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Interactive effects of boron and molybdenum fertilizers on growth and yield of groundnut (*Arachis hypogaea* L.) under calcareous soil

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Abstract
A pot experiment with medium black calcareous soil was conducted to assess the interactive effects of boron (B) and molybdenum (Mo) fertilizers on the growth and yield of groundnut. The experiment comprising of five levels of boron viz., 0, 2, 4, 8 and 10 kg B ha^{-1} and three levels of molybdenum viz., 0, 1, 2 kg Mo ha^{-1}. Experiment was laid out in Factorial Completely Randomization Design and replicated thrice. The results of the experiment revealed that the application of 8 kg B ha^{-1} along with 1 kg Mo ha^{-1} significantly increased the value of number of nodules per plant, nodules dry weight per plant, number of mature pods per plant, pod yield. In case haulm yield significantly higher value was recorded with application 10 kg B ha^{-1} and 1 kg Mo ha^{-1}.

Keywords: *Arachis hypogaea* L., boron, molybdenum, interaction

Introduction

Groundnut (*Arachis hypogaea* L.) is a legume crop of family *Fabaceae* (or *Leguminosae*) mostly grown for its edible seeds and oil production in the world. It is also known as pea-nut. It is native to South America (Brazil), best grown in tropical and sub tropical region of the world at a latitudes 400 N to 400 S. Seed oil content of groundnut is 46-52 %, while carbohydrates and protein percentage is 18 and 30% respectively. Like other legumes groundnut has the capacity to fix atmospheric nitrogen through symbiotic nitrogen fixing bacteria in root nodules which mean peanut plant required less N containing fertilizers, it also improve N content in soil which make this plant valuable in crop rotation (Sakarvadia *et al.*, 2019) [17]. In India, groundnut is grown in 11 states, accounts for 29 percent of total production of oilseed. Oilseed occupies an important position in Indian economy by contributing about 4% Gross National Product (GNP). At the present level area and production, it occupies about 75.72 lakh tones and productivity is about 1210 kg ha^{-1} in India. Though the share of groundnut in the total oil seed production in India has been falling since 1950, when it was 70% to the present level of 33%, groundnut is still a major oilseed crop in India. Its production decides not only the price of groundnut oil in any year, but also the price of most of other edible oils. Groundnut is annually grown on about 24 M ha of land in about 120 countries under different agro-climatic zones between 400S and 400N (Anon., 2013) [2]. In India, it is cultivated on an area of 5.53 M ha with production of 9.67 M tones and productivity of 1750 kg ha^{-1} during 2013-2014 (Anon., 2015) [4]. Gujarat produce 6.84 M tones of oilseed with the share of 20.80 % Gujarat is leading state in term of total oilseed production. In India total groundnut production is 9.67 M tones from area of 5.5 M ha, with Gujarat produce 4.92 M tones which share 50% of total groundnut production (Anon., 2014) [3]

Groundnut production in Saurashtra exhibited diminishing trend during last three decade, this may be partly because of nutritional disorder caused due to continuous mono cropping of groundnut. Boron is one of them as the soils are calcareous, which restricts the boron availability. Boron is unique among the essential mineral micronutrients because it is the only element that is normally present in soil solution as a non - ionized molecule over the pH range suitable for plant growth. Boron is involved in the transformation of sugar and starch formation. It also influences cell development and elongation. Boron affects carbohydrate metabolisms and starch formation and synthesis of proteins of proteins. Addition of boron (2 ppm) in groundnut increased the yield by 18 per cent (Golakiya and Patel, 1986a) [7] and improved the quality (Golakiya, 1988) [6] through suitable changes in yield attributes (Sutaria and Golakiya, 1990) [20]. 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 and without adequate quantities of these elements, nitrogen fixation can't occur. Muralidharan and George (1971) [13] found that Mo increased the vegetative growth and weight of nodular materials and finally the yield of groundnut. The studies by Noor *et al.*, 1997 [16] indicated that application of molybdenum increased the yield, nodulation and oil content in groundnut. The functions of molybdenum in leguminous plants include nitrate reduction, nodulation, nitrogen fixation and general metabolism (Togay *et al.*, 2008) [22].

