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RESEARCH PAPER

Effect of boron and molybdenum on chickpea under rainfed ecosystem

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Abstract: A field experiment was conducted at Regional Agricultural Research Station, Vijayapur, during *rabi,* season 2021-22, to study the effect of boron and molybdenum on chickpea under rainfed ecosystem. The experiment was laid out in RCBD (factorial concept) with three replications. There were sixteen treatment combinations, consisting of four levels of boron and four levels of molybdenum. Among the boron levels, soil feeding of boron @ 5 kg ha^{-1} recorded significantly higher grain and haulm yield (2124 and 2943 kg ha^{-1} respectively), similarly significantly higher yield attributes were also recorded in above treatment. However, it was on par with soil application of boron @ 2.5 kg ha^{-1} (2082 kg ha^{-1} and 2888 kg ha^{-1} respectively). Among the molybdenum treatments, seed treatment with molybdenum @1.5 g kg^{-1}seed recorded significantly higher grain yield (2052 kg ha^{-1}) and haulm yield (2831 kg ha^{-1}) as compare to other levels of molybdenum seed treatment. However, it was on par with seed treating with molybdenum @ 1.0 g kg^{-1} seed. Different combination of treatments had significant influence on chickpea yield. The treatment combination of soil application of boron @ 5 kg ha^{-1}and seed treatment with molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher grain yield (2418 kg ha^{-1}) and haulm yield (3206 kg ha^{-1}). Soil application of boron @ 5 kg ha^{-1} and seed treatment with molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher gross returns (₹ 1,08,804 ha^{-1}), net return (₹ 79,806 ha^{-1}) and BC ratio (3.75) than other treatments combination.

Key words: Boron, Chickpea, Molybdenum, Seed treatment

Introduction

Chickpea is the most important ancient pulse crop being traditionally grown during *rabi* season in India and cultivated mainly in semi-arid regions of the world. Chickpea is an ancient crop of modern time, which is cultivated in nearly 50 countries across the world. Chickpea accounts for more than 20 per cent of world pulse production and most of the world chickpea supply (80-90 per cent) comes from India. India ranks first in area and production in the world, with an area of 9.99 m ha, production of 11.97 m tonnes and productivity of 1192 kg ha^{-1}. Karnataka ranks fifth in the cultivation of chickpea with an area of 7.13 lakh ha and annual production of 4.45 lakh tons further the average productivity was 625 kg ha^{-1} (Indiastat, 2021). In the state, it is grown mainly during *rabi* season in black soil areas particularly in the Northern districts of the state *viz.,* Vijayapura, Dharwad, Belagavi, Gadag, Kalburgi, Bagalkot, Bidar, Haveri and Bellary.

Micronutrients plays pivotal role in increasing yield of pulses and oilseed legumes through their effects on symbiotic nitrogen fixing process. The deficiency of these nutrients has been very pronounced under multiple cropping systems due to excess removal by high yielding variety of crops and hence their exogenous supplies are very much required. Micronutrients often act as co-factors in enzyme system and they are also involved in the key physiological processes of photosynthesis and respiration (Mengal *et al.,* 2001) micronutrient deficiency can greatly disturb plant yield and quality.

Boron ranks third place among micronutrients in its concentration in seed and stem as well as its total amount after zinc. The critical level of boron with reference to crops in general was reported to be 0.15 to 0.20 ppm depending on soil types. Effects of molybdenum and boron on different grain legumes have been reported by many researchers. Boron is the only element that is normally present in soil solution and taken up by plants as non-ionized molecule over the pH range suitable for the plant growth. Boron plays a very important role in flower retention, pollen fertility and germination, pod setting and development and thus it appears, the requirement of Boron for reproductive development is more than for vegetative growth. Boron deficiency affects rate of water adsorption, carbohydrate translocation and the reproductive yield more than biomass yield. Boron deficiency severely inhibits pollen germination and pollen tube growth as well as the viability of pollen grains.

Molybdenum is required for the formation of the nitrate reductase enzyme and in the legume it plays an additional role in symbiotic nitrogen fixation. The nitrogen fixing enzyme, nitrogenase is composed of molybdenum and iron, without adequate quantities of these elements, nitrogen fixation process gets hampered. Molybdenum is an essential component of the enzyme nitrate reductase, which catalyzes the conversion of NO^-_3 to NO^-_2. It is also structural component of enzyme nitrogenase which is actively involved in atmospheric N_2 fixation by root nodule bacteria of leguminous crops. Molybdenum is essential for the process of atmospheric nitrogen fixation. Molybdenum acts in enzyme systems, which brings about oxidation-reduction reactions, especially the reduction of nitrates to ammonia prior to amino acids and protein synthesis in the cells of plant. It also acts as an activator of some dehydrogenase and phosphatase and co-factor in the synthesis of ascorbic acid. It must be present in plant if nitrates are to be metabolized in amino acids and proteins.

