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Growth and Yield Response of Chickpea (*Cicer arientinum*) to Various *Rhizobium* Strains Fertilized with different Phosphorus Levels

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ABSTRACT

Four different phosphorus levels (0, 60, 90 and 120 kg P_2O_5 ha^{-1}) applied to chickpea in combination with various *Rhizobium* strains, i.e. Thal-8, TAL-620 and their mixture (1:1) were studied under natural field conditions. The seeds for each treatment (except control) were inoculated with the respective *Rhizobium* just before sowing and fertilized with the mentioned dose of phosphorus accordingly by side drilling at the time of seeding. Mixture of both *Rhizobium* strains gave the most promising results and significantly increased nodulation, growth and yield even with 60 kg P_2O_5 ha^{-1} while increasing the phosphorus dose decreased the yield. Although, individual *Rhizobium* strains were statistically *at par* with fertilization @ 90 kg P_2O_5 ha^{-1} in all growth parameters producing higher yield as compared to control treatment but their mixture inoculation proved to be the most efficient source in yielding more grains and biomass production even with lower rate of phosphorus application. Higher rate of phosphorus application (120 kg P_2O_5 ha^{-1}) caused significant reduction in growth and yield under both inoculated as well as un-inoculated treatments.

Key Words: *Rhizobium*; Chickpea; Phosphorus; Nutrition; Growth; Pakistan

INTRODUCTION

Chickpea crop is grown on marginal poorly fertile sandy lands, almost exclusively under rain-fed conditions in areas of low rainfall. By land area planted to chickpea, the country ranks second in the world. But, until recently, inadequate attention has been paid to increasing its production, which is either stagnant or declining. Major constraints in increasing production of chickpea are poor soils, inadequate moisture, harsh climatic conditions, weeds and inadequate or even no fertilizer supply (Khan *et al.,* 1989; Aslam *et al*., 1996). Uncertain rains, low incentives, and poor economic factors of the farmers restrain them to supply any plant nutrition. Usually, most of the farmers do not use chemical fertilizers at all in growing chickpea and other grain legumes. Moreover, due to the harsh climate, *Rhizobium* population is very low resulting in less yields (Aslam *et al*., 1997). It is possible to increase chickpea yield by inoculation with *Rhizobium* strains even in fields where chickpea have been grown for many years. More attention is required to phosphorus management, especially in wheat based cropping system. In practice, nodulation and nitrogen fixation are frequently poor and responses to inoculation inconsistent, probably due to unfavourable soil conditions, such as inadequate moisture level. Insufficient work regarding phosphorus requirements on such marginal lands for legume crops have been reported. Therefore, comprehensive studies regarding fertilizer management as well as *Rhizobium* inoculations under uncertain climates and unfavourable socio-economic factors need to be initiated for improving legume grain yields from the lands having either nil or low populations of effective *Rhizobia* and low nitrogen supplying capacity because of low organic matter and phosphorus level in sandy soils of rain-fed areas.

MATERIALS AND METHODS

A field experiment was conducted during chickpea growing season 1995-96 at National Agricultural Research Centre, Islamabad to evaluate the best phosphorus dose in interaction with different *Rhizobium* inoculants. Soil at the selected site was Sandy Clay Loam with P=0.386 µg g^{-1}, $NO_3^-N = 1.067$ µg g^{-1}; total N=0.0218% and OM=0.436% estimated according to the methods described by Richards (1954), and Soltanpour and Workman (1979). Sixteen treatments in four replicates according to RCBD were four phosphorus (0, 60, 90 and 120 kg P_2O_5 ha^{-1}) levels in interaction with the following four *Rhizobium* strains: S_1 = Control (non-inoculated); S_1 = Thal-8; S_2 = TAL-620; S_3 = Mixture of S_3 and S_2 (1:1)

Recommended seed rate of chickpea variety Paidar-91 was seed inoculated according to the treatments in plan just before sowing. Phosphorus was applied in the respective treatments accordingly at the time of sowing. After germination necessary weeding and thinning was done to keep the uniform crop stand. Data regarding nodulation and root fresh weight was collected at grain filling stage. Five uniform plants from each treatment were uprooted carefully and washed nodules were dried to record nodule mass. Root fresh weight was noted after separating the nodules. At maturity, the crop was sampled per square meter for total biomass as well as grain yield. The data thus obtained were analyzed statistically by ANOVA technique following RCBD (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Root fresh biomass and nodulation. The data in Table I indicate that inoculation by different strains had a pronounced effect on nodule mass as well as root fresh weight as compared to non-inoculated treatments. Similarly phosphorus levels increased nodulation and root biomass than that of control treatment. Among the fertilizer doses, phosphorus level @ 90 kg P_2O_5 ha^{-1} was found to be the best rate for single strain inoculated treatments. Higher rate of phosphorus yielded same results as that of lower rates. Results obtained with mixture inoculation by *Rhizobium* strains (Thal-8 and TAL-620) have interesting information that produced the most promising yields even with he lower rate of phosphorus application, i.e. 60 kg P_2O_5 ha^{-1}. The reason may be the better utilization of applied nutrients due to the supply of appropriate nitrogen fixing bacteria in the root zone. This further confirmed that association of *Rhizobium* strains acquired more nodules through moderate application of phosphorus (60 kg P_2O_5 ha^{-1}) as compared to single strain inoculated plants with the same dose of phosphorus probably occurred due to poor efficiency of individual *Rhizobium*. Plants treated with single strain inoculant have manifested the desirable results with fertilizing @ 90 kg P_2O_5 ha^{-1} but further increase in phosphorus level caused reduction in root as well as nodule biomass perhaps might be due to the ill effect of high concentration of phosphorus nutrition in the soil. Similar findings have been reported by Witty (1983), Davis *et al.* (1985), Hart *et al.* (1986), Nambiar *et al.* (1988), Rupela (1992), Sadiq (1994) and Aslam *et al.* (1997).

