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Effect of row spacing with different levels of phosphorous and biofertilizer on growth and yield of maize (*Zea mays* L.)

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Abstract
A field experiment was conducted at Crop Research Farm (CRF), SHUATS, Allahabad, during the *kharif* season of 2017 with 12 treatments replicated thrice in randomized block design, to determine the effect of row spacing with different levels of Phosphorous and biofertilizer on growth and yield of maize (*Zea mays* L.). This treatment consisted of two treatment of planting geometry 60 cm x 20 cm, 45 cm x 20 cm, three different levels of phosphorous 60 kg/ha, 80 kg/ha and 100 kg/ha. Seed was inoculated and uninoculated with PSB. The results revealed that spacing of 60 cm x 20 cm and 80 kg P ha^{-1} with phosphate solubilising bacteria was found to be the best treatment for obtaining higher grain yield (5.22 t ha^{-1}), harvest index (43.13%), test weight (28.33 g) and other growth and yield attributes like higher net returns (Rs 40,303.50/-ha^{-1}) and B:C ratio (2.18) was also observed. However, seed inoculation with PSB showed positive differences in effecting the grain yield.

Keywords: row spacing, Phosphorous levels and biofertilizer

1. Introduction

Maize (*Zea mays* L.) is one of the important crop cereals crop in the world's agricultural economy both as food for human consumption and feed for animal. It is the third most important cereal crop of the world after wheat and rice. It has got immense potential. It is known as "Queen of cereals" due to the high productiveness, easy to process, low cost than the other cereals (Jaliya et al. 2013) [3]. At global level maize accounts for 15% protein and 20% of calories in world food diet. Maize is a major component of livestock feed and it is palatable to poultry, cattle and pigs as it supplies them energy. In India, about 50 to 55 % of the total maize production is used as food, 30 to 35% goes for poultry, piggery and fish meal industry and 10 to 12 % to wet milling industry. In advance 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 lubricant. Being a C_4 plant, it is an efficient converter of absorbed nutrients into food. Maize contains zein protein which has two essential amino acids named Tryptophan and Lysine (Singh, 2010) [6].

Plant spacing or plant density plays an important role in the competitive balance between weeds and maize. Maize green yield is affected by spatial arrangement of row spacing and plant density due to its low tillering ability and presence of flowering period. Maize is a plant with individual productivity therefore plant densities determines yield significantly. Row spacing is an agronomic management strategy used by producers to optimize husbandry of the soil and plant ecosystem from sowing to harvest with the goal of blostering the production of crops. Plant density, number of plants per unit area, is one of the most important yield determinants of maize. Several researchers reported that the effect of row spacing on maize dry matter yield and quality characteristics is variable.

Phosphorous is one of the most important nutrients for higher yield in larger quantity. It is one of the major essential plant nutrients after nitrogen and is the second most deficient plant nutrient. P is the second most crop-limiting nutrient in most soils. Plant growth behaviour is influenced by the application of Phosphorous. Phosphorous is associated with several vital physiological, metabolic and biochemical functions such as utilisation of sugars and starch, photosynthesis, cell division, fat, and albumin formation. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and production. Growth components of maize such as leaf area per plant increases with increasing levels of phosphorous. It is known stimulate early and extensive development of root systems, which enables rapid maize growth and to maize early. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and production

Biofertilizer also plays an important role because they possesses many desirable soil properties and exerts beneficial effect on the soil physical, chemical and biological characteristics of the soil. Among the biofertilizers, *Azotobacter* represents the main group of heterotrophic, non-symbiotic, gram negative, free living nitrogen fixing bacteria. The genus *Azotobacter* include 6 species with *Achroococum* most commonly inhabiting in various soils all over the world. Phosphate solubilizing bacteria are able to change insoluble phosphorus in soil into the absorbed soluble. It facilitates sustained P supply for the growth of plants (Walpola and Yoon, 2012; but also stimulates the efficiency of nitrogen fixation and accessibility of other trace elements by synerthesizing important growth promoting substances like siderophore, antibiotics, etc. (Kumar *et al.* 2012) [4] and improves crop productivity (Abbas *et al.* 2013) [1] by solubilising insoluble phosphorous and providing protection to plants against soil borne pathogens. Plants root assoiciated fungus 'mycorrhiza' exhibit symbiotic association in many vascular plants.

