Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(2): 950-955
Received: 04-01-2019
Accepted: 07-02-2019

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Productivity, quality, energetics and marginal rate of return of wheat (*Triticum* spp.) varieties as influenced by zinc and boron application in vertisols of Central India

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Abstract
The field experiment was conducted for three consecutive years during *rabi* seasons from 2009-12 at Indore (Madhya Pradesh) to find out the effect of zinc and boron levels on the productivity, quality and economic viability of wheat. Two wheat varieties viz., HI 1544 (*Triticum aestivum* L.) and HI 8498 (*Triticum turgidum ssp. Durum*) were tested under three levels each of zinc (0, 5.0 and 10 kg ha^{-1}) and boron (0, 1.0 and 2.0 kg ha^{-1}). Pooled over data of 3 years revealed that the yield performance of bread wheat variety HI 1544 (grain yield 5.69 t ha^{-1}) was significantly higher over durum wheat variety HI 8498. In case of Zn and B application, grain yields recorded with 5.0 kg Zn ha^{-1} (5.63 t ha^{-1}) and 1.0 kg B ha^{-1} (5.63 t ha^{-1}) were significantly higher to the tune of 6.63 and 5.23 percent, respectively over control and thereafter differences were non-significant. While crude protein (12.9%) and yellow pigment (4.45 ppm) contents observed with durum wheat variety HI 8498 were significantly higher over bread wheat variety HI 1544. However, SDS (sedimentation) value (37.9 ml) recorded with bread wheat variety HI 1544 was significantly higher over durum wheat variety HI 8498. None of the nutrients viz., Zn and B had significant effect on any of quality traits. Zinc (24.14 and 13.57 mg kg^{-1}) and boron (7.40 and 11.83 mg kg^{-1}) contents recorded in grain and straw of wheat variety HI 8498 were significantly higher over HI 1544. But, total uptakes of Zn and B were more in HI 1544 than HI 8498 due to higher wheat tonnage. Due to synergistic effect of zinc and boron to each other, their contents and uptakes were gradually increased with each increase in nutrients level. Energy relationships values were followed the trend of wheat yields. Whereas, analysis of marginal rate of return showed that application of Zn @ 5.0 kg/ha and B @ 1.0 kg ha^{-1} were found safe doses for farmers' recommendations. On the basis of 3 years study, it may be inferred that bread wheat variety HI 1544 under application of Zn @ 5.0 kg ha^{-1}and B @ 1.0 kg ha^{-1} holds promise to provide higher wheat productivity in vertisols of Central India.

Keywords: Boron, energy relationships, grain yield, marginal rate of return, varieties, wheat, zinc

Introduction

Wheat (*Triticum spp.*) is the most important cereal crop of the world and in India it ranks second after rice. Due to increased cropping intensity, higher application of NPK through inorganic sources, use of more nutrients responsive and high yielding varieties etc. the problem of micronutrients deficiency has arisen in wheat crop in almost all parts of the country. As per practical experience presently deficiency of zinc and boron in standing wheat crop is very common in soils of Central India. Zinc was one of the first micronutrients, essentiality of which for plant growth has been confirmed. Although crops require small amount of Zn for their normal growth but its application rate is high due to very low fertilizer use efficiency. Zinc is essential for the normal healthy growth and reproduction of plants and plays a key role as a structural constituent or regulatory co-factor of a wide range of enzymes in many important biochemical pathways (Kabata-Pendias & Pendias, 2001) [12]. As a fact zinc also plays a vital role in nucleic acid and protein synthesis, and helps in the utilization of phosphorus and nitrogen as well as in seed formation. Zinc deficiency in wheat resulted in severe reduction in growth, grain yield and seedlings vigour, and enhances sensitivity of plants to pathogens. Decrease in grain quality is another typical consequence of zinc deficiency in wheat (Graham and Wilch, 1996) [6]. Sekimoto *et al.*, (1997) [21] also elucidated that zinc deficiency in *Zea mays* L., markedly reduced the level of GA_1 and the level of IAA was also decreased although not as markedly. According to an estimate, wheat crop removes 66-209 g zinc for producing 2 t ha^{-1} grains (NFDC, 1998) [17]. While in case of boron, it is also an essential micronutrient for crop like wheat. It plays a vital role in the physiological process of wheat plant such as cell elongation, cell maturation, sugar translocation, development of meristematic tissues, protein synthesis and ribosome formation (Gupta, 1971) [7].

