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Direct effect of boron and zinc on productivity, quality and nutrient uptake by Indian mustard (*Brassica juncea*) and their residual effect on succeeding pearl millet (*Pennisetum glaucum*) in mustard-pearl millet crop sequence

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ABSTRACT

A field experiment was conducted at Research farm of Raja Balwant Singh College, Bichpuri, Agra to study the effect of boron and zinc on productivity, nutrient uptake and quality of Indian mustard [*Brassica juncea* (L.) Czernj and coss.) in mustard-pearl millet [*Pennisetum glaucum* (L.) R. Br.] cropping sequece during 2015-16 and 2016-17. Boron and zinc levels alone and in different combinations were applied to mustard crop during 2015 and 2016 and their residual effect was studied in succeeding pearl millet crop. Higher levels of B and Zn along with RDF recorded higher growth and yield attributes at harvest, viz. plant height, branches/plant, siliquae/plant, seeds/siliqua and test weight of mustard crop than recommended dose of fertilizers and other treatments. Highest seed and stover yield of mustard crop was recorded with the combined application of 2 kg B + 8 kg Zn/ha along with recommended dose of NPK fertilizers (RDF) which was at par with RDF + 1 kg B + 8 kg Zn/ha, RDF + 1 kg B + 4 kg Zn/ha and RDF + 2 kg B + 4 kg Zn/ha, and significantly superior to RDF only and other treatments. The uptake of B and Zn by both seed and stover of mustard crop also increased with increasing levels of both these elements and was superior to RDF as well as RDF along with sole application of B or Zn. Oil and protein contents also followed the same increasing trend. The residual effect of combined application of 2 kg B and 8 kg Zn/ha on the grain and stover yields of succeeding pearl millet crop was also significant; the increases were 18.9 and 20.3% for grain and stover yield, respectively over RDF. Protein content in grain and stover of pearl millet also increased significantly with residual effect of 2 kg B + 8 kg Zn/ha. Boron and zinc uptake by pearl millet crop also showed an increasing trend which was statistically significant over RDF alone and other treatments. The status of B and Zn in post harvest soil also improved with their application.

Key words: Boron, Mustard-pearl millet crop sequence, Productivity, Yield, Zinc

Indian mustard [*Brassica juncea* (L.) Czernj and Coss.] is the third most important oil seed crop after groundnut and soybean in India. The productivity of mustard is quite low mainly due to sub optimal application of fertilizers and cultivation on marginal land under rainfed conditions. Further, the quality of mustard oil and its cake is an important aspect affected greatly by mineral nutrition. Mustard- pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a popular cropping sequence adopted in sandy loam areas, where deficiency of Zn is a common occurrence. Even with the application of recommended dose of fertilizers, yield potential of mustard – pearl millet has reached a plateau (Chaube *et al*. 2007). Mustard is an energy rich crop which requires the major, secondary and micronutrients in adequate quantity for higher production. Mustard is quite responsive to micronutrients boron and zinc, which plays an important role in growth and development of this crop. Zinc has vital role in carbohydrate and protein metabolism as well as it controls the plant growth hormone indole acetic acid (IAA). It is an essential component of dehydrogenase, proteinase and promotes starch formation, seed maturation and production. Boron plays an important role in the development and differentiation of sugar in plant. It helps in the normal growth of plant and in absorption of nitrogen. Boron also helps in root development, flower and pollen grain formation. Boron application produced the best quality seeds in respect of oil and protein content of mustard (Choudhary and Bhogal 2017). Boron deficiency in mustard may cause sterility, i.e. less pods and less seeds per pod, attributing low seed yield. The deficiencies of any one of the micronutrients adversely affect plant growth, development and ultimately yield thus minimizing the usefulness of other agricultural inputs including recommended dose of fertilizers comprising nitrogen, phosphorus and potassium. Moreover, it has been reported that Zn and B fertilizers have residual effects on crops (Rattan *et al.* 2009, Jaiswal *et al.*

