Assessing the Zinc, Boron and Rhizobium inoculation on yield and economics of Kharif Mungbean (*Vigna radiata* L.)

ABSTRACTS

The present experiment entitled **"Assess the Zinc, Boron and Rhizobium inoculation on growth and yield of Kharif Mungbean (*Vigna radiata* L.)** was carried out during *kharif* season of 2021 and 2022 at Instructional farm, Kamla Nehru Institute of Physical and Social Sciences Sultanpur, U.P. India. Four levels of zinc (0, 2.5, 5.0 and 7.5 Kg Zn ha^{-1}), three levels of boron (0, 0.5 and 1.0 Kg B ha^{-1}) and two levels of rhizobium *i.e*. Uninoculated (Control) and inoculated. A split-split plot design with three replications was used. Zinc levels were allocated to the main plots, boron levels in the sub-plot, while Rhizobium inoculation in the sub-sub plot. Results revealed that dry weight and seed and stover yield was observed that Rhizobium inoculation with application of zinc 7.5 kg ha^{-1} and Application of boron 1.0 kg ha^{-1}. The highest net return (Rs. 58211.0 and 65488.50 ha^{-1}) and benefit cost ratio (1.75 and 1.97) were obtained with 7.5kg Zn ha^{-1} +1 kg B ha^{-1}+seed inoculation with rhizobium. It could be recommended for cultivation of mungbean.

Keywords: Boron, Growth, Inoculation, Rhizobium, Zinc.

INTRODUCTION:

In India, mungbean [*Vigna radiata* (L.) Wilczek] is grown round the year in all the three distinct crop seasons, i.e. *kharif*, *rabi* and summer. In general, this crop is grown as rainfed during rainy season and on residual soil moisture in winter.

It is known for its high vitamin A and protein, which can supply a balanced diet when taken in mixture with cereal, which contains low level of protein (Rahman *et al.,* 2008). It is a short maturity and drought resistance crop, which conferees its adaptation to adverse environmental conditions and successfully grows in rain-fed areas (Anjum *et al.,* 2006). Furthermore, it is adaptable for the semiarid and arid areas due to its short growing cycle (Kidane, 2010), which may be related to attainment of the required degree days to reach maturity in a short period of time due to high temperature condition.Mungbean is also a low-input crop that can be used as livestock feed and green manure.

The Zn essentially is being employed in functional and structural component of several enzymes, such as carbonic anhydrase, alcohol dehydrase, alkaline phosphatase, phospholipase, carboxypeptidase (Coleman, J.E. 1991) and RNA polymerase (Romheld, V. and Marschner, H. 1991). Further, plants emerging from seeds with lower Zn could be highly sensitive to biotic and abiotic stresses (Obata et al., 1999). Zn enriched seeds performs better with respect to seed germination, seedling growth and yield of crops (Cakmak et al., 1996).

MATERIALS AND METHODS

A field experiment was conducted during two consecutive seasons of *kharif* 2020 and 2021 at Instructional farm, Kamla Nehru Institute of Physical and Social Sciences Sultanpur, U.P. (India). The experimental site falls under sub-tropical conditions with remarkable humidity and lies between 26.2927^0 North latitude and 82.1278^0 East longitude with an altitude of about 95 m from mean sea level. The experimental field was well levelled having good irrigation and drainage facilities. The source of irrigation was tube well. Four levels of zinc (0, 2.5, 5.0 and 7.5 Kg Zn ha^{-1}), three levels of boron (0, 0.5 and 1.0 Kg B ha^{-1}) and two levels of rhizobium *i.e.* Uninoculated (Control) and inoculated. A split-split plot design with three replications was used. Zinc levels were allocated to the main plots, boron levels in the sub-plot, while Rhizobium inoculation in the sub-sub plot. Soil was sampled before sowing/transplanting and after harvest of the crop to know the fertility status of the experiment field. The growth and yield analysis were done as per standard procedures.

RESULTS AND DISCUSSION

Dry weight (g) plant^{-1}

Data pertaining to dry weight of plant as influenced by different levels of zinc, boron and rhizobium inoculation have been presented in Table 1.

A perusal of data clearly indicated that marked variations in dry matter of mungbean was recorded due to varying levels of zinc. Application of zinc at 7.5 kg/ha being on par with 5 kg/ha recorded significantly higher dry matter accumulation (3.57 and 3.68), (8.51 and 8.77), (12.18 and 12.57) and (13.02 and 13.43) g plant^{-1}at 30, 45, 60 days after sowing and harvest stage during first and second years of study, respectively. Percentage increase in dry matter production due to application of zinc at the rate of 2.5, 5, 7.5 kg/ha was 4.20, 9.52 and 11.66% during first year and 4.50, 9.75 and 11.92% during second year at harvest stage.

