Research Article

Nutrient Content and Uptake of Wheat as affected by Phosphorus, Zinc and Iron Fertilization in Loamy Sand Soils of Rajasthan

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Abstract

A field experiment was carried out during two consecutive *rabi* seasons of 2009-10 and 2010-11 at the Agronomy farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner to find out the effect of phosphorus, zinc and iron on growth attributes and yield attributes of wheat (*Triticum aestivum* L.) in Loamy sand soils of Western Rajasthan with ten treatments comprising 4 levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and zinc (0, 3 and 6 kg ha^{-1}) in main plots and 3 levels of iron (0, 3 and 6 kg ha^{-1}) in split-plot design with three replications. Application of phosphorus up to 40 kg P_2O_5 ha^{-1} significantly influenced the N, P and K content in all growth stages as well as in grain and straw and their uptake except P uptake in grain and straw which is significantly influenced with 60 kg P_2O_5 ha^{-1} in pooled analysis. However, zinc and iron content in plant decreases with application of phosphorus. Application of increasing level of zinc up to 3 kg Zn ha^{-1} and 3 kg Fe ha^{-1} significantly influenced the N and K content in all growth stages as well as in grain and straw and their uptake. Whereas, application of iron up to 6 kg Zn ha^{-1} and 6 kg Fe ha^{-1} significantly increase the Fe content in all growth stags as well as in grain and straw and there uptake. With each successive increase in the level of iron up to 6 kg Fe ha^{-1}, there was a significant decline in the P and Zn content in grain and straw in pooled mean analysis.

Keywords: Phosphorus, zinc, iron, nutrient content, uptake, wheat

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Introduction

India occupies second position next to China in the World with regard to area 30.96 million hectares and production 88.94 million tonnes with average productivity of 28.72 q ha^{-1} of wheat [1]. In India, main wheat growing states are UP, Punjab, Haryana, M.P., Rajasthan and Bihar. In Rajasthan, wheat has an area of 2.94 million hectares with the production of 9.86 million tonnes. The average productivity of wheat in the state is 33.65 q ha^{-1} [1]. This clearly indicates that in spite of considerable improvement in genetic potential of the crop, productivity is still very poor in the country as well as in the state of Rajasthan. The high productivity of wheat can only be achieved by the adoption of suitable variety and improved agronomic practices with balanced and judicious use of chemical fertilizers in an integrated way.

With the increase in the high yielding varieties, irrigated area, fertilizer use and appropriate agro-technology, it has been possible to achieve continuous increase in production and productivity of wheat but at the same time, nutrient removal by crop has also increased. Therefore, nutrient must be supplied to replace those removed from the soil to achieve higher yield from limited land resources. To meet these demands, nutrient needs must be accurately worked out. Large scale depletion of soil fertility is an index towards the occurrence of even more extensive and acute nutrient deficiencies. This calls for a serious thought on the nutrient management to sustain food grain production. Fertilizer is the single most important input in modern agriculture to raise the crop productivity. It has, therefore, become imperative to dwell upon the rationalization of efficient and balanced use of fertilizers for increasing the wheat productivity.

Deficiency of soil Phosphorus is one of the important chemical factors restricting plant growth in soils. Therefore, sufficient quantity of soluble form of phosphorus fertilizers is applied to achieve maximum plant productivity. Zinc exerts a great influence on basic plant life processes, such as: nitrogen metabolism and uptake of nitrogen and protein quality; photosynthesis and chlorophyll synthesis, carbon anhydrase activity; resistance to abiotic and biotic stresses and protection against oxidative damage. Iron is taken up as ferrous ions by plants. Iron is necessary for the synthesis and maintenance of chlorophyll in plants and it is essential component of many enzymes viz., nitrogenase, catalase, peroxydase, aconitase and cofactor like ferrodoxin, cytochromes etc. The present investigation was carried out to evaluate and describe the fertilizer phosphorus, zinc and iron application on yield, nutrient content and uptake by wheat in Loamy sand soils of Western Rajasthan.

