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Growth and yield of hybrid maize (*Zea mays* L.) an influenced by levels of phosphorus with PSB+VAM seed inoculation

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Abstract
A Field experiment was conducted in Kharif season 2015 at crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Allahabad (U.P) to study the effect of levels of phosphorus with VAM and PSB on growth and yield of hybrid maize (*Zea mays* L.). The treatments comprised of nine treatments, consisting of three phosphorus levels (40, 60 and 80 kg ha^{-1}) and seed inoculation with which was laid out in Randomized Block Design with three replications, in a plot size of 4 x 3 m with a spacing of 60 cm x 30 cm. The result revealed that the treatment T_6 (60 kg ha^{-1}of phosphorus + RSB + VAM) produced significantly higher plant dry weight (51.72 g), grain yield (4955.67 kg ha^{-1}), harvest index (40%) and B:C Ratio (1.41) in hybrid maize cultivation.

Keywords: yield, levels of phosphorus, PSB+VAM, seed inoculation, growth, hybrid maize

Introduction
Maize is the third major cereal crop after wheat and rice and belonging to gramineae family. Maize is considered as native of Central America & Mexico. In India, it is cultivated in about 1943 million hectares with a production of 24.35 million tonnes and productivity of 2583 kg ha^{-1} (GOI, 2014). The maximum area under maize is in Rajasthan while highest production in Andhra Pradesh and Karnataka.

Use of VAM and PSB might be useful in reversing the process of Phosphorus fixation in acidic soil, thereby enhancing Phosphorus availability to maize crop. The VAM mobilizes Phosphorus by increasing the surface area of roots and greater exploration of soil volume as a result of hyphal network, leading to higher nutrient use efficiency. (George *et al*, 1992). The present study was undertaken with an objective of finding the extent to which the combined application of VAM and PSB might reduce Phosphorus dose in hybrid maize without adverse effect on maize yield.

Phosphorus is 2nd essential plant nutrient after nitrogen but it is one of the least mobile nutrients and thus not readily available to plants as it gets fixed in soil particles. Balanced and optimum use of phosphorus fertilization plays a pivotal role in increasing the yield of cereals. The soils acidic in nature, which have high P-fixing power due to excessive presence of Fe and Al ion resulting into low availability of phosphorus to crop plants. Under such P-deficient soils, use of VAM (Vesicular arbuscular mycorrhizal fungi) might be useful in mobilization and absorption of Phosphorus fixed in soil as well as applied Phosphorus which may enhance Phosphorus availability, improved soil health and finally maize yield.

Material and Methods
A field experiment was conducted during Kharif season of 2015 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Allahabad (U.P.) which is located at 25^{0}24′42″ latitude, 81^{0}50′56″ longitude and at an 98m altitude above the mean sea level.

The experimental soil was sandy loam in texture with pH 7.34, EC 0.13dS m^{-1}, medium in available N (190.03 kg ha^{-1}), low in available P (22.5 kg ha^{-1}) and medium in available K (187.00kg ha^{-1}). The experiment entitled "Effect of levels of phosphorus with PSB and VAM on growth and yield of hybrid maize (*Zea mays* L.)" was laid out in a Randomized Block Design with 9 treatments replicated thrice. The plot size of each treatment was 12m^2 and crop was sown at a spacing of 60 × 30 cm. Seeds variety 'Ganga Safed-2'were inoculated with PSB (Phosphorus Solublizing Bacteria) and VAM (Vesicular Arbuscular Mycorrhizal Fungi) @ 200gm kg^{-1} seed of each respectively. After inoculation, the seeds were sown using seed rate of 20 kg-^{1}. The treatment comprises of three levels of phosphorus (40, 60, 80 kg ha^{-1}) and

inoculated seeds with PSB and VAM. All other recommended agronomic practices and plant protection measures were carried out in all treatments uniformly during the experimental trail.

Results and Discussion

Plant growth, quality and yield

Plant height showed significant increase due to various treatments. Maximum plant height (187.08 cm) was recorded in T_9 (80 kg ha^{-1} of P+PSB+VAM). Similar results have also been reported by Ojaghloo *et al*. 2007 [5]. This increase may be attributed to auxin production by PSB and increased supply of phosphorus by PSB and VAM (Fankem *et al*. 2008) [1]. It was found that seeds inoculated with both VAM +PSB, plants attained more height than plants in single inoculation. Similar results have been reported by Yousefi *et al*. 2011 [8] and Walpola and Yoon, 2012 [7]. Enhanced availability of phosphorus and its active involvement in shoot and root growth lead to attain taller plants. The findings are in conformity with Hussain *et al.* 2013 [2].

