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Effect of irrigation and phosphorus fertilization on growth, yield and nodulation of broad bean (*Vicia faba* L.)

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ABSTRACT

A field experiment was carried out during *rabi* seasons of 2009-10 and 2010-11 to study the effect of irrigation and phosphorus levels on growth, yield and nodulation of broad bean. Treatment receiving irrigation at ψ = -0.03 MPa at 30 cm soil depth (I_3) maintained its superiority with 5.11 and 34.97% higher seed yield compared to irrigation at ψ = -0.05 MPa at 30 cm soil depth (I_2) and rainfed (I_1), respectively. Treatment receiving 75 kg P_2O_5 ha^{-1} (P_4) was significantly superior with 9.26 and 28.26% higher seed yield over 50 kg P_2O_5 ha^{-1} (P_3) and 25 kg P_2O_5 ha^{-1} (P_2) treatments, respectively. Growth, yield attributing characters and nodulation also followed the trend of seed yield. The treatment combination receiving irrigation at = -0.03 MPa at 30 cm soil depth along with 75 kg P_2O_5 ha^{-1} (I_3P_4) proved as best treatment combination.

Key words: Broadbean, Growth, Irrigation, Nodulation, Phosphorus, Yield.

INTRODUCTION

India supports 16.8 % world's population, 4.2 % world's water resources and 2.3 % global land. Per capita availability of resources is 4 to 6 times lesser compared to world average. Foreseeably, this will further decrease due to increasing demographic pressure and consequent diversion of land for non-agricultural use. Role of pulses in Indian agriculture *vis-a-vis* in dietary programme needs hardly any emphasis. Broad bean (*Vicia faba* L.) is the most important pulse crop in the term of popularity, seed protein content and world's cultivated area. Due to their symbiotic nitrogen fixation, this crop can reach potential yields without any nitrogen fertilizer (Mi´nguez *et al*., 1993). Unlike most legumes, broad bean can be grown in soils with high salinity. However, it does prefer to grow in rich loams. Mature grains are good resource of protein, starch, cellulose and minerals. Therefore, it is of importance for human and animal food (Haciseferogullari *et al*., 2003). Water has been prioritized to be the most crucial resource. Not only per capita land availability but also per capita water availability is decreasing day by day. Inefficient use of water leads to inefficiency of all other resources/inputs like seeds, fertilizers etc. Optimum irrigation scheduling not only saves the irrigation water but also improve the efficiency of the added fertilizers as soil water acts as a solvent for the nutrients. Next to water, nutrients are an important input for guiding sustainable growth of agriculture. Pulses have a relatively high requirement of phosphorus and are particularly sensitive to phosphorus deficiency. In Indian soils, phosphorus content is normally low. The P concentration in the most soil solution ranges between 0.1 and 10 μM, this is much lower than the adequate P concentration for optimal growth of many crop plants (Hinsinger 2001; Raghothama 1999). Further, a major fraction of applied phosphorus is retained in the soil as unavailable form. Hence it is essential to increase the efficiency of applied phosphorus through proper rate of application. With such background information, a field experiment was undertaken to assess the response of broad bean to irrigation and phosphorus levels.

MATERIALS AND METHODS

The experiment was carried out at the Central Research Farm of Gayeshpur under Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *rabi* seasons of two consecutive years 2009-10 and 2010-11. The soil of the experimental field was alluvial and sandy clay loam in texture having pH 7.62, Organic carbon 0.64 %, total nitrogen 0.059 %, available P and K of 14.6 and 162.4 kg ha^{-1}, respectively. The total rainfall received by the crop was 26.9 and 106.4 mm during the first and second year of experiment, respectively.