Dry matter accumulation was recorded highest under application of 1 kg B ha^{-1} which was non- significantly followed by 5 kg B ha^{-1} and significantly superior to control at all stages of growth. The trend of data was similar during both the years of investigation. Rhizobium inoculation showed marked impact on dry matter accumulation of mungbean at all stages of growth. Significantly more dry matter was noted under rhizobium inoculated plants as compared to uninoculated ones during both respective years of experimentation.

Interactions of different treatments were not significant during both the years of investigation.

Table 1. Effect of Zn, Bo and rhizobium inoculation on dry weight plant^{-1} of mung- bean at different stages of growth

Treatments	Dry weight (g plant^{-1})							
	30 DAS		45 DAS		60 DAS		At harvest	
	2020	2021	2020	2021	2020	2021	2020	2021
Zinc levels (kg ha^{-1})								
Z_0: 0	3.20	3.29	7.61	7.85	10.90	11.23	11.66	12.00
Z_1: 2.5	3.33	3.45	7.94	8.18	11.37	11.72	12.15	12.54
Z_2: 5.0	3.50	3.62	8.34	8.60	11.95	12.32	12.77	13.17
Z_3: 7.5	3.57	3.68	8.51	8.77	12.18	12.57	13.02	13.43
SEm±	0.064	0.066	0.147	0.128	0.221	0.177	0.179	0.227
CD (P=0.05)	0.182	0.188	0.418	0.364	0.629	0.503	0.508	0.647
Boron levels (kg ha^{-1})								
B_0: 0	3.23	3.33	7.70	7.93	11.02	11.35	11.78	12.15
B_1: 0.5	3.43	3.55	8.18	8.43	11.72	12.08	12.52	12.93
B_2: 1.0	3.54	3.65	8.42	8.69	12.06	12.44	12.90	13.28
SEm±	0.055	0.057	0.127	0.111	0.191	0.153	0.155	0.197
CD (P=0.05)	0.157	0.163	0.362	0.316	0.545	0.435	0.440	0.560
Rhizobium inoculation								
I_1: Un-inoculated	3.33	3.30	7.61	7.85	10.91	11.25	11.66	12.04
I_2: Inoculated	3.50	3.72	8.59	8.85	12.30	12.66	13.14	13.53
SEm±	3.57	0.047	0.104	0.091	0.156	0.125	0.126	0.161
CD (P=0.05)	0.064	0.133	0.296	0.258	0.445	0.355	0.359	0.457

5. Seed yield (q ha^{-1})

Seed yield is an important parameter which decides the efficiency and superiority of a particular treatment over other treatments. Data pertaining to seed yield plant^{-1} as influenced by zinc, boron and rhizobium inoculation are presented in Table 2.

It is clear from data, yield ofmungbean was improved significantly with every increasing level of zinc upto 7.5 kg ha^{-1}. It attained the yield of (8.53 and 8.79) q ha^{-1} with a remarkable increase of 10.64 and 10.71 per cent over control during 2019-20 and 2020-21 respectively.

Whereas, (9.60 and 9.70) and (5.32 and 5.42) per cent increments in yield were obtained under 5 and 2.5 kg zinc/ha over control, respectively. Likewise, application of zinc to mungbean at 7.5 kg/ha enhanced grain yield by 0.82, 0.41, 0.08 and 0.85, 0.42, 0.08 q/ha over control, 2.5 and 5 kg Zn/ha during 2019-20 and 2020-21, respectively.

A further reference to data revealed that increasing levels of boron significantly increased the seed yield of mungbean. Application of 1kg B ha^{-1} recorded an increase of 8.47 per cent over control during both years of study.

Rhizobium inoculation also registered significant impact on yield q ha^{-1} of mungbean. Percent increase in seed yield due to inoculation over uninoculated plants was 8.39% and 8.25 % during first and second years of study.

Table 2. Effect of Zn, Bo and rhizobium inoculation on Seed and stower yield q ha^{-1} of mungbean

Treatments	Seed yield (q ha^{-1})		Stower yield (q ha^{-1})	
	2020	**2021**	**2020**	**2021**
Zinc levels (kg ha^{-1})				
Z_0: 0	7.71	7.94	31.04	31.91
Z_1: 2.5	8.12	8.37	32.56	33.46
Z_2: 5.0	8.45	8.54	33.75	34.02
Z_3: 7.5	8.53	8.79	33.98	34.89
SEm±	0.140	0.160	0.527	0.564
CD (P=0.05)	0.40	0.46	1.50	1.60
Boron levels (kg ha^{-1})				
B_0: 0	7.79	8.03	31.22	32.11
B_1: 0.5	8.37	8.49	33.48	33.90
B_2: 1.0	8.45	8.70	33.80	34.70
SEm±	0.121	0.139	0.457	0.489
CD (P=0.05)	0.35	0.40	1.30	1.39
Rhizobium inoculation				
I_1: Un-inoculated	7.87	8.11	31.56	32.44
I_2: Inoculated	8.53	8.71	34.10	34.70
SEm±	0.099	0.113	0.373	0.399
CD (P=0.05)	0.28	0.32	1.06	1.14

5. Stower yield (q ha^{-1})

Data pertaining to seed yield $plant^{-1}$ as influenced by zinc, boron and rhizobium inoculation are presented in Table 3.

