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Effect of Biofertilizers and Chemical Fertilizers on Phosphorus Uptake and Wheat Yield

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ABSTRACT

The use of phosphorus solubilising bacteria (PSB) as seed or soil inoculants can potentially enhance P uptake by plants and thereby enhance crop yields. A field study was conducted to investigate the effect of integrated use of PSB and chemical phosphate fertilizer on P uptake and grain yield of wheat (*Triticum aestivum* L., cv. Chamran). Fertilizer treatments comprised four levels of chemical fertilizer (0, 25, 50, and 75 kg P_2O_5 ha^{-1} as ammonium phosphate) and three inoculation rates i.e. 0, 100 and 200 g per 50 kg seed, of Barvar 2 biofertilizer containing P solubilising bacteria (*Pseudomonas putida* and *Pantoea agglomerans*). An increase in grain yield and P uptake was found with the increasing rate of mineral phosphorus. Inoculation of bio-fertilizer (Barvar 2) along with lower rate of mineral phosphorus (25 kg P_2O_5 ha^{-1}) produced maximum grain yield and accumulated maximum phosphorus in grain. There were significant treatment interactions, with evidence of antagonism between P fertilizer and PSB inoculation at their highest rates, particularly in case of grain yield, P uptake and harvest index.

Key words: Biofertilizer, Grain yield, Phosphorus uptake, Wheat.

INTRODUCTION

Phosphorus (P) is one of the major macronutrients for plants and is applied to soil in the form of chemical fertilizers. However, huge losses of applied chemical P fertilizer (Chen *et al*., 2006) increase cost of crop production and the increased fertilization causes environmental contamination (Kannayan, 2002). These factors encouraged the combined use of organic and inorganic fertilizer to improve the efficiency of the latter one and to promote sustainable agricultural system (Ehteshami *et al*., 2007). Biofertilizers can be beneficial, and have often been claimed to promote plant growth and reduce chemical inputs (Mirzaei Heydari *et al*., 2019; Rai, 2006).

The use of bio-fertilizer was found successful to improve efficiency of inorganic P fertilizer and yield of crops (Mitra *et al*., 2020; Ali *et al*., 2008; Hasaneen *et al*., 2009). However, the usefulness of the use of biofertilizers possessing mineral P solubilizing (MPS) bacteria is affected because of limitations such as their poor ecological fitness, low metabolite production, variability in inoculate-delivery systems and inconsistent performance in field applications (Mark *et al*., 2003).

There is a large population of PSB in soil and in the rhizosphere (Sperberg, 1958; Alexander, 1977). These include both aerobic and anaerobic strains, with a prevalence of anaerobic strains in submerged soils (Raghu, 1996). Considerably higher population densities of P-solubilizing bacteria are commonly found in the rhizosphere in comparison with non-rhizosphere soil (Katznelson *et al*., 1962). Plant growth promoting bacteria (PGPB) are soil and rhizosphere bacteria that can enhance plant growth by different mechanisms of which P-solubilization is considered to be one of the most important traits associated with plant P nutrition. Given the negative environmental impacts of chemical fertilizers and their increasing costs, the use of PGPB is advantageous in sustainable agricultural practices (Lin *et al*. (2020; Chen *et al*., 2006).

Several reports have examined the ability of different bacterial species to solubilise insoluble inorganic P compounds, such as tricalcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphate (Goldstein, 1986). Among the bacterial genera with this capacity are *Pseudomonas, Bacillus, Rhizobium, Byrkholderia*, *Achromobacter*, *Agrobacterium, Microccocus, Aereobacter, Flavobacterium* and *Erwinia.* Strains of *Pseudomonas putida* and *Pseudomonas fluorescens* have been shown to increase root and shoot elongation in canola (*B. campestris* L.), lettuce (*Lactuca sativa* L) and tomato (*Solanum lycopersicum* L.) (Hall *et al*., 1996), and also yields in wheat (*Triticum aestivum* L.) and many other crop species. Wheat yields have been shown to increase by up to 30% with *Bacillus* inoculants (Rodriguez and Fraga, 1999). The present study was conducted to compare the efficiency of different levels of P solubilising bacteria with different doses of inorganic P fertilizer on yield and yield components of wheat in Iran.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the experimental research farm of Agriculture College, Azad University of Ilam, Iran. The experimental site was situated in the cold mountainous region of Iran at a height of 1319 m above mean sea level, in the west of Iran at latitude 33º 38´ north and longitude 46º 26´ east.