2. Materials and method

The experiment was conducted during the *kharif* season of 2017 to study the effect of row spacing with different levels of phosphorous and biofertilizer on growth and yield of maize (*Zea mays* L.) with 12 treatments replicated thrice in randomized block design at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad. The Crop Research Farm is situated at 25^0 57' N latitude, 87^0 19' E longitudes and at an altitude of 98 m above mean sea level. This area is situated on the right side of the river yamuna and by the opposite side of Allahabad City. The soil of the experimental field constituting a part of central Gangetic alluvium is neutral and sandy loam with pH 7.4, the sowing of crop was done on 11^{th} July 2017 and was harvested in the last week of October, 2017. This treatment consisted of two treatment of planting geometry 60 cm x 20 cm, 45 cm x 20 cm, three different levels of phosphorous 60 kg/ha, 80 kg/ha and 100 kg/ha and seed was inoculated and uninoculated with PSB. Half dose of N and full doses of P and K was applied in two equal splits at knee height and tasseling stage.

Regular plant protective measures and irrigations were provided as when needed. Phorate was used against insects and borers. Weeding was done before the application of split urea application to reduce the competition among the crops and weeds. Measures like using reflectors during the cob growth stages was taken to protect the cobs from being harmed by birds and rodents. The picking of cobs was done once the grains contain not more than 20 % moisture.

Table 1: Physiological Growth Parameters at 60 Das

Treatment	Plant Height (cm)	No. of leaves	Dry weight (g)	CGR (g m^{-2} day^{-1})	RGR (g g^{-1} day^{-1})	Cobs $plant^{-1}$ (No)
45 cm x 20 cm + 60 kg P ha^{-1} + un inoculated	159.02	14.00	120.00	2.66	2.66	1.73
45 cm x 20 cm + 60 kg P ha^{-1} + inoculated with PSB	158.52	13.47	140.00	4.65	4.65	1.47
45 cm x 20 cm + 80 kg P ha^{-1} + un inoculated	160.47	12.60	153.33	4.83	4.83	1.93
45 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB	161.87	12.73	143.33	3.06	3.06	1.40
45 cm x 20 cm + 100 kg P ha^{-1} + un inoculated	177.42	13.33	120.00	2.36	2.36	1.87
45 cm x 20 cm + 100 kg P ha^{-1} + inoculated with PSB	165.65	12.80	140.00	3.52	3.52	1.60
60 cm x 20 cm + 60 kg P ha^{-1} + un inoculated	174.87	12.53	130.00	2.43	2.43	1.47
60cm x 20 cm + 60 kg P ha^{-1} + inoculated with PSB	165.91	14.00	120.00	2.78	2.78	1.80
60 cm x 20 cm + 80 kg P ha^{-1} + un inoculated	165.77	12.87	166.67	5.35	5.35	1.87
60 cm x 20 cm+ 80 kg P ha^{-1} + inoculated with PSB	175.62	15.00	126.67	2.09	2.09	1.73
60 cm x 20 cm + 100 kg P ha^{-1} + un inoculated	175.37	13.60	126.67	2.49	2.49	1.80
60 cm x 20 cm + 100 kg P ha^{-1} + inoculated with PSB	166.12	13.00	106.67	2.08	2.08	2.00
F test	S	S	S	S	S	S
SEd (±)	6.22	0.67	13.99	0.96	0.96	0.18
CD (P=0.05)	12.91	1.40	29.02	1.99	1.99	0.38