It is clear from data, stower yield of mungbean was improved significantly with every increasing level of zinc upto 7.5 kg ha^{-1}. It attained the stower yield of (33.98 and 34.89) q ha^{-1}

with a remarkable increase of 9.34 and 9.57 per cent over control during both the years respectively. It was non significantly followed by 5 kg Zn ha^{-1} and significantly followed by rest levels of zinc. Minimum stower yield of 31.04 and 31.91 q ha^{-1} was noted under control plots during both years of investigation respectively. Application of boron significantly increased the stower yield of mungbean. Application of 1kg B ha^{-1} recorded highest stower yield of 33.80 and 34.70 q ha^{-1} during 2019-20 and 2020-21 respectively and it was statistically superior to control. Minimum stower yield of 31.22 and 32.11 q ha^{-1} was recorded in control plots. Rhizobium inoculation also registered significant impact on stower yield of mungbean. Significantly more stower yield was noted under inoculated plots than that in uninoculated ones during both respective years of study.

Cost of cultivation

As data presented in table 3 clearly indicate that cost of cultivation increased linearly with increasing levels of zinc. The maximum cost of cultivation (Rs. 32447.5 ha^{-1}) was obtained at application of 7.5 kg Zn ha^{-1}. Boron application also showed variation in cost of cultivation and maximum cost of cultivation of Rs 31903.8 $ha^{-1}$was incurred when 1 kg B ha^{-1} was applied. Variation in values of cost of cultivation was also noted due to seed inoculation. More cost of cultivation was incurred (Rs 31561.4 ha^{-1}) under inoculated plots as compared to un inoculated ones. Combination of 7.5 kg Zn ha^{-1} and 1 kg B ha^{-1} along with seed inoculation fetches maximum cost of cultivation of Rs 33221.5 ha^{-1} which was followed by rest treatment combinations.

Gross return (Rs.)

Data on account of gross return Rs ha^{-1} have been presented in Table 3. Summary of data given in above table revealed that maximum gross return (Rs. 85260.42 and 91337.50 ha^{-1} during both the years respectively) was recorded under highest dose of zinc *i.e.*, 7.5 kg ha^{-1} which was at par with 5 kg ha^{-1} and significantly superior to rest doses of zinc. Significant impact of boron doses was also noted and maximum gross return of Rs 84485.94 and 91337.50 ha^{-1} during 2019-20 and 2020-21 respectively was noted with application of 1 kg B ha^{-1} which was significant superior to control. Significantly more gross return of Rs 85293.33 and 91345.63 ha^{-1} during both respective years of study was noted under inoculated plots as compared to un inoculated ones. Treatment combination of 7.5 kg Zn ha^{-1} and 1 kg B ha^{-1} along with seed inoculation recorded highest gross return of Rs 91432.5 and 98710.0 ha^{-1} followed by rest combinations. Minimum gross return was associated with control treatment.

Net return (Rs.)

Data on account of net return Rs ha^{-1} have been presented in Table 3. Summary of data given in above table revealed that maximum net return (Rs. 53295.54 and 60214.58 ha^{-1} during 2019-20 and 2020-21 respectively) was recorded under highest dose of zinc i.e., 7.5 kg ha^{-1}which was at par with 5 kg ha^{-1} and significantly superior to rest doses of zinc. Significant impact of boron doses was also noted and maximum net return of Rs 53257.19 and 60108.75 ha^{-1} during 2019-20 and 2020-21 respectively was noted with application of 1 kg B ha^{-1} which was significant superior to control. Significantly more net return of Rs 54206.90 and 60242.88 ha^{-1} during both respective years of study was noted under inoculated plots as compared to un inoculated ones. Treatment combination of 7.5 kg Zn ha^{-1} and 1 kg B ha^{-1} along with seed inoculation recorded highest net return of Rs 59561.0 and 66838.50 ha^{-1} followed by rest combinations. Minimum net return was associated with control treatment.