Table 1: Effect of levels of phosphorus with PSB and VAM on growth, grain yield and quality of Maize

Treatments	Plant Height (cm)	Dry weight (g)	Grain yield (kg ha^{-1})	Protein Content (%)
T_1 40 kg ha^{-1} of P+ PSB	169.58	49.69	3683.33	3.77
T_2 40 kg ha^{-1} of P + VAM	177.33	50.39	4436.67	4.03
T_3 40 kg ha^{-1} of P + PSB+VAM	170.05	51.47	4706.33	4.36
T_4 60 kg ha^{-1} of P+ PSB	171.5	51.65	3920.00	3.92
T_5 60 kg ha^{-1} of P + VAM	162.08	51.35	4500.67	4.18
T_6 60 kg ha^{-1} of P + PSB+VAM	151.16	51.72	4955.67	4.61
T_7 80 kg ha^{-1} of P+ PSB	154.91	50.37	3870.00	3.93
T_8 80 kg ha^{-1} of P+VAM	168.91	51.38	4073.33	4.63
T_9 80 kg ha^{-1} of P + PSB+VAM	187.08	51.07	4790.00	4.80
CD (P=0.05)	12.42	1.24	301.31	0.26

Yield attributes

With increase in phosphorus levels, yield components linearly and significantly increased except number of cob per plant (Table. 2). Treatment with higher dose of phosphorus (80 $kgha^{-1}$) resulted in significantly higher number of grains cob^{-1}(592.22), test weight (27.37 g), stover yield (7445.33$kgha^{-1}$). Phosphorus being the 2nd essential nutrient required for the promotion of meristematic and physiological activities such as leaf spread, root and shoot development, plant dry matter production, results in efficient absorption and translocation of water, nutrients and interception of solar radiation. These activities promote higher photosynthetic process which is translocated to assimilates into various sink producing components like cob length, number of grains cob^{-1} and test weight. (Singh and Nepalia, 2009) [6].

Yield

Significantly higher stover yield (7445.33 kgha-1) was recorded with application of highest phosphorus doses (80 $kgha^{-1}$) and minimum with other lower levels. Maximum grain yield (4955.67 $kgha^{-1}$) was recorded in Treatment T_6 (60kg ha^{-1} of P+PSB+VAM) may be attributed to enhanced availability of phosphorus and its active involvement in shoot and root growth lead to higher yield (Table.1). The findings are conformity Hussain *et al.* 2013 [2]. Co- inoculations of PSB and VAM significantly increase maize grain yield and plant biomass over single inoculated onces. Maximum HI (40.00 %) was observed in T_6 (60$kgha^{-1}$ of P+PSB+VAM). The maximum grain yield and harvest index was due to better translocation of photosynthates from source to sink and higher growth attributing characters into different parts of plant and yield attributing characters like cob length, number of grains per cob, test weight etc. (Naik *et al*. 2012) [4].

Protein content

Significantly higher Protein content (4.80%) was recorded in treatment T_9 (80$kgha^{-1}$ of P+PSB+VAM), while lowest Protein (3.77%) was obtained in T_1 (40$kgha^{-1}$ of P+PSB) (Table.1). Increased phosphorus fertilization increases available phosphorus, which in turn increases nitrogen concentration in grain, which is an integral part of protein synthesis and there by accelerating the protein content (Jaliya *et al.* 2013) [3].

Table 2: Effect of levels of Phosphorus with PSB and VAM on yield attributes of Hybrid Maize

Treatments	Number of grains cob^{-1}	Test weight (g)	Stover yield (kg ha^{-1})	Harvest index (%)
T_1 40 kg ha^{-1} of P+ PSB	492.78	21.45	7000.00	34.46
T_2 40 kg ha^{-1} of P + VAM	462.33	23.87	7203.67	38.11
T_3 40 kg ha^{-1} of P + PSB+VAM	463.89	26.53	7413.33	38.82
T_4 60 kg ha^{-1} of P+ PSB	478.11	21.87	7011.67	35.83
T_5 60 kg ha^{-1} of P + VAM	465.55	24.40	7260.00	38.26
T_6 60 kg ha^{-1} of P + PSB+VAM	430.33	26.10	7435.33	40.00
T_7 80 kg ha^{-1} of P+ PSB	475.78	23.47	7088.00	35.29
T_8 80 kg ha^{-1} of P+VAM	496.00	25.73	7331.00	135.71
T_9 80 kg ha^{-1} of P + PSB+VAM	592.22	27.37	7445.33	39.15
CD (P-0.05)	58.83	1.06	136.17	1.62

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