The Pharma Innovation Journal 2022; 11(2): 2231-2234

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 2231-2234

www.thepharmajournal.com
Received: 15-12-2021
Accepted: 27-01-2022

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Performance of hybrid maize (*Zea mays* L.) under various liquid and carrier based bio-fertilizers at different phosphorus levels

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Abstract
A field experiment was conducted during *kharif* season of 2016 at Udaipur, Rajasthan on clay loam soil to assess the effect of phosphorus levels (30, 45 and 60 kg ha-1) and bio fertilizer inoculums (LBF1, LBF2, CB, LBF1+CB and LBF2+CB) of hybrid maize. The results revealed that application of LBF1+CB at 60 kg P2O5 ha-1 significantly increased plant growth parameters *viz.* plant height, dry matter, LAI at various stages as well as Net returns and B C ratio.

Keywords: Hybrid maize, phosphorus, bio fertilizer, plant growth parameters and economics

Introduction
Maize (*Zea mays* L.) is one of the major cereal crops and is a very versatile grain that benefits mankind in many ways. It is a versatile crop and ranks third following wheat and rice in world production as reported by Food and Agriculture Organization. Maize is a staple human food, a feed for livestock and raw material for many industrial products. It is an important food crop grown commercially in large scale and at subsistence level by many resource poor farmers. In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewer's grit and alcohol. Corn oil is used for salad, soap-making and lubrication (Amin and Hamidreaza, 2015) [1].

Phosphorus (P), one of the main plant nutrients, is essential for plant growth and development. It is involved in several key plant functions, such as energy metabolism, photosynthesis, respiration, nitrogen fixation, enzyme regulation, nutrient movement within the plant and transfer of genetic characteristics (DNA) from one generation to the next. Therefore, P is important in cell division and development of new tissue (Hameeda *et al*., 2008) [5]. Interest in liquid bio-fertilizer formulations has grown rapidly all over the world, since the liquid bio-fertilizers of good quality hold great promise in agriculture because of benefits over the conventional carrier based bio-fertilizers such as longer shelf life, better survival on seed and better nodulation, cost saving on carrier material i.e. pulverization, neutralization, sterilization, contamination free and convenience of handling, storage and transportation. Bio- fertilizer usually contains microorganisms having specific function such as *Azospirillum* to fix nitrogen and P solubilizing bacteria to solubilize P from the soil and fertilizer to be available to the plants. Application of bio fertilizers became of great necessity to get a yield of high quality and to avoid the environmental pollution. For gave to highest seed yield in agriculture addition to both nitrogen and phosphate fertilizer is very important. Bio-fertilizers contain beneficial bacteria and fungi that improve soil chemical and biological characteristics, phosphate solutions and agricultural production. The efficiency of EM (Effective recommended Microorganisms) as a bio-fertilizer is attributed to its role in accelerating the mineralization processes of organic matter and helping the release of nutrients resulting in enhancing the utility values of soil organic matter contents and cations exchange capacity. Therefore, bio-fertilizers are gaining importance as they are eco-friendly, nonhazardous and nontoxic products.

Phosphatic fertilizer when applied to the soil it has been seen that only a small amount is actually utilized by the plants. In India, it has been estimated that about 98% of the soil have some amount of deficit in phosphorus. Chemical fertilizer having phosphorus have a disadvantage, inorganic phosphates when applied to the soil are immobilized and thus not totally available to the plant (Karpagam and Nagalakshmi, 2014) [7]. PSBs or Phosphate solubilizing bacteria helps in converting phosphorus into soluble forms by acidification by organic acids, chelating oxalic acids from sugars. They also produce enzymes like phosphatase enzymes that help in further degradation. Inoculation of PSBs in soil or near the rhizosphere of the plants has shown to promote growth of plants as a stimulatory effect. Plant roots can take up different forms of phosphorus like H2PO4, HPO4-2, this take up normally depends upon the soil pH, temperature, moisture content and other nutrients or minerals present in the soil (Rajsekaran *et al*., 2012).

Higher yield of maize can be obtained through the judicious use of plant nutrients. The mineral fertilizers will continue to play the key role in the augmentation of the food production in the entire world.

Materials and Methods

A field experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Raj) during *kharif* season 2016. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.6), low in available nitrogen (226.7 kg ha-1), and available phosphorus (19.4 kg ha-1) while medium in available potassium (254.6 kg ha-1). The experiment was laid out in factorial randomized block design and replicated thrice with three levels of phosphorus (30, 45, 60 kg ha-1 and five treatments of Bio fertilizer i.e. Liquid bio fertilizer-1* (LBF1), Liquid bio fertilizer-II*, (LBF2), Carrier based culture (CB). Liquid bio fertilizer-1 + Carrier based culture and Liquid bio fertilizer-1I +Carrier based culture. As per treatment whole P was applied at sowing through DAP adjusting the amount of nitrogen PSB bio-fertilizer was applied through seed treatment as per their recommendation. The Liquid biofertilizer1 and Liquid bio fertlizer2 contain 1010 cfu/ml and 109 cfu/ ml, respectively. Uniform recommended dose of nitrogen was supplied to crop through splitting urea and adjusting the amount of nitrogen present in DAP.