Table 2: Yield Attributes Parameters

Treatment	Cob length (cm)	Grains per cob (No)	Test weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
45 cm x 20 cm + 60 kg P ha^{-1} + un inoculated	15.13	15.13	23.60	4.10	5.92	40.76
45 cm x 20 cm + 60 kg P ha^{-1} + inoculated with PSB	14.93	14.93	22.73	5.09	6.87	42.51
45 cm x 20 cm + 80 kg P ha^{-1} + un inoculated	16.00	15.40	23.73	4.56	6.12	42.70
45 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB	14.47	14.47	24.73	4.02	5.79	41.02
45 cm x 20 cm + 100 kg P ha^{-1} + un inoculated	14.60	14.60	23.80	4.79	6.72	41.61
45 cm x 20 cm + 100 kg P ha^{-1} + inoculated with PSB	15.80	15.80	23.40	3.71	5.18	41.77
60 cm x 20 cm + 60 kg P ha^{-1} + un inoculated	16.60	16.07	23.27	5.02	6.63	43.07
60 cm x 20 cm + 60 kg P ha^{-1} + inoculated with PSB	16.27	17.13	26.80	4.93	6.65	42.57
60 cm x 20 cm + 80 kg P ha^{-1} + un inoculated	13.60	13.93	23.13	4.91	6.56	43.01
60 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB	17.20	18.20	28.33	5.22	6.90	43.13
60 cm x 20 cm + 100 kg P ha^{-1} + un inoculated	13.20	13.60	23.73	4.13	5.89	41.22
60 cm x 20 cm + 100 kg P ha^{-1} + inoculated with PSB	14.67	14.67	23.93	4.82	6.66	42.06
F test	S	S	S	S	S	S
SEd (±)	1.00	1.10	0.89	0.26	0.35	1.42
CD (P=0.05)	2.07	2.29	1.84	0.54	0.72	2.94

3. Results and discussion

The result of the experiment revealed that the treatments having spacing of 60 cm x 20 cm, 80 kg P inoculated with PSB gave the highest grain yield among all the treatments. As per the data given in the table it is clear that treatment T_5 (45 cm x 20 cm + 100 kg P ha^{-1} + un inoculated) shows the maximum plant height is due to increase in nitrogen fixing and phosphate solubilising microoganisms to enhance growth and yield of maize crop and have possibility of substituting a part of demand of chemical fertilizers of the crop. The maximum number of leaves $plant^{-1}$, cob length (cm) and No. of cobs $plant^{-1}$ was observed in treatment T_{10} (60 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB) is due to increase in nitrogen fixing and phosphate solubilising microoganisms to enhance growth and yield of maize crop and have possibility of substituting a part of demand of chemical fertilizer. These findings are in confirmation of Surendra and Sharanappa, 2000.

Higher dry weight, CGR, RGR, stover yield and harvest index was observed in treatment T_{10} (60 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB) is due to synergistic action of organisms which increased the phosphorous uptake. These findings are in confirmation of Singh *et al*., 2010 [6]. Higher grains per cob (No) and test weight (g) was recorded under treatment T_{10} (60 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB) was because of the better translocation of photosynthates from source to sink and higher growth attributing characters into different parts of plant and yield like cob length, cob girth, number of grains per cob, test weight, etc. Higher grain yield (t ha^{-1}) was observed under treatment T_{10} (60 cm x 20 cm + 80 kg P ha^{-1} + inoculated with PSB) is due to phosphorous application because phosphorous was directly related to the vegetative and reproductive phases of the crop and attributes complex phenomenon of phosphorous utilization in plant metabolism. It also helped in the efficient absorption and utilisation of the other required plant nutrients which ultimately increased the grain yield.

4. Conclusion

It can be conducted from the conducted experiment that the treatment (T_{10}) is found best for the farmers because it produces the highest grain yield. Therefore, 80 kg P inoculated with PSB may be recommended for higher yield with 60 cm x 20 cm row spacing.

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