The experiment was conducted in split plot design with 12 treatments, 4 replications and 48 plots. Three levels of irrigation were randomly allotted in three main plots as I_1 – Rainfed, I_2 – ψ = -0.05 MPa at 30 cm soil depth, I_3 – ψ = -0.03 MPa at 30 cm soil depth while four levels of phosphorus were allotted randomly in four subplots of each main plot as P_1 (no phosphorus application), P_2 (25 kg P_2O_5 ha^{-1}), P_3 (50 kg P_2O_5 ha^{-1}), P_4 (75 kg P_2O_5 ha^{-1}). N @ 15 kg ha^{-1}, P_2O_5 @ 0 / 25 / 50 / 75 kg ha^{-1} (as per treatment) and

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k_2O @ 25 kg ha^{-1} were applied as basal through urea, single superphosphate and muriate of potash, respectively during both the years of experiment. Before sowing *Rhizobium* inoculums (1.5 kg ha^{-1}) was mixed with jaggery solution and sprinkled over the healthy seeds. Then the seeds were thoroughly mixed to spread the inoculums over the entire surface of the seeds. After shade drying the broad bean 'Local Red' was sown at a spacing of 20 cm x 15 cm with a seed rate of 60 kg ha^{-1} on 2^{nd} week of November. Irrigations were applied as and when required depending on soil moisture tension. Two irrigations in plots under I_2 treatment and three irrigations in plots under I_3 treatment were applied. Depth of irrigation was 5 cm for each application. The same process was followed in the second year of experimentation. The crop was harvested at maturity on 3^{rd} week of March and yield data was recorded. Growth and yield parameters were recorded during the crop growth period. The data were analyzed statistically using analysis of variance (ANOVA) as described by Panse and Sukhatme (1984).

RESULTS AND DISCUSSION

Growth attributes: Growth attributes of broad bean significantly varied with three levels of irrigation and four levels of phosphorus (Table1). Pooled data showed that irrigation applied at ψ = –0.03 MPa at 30 cm soil depth (I_3) recorded tallest plant with 02.12% and 22.62% more height over those recorded with the application of irrigation at ψ = –0.05 MPa at 30 cm soil depth (I_2) and rainfed condition (I_1), respectively. Similar results also reported by Gendy *et al.* (1995). Maximum height was recorded in plants treated with 75 kg P_2O_5 ha^{-1} (P_4) while application of 50 kg P_2O_5 ha^{-1} (P_3) and 25 kg P_2O_5 ha^{-1} (P_2) recorded 4.75% and 9.61% shorter plants, respectively. The shortest plant was recorded with 0 kg P_2O_5- ha^{-1} (P_1). Favorable influence of phosphorus on plant height was also observed by Radwan (1992). Dry matter (DM) was found to increase progressively with the advancement of growth of the crop and reached their maximum values at 120 DAS. It was noticed that DM increased with the increasing levels of irrigation and recorded the maximum value with irrigation at ψ = –0.03 MPa at 30 cm soil depth (I_3) which significantly differed with other levels of irrigation probably due to the fact that irrigation enhanced higher rate of photosynthesis resulting better accumulation of biomass as compared to moisture stress condition. Application of 75 kg P_2O_5 ha^{-1} (P_4) recorded the maximum DM at all the growth stages and proved as the best treatment. Plants fertilized with 50 kg P_2O_5 ha^{-1} (P_3) gave better performances than the plants receiving 25 kg P_2O_5 ha^{-1} (P_2) in all dates of observation. The beneficial effect of phosphorus on dry matter production in broad bean was also observed by Hussien *et al.* (2002). Leaf area index was found to be increased with the advancement in growth of the crop and reached their maximum values at 90 DAS and thereafter declined with the increase in age. Treatment receiving irrigation at ψ = –0.03 MPa at 30 cm soil depth (I_3) recorded the highest LAI at all growth stages where as moisture scarcity under rainfed condition (I_1) maintained poor canopy coverage resulting in lower LAI values. Podsiadlo *et al.* (1999) reported the similar results. The maximum LAI was recorded for the dose of 75 kg P_2O_5 ha^{-1} (P_4) and the minimum for control treatment (P_1). Broad bean gave significantly higher LAI when treated with 50 kg P_2O_5 ha^{-1} (P_3) than 25 kg P_2O_5 ha^{-1} (P_2). Crop growth rate **(**CGR) was found higher during earlier growth stages and reached minimum values during 90-120 DAS. The maximum CGR of 7.51 g m^{-2} day^{-1} was observed with irrigation applied at ψ = –0.03 MPa at 30 cm soil depth (I_3) and was followed by irrigation at ψ = –0.05 MPa at 30 cm soil depth (I_2) with CGR values of 7.26 g m^{-2} day^{-1}, while the minimum value (6.65 gm^{-2} day^{-1}) was observed when the crop was grown as rainfed (I_1) during 30-60 DAS. Same trend was found during 60 to 90 DAS. Mohamed *et al.* (1999) also reported increase in CGR with the increasing levels of irrigation. During all the periods, CGR increased with enhanced dose of phosphorus and the minimum rate was registered for control treatment (P_1). At all stages, plants treated with 75 kg P_2O_5 ha^{-1} (P_4) maintained maximum growth rate which was significantly greater than all other nutrient treatments. The next best performance was achieved with the application of 50 kg P_2O_5 ha^{-1} (P_3) which was followed by the treatment comprised of application of 25 kg P_2O_5 ha^{-1} (P_2). The increase in dry weight of plant per unit leaf area per unit time is known as Net assimilation rate (NAR). The NAR values reached at maximum during 30 to 60 DAS and there after gradually lowered down to minimum during 90 to 120 DAS. During 30 to 60 DAS the maximum NAR of 16.33 g m^{-2} day^{-1} was achieved under rainfed (I_1) treatment which was 34.29 and 37.92% higher over irrigation at ψ = –0.05 MPa at 30 cm soil depth (I_2) and at ψ = –0.03 MPa at 30 cm soil depth (I_3) treatment, respectively. NAR values seemed to decrease with the increasing rate of phosphorus application. The maximum NAR value was observed at control (P_1) treatment. Application of 25 kg P_2O_5 ha^{-1} recorded higher NAR values compared to application of 50 kg P_2O_5 ha^{-1} (P_3) while the minimum value was recorded with the application of 75 kg P_2O_5 ha^{-1} (P_4). Number of primary branches $plant^{-1}$ was significantly increased with increasing levels of irrigation and It was highest (8.78) when the crop was irrigated at ψ = –0.03 MPa at 30 cm soil depth (I_3) followed by the treatment receiving irrigation at ψ = –0.05 MPa at 30 cm soil depth (I_2) (Table2). The result is in conformity with Al- Naeem (2008). Broad bean fertilized with 75 kg P_2O_5 ha^{-1} (P_4) maintained its superiority with maximum number of branches $plant^{-1}$ (8.45). The positive influence of phosphorus on number of branches $plant^{-1}$ had been reported by Bolland *et al.* (2001).

Table 1: Effect of irrigation and phosphorus levels on growth attributes of broad bean (pooled data).

Treatments	Plant height (cm)	Dry matter accumulation ($g\ m^{-2}$) Days after sowing				Leaf area index Days after sowing			Crop growth rate ($g\ m^{-2}\ day^{-1}$) Days after sowing			Net assimilation rate ($g\ m^{-2}$ leaf area day^{-1}) Days after sow ing		
		30	**60**	**90**	**120**	**60**	**90**	**120**	**30-60**	**60-90**	**90-120**	**30-60**	**60-90**	**90-120**
Irrigation levels														
I_1 : Rainfed	58.13	33.42	232.72	435.95	581.16	0.86	3.51	3.26	6.65	6.77	4.84	16.33	3.69	1.49
I_2 : ψ = -0.05 MPa at 30 cm soil depth	69.80	44.43	262.09	465.83	624.23	1.30	3.91	3.72	7.26	6.79	5.28	12.16	2.90	1.39
I_3 : ψ = -0.03 MPa at 30 cm soil depth	71.28	48.31	273.55	492.53	659.39	1.39	3.98	3.82	7.51	7.31	5.56	11.84	2.99	1.44
S.Em (±)	0.091	0.459	1.681	3.294	4.965	0.009	0.031	0.030	0.050	0.049	0.027	0.070	0.030	0.035
C.D. at 5%	0.285	1.413	5.181	10.149	15.298	0.029	0.094	0.094	0.153	0.151	0.084	0.215	0.093	0.098
Phosphorus levels														
P_1=0 kg P_2O_5/ha	61.25	25.68	223.63	424.35	576.08	0.89	3.45	3.25	6.60	6.70	5.05	16.01	3.62	1.52
P_2=25 kg P_2O_5/ha	64.63	36.20	241.93	449.27	603.82	1.09	3.65	3.46	6.86	6.91	5.15	14.18	3.36	1.45
P_3=50 kg P_2O_5/ha	67.63	48.63	269.69	480.23	638.57	1.30	3.90	3.71	7.37	7.02	5.28	12.20	2.99	1.39
P_4=75 kg P_2O_5/ha	70.84	57.69	289.22	505.22	667.90	1.44	4.20	3.98	7.72	7.20	5.42	11.38	2.81	1.33
S.Em (±)	0.152	0.528	2.287	3.257	6.199	0.022	0.034	0.044	0.079	0.073	0.033	0.073	0.039	0.040
C.D. at 5%	0.425	1.498	6.483	9.236	17.577	0.063	0.098	0.126	0.225	0.208	0.094	0.208	0.111	0.113

Table 2: Effect of irrigation and phosphorus levels on number of branches plant^{-1}, yield attributes, yield and nodulation of broad bean (pooled data).

Treatments	Number of branches plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	100 seed weight (g)	Seed yield ($t\ ha^{-1}$)	Stalk yield ($t\ ha^{-1}$)	Number of 75 DAS nodules plant^{-1}	Dry weight of nodules plant^{-1} (g) 75 DAS
Irrigation levels								
I_1 : Rainfed	3.95	7.41	1.82	23.22	3.66	4.05	202.11	0.413
I_2 : ψ = -0.05 MPa at 30 cm soil depth	7.49	11.70	2.30	24.15	4.70	5.37	225.41	0.455
I_3 : ψ = -0.03 MPa at 30 cm soil depth	8.78	12.23	2.94	24.81	4.94	5.88	246.07	0.499
S.Em (±)	0.091	0.070	0.025	0.152	0.043	0.134	3.780	0.005
C.D. at 5%	0.280	0.215	0.063	0.472	0.139	0.482	11.923	0.014
Phosphorus levels								
P_1=0 kg P_2O_5/ha	4.33	9.38	2.12	23.16	3.33	3.92	164.41	0.280
P_2=25 kg P_2O_5/ha	5.54	10.25	2.33	23.57	4.14	4.64	207.74	0.401
P_3=50 kg P_2O_5/ha	7.84	10.76	2.58	23.98	4.86	5.51	245.83	0.550
P_4=75 kg P_2O_5/ha	8.45	11.39	2.84	24.12	5.31	5.86	275.64	0.607
S.Em (±)	0.116	0.087	0.028	0.143	0.058	0.084	4.521	0.004
C.D. at 5%	0.330	0.246	0.075	0.418	0.163	0.262	10.625	0.013