Material and methods

A field experiment was conducted to study the response of chickpea to graded levels of boron and molybdenum under rainfed condition during *rabi* 2021-22 at Regional Agricultural Research Station, Vijayapur, Karnataka on *vertisol* having pH 8.26 and EC 0.24 dSm^{-1}. Low in available Nitrogen (162 kg N ha^{-1}), medium in available Phosphorus (28 kg P_2O_5 ha^{-1}), high in available Potassium (325 kg K_2O ha^{-1}), boron (0.24 mg ha^{-1}) and Molybdenum (0.17 mg ha^{-1}). The experimental site was located at 16Ú 49' North latitude, 75Ú 43' East longitudes and at an altitude of 593 m above the mean sea level in the Northern Dry zone of Karnataka (Zone 3). During the year 2021-22, a total rainfall of 632.8 mm was received in 52 rainy days from January 2021 to December 2021 as against the normal rain of 594.4 mm which was received in 38 rainy days. During the experimental year July and September were the wettest months as compared to other months which received 146.4 and 161.7 mm rainfall, respectively. The total rainfall received during cropping period (October-2021 to January-2022) was 85.0 mm.

The experiment was laid out in Randomized Complete Block Design (factorial concept) with three replications. There were 16 treatment combinations consisting four levels of boron (soil application of boron @ 2.5, 5.0, 7.5 kg ha^{-1} and Control). And four levels of molybdenum (seed treatment with ammonium molybdate @ 1.0, 1.5, 2.0 g kg^{-1} seed and Control). The boron as per treatment is mixed with vermicompost at the rate of 50 kg ha^{-1} and incorporated/applied to soil at the time of sowing. The dose of ammonium molybdenum as per treatment dissolved in 50 ml of water and thoroughly mixed with seeds and shade dried for one hour at the time of sowing. The variety JG-11 was used and fertilizer application was followed on the basis of recommended package of practice (10:25:00 kg N, P_2O_5 and K_2O per ha) the N and P was applied in the form of urea and di ammonium phosphate respectively. Entire quantities of fertilizers were applied to the crops at the time of sowing as basal dose.

The yield attributes and yield observations of chickpea were recorded from the net plots and seed yield was converted to hectare basis and expressed in kilograms. The economics of each treatment was computed with prevailing market prices of the year. The yield was further computed for gross and net

Table 1. Yield attributes of chickpea as influenced by soil application of boron, seed treatment with molybdenum and their interactions

Treatment	Number of pods $plant^{-1}$	Grain weight $plant^{-1}$ (g)	Hundred grain weight (g)
Soil application of boron (M)			
M_1 : Soil application of boron @ 2.5 kg ha^{-1}	46.99	13.49	20.5
M_2 :Soil application of boron @ 5 kg ha^{-1}	47.14	13.78	20.6
M_3 : Soil application of boron @ 7.5 kg ha^{-1}	31.93	10.51	20.1
M_4 : Control (without boron application)	32.50	12.63	20.4
S.Em ±	1.37	0.26	0.51
C.D at 5%	3.96	0.76	NS
Seed treatment with molybdenum (S)			
S_1 : Seed treatment with molybdenum @ 1.0 g kg^{-1} seed	41.76	12.91	20.6
S_2 : Seed treatment with molybdenum @ 1.5 g kg^{-1} seed	42.48	13.31	20.7
S_3 : Seed treatment with molybdenum @ 2.0 g kg^{-1} seed	39.71	12.36	20.4
S_4 : Control (no seed treatment)	34.62	11.81	19.8
S.Em ±	1.37	0.26	0.51
C.D at 5%	3.96	0.76	NS
Interactions (M×S)			
M_1S_1	51.51	13.53	21.7
M_1S_2	50.11	14.60	19.9
M_1S_3	53.80	13.66	20.7
M_1S_4	32.54	12.16	19.6
M_2S_1	52.99	12.77	20.2
M_2S_2	53.94	15.42	22.3
M_2S_3	42.08	13.39	20.1
M_2S_4	39.54	13.53	19.7
M_3S_1	31.98	11.53	20.5
M_3S_2	33.38	10.57	20.0
M_3S_3	30.75	9.94	20.5
M_3S_4	31.62	9.99	19.5
M_4S_1	30.57	13.81	20.3
M_4S_2	32.47	12.67	20.5
M_4S_3	32.19	12.47	20.5
M_4S_4	34.76	11.58	20.5
S.Em ±	2.74	0.53	1.01
C.D at 5%	7.92	1.53	NS

NS –Non significant

returns as well BC ratio to assess the productivity. The benefit-cost ratio was worked out by dividing the gross returns by the total cost of cultivation of respective treatments. The data collected from the experiment at different growth stages and at harvest were subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used for 'F' and 't' tests was P=0.05. Critical Difference (CD) values were calculated at 5 per cent probability level if the F test is significant.