4.6.4 B:C ratio (Rs Re^{-1})

Data on account of B:C ratio have been presented in Table 3. Summary of data given in above table revealed that application of 7.5 kg Z ha^{-1} being at par with 5 kg Z ha^{-1} gave significantly more B:C ratio during 2019-20 and 2020-21 respectively than that of rest doses. Significant impact of boron doses was also noted and maximum B:C ratio of 1.71 and 1.93 during 2019-20 and 2020-21 respectively was noted with application of 1 kg B ha^{-1} which was significant superior to control. Significantly more B : C ratio of 1.74 and 1.94 during both respective years of study was noted under inoculated plots as compared to un inoculated ones. Treatment combination of 7.5 kg Zn ha^{-1} and 1 kg B ha^{-1} along with seed inoculation recorded highest B:C ratio of 1.87and 2.10 followed by rest combinations. Minimum gross return was associated with control treatment.

Table 3: Effect of Zn, Bo and rhizobium inoculation on economics of Mungbean

Treatments	Cost of cultivation (Rs.)	Gross Return (Rs.)		Net Return (Rs.)		B:C	
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Zinc levels (kg ha^{-1})							
Z_0: 0	30610.00	77150.0	83434.6	46990.0	53274.6	1.56	1.77
Z_1: 2.5	31239.86	81205.8	87832.0	50433.3	57059.6	1.64	1.85

Z_2: 5.0	31835.00	84441.7	89603.3	53056.7	58218.3	1.69	1.85
Z_3: 7.5	32447.50	85260.4	92212.1	53295.5	60214.6	1.66	1.88
SEm±		645.49	925.38	668.47	672.19	0.03	0.01
CD (P=0.05)		1837.51	2634.27	1902.94	1913.52	0.08	0.04
Boron levels (kg ha^{-1})							
B_0: 0	31166.77	77903.4	84308.4	46749.7	53154.7	1.50	1.70
B_1: 0.5	31528.75	83654.1	89165.6	52824.8	58311.9	1.71	1.89
B_2: 1.0	31903.75	84485.9	91337.5	53257.2	60108.7	1.71	1.93
SEm±		559.02	801.44	578.92	582.14	0.02	0.01
CD (P=0.05)		1591.33	2281.34	1647.99	1657.16	0.07	0.04
Rhizobium inoculation							
I_1: Un-inoculated	31504.6	78735.6	85195.4	47680.9	54140.7	1.53	1.74
I_2: Inoculated	31561.4	85293.3	91345.6	54206.9	60242.9	1.74	1.94
SEm±		456.43	654.35	472.69	475.32	0.02	0.01
CD (P=0.05)		1299.31	1862.71	1345.58	1353.06	0.06	0.03

DISCUSSION

The favourable influence of zinc on photosynthetic and enzymatic activities would in turn increase vegetative growth of plants (Thalooth *et al*., 2006) Singh *et al*. (2022).Such improvement under increased availability of zinc in rhizosphere might be resulted in greater uptake by the plant, consequently leading to a favourable stimulatory effect on physiological and metabolic processes of plant. Thus, the application of zinc in a soil deficient in its content (0.48 mg/kg), improved the overall growth and development of plant. These results are in close conformity with the findings of Haider *et al*. 2018b. The importance of zinc for nodulation was reported that zinc nutrition is essential and paramount for *Rhizobium* activity to fix nitrogen and increase weight of nodules. Upadhyay *et al*. (2016) and Singh *et al*. (2023) also reported increased nodule weight with the application of zinc. More nodules formation is associated with zinc application. Increase in nodulation by zinc could be due to increase in root weight or size, which provided sufficient site for nodulation.

The maximum values of these parameters were recorded with zinc application at 7.5 kg/ha. The effect of zinc nutrition on physiological and metabolic processes of plants, role in more absorption of essential elements due to increased cation exchange capacity of roots and thereby bearing more yield contributing characters are possible basis of more yield. Zinc application at 7.5 kg/ha enhanced grain yield and stover yield significantly, compared with no zinc application. This indicated that mungbean respond better to zinc application even at higher rates without showing the symptoms of zinc toxicity. In an earlier study Jamal *et al*. (2018)

reported that mungbean responded upto application of zinc at 10 kg/ha. Zinc also has significant role in primordia initiation, indole-acetic acid synthesis and partitioning of food material from leaves to reproductive parts which ultimately results in good fruiting (Kalyanaraman and Sivagurunath, 1993 and Quah *et al*., 2004). Application of 1 kg B ha^{-1} boron significantly fetched higher net returns of Rs 6507.5 and 6954.06 over control and 432.42 and 1796.87 over 05.kg B ha^{-1}. The results of the present investigation are in close conformity with findings of Praveena *et al.* (2018) and Dixit and Elamathi (2007).

CONCLUSIONS

On the basis of results obtained from the present investigation, the following conclusion may be drawn, Rhizobium inoculation of seed with Zinc 7.5 kg ha^{-1} and Boron 1.0 kg ha^{-1} have proved its superiority for better plant growth, dry matter, yield and Economics of mungbean.

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