Results and Discussion Effect of phosphorus

A perusal of the data (Table 1) indicated that plant population recorded at 15 DAS and at harvest was not significantly influenced amongst P2O5 levels. The data showed that increasing P2O5 levels tended to increase plant height significantly at 30, 60 DAS and at harvest. Application of 60 kg P2O5 ha-1 significantly increased the plant height over 45 and 30 kg P2O5 ha-1 by 7.5 and 15.5 per cent at 30 DAS and 9.8 and 4.9 per cent at 60 DAS, respectively. The plant height at harvest was significantly higher with application of 60 kg P2O5 ha-1. It was noticed that plant height increased by 5.2 and 12.2 per cent, respectively over 45 and 30 kg P2O5 ha-1. The data indicate that increasing rates of P2O5 failed to exhibit significant effect on days to 50 per cent tasseling and sillking. Amongst mineral nutrients, N and P are considered to be the most important for exploiting genetic potential of crop through growth and development. Phosphorus stimulates early root development and growth and there by helps to establish seedlings quickly. It also plays an active role in formation of high energy phosphates, which are unstable in water and act as a carrier for vital reactions like oxidation of sugars through enhancing enzymatic activities and in initial reaction for photosynthesis, respiration of plants etc. In fact it is considered as energy currency in plant system which is of great physiological significance (Halvin *et al*., 2005) [4].

₹It is apparent from the (Table 2) the data show that application of different levels of phosphorus significantly proved the dry matter accumulation and leaf area index at various growth stages. Application of 60 kg P2O5 ha-1 significantly enhanced dry matter by 1.1 and 3.0 g plant-1, respectively over 45 and 30 kg P2O5 ha-1 at 30 DAS. At 60 DAS crop fertilized with 60 kg P2O5 ha-1 significantly increased dry matter by 14.7 and 40.1 per cent over 45 and 30 kg P2O5 ha-1. Likewise at harvest significantly increase in dry matter with application of different levels of phosphorus. The increase in dry matter was to the tune of 5.9 and 17.6 g plant-1 with the application of 60 kg P2O5 ha-1 over 45 and 30 kg P2O5 ha-1, respectively. The increasing levels of phosphorus application significantly increased LAI. The highest LAI was recorded with application of 60 kg P2O5 ha-1 which was significantly higher over 45 and 30 kg P2O5 ha-1 at various growth stages. The nutrients are harvestable plant part and mostly translocated from vegetative to reproductive parts. Thus better nutritional environment in plants under the influence of increasing phosphorus levels seems to have promoted height of plants and growth of individual leaf by the way of active cell division and their elongation. The larger canopy development and increased plant height under the application of higher doses of phosphorus could be reasoned for increased interception, absorption and utilization of radiant energy which in turn increased overall growth, photosynthesis, LAI, and finally dry matter at successive growth stages. The results of significant improvement in overall growth of crop under the influence of 60 kg P2O5 ha-1 are in close conformity with the findings of Paramasivan *et al*., (2011) [8] and Sepat and Rai, (2013) [10]. The data show that application of 60 kg P2O5 ha-1 recorded maximum net return (₹ 45013 ha-1) and B C ratio (1.75) which was significantly higher over 45 and 30 kg P2O5 ha-1.

Effect of bio fertilizer

The data (table 1) reveal that application of bio fertilizers were not influenced plant population 15 DAS and at harvest, days to 50 per cent tasseling and days to 50 per cent sillking. The data show that application of phosphatic bio fertilizers were influenced the plant growth parameters at various stages of maize. The result show that dual inoculation of bio fertilizer had significant different in plant height, dry matter and LAI. Highest plant height at 30 DAS (71.46 cm), 60 DAS (197.77 cm) and at harvest (219.31 cm), dry matter at 30 DAS (8.75 g plant-1), at 60 DAS (88.19 g plant-1) and at harvest (141.22 g plant-1) and the maximum LAI at 30 DAS (1.51) and 60 DAS (3.08) with the inoculation with liquid and carried based bio fertilizer (LBF1 + CB). Further results show that seed inoculation with LBF1 + CB significantly increased plant height over LBF1, LBF2 and CB alone, respectively. Further it was recorded that LBF1+CB was at par with LBF2+CB.