Soil analysis

The soil sample was collected from the experimental site, air dried, ground and passed through a 2 mm sieve to determine the physical and chemical properties (Table 1). The soil saturated paste was prepared to determine the water holding capacity of the soil (Rhoades, 1982). Soil chemical properties like pHs, electrical conductivity (ECe) were determined using saturated paste and extract of soil, respectively (U.S. Salinity Lab. Staff, 1954). It was analyzed for texture by hydrometer method (Moodie *et al.*, 1959) and organic matter by Walkley and Black method (Page *et al.*, 1982). Phosphorus was extracted by 0.5*M* $NaHCO_3$ and determined using spectrophotometer (Watanabe and Olsen, 1965) while total mineral Nitrogen (N) was determined using 2 *N* KCl extract (Keeney and Nelson, 1982).

Table1. Physical and chemical properties of the soil used

Soil properties	Units	Value
pHs	-------	7.2
ECe	dS m^{-1}	2.5
Total mineral N	mg kg^{-1}	10.2
Organic matter	%	1.12
Olsen's P	mg kg^{-1}	8.1
Clay	%	31
Silt	%	29
Sand	%	40
Textural class	--------	Clay loam

The experimental treatments were arranged as split plot factorial in a randomized complete block design with four replications. Four levels of phosphorus fertilizer (0, 25, 50 and 75 kg P_2O_5 ha^{-1} as ammonium phosphate) were applied to the main plots. Before sowing, wheat (cv. Charman) seeds were inoculated with three levels (0, 100 and 200 g/50 kg seed) of commercially used Barvar phosphate biofertilizer (Barvar-2) for improving efficiency of inorganic phosphate fertilizer. A suspension of the biofertilizer of desired concentrations was prepared in 10% solution of sugar. The commercial name of the biofertilizer used for this study is Barvar-2. This fertilizer was produced/supplied by Green Bio-tech Co. Barvar 2 contained two types of phosphate solubilizing bacteria: 1) Bacterial strain P^5 (*Bacillus lentus*) releases phosphate from inorganic compounds by producing organic acids while, 2) the strain P^{13} (*Pseudomonas putida*) releases phosphate from organic compounds by producing enzymes (Khalil *et al*., 2008).

The recommended basal doses of N (100 kg N ha^{-1}) as urea and Zn (5 kg ha^{-1}) as $ZnSO_4$ were also applied. All P and half of N was applied at sowing (including N from ammonium phosphate) while the other half was top-dressed at 1st irrigation, 25 days after sowing. The crop was harvested at physiological maturity. The grain and straw yields per m^2 were recorded. Plant samples were oven dried at 70 °C and digested to determine P uptake (Van Schouwenberg and Walinge, 1973).

The data were analysed statistically and treatment means were compared by employing Duncan's multiple range test at 5% level of probability.

RESULTS AND DISCUSSION

The results showed that the application of P fertilizer significantly improved yield and P uptake by grain. However, the effect of using P fertilizer along with bio-inoculums as seed dressing was more pronounced in increasing yield and P uptake by grain (Table 2 & 3). The highest seed yield (5.44 t ha^{-1}) and P uptake (18 kg ha^{-1}) were obtained by applying P at 25 kg P_2O_5 ha^{-1} accompanied with 200 g inoculums per 50 kg seed. The beneficial effect of bio-inoculums on plant growth and P fertilizer saving was also reported by Rai (2006). Earlier studies also reported that application of mineral P fertilizer associated with bio-fertilizer increased yield and P uptake by grain (Gupta *et al*., 1999; Ghoname and Shafeek *et al*., 2004). The results showed an antagonism between high levels of P fertilizer and PSB inoculums. A decrease in yield was observed with the increase in combined application of highest rate of fertilizer and bio-inoculums. The highest P fertilizer alone treatment produced grain yield of 5.41 ton ha^{-1} while the yield was decreased (4.69 t ha^{-1}) by using the highest P rate (75 kg P_2O_5 ha^{-1}) and bio-inoculums (200 g/50 kg seed). The grain yield of 3.23 t ha^{-1} was obtained in control treatment (0 P fertilizer and 0 inoculums). Majid *et al*. (2007) also reported antagonistic effect of highest level of chemical P fertilizer on performance of P solubilizing bacteria.

