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Yasmin Gulnaz
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Fathima P S
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Denesh G R
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Akhilesh Kumar Kulmitra
Department of Plant Pathology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Shivraj kumar H S
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Sathisha C
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Prakash Ajagol
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Nagesh C R
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Correspondence
Yasmin Gulnaz
Department of Agronomy, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Effect of plant growth promoting Rhizobacteria (PGPR) and PSB on growth and yield of irrigated maize under varying levels of phosphorus

Yasmin Gulnaz, Fathima PS, Denesh GR, Akhilesh Kumar Kulmitra, Shivraj Kumar HS, Sathisha C, Prakash Ajagol and Nagesh CR

Abstract
A field experiment was conducted during *kharif,* 2015 at College of Agriculture, V.C. Farm, UAS, Bangalore. The experiment comprised of thirteen treatments consisting of three levels of phosphorus (75, 100 and 125 *per cent* of recommended dose) and various phosphorus biofertilizers and Plant Growth Promoting Rhizosphere (PGPR) and their combinations. The experiment was laid out in RCBD with three replications. The soil type was sandy loam. The maize hybrid used was NAH-1137. The results revealed that the application of 75, 100 and 125 *per cent* of recommended dose of phosphorus fertilizer along with PGPR II (*Pseudomonas fluorescens* + *Bacillus megaterium* + *Azospirillum brasilense*) improved the growth parameters *viz.,* plant height, LAI, CGR and Total dry weight (TDW) of the crop. It also increased the yield parameters like number of rows cob^{-1}, kernels row^{-1}, kernels cob^{-1}, kernel weight cob^{-1}, cob weight, test weight and harvest index over the use of RDF. The kernel yield was significantly higher over control in all the treatments involving biofertilizers except with the application of 75, 100 and 125 *per cent* of recommended dose of phosphorus fertilizer along with *Bacillus megaterium.*

Keywords: biofertilizer, PGPR, PSB, LAI, CGR, TDW.

1. Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 179 million ha in the world (Anon., 2014) [2]. with an estimated grain production of 1011.76 million tonnes with an estimated productivity of 5.70 tonnes ha^{-1} during 2016-17. The area and production of maize in India is 11.52 million ha and 21 million tonnes respectively during 2015-16 (Anon., 2016) [3]. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. The maize plant produces high dry matter yield and therefore has a high requirement for nutrients especially the primary nutrients *viz.,* nitrogen (N), phosphorus (P) and potassium (K). Low soil fertility is a major constraint to maize production in the small farms in many parts of India. Phosphorus is an essential nutrient in plants. Phosphorus in adequate amount is necessary for early maturity, rapid growth and improves the quality of vegetative growth. Deficiency of phosphorus is responsible for small ears in maize due to crooked and missing rows as kernel twist (Masood *et al.*, 2011) [7]. The biofertilizers, an alternate low cost plant nutrient resource, has gained prime importance in recent decades and play a vital role in maintaining long-term soil fertility sustenance. Biological nitrogen fixing microorganisms significantly contributed for nitrogen addition to soil while phosphate solubilizers help in solubilising bound form of phosphorus. These beneficial microorganisms are known to secrete plant growth promoting substances for improved plant growth and crop yield (Venkatashwarlu, 2008) [9].

2. Materials and Methods
1. Location and Soil Characteristics
The field experiment was conducted at Department of Agronomy, College of Agriculture, V.C. Farm, UAS, Bengaluru. It falls under the region III and agro climatic zone VI (Southern Dry

Zone) of Karnataka. Geographically, the experimental site was located at 12º 34.31' North latitude and 76º 49.8' East longitude of 697 meters above mean sea level. The experimental soil was sandy loam. The soil was neutral in reaction (pH 7.13), organic carbon content was medium (0.59 per cent) with electrical conductivity of 0.19 dSm^{-1}. The soil was low in available nitrogen (219.70 kg ha^{-1}), medium in available phosphorus (41.61 kg ha^{-1}) and medium in available potassium (227.20 kg ha^{-1}).

1.1 Treatment Details

The field experiment with three replications was laid out in RCBD with the following treatments: T_1 (75% Rec. P + *Bacillus megaterium*), T_2 (75% Rec. P + *Pseudomonas fluorescens*), T_3 [75% Rec. P + PGPR-I (*P. fluorescens* + *B. megaterium*)], T_4 [75% Rec. P + PGPR-II (*P. fluorescens* + *B. megaterium* + *A. brasilense*)], T_5 (100% Rec. P + *B. megaterium*), T_6 (100% Rec. P + *P. fluorescens*), T_7 (100% Rec. P + PGPR-I), T_8 (100% Rec. P + PGPR-II), T_9 (125% Rec. P + *B. megaterium*), T_{10} (125% Rec. P + *P. fluorescens*), T_{11} (125% Rec. P + PGPR-I), T_{12} [125% Rec. P + PGPR-II) and T_{13} (100% Recommended Phosphorus(Rec. P) (Control)].

