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Effect of different levels of boron and zinc nutrition on growth and yield of black gram (*Vigna mungo* L.)

Brijesh Kumar Pandey and Awadhesh Kumar Singh

Abstract

A field experiment was carried out at the Research farm, Department of Agricultural Chemistry, P.G. College, Ghazipur during *kharif* season of two consecutive years (2019 and 2020) to study the "Effect of boron and zinc on productivity of black gram (*Vigna mungo* L.) and fertility status of soil". The experiment was laid out in Factorial Randomized block design keeping levels of born as a factor A and levels of zinc as a factor B with three replications. kg^{-1} zinc ha^{-1}, Zn2- 2.0 kg zinc ha^{-1}, Zn3- 3.0 kg zinc ha^{-1}, Zn4- 4.0 kg zinc ha^{-1}. The experiment was sown on 25th July during 2019 and 03th August during 2020 using UPU- 1 crop variety of black gram. Soil of the experimental field was sandy loam in texture having 1.52 and 1.51 Mg m-3 bulk density, 2.70 and 2.69 Mg m-3 particle density, 43.17 and 42.57% porosity, 62.01 and 63.42% water holding capacity, 0.72 and 0.73% organic carbon, 161.44 and 162.67 kg ha^{-1} available N, 14.71 and 14.74 kg ha^{-1} available P2O5, 240.90 and 242.57 kg ha^{-1} available K, 0.139 and 0.141 mg kg^{-1} boron, 0.50 and 0.51 mg kg^{-1} zinc, soil pH 7.20 and 7.21 and EC 0.237 and 0.238 dsm^{-1} at 0-15 cm depth of soil in respective years of experimentation. The recommended dose of fertilizers (NPK: 20:20:30 kg ha^{-1}) were applied uniformly in each plot. The levels of boron and zinc were applied as per treatments concluded from two years of study application of 2.0 kg boron along with 4.0 kg zinc ha^{-1} enhance growth parameters yield attributes. Recommended for UPU^{-1} variety of black gram under irrigated condition during *kharif* season in Eastern Plain Zone of Uttar Pradesh.

Keywords: Black gram zinc, boron, growth, yield

Introduction

Black gram (*Vigna mungo* L.) is one of the most important highly remunerative legume crops introduced from India and cultivated throughout the Southern Asia**.** It is a one of the most promising pulse crops and it is preferred much for its nutritional quality mainly high protein. Because of its short duration, this crop fits well under different cropping systems and thus has enormous potential for the future which needs to be better utilized. It is one of the most highly prized pulse crops, cultivated in almost all parts of India. It is perfect combination of all nurturance which includes proteins (23-25%), carbohydrates (60%), fat (1.5%), minerals, amino acids and Vitamins (Karamany, 2006) [8]. It is an important legume crops, which like other pulse crops has unique capability of maintaining and restoring soil fertility through biological nitrogen (N) fixation, and its deep root system also maintains physical properties of soil (Rathi *et al.*, 2009) [16].

Pulses are the important group of crops belonging to the family *Fabaceae*. Major pulses of the Indian subcontinent include chickpea, pigeonpea, greengram, blackgram, kidney beans, field pea, rajmas, etc. India is the largest producer and consumer of pulses in the world. It accounts for 25-28 per cent of the global pulse production in India.

In India, blackgram is grown on 3.96-million-hectare (mha) area with a production of 2.84 million tonnes (mt) and an average productivity of 652 kg ha^{-1} (Anonymous, 2021) [2]. It occupies an area of 6.99 lakh hectare area with a production of 3.37 lakh tonnes. However, the productivity (659 kg ha^{-1}) of blackgram is low in Utter Pradesh (Anonymous, 2020) [1]. Productivity of urd bean is low due to, our poor socio-economic condition and lack of proper knowledge, inefficient population of root nodule bacteria, application of sub-optimal nutrition and low fertility status soils, the farmers of our country generally produced urd by one ploughing and hardly use minimum fertilizers and irrigations. There is an ambient scope to increase the Blackgram yield through proper fertilizers management practices.

Micronutrients are just as important for plant nutrition as macronutrients. Importance of these mineral nutrients has increased in recent years due to use of high yielding cultivars and exhaustive cropping systems.

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Moreover, the climatic as well as adverse soil conditions of different regions are the major causes for the micronutrients deficiency. In the present scenario, micronutrient deficiency drastically affects the growth, metabolism and reproductive phase of crop plants, animal and human beings. Micronutrient deficiencies in crop plants are widespread because of increased micronutrient demand from intensive cropping practices and adaptation of high-yielding crop cultivars, enhanced crop production on marginal soils that contain low levels of essential micronutrients, increased use of high analysis fertilizers with low amounts of micronutrients, decreased use of animal manures, composts and crop residues, use of soils low in micronutrient reserves, use of liming in acid soils, involvement of natural and anthropogenic factors that limit adequate supplies and create elemental imbalance in soil (Fageria *et al.*, 2002) [4]. Singh and Behera, (2011) reported that as much as 48, 12, 5, 4, 33, 13 and 41 per cent soils in India are affected with deficiency of Zn, Fe, Mn, Cu, B, Mo and S respectively. In India, the trends of micronutrient deficiencies are now changing. Instead of single nutrient deficiency, cluster of micronutrient deficiencies are emerging fast in vast areas. This suggests that increasing multi-micronutrients deficiencies in soil and crops not only affect the crop productivity, but also create malnutrition and health problems.

Among the micronutrients, zinc deficiency in the plant and soil has been reported across the world (Alloway, 2008) [3]. Zn deficiency is one of the most common widespread disorders in plants and soils of different regions of India. Importance of Zn as a micronutrient in crop production has increased in recent years, hence considered to be the most yield-limiting micronutrient. Zn is essentially being employed in functional and structural component of several enzymes s (Hafeez *et al.*, 2013) [6], such as carbonic anhydrase, alcohol dehydrate, alkaline phosphatase, phospholipase, carboxypeptidase and RNA polymerase, it is also involved in auxin formation, stabilization of ribosomal fractions. Ozturk *et al.*, (2006) [15] found that newly developed radicles and coleoptiles in germinating seeds contained Zn as much higher as up to 200 mg kg^{-1}. Further, plants emerging from seeds with lower Zn could be highly sensitive to biotic and abiotic stresses. Zinc deficiency in plants also affects photosynthesis due to altered chloroplast pigments (Kosesakal and Unal, 2009) [7]. Zn enriched seeds performs better with respect to seed germination, seedling growth and yield of crops (Matwa *et al.*, 2017). The Zn content in grains increased with increased levels of Zn in soil, and the content of Cu and Mn was not influenced with applied Zn (Guo *et al.*, 2016).