Table 2. Impact of using bio- and chemical P fertilizer on wheat yield (t ha^{-1})

P rates (kg $P_2O_5ha^{-1}$)	BF/50 kg seed (g)		
	0	100	200
0	3.23d	3.45cd	3.55c
25	3.47cd	4.25b	5.44a
50	4.42b	5.43a	5.11ab
75	5.41a	4.56b	4.69b

Means with the same letter(s) in table are not significantly different at p<0.05; BF = biofertilizer

Table 3. Impact of using bio- and chemical P fertilizer on P uptake by grain (kg ha^{-1})

P rates (kg P_2O_5ha^{-1})	BF/50 kg seed (g)		
	0	100	200
0	8.7d	9.7d	9.9d
25	10.1d	14.0cd	18.0a
50	14.1cd	17.6ab	16.9ab
75	17.9a	15.5c	15.5c

Means with the same letter(s) in table are not significantly different at p<0.05; BF = biofertilizer

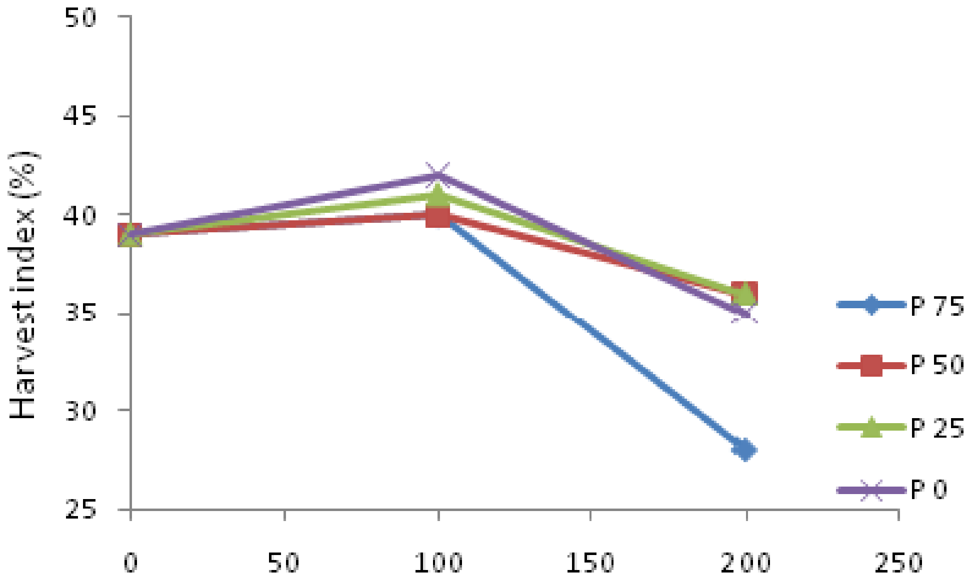

Fig.1. Impact of using bio- and chemical P fertilizer on harvest index of wheat

The results showed that harvest index was significantly affected by P fertilizer (Fig. 1). Application of lower rate of P fertilizer along with the highest level of the biofertilizer inoculation (200 g/50 kg seed) was more pronounced in increasing harvest index. While the highest rate of P fertilizer accompanied with the highest rate of biofertilizer resulted in decrease in allocation of dry matter to the grains at all levels of P fertilizer, and resultantly the harvest index was decreased. Earlier studies also showed antagonistic effect of the highest rates of inorganic and bio-fertilizers on harvest index of crops (Aslam *et al.*, 2005; Yosefi *et al.*, 2011)

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