Rerkasem *et al*. (1993) [20] found that in B deficient wheat, the pollen did not accumulate starch and the nuclei, when its presence was abnormal. Boron deficiency also causes grain sterility in wheat as reported by Li *et al.* (1978) [15] in China and Mandal and Das (1988) [16] in India. The range between deficiency and toxicity of B is quite narrow and an application of B can be extremely toxic to plant at concentrations only slightly above the optimum rate (Gupta *et al*., 1985) [8]. As general guidelines for B fertilizer recommendations, hot water soluble B in soil is less than 0.5 mg kg^{-1}, deficiency is likely to occur and all crops are to be treated with B; when it is <0.5 mg kg^{-1}, deficiency may appear and insurance dressings are to be considered; when it is more than 1.0 mg kg^{-1}, B deficiency is unlikely and B treatment is not necessary; and when it is 3-5 mg kg^{-1} B, crops may be poisoned from excess B. Thus, a careful and judicious application of zinc and boron is necessary for achieving higher and sustainable crop yield. Considering the aforementioned facts, it was felt necessary to determine the proper doses of Zn and B for higher productivity of different wheat species (Bread and Durum wheat) in Central India and this trial was undertaken.

Methods and Materials

The field experiment was undertaken for three consecutive years from 2009-10 to 2011-12 at ICAR- IARI, Regional Station, Indore, Madhya Pradesh (22^{0}37’ N, 75^{0}50’ E with an altitude of 557 m above MSL). The soil of the experimental site was light black (vertisols), medium in organic carbon (0.52%), available N (242.0 kg ha^{-1}) and available P (12.7 kg ha^{-1}), and high in available K (460.0 kg ha^{-1}) alongwith pH 7.6 and EC 0.23 dSm^{-1}. The content of DTPA Zn in soil was 0.54 mg kg^{-1}and hot water soluble B was low (0.38 mg kg^{-1}). Treatments consisted of two wheat varieties viz., HI 1544 (*Triticum aestivum* L.) and HI 8498 (*Triticum turgidum ssp. Durum* (Desf.) Husn.), three levels each of Zn viz., 0, 5.0 and 10.0 kg ha^{-1}, and B 0, 1.0 and 2.0 kg ha^{-1} were laid out in factorial randomized block design with three replications. Recommended doses of NPK (120:60:40 kg ha^{-1}) were applied as 1/3rd N + full doses of P, K, Zn and B at sowing as basal dose and remaining 2/3rd of N was applied in two equal dose of N at first and second irrigation. Rests of the package of practices were followed as recommended to grow a healthy crop. The soil samples were analysed for available N, P and K contents and determined by modified Kjeldahl procedure by using Kjeltec Auto Analyser, Calorimetric by Vanado-molybdate yellow colour method and Flame photometer method (Jackson, 1973) [10], respectively. Grain and straw samples were also analysed for quality traits viz., protein, yellow pigment and sedimentation values as well as Zn and B contents with their standard methods of analysis. Growth data i.e. plant height and number of tillers m^{-2} were observed from two places of each plot and averaged. Randomly five tillers were uprooted from each plot and used for recording data on yield attributes. All the data were statistically analyzed using analysis of variance (ANOVA) as applicable to randomized block design (Gomez and Gomez, 1984) [5]. The significance of the treatment effects was determined using F-test, and the difference between the means was estimated by using critical difference at 5% probability level. Energy inputs and outputs were calculated using the energy equivalents as suggested by Panesar and Bhatnagar (1987) [18]. Marginal rate of return was analysed as suggested in manual of CIMMYT, 1988 [3].

