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Kelothu Vijay Kumar
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Dr. Biswarup Mehera
Associate Professor, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Kelothu Vijay Kumar
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Effect of bio-fertilizers and potassium on growth and yield of maize (*Zea mays* L.)

Kelothu Vijay Kumar and Biswarup Mehera

Abstract
The field experiment was conducted during *zaid* season of 2021 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P). The soil of the experiment plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.82%), available N (291.24 kg/ha), available P (32.85 kg/ha) and available K (264.78 kg/ha). The treatments consisted of three sources (Azotobacter seed treatment), (KSB seed treatment), (potassium levels 30, 40, 50kh/ha) and one control plot, respectively. The experiment was laid out in randomized block design with ten treatments and were replicated thrice. Result defined that maximum plat height (222.60 cm), dry weight (229.5g/plant), crop growth rate (27.44g/m^2 /day), cobs (1.6/pant), row /cob (15.03), seeds/row (25.07), seed yield (7.97t/ha) and Stover yield (11.50t/ha), harvest index (40.91%), test weight (243.33g), maximum gross returns (1,59,400/ha), net returns(1,24,245.3/ha), and benefit: cost ratio (2.94) were obtained in the treatment combination of Azotobacter + KSB + potassium 50kg/ha compared to other treatments.

Keywords: Economics, seed yield, azotobacter, KSB, stover yield

Introduction
Among the cereals, maize (*Zea mays* L.) ranks third in total world production after wheat and rice and it is principle staple food in many countries, particularly in the tropics and sub - tropics. Maize is considered as the “Queen of Cereals”. Being a C4 plant, it is capable to utilize solar radiation more efficiently even at higher radiation intensity. It is one of the most versatile crops which can be grown in diverse environment and geographical range. The major maize produce countries in the world are USA, China, South and Central Africa, Argentina, Brazil and Mexico. In India, the important maize growing states are Utter Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Karnataka, Himachal Pradesh and Andhra Pradesh.
In India 45 to 48% of Maize produced is consume by human and the rest is use in cattle and poultry feed and by the starch and oil industries. Maize is utilized in many ways like other grain crops in food dishes including “Chapati”. Maize is also utilized for starch, oil, fuel, and feed. It is used as major cereal in the form of processed foods for breakfast and snacks. In addition, green cobs are consumed as roasted form. Popping the corn is a method of starch cookery. Maize is used for number of products *viz*., starch, glucose, dextrose, protein, high fructose syrup, maldextrin, meal fiber and gluten products which have application in industries such as alcohol, textile, paper, pharmaceuticals, organic chemicals, cosmetics and edible oil, so it is called as industrial crop.
Maize grain contains about 10% protein, 4% oil, 70% carbohydrates, 2.3% crude fiber, 10.4% albuminoides and 1.4% ash. Maize grain has significant quantities of vitamin A, nicotinic acid, riboflavin, vitamin E and low in calcium but fairly high in phosphorus. Fundamentally, potassium is a macronutrient in plants and animals. Potassium is essential macronutrient for plant growth and plays significant role in activation of several metabolic processes including protein synthesis, photosynthesis, enzymes as well as in resistance to diseases, insects, abiotic stress, etc. Potassium though present as abundant element in soil or is applied to fields as natural or synthetic fertilizers, only 1-2% of this is available to plants, the rest being bound with other minerals and therefore unavailable to plants. The most common soil components of potassium, 90 to 98% are feldspar and mica. Soil microorganisms influence the availability of soil minerals, playing a central role in ion cycling and soil fertility. Very little of this potassium source is available for plant use. A wide range of bacteria namely Pseudomonas, Burkholderia, Acido Thiobacillus Ferrooxidans, Bacillus mucilaginosus, Bacillus edaphicus, Bacillus circulans and Paenibacillus spp. has been reported to release potassium in accessible

form from potassium bearing minerals in soils. These potassium solubilizing bacteria (KSB) were found to dissolve potassium, silicon and aluminium from insoluble K-bearing minerals such as micas, illite and orthoclases by excreting organic acids which either directly dissolved rock K or chelated silicon ions to bring K into the solution (Bin *et al.* 2010).

Azotobacter is Plant Growth Promoting Rhizobacteria through the mechanism of nitrogen fixation and phytohormon production but this rhizobacteria has a role to control plant diseases. Azotobacter bacteria belong to the family of azotobacteriaceae, aerobic, free living, and heterotrophic in nature. They are found in neutral or alkaline soils. There is increment in Maize biomass with the application of manure and Azotobacter. In nitrogen-deficient sand, seed inoculation increased plant length, dry weight, and nitrogen content in addition to a significant increase in soil nitrogen.