The addition of micronutrients in combination with NPK fertilizers in deficient soils ensures the sustainability of cropping through balanced nutrition and provides double benefit in increasing grain yield and nutritional quality and increases the concentration of micronutrients in grains (Kugbe *et al.*, 2019). Micronutrient fertilizers increase the crop yield, enhance the efficiency of macronutrient fertilizers considerably and farmers' economical return. In order to maximize fertilizer use efficiency in crop production, micronutrient-fertilizers should be applied based on the soil test values. Decline in production of pulse crops is a cause of concern that requires immediate attention.

Among micronutrients, zinc and boron deficiency accounts about 49% and 33% respectively in Indian soils, which reduce not only the yield but also the nutritional quality of the produce. Hence, the determination of the amount of dose of boron and zinc well depend on the availability of the nutrient in soil and efficiency of utilization of a nutrient with the demand for obtaining higher yield of black gram. Therefore, supply of nutrient in adequate amount during the period of growth and reproduction is essential.

Material and Methods

The study the " Effect of different levels of boron and zinc nutrition on growth and yield of black gram (*Vigna mungo L.*) involves field experiment was conducted during kharif season of 20121 and 2022. The materials used and methods employed are presented in given below. The soil of experiment site was sandy clay loam in texture, slightly saline and non-alkaline in reaction. Before sowing, initial soil sample was collected randomly from 0-30 cm depth covering experimental area which was analyzed for various physio-chemical properties. Experiment was laid out in Factorial Randomized Block Design with twenty five treatments combination and three replications. Details of treatment.

Details of treatment.

S. No.	Level of boron	Level of Zinc	Treatment combination
1	0 kg ha^{-1}	0 kg ha^{-1}	B_0Zn_0
2	0 kg ha^{-1}	1 kg ha^{-1}	B_0Zn_1
3	0 kg ha^{-1}	2 kg ha^{-1}	B_0Zn_2
4	0 kg ha^{-1}	3 kg ha^{-1}	B_0Zn_3
5	0 kg ha^{-1}	4 kg ha^{-1}	B_0Zn_4
6	1 kg ha^{-1}	0 kg ha^{-1}	B_1Zn_0
7	1 kg ha^{-1}	1 kg ha^{-1}	B_1Zn_1
8	1 kg ha^{-1}	2 kg ha^{-1}	B_1Zn_2
9	1 kg ha^{-1}	3 kg ha^{-1}	B_1Zn_3
10	1 kg ha^{-1}	4 kg ha^{-1}	B_1Zn_4
11	1.5 kg ha^{-1}	0 kg ha^{-1}	$B_{1.5}Zn_0$
12	1.5 kg ha^{-1}	1 kg ha^{-1}	$B_{1.5}Zn_1$
13	1.5 kg ha^{-1}	2 kg ha^{-1}	$B_{1.5}Zn_2$
14	1.5 kg ha^{-1}	3 kg ha^{-1}	$B_{1.5}Zn_3$
15	1.5 kg ha^{-1}	4 kg ha^{-1}	$B_{1.5}Zn_4$
16	2 kg ha^{-1}	0 kg ha^{-1}	B_2Zn_0
17	2 kg ha^{-1}	1 kg ha^{-1}	B_2Zn_1
18	2 kg ha^{-1}	2 kg ha^{-1}	B_2Zn_2
19	2 kg ha^{-1}	3 kg ha^{-1}	B_2Zn_3
20	2 kg ha^{-1}	4 kg ha^{-1}	B_2Zn_4
21	2.5 kg ha^{-1}	0 kg ha^{-1}	$B_{2.5}Zn_0$
22	2.5 kg ha^{-1}	1 kg ha^{-1}	$B_{2.5}Zn_1$
23	2.5 kg ha^{-1}	2 kg ha^{-1}	$B_{2.5}Zn_2$
24	2.5 kg ha^{-1}	3 kg ha^{-1}	$B_{2.5}Zn_3$
25	2.5 kg ha^{-1}	4 kg ha^{-1}	$B_{2.5}Zn_4$

Black gram (*Vigna mungo* L.) i.e. Azad was selected for sowing. The germination test was carried out before sowing. The sowing was done at spacing 30 cm × 5 cm. Gap filling was done wherever it is necessary to maintain the plant population in each plot. Periodical intercultural operations like Weeding and thining were performed mechanically by hand when required to maintain good cropping condition.

Plant height: The height of four marked plants from each plot was measured from ground level to the tip of the tallest leaf at 30 and 60 days after sowing and at harvest.

Number of leaves: Number of leaves per plant were counted in each plot at 30 and 60 days after sowing from same plants selected for plant height.

Number of branches: Number of branches per plant was counted in each plot at 45 and 60 days after sowing from same plants selected for plant height.

Number of nodules: Five plants from observation plot were randomly removed with the help of the fork without damaging the roots at flowering stage of Black gram. The roots were washed carefully to remove the soil stocking to them and nodules were counted.

Number of pods: Number of pods from marked plant were recorded in each plot. The average of all the observation in each plot were worked out and designated as mean number of pods plant^{-1}.

Seed and stover yield: After threshing the bundles of each plot, seed and stover yield were recorded plot wise. Seed and stover yield were presented in q ha^{-1}.

Result

Plant height

The data pertaining to plant height of black gram under different treatments recorded during 2019 and 2020 are summarized in Table 1 (a and b) to 3 (a and b) and depicted through diagrammatically in Fig. 1. In general, plant height increased with advancement of crop age up to harvest. The plant height of black gram was varied significantly due to different levels of boron and zinc alone and in combinations at all the stages during both the years.