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2015). Therefore, suitable combinations of B and Zn needs to be developed under mustard-pearl millet sequence. No information is available for the optimum dose and residual effect of boron and zinc fertilizers application for mustard-pearl millet system practised in Agra region of Uttar Pradesh. Accordingly, the present investigation was undertaken to study the effect of B and Zn levels on yield, uptake and quality of mustard and their residual effect on pearl millet grown in alluvial soils of Agra region.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of Raja Balwant Singh College, Bichpuri, Agra (Uttar Pradesh) during *rabi* and *kharif* seasons of 2015-16 and 2016-17.The experimental site is characterized by semi arid climate with extreme temperature during summer (45^0 to 48^0 C) and very low temperature during winter (as low as 2^0 C). The average rainfall is about 650 mm, most of which is received from June to September. The soil of the experimental site is sandy loam in texture having pH 8.0 with low organic carbon content (3.1 g/kg) and low in available N (175 kg/ha) and medium in available P (11 kg/ha) and K (120 kg/ha). The soil had $CaCl_2$ extractable sulphur content of 16 kg/ha, DTPA extractable Zn 0.54 kg/ha and hot water soluble B 0.45 mg/kg. The experiment was conducted in randomized block design with nine treatments replicated thrice. The treatments were T_1: recommended dose of fertilizers (RDF) @ 60:30:15:20 kg/ha NPKS, T_2: RDF + 4 kg Zn/ha, T_3: RDF + 8 kg Zn/ha, T_4 : RDF + 1 kg B/ha, T_5: RDF + 2 kg B/ha, T_6: RDF + 1 kg B + 4 kg Zn/ha, T_7: RDF + 2 kg B + 4 kg Zn/ha, T_8: RDF + 1 kg B + 8 kg Zn/ha T_9: RDF + 2 kg B + 8 kg Zn/ha. Mustard (var. Rohini) was grown as a test crop and sown in rows 30 cm apart in the first week of November and harvested in first week of February during both the years. Half dose of N and full amounts of P, K, S, Zn and B were applied at the time of sowing and the remaining N was top-dressed at first irrigation. The nutrients were supplied using urea, diammonium phosphate , muriate of potash, elemental sulphur, zinc oxide and borax. The residual effect of B and Zn levels was studied in succeeding pearlmillet crop with Pioneer 86 M 86 as test crop. The RDF, viz. 80:60:30 kg/ha N, P_2O_5 and K_2O was applied to pearl millet during the following *kharif* season in both the years of experimentation. The plant height, branches/plant, siliquae/plant, seeds/siliqua, test weight, seed and stover yields were recorded at maturity. The grain and stover yields were recorded plot-wise after threshing of the produce. The grain and stover samples of mustard and pearl millet were collected for the chemical analysis of Zn and B. The Zn content in seed and stover of mustard and pearl millet was determined using atomic absorption spectrophotometer from di-acid (nitric and perchloric acid) digest (Jackson 1973). Boron content in the seed and stover samples was analyzed using azomethine - H method. Boron content in soil was extracted with boiling water and determined by spectrophotometer using azomethine-H (John *et al. 1975*). The DTPA extractable Zn in soil was estimated in post-harvest samples after pearl millet crop as per method of Lindsay and Norvell (1978). Total N content in mustard seed samples was determined by Kjeldahl method and protein content was obtained by multiplying with a factor of 6.25. Oil content in seeds of mustard was determined using Soxhlet apparatus (AOAC 1970). The uptake of nutrients was computed from their concentrations in grain/seed and stover and respective yields of both crops. Data obtained from consecutive two years were statistically analyzed as per procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield attributes and yield of mustard

Growth and yield parameters like plant height, branches/plant, number of siliquae/plant, number of seeds/siliqu and 1000 seeds weight were influenced significantly with different treatments of B and Zn (Table 1). Higher values of these parameters were recorded in treatment where highest dose of nutrients were supplied, viz. RDF + 2 kg B + 8 kg

Table 1 Effect of boron and zinc levels on growth, yield attributes and yield of mustard in mustard- pearl millet crop sequence (pooled data of 2 years)

Treatment	Plant height (cm)	Branchis/ plant	Silique/ plant	Seeds/ siliqua	Test weight (g)	Yield (q/ha	
						Seed	Stover
T_1 RDF	182	9,5	188	11.6	3.90	11.41	35.18
T_2 RDF + 1 kg B /ha	185	11.0	203	12.0	4.05	12.01	37.44
T_3 RDF + 2 kg B /ha	189	11.6	205	12.2	4.08	12.51	39.00
T_4 RDF + 4 kg Zn /ha	188	12.1	207	12.2	4.14	12.82	40.12
T_5 RDF + 8 kg Zn /ha	193	12.7	214	12.5	4.19	13.26	41.63
T_6 RDF + 1 kg B + 4 kg Zn/ ha	198	13.1	215	12.8	4.21	13.73	43.24
T_7 RDF + 2 kg B + 4 kg Zn /ha	204	13.6	218	13.0	4.23	14.14	44.61
T_8 RDF + 1 kg B + 8 kg Zn/ ha	208	15.0	223	13.3	4.27	14.63	46.11
T_9 RDF + 2 kg B + 8 kg Zn /ha	211	15.9	228	13.5	4.30	15.01	47.35
CD (P=0.05)	5.4	1.14	10.5	0.81	0.22	0.75	3.86

Zn/ha. Plant height (211 cm), branches/plant and number of siliquae/plant (228) was recorded significantly highest in RDF + 2 kg B + 8 kg Zn/ha which was at par with RDF +1 kg B + 8 kg Zn/ha and RDF +2 kg B + 4 kg Zn/ha but found significantly superior over other treatments. Number of seeds/siliqua and test weight were also recorded higher in RDF + 2 kg B + 8 kg Zn/ha and remained at par with RDF +1 kg B + 8 kg Zn/ha but significantly superior over RDF and other treatments. Test weight, however, showed non-significant increase over RDF + 1 kg B + 4 kg Zn/ha, RDF +2 kg B + 4 kg Zn/ha and RDF +1 kg B + 8 kg Zn/ha. Singh and Singh (2017) also reported increased growth and yield attributes with zinc in mustard crop. Positive effect of boron and zinc on growth and yield attributes of Indian mustard was also reported by Jaiswal et al. (2015) and Choudhary and Bhogal (2017). Significantly highest mustard seed yield of 15.01 q/ha was observed in treatment RDF + 2 kg B + 8 kg Zn/ha, which was at par with treatments RDF + 8 kg Zn/ha, RDF + 1 kg B + 4 kg Zn/ha, RDF + 2 kg B + 4 kg Zn/ha and RDF +1 kg B + 8 kg Zn/ha but remained significantly superior over RDF and other treatments (Fig 1). The increase in seed yield was recorded to the tune of 31.5 per cent in the treatment of RDF + 2 kg B + 8 kg Zn/ha over RDF. Stover yield was also recorded highest in T_9 but remained significantly superior to RDF and other treatments (Table 1). The higher values of yield may be attributed to application of Zn and B along with RDF as Zn and B are involved in cell division, enzyme activation and with their increased supply to mustard, their availability, acquisition, mobilization and influx into the plant tissuse increased and thus improved growth attributes and yield components and finally the yield. These results are in conformity with those of Jaiswal *et al*. (2015) and Singh *et al.* (2017) who also observed that the combined application of Zn and B resulted in higher seed yield than the application of B and Zn alone.

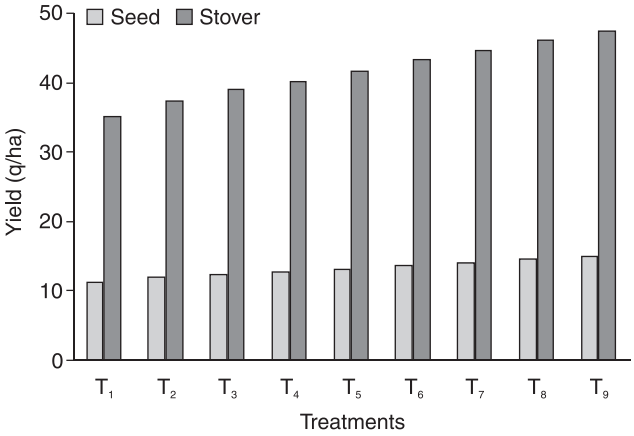

Fig 1 Effect of various treatments on seed and stover yield of mustard.

Boron and zinc uptake by mustard

Boron and Zn uptake differed in different treatment combinations and higher uptake of these micronutrients was observed in treatment supplying nutrients in high quantity. Boron uptake by both seed and stover of mustard was observed highest in treatment RDF + 2 kg B + 8 kg Zn/ha though it remained at par with treatment RDF + 1 kg B + 8 kg Zn/ha, but was found significantly superior to RDF and other treatments (Table 2). Zinc uptake was also reported highest in RDF + 2 kg B + 8 kg Zn/ha though it remained at par with treatments RDF + 2 kg B + 4 kg Zn/ha and RDF + 1 kg B + 8 kg Zn/ha and significantly superior to RDF and other treatment combinations (Table 2). The higher nutrient uptake (Zn and B) in seed and stover of mustard was mainly attributed to higher levels of these nutrients as the nutrient uptake was increased with successive increase in chemical fertilization. The balanced nutrition also enhanced the synergistic effect on uptake of plant nutrients (Singh *et al*. 2017).

Protein and oil content

Protein content of mustard seed increased significantly over RDF with application of Zn and B (Table 2). The maximum protein content of 22.2% was recorded with RDF + 2 kg B + 8 kg Zn/ha which was significantly superior

Table 2 Effect of various treatments on boron and zinc uptake,quality indices of mustard in mustard-Pearl millet crop sequence (pooled data of 2 years)

Treatment	Boron uptake (g/ha)		Zinc uptake (g/ha)		Oil content (%)	Protein content (%)
	Seed	Stover	Seed	Stover		
T_1 RDF	16.7	59.8	32.06	121.37	39.0	20.2
T_2 RDF + 1 kg B /ha	23.1	84.2	34.1	131.0	39.6	20.5
T_3 RDF + 2 kg B/ha	32.5	109.9	35.9	139.2	40.8	20.8
T_4 RDF + 4 kg Zn/ha	19.8	96.2	41.0	155.6	39.8	20.7
T_5 RDF + 8 kg Zn/ha	22.1	106.5	47.3	174.8	41.0	21.0
T_6 RDF + 1 kg B + 4 kg Zn/ha	23.1	112.4	44.6	157.8	41.2	20.6
T_7 RDF + 2 kg B + 4 kg Zn/ha	30.5	141.8	48.9	176.6	42.0	21.1
T_8 RDF + 1 kg B + 8 kg Zn/ha	25.1	124.4	47.9	157.8	41.5	21.6
T_9 RDF + 2 kg B + 8 kg Zn/ha	33.6	155.6	54.0	199.2	42.3	22.2
CD (P=0.05)	2.26	5.68	3.61	5.19	0.43	0.30

to RDF. This might be due to increased N content with concomitant application of Zn and B in seed leading to higher protein. Oil content also increased with application of Zn and B in soil. The highest oil content (42.3%) was recorded in RDF + 2 kg B + 8 kg Zn/ha and the lowest in control (39.0%). Jaiswal *et al.* (2015) also found an increase in protein and oil content in mustard crop with increased application of S and B. Verma *et al.* (2012) and Singh *et al*. (2017) also reported that the application of Zn and B significantly increased seed yield, oil and protein content and nutrient uptake in mustard crop.

Residual effect of boron and zinc on pearl millet

Yield attributes and yield: Residual effect of applied B and Zn levels to mustard crop was evident on succeeding pearl millet crop (Table 3). Impact of residual B and Zn was more pronounced at their higher levels (2 kg B+8 kg Zn/ha) along with RDF than at lower level (1 kg B+4 kg Zn/ha). Residual effect of B and Zn showed significant effect on yield attributes of pearl millet. The residual effect of higher levels B (2 kg/ha) and Zn (8 kg/ha) along with RDF was significant on length of ear, width of ear, grain weight/ear and test weight. The favourable effect of residual B and Zn on growth and yield attributes may be attributed to their role in many physiological processes and cellular functions in plant. It is quite obvious that the experimental soil was deficient in B and Zn, so residual effect was found favourable on the growth and yield attributes of pearl millet (Jain and Dahama 2006, Singh *et al.* 2015). The grain and stover yield of pearl millet increased under the residual effect of increasing B and Zn levels (Fig 2). The residual effect of different combinations of B and Zn in preceding mustard crop resulted in increased yield of succeeding pearl millet crop. In pearl millet crop, increased level of B up to 2 kg/ha and Zn up to 8 kg/ha in combination with RDF recorded highest grain (39.05 q/ha) and stover (104.70 q/ha) yield in pearl millet crop. Increase in grain and stover yield was to the tune of 18.9 and 20.3% more in treatment supplying 2 kg B+8 kg Zn/ha over RDF, respectively (Table 3). In general, the marked empowerment in productivity of pearl millet with residual effect of B and Zn could be ascribed to the enhancement of B and Zn content in soil. These findings are in accordance with those reported by Chaube *et al*. (2007) and Singh *et al*. (2015).

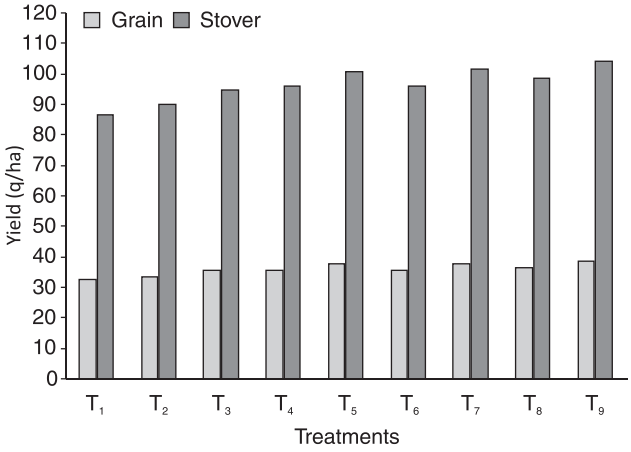

Fig 2 Effect of various treatments on grain and stover yield of pearl millet.

Protein: Residual effect of boron and zinc levels had significant beneficial effect on protein per-centage in pearl millet grain and stover over RDF alone. The maximum percentage of protein content in grain (11.3%) was recorded under RDF + 2 kg B+8 kg Zn/ha applied in preceding mustard crop. Similar increase in protein content in pearl millet was also reported by Singh *et al*. (2015).

Uptake of nutrients: The uptake of B and Zn by pearl millet grain and stover was significantly affected by their residual effect. The uptake of B and Zn by grain and stover increased with combined application of B and Zn in different proportions and maximum values of B and Zn uptake were recorded with residual effect of 2 kg B+8 kg Zn/ha treatment. The response of pearl millet crop to applied B and Zn in preceding mustard crop may be attributed to an enhanced availability of B and Zn in soil at a level below which the optimum requirement of crop is fulfilled. This showed that

Table 3 Residual effect of boron and zinc on growth , yield attributes and yield of pearl millet in mustard - pearl millet crop sequence (pooled data of 2 years)

Treatment	Plant height (cm)	Length of ear (cm)	Width of ear (cm)	Grain weight/ ear (g)	Test weight (g)	Yield (q/ha)	
						Grain	Stover
T_1 RDF	197	23.80	11.50	22.62	11.50	32.83	87.00
T_2 RDF + 1 kg B /ha	200	23.90	11.61	22.96	11.65	34.10	90.30
T_3 RDF + 2 kg B/ha	203	24.05	11.75	23.18	11.76	35.83	95.03
T_4 RDF + 4 kg Zn/ha	204	24.12	11.81	24.05	11.82	36.15	96.58
T_5 RDF + 8 kg Zn/ha	208	24.48	11.98	24.78	12.10	38.00	101.04
T_6 RDF + 1 kg B + 4 kg Zn/ha	206	24.22	11.84	24.17	11.80	36.20	96.65
T_7 RDF + 2 kg B + 4 kg Zn/ha	208	24.35	12.00	24.80	12.11	38.27	102.18
T_8 RDF + 1 kg B + 8 kg Zn /ha	210	24.60	12.17	26.00	12.17	37.10	99.06
T_9 RDF + 2 kg B + 8 kg Zn /ha	215	24.80	12.37	27.10	12.33	39.05	104.70
CD (P=0.05)	1.87	0.59	0.35	1.06	0.23	3.54	5.66

Table 4 Residual effect of boron and zinc on their uptake by pearl millet crop and status of B and Zn in post harvest soil (pooled data of 2 years)

Treatment	Boron uptake (g/ ha)		Zinc uptake (g/ ha)		Protein content (%)	Available B (mg /kg)	Available Zn (mg /kg)
	Grain	Stover	Grain	Stover			
T_1 RDF	37.10	130.50	82.07	252.30	10.0	0.41	0.50
T_2 RDF + 1 kg B /ha	47.74	166.15	85.39	264.58	10.3	0.59	0.51
T_3 RDF + 2 kg B/ha	63.78	206.22	92.80	282.24	10.7	0.70	0.53
T_4 RDF + 4 kg Zn/ha	41.93	150.66	102.67	316.78	10.5	0.43	0.71
T_5 RDF + 8 kg Zn/ha	45.60	163.68	121.60	368.80	11.0	0.42	0.85
T_6 RDF + 1 kg B + 4 kg Zn/ha	60.81	183.63	103.89	289.95	10.2	0.60	0.72
T_7 RDF + 2 kg B + 4 kg Zn/ha	66.97	231.95	120.55	348.43	10.9	0.73	0.74
T_8 RDF + 1 kg B + 8 kg Zn/ha	74.94	217.93	121.32	332.84	11.1	0.61	0.90
T_9 RDF + 2 kg B + 8 kg Zn/ha	83.57	228.23	140.97	369.33	11.3	0.75	0.93
CD (P=0.05)	4.71	9.35	6.75	13.8	0.35	0.15	0.11

enhancement in B and Zn levels not only increased the yield but also increased their content and ultimately their uptake (Chaube *et al*. 2007, Singh *et al*. 2015).

Soil fertility status: Different levels of Zn (4 and 8 kg/ha) and B (1 and 2 kg/ha) significantly increased the available Zn and B content in post harvest soil over RDF (Table 4). However, Zn applied @ 4 and 8 kg/ha alone or in combination with B were found at par but proved significantly superior to RDF with respect to available Zn status in post harvest soil. Higher Zn content of 0.93 mg/ kg was reported in treatment RDF + 2 kg B + 8 kg Zn/ha which was significantly superior to RDF and treatments where only B was applied (T_4 and T_5). The lowest content of Zn was observed in RDF (0.50 mg/kg). Boron content in post harvest soil was observed highest (0.75 mg/kg) in RDF + 2 kg B + 8 kg Zn/ha and lowest (0.41 mg/kg) in RDF These results are in conformity with those of Singh and Singh (2017) who also reported increased Zn status in soils after harvesting of mustard.

The study showed that the application of 2 kg B + 8 kg Zn/ha along with RDF in soil might be useful in enhancing productivity and quality of mustard. The residual effect on pearl millet was evident up to 2 kg B + 8 kg Zn/ha. The highest B and Zn uptake by both crops was recorded with 2 kg B + 8 kg Zn/ha. These results can be applicable for obtaining higher productivity and quality of both crops in mustard – pearl millet crop sequence in alluvial soils of Agra having deficiency of B and Zn.

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