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IMPACT OF PSB (*Bacillus subtilis*) AND ENDOMYCORRHIZA ON GROWTH, YIELD, QUALITY AND NUTRIENT UPTAKE IN MAIZE (*Zea mays* L.) UNDER TEMPERATE CONDITIONS OF KASHMIR

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ABSTRACT

A field experiment was conducted at Regional Research Station Wadura, Sopore (Kashmir) during *kharif* 2013 to assess the impact of a phosphate solubilizing bacterium (PSB) *Bacillus subtilis* and vesicular arbuscular mycorrhiza (VAM) on maize cv. 'KG-2'. The treatments comprised of 3 levels of biofertilizers (control, PSB and VAM) and 4 levels of inorganic phosphorus fertilizer [0, 25, 50 and 100% recommended dose of fertilizer (RDF) i.e. 60 kg P ha^{-1}]. The experiment was laid out in a randomized complete block design with each treatment replicated thrice. Maximum plant height (166 cm), biomass production (104 q ha^{-1}), grain yield (46.0 q ha^{-1}) and crude protein (10%) were recorded in treatment VAM + PSB + 50% RDF. The use of VAM and PSB in combination with different P levels enhanced plant NPK uptake over control. Maximum uptake of N (103.0 kg ha^{-1}), P (29.1 kg ha^{-1}) and K (95.6 kg ha^{-1}) was observed in treatment combination of VAM +PSB + 50% RDF.

Keywords: Growth, maize, nutrient uptake, PSB, quality, VAM, yield

INTRODUCTION

Phosphorus is 2nd essential plant nutrient after nitrogen. It contributes to microbial biomass production, metabolic process for energy transfer, macromolecular biosynthesis and respiration chain reactions; and improves the crop quality. It is one of the least available and least mobile nutrients in soil. The relative amounts of phosphorus in organic and inorganic forms vary from soil to soil with inorganic form being unavailable to the growing plants and microbes. This fraction is mostly attached to Fe and Al in acid soils and to Ca in slightly acidic to alkaline soils. Phosphate fertilizers when applied to soils get transformed into various insoluble products, therefore plants use only a small fraction of applied phosphatic fertilizers, which does not fulfill plant needs to perform metabolic activities (Vassilev and Vassileva, 2003). Phosphate solubilizing microorganisms (PSM) offer an ecologically acceptable means for converting insoluble phosphate to soluble forms by acidification, chelation and exchange reaction. Several strains of bacteria (*Pseudomonas*, *Bacillus*, *Rhizobium*, *Enterobacter*, etc.) and fungi (*Aspergillus* and *Penicillium*) have been recognized as powerful phosphate solubilizers (Whitelaw, 2000; Peela *et al.*, 2013). Release of organic anions and production of siderophores and acid phosphatase by plant roots /microbes or alkaline phosphatase enzymes hydrolyze the soil organic P or split P from organic residues. Therefore, the use of phosphate solubilizing bacteria (PSB) in agricultural would not only offset the high cost of manufacturing phosphatic fertilizers but would also mobilize insoluble natural phosphorus in soils. PSB facilitate sustained P supply for the growth of plants (Walpola and Yoon, 2012; Hussain *et al.*, 2013) but also stimulate the efficiency of nitrogen fixation and accelerate the accessibility of other trace elements by synthesizing important growth promoting substances like siderophores, antibiotics, etc. (Kumar *et al*., 2012) and improve crop productivity (Abbas *et al.*, 2013) by solubilizing insoluble phosphorus and providing protection to plants against soil borne pathogens. Plant root associated fungus 'mycorrhiza' exhibit symbiotic association in many vascular plants (Dar, 2010). This association favours water and nutrient uptake, soil structure development and stability and biological control of plant pathogens besides improving crop yield (Marschner and Dell, 1994). The present study was aimed to assess the impact of PSB and VAM on the growth, yield and nutrient uptake in maize under temperate conditions of Kashmir.