Result and Discussion

Growth and yield attributes, and yield

Pooled over analysis of 3 years data indicated that the bread wheat variety HI 1544 recorded significantly taller tiller height (100.4 cm.) and higher fertile tillers m^{-2} (346.2), length of spike (9.24 cm.) and grains spike^{-1} compared with durum wheat variety HI 8498 (Table 1). However, spikelet spike^{-1} of both varieties were almost similar, but 1000 grain weight (56.8 g) observed with durum variety HI 8498 was significantly higher over HI 1544 (43.5 g). This might be due to varietal characters of different wheat varieties/species. In case of zinc and boron application, all growth and yield attributes values did not show any significant difference among them. On the perusal of data, it was noted that although maximum plant height and no. of tillers m^{-2} were observed with highest level of zinc i.e. 10 kg Zn ha^{-1} but spikelets spike^{-1}, grains spike^{-1} and 1000 grain weights recorded with 5.0 and 10 kg Zn ha^{-1} were almost similar but substantially higher over control. Similar trend was followed by boron application and growth and yield attributes recorded with 1.0 and 2.0 kg B ha^{-1} were almost similar but notably higher over control.

Grain and biological yields performance of bread wheat variety HI 1544 was significantly better than durum wheat variety HI 8498. The magnitude of increase in grain and biological yields of variety HI 1544 was to the tune of 5.56% and 6.25%, respectively over HI 8498. This improvement in wheat yield of variety HI 1544 was the function of higher fertile tillers per unit area, spike length and no. of grains spike^{-1} compared with HI 8498. However, difference in grain yield between two varieties might be narrow down due to greater differences in 1000 grain weights of both the varieties. Favourable effect of Zn and B on yield attributes further got reflected on grain and biological yields and significantly increased the grain and biological yields upto the level of 5.0 and 1.0 kg ha^{-1} of zinc and boron, respectively. Data revealed that Zn application @ 5.0 and 10.0 kg ha^{-1} increased the grain yields by 6.63 & 8.14% and biological yields by 3.94 and 6.30%, respectively over control. Whereas, grain and biological yields recorded with 1.0 and 2.0 kg B ha^{-1} were also increased to the extent of grain yield by 4.8 & 6.7% and biological yields by 3.91 & 3.91%, respectively over control. Increased yields due to Zn and B application were the function of improved growth and yield attributes as compared to their respective control. Increased grain and biological yields under Zn application may be attributed to its role in various enzymic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to reproductive parts thereby leading to higher yield of the crop (Chaudhary *et al*. 2014) [2]. Jat *et al.* 2013 [11] also reported similar results. The increase in grain yield of wheat due to boron application might be due to putting favourable impact on nutrients absorption from soil and its positive role in reproductive physiology essential for grain formation. Regarding harvest index, durum wheat variety HI 8498 recorded greater value of HI (42.1) than HI 1544. This was result of proportionately lower biological yield under HI 8498 due to lower plant height and lesser no. of tillers per unit area than HI 1544.

Nutrients content (mg kg^{-1}) and their uptakes (g ha^{-1})