The data revealed that plant height was influenced significantly due to different levels of boron at all the stages of crop growth. The plant height recorded at 30, 45 days after seeding and at harvest stage, both the higher levels of born recorded significantly more plant height over low levels of boron. It is also clear from the data given in the Table that both of the higher levels of boron (2.0 and 2.5 kg ha^{-1}) being at par recorded significantly more plant height over low levels of boron treatment, likewise, both of the low levels of boron (0 and 1.0 kg ha^{-1}) also recorded plant height at par to each other except 1.5 kg ha^{-1} of Boron application. However, 2.0 kg and 1.0 kg boron application recorded numerically higher values of plant height over 2.5 kg and 0 kg boron application, respectively, but statically similar to each group of boron application at all the stages. While 1.5 kg ha^{-1} application of boron recorded significantly more plant height over 1.0 or 0 kg ha^{-1} application of boron at all stage of crop growth during both the year of experimentation.

Table 1(a): Effect of boron and zinc on plant height at 30 DAS (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	21.20	21.38	21.37	21.36	21.35	21.33
B_{01}	21.33	22.18	22.17	22.16	22.15	22.00
$B_{1.5}$	23.60	23.59	23.58	23.57	23.56	23.58
B_{02}	23.65	25.67	26.97	28.13	29.57	26.80
$B_{2.5}$	23.68	24.06	25.65	26.99	28.11	25.70
Mean Zn	22.69	23.38	23.95	24.44	24.95	
	Boron		Zinc		Interaction	
SEm±	0.52		0.52		1.16	
CD (P=0.05)	1.48		1.48		NS	

Table 1(b): Effect of boron and zinc on plant height at 30 DAS (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	21.63	21.82	21.81	21.80	21.79	21.77
B_{01}	21.77	22.63	22.62	22.61	22.60	22.45
$B_{1.5}$	24.08	24.07	24.06	24.05	24.04	24.06
B_{02}	24.13	26.19	27.52	28.70	30.17	27.34
$B_{2.5}$	24.16	24.55	26.17	27.54	28.68	26.22
Mean Zn	23.16	23.85	24.44	24.94	25.46	
	Boron		Zinc		Interaction	
SEm±	0.56		0.56		1.25	
CD (P=0.05)	1.60		1.60		NS	

Table 2(a): Effect of boron and zinc on plant height at 45 DAS (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	30.75	31.01	31.00	30.98	30.97	30.94
B_{01}	30.94	32.17	32.16	32.14	32.13	31.91
$B_{1.5}$	34.23	34.22	34.20	34.19	34.17	34.20
B_{02}	34.31	37.24	39.12	40.80	42.89	38.87
$B_{2.5}$	34.35	35.90	37.21	39.15	40.77	37.48
Mean Zn	32.92	34.11	34.74	35.45	36.19	
	Boron		Zinc		Interaction	
SEm±	0.50		0.50		1.12	
CD (P=0.05)	1.43		1.43		3.19	

Table 2(b): Effect of boron and zinc on plant height at 45 DAS (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	31.49	31.75	31.74	31.72	31.71	31.68
B_{01}	31.68	32.94	32.93	32.91	32.90	32.67
$B_{1.5}$	35.05	35.04	35.02	35.01	34.99	35.02
B_{02}	35.13	38.13	40.06	41.78	43.92	39.80
$B_{2.5}$	35.17	36.73	38.10	40.09	41.75	38.37
Mean Zn	33.70	34.92	35.57	36.30	37.05	
	Boron		Zinc		Interaction	
SEm±	0.51		0.51		1.14	
CD (P=0.05)	1.45		1.45		3.25	

Table 3(a): Effect of boron and zinc on plant height at harvest (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	46.67	47.07	47.04	47.02	47.01	46.96
B_{01}	46.96	48.83	48.81	48.78	48.77	48.43
$B_{1.5}$	51.95	51.93	51.91	51.89	51.87	51.91
B_{02}	52.06	56.51	59.37	61.93	65.10	58.99
$B_{2.5}$	52.13	54.17	56.47	59.42	61.88	56.81
Mean Zn	49.95	51.70	52.72	53.81	54.93	
	Boron		Zinc		Interaction	
SEm±	0.78		0.78		1.74	
CD (P=0.05)	2.22		2.22		4.95	

Table 3(b): Effect of boron and zinc on plant height at harvest (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	47.75	48.16	48.14	48.11	48.10	48.05
B_{01}	48.04	49.96	49.94	49.91	49.90	49.55
$B_{1.5}$	53.16	53.14	53.11	53.09	53.07	53.11
B_{02}	53.27	57.82	60.75	63.36	66.60	60.36
$B_{2.5}$	53.34	55.39	57.78	60.79	63.32	58.12
Mean Zn	51.11	52.89	53.94	55.05	56.20	
	Boron		Zinc		Interaction	
SEm±	0.80		0.80		1.79	
CD (P=0.05)	2.27		2.27		5.08	

As far as the various level of zinc applications were concerned, plant height was influenced significantly at all the stage of crop growth due to various levels of zinc application. The maximum plant height recorded with the treatment where 4.0 kg ha^{-1} zinc were applied followed by the application of zinc @ 3.0 and 2.0 kg ha^{-1} they were statistically at par but significantly superior over all other treatments at all stages of growth during both the years. The minimum Plant height was recorded in control plots which was significantly at par with the treatment where 1.0 kg ha^{-1} of zinc were applied at all stage of growth during both the years.

Plant height was influenced significantly due to combined effect of Boron and Zinc treatments at 45 and at harvest stages. The data presented in Table- 2 (a and b), 3 (a and b) indicate that the plant height was recorded significantly higher in combined application of 2.0 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} as compared to rest of the treatment combinations but being recorded at par with the combined application of 2.0 kg boron ha^{-1} and 3.0 kg zinc ha^{-1} and 2.5 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} at all stage of growth during both the years of experimentation. While the shortest plant height was recorded with the combined application of no boron and zinc at all stage of growth during both the years.

Number of leaves plant^{-1}

The data pertaining to number of Functional leaves plant^{-1} of black gram at different successive growth stages are given in Table 4 (a and b) to 6 (a and b) and depicted diagrammatically in Fig. 2 for individual years. The number of Functional leaves plant^{-1} were affected significantly due to different treatments at successive growth stages of black gram crop.