Materials and Methods

The pot experiment was conducted at net house, Department of Agricultural Chemistry and Soil Science, College of Agriculture, Junagadh Agricultural University, Junagadh during summer season of 2016.

Table 1: Soil physicochemical characteristics and mineral nutrient status of the experimental

Soil depth (cm)	Mechanical Composition			
	Sand %	Silt %	Clay %	Texture class
0-15	15.01	28.96	56.03	Clayey

Soil depth (cm)	Chemical Composition												
	$pH_{2.5}$	$EC_{2.5}$	O.C	N	P	K	S	Fe	Mn	Zn	Cu	B	Mo
		(dSm^{-1})	(g kg^{-1})	(kg ha^{-1})			(ppm)						
0-15	8.00	0.58	4.10	212.0	28.63	257.0	10.02	5.24	12.78	0.72	1.21	0.63	0.070

The experiment comprised of total fifteen treatment combinations in which five levels of boron (0, 2, 4, 8 and 10 B kg ha^{-1}) and three levels of molybdenum (0, 1 and 2 Mo kg ha^{-1}) were laid out in Completely Randomization Design having factorial concept with three replications. The fertilizer application was done with fixed doses of nitrogen at 25 kg ha^{-1}, phosphorus at 50 kg ha^{-1} and potassium at 50 kg ha^{-1}. Boron and molybdenum application was done according to the treatments. The nutrients of N, P, K, B and Mo were applied by using sources of Urea, DAP, MOP, Boric acid and Ammonium molybdate, respectively. The Groundnut variety "Gujarat Groundnut-31" was planted in fourth week of February. A week after germination five plants per each pot were maintained under normal practices. The crop was raised with all the standard package of practices and protection measures also timely carried out as they required. The experimental data recorded for growth parameters, yield attributes and yield parameters were statistically analyzed for level of significance.

Results and Discussion

Growth parameters, yield attributes and yield

Effect of Boron

Branches per plant (3.89) recorded significantly the highest value with application of 10 kg B ha^{-1} (B_4). While, significantly higher value of plant height (23.30 cm), numbers of pegs per plant (26.04), number of nodules per plant (91.57) and nodules dry weight per plant (0.231 g $plant^{-1}$) were recorded with application of 8 kg B ha^{-1} (B_3) as compare to control. Boron is important for root and shoots growth, flower fertility and responsible for the cell wall formation and stabilization. Boron is essential nutrient for nodule forming bacteria therefore, increased nodule count resulting in positive effect on biometric parameters of plants. These results already agreement with those reported by Bhagiya *et al.* (2005) [5], Mallick and Raj (2015) [10] and Hirpara *et al.* (2017) [8]. Application of 8 kg B ha^{-1} recorded significantly the highest values of number of pods per plant (10.556), number of mature pods per plant (7.572), shelling percentage (67.15), pod yield (19.75 g $plant^{-1}$). Significantly higher value of haulm yield (18.56 g $plant^{-1}$) was recorded with application of 10 kg B ha^{-1} (Table 2). As boron is required for cell differentiation, development and growth of pollen grains. Boron might have brought increase translocation of photosynthates, resulting in increased pollination and seed setting which in turn might have brought yield characters. Close agreement with the results obtained by Naiknaware *et al.* (2015) [15], Modhavadiya *et al.* (2018) [11] and Srinivasan *et al.* (2008).

