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Response of phosphorus, boron and *rhizobium* inoculation on growth attributes and productivity of chickpea

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Abstract
Field experiments were conducted to evaluate Phosphorus, Boron and *Rhizobium* on growth attributes and yield of chickpea during rabi season 2018-19 and 2019-20 at students instructional farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur three levels of each phosphorus (0, 60, 90) kg ha^{-1} and boron (0, 1, 2) kg ha^{-1} was tested with and without *rhizobium* inoculation. The experiment consists of eighteen treatments with three replications. Results of the experiment indicated that plant height, number of nodules plant^{-1} and dry weight of nodules plant^{-1} increased with lapse of time and also due to application of phosphorus, boron and *rhizobium* inoculation during both the years of experimentation. Maximum plant height 23.03 cm, number of nodules plant^{-1} 16.21 and dry weight of nodules plant^{-1} 93.47 mg were recorded with T_{18} (P_{90}+B_2+Rh) during second year. Grain, stover and biological yield significantly increased by the use of phosphorus, boron and inoculation of *rhizobium* during both the years. Significant increase was noted with T_{14} (60 kg P_2O_5+1kg B ha^{-1} + rhizobium). Grain, yield increased from 12.40 to 19.90 Q ha^{-1} (60.48%) and stover 17.34 - 25.94 Q ha^{-1} (48.48%) during second year. Biological yield also increased from 29.74 Q ha^{-1} to 44.93 Q ha^{-1}(51.08%).

Keywords: Growth attributes, yield, chickpea, phosphorus, boron and *rhizobium*, Uday

Introduction
Pulses play a pivotal role and occupy a unique position in Indian agriculture by virtue of their inherent capacity to grow on marginal lands. It is an easily available source of protein in the rural heart of India. Pulses provide significant nutritional and health benefits and are known to reduce several non- communicable diseases such as colon cancer and cardio-vascular diseases (Jukanti *et al.* 2012) [8]. Chickpea (*Cicer arietinum* L.) is a major legume crop cultivated for its edible seeds legume of the genus *Cicer*, Tribe *Cicereae*, family *Fabaceae* (*leguminaceae*), and subfamily *Papilionaceae*. It provide protein rich diet to the vegetarian of the Indian and complement the stable cereals in the diets with proteins, essential amino acids, vitamins and minerals (Pingoliya *et al.* 2013) [27]. They contain 22-24% protein, which is almost twice the protein in wheat & thrice that of rice (Shukla *et al.* 2013) [43] and carbohydrate (61.51%), fat (4.5%) and relatively free from anti nutritional factors (Saxena, 1990) [34]. Chickpea is rich in protein content (20.47g/100g), carbohydrate (62.95g/100g), fibre (12.2g/100g), phosphorous (252mg/l00g), high amount of minerals such as calcium (57mg/100g), magnesium (79mg/100g), iron (4.31mg/l00g) and zinc (15mg/100g), low in fat content and most of it is polyunsaturated (Wallace *et al.* 2016) [49]. Its nomenclature in different countries is well documented as gram, chickpea, hommos, chana, chieting vetch, nakhud, nakhut, kicher, pois chice, garbarzo etc. (Malik *et al.* 2003) [12]. Chickpea has many local names: hamaz (Arab world), shimbra (Ethiopia), nohud or lablabi (Turkey), chana (India) and garbanzo (Latin America) (Muehlbauer and Tullu, 1997) [16]. It is originated in south eastern turkey (Redden *et al.* 2007) [30]. Chickpea is the second most important pulse crop after pigeon pea in the world for human diet and other uses. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen (Balai *et al.* 2017) [4].

Legumes are heavy feeder of phosphorus and less responsive to nitrogen because of their capacity to meet their own nitrogen requirement through symbiotic nitrogen fixation (kumar *et al.* 2016). Phosphorus nick named as “energy currency” is a major plant nutrient next to nitrogen in augmenting plant metabolic activity ultimately affecting the crop yield. Phosphorus deficiency can limit nodule number, leaf area, and biomass and grain development in legumes.

Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy (Schulze *et al.* 2006) [35] and energy generating metabolism strongly depends upon the availability of P (Plaxton, 2004) [25].

Boron significantly affected the seed yield of chickpea (Khanam *et al.* 2000) [9]. Boron deficiency limits chickpea productivity less than Zn deficiency (Ahlawat *et al.* 2007) [1]. Boron application is most important when boron concentration in soil is below 0.3 mg kg^{-1} and crop response to boron application is higher in chickpea than in some cereals (Ahlawat *et al.* 2007) [1]. Seed yield of chickpea increased with the application of boron @ 1.5-2.5 kg ha^{-1} (Bharti *et al.* 2002).

Rhizobium are symbiotic bacteria that facilitate formation of nodules on the roots of legume hosts, within which the bacteria fix atmospheric nitrogen into ammonia. Symbiotic nitrogen fixation is the main route for sustainable input of nitrogen into ecosystems. Chick-pea (*Cicer arietinum* L.) is a major pulse crop in India. There is a good possibility to increase its production by exploiting better colonization of the roots and rhizosphere through application of effective nitrogen fixing bacteria to the seed or to the soil. This can minimize uses of nitrogenous fertilizer, which is very costly in this country.

Materials and Methods

Site Description: Field experiments were conducted at students instructional farm, Chandra Shekhar Azad university of Agriculture & Technology, Kanpur during the rabi season 2018-19 and 2019-20. The experimental field was well drained with uniform topography and assured source of water supply through tube well.

Geographical Location: Kanpur Nagar District is situated in subtropical and semi-arid zone between $25^0$26’ and $26^0$58’ north latitude and $79^0$31’ & $80^0$34’east longitude with an elevation of 125.8 m from sea level in the alluvial belt of indo- gangetic plains of central Uttar Pradesh in India.

Soil Status and Analysis method: The soil was, sandy loam texture having organic carbon 0.35% (by Walkley and Black, 1934) [50], pH 7.97, EC 0.36 dsm^{-1} by (Jackson 1973) [7] available N 197.25 kg ha^{-1}, (by Subbiah and Asija 1956) [44] P_2O_5 12.14 kg ha^{-1} (by Olsen *et al.* 1954) [22], K_2O 265.15 kg ha^{-1} (by Jackson 1973) [7] and B 0.33 mg ha^{-1} (by Jackson 1973) [7] at the start of the experiment in 0 to 15 cm soil layer during 2018-19.

Use of design, variety and sowing time: The experiment was laid out factorial randomized block design with three replications. Chickpea cultivar uday was sown in row 45 cm apart on 20 November in 2018 and 21 November in 2019 in field and harvested on 10^{th} April 2019 and 11^{th} April in 2020 respectively.

Time and method of fertilizer and irrigation application: Full dose of nitrogen and potash were applied uniformly at the time of sowing. Phosphorus, boron and *rhizobium* were applied as per treatments. N, P, K and B were applied through urea, SSP, muriate of potash and borax respectively. The crop received two uniform irrigations (pre sowing and pre flowering time).

Recorded observation

The observations for evaluation of the treatment effects were recorded on various plant characters during the course of investigation. In the present investigation, the plants were selected randomly in each plot and tagged with a level for recording various observations on growth and yield parameters. The Plant height, number of nodules $plant^{-1}$, dry wt. of nodules $plant^{-1}$, grain, straw and biological yield were recorded following standard procedures.

Plant height (cm): The height of the plants was recorded at periodic interval of crop growth i.e. at 30 and 60 DAS of crop. The plant height was taken from base of the plant (ground level) upto the last pair of leaves in cm. The already selected plants were used for this purpose. The average height of the five selected plants were taken for the purpose at each stage.

Number of nodules: Five plants were selected randomly from each plot for counting of nodules. Plants were digging out with the help of khurpi along with adhered soil. Nodules number counted and mean value of five plants was calculated as the number of nodules per plant. Observation was recorded after 30 and 45 days of sowing.