A perusal of data revealed that number of functional leaves plant^{-1} was influenced significantly due to different levels of boron at all the stages of crop growth, during both the years. The application of 2.0 kg boron ha^{-1} recorded maximum number of functional leaves plant^{-1} followed by the treatment where 2.5 kg born ha^{-1} were applied, both were recorded statistically at par but significantly superior over all other application of boron at all stages of crop growth during both the years. While the treatment where 1.5 kg boron ha^{-1} were applied recorded significantly maximum number of functional leaves plant^{-1} over the application where 1.0 kg boron ha^{-1} and 0 kg boron ha^{-1} were applied at all stages of crop growth during both the years of experimentation. The minimum number of functional leaves plant^{-1} was recorded with the application 0 kg boron ha^{-1} which was statistically at par with the application of 1.0 kg boron ha^{-1} at all stages of crop growth during both the years of experimentation.

In case of various levels of zinc application, number of functional leaves plant^{-1} was influenced significantly due to different levels of zinc at all the stages of crop growth. Data shows that increasing levels of zinc up to 4.0 kg ha^{-1} significantly increased the number of functional leaves plant^{-1} over lower level of zinc (1.0 kg and 0 kg ha^{-1}) and being statistically at par with the application of zinc @ 3.0 kg and 2.0 kg ha^{-1} at all stage of crop growth during both the years.

However, the minimum number of functional leaves plant^{-1} recorded in control plots which was significantly at par with the treatment where 1.0 kg zinc ha^{-1} were applied at all stage of growth during both the years.

Table 4(a): Effect of boron and zinc on number of functional leaves plant^{-1} at 30 DAS (2019-2020)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	16.10	16.25	16.24	16.23	16.22	16.21
B_{01}	16.20	16.85	16.84	16.83	16.82	16.71
$B_{1.5}$	17.93	17.92	17.91	17.90	17.89	17.91
B_{02}	17.97	19.50	20.49	21.37	22.46	20.36
$B_{2.5}$	17.99	18.28	19.49	20.50	21.35	19.52
Mean Zn	17.24	17.76	18.19	18.57	18.95	
	Boron		Zinc		Interaction	
SEm±	0.41		0.41		0.92	
CD (P=0.05)	1.17		1.17		NS	

Table 4(b): Effect of boron and zinc on number of functional leaves plant^{-1} at 30 DAS (2020-2021)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	16.46	16.60	16.59	16.58	16.57	16.56
B_{01}	16.56	17.22	17.21	17.20	17.19	17.08
$B_{1.5}$	18.32	18.31	18.30	18.30	18.29	18.30
B_{02}	18.36	19.93	20.94	21.84	22.95	20.80
$B_{2.5}$	18.38	18.68	19.91	20.95	21.82	19.95
Mean Zn	17.62	18.15	18.59	18.97	19.36	
	Boron		Zinc		Interaction	
SEm±	0.42		0.42		0.94	
CD (P=0.05)	1.20		1.20		NS	

Table 5(a): Effect of boron and zinc on number of functional leaves plant^{-1} at 45 DAS (2019-2020)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	24.95	25.06	25.05	25.04	25.03	25.03
B_{01}	25.01	26.00	25.99	25.98	25.97	25.79
$B_{1.5}$	27.67	27.65	27.64	27.63	27.62	27.64
B_{02}	27.72	30.09	31.62	32.98	34.66	31.42
$B_{2.5}$	28.06	28.45	30.07	31.64	32.95	30.23
Mean Zn	26.68	27.45	28.07	28.65	29.25	
	Boron		Zinc		Interaction	
SEm±	0.42		0.42		1.12	
CD (P=0.05)	1.19		1.19		2.67	

Table 5(b): Effect of boron and zinc on number of functional leaves plant^{-1} at 45 DAS (2020-2021)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	25.37	25.58	25.57	25.56	25.56	25.53
B_{01}	25.52	26.54	26.53	26.52	26.51	26.33
$B_{1.5}$	28.24	28.23	28.22	28.20	28.19	28.22
B_{02}	28.30	30.72	32.27	33.66	35.38	32.07
$B_{2.5}$	28.51	29.25	30.69	32.30	33.64	30.88
Mean Zn	27.19	28.06	28.66	29.25	29.86	
	Boron		Zinc		Interaction	
SEm±	0.43		0.43		0.95	
CD (P=0.05)	1.21		1.21		2.71	

Table 6(a): Effect of boron and zinc on number of functional leaves plant^{-1} at harvest (2019-2020)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	20.53	20.70	20.69	20.68	20.67	20.65
B_{01}	20.65	21.48	21.46	21.45	21.45	21.30
$B_{1.5}$	22.85	22.84	22.83	22.82	22.81	22.83
B_{02}	22.90	24.85	26.11	27.24	28.63	25.95
$B_{2.5}$	23.13	23.55	24.84	26.13	27.22	24.97
Mean Zn	22.01	22.68	23.19	23.66	24.16	
	Boron		Zinc		Interaction	
SEm±	0.35		0.35		0.77	
CD (P=0.05)	0.98		0.98		2.20	

Table 6(b): Effect of boron and zinc on number of functional leaves plant^{-1} at harvest (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	20.91	21.08	21.07	21.07	21.06	21.04
B_{01}	21.03	21.87	21.86	21.85	21.84	21.69
$B_{1.5}$	23.27	23.26	23.25	23.24	23.23	23.25
B_{02}	23.32	25.32	26.60	27.74	29.16	26.43
$B_{2.5}$	23.55	24.09	25.30	26.62	27.72	25.45
Mean Zn	22.42	23.12	23.62	24.10	24.60	
	Boron		Zinc		Interaction	
SEm±	0.35		0.35		0.78	
CD (P=0.05)	0.99		0.99		2.22	

Number of functional leaves plant^{-1} was influenced significantly due to interaction effect of boron and zinc at all stages of crop growth except at 30 DAS where Number of functional leaves plant^{-1} recorded at par. At 45 days after sowing and at harvest stage, the maximum number of functional leaves plant^{-1} was recorded with the combined application where 2.0 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} were applied followed by the combined application where 2.0 kg boron ha^{-1} and 3.0 kg zinc ha^{-1} and 2.5 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} were applied they were statistically at par but significantly superior over all other treatment combinations at all stage of growth during both the years. The minimum number of functional leaves plant^{-1} was recorded with the combined application where 0 kg boron and 0 kg zinc ha^{-1} were applied at all stage of growth during both the years.