Materials and Methods

The present examination was carried out during *Zaid* 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, UP, which is located at 25.28ºN latitude, 81.54ºE longitude and 98 m altitude above the mean sea level. KSMH-1980 variety used for sowing Maize. The experiment laid out in Randomized Block Design which consisting of ten treatments with T_1: Control,T_2: Azotobacter + Potassium at 30 kg/ha, T_3: Azotobacter + potassium at 40 kg/ha, T_4: Azotobacter + potassium at 50 kg/ha, T_5: KSB + Potassium at 30 kg/ha, T_6: KSB + Potassium at 40 kg/ha, T_7: KSB + Potassium at 50 kg/ha, T_8: Azotobacter + KSB + Potassium at 30 kg/ha, T_9: Azotobacter + KSB + Potassium at 40 kg/ha,T_{10}: Azotobacter + KSB + Potassium at 50 kg/hawere replicated thrice.

The experimental site was uniform in topography and sandy loam in texture, nearly neutral in soil reaction (P^H 7.1), low in Organic carbon (0.38%), medium available N (225 kg ha^{-1}), higher available P (19.50 kg ha^{-1}) and medium available K (213.7 kg ha^{-1}). Nutrient sources were Urea and DAP to fulfill the necessity of Nitrogen and phosphorous. The application of fertilizers were applied as basal at the time of sowing. The seeds were inoculated with respective bio fertilizers as per the treatment combinations. MOP was applied in the treatment plots to fulfill the needs of potassium. In the period from germination to harvest several plant growth parameters were recorded at frequent intervals along with it after harvest several yield parameters were recorded those parameters are growth parameters, plant height, plant dry weight and CGR are recorded. The yield parameters like cobs per plant, rows per cob, seeds per row, test weight (g), seed yield (t/ha), stover yield (t/ha) and harvest index (%) were recorded and statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design (Gomez K.A. and Gomez A.A. 1984) [3].

Results and Discussion

Growth attributes

Plant height

Data in table 1 tabulated that significantly highest plant height (222.60 cm) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (219.27 cm) with Azotobacter + KSB + potassium 40kg/ha, treatment T_7 (215.00 cm) with KSB + potassium 50kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha. Azotobacter inoculation augment plant growth attributed to the production of higher quantities of growth promoting substance and complementary effect of enhanced the conjoint use of chemical and nitrogen availability (Meena *et al.* 2013) [5] in maize. The results are conformity with those reported by Sushila and Gajendra (2000) [9] and Tetarwal *et al.* (2011) [10]. KSB is able to solubilize inorganic source of K like muriate of potash and sulphate by means of production of organic acids in order toimprove yield. Application of indigenous KSB formulation with various doses of potash fertilizers with N and P enhanced green leaf yield andp roductivity in tea.The increase in yield might be due to the solubilisation of nutrients in the soil by producing organic acids by KSB. The results were in accordance to Archna *et al.* (2007) and Bagyalakshami *et al.* (2012) [2].

Table 1: Effect of bio fertilizers and potassium levels on growth attributes in maize

Treatments	Plant height (cm)	Dry weight (g/plant)	Crop growth rate (g/m^2/day)
Control	196.00	157.5	15.73
Azotobacter + Potassium 30 kg/ha	201.20	168.3	17.84
Azotobacter + potassium 40 kg/ha	204.50	179.5	20.50
Azotobacter + potassium 50 kg/ha	207.40	186.7	21.59
KSB + Potassium 30 kg/ha	203.33	177.2	20.21
KSB + Potassium 40 kg/ha	210.00	206.0	23.41
KSB + Potassium 50 kg/ha	215.00	207.9	25.75
Azotobacter + KSB + Potassium 30 kg/ha	206.23	193.2	23.05
Azotobacter + KSB + Potassium 40 kg/ha	219.27	214.0	26.43
S. EM (±)	2.57	5.46	2.12
C. D. (P = 0.05)	7.66	16.23	6.30

Plant dry weight (g/plant)

Significantly highest plant dry weight (229.5 g) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (214.0 g) with Azotobacter + KSB + potassium 40kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha.

Possible direct effect of the nitrogen fixing bacteria and potassium solubilizing bacteria on plant growth *via* phytohormones, they mainly acted by an indirect way via mineral weathering, which increased the amount of available nutrients for the plant and/or a direct effect of the bacteria on plant roots by phytohormones which stimulate the formatio n of lateral root sand absorbent root hairs, which eventually helped in uptake of higher nutrients and minerals by plants and leads to increase in higher biomass accumulation and higher plant dry weight. The results were found to be in resonance with Mikhailouskaya *et al.* 2005 [6], Zhanga Prajapati *et al.* 2014 [11] and Konga 2014 [11].

Crop Growth Rate (g/m^2/day)

At 80- till harvest significantly highest crop growth rate (27.44 g/m^2/day) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (26.85 g/m^2/day) with Azotobacter + KSB + potassium 40kg/ha, treatment T_7 (25.75 g/m^2/day) with KSB + potassium 50kg/ha, treatment T_6 (23.41 g/m^2/day) with KSB + potassium 40kg/ha, treatment T_8 (23.05 g/m^2/day) with Azotobacter + KSB + potassium 30kg/ha, treatment T_4 (21.59 g/m^2/day) with Azotobacter + potassium 50k/ha found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha.