Dry matter accumulation: This observation was taken at 30, 45 and 60 DAS. Roots of the five sampled were cut and separated. Above ground part of all five plants was weighed at physical balance. These sample plants of fresh weight were sun dried and then oven dried at 60 ^{0}C for 24 hours and weight on electric operated top balance. The dry weight of individual components was recorded and to obtain dry weight (g $plant^{-1}$).

Harvesting and threshing: the crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually.

Grain yield: After threshing the grain yield from each plot was separately weighed and recorded after converting into quintals per hectare.

Stover yield: After subtracting the grain yield per plot from the total biological yield. After converting the yields into quintals per hectare, yields were recorded.

Biological yield (t ha^{-1}): Seed yield and Stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield

Statistical analysis: The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

Results and Discussion

Growth and yields

The data pertaining to growth parameter and yield of chickpea were presented in table 1 and 2.

Results of the experiment showed that plant height, number of nodules plant^{-1}, dry weight of nodules plant^{-1} positively influenced by the use of phosphorus, boron and *rhizobium* over their respective control. The growth parameter also increased with lapse of time. Maximum plant height 23.05 cm, number of nodules plant^{-1} 16.21 and dry weight nodules plant^{-1} 93.47 mg were recorded with T_{18} (P_{90}+B_2+Rh) at 60 days during second year and minimum plant height 9.10 cm, number of nodules plant^{-1} 8.14 and dry weigh of nodules plant^{-1} 42.78 mg recorded under T_1 (P_0+B_0) at 30 days during first year. The interaction between phosphorus, boron and *rhizobium* levels on growth attributes was not statistically significant. The growth parameters of chickpea might be increased due to essentiality of phosphorus and boron for growth and developments. Phosphorus play positive role in increasing nodule number, biomass and developments. Boron is essential micronutrient and very essential for cell division, nitrogen fixation and ultimately increased growth of chickpea. *Rhizobium* fix atmosphere nitrogen by symbiotic process and mobilize other nutrient to the plant. Since the aforesaid characters together are responsible for the growth and developments that they were improved due to application of P, B and *rhizobium*. This finding supported by Meena *et al.* (2001) [14] Ram and Dixit (2001) [29] Singh and Vaishya (2001) [42], Meena *et al.* (2002) [15], Sharma *et al.* (2002) [36], Rajput *et al.* (2002) [28], Nadeem *et al.* (2003) [18], Pathak *et al.* (2003) [23], Samiullah and Khan (2003) [32], Satish *et al.* (2003) [33] Sharma and Singh (2003) [38], Meena *et al.* (2004) [4], Shiva Kumar *et al.* (2004) [39] Choudhary and Goswami (2005) [5], Kumar and Sharma (2005) [10] Thenua *et al.* (2010) [45], Nawange *et al.* (2011) [20], Thenua and Ravindra (2011) [46], Kumar *et al.* (2019) [11] and Tripathy *et al.* (2019) [48].

Grain, stover and biological yield significantly increased due to use of phosphorus, boron and *rhizobium*. Significantly response on yield was recorded with T_{14} (P_{60}+B_1+Rh) over other treatments. The grain, stover and biological yield increased to the magnitude of 12.40 to 19.90 Q ha^{-1} (60.48%) 17.34- 25.94 Q ha^{-1} (48.48%) and 29.74- 44.93 (51.08%). The growth parameters and yield of chickpea might be increased due to essentiality of phosphorus and boron for growth and developments. Phosphorus play positive role in increasing nodule number, biomass and grain developments. Boron is essential micronutrient and very essential for cell division, nitrogen fixation and ultimately increased growth and yield of chickpea. *Rhizobium* fix atmosphere nitrogen by symbiotic process and mobilize other nutrient to the plant. Since the aforesaid characters together are responsible for the production of grain and straw and they were improved due to application of P, B and *rhizobium*. Considerable increased in grain and stover yield were observed because of the application of each fertilizer nutrients (P& B). This finding supported by Rao and shaktawat (2001) [31], Sharma *et al.* (2002) [36], Yadav and Rathore (2002) [51], Nilambari *et al.* (2003) [19], Pramanik and Singh (2003) [26], Tripathy *et al.* (2004) [47], Bhat *et al.* (2005) [2], Sharma and Rana (2006) [37], Singh and Yadav (2008) [41], Pawar *et al.* (2009) [24], Nawange *et al.* (2011) [20], Singh and Singh (2012) [40], Murari *et al.* (2013) [17], Neenu *et al.* (2014) [21] and Kumar *et al.* (2019) [11].

Table 1: Effect of treatments on growth attributes of chickpea crop

Treatments	Plant height (cm)				No. of nodules plant^{-1}				Dry wt. of nodules at plant^{-1}			
	30 DAS		60 DAS		30 DAS		45 DAS		30 DAS		45 DAS	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
T_1	9.10	9.40	19.30	19.60	8.14	8.17	11.12	11.18	42.78	50.62	62.39	66.52
T_2	9.73	9.82	20.98	21.02	8.26	8.34	11.38	11.49	46.02	54.12	68.49	71.20
T_3	9.92	9.95	21.55	21.77	8.28	8.37	11.80	11.88	51.92	61.30	74.31	76.49
T_4	9.99	10.17	20.48	20.54	8.20	8.32	13.44	13.53	45.23	53.05	65.49	72.03
T_5	10.35	10.41	22.10	22.22	8.29	8.37	14.88	14.97	52.45	59.21	73.94	81.79
T_6	10.52	10.61	22.18	22.34	8.31	8.41	15.04	15.17	59.63	65.42	78.34	83.21
T_7	10.02	10.22	20.53	20.62	8.22	8.35	13.47	13.59	47.14	54.15	68.92	78.23
T_8	10.41	10.49	22.15	22.29	8.30	8.39	14.92	15.05	54.05	61.72	78.21	84.32
T_9	10.57	10.66	22.79	22.85	8.32	8.43	15.25	15.41	60.03	67.40	81.32	86.32
T_{10}	9.34	9.61	20.45	20.78	8.21	8.24	11.54	11.65	46.05	53.17	67.43	71.92
T_{11}	9.85	9.89	21.22	21.31	8.29	8.39	11.62	11.82	50.12	57.23	72.12	76.04
T_{12}	9.94	9.97	21.67	21.88	8.34	8.42	12.10	12.18	56.13	63.29	77.39	81.23
T_{13}	10.11	10.25	20.82	20.98	8.26	8.39	14.20	14.26	52.14	57.49	70.92	78.48
T_{14}	10.44	10.49	22.85	22.88	8.34	8.40	15.42	15.48	58.19	64.20	81.93	88.89
T_{15}	10.55	10.64	22.92	22.97	8.37	8.49	15.92	15.99	63.17	68.93	84.74	90.43
T_{16}	10.15	10.32	20.99	21.12	8.27	8.41	14.28	14.30	53.28	59.09	73.47	82.37
T_{17}	10.47	10.56	22.88	22.99	8.37	8.42	15.48	15.64	59.27	66.01	85.92	91.92
T_{18}	10.59	10.71	22.97	23.05	8.39	8.53	16.21	16.11	65.92	70.14	87.80	93.47
Overall mean	10.11	10.23	21.60	21.73	8.29	8.38	13.78	13.87	53.53	60.36	75.17	80.83
SEm±	P 0.17 B 0.17	P 0.16 B 0.16	P 0.31	P 0.32	P 0.16	P 0.17	P 0.36	P 0.33	P 0.82	P 0.95	P 1.79	P 2.03
			B 0.31	B 0.32	B 0.16	B 0.17	B 0.36	B 0.33	B0.82	B0.95	B 1.79	B 2.03
			Rh 0.25	Rh 0.26	Rh 0.13	Rh 0.13	Rh 0.29	Rh 0.27	Rh0.67	Rh0.78	Rh 1.47	Rh 1.66
C.D. at 5%	P 0.35 B 0.35	P 0.33 B 0.33	P 0.63	P 0.65	P N.S.	P N.S.	P 0.72	P 0.68	P 1.66	P 1.93	P 3.63	P 4.12
			B 0.63	B 0.65	B N.S.	B N.S.	B 0.72	B 0.68	B 1.66	B 1.93	B 3.63	B 4.12
			Rh0.51	Rh 0.53	Rh N.S.	Rh N.S.	Rh 0.59	Rh 0.55	Rh 0.95	Rh 1.57	Rh 2.97	Rh 3.36