Number of branches plant^{-1}

The data pertaining to number of branches plant^{-1} of black gram at different successive growth stages are given in Table 7 (a and b) to 9 (a and b) and depicted diagrammatically in Fig. 3 for individual years. The number of branches plant^{-1} were affected significantly due to different treatments at successive growth stages of black gram crop.

The data revealed that number of branches plant^{-1} was influenced significantly due to different levels of boron at all the stages of crop growth. The number of branches plant^{-1} recorded at 30, 45 days after seeding and at harvest stage, both the higher levels of born recorded significantly more number of branches plant^{-1} over lower levels of boron. It is also clear from the data given in the Table that both of the higher levels of boron (2.0 and 2.5 kg ha^{-1}) being at par recorded significantly more number of branches plant^{-1} over low levels of boron treatment, likewise, the lower levels of boron (0 and 1.0 kg ha^{-1}) also recorded number of branches plant^{-1} at par to each other except 1.5 kg ha^{-1} of Boron application. However, 2.0 kg and 1.0 kg boron application recorded numerically higher values of number of branches plant^{-1} over 2.5 kg and 0 kg boron application, respectively, but statistically similar to each group of boron application at all the stages. While 1.5 kg ha^{-1} application of boron recorded significantly more number of branches plant^{-1} over 1.0 or 0 kg ha^{-1} application of boron at all stage of crop growth during both the year of experimentation.

As far as the various level of zinc applications were concerned, number of branches plant^{-1} was influenced significantly at all the stage of crop growth due to various levels of zinc application. The maximum number of branches plant^{-1} recorded with the treatment where 4.0 kg zinc ha^{-1} were applied followed by the application of zinc @ 3.0 and 2.0 kg ha^{-1} they were statistically at par but significantly superior over all other treatments at all stages of growth during both the years. The minimum number of branches plant^{-1} was recorded in control plots (0 kg zinc ha^{-1}) which was significantly at par with the treatment where 1.0 kg zinc ha^{-1} were applied at all stage of growth during both the years.

Number of branches plant^{-1} was influenced significantly due to combined applications of boron and zinc at 30, 45 days after sowing and at harvest stages. The data presented in Table- 7 (a and b) to 9 (a and b) indicate that the maximum number of branches plant^{-1} was recorded significantly higher in combined application of 2.0 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} as compared to rest of the treatment combinations but being recorded statistically at par with the combined application of 2.0 kg boron ha^{-1} and 3.0 kg zinc ha^{-1} and 2.5 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} at all stage of growth during both the years of experimentation. While the minimum number of branches plant^{-1} was recorded with the no application of boron and zinc at all stage of growth during both the years

Table 7(a): Effect of boron and zinc on number of branches plant^{-1} at 30 DAS (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	2.94	3.10	3.07	3.05	3.04	3.04
B_{01}	3.00	3.18	3.17	3.16	3.15	3.13
$B_{1.5}$	3.42	3.37	3.34	3.32	3.30	3.35
B_{02}	3.45	3.71	3.88	4.13	4.29	3.89
$B_{2.5}$	3.50	3.56	3.69	3.93	4.11	3.76
Mean Zn	3.26	3.38	3.43	3.52	3.58	
	Boron		Zinc		Interaction	
SEm±	0.05		0.05		0.11	
CD (P=0.05)	0.14		0.14		0.30	

Table 7(b): Effect of boron and zinc on number of branches plant^{-1} at 30 DAS (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	2.98	3.14	3.11	3.09	3.08	3.08
B_{01}	3.04	3.23	3.22	3.20	3.19	3.18
$B_{1.5}$	3.47	3.42	3.39	3.37	3.35	3.40
B_{02}	3.50	3.76	3.94	4.19	4.35	3.95
$B_{2.5}$	3.54	3.59	3.74	3.99	4.17	3.81
Mean Zn	3.31	3.43	3.48	3.57	3.63	
	Boron		Zinc		Interaction	
SEm±	0.06		0.06		0.13	
CD (P=0.05)	0.16		0.16		0.36	

Table 8(a): Effect of boron and zinc on number of branches plant^{-1} at 45 DAS (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	3.50	3.63	3.61	3.60	3.59	3.59
B_{01}	3.53	3.74	3.73	3.72	3.71	3.69
$B_{1.5}$	4.00	3.93	3.88	3.85	3.83	3.90
B_{02}	4.03	4.36	4.52	4.79	5.08	4.56
$B_{2.5}$	4.08	4.12	4.34	4.58	4.77	4.38
Mean Zn	3.83	3.96	4.02	4.11	4.20	
	Boron		Zinc		Interaction	
SEm±	0.06		0.06		0.14	
CD (P=0.05)	0.18		0.18		0.40	

Table 8(b): Effect of boron and zinc on number of branches plant^{-1} at 45 DAS (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	3.56	3.67	3.65	3.64	3.63	3.63
B_{01}	3.58	3.79	3.76	3.74	3.73	3.72
$B_{1.5}$	4.05	3.98	3.93	3.90	3.88	3.95
B_{02}	4.08	4.41	4.61	4.85	5.15	4.62
$B_{2.5}$	4.13	4.17	4.38	4.64	4.83	4.43
Mean Zn	3.88	4.00	4.07	4.15	4.24	
	Boron		Zinc		Interaction	
SEm±	0.07		0.07		0.15	
CD (P=0.05)	0.19		0.19		0.43	

Table 9(a): Effect of boron and zinc on number of branches plant^{-1} at harvest (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	3.83	3.97	3.95	3.94	3.93	3.92
B_{01}	3.86	4.09	4.08	4.07	4.06	4.03
$B_{1.5}$	4.38	4.30	4.25	4.21	4.19	4.27
B_{02}	4.41	4.77	4.95	5.24	5.56	4.99
$B_{2.5}$	4.46	4.51	4.75	5.01	5.22	4.79
Mean Zn	4.19	4.33	4.40	4.49	4.59	
	Boron		Zinc		Interaction	
SEm±	0.07		0.07		0.16	
CD (P=0.05)	0.20		0.20		0.45	

Table 9(b): Effect of boron and zinc on number of branches plant^{-1} at harvest (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	3.88	4.02	4.00	3.99	3.98	3.97
B_{01}	3.91	4.14	4.13	4.12	4.11	4.08
$B_{1.5}$	4.43	4.35	4.30	4.26	4.24	4.32
B_{02}	4.46	4.83	5.01	5.30	5.60	5.04
$B_{2.5}$	4.55	4.59	4.81	5.07	5.28	4.86
Mean Zn	4.25	4.39	4.45	4.55	4.64	
	Boron		Zinc		Interaction	
SEm±	0.06		0.06		0.14	
CD (P=0.05)	0.18		0.18		0.41	

Number of nodule plant^{-1}

The data pertaining to number of nodules plant^{-1} of black gram at 45 days after sowing are given in Table 10 (a and b) and depicted in Fig. 4. It is clear from the data that number of nodules plant^{-1} of black gram was affected significantly due different levels of boron as well as various levels of zinc alone and in combinations applied during both years of experimentation.

A perusal of data revealed that number of nodules plant^{-1} was influenced significantly due to different levels of boron, during both the years. The application of 2.0 kg boron ha^{-1} recorded maximum number of nodules plant^{-1} followed by the application where 2.5 kg born ha^{-1} were applied, both results were statistically at par but significantly superior over all other application of boron at successive growth stage during both the years. Both years of the experiment, the application of 1.5 kg boron ha^{-1} resulted in significantly more nodules plant^{-1} than the application where 1.0 kg boron ha^{-1} and 0 kg boron ha^{-1} were applied. The minimum number of nodules plant^{-1} was observed with the application of 0 kg boron ha^{-1} which was statistically at par with the application of 1.0 kg boron ha^{-1} successive growth stage during both years of experimentation.

Due to varying levels of zinc application at successive growth stage, the number of nodules plant^{-1} varied significantly. Zinc application of 4.0 kg ha^{-1} resulted in the greatest number of nodules plant^{-1} at 45 days after sowing stages, followed by zinc applications of 3.0 and 2.0 kg ha^{-1}. At 45 DAS stages during both years, these treatments were statistically equivalent, but significantly superior to all other treatments. In both years, the minimum number of nodules plant^{-1} obtained in the control plots (0 kg zinc ha^{-1}) was significantly equal to that in the treatment where 1 kg zinc ha^{-1} was applied at 45 DAS stage.

The number of nodules plant^{-1} increased with the combined use of boron and zinc. Data revealed that the interaction effect as also found to be significant regarding number of nodules plant^{-1} of black gram. Highest number of nodules plant^{-1} was obtained in treatment where combination of 2.0 kg boron and 4 kg zinc ha^{-1} were applied followed by the treatment where combination of 2.0 kg boron and 3 kg zinc ha^{-1} as well as 2.5 kg boron and 4 kg zinc ha^{-1} were applied, they were statistically at par but significantly superior over other treatment combinations, during both years. However, the minimum number of nodules plant^{-1} of blackgram was observed with the treatment where 0 kg boron and 0 kg zinc ha^{-1} were applied during both years.

Table 10(a): Effect of boron and zinc on number of nodules plant^{-1} at 45 DAS (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	23.88	24.08	24.07	24.06	24.06	**24.03**
B_{01}	24.02	24.98	24.97	24.96	24.96	**24.78**
$B_{1.5}$	26.58	26.57	26.56	26.55	26.54	**26.56**
B_{02}	26.64	28.91	30.38	31.68	33.31	**30.18**
$B_{2.5}$	26.97	27.40	28.89	30.40	31.66	**29.06**
Mean Zn	25.62	26.39	26.97	**27.53**	**28.10**	
	Boron		Zinc		**Interaction**	
SEm±	0.40		0.40		0.89	
CD (P=0.05)	1.13		1.13		2.53	

Table 10(b): Effect of boron and zinc on number of nodules plant^{-1} at 45 DAS (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	24.17	24.38	24.37	24.35	24.35	24.32
B_{01}	24.32	25.29	25.28	25.27	25.27	25.08
$B_{1.5}$	26.91	26.90	26.89	26.87	26.86	26.88
B_{02}	26.97	29.27	30.75	32.07	33.71	30.55
$B_{2.5}$	27.30	27.68	29.25	30.77	32.05	29.41
Mean Zn	25.93	26.70	27.30	27.87	28.45	
	Boron		Zinc		Interaction	
SEm±	0.41		0.41		0.91	
CD (P=0.05)	1.15		1.15		2.58	

Number of pods plant^{-1}

The data pertaining to number of pods plant^{-1} of black gram are given in Table 11 (a and b) and depicted diagrammatically in Fig. 4 for individual years. The number of pods plant^{-1} were affected significantly due to different treatments at successive growth stages of black gram crop.

The scrutiny of data revealed that there was a significant increase in the number of pods plant^{-1} with successive growth stage. Both the higher levels of born recorded significantly more number of pods plant^{-1} over lower levels of boron. It is also clear from the data that both of the higher levels of boron (2.0 and 2.5 kg ha^{-1}) being at par recorded significantly more number of pods plant^{-1} over lower levels of boron treatment, likewise, the lower levels of boron (0 and 1.0 kg ha^{-1}) also recorded number of pods plant^{-1} at par to each other except 1.5 kg ha^{-1} of Boron application, which recorded significantly more number of pods plant^{-1} over 0 or 1.0 kg ha^{-1} application of boron at successive growth stage. However, 2.0 kg and 1 kg boron application recorded numerically higher values of number of pods plant^{-1} over 2.5 kg and 0 kg boron application, respectively, but statistically similar to each group of boron application at successive stages during both the year of experimentation.

As far as the various level of zinc applications were concerned, number of pods plant^{-1} was influenced significantly due to various levels of zinc application. The maximum number of pods plant^{-1} recorded with the treatment where 4.0 kg zinc ha^{-1} was applied followed by the application of zinc @ 3.0 and 2.0 kg ha^{-1} they were statistically at par but significantly superior over all other treatments during both the years. The minimum number of pods plant^{-1} was recorded in control plots (0 kg zinc ha^{-1}) which was significantly at par with the treatment where 1.0 kg zinc ha^{-1} was applied during both years.

Number of pods plant^{-1} was influenced significantly due to combined applications of boron and zinc. The data indicate that the maximum number of pods plant^{-1} was recorded significantly higher in combined application of 2.0 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} as compared to rest of the treatment combinations but being recorded statistically at par with the combined application of 2.0 kg boron ha^{-1} and 3.0 kg zinc ha^{-1} and 2.5 kg boron ha^{-1} and 4.0 kg zinc ha^{-1} during both years of experimentation. While the minimum number of pods plant^{-1} was recorded with the no application of boron and zinc at successive growth stage during both years.