Materials and Methods

The experiment was conducted at the Agronomy farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *rabi* seasons of 2009-10 and 2010-11. The experimental site is located at 28.01^0N latitude and 73.22^0E longitude at an altitude of 234.7m above mean sea level and falls under Agro-ecological region No. 2 (M9E1) under Arid ecosystem (Hot Arid Eco-region), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity and hot and arid climate. Annual PET in this region ranges between 1500-2000 mm. The soils of experimental field was loamy sand in texture having pH -8.2, EC -0.22 dS m^{-1}, available N – 90.1 kg ha^{-1}, available P_2O_5 – 14.2 kg ha^{-1}, available K_2O – 160.4 kg ha^{-1}, avalable Zinc- 0.34 mg kg^{-1}, avalable iron- 2.90 mg kg^{-1} and organic carbon-0.15%.

The field experiment on wheat in *rabi* seasons of 2009-10 and 2010-11 was laid out comprising 4 levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and zinc (0, 3 and 6 kg ha^{-1}) in main plots and 3 levels of iron (0, 3 and 6 kg ha^{-1}) in sub plots. A total of 36 treatment combinations were tested in split plot design with three replications. The treatment details are follows:

Main plot treatments
- Phosphorus levels
  - P_0 = Control, P_1 = 20 Kg ha^{-1}, P_2 = 40 Kg ha-1 and P3 = 60 Kg ha^{-1}
- Zinc levels
  - Zn_0 = Control, Zn_1 = 3 Kg ha^{-1} and Zn_2 = 6 Kg ha^{-1}

Sub plot treatments
- Iron levels
  - Fe_0 = Control, Fe_1 = 3 Kg ha^{-1} and Fe_2 = 6 Kg ha^{-1}

Nitrogen was applied @ 120 kg N ha^{-1} was applied RDF. Half dose was applied as basal through urea after adjusting the quantity of N supplied by DAP. Remaining half dose of N was applied through broadcasting of urea in two equal split doses just after irrigation at 25 and 75 DAS. Potassium was applied @20 kg K_2O ha^{-1} was applied through muriate of potash before sowing. Phosphorus: Phosphorus was applied through DAP, zinc was applied through zinc sulphate and iron was applied through ferrous sulphate before sowing as per treatment. Seeds were treated with thiram (2 g kg^{-1} seed) as prophylactic measures against seed borne diseases. The wheat variety 'Raj-3077' was sown by "*kera"* method at a depth of 5 cm in rows spaced at 22.5 cm apart on 25th and 28th November in the years 2009-10 and 2010-11, respectively using seed rate of 120 kg ha^{-1}.

The grain yield of each net plot was recorded in kg $plot^{-1}$after cleaning the threshed produce and was converted as kg ha^{-1}. Straw yield was obtained by subtracting the grain yield (kg ha^{-1}) from biological yield (kg ha^{-1}).

The wheat plant samples were collected at 30, 60, 90 DAS and at harvest (grain and straw) stages from each plot and oven dried. The dried samples were finely ground and used for determination of N, P, K, Zn and Fe content as per standard methods. The uptake of nitrogen, phosphorus, potassium, zinc and iron after harvest in seed and straw was estimated by using the following relationship:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content in seed/straw (\%) x Seed/straw yield (kg ha}^{-1})}{100}$$

The uptake of zinc and iron by grain and straw was computed from zinc/iron content in grain and straw using the following relationship.

$$\text{Zinc/ iron uptake by grain/straw (g ha}^{-1}) = \frac{\text{Nutrient content in seed/straw (ppm) x Seed/straw yield (kg ha}^{-1})}{1000}$$

Results and Discussions

Application of phosphorus at 40 kg P_2O_5 ha^{-1} significantly increased the grain and straw yield (**Table 1**). The significant increase in grain yield of wheat due to application of phosphorus up to 40 kg P_20_5 ha^{-1} was largely a function of improved growth and the consequent increase in different yield attributes as mentioned above. The grain yield of wheat increased by 762 kg ha^{-1} due to application of 40 kg P_2O_5 ha^{-1} over control [2]. The significant increase in straw yield due to application of phosphorus could be attributed to the increased vegetative growth as evident from dry matter production and CGR (Table 1) possibly as a result of the effective uptake and utilization of nutrients absorbed through its extensive root system developed under phosphorus fertilization [3, 4].