Data presented in Table 2 showed that durum variety HI 8498 had significantly higher concentration of both the nutrients (Zn and B) than HI 1544 except Zn concentration in straw, where difference was statistically not-significant. Zn and B concentration in durum wheat variety HI 8498 was higher by 4.14 and 1.27 percent of Zn and 6.32 and 2.51 percent of B, respectively in grain and straw of wheat as compared to bread wheat variety HI 1544. This difference was mainly because of varietal potential of nutrients absorption and their retention in grain and straw. Application of Zn had significant effect on concentration of zinc in grain and straw upto the highest level i.e. 10 kg ha^{-1}, but B concentration was significantly increased only upto the level of 5.0 kg Zn ha^{-1} and thereafter increase was not-significant. Application of zinc @ 5.0 and 10.0 kg ha^{-1} brought about increase in Zn concentration by 22.9 and 37.6 percent in grain and 12.6 and 25.8 percent in straw, and boron concentration to the extent of 4.60 and 5.18 percent increase in grain and 2.17 and 2.34 percent in straw respectively over their respective control. Increased Zn concentration due to Zn application was also reported by other workers like Patel *et al.* (2008) [19], Aref (2010) [1] and Shivay & Prasad (2009). In case of boron application, Zn concentration was increased significantly only upto the level of 1.0 kg B ha^{-1} and thereafter difference was non-significant. There was significant increase due to boron application in B concentration in grain and straw upto highest level of 2.0 kg B ha^{-1}. Boron application @ 1.0 and 2.0 kg ha^{-1} increased the B concentration by 16.3 and 20.8 percent in grain, and 16.8 and 24.4 percent in straw, respectively over no boron application. Similar results were also observed by Aref (2010) [1] and Debnath *et al.* (2011) [4]. Boron increased the zinc concentration by 4.49 and 5.19 percent in grain and by 12.5 and 14.7 percent in straw under 1.0 and 2.0 kg B ha^{-1}, respectively compared with control. The results are substantiated by the findings of the studies conducted by Kaur (2012) [14] and Hossain *et al.* (2011) [9]. Such an increase in zinc and boron concentrations due to application of Zn and B could be attributed to the synergistic effect of each other on absorption and their retention in plant body.

Despite of higher concentration of zinc and boron in durum wheat variety HI 8498, their uptakes were higher in bread wheat variety HI 1544 due to higher grain and straw yields. However, difference was non-significant for both the nutrients. Total Zn (238.2 g ha^{-1}) and B (130.3 g ha^{-1}) uptakes recorded with HI 1544 were higher by 3.07 and 2.04 percent, respectively over values obtained with HI 8498. Whereas, with increasing level of zinc, its uptake was increased consistently and ranged from 103.4 g ha^{-1} in control to 154.8 g ha^{-1} with 10.0 kg Zn ha^{-1} in grain and from 89.2 g ha^{-1} in control to 117.7 g under 10.0 kg Zn ha^{-1} in straw. Likewise, maximum boron uptakes recorded were 41.7 g ha^{-1} in grain, 92.2 g ha^{-1} in straw and 133.9 g ha^{-1} as total under the application of Zn @10.0 kg ha^{-1}. These values were statistically at par with 5.0 kg Zn ha^{-1} but significantly higher over control and the magnitude of increase under the application of Zn @ 5.0 and 10.0 kg ha^{-1} was to the tune of 11.4 and 13.3 percent in grain, 4.91 and 7.84 percent in straw and 6.87 and 9.48 percent as total, respectively over control. In case of boron application, Zn and B uptakes were gradually increased with each increase in B level. Maximum boron uptakes recorded at highest level of B i.e. @ 2.0 kg ha^{-1} were 43.6, 98.3 and 141.9 g ha^{-1} in grain, straw and total, respectively. These values were significantly higher over lower levels (1.0 kg B ha^{-1} and control) except straw, where difference was non-significant. These values were higher by 4.30 and 27.8 percent in grain, 6.15 and 28.5 percent in straw and 5.58 and 28.3 percent in total uptakes, respectively over 1.0 kg B ha^{-1} and control. The above findings are in accordance with Keram *et al*. (2012) [13]. Zinc uptakes recorded at 1.0 and 2.0 kg B ha^{-1} in grain (135.0 and 136.4 g ha^{-1}), straw (107.7 and 109.3 g ha^{-1}) and total (242.7 and 245.6 g ha^{-1}) were at par but significantly higher over control. These values were higher by 9.67 and 10.8 percent in grain, 16.3 and 18.0 percent in straw and 12.5 and 13.9 percent in total uptakes, respectively over control. An increase in Zn uptake with B application was also reported by Hossain *et al*. (2011) [9]. Similar results have also been recorded by Sinha and Sakal (1983) [23].