Table 11(a): Effect of boron and zinc on number of pods plant^{-1} (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	14.23	14.42	14.41	14.38	14.36	14.36
B_{01}	14.29	14.96	14.91	14.85	14.83	14.77
$B_{1.5}$	15.92	15.82	15.74	15.68	15.65	15.76
B_{02}	15.95	17.31	18.05	18.99	19.84	18.03
$B_{2.5}$	15.97	16.28	17.30	18.29	18.94	17.36
Mean Zn	15.27	15.76	16.08	16.44	16.72	
	Boron		Zinc		Interaction	
SEm±	0.24		0.24		0.53	
CD (P=0.05)	0.68		0.68		1.51	

Table 11(b): Effect of boron and zinc on number of pods plant^{-1} (2020-2021)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	14.37	14.57	14.56	14.53	14.51	14.51
B_{01}	14.44	15.12	15.06	15.00	14.98	14.92
$B_{1.5}$	16.08	15.98	15.90	15.84	15.81	15.92
B_{02}	16.12	17.49	18.23	19.18	20.04	18.21
$B_{2.5}$	16.13	16.45	17.48	18.48	19.13	17.53
Mean Zn	15.43	15.92	16.25	16.61	16.89	
	Boron		Zinc		Interaction	
SEm±	0.25		0.25		0.56	
CD (P=0.05)	0.71		0.71		1.59	

Seed yield

The data pertaining to seed yield of black gram are given in Table 14 (a and b) and depicted in Fig. 5. It is clear from the data that grain yield of black gram was affected significantly due different levels of boron as well as various levels of zinc alone and in combinations applied during both the years of experimentation.

Boron significantly increased the seed yield of black gram compared to no use of boron. The maximum seed yield recorded with the treatment where 2.0 kg ha^{-1} of boron was applied followed by the treatment where 2.5 kg of boron was applied though both were statistically at par but significantly superior over nil boron application, and lower level of application.

Data related to seed yield indicated that the application of zinc significantly increased seed yield over no zinc application. The highest seed yield was recorded under the application of 4 kg zinc ha^{-1} followed by the application of 3 kg zinc and 2 kg zinc ha^{-1} treatments and statistically being at par with each other. However, the increase was significant up to the application of 2 kg zinc ha^{-1} which was also found to be statistically at par with the application of 3 kg zinc ha^{-1}. Plots that did not receive zinc application during both years produced the lowest seed yield.

The seed yield further increased with the combined use of boron and zinc. Data revealed that the interaction effect was also found to be significant regarding seed yield of black gram. Highest seed yield was obtained in treatment where combination of 2.0 kg boron and 4 kg zinc ha^{-1} was applied followed by the treatment where combination of 2.0 kg boron and 3 kg zinc ha^{-1} was applied. However, both were statistically at par but significantly superior over other treatment combinations, during both the years.

Table 14(a): Effect of boron and zinc on number of seed yield (q ha^{-1}) (2019-2020)

Treatments	**Zn_0**	**Zn_1**	**Zn_2**	**Zn_3**	**Zn_4**	**Mean B**
B_{00}	7.25	7.55	7.54	7.53	7.52	7.48
B_{01}	7.46	7.96	7.95	7.94	7.93	7.85
$B_{1.5}$	8.37	8.35	8.33	8.31	8.29	8.33
B_{02}	8.62	9.28	9.61	10.18	10.43	9.62
$B_{2.5}$	8.61	8.82	9.27	9.88	10.14	9.35
Mean Zn	8.06	8.39	8.54	8.77	8.86	
	Boron		Zinc		Interaction	
SEm±	0.12		0.12		0.26	
CD (P=0.05)	0.33		0.33		0.74	

Table 14(b): Effect of boron and zinc on number of seed yield (q ha^{-1}) (2020-2021)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	7.32	7.63	7.62	7.61	7.59	7.55
B_{01}	7.54	8.04	8.03	8.02	8.02	7.93
$B_{1.5}$	8.46	8.43	8.41	8.39	8.37	8.41
B_{02}	8.71	9.38	9.71	10.28	10.54	9.72
$B_{2.5}$	8.70	8.91	9.37	9.98	10.24	9.44
Mean Zn	8.14	8.48	8.63	8.86	8.95	
	Boron		Zinc		Interaction	
SEm±	0.12		0.12		0.26	
CD (P=0.05)	0.34		0.34		0.75	

Stover yield

The data pertaining to stover yield of black gram are given in Table 15 (a and b) and depicted in Fig. 5. It is clear from the data that stover yield of black gram was affected significantly due different levels of boron as well as various levels of zinc alone and in combinations applied during both years of experimentation. A perusal of data revealed that stover yield was influenced significantly due to different levels of boron, during both the years. The application of 2.0 kg boron ha^{-1} recorded maximum stover yield followed by the application where 2.5 kg born ha^{-1} were applied, both results were statistically at par but significantly superior over all other application of boron during both the years. The minimum stover yield was observed with the application of 0 kg boron ha^{-1} during both years of experimentation. Due to varying levels of zinc application at successive growth stage, stover yield varied significantly. Zinc application of 4.0 kg ha^{-1} resulted in the greatest stover yield, followed by zinc applications of 3.0. During both years, these treatments were statistically equivalent, but significantly superior to all other treatments. The minimum stover yield obtained in the control plots (0 kg zinc ha^{-1}) was significantly equal to that in the treatment where 1 kg zinc ha^{-1} was applied during both years of experiment. 00

The straw yield further increased with the combined use of boron and zinc. Data revealed that the interaction effect was also found to be significant regarding stover yield of black gram. Highest stover yield was obtained in treatment where combination of 2.0 kg boron and 4.0 kg zinc ha^{-1} were applied followed by the treatment where combination of 2.0 kg boron and 3 kg zinc ha^{-1} as well as 2.5 kg boron and 4.0 kg zinc ha^{-1} and 2.5 kg boron and 3.0 kg zinc ha^{-1} were applied, they were statistically at par but significantly superior over other treatment combinations, during both years. However, the minimum stover yield of black gram was observed with the treatment where 0 kg boron and 0 kg zinc ha^{-1} was applied during both years.