Increasing level of phosphorus up to 40 kg P_2O_5 ha^{-1} significantly increased the nitrogen, phosphorus and potassium content in grain and straw of wheat and their uptake. The increase in N, P and K content might be due to effective and well developed root system and increased availability of nutrients in the root zone and the plant system. The soil of the experimental field was nearly medium in phosphorus and fertilization with phosphorus improved its status (**Table 2**).

Table 1 Effect of phosphorus, zinc and iron on nutrient uptake by wheat (pooled basis)

Treatments	Yield (kg ha^{-1})		Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})		Zinc uptake (g ha^{-1})		Iron uptake (g ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Phosphorus levels (P_2O_5 Kg ha^{-1})												
Control	2901	4192	42.81	23.49	12.86	7.31	15.70	44.80	90.19	91.47	306.90	767.87
20	3416	4975	54.63	33.31	16.12	8.92	19.95	59.27	94.10	95.81	343.68	842.94
40	3663	5476	59.48	37.58	18.73	10.63	22.33	67.52	96.57	100.85	350.01	853.76
60	3735	5593	61.14	38.84	19.49	11.16	23.08	70.17	97.09	102.27	351.69	858.02
SEm±	36	49	0.79	0.46	0.19	0.19	0.33	0.95	0.35	0.56	1.61	4.05
CD (P=0.05)	101	138	2.24	1.32	0.53	0.56	0.93	2.74	0.98	1.60	4.66	11.55
Zinc levels (Zn Kg ha^{-1})												
Control	3127	4733	48.72	28.73	16.18	9.23	17.29	54.49	80.09	86.03	328.74	814.45
3	3539	5170	56.36	35.04	17.03	9.61	21.39	62.39	98.47	99.23	340.50	835.90
6	3620	5275	58.46	36.14	17.20	9.67	22.12	64.43	106.16	107.54	344.97	841.59
SEm±	31	42	0.76	0.40	0.14	0.07	0.28	0.74	0.85	1.09	2.06	3.51
CD (P=0.05)	88	120	2.15	1.14	0.41	0.19	0.80	2.11	2.45	3.12	5.95	10.01
Iron levels (Fe Kg ha^{-1})												
Control	3109	4658	48.56	29.15	15.89	8.95	17.26	53.09	90.77	96.22	290.06	719.01
3	3538	5202	56.26	34.93	17.12	9.73	21.43	63.50	95.91	98.60	347.11	840.57
6	3640	5317	58.73	35.84	17.39	9.83	22.10	64.72	96.94	99.39	377.04	932.36
SEm±	38	43	0.89	0.50	0.28	0.18	0.31	0.73	0.65	0.44	2.51	5.15
CD (P=0.05)	107	119	2.51	1.39	0.78	0.50	0.88	2.04	1.89	1.31	7.23	14.84

Table 2 Effect of phosphorus, zinc and iron on nutrient content in wheat at different stages (pooled basis)

