (Piper, 1966), while P, K, S and Zn in HNO_3-$HClO_4$ extracts was determined by vanado-molybdate phosphate yellow colour method using a UV-VIS spectrophotometer, flame photometric method, turbidimetric and AAS, respectively. Nutrient uptake in grain and straw was worked out by multiplying the yield with nutrient concentration. The economics was computed using the prices of inputs and outputs as per prevailing market rates. The data generated for both growing seasons were pooled together and then analyzed statistically. Statistical analyses were performed using analysis of variance (ANOVA) for randomized block design (Gomez and Gomez, 1984). For treatment comparisons in the field experiments, the 'F-test' was used. Agronomic and economic efficiency indices were computed with the formulae given below:

Agronomic Efficiency (AE) (kg grain/kg nutrient applied) = (Yt–Yo)/Na

Economic Efficiency (EE) (kg/₹ invested) = Yt–Yo/Ni

Where Yt = Grain yield in the test treatment (kg/ha), Yo = Grain yield in the control plot (kg/ha), Na = Nutrient applied to the test treatment (kg/ha) and Ni = Amount invested on particular nutrient fertilizer (₹/ha).

RESULTS AND DISCUSSION

Growth and yield attributes

Effects of K fertilization on wheat were different for different characters (Table 1). Dry matter accumulation (DMA) and grains/spike increased significantly over control, when 40 kg K_2O/ha was applied, there being no further significant increase, when the level of K was raised to 60 kg K_2O/ha. A significant increase in effective tillers over control was recorded only when 60 kg K_2O/ha was applied. As regards test weight it increased significantly over control even when 20 kg K_2O/ha was applied, a further significant increase was recorded only when K level was increased to 60 kg K_2O/ha.

As regards Zn fertilization DMA, effective tillers/m^2, grains/spike and test weight were significantly increased over control with an application of 3 kg Zn/ha, a further significant increase was recorded when the level of Zn

Table 1. Effect of K and Zn levels on yield attributes and yield of wheat (pooled mean of two years)

Treatment	Dry matter accumulation (g/m^2)	Effective tillers (m^2)	Grains/spike	Test weight (g)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index
K levels (kg K_2O/ha)							
0	820	246	43.2	35.9	2.41	6.18	0.39
20	840	249	44.5	38.2	2.84	7.11	0.40
40	857	252	45.1	39.1	3.08	7.69	0.40
60	881	257	46.2	39.4	3.20	8.00	0.40
SEm$\pm$	11.5	3.1	0.54	0.44	0.06	0.11	0.01
CD (P=0.05)	32.8	8.8	1.5	1.2	0.18	0.33	NS
Zn levels (kg/ha)							
0	786	234	41.7	35.6	2.47	6.28	0.39
3	841	249	44.3	37.9	2.80	7.04	0.40
6	878	259	46.1	39.3	3.06	7.65	0.40
9	893	263	46.8	39.9	3.21	8.01	0.40
SEm$\pm$	11.5	3.1	0.54	0.44	0.06	0.11	0.01
CD (P=0.05)	32.8	8.8	1.50	1.20	0.18	0.33	NS

was raised to 6 kg Zn/ha. However, there was no further increase in any character when the level of Zn was raised to 9 kg Zn/ha.

Yield

A significant increase in grain yield of wheat due to K fertilization was recorded even at 20 kg K_2O/ha, however, a further significant increase was recorded with 60 kg K_2O/ha (Table 1). As regards total biological yield, it increased over control significantly with each increase of 20 kg K_2O/ha upto 40 kg K_2O/ha, there being no further significant increase with an increase in K level up to 60 kg K_2O/ha. Harvest index in wheat was not significantly influenced by K fertilization. The grain yield and biological yield of wheat were increased to the tune of 18, 28 and 33%; and 15, 24 and 29% at 20, 40 and 60 kg K_2O/ha, respectively over control. 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 biological yields. The results are in close conformity with that of Pandey *et al*. (2001) and Majumdar and Saxena (1992).

With successive increase in Zn levels, grain and biological yields increased significantly up to 6 kg Zn/ha and but a further increase in Zn levels did not significantly increase grain or biological yield. However, the highest grain (3.21 t/ha) and biological yield (8.01 t/ha) were recorded with 9 kg Zn/ha, which registered 29.9 and 29.4% higher grain and biological yield, respectively over control. This increase in grain and biological yields due to Zn application may be attributed to the fact that Zn is main yield limiting plant nutrient in arid and semi-arid regions, where the soils are deficient in Zn. Applied Zn is reported to enhance the absorption of native as well as added major nutrients such as N and P and thereby improves overall growth and development of plants and ultimately the grain and straw yield. These findings are in agreement of Varshney *et al*. (2008). However, with K and Zn application there was no significant differences in harvest index of wheat. Profuse tillering due to K application increased inter-plant competition leading to higher dry matter with the same amount of grain yield, ultimately results in low harvest index.

Nutrient uptake

The pooled data of two years (Table 2) indicates that N, P, K, S and Zn uptake in grain and straw of wheat differed significantly due to varying levels of K and Zn. With the successive increase in K levels from 0 to 60 kg K_2O/ha, the total uptake of N, K, S and Zn increased significantly, while P uptake increased significantly up to 40 kg K_2O/ha and was statistically on par with 60 kg K_2O/ha. Application of 60 kg K_2O/ha recorded highest uptake of nutrients and registered 51.8, 47.8, 45.5, 54.4 and 46.7% higher N, P, S, K and Zn uptake in grain and 46.9, 48.9, 45.2, 44.3 and 42.9% higher N, P, S, K and Zn uptake in straw of wheat, respectively over control. The results are in conformity with the findings of Abedin *et al*. (1998).