Yield attributes: Yield attributing characters such as length of pod, number of seeds/pod, 100 seed weight were significantly influenced by different levels of irrigation and phosphorus during both the years of experiment (Table 2). Among the irrigation treatments, the longest pod (12.23cm) was observed under irrigation at ψ = -0.03 MPa at 30 cm soil depth (I_3) which was 4.53% longer than the pod (11.70 cm) noticed in irrigation at ψ = -0.05 MPa at 30cm soil depth (I_2). The shortest pod (7.41 cm) was observed when the crop was grown as rainfed (I_1). This is due to increase in the stress condition or reduction in the moisture percentage, the growth of the plant was hampered which ultimately affect the pod length. Abdulsalam *et al.* (1996) opined alike. With increase in phosphorus level pod length also increased significantly. Plants fertilized with 75 kg P_2O_5 ha^{-1} (P_4) produced the longest pod of 11.39 cm which was 5.86, 11.12 and 21.43% longer than the pod produced in plants receiving 50 kg P_2O_5 ha^{-1} (P_3), 50 kg P_2O_5 ha^{-1} (P_3) and control (P_1), respectively. Number of seeds pod^{-1} and 100 seed weight increased with the increment of levels of irrigation. Broad bean irrigated at ψ= -0.03 MPa at 30 cm soil depth (I_3) recorded the maximum number of seeds pod^{-1} (2.94), 100 seed wt (24.81) which were 27.83 and 2.73% higher as compared to that recorded with the application of irrigation at ψ = -0.05 MPa at 30 cm soil depth (I_2), respectively. Moisture scarcity under rainfed (I_1) condition might be responsible for the poorest result. Kassab and El zeiny (2004) also reported the same. Maximum number of seeds pod^{-1} (2.59) and 100 seed weight (24.12 g) were observed with the application of 75 kg P_2O_5 ha^{-1} (P_4) which was significantly superior to other phosphorus treatments and proved as a superior one. It was followed by 50 kg P_2O_5 ha^{-1} (P_3), 25 kg P_2O_5 ha^{-1} (P_2) and control (P_1) treatments. Shafeek (2003) also reported the increment of number of seeds pod^{-1} and 100 seed weight of broad bean with the application of phosphorus.

Yield: Irrigation increased seed and stalk yield significantly due to the improvement in yield attributing characters of broad bean during both the years of experiment. Pooled data (Table 2) shows that treatment receiving irrigation at ψ = -0.03 MPa at 30 cm soil depth (I_3) maintained its superiority by producing maximum seed and stalk yield which were 5.11 and 9.49% higher over the next best treatment receiving irrigation at ψ = -0.05 MPa at 30 cm soil depth (I_2), respectively. Rainfed (I_1) crop recorded the minimum yield due to moisture stress during the growth period. Significant variation in seed yield by providing irrigation was also reported by Pavani *et al.* (2008). Phosphorus increased yield attributing characters of the crop. As a result, yield both seed and stalk increased and reached at maximum values with application of 75 kg P_2O_5 ha^{-1} (P_4). Treatment receiving 50 kg P_2O_5 ha^{-1} (P_3) performed as the 2^{nd} highest treatment with 17.39% and 18.75% higher seed and stalk yield over the treatment receiving 25 kg P_2O_5 ha^{-1} (P_2), respectively. The result confirm to the findings of Bolland *et al.* (2001).

Nodulation: Number and dry weight of nodules $plant^{-1}$ were significantly influenced due to different levels of irrigation and phosphorus (Table 2). It was observed from the pooled observation that both number and dry weight of nodules $plant^{-1}$ were increased progressively with the increase in age of the plant and reached their peak at 75 DAS. At 75 DAS the maximum number and dry weight were achieved under irrigation at ψ = –0.03 MPa at 30 cm soil depth (I_3) where the rate of increment were 9.17 and 9.67% over the treatment receiving irrigation at ψ = –0.05 MPa 30 cm soil depth (I_2), respectively. Water restriction drastically affected nodulation of the crop was stated by Kurdali *et al*. (2002). Broad bean treated with 75 kg P_2O_5 ha^{-1} (P_4) recorded maximum nodule number and dry weight $plant^{-1}$ which was followed by the treatment comprised of 50 kg P_2O_5 ha^{-1} (P_3). Plants receiving no phosphorus fertilizer (P_1) recorded the minimum values. The beneficial effect of phosphorus on the number of nodules was also studied by Luikham *et al.* (2009).

Thus, the result of the present study substantiate that both irrigation at ψ = -0.03 MPa at 30 cm soil depth (I_3) and phosphorus fertilization with 75 kg P_2O_5 ha^{-1} (P_4) are necessary for proper growth, nodulation and higher yield of broad bean.

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