Treat ments	Nitrogen content (%)					Phosphorus content (%)					Potassium content (%)				
	30 DAS	60 DAS	90 DAS	Grain	Straw	30 DAS	60 DAS	90 DAS	Grain	Straw	30 DAS	60 DAS	90 DAS	Grain	Straw
Phosphorus levels (P_2O_5 Kg ha^{-1})															
Control	1.567	1.368	1.152	1.413	0.541	0.352	0.301	0.262	0.436	0.169	1.687	1.505	1.207	0.536	1.036
20	1.658	1.438	1.217	1.546	0.661	0.402	0.334	0.284	0.476	0.180	1.811	1.611	1.289	0.579	1.179
40	1.717	1.479	1.255	1.622	0.683	0.430	0.350	0.301	0.510	0.193	1.875	1.667	1.339	0.608	1.232
60	1.737	1.495	1.266	1.644	0.690	0.440	0.357	0.307	0.520	0.199	1.910	1.691	1.356	0.617	1.245
SEm±	0.009	0.008	0.008	0.014	0.003	0.004	0.003	0.002	0.004	0.002	0.014	0.010	0.008	0.004	0.013
CD (5%)	0.024	0.022	0.024	0.039	0.010	0.011	0.007	0.007	0.012	0.005	0.039	0.028	0.023	0.010	0.037
Zinc levels (Zn Kg ha^{-1})															
Control	1.598	1.384	1.166	1.502	0.589	0.413	0.342	0.297	0.508	0.192	1.718	1.531	1.227	0.543	1.119
3	1.696	1.468	1.239	1.574	0.668	0.408	0.337	0.288	0.485	0.184	1.861	1.654	1.332	0.602	1.189
6	1.715	1.484	1.255	1.593	0.674	0.396	0.328	0.280	0.471	0.179	1.889	1.677	1.349	0.610	1.211
SEm±	0.007	0.007	0.007	0.012	0.003	0.003	0.003	0.001	0.003	0.001	0.012	0.009	0.007	0.003	0.011
CD (5%)	0.021	0.019	0.021	0.034	0.008	0.009	0.009	0.004	0.008	0.003	0.034	0.025	0.020	0.009	0.032
Iron levels (Fe Kg ha^{-1})															
Control	1.604	1.392	1.171	1.506	0.610	0.411	0.338	0.297	0.505	0.191	1.728	1.538	1.231	0.549	1.116
3	1.695	1.466	1.240	1.571	0.658	0.406	0.336	0.286	0.486	0.183	1.861	1.654	1.332	0.601	1.194
6	1.711	1.479	1.249	1.593	0.662	0.400	0.333	0.277	0.475	0.175	1.879	1.671	1.345	0.605	1.209
SEm±	0.007	0.007	0.006	0.014	0.004	0.003	0.002	0.001	0.002	0.001	0.011	0.008	0.006	0.002	0.012
CD (5%)	0.019	0.020	0.018	0.039	0.011	NS	NS	0.004	0.005	0.004	0.030	0.022	0.016	0.007	0.035

Zinc and iron content in grain and straw decreased with the increase in level of phosphorus from 0 to 60 kg P_2O_5 ha^{-1} (**Table 3**). Decrease in Zn and Fe content at higher P level may be due to either (i) decrease in the available Zn and Fe content as a result of reaction of zinc and iron with phosphorus in the soil (ii) dilution of Zn and Fe in the plant tissues by growth responses to phosphorus (iii) slower rate of translocation of Zn from the root to shoot (iv) metabolic disorder within plant cells related to an imbalance. Increased uptake of N, P, K, Zn and Fe is the cumulative effect of increased nutrient content and increased grain and straw yields [4, 5] and decrease in Zn and Fe content and uptake due to application of phosphorus to the crop [6].

Table 3 Effect of phosphorus, zinc and iron on nutrient content in wheat at different stages (pooled basis)