Data (Table 2) indicated that at 30 DAS seed treatment with LBF1+CB recorded significantly higher dry matter over LBF1, LBF2, CB and LBF2+ CB by 1.4, 1.8, 3.0 and 0.9 g plant-1, respectively. It was noticed that at 60 DAS and harvest seed inoculation with LBF1+CB was significant increased in the dry matter to the tune of 8.7, 9.1 and 10.6 per cent and 7.7, 7.9 and 8.7 per cent, respectively over LBF1, LBF2 and CB. But it was also noticed that LBF1+CB was at par with LBF2+ CB at harvest. Data clearly indicated that seed inoculation with LBF1+CB at 30 DAS and 60 DAS brought significant increase in LAI over LBF1, LBF2 and CB by 12.7, 13.5 and 16.1 per cent, 32.0, 11.7 and 58.8 per cent, respectively. However, it was at par with LBF2+ CB. This improvement may be attributed to the auxin production by PSB and increased supply of phosphorus through solubilisation of native and applied phosphorus by producing different organic acids by PSB. This was considered to be important for proper growth and development of plant. Further, the production of amino acid, vitamins and growth promoting substances by PSB might resulted in improving plant growth and yield attributes of maize. These results are in close conformity with the findings of (Baral and Adhikari, 2013) [2]. The phosphate solubilizing bacteria (PSB) is capable to solubilizing the fixed soil phosphate by the secretion of number of organic acid. The potential of these phosphate solubilize has been realized and are used as bio inoculants for plant growth. Significant improvement in overall growth of maize crop recorded due to inoculation with LBF1+CB and was close with findings of Jat and Ahlawat (2004) and Choudhary and Gautam (2007) [3]. The bio-fertilizer LBF1+CB recorded maximum net return (₹ 44553 ha-1) which was higher by 7408, 6936 and 8660 over LBF1, LBF2 and CB, respectively, and the highest B C ratio (1.78) was obtained when inoculated with LBF1+CB, which was higher over rest of bio-fertilizers LBF1(1.49), LBF2 (1.44) and CB (1.50).

Table 1: Effect of phosphorus levels and bio-fertilizers on plant population and growth parameters of maize

Treatments	Plant population ('000 ha-1)			Plant height (cm)		Days to 50% Tasseling	Days to 50% Silking
15 DAS		At harvest	30 DAS	60 DAS	At harvest		
			Phosphorus levels (P2O5 kg ha-1)				
30	65.50	63.24	63.15	180.55	191.58	46.07	52.00
45	65.59	63.66	67.65	189.69	204.29	46.00	51.93
60	65.57	63.48	72.95	199.00	215.01	46.00	52.00
S.Em±	0.210	0.510	1.12	3.10	4.029	0.599	0.740
CD (P = 0.05)	NS	NS	3.26	8.99	11.67	NS	NS
			Bio-fertilizers				
LBF1	65.36	63.58	66.18	184.99	192.74	46.00	52.00
LBF2	65.48	63.29	65.59	184.62	196.16	46.00	51.89
CB	65.62	63.53	65.44	183.68	191.98	46.00	52.00
LBF1+CB	65.59	63.19	71.46	197.77	219.31	46.11	52.00
LBF2+CB	65.73	63.71	70.91	197.68	217.93	46.00	52.00
S.Em±	0.272	0.658	1.45	4.01	5.20	0.77	0.95
CD (P = 0.05)	NS	NS	4.219	11.616	15.068	NS	NS

*LBF: liquid bio-fertilizer
*CB: carrier based

Table 2: Effect of phosphorus levels and bio-fertilizers on dry matter accumulation, leaf area index and economics of maize

Treatments	Dry matter accumulation (g plant-1			Leaf area index		Net return (₹ ha-1)	B C ratio
30 DAS		60 DAS	At harvest	30 DAS	60 DAS		
			Phosphorus levels (P2O5 kg ha-1)				
30	5.90	68.95	124.74	1.28	2.38	32002	1.32
45	7.73	84.17	136.39	1.40	2.78	40546	1.62
60	8.92	96.58	142.38	1.50	3.29	45013	1.75
S.Em±	0.223	1.623	2.671	0.034	0.069	1485	0.06
CD (P = 0.05)	0.647	4.703	7.738	0.098	0.201	4302	0.17
			Bio-fertilizers				
LBF1	7.38	81.12	131.14	1.34	2.81	37145	1.49
LBF2	6.98	80.78	130.91	1.33	2.30	35893	1.44
CB	6.66	79.76	129.87	1.30	1.94	37617	1.50
LBF1+CB	8.75	88.19	141.22	1.51	3.08	44553	1.78
LBF2+CB	7.82	86.33	139.38	1.49	2.94	40728	1.62
S.Em±	0.28	2.09	3.44	0.04	0.09	1917	0.08
CD (P = 0.05)	0.83	6.07	9.98	0.12	0.25	5553	0.22

*LBF: liquid bio-fertilizer
*CB: carrier based

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