Wheat grain quality

Analysis of wheat grain samples for different quality parameters like crude protein, yellow pigment (which is beneficial for eyes) and SDS (sedimentation) values showed that there was significant variation between varieties (Table 3). Crude protein (12.9%) and yellow pigment (4.45 ppm) contents recorded with durum variety HI 8498 were significantly higher to the tune of 7.5 and 119.2 percent, respectively as compared to bread wheat variety HI 1544. Whereas, SDS (sedimentation) value (37.9 ml) observed with bread wheat variety HI 1544 was significantly higher to the tune of 22.2 percent over durum wheat variety HI 8498. Results also revealed that Zn and B application did not affect significantly to any of quality traits but as per trend observed, Zn application increased CP content (12.6%) upto 5.0 kg ha^{-1} and yellow pigment content 3.22 ppm upto @10.0 kg zinc ha^{-1}, but SDS value was decreased with each increase in Zn levels with minimum under highest level of Zn i.e. 10 kg ha^{-1}. However, all quality traits showed decreasing trend due to increase in B levels and highest values (CP 12.5%, yellow pigment 3.31 ppm and SDS value 35.3 ml) were observed under their respective control.

Energetics

Computation of energetic values revealed that energy output, energy ratio and energy productivity values recorded with variety HI 1544 were higher by 6.17, 6.16 and 5.56 percent over durum variety HI 8498 (Table 3). It was mainly due higher crop yields with usage of similar energy inputs. In case of zinc levels, energy output, energy ratio and energy productivity recorded under the application of Zn @ 5.0 and 10 kg ha^{-1} were almost similar but substantially higher over control. However, despite of higher energy output with 10 kg Zn/ha due to higher wheat productivity, energy productivity was highest under Zn applied @ 5.0 kg/ha. This was mainly because of proportionately lower increase in wheat yield than the use of energy input used in the form of Zn nutrition. Similarly, among boron levels, energy output values observed with 1.0 and 2.0 kg B ha^{-1} were almost similar but energy ratio (7.93) and energy productivity (249.8 g MJ^{-1}) values were observed maximum under the application of 1.0 kg B ha^{-1}, and these values were higher by 0.88 & 3.12 percent and 0.52 & 4.30 percent, respectively over 2.0 kg B ha^{-1} and control. It was mainly due to small increase in wheat yields under 2.0 kg B ha^{-1} compared with 1.0 kg B ha^{-1} resulted almost similar energy output values, but increase in energy input values at B level of 2.0 kg ha^{-1} substantially decreased the values of energy ratio and energy productivity.

Marginal rate of return

The marginal rate of return (MRR) analysis revealed that what farmers can expect to gain as return for their investment when they decide to change from one practice to another. On the basis of pooled data of three years (Table 4), adoption of Zn nutrition implies a 195.0% rate of return in bread wheat variety HI 1544 at application of Zn @ 5.0 kg ha^{-1} and thereafter returns was decreased to the tune of 121.2%, which was also under acceptable limit to recommend. Whereas, MRR value due to B application in same variety was maximum (1240.6%) at 1.0 kg ha^{-1} and thereafter return was drastically decreased to 146.1% at 2.0 kg B ha^{-1}. Whereas, in case of durum wheat variety HI 8498, both nutrients application implies a higher rate of return viz., 358.8% and 1106.7% with Zn @ 5.0 kg/ha and B @ 1.0 kg ha^{-1} application, respectively over their respective control and thereafter higher doses of nutrients recorded negative values. This indicates that higher doses of Zn and B in durum wheat varieties are not safe for farmers' recommendation. However, overall values of MRR showed that application of zinc @ 5.0 kg ha^{-1} and B upto the level of 1.0 kg ha^{-1} were economically viable and recorded higher values of MRR to the extent of 282.3 and 1151.2 percent, respectively over their controls and thereafter increase in levels of zinc and boron recorded either values in negative (Zn -1.67% @ 10.0 kg/ha) or less than acceptable limit (B - 63.9% at 2.0 kg/ha) and are not safe for farmers' recommendation.