Treatments	**Zinc content (ppm)**					**Iron content (ppm)**				
	30 DAS	**60 DAS**	**90 DAS**	**Grain**	**Straw**	**30 DAS**	**60 DAS**	**90 DAS**	**Grain**	**Straw**
Phosphorus levels (P_2O_5 Kg ha^{-1})										
Control	30.86	25.29	24.35	31.36	22.02	338.76	306.76	273.81	104.03	186.89
20	30.06	24.90	23.12	28.73	19.96	337.47	304.36	272.71	100.84	174.79
40	29.70	24.56	21.93	25.96	18.91	336.53	303.58	271.57	96.85	156.04
60	28.95	23.75	21.72	24.01	17.90	335.48	302.27	270.89	93.75	141.46
SEm±	0.24	0.23	0.27	0.35	0.20	2.83	2.27	1.93	0.54	1.48
CD (P=0.05)	0.67	0.66	0.78	0.99	0.56	NS	NS	NS	1.54	4.21
Zinc levels (Zn Kg ha^{-1})										
Control	27.25	21.97	19.94	26.07	18.44	338.28	306.03	272.89	105.41	170.33
3	30.07	24.92	23.88	28.26	19.42	337.15	304.10	272.26	98.72	158.84
6	32.34	26.99	24.53	29.67	20.78	335.75	302.60	271.57	95.60	151.70
SEm±	0.20	0.20	0.24	0.30	0.17	2.45	1.97	1.67	0.47	1.28
CD (P=0.05)	0.58	0.57	0.68	0.86	0.49	NS	NS	NS	1.33	3.64
Iron levels (Fe Kg ha^{-1})										
Control	30.26	24.98	22.87	29.06	20.73	299.88	274.56	247.20	94.76	146.68
3	29.85	24.62	22.82	27.48	18.96	341.18	305.54	271.77	98.78	156.05
6	29.56	24.28	22.66	25.46	17.94	360.12	322.62	287.76	104.19	176.66
SEm±	0.22	0.19	0.23	0.30	0.15	2.12	1.70	1.45	0.58	1.17
CD (P=0.05)	NS	NS	NS	0.83	0.43	5.96	4.76	4.06	1.62	3.28

Application of zinc at 3 kg ha^{-1} significantly increased the content and uptake of N, K and Zn in all growth stages as well as in grain and straw by the wheat plant over control while zinc uptake in grain and straw was significantly increased up to 6 kg Zn ha^{-1} during both the years and also in pooled analysis (Tables 1-3). The Zn content and uptake in grain and straw increased significantly up to 6 kg Zn ha^{-1}. The P content at all growth stages and in grain and straw decreased significantly up to 6 kg Zn ha^{-1}. The application of zinc in the soil deficient in Zn content, increased the availability of zinc in the root zone which in turn resulted in improved zinc content in plant. The beneficial role of zinc in increasing the cation exchange capacity of roots helped in increased absorption of nutrients from the soil. This might be due to favourable influence of zinc on photosynthesis and metabolic processes augmented the production of photosynthates and their translocation to different plant parts including grain which ultimately increased the concentration of nutrients in all growth stages as well as in grain and straw. The increased uptake of N, K and Zn seem partly due to increased content in grain and straw and increased grain and straw yield [7, 8].

The reduction in the content of phosphorus and iron due to application of zinc may be due to the antagonistic reaction between zinc with phosphorus and iron. The increased concentration of zinc created hinderance in absorption and translocation of phosphorus from the roots to the above ground parts [9]. Results of the present investigation showed that with increasing levels of iron upto 3 kg Fe ha^{-1} increased the percent N and K (Table 1 and 2) content and uptake in all growth stages as well as in grain and straw and protein content in grain during both the years and in pooled analysis. This might be due to increased supply of Fe and good response by the plants to them leading to enhanced translocation of nutrients to reproductive structures *viz.*, spikes, and grains. The significant response of wheat to iron is due to low status of iron availability in experimental soil due to alkalinity of soil. The application of iron had favourable effect on the absorption of various nutrients which is supported by lower concentration of P and higher concentration of Fe in grain and straw. Iron might have helped in greater nitrogen uptake by plant and translocation in various plant parts including grain. Since nitrogen is essential constitute of protein, increased nitrogen content led to higher protein content [5, 10].

Application of iron decreased the phosphorus and zinc content in all growth stages as well as in grain and straw of wheat (Table 1 and 2). This might be due to its antagonistic effect with phosphorus and zinc. The proportion of phosphate taken up by roots that translocated to the leaves reduced, if the available ferric ion concentration in medium was too high. This might also be due to formation of ferrous phosphate which is less available form of iron in soil to plant which reduce uptake of iron to wheat. Application of iron significantly increased the iron content in grain and straw and its uptake. This might be due to the fact that the iron content of soil increased owing to its application in the soil as it was deficient in its content (Table 3). The plant absorbed greater iron through well developed root system which ultimately increased the content and uptake of iron in grain and straw [11]

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