MATERIALS AND METHODS

A field experiment was conducted at Regional Research Station, SKUAST, Wadura, Kashmir during *kharif,* 2013. The experimental soil was silty clay loam and neutral in reaction with pH 7.6, EC 0.14 dS m^{-1}, medium in available N (272 kg ha^{-1}), available P (14 kg ha^{-1}) and available K (218 kg ha^{-1}). The treatments comprised of 3 levels of biofertilizers (control, PSB, VAM) in combination with 4 levels of inorganic phosphorus fertilizers [0, 25, 50 and 100% recommended dose of fertilizers (RDF) i.e. 60 kg P ha^{-1}] laid out in a randomized complete block design with each treatment replicated three times. The plot size for each treatment was 12 m^2. Phosphorus was applied as per treatments and all the plants received a uniform dose of 90 kg N and 30 kg K ha^{-1} through single super phosphate, urea and muriate of potash. Maize seeds variety 'KG-2' was inoculated as per standard methods with the inoculant of PSB culture @ 300 ml 10 kg^{-1} seed. Both PSB (*Bacillus subtilis*) and VAM culture (mixed genera of *Glomus, Acaulospora, Gigaspora* and *Scutellospora*) was procured from the Biofertilizer Lab, RRS, Wadura (Kashmir). After 15 days of fertilizer application VAM was applied @ 100 g m^{-2}. After inoculation, the seeds were sown at a spacing of 60 × 20 cm in the last week of May and harvested in the 2nd week of September. All the cultural operations were followed as per the package of practices. Plant height was measured at harvesting from the base of plant to the base of fully opened top leaf with the help of a scale. The grain yield was recorded at harvest. The plant samples collected from maize (grain and plant biomass) at harvest time were oven-dried, processed and digested with conc. sulphuric acid for estimation of nitrogen (Subbiah and Asija, 1956) in Kjedahl apparatus and with diacid (nitric acid and perchloric acid in 3:1 ratio) for estimation of phosphorus by Systronics UV-VIS Spectrophotometer 108 (Olsen *et al*., 1954) and potassium by Systronics Flame photometer 130 (Jackson, 1973). The protein content in maize was determined by multiplying N content in grain with 6.25.The nitrogen, phosphorus and potassium uptake was calculated by multiplying N or P or K content (%) in plant with dry plant biomass. The data was subjected to the analysis of variance as per the standard method given by Panse and Sukhatme (1967). The data was analyzed by using 'R' software and significance of treatment effects tested by "F" test.

RESULTS AND DISCUSSION

Plant growth, quality and yield

Plant height showed a significant increase due to various treatments as compared to control with maximum height (166 cm) in VAM + PSB + 50% RDF treatment which was at par with PSB + 100%

Table 1: Effect of PSB (*Bacillus subtilis*) and VAM (endomycorrhiza) on growth, yield and quality of maize (*Zea mays* L.)

Treatments	Plant height (cm)	Plant biomass (q ha^{-1})	Grain yield (q ha^{-1})	N content in grains (%)	Crude protein (%)
Control	150.00	81.10	32.00	0.96 (0.98)	6.0 (2.45)
100% RDFP	163.00	102.20	44.00	1.54 (1.24)	9.6 (3.10)
PSB	153.10	87.00	34.00	1.41 (1.19)	8.8 (2.96)
PSB + 100% RDF	164.00	103.00	45.00	1.57 (1.25)	9.8 (3.13)
PSB + 50% RDF	162.00	100.43	42.86	1.51 (1.23)	9.4 (3.06)
PSB + 25% RDF	160.00	98.84	42.00	1.46 (1.21)	9.1 (3.01)
VAM	152.15	87.50	33.96	1.30 (1.14)	8.1 (2.84)
VAM + 100% RDF	163.38	103.50	44.96	1.58 (1.26)	9.9 (3.14)
VAM + 50% RDF	161.10	100.48	42.82	1.52 (1.23)	9.5 (3.07)
VAM + 25% RDF	158.80	98.93	41.97	1.48 (1.21)	9.2 (3.03)
VAM + PSB + 50% RDF	166.00	104.00	46.00	1.60 (1.26)	10.0 (3.16)
VAM + PSB + 25% RDF	160.92	99.17	42.20	1.50 (1.22)	9.3 (3.05)
$CD_{0.05}$	2.46	2.00	1.75	0.013	0.035

*Values in parentheses are square root transformed values; RDF = Recommended dose of P fertilizer

RDF (Table 1). This increase may be attributed to the auxin production by PSB and increased supply of phosphorus by PSB and VAM (Fankem *et al.*, 2008). In dual inoculation with VAM + PSB, plants attained more height than plants in individual treatments. Similar results have been reported by Yousefi *et al*. (2011) and Walpola and Yoon (2012). The maximum grain yield (46 q ha^{-1}) and plant biomass (104 q ha^{-1}) was recorded in VAM + PSB + 50% RDF treatment which was at par with PSB + 100% RDF. Enhanced availability of P and its active involvement in shoot and root growth lead to improvement in plant growth which later boosted higher yields. The findings are in agreement with Hussain *et al.* (2013). Sole inoculations of VAM fungi and PSB significantly improved maize grain yield and plant biomass over uninoculated ones and were at par with each other. The increase in maize grain yield due to PSB inoculation may be attributed to the improved P availability because of solubilization of insoluble inorganic phosphate by organic acid, decomposition of phosphate-rich organic compounds and production of plant growth promoting substances (Gaur and Sunita, 1999). The increase in grain yield and plant biomass due to the dual inoculations of VAM and PSB could be attributed to the synergistic action of two organisms which increased the P uptake (Subba Rao, 1986). The findings are in line with Singh *et al*. (2011).