Table 1: Effect of Zn and B on the growth and yield attributes, and yield of wheat varieties (pooled data of 3 years)

Treatment	Tiller height (cm.)	Fertile tillers/m^2	Length (cm) of spike	Spikelet/ spike	Grains/ spike	1000 grain weight (g)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index
(A) Wheat varieties									
HI 1544	100.4	346.2	9.24	15.9	46.9	43.5	5.69	13.6	41.8
HI 8498	89.8	304.2	6.46	15.8	42.6	56.8	5.39	12.8	42.1
S Em±	0.76	7.95	0.07	0.19	0.53	0.31	0.05	0.05	-
CD (P=0.05)	2.20	22.89	0.20	NS	1.52	0.88	0.16	0.16	-
(B) Zinc levels (Kg/ha)									
0	94.8	316.8	7.81	15.7	43.4	49.4	5.28	12.7	41.6
5.0	94.0	322.4	7.84	15.9	45.2	50.6	5.63	13.2	42.6
10.0	96.5	336.4	7.88	16.0	45.6	50.4	5.71	13.5	42.3
S Em±	0.93	0.65	0.09	0.24	0.65	0.37	0.07	0.19	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.19	0.57	-
(C) Boron levels (Kg/ha)									
0	93.3	312.2	7.70	15.5	43.5	49.6	5.35	12.8	41.8
1.0	96.1	331.9	7.89	15.9	45.3	50.1	5.63	13.3	42.3
2.0	95.8	331.4	7.95	16.2	45.4	50.6	5.65	13.3	42.5
S Em±	0.93	0.65	0.09	0.24	0.65	0.37	0.07	0..19	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.19	0.57	-

Table 2: Zn and B content (mg/kg), uptakes and nutrients use efficiency of wheat varieties as influenced by treatment variables

Treatment	Nutrient contents (mg/kg)				Nutrient Uptakes (g/ha)					
	Zn		B		Zn			B		
	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total
(A) Wheat varieties										
HI 1544	23.18	13.40	6.96	11.54	132.5	105.7	238.2	39.7	90.6	130.3
HI 8498	24.14	13.57	7.40	11.83	130.5	100.6	231.1	40.0	87.7	127.7
S Em±	0.20	0.14	0.06	0.06	1.87	1.98	3.07	0.49	1.67	1.94
CD (P=0.05)	0.57	NS	0.17	0.18	NS	NS	NS	NS	NS	NS
(B) Zinc levels (Kg/ha)										
0	19.69	11.95	6.95	11.51	103.4	89.2	192.6	36.8	85.5	122.3
5.0	24.20	13.46	7.27	11.76	136.3	102.6	238.9	41.0	89.7	130.7
10.0	27.09	15.04	7.31	11.78	154.8	117.7	272.5	41.7	92.2	133.9
S Em±	0.24	0.17	0.07	0.08	2.29	2.42	3.76	0.60	2.05	2.37
CD (P=0.05)	0.70	0.48	0.21	0.22	6.59	6.97	10.83	1.72	5.09	6.84
(C) Boron levels (Kg/ha)										
0	22.92	12.36	6.39	10.27	123.1	92.6	215.7	34.1	76.5	110.6
1.0	23.95	13.91	7.43	12.00	135.0	107.7	242.7	41.8	92.6	134.4
2.0	24.11	14.18	7.72	12.78	136.4	109.3	245.6	43.6	98.3	141.9
S Em±	0.24	0.17	0.07	0.08	2.29	2.42	3.76	0.60	2.05	2.37
CD (P=0.05)	0.70	0.48	0.21	0.22	6.59	6.97	10.83	1.72	5.90	6.84

Table 3: Effect of Zn and B on quality and energy relationships of wheat varieties