Table 2: Effect of boron and molybdenum on growth parameters, yield attributes, yield of summer groundnut at harvest

Treatments	Plant height (cm)	No. of branches per plant	No. of pegs per plant	No. of nodules per plant	Nodules dry weight per plant (g)	No. of pods per plant	No. mature pods per plant	No. of immature pods per plant	Shelling %	Pod yield per plant (g)	Haulm yield per plant (g)
Boron levels (kg ha^{-1})											
B_0- Control	15.14	3.20	14.67	74.68	0.178	7.018	3.961	3.057	61.83	13.05	13.48
B_1 – 2	21.33	3.58	16.89	84.91	0.207	7.320	4.253	3.067	64.83	14.99	16.34
B_2 – 4	22.40	3.71	20.05	89.87	0.222	9.928	6.924	3.003	66.14	19.31	17.08
B_3 – 8	23.30	3.80	26.04	91.57	0.231	10.556	7.572	2.983	67.15	19.75	17.59
B_4- 10	22.10	3.89	25.72	91.18	0.227	10.534	7.541	2.993	66.55	19.28	18.56
S.Em±	0.63	0.07	0.51	1.16	0.003	0.176	0.121	0.058	0.87	0.34	0.41
C.D. at 5%	1.82	0.20	1.47	3.36	0.009	0.509	0.348	NS	2.52	0.99	1.17
Molybdenum levels (kg ha^{-1})											
Mo_0-Control	19.87	3.22	18.79	70.28	0.170	8.576	5.510	3.066	62.52	16.04	14.44
Mo_1- 1	21.50	4.02	21.78	95.01	0.236	9.589	6.625	2.964	68.89	18.23	18.64
Mo_2- 2	21.19	3.67	21.45	94.04	0.232	9.048	6.016	3.032	64.49	17.56	16.76
S.Em±	0.49	0.05	0.40	0.90	0.002	0.137	0.093	0.045	0.68	0.26	0.31
C.D. at 5%	NS	0.15	1.14	2.60	0.007	0.395	0.270	NS	1.96	0.76	0.91

Interaction (B×Mo)											
S.Em±	1.09	0.12	0.88	2.01	0.005	0.306	0.209	0.100	1.51	0.59	0.70
C.D. at 5%	NS	NS	NS	5.81	0.016	NS	0.603	NS	NS	1.71	2.03
C.V.%	9.0	5.6	7.4	4.0	4.3	5.8	5.9	5.7	4.02	5.93	7.32

Effect of molybdenum

Application of 1 kg Mo ha^{-1} recorded significantly the highest value of number of branches per plant (4.022), number of pegs per plant (21.78) at harvest, number of nodules per plant (95.01) and nodules dry weight per plant (0.236 g $plant^{-1}$) at harvest as compare to control. Molybdenum can play a vital role in increasing the nitrogen fixation process by *Rhizobium* and is responsible for the formation of nodule tissue and increase in N_2 fixation. Molybdenum is a constituent of the *nitrogenase* enzyme and every bacterium, which fixes. nitrogen, need molybdenum during the fixation process. These results already agreement with those reported by Nadia Gad (2012) and Movalia *et al.* (2018). Application of 1 kg Mo ha^{-1} (Mo_1) recorded significantly the highest values of number of pods per plant(9.589), number of mature pods per plant(6.625), shelling percentage (68.89 %), pod yield (18.23 g $plant^{-1}$) and haulm yield (18.64 g $plant^{-1}$) as compare to control (Table 2). Molybdenum is essential for N_2 fixation, which has ensured better N supply to the crop and activation of enzyme *nitrate reductage*, a soluble molybdoflavoprotein (Tandan, 1995) contributing to better growth and yield of the crop, nodulation, nitrogen fixation and general metabolism. The present findings are in close agreement with the results obtained by Bhagiya *et al.* (2005) [5], Srinivasan *et al.* (2007) [18] and Hirpara *et al.* (2019) [9].