The N, K, S and Zn uptake by wheat grain and straw increased significantly with each increment in Zn levels, but P uptake was not influenced significantly by Zn application. The maximum uptake of N, K, S and Zn in wheat was recorded at 9 kg Zn/ha. Uptake of N, S, K and Zn in wheat grain was 49.3, 50, 51.4 and 53.7% higher and in straw was 44.8, 50, 41.8, and 48.2% higher under 9 kg Zn/ha over control, respectively. Significant response of wheat to Zn by the application of 9 Zn kg/ha could be directly attributed to an enhanced availability of Zn in soil at

Table 2. Effect of K and Zn levels on nutrient uptake in grain and straw of wheat crop (pooled data of two years)

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		S uptake (kg/ha)		K uptake (kg/ha)		Zn uptake (g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
K levels (kg K_2O/ha)										
0	36.1	19.4	11.7	4.9	7.9	7.3	13.4	50.8	54.0	62.4
20	45.2	23.4	14.5	6.1	9.6	8.9	16.9	60.7	66.3	74.1
40	51.1	26.5	16.3	6.8	10.8	10	19.2	68.3	74.4	83.5
60	54.8	28.5	17.2	7.3	11.5	10.6	20.7	73.3	79.4	89.2
SEm±	1.3	0.63	0.43	0.17	0.25	0.21	0.35	1.05	1.23	1.32
CD (P=0.05)	3.7	1.8	1.2	0.5	0.7	0.6	0.9	2.9	3.4	3.7
Zn levels (kg/ha)										
0	36.7	19.6	14.1	6.1	7.8	7.2	13.6	51.1	52.8	61.1
3	44.6	23.4	14.8	6.2	9.5	8.8	16.8	60.7	64.9	73.2
6	51.2	26.5	15.4	6.4	10.8	10.1	19.2	68.8	75.2	84.3
9	54.7	28.4	15.6	6.5	11.7	10.8	20.6	72.5	81.2	90.6
SEm±	1.3	0.63	0.43	0.17	0.25	0.21	0.35	1.05	1.23	1.32
CD (P=0.05)	3.7	1.8	NS	NS	0.7	0.6	0.9	2.9	3.4	3.7

Table 3. Effect of K and Zn levels on agronomic and economic efficiency and economics of wheat cultivation (pooled mean of two years)

Treatment	Cultivation cost (× 10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	B:C ratio	Returns/₹ invested	Agronomic efficiency (kg grain/kg nutrient applied)	Economic efficiency (kg grain/₹ invested)
K levels (kg K_2O/ha)							
0	18.6	36.6	18.4	0.99	1.97	-	-
20	18.8	42.5	24.2	1.29	2.26	21.5	16.1
40	18.9	46.1	27.8	1.47	2.43	16.8	10.3
60	19.1	47.9	29.5	1.55	2.51	13.2	7.1
Zn levels (kg/ha)							
0	18.3	37.2	19.2	1.05	2.04	-	-
3	18.7	42.1	23.8	1.28	2.25	110.0	6.9
6	19.1	45.8	27.4	1.44	2.40	98.3	4.3
9	19.4	48.0	29.4	1.52	2.47	82.2	3.0

a level below where the optimum requirement of crop is fulfilled. This showed that enhancement in Zn levels not only increased the yields, but also increased the nutrient concentration and ultimately their uptake. Owing to the antagonistic relationship of Zn and P reduction in the P uptake was recorded with the application of Zn. The increased concentration of Zn created hindrance in absorption and translocation of P from the root to the above parts (Damodhar Reddy and Yadav, 1994). A significant increase in uptake of Zn by wheat grain and straw with increasing levels of Zn over control was due to increase in yield and Zn content as a result of Zn application as reported by Singh *et al*. (2004).

Economics

From the economics point of view, each successive increment in K levels from 0 to 60 kg K_2O/ha and Zn levels from 0 to 9 kg Zn/ha increased the values of cultivation cost, net returns, B:C ratio and returns/ ₹invested in fertilizer (Table 3). The maximum net returns (₹29,502/ ha) and B:C ratio (2.51) was obtained with 60 kg K_2O/ha. From Zn application perspective, the maximum net returns (₹29,425/ ha) and B:C ratio (2.47) were obtained with 9 kg Zn/ha. Application of 60 kg K_2O/ha and 9 kg Zn/ha to the wheat crop gave higher return per rupee invested than other treatments. This means that the higher quantity of inorganic fertilizers required for obtaining higher yield resulted in higher investment but ultimately gave the higher returns.

Efficiency indices

Both agronomic efficiency (AE) and economic efficiency (EE) decreased as the level of K or Zn fertilization increased (Table 3). This is generally expected. For K agronomic efficiency declined from 21.5 to 13.2 when the level of K was increased from 20 to 60 kg K_2O/ha. Similarly, the EE of K fertilization decreased from 16.1 to 7.1 when the level of K fertilization was increased from 20 to 60 kg K_2O/ha. AE of Zn decreased from 110.0 to 82.2 when Zn level was raised from 3 to 9 kg Zn/ha, while the values for EE were 6.9 and 3.0 from 3 and 9 kg Zn/ha.

The findings of present study can be concluded that in coarse textured soils medium in K and deficient in Zn, K 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 to be optimum for wheat crop for getting higher growth, yield and net returns in loamy sand soil of Rajasthan.

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