T_1: P_0B_0 Rh_0 (0kg P+0 kg B ha^{-1} without *Rhizobium*), T_2: P_0B_1 Rh_0 (0 kg P+1 kg B ha^{-1} without *Rhizobium)*, T_3: P_0B_2 Rh_0 (0 kg P+2 kg B ha^{-1} without *Rhizobium*), T_4: P_1B_0 Rh_0 (60 kg P+0 kg B ha^{-1} without *Rhizobium*), T_5: P_1B_1 Rh_0 (60 kg P+1 kg B ha^{-1} without *Rhizobium*), T_6: P_1B_2 Rh_0 (60 kg P+2 kg B ha^{-1} without *Rhizobium*), T_7: P_2B_0 Rh_0 (90 kg P+0 kg B ha^{-1} without *Rhizobium*), T_8: P_2B_1 Rh_0 (90 kg P+1 kg B ha^{-1} without *Rhizobium*), T_9: P_2B_2 Rh_0 (90 kg P+2 kg B ha^{-1} without *Rhizobium*), T_{10}: P_0B_0 Rh_1 (0 kg P+0 kg B ha^{-1} with *Rhizobium*), T_{11}: P_0B_1 Rh_1 (0 kg P+1 kg B ha^{-1} with *Rhizobium*), T_{12}: P_0B_2 Rh_1 (0 kg P+2 kg B ha^{-1} with *Rhizobium*), T_{13}: P_1B_0 Rh_1 (60 kg P+0 kg B ha^{-1} with *Rhizobium*), T_{14}: P_1B_1 Rh_1 (60 kg P+1 kg B ha^{-1} with *Rhizobium*), T_{15}: P_1B_2 Rh_1 (60 kg P+2 kg B ha^{-1} with *Rhizobium*), T_{16}: P_2B_0 Rh_1 (90 kg P+0 kg B ha^{-1} with *Rhizobium*), T_{17}: P_2B_1 Rh_1 (90 kg P+1 kg B ha^{-1} with *Rhizobium*), T_{18}: P_2B_2 Rh_1 (90 kg P+2 kg B ha^{-1} with *Rhizobium*).

Table 2: Effect of treatments on grain, stover and biological yield of chickpea crop