The application of KSB (*Frateuria aurantia*) helped in production of aminoacids Vitamins and growth promoting substances like indole-3-acetic acid (IAA) and gibberellic acid (GA3) which help in better growth of the plants and application of elemental potassium added the additional benefit to the crop and helped in higher biomass accumulation which resulted in higher crop growth rate. The results were found to be similar with Ponmurugan and Gopi, 2006 [7]

Yield attrubutes and Yield

From the observations significantly highest cobs/plant (1.6) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (1.5) with Azotobacter + KSB + potassium 40kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha and significantly highest seeds/row (25.07) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (23.40) with Azotobacter + KSB + potassium 40kg/ha, treatment T_7 (23.30) with KSB + potassium 50kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha.

Significantly highest row/cob (15.03) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (14.73) with Azotobacter + KSB + potassium 40kg/ha, treatment T_7 (14.57) with KSB + potassium 50kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. Significantly higher yield parameters were recorded under application of Azotobacter and KSB Inoculation as it increased the biomass may have favorably contributed for the grain weight. As the bio - fertilizers treated seed are well nourished, this seed are capable of transporting sufficient quantities of minerals and metabolites to the developing seeds. Hence the grain weight registered was higher in the Azotobacter + KSB treatment. The present results are in accordance with those reported by Tetarval *et al.* (2011) and Singh *et al.* (2012) [8]. Test weight (243.33g) was observed higher in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (236.67g) with Azotobacter + KSB + potassium 40kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha.

Significantly highest seed yield (7.97 t/ha) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (7.59 t/ha) with Azotobacter + KSB + potassium 40kg/ha, treatment T_7 (7.38 t/ha) with KSB + potassium 50kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter +KSB + potassium 50kg/ha. Increase in yield attributes and yield through bio-fertilizer might be attributed to supply of more plant hormones (auxin, cytokinin, gibberellin etc.) by the microorganisms inoculated or by the root resulting from reaction to microbial population similar results were obtained by Marngar and Dawson (2017) [4]. The presence of potassium stimulates the cumulative effect of improvement in yield attributes *viz.*, number of effective tillers per plant, ear head length and thickness and test weight and increased availability, absorption, and translocation of K nutrient. Findings were found to be similar with Kacha *et al.* (2011).

The higher Stover yield (11.50 t/ha) was observed in the treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. However, treatment T_9 (11.37 t/ha) with Azotobacter + KSB + potassium 40kg/ha, treatment T_7 (11.22 t/ha) with KSB + potassium 50kg/ha, found to be statistically at per with treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. Potassium application enhances the development of strong cel lwall sand therefore stiffer straw which might be resulted into profuse tillering and increased availability, absorption, and translocation of K nutrient. These results are agreement with those reports by Tamboli *et al.* (2012). There was no significant difference among treatments combinations. However, highest harvest index (40.91) was noticed in treatment (T_{10}) Azotobacter + KSB + potassium 50kg/ha. And least was in control plot (37.93), respectively.

Table 2: Effect of bio fertilizers and potassium levels on yield attributes and yield of maize

Treatments	No. of cobs per plant	No. of seeds per row	No. of rows per cob	seed yield (t/ha)	Stover yield (t/ha)	Test weight(g)	Harvest index (%)
Control	1.0	15.40	12.40	5.48	8.93	206.67	37.73
Azotobacter + Potassium 30 kg/ha	1.1	17.40	13.07	6.17	9.22	210.00	40.10
Azotobacter + potassium 40 kg/ha	1.1	19.00	13.13	6.49	9.69	216.67	40.10
Azotobacter + potassium 50 kg/ha	1.3	19.33	13.47	6.58	9.90	216.67	39.93
KSB + Potassium 30 kg/ha	1.1	18.13	13.07	6.37	9.51	210.00	40.08
KSB + Potassium 40 kg/ha	1.1	21.87	14.00	7.11	10.89	223.33	39.47
KSB + Potassium 50 kg/ha	1.3	23.30	14.57	7.38	11.22	226.67	39.68
Azotobacter + KSB + Potassium 30 kg/ha	1.2	20.60	13.80	6.70	10.27	220.00	39.50
Azotobacter + KSB + Potassium 40 kg/ha	1.5	23.40	14.73	7.59	11.37	236.67	40.03
Azotobacter + KSB + Potassium 50 kg/ha	1.6	25.07	15.03	7.97	11.50	243.33	40.91
S.Em+	0.069	0.67	0.16	0.21	0.19	3.35	0.60
CD (5%)	0.21	2.01	0.49	0.63	0.57	9.96	1.80

Conclusion

It is concluded that application of treatment Azotobacter + KSB + potassium 50kg/ha was recorded significantly higher Seed yield (1168.27 kg/ha), higher gross returns (Rs.

1,59,400/ha), net returns (Rs. 1,24,245.3/ha) and benefit cost ratio (2.94) as compared to other treatments. Since, the findings based on the research done in one season.

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