Table 15(a): Effect of boron and zinc on number of stover yield (q ha^{-1}) (2019-2020)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	15.61	15.95	15.94	15.92	15.91	15.86
B_{01}	15.82	16.44	16.42	16.41	16.40	16.30
$B_{1.5}$	16.94	16.93	16.92	16.91	16.89	16.92
B_{02}	17.44	18.16	18.48	19.20	19.65	18.59
$B_{2.5}$	17.43	17.60	18.15	18.88	19.25	18.26
Mean Zn	16.65	17.02	17.18	17.46	17.62	
	Boron		Zinc		Interaction	
SEm±	0.13		0.13		0.30	
CD (P=0.05)	0.38		0.38		0.84	

Table 15(b): Effect of boron and zinc on number of stover yield (q ha^{-1}) (2020-2021)

Treatments	Zn_0	Zn_1	Zn_2	Zn_3	Zn_4	Mean B
B_{00}	15.69	16.03	16.02	16.00	15.99	15.94
B_{01}	15.90	16.53	16.50	16.49	16.48	16.38
$B_{1.5}$	17.03	17.01	17.00	16.99	16.98	17.00
B_{02}	17.53	18.25	18.57	19.29	19.75	18.68
$B_{2.5}$	17.51	17.69	18.24	18.98	19.34	18.35
Mean Zn	16.73	17.10	17.27	17.55	17.71	
	Boron		Zinc		Interaction	
SEm±	0.14		0.14		0.31	
CD (P=0.05)	0.40		0.40		0.74	

Discussion:

As far as the various level of zinc applications were concerned, growth parameters *viz*., plant height (cm), number of functional leaves plant-1, and number of branches plant-1 was influenced significantly at all the stage of crop growth due to various levels of zinc application. The maximum growth parameters *viz*., plant height, number of functional leaves plant-1, and number of branches plant-1 recorded with the treatment where 4.0 kg ha-1 zinc were applied followed by the application of zinc @ 3.0 and 2.0 kg ha-1 they were statistically at par but significantly superior over all other treatments at all stages of growth during both the years. The minimum growth parameters *viz*., plant height, number of functional leaves plant-1, and number of branches plant-1 was recorded in control plots which was significantly at par with the treatment where 1.0 kg ha-1 of zinc were applied at all stage of growth during both the years. The reason for higher values of growth parameter under these treatments had involvement of Zn in physiological processes possibly by promoting the production of auxin which are involved in the cell elongation and division, protein synthesis, membrane function, resistance to abiotic stresses and role of zinc in biosynthesis of Indole acetic acid and also increases chlorophyll production and photosynthesis, which can lead to increase biomass accumulation and overall plant growth. Seed and straw yield was influenced due to various levels of zinc application. Significantly, the highest seed, as well as straw yield of black gram can be attributed due to marked improvement in yield attributes under the application where 4.0 kg Zinc ha-1 were applied followed by the treatment where 3.0 and 2.0 kg zinc ha-1 were applied, these were statistically equivalent, but significantly superior to all other treatments. However, the increase was significant up to the application of 2 kg zinc ha-1 which was also found to be statistically at par with the application of 3 kg zinc ha-1. Plots that did not receive zinc application during both years produced the lowest seed, and stover yield. These results are corroborated with the finding of Ram and Habib *et al.* (2018) [5], Kuniya *et al.* (2018) [10], Kuldeep *et al.* (2018) [9] and Mahilane and Singh (2018) [11].

Application of 2.0 kg boron ha-1 was significantly increased plant height, number of functional leaves plant-1, number of branches plant-1 over 1.0 kg boron ha-1 and control (0 kg ha-1). The boron plays an important role in tissue differentiation and carbohydrate metabolism seed and stover yield is an ultimate result of growth and yield components. Boron showed significant influence on yield of crop. Significantly higher seed yield, stover yield as well as harvest index was obtained with 2.0 kg boron ha-1 as compared to 0 kg boron ha-1. The increased in yield might be due to positive effect of boron on yield attributes *viz*., pods plant-1, seeds pod-1 , and seed weight plant-1 and it play an important role in metabolic process. These primary yield components have been shown to be directly correlated with the yield. Movalia *et al.* (2020) [12], Naznin *et al.* (2020) [14], Kumar *et al*. (2020b), and MV and Singh (2022) [13].

Seed as well as straw yield further increased with the combined use of boron and zinc. Data revealed that the interaction effect was also found to be significant regarding seed and stover yield of black gram. Highest seed and stover yield were obtained in treatment where combination of 2.0 kg boron and 4 kg zinc ha-1 was applied followed by the treatment where combination of 2.0 kg boron and 3 kg zinc ha-1 was applied. However, both were statistically at par but significantly superior over other treatment combinations, during both the years.

Conclusion

On the basis of two years experimentation (*kharif* 2019 and 2020) conducted on sandy sandy loam soil of Eastern Plain Zone of Uttar Pradesh, it is concluded that. Application of 2.0 kg boron ha-1 alone proved most effective in enhancing growth parameters, yield attributes, seed yield, stover yield, nutrient concentration and uptake by seed and stover, protein content, porosity, water holding capacity, organic carbon (%), available nitrogen, available phosphorous, available potassium, available boron, available zinc, gross and net returns, as well as B: C ratio while also effective in minimizing the bulk and maximizing the particle density than 1.0 kg and 0 boron ha-1 respectively. The use of zinc application @ 4.0 kg ha-1 alone was most effective in enhancing growth parameters, yield attributes, seed yield, stover yield, nutrient concentration and uptake by grain and straw, protein content, porosity, water holding capacity, soil organic carbon (%), available nitrogen, available phosphorous, available potassium, available boron, available zinc, gross and net returns, as well as B: C ratio while also effective in minimizing the bulk and maximizing the particle density as compared to 1.0 kg zinc and 0 kg ha-1 respectively. Combined application of 2.0 kg boron + 4 kg zinc ha-1 was most effective in enhancing growth promoters, yield attributes, seed yield, stover yield, boron and zinc concentration in seed, nutrient uptake by seed, stover, organic carbon, available nitrogen, available boron, available zinc, net income as well as benefit cost ratio than control plot (0 kg boron and 0 kg zinc ha-1).

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