Treatments	Yield (q ha^{-1})								
	Grain			Stover			Biological		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_1	12.07	12.40	12.24	16.88	17.34	17.11	28.94	29.74	29.34
T_2	13.92	14.10	14.01	19.40	19.62	19.51	33.32	33.38	33.35
T_3	14.85	15.10	14.98	20.59	20.91	20.75	35.44	36.01	35.73
T_4	14.37	14.65	14.51	19.54	19.86	19.70	33.91	34.51	34.21
T_5	16.65	16.90	16.78	22.22	22.46	22.34	38.87	39.36	39.11
T_6	17.71	17.89	17.80	23.11	23.29	23.20	40.82	41.18	41.00
T_7	15.68	15.82	15.75	20.22	20.37	20.30	35.90	36.17	36.04
T_8	17.95	18.13	18.04	22.94	23.00	22.97	40.87	41.13	41.01
T_9	18.51	18.72	18.62	23.41	23.56	23.48	41.92	42.28	42.10
T_{10}	13.42	13.85	13.64	18.76	19.34	19.05	32.19	33.19	32.69
T_{11}	15.15	15.80	15.47	21.10	21.96	31.53	36.25	37.76	37.00
T_{12}	16.05	16.30	16.18	22.21	22.49	22.35	38.26	38.79	38.53
T_{13}	16.92	17.05	16.99	22.92	22.96	22.94	39.84	40.01	39.92
T_{14}	18.15	18.52	18.33	24.06	24.44	24.25	42.21	42.96	42.59
T_{15}	19.05	19.33	19.19	24.76	25.03	24.89	43.81	44.36	44.09
T_{16}	17.82	18.03	17.93	22.93	23.16	23.05	40.75	41.19	40.97
T_{17}	19.00	19.32	19.16	24.13	24.49	24.31	43.13	43.81	43.47
T_{18}	19.65	19.90	19.78	24.77	25.94	25.35	44.42	44.93	44.67
Overall Mean	16.50	16.76	16.63	21.89	22.23	22.06	38.38	38.93	38.66
SEm±	P 0.55	P 0.61	P 0.40	P 0.69	P 0.89	P 0.54	P 0.82	P 0.93	P 0.61
	B 0.55	B0.61	B 0.40	B 0.69	B 0.89	B 0.54	B 0.82	B0.93	B 0.61
	Rh0.45	Rh0.50	Rh 0.32	Rh 0.56	Rh 0.72	Rh 0.42	Rh 0.67	Rh 0.76	Rh 0.52
C.D. at 5%	P 1.12	P 1.24	P 0.82	P 1.39	P 1.79	P 1.11	P 1.66	P 1.89	P 1.24
	B 1.12	B1.24	B 0.82	B 1.39	B1.79	B 1.11	B 1.66	B 1.89	B 1.24
	Rh 0.92	Rh1.01	Rh0.67	Rh 1.13	Rh 1.46	Rh 0.87	Rh 1.35	Rh 1.51	Rh 1.06

T_1: P_0B_0 Rh_0 (0kg P+0 kg B ha^{-1} without *Rhizobium*), T_2: P_0B_1 Rh_0 (0 kg P+1 kg B ha^{-1} without *Rhizobium)*, T_3: P_0B_2 Rh_0 (0 kg P+2 kg B ha^{-1} without *Rhizobium*), T_4: P_1B_0 Rh_0 (60 kg P+0 kg B ha^{-1} without *Rhizobium*), T_5: P_1B_1 Rh_0 (60 kg P+1 kg B ha^{-1} without *Rhizobium*), T_6: P_1B_2 Rh_0 (60 kg P+2 kg B ha^{-1} without *Rhizobium*), T_7: P_2B_0 Rh_0 (90 kg P+0 kg B ha^{-1} without *Rhizobium*), T_8: P_2B_1 Rh_0 (90 kg P+1 kg B ha^{-1} without *Rhizobium*), T_9: P_2B_2 Rh_0 (90 kg P+2 kg B ha^{-1} without *Rhizobium*), T_{10}: P_0B_0 Rh_1 (0 kg P+0 kg B ha^{-1} with *Rhizobium*), T_{11}: P_0B_1 Rh_1 (0 kg P+1 kg B ha^{-1} with *Rhizobium*), T_{12}: P_0B_2 Rh_1 (0 kg P+2 kg B ha^{-1} with *Rhizobium*), T_{13}: P_1B_0 Rh_1 (60 kg P+0 kg B ha^{-1} with *Rhizobium*), T_{14}: P_1B_1 Rh_1 (60 kg P+1 kg B ha^{-1} with *Rhizobium*), T_{15}: P_1B_2 Rh_1 (60 kg P+2 kg B ha^{-1} with *Rhizobium*), T_{16}: P_2B_0 Rh_1 (90 kg P+0 kg B ha^{-1} with *Rhizobium*), T_{17}: P_2B_1 Rh_1 (90 kg P+1 kg B ha^{-1} with *Rhizobium*), T_{18}: P_2B_2 Rh_1 (90 kg P+2 kg B ha^{-1} with *Rhizobium*).

Conclusions

On the basis of above results it can be concluded that application of 60 kg P_2O_5 and 1 kg B ha^{-1} along with *rhizobium* inoculation to the chickpea crop with recommended N K fertilizer is the best way for achieving higher growth attributes and productivity by chickpea crop.

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