Results and discussion

Effect of different levels of boron and molybdenum application on yield and yield attributes of chickpea

The yield and yield attributes of chickpea were greatly influenced by soil application of boron and seed treatment with molybdenum. The number of pods per plant of chickpea was significantly differed due to different levels of boron and molybdenum application. The higher number of pods per plant (47.14) was reported with soil feeding of boron @ 5.0 kg ha^{-1} over other levels of boron application which is depicted in Table 1.

Among the molybdenum treatments, seed treated with molybdenum @ 1.5 g kg^{-1} seed recorded significantly highest number of pods per plant (42.48) as compared to other levels of molybdenum. Among different treatments combinations, soil feeding of boron @ 5.0 kg ha^{-1} and seed treatment with molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher number of pods per plant (53.94) as compared to other treatment combinations.

Grain weight per plant differed significantly due to soil application of boron, seed treatment with molybdenum and their interactions however the hundred grain weight was not significant (Table 1). Significantly highest grain weight (13.78 g) and hundred grain weight (20.06 g) was documented with soil feeding of boron @ 5.0 kg ha^{-1} over the other levels of boron but it was on par with soil feeding of boron @ 2.5 kg ha^{-1} (13.49 g plant^{-1} and 20.5 g).

Among the molybdenum treatments, seed treated with molybdenum @ 1.5 g kg^{-1} seed (13.3 g) recorded significantly the highest grain weight per plant and numerically higher hundred grain weight (20.07 g) as compared to other levels of molybdenum. Among different treatments combinations, soil feeding of boron @ 5.0 kg ha^{-1} and seed treated with

Table 2. Grain yield, haulm yield and harvest index of chickpea as influenced by soil application of boron, seed treatment with molybdenum and their interactions

Treatment	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{1})	Harvest index (%)
Soil application of boron (M)			
M_1 : Soil application of boron @ 2.5 kg ha^{-1}	2083	2889	41.91
M_2 :Soil application of boron @ 5 kg ha^{-1}	2124	2944	41.86
M_3 : Soil application of boron @ 7.5 kg ha^{-1}	1657	2323	41.87
M_4 : Control (without boron application)	1855	2433	43.37
S.Em ±	48	70	0.94
C.D at 5%	137	201	NS
Seed treatment with molybdenum (S)			
S_1 : Seed treatment with molybdenum @ 1.0 g kg^{-1} seed	2033	2739	42.87
S_2 : Seed treatment with molybdenum @ 1.5 g kg^{-1} seed	2052	2831	42.04
S_3 : Seed treatment with molybdenum @ 2.0 g kg^{-1} seed	1904	2681	41.43
S_4 : Control (no seed treatment)	1730	2338	42.68
S.Em ±	48	70	0.94
C.D at 5%	137	201	NS
Interactions (M×S)			
M_1S_1	2271	2999	43.34
M_1S_2	2260	3067	42.43
M_1S_3	1949	2820	40.91
M_1S_4	1851	2669	40.96
M_2S_1	2194	3192	40.82
M_2S_2	2418	3206	43.03
M_2S_3	2192	2834	43.62
M_2S_4	1694	2543	39.98
M_3S_1	1739	2626	39.87
M_3S_2	1620	2218	42.42
M_3S_3	1658	2510	39.78
M_3S_4	1611	1938	45.41
M_4S_1	1928	2137	47.44
M_4S_2	1912	2835	40.28
M_4S_3	1817	2559	41.40
M_4S_4	1763	2202	44.36
S.Em ±	95	139	1.89
C.D at 5%	275	402	NS

NS –Non significant

molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher grain weight per plant (15.42 g) as compared to other treatment combinations. However, it was on par with soil feeding of boron @ 2.5 kg ha^{-1} and seed treated with molybdenum @ 1.5 g kg^{-1} seed (14.60 g $plant^{-1}$). These results were in concurrence with the findings of Rathi (2016) in black gram and Alam and Islam (2016) in green gram.

Significantly higher grain yield per hectare was recorded in the treatment soil feeding with boron @ 5 kg ha^{-1} (2124 kg ha^{-1}) compared to soil application of boron @ 7.5 kg ha^{-1} and control (without boron application). However, it was on par with soil application of boron @ 2.5 kg ha^{-1} (2083 kg ha^{-1}) (Table 2). Increase in the grain yield may be attributed due to proper nutrition, which play an important role in hormone synthesis and translocation, carbohydrate metabolism and DNA synthesis and probably contributes to additional growth and yield. Similar result was obtained by Kalyani *et al.* (1993) in pigeonpea. Boron is involved in cell wall development, cell distribution root and shoot elongation and pollen tube germination which might have contributed to better growth. Similar results were also recorded by Ali and Mishra (2001) in chickpea.

Among the molybdenum treatments, seed treated with molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher grain yield (2052 kg ha^{-1}) as compared to other levels of molybdenum. Seed treated with Mo resulted an increase in seed yield might be due to enhanced chlorophyll formation which enhances photosynthesis resulting in increased yield attributes which ultimately increased the seed yield. Similar results were reported by Deo and Kothari (2002) they reported that the seed yield was enhanced by seed treatment with 3.5 g sodium molybedate kg^{-1} seed in chickpea. Among different combinations of treatments, soil feeding of boron @ 5.0 kg ha^{-1} and seed treated with molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher grain yield (2418 kg ha^{-1}) as compared to other combinations

The significant increase in yield and yield attributes in this treatment combination may be due to better nodulation and uptake of nutrient and also boron helps for better retention of flower and good pod setting which is evidenced from more number of pods per plant recoded in above treatment combination. Similar response has also been reported by Das *et al.* (2012).

Table 3. Economics of chickpea as influenced by soil application of boron, seed treatment with molybdenum and their interactions

Treatment	Gross returns (₹ ha^{-1})	Cost of Cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C
Soil application of boron (M)				
M_1 : Soil application of boron @ 2.5 kg ha^{-1}	93726	28698	65028	3.27
M_2 :Soil application of boron @ 5 kg ha^{-1}	95599	28973	66626	3.30
M_3 : Soil application of boron @ 7.5 kg ha^{-1}	74571	29248	45322	2.55
M_4 : Control (without boron application)	83467	28423	55044	2.94
S.Em ±	1970	-	1970	0.07
C.D at 5%	5691	-	5691	0.20
Seed treatment with molybdenum (S)				
S_1 : Seed treatment with molybdenum @ 1.0 g kg^{-1} seed	91494	28828	62666	3.18
S_2 : Seed treatment with molybdenum @ 1.5 g kg^{-1} seed	92356	28861	63496	3.20
S_3 : Seed treatment with molybdenum @ 2.0 g kg^{-1} seed	85683	28893	56791	2.97
S_4 : Control (no seed treatment)	77830	28763	49067	2.71
S.Em ±	1970	-	1970	0.07
C.D at 5%	5691	-	5691	0.20
Interactions (M×S)				
M_1S_1	102214	28690	73524	3.56
M_1S_2	101686	28723	72963	3.54
M_1S_3	87715	28755	58960	3.05
M_1S_4	83289	28625	54664	2.91
M_2S_1	98749	28965	69784	3.41
M_2S_2	108804	28998	79806	3.75
M_2S_3	98636	29030	69606	3.40
M_2S_4	76207	28900	47307	2.64
M_3S_1	78271	29240	49031	2.68
M_3S_2	72899	29273	43626	2.49
M_3S_3	74620	29305	45315	2.55
M_3S_4	72493	29175	43318	2.48
M_4S_1	86740	28415	58325	3.05
M_4S_2	86036	28448	57588	3.02
M_4S_3	81763	28480	53283	2.87
M_4S_4	79330	28350	50980	2.80
S.Em ±	3941	-	3941	0.14
C.D at 5%	11381	-	11381	0.40

Effect of different levels of boron and molybdenum application on economics of chickpea

Soil feeding with boron @ 5 kg ha^{-1} recorded significantly higher gross returns (₹ 95,599 ha^{-1}), net returns (₹ 66,626 ha^{-1}) and BC ratio (3.30) as compared to other levels of boron. Among molybdenum treatment, significantly higher gross returns (₹ 92,356 ha^{-1}), net returns (₹ 63,496 ha^{-1}) and BC ratio (3.20) was obtained from the treatment seed treated with molybdenum @ 1.5 g kg^{-1} seed compared to Mo levels.

Among different combinations of boron and molybdenum treatments, soil feeding with boron @ 5 kg ha^{-1} and seed treating with molybdenum @ 1.5 g kg^{-1} seed recorded significantly higher gross returns (₹ 1,08,804 ha^{-1}), net returns (₹ 79806 ha^{-1}) and BC ratio (3.75) than other combinations. This might be due to increase in grain and haulm yield as a result of better utilization of both applied and native nutrients. Similar results were also reported by Kathyayani *et al.* (2021) in black gram.

From the present investigation, it can be concluded that combined effect of, soil feeding of boron @ 5 kg ha^{-1} and seed treating with molybdenum @ 1.5 g kg^{-1} seed resulted in increased yield parameters, seed yield, maximum net returns and benefit cost ratio in chickpea.

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