Total Biomass and Grain Yield. The average maximum total biomass and grain yield was observed when phosphorus was applied @ 90 kg P_2O_5 ha^{-1} (Table II). Among the *Rhizobium* strains, similar trend as that of nodulation and root dry mass was found. Mixture of *Rhizobium* strains yielded leading results even with lower rate, of phosphorus i.e., 60 kg P_2O_5 ha^{-1} as compared to rest of the treatments. On average basis it again produced outstanding yield for both grain and total biomass production over control receiving no *Rhizobium* inoculation. As discussed earlier, it is interesting to note that application of phosphorus even double to 60 kg P_2O_5 ha^{-1} with individual *Rhizobium* treatments produced statistically similar yield to that of the lower rate (60 kg P_2O_5 ha^{-1}) with mixture of *Rhizobium* treatment proving that application of phosphorus @ 90 kg P_2O_5 ha^{-1} is comparatively better for inoculation by single *Rhizobium* strain but in case of mixture *Rhizobium* inoculation the phosphorus (60 kg P_2O_5 ha^{-1}) might be the sufficient rate. This may be due to better nodulation and healthy root system (Table I) in the root zone or it could be possible that the mixture of Rhizobia have worked more efficiently in combination which caused maximum utilization of phosphorus applied to the crop resulting in higher yields. A large number of *Rhizobium* strains increase nitrogen fixing ability in combination and hence better nutrients utilization by legume crop. These results are

Table I. Root and nodule biomass as affected by *Rhizobium* strains and different levels of phosphorus

P Levels (kg ha^{-1})	Root fresh weight (g $plant^{-1}$)					Nodule dry weight (mg $plant^{-1}$)				
	S_0	S_1	S_2	S_3	Average	S_0	S_1	S_2	S_3	Average
Control	56.31	61.52	58.89	72.73	62.36 C	99 g	189 e	139 f	212 d	160 C
60	68.43	74.45	64.32	88.57	73.94 B	121 fg	196 de	187 e	398 a	226 B
90	70.89	80.33	77.48	79.95	77.16 A	186 e	223 c	214 d	345 ab	242 A
120	61.04	76.80	71.92	73.14	70.73 BC	191 de	178 e	192 de	316 b	219 B
Average	64.17 C	73.28 B	68.15BC	78.60 A		149 C	197 B	183 BC	318 A	

Values with same letters for each parameter are statistically similar at P=0.01

Table II. Total biomass and grain yield as affected by *Rhizobium* strains and different levels of phosphorus

P Levels (kg ha^{-1})	Total biomass (t ha^{-1})					Grain yield (t ha^{-1})				
	S_0	S_1	S_2	S_3	Average	S_0	S_1	S_2	S_3	Average
Control	2.18 g	2.69 ef	2.51 f	2.79 e	2.54 D	1.17 g	1.39 ef	1.38 ef	1.41 e	1.34 C
60	2.87 de	3.84 bc	3.72 c	4.61 a	3.76 BC	1.37 ef	1.90 e	1.88 e	2.30 a	1.86 BC
90	3.82 bc	4.13 ab	3.91 bc	4.34 ab	4.05 A	1.88 e	2.16 bc	2.12 c	2.26 ab	2.11 A
120	3.10 d	3.36 d	3.01 de	3.88 bc	3.34 C	1.67 ef	1.98 d	1.87 ef	2.19 b	1.93 B
Average	2.99 D	3.51 B	3.29 C	3.91 A		1.52 C	1.86 B	1.81 B	2.04 A	

Values with same letters for each parameter are statistically similar at P=0.01

in line with Witty (1983), Elkan (1986), Doughton *et al*. (1993), Herridge *et al*. (1995) and Aslam *et al*. (1997).

CONCLUSIONS

It may be tentatively concluded from the study that, chickpea crop yield can be improved through proper *Rhizobium* inoculation and phosphorus management in the limited environmental conditions of arid and semi-arid regions. There are advantages to be gained successfully through inoculation with efficient inocula as well as 60-90 kg P_2O_5 ha^{-1} under existing environments.

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