Treatment	Quality parameters of wheat			Energy relationships			
	Crude protein content (%)	**Yellow pigment (ppm)**	**SDS values (ml.)**	**Energy input (x 10^3 MJ/ha)**	**Energy ouput (x 10^3 MJ/ha)**	**Energy ratio**	**Energy productivity (g/MJ)**
(A) Wheat varieties							
HI 1544	12.0	2.03	37.9	22.5	182.5	8.10	252.5
HI 8498	12.9	4.45	31.0	22.5	171.9	7.63	239.2
S Em±	0.10	0.06	0.61	-	-	-	-
CD (P=0.05)	0.28	0.16	1.76	-	-	-	-
(B) Zinc levels (Kg/ha)							
0	12.4	3.20	35.7	22.0	170.4	7.73	239.6
5.0	12.6	3.22	34.5	22.5	177.4	7.87	249.8
10.0	12.4	3.31	33.1	23.0	181.3	7.87	247.9
S Em±	0.12	0.07	0.75	-	-	-	-
CD (P=0.05)	NS	NS	NS	-	-	-	-
(C) Boron levels (Kg/ha)							
0	12.5	3.31	35.3	22.3	171.8	7.69	239.5
1.0	12.5	3.25	33.9	22.5	178.6	7.93	249.8
2.0	12.4	3.17	34.0	22.7	178.7	7.86	248.5
S Em±	0.12	0.07	0.75	-	-	-	-
CD (P=0.05)	NS	NS	NS	-	-	-	-

Table 4: Marginal rate of return analysis as influenced by treatment variables

Treatments	Partial budget analysis							Marginal rate of return analysis		
	Average yield (kg/ha) (a)	**Adjusted yield (kg/ha) (b)**	**Gross field benefits (Rs./ha) (c)**	**Cost of nutrient (Rs./ha) (d)**	**Cost of nutrient application (e)**	**Total cost that vary (f)**	**Net benefits (Rs./ha) (g)**	**Marginal cost (Rs./ha) (h)**	**Marginal benefits (Rs./ha) (i)**	**MRR (%) (j)**
(A) HI 1544 : Zinc levels (Kg/ha)										
0	5450	4632	80374	0	0	0	80374	-	-	-
5.0	5720	4862	84356	1200	150	1350	83006	1350	2632	195.0
10.0	5900	5015	87010	2400	150	2550	84460	1200	1454	121.2
Boron levels (Kg/ha)										
0	5480	4658	80816	0	0	0	80816	-	-	-
1.0	5780	4913	85240	180	150	330	84910	330	4094	1240.6
2.0	5810	4938	85683	360	150	510	85173	180	263	146.1
(B) HI 8498: Zinc levels(kg/ha)										
0	5110	4343	75360	0	0	0	75360	-	-	-
5.0	5530	4700	81554	1200	150	1350	80204	1350	4844	358.8
10.0	5530	4700	81554	2400	150	2550	79004	1200	-1200	-100
Boron levels (kg/ha)										
0	5210	4428	76834	0	0	0	76834	-	-	-
1.0	5480	4658	80816	180	150	330	80486	330	3652	1106.7
2.0	5480	4658	80816	360	150	510	80306	180	-180	-100
(C) Overall: Zinc levels (kg/ha)										
0	5280	4488	77867	0	0	0	77867	-	-	-
5.0	5630	4785	83028	1200	150	1350	81678	1350	3811	282.3
10.0	5710	4853	84208	2400	150	2550	81658	1200	-20	-1.67
Boron levels (kg/ha)										
0	5350	4547	78899	0	0	0	78899	-	-	-
1.0	5630	4785	83028	180	150	330	82698	330	3799	1151.2
2.0	5650	4802	83323	360	150	510	82813	180	115	63.9

Note: Adjusted yield – 15% and minimum acceptable limit – 100%, Wheat sale price Rs. 17.35 per kg

Conclusions

On the basis of three years study, it was concluded that basal application of zinc @ 5.0 kg, B @ 1.0 kg/ha in bread wheat variety HI 1544 are economical doses and safe for farmers' recommendation and can be used for higher productivity of wheat in vertisols of Central India.