The nitrogen and crude protein contents in maize grains were markedly influenced by PSB and VAM applied in combination with various P levels. The increase in crude protein may be attributed to the nutrient mobilization, especially P, from unavailable pool to available pool. Maximum nitrogen and crude protein content of 1.6 and 10.0% was observed in treatment VAM + PSB + 50% RDF which was at par with treatments PSB + 100% RDF and VAM + 100% RDF (Table 1). The effect could be due to the synergistic action of PSB, VAM and phosphorus fertilizer. The results are in unison with the findings of Taipodia and Yubbey (2013).

Nutrient uptake

The highest plant N content of 0.99% was observed in treatment VAM + PSB + 50% RDF which was at par with treatments 100% RDF, PSB + 100% RDF and VAM + 100% RDF (Table 2). However, the application of VAM + PSB + 50% RDF exhibited highest N uptake (103.0 kg ha^{-1}) which was significantly superior over all other treatments. Sole inoculation of VAM and PSB also significantly increased N uptake over control (Table 3). The increase in nitrogen uptake may be attributed to enhancement of nutrient uptake by VAM (Danie *et al.*, 2013). VAM enhance nutrient acquisition through the exploration of a larger soil volume (Dar, 2010), increase in root surface, solubilization and mobilization of nutrients by VAM and PSB. The results corroborate the findings

Table 2: Effect of PSB (*Bacillus subtilis*)and VAM (endomycorrhiza) on NPK content in plants at harvest and plant nutrient uptake in maize (*Zea mays* L.)

Treatments	Nutrient content (%)			Nutrient uptake (kg ha^{-1})		
	N	P	K	N	P	K
Control	0.72 (0.84)	0.17 (0.41)	0.64 (0.79)	58.3	13.7	51.9
100% RDF	0.93 (0.96)	0.28 (0.52)	0.85 (0.92)	95.0	28.6	86.8
PSB	0.77 (0.87)	0.19 (0.43)	0.72 (0.84)	67.0	16.5	62.6
PSB + 100% RDF	0.96 (0.97)	0.28 (0.52)	0.88 (0.93)	98.8	28.8	90.6
PSB + 50% RDF	0.90 (0.94)	0.24 (0.48)	0.82 (0.90)	90.3	24.1	82.3
PSB + 25% RDF	0.85 (0.92)	0.22 (0.46)	0.77 (0.87)	84.0	21.7	76.1
VAM	0.80 (0.89)	0.20 (0.44)	0.69 (0.83)	70.0	17.5	60.3
VAM + 100% RDF	0.97 (0.98)	0.28 (0.52)	0.89 (0.94)	100.3	28.9	92.1
VAM + 50% RDF	0.91 (0.95)	0.26 (0.50)	0.83 (0.91)	91.4	26.1	83.3
VAM + 25% RDF	0.87 (0.93)	0.23 (0.47)	0.79 (0.88)	86.0	22.7	78.1
VAM + PSB + 50% RDF	0.99 (0.99)	0.28 (0.52)	0.92 (0.95)	103.0	29.1	95.6
VAM + PSB + 25% RDF	0.89 (0.94)	0.25 (0.49)	0.81 (0.89)	88.2	25.0	80.3
$CD_{0.05}$	0.06	0.02	0.02	1.98	1.66	1.73

*Values in parentheses are square root transformed values; RDF = Recommended dose of P fertilizer

of Sathish *et al*. (2011) and Taipodia and Yubbey (2013).

The highest P content of 0.28% was observed in treatment VAM + PSB + 50% RDF which was at par with treatments 100% RDF, PSB + 100% RDF and VAM + 100% RDF (Table 2). Sole inoculation of VAM and PSB significantly increased P uptake over control which were at par with each other but the impact due to VAM was more than PSB. The application of VAM + PSB + 50% RDF exhibited highest P uptake (29.1 kg ha^{-1}) which was at par with treatments 100% RDF, PSB + 100% RDF and VAM + 100% RDF (Table 2). This might be due to the increased exploration of greater soil volume by VAM fungi for increased root growth and more absorptive surface available for P utilization (Miller, 2000) and solubilization and mobilization by VAM and PSB. The results are in conformity with Singh *et al*. (2011), Danie *et al*. (2013) and Taipodia and Yubbey (2013).

The highest K content of 0.92% was recorded in treatment VAM + PSB + 50% RDF which was at par with VAM + 100% RDF (Table 2). Sole use of PSB and VAM also significantly improved K uptake over control. However, the treatment VAM + PSB + 50% RDFP exhibited significantly highest K uptake (95.6 kg ha^{-1}). The increase in plant K content and uptake may be attributed to VAM effect (Danie *et al*., 2013). However, dual inoculation with VAM and PSB showed more K content and uptake perhaps due to the synergistic effect of PSB, VAM and inorganic fertilizers. The results are in close conformity with Sathish *et al*. (2011) and Taipodia and Yubbey (2013).

The present study revealed that the use of 50% RDF along with VAM and PSB influenced growth, yield and quality of maize as well as improved nutrient availability. The application of 50% RDF along with VAM and PSB appears to be suitable combination for high yield under temperate rainfed conditions of Kashmir valley.

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