Interaction Effect

Number of nodules per plant (104.45), nodules dry weight (0.262 g $plant^{-1}$), number of mature pods per plant (8.700) and pod yield (21.30 g $plant^{-1}$) were obtained significantly higher under application of boron @ 8 kg ha^{-1} (B_3) along with molybdenum @ 1 kg ha^{-1} (Mo_1). While, Application of boron @ 10 kg ha^{-1} (B_4) along with molybdenum @ 1 kg ha^{-1} (Mo_1) resulted in significantly higher haulm yield obtained with the value of 21.23 g $plant^{-1}$ (Table 5). The synergistic influence of these micronutrients helped augmenting nitrogen fixation, better *Rhizobial* growth, increase pollination, seed setting and photosynthesis. The present findings are in close agreement with the results obtained by Bhagiya *et al.* (2005) [5] and Adkine *et al.* (2011) [1].

Table 3: Interaction effect of boron and molybdenum on number of nodules per plant and nodules dry weight (g $plant^{-1}$) of summer groundnut

Number of nodules $plant^{-1}$					Nodules dry weight (g $plant^{-1}$)				
Level of Boron	Level of molybdenum				Level of Boron	Level of molybdenum			
	Mo_0	Mo_1	Mo_2	Mean		Mo_0	Mo_1	Mo_2	Mean
B_0	68.31	76.38	79.35	74.68	B_0	0.163	0.181	0.188	0.178
B_1	69.34	91.52	93.88	84.91	B_1	0.165	0.230	0.228	0.207
B_2	70.28	100.45	98.88	89.87	B_2	0.166	0.252	0.248	0.222
B_3	72.43	104.45	97.83	91.57	B_3	0.186	0.262	0.245	0.231
B_4	71.02	102.26	100.25	91.18	B_4	0.172	0.256	0.251	0.227
Mean	70.28	95.01	94.04		Mean	0.170	0.236	0.232	
S.Em±	2.01				S.Em±	0.005			
C.D. at 5%	5.81				C.D. at 5%	0.016			

Table 4: Interaction effect of boron and molybdenum on number of mature pods per plant and pod yield (g $plant^{-1}$) of summer groundnut

Number of mature pods per plant					Pod yield (g $plant^{-1}$)				
Level of Boron	Level of molybdenum				Level of Boron	Level of molybdenum			
	Mo_0	Mo_1	Mo_2	Mean		Mo_0	Mo_1	Mo_2	Mean
B_0	3.707	4.117	4.060	3.961	B_0	10.43	14.05	14.69	13.05
B_1	4.013	4.697	4.050	4.253	B_1	14.07	15.18	15.72	14.99
B_2	6.083	7.653	7.037	6.924	B_2	18.42	20.11	19.41	19.31
B_3	6.683	8.700	7.333	7.572	B_3	18.91	21.30	19.04	19.75
B_4	7.063	7.960	7.600	7.541	B_4	18.36	20.52	18.96	19.28
Mean	5.510	6.625	6.016		Mean	16.04	18.23	17.56	
S.Em±	0.209				S.Em±	0.59			
C.D. at 5%	0.603				C.D. at 5%	1.71			

Table 5: Interaction effect of boron and molybdenum on haulm yield (g $plant^{-1}$) of summer groundnut

Haulm yield (g $plant^{-1}$)				
Level of Boron	Level of molybdenum			
	Mo_0	Mo_1	Mo_2	Mean
B_0	11.84	13.80	14.81	13.48
B_1	15.08	17.71	16.23	16.34
B_2	14.50	20.10	16.64	17.08
B_3	15.02	20.36	17.39	17.59
B_4	15.74	21.23	18.72	18.56
Mean	14.44	18.64	16.76	
S.Em±	0.70			
C.D. at 5%	2.03			

Conclusion
Based on the experimental results, it can be concluded that obtaining significantly higher growth parameters, yield attributes, pod and haulm yield of groundnut (Summer, Variety GJG-31) was fertilizing with boron 8 kg ha^{-1} along with molybdenum 1 kg ha^{-1} in medium black calcareous soils of South Saurashtra region of Gujarat.

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