References

1. Aref F. Application of different levels of zinc and boron on concentration and uptake of zinc and boron in corn grain. Journal of American Science. 2010; 6(5):100-106.
2. Chaudhary S, Singh H, Singh S, Singh V. Zinc requirement of green gram (*Vigna radiata*) – wheat (*Triticum aestivum*) crop sequence in alluvial soil. Indian Journal of Agronomy. 2014; 59:48-52.
3. CIMMYT. From Agronomic Data to Farmer Recommendations. An economic training manual, completely revised edition, Mexico DF, 1988.
4. Debnath MR, Jahiruddin M, Rahman MM, Haque MA. Determining optimum rate of boron application for higher yield of wheat in Old Brahmaputra Floodplain soil. Journal of Bangladesh Agricultural University. 2011; 9(2):205-10.
5. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd Edt. A Wiley Inter Sci. Publi. John Wiley & Sons., New York, 1984.

6. Graham RD, Wilch RM. Breeding for staple food crops with high micronutrient density. Working papers on agricultural strategies for micronutrients. International Food Policy Research Institute, Washington DC, 1996.
7. Gupta UC. Boron and molybdenum nutrition in wheat, barley and oats grown in Prince Edward Island soils. Canadian Journal of Soil Science. 1971; 51(3):415-422.
8. Gupta UC, Jame YW, Cambell CA, Leyshon AJ, Nicholaichuk W. Boron and its role in crop production. Canadian Journal of Soil Science. 1985; 65:381.
9. Hossain I, Asad-ud-doullah M, Kundu S. Interaction and mean effects of boron and varieties on agronomic, seed quality and yield contributing character of wheat. Bangladesh Journal of Agricultural Sciences. 2011; 29(1):69-73.
10. Jackson ML. Soil Chemical Analysis. Practice Hall of India Pvt. Ltd., New Delhi, 1973, 187.
11. Jat G, Majumdar SP, Jat NK, Majumdar SP. Potassium and zinc fertilization of wheat (*Triticum aestivum*) in western arid zone of India. Indian Journal of Agronomy 2013; 58:67-71.
12. Kabata-Pendias A, Pendias H. Trace elements in soils and plants. CRC. Press, Boca Raton. Fla., USA, 2001, 413.
13. Keram KS, Sharma BL, Sawarkar SD. Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (vertisol). International Journal of Science and Environment. 2012; 1(5):563-571.
14. Kaur R. Influence of zinc and boron on wheat productivity and phosphorus use efficiency in an acid Alfisol. M.Sc. Thesis. Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India, 2012.
15. Li WH, Kui MC, Chao NS, Jern MP, Li CR, Chu WJ *et al*. Studies on the cause of sterility in wheat. Journal of Northern Agricultural College. 1978; 3:1-19.
16. Mandal AB, Das AD. Response of wheat (*Triticum aestivum*) to boron application. Indian Journal of Agricultural Sciences. 1988; 58(9):681-83.
17. NFDC. Micronutrients in Agriculture: Pakistan Perspective. NFDC Publication No. 4/98, Islamabad, 1998.
18. Panesar SB, Bhatnagar AP. Energy norms for input and output of agricultural sector. In.: Proceedings of National Conference on “Energy in Production Agriculture and Feed Processing”, during 30-31 October held at Punjab Agricultural University, Ludhiana, 1987, 8-26.
19. Patel KP, Patel AK, Patel AM, Patel KC, Ramani VP. Response of wheat to micronutrient application. Asian Journal of Soil Science. 2008; 3(1):84-87.
20. Rerkasem B, Netsangtip R, Lordkaew S, Cheng C. Grain set failure in boron deficient wheat. In proc: twelfth International Plant Nutrition Colloquim, N. J. Barrow (ed.), 1993, 401-404.
21. Sekimoto HM, Hoshi TN, Yokota T. Zinc deficiency affects the levels of endogenous Gibberellins in *Zea mays* L. Plant and Cell Physiology. 1997; 38(9):1087-90.
22. Shivay YS, Prasad R. Zinc fertilization for higher yield and quality in basmati rice. Indian farming. 2009; 9:36-37, 52.
23. Sinha RB, Sakal R. Effect of zinc and iron application in calcareous soil on zinc and iron nutrition of rice. Journal of the Indian Society of Soil Science. 1983; 31:527-533.