1.2 Imposition of Treatments

The recommended dose of fertilizer is 150 kg N, 75 kg P_2O_5 and 40 kg K_2O ha^{-1}. For treatments T_1, T_2, T_3 and T_4, 75% of the required P_2O_5 was applied and for treatments T_9, T_{10}, T_{11} and T_{12}, 125% of the required quantity of P_2O_5 was applied. The fertilizers were applied as per package of practices i.e. 50 per cent of nitrogen along with required dose of phosphorus and potassium as basal dose and remaining 50 per cent of N was applied in two splits as top dressing at 25 and 45 DAS. Zinc was applied at the rate of 10 kg ha^{-1} through $ZnSO_4$ and boron was applied in the form of borax at the rate of 2 kg ha^{-1}. Biofertilizers were applied @ 5 kg ha^{-1} at the time of sowing after incubation with FYM in a ratio of 1:10 of biofertilizers to maize. Also, the biofertilizers were combined in a ratio of 1:1 of *P. fluorescens* to *B. megaterium* for T_3, T_7 and T_{11} and in 1:1:1 ratio of *P. fluorescens* to *B.megaterium* to *A. brasilense* for T_4, T_8 and $T_{12.}$

3. Results and Discussion

The results of the experiment revealed that there was significant difference in growth parameters *viz.*, plant height, Leaf Area Index (LAI), Crop Growth Rate (CGR) and total dry weight of plants recorded at 90 days after sowing among the treatments. The highest plant height was recorded with T_8 (204.27 cm) which was on par T_{12} (202.70 cm) and significantly higher than all the other treatments. The lowest plant height was observed by control (178.03 cm). The highest LAI was recorded with T_8 (3.65) which was on par with all the other treatments and superior over the control (3.35) and T_2. The highest CGR was recorded by T_8 (26.30 g m^{-2} day^{-1}) which was on par T_1, T_4, T_7, T_9 and T_{12} and was significantly higher over other treatments. The lower CGR was obtained by control (23.86 g m^{-2} day^{-1}). This increment in growth parameters was due to the enhanced supply of nutrients in those treatments because of beneficial effect of PSB and *Azospirillum.* The microbes were able to supply the native soil nutrient as well as applied nutrients in available forms to the plant. The Phosphorus solubilising bacteria such as *Bacillus megaterium* and *Pseudomonas sp.* also enhance the ability of plants to fix atmospheric nitrogen. The higher accumulation of dry matter was due to increase in photosynthesis due to increased supply of nitrogen from *Azospirillum* which is a constituent of chlorophyll. These observations were in line with the findings of Priya and Geetham (2015) [8]. Similar results were shown by Afzal and Bano (2008) [1] for shoot weight, plant height and root weight of wheat and Kaur and Reddy (2015) [5] for shoot length and shoot dry weight of maize.

Table 1: Effect of PGPR and PSB on Growth Parameters of Irrigated Maize Under Varying Levels of Phosphorus

Treatments	Plant height (cm)	LAI	CGR (g m^{-2} day^{-1})	TDW (g)
T_1	187	3.59	25.31	258.06
T_2	190	3.47	24.86	256.09
T_3	198	3.62	25.08	260.09
T_4	200	3.64	26.11	268.89
T_5	186	3.59	25.07	257.69
T_6	189	3.60	24.82	257.36
T_7	199	3.64	25.37	261.59
T_8	204	3.65	26.30	270.79
T_9	187	3.59	25.49	259.42
T_{10}	188	3.62	25.01	256.96
T_{11}	198	3.59	25.19	261.29
T_{12}	203	3.65	26.12	269.66
T_{13}	178	3.35	23.86	231.09
S.Em ±	0.78	0.05	0.36	1.90
CD @ 5%	2.26	0.15	1.04	5.55

The experimental data pertaining to kernel yield, stover yield, harvest index, shelling percentage and yield attributes *viz.*, number of rows per cob, number of kernels per row, total number of kernels per cob, kernel weight per cob, cob weight and hundred kernel weight as influenced by PGPR and phosphorus biofertilizers under varying levels of phosphorus are presented in Table 2. The yield parameters like number of rows cob^{-1}, kernels row^{-1}, kernels cob^{-1}, kernel weight cob^{-1}, cob weight, test weight and harvest index in T_4 was on par with T_8 and T_{12} and superior the control. The kernel yield was significantly higher over control in all the treatments involving biofertilizers except T_1, T_5 and T_9. Similar trend was seen in shelling percentage. The stover yield was significantly higher over control in all the treatments involving biofertilizers. The significant improvement in the yield could be due to application of biofertilizers to the root zone which increased the nutrient supply favouring higher uptake of nutrients and thereby production of more growth parameters which resulted in higher yield parameters, kernel and stover yield of maize. This may also be due to higher biomass, LAI and CGR as evidenced in the present study. The improved shelling percentage may be attributed to the increased grain filling due to enhanced nutrient uptake and increased photosynthesis. These results were also in conformity with Kushare *et al.* (2009) [6] for grain and straw yield in maize and Chinnusamy *et al.* (2006) [4] for number of productive tillers per plant, number of filled grains per panicle, test weight, grain and straw yield in rice.

Table 2: Effect of PGPR and PSB on Yield Parameters and Yield of Irrigated Maize Under Varying Levels of Phosphorus

Treatments	Rows per cob	Kernels per row	Kernels per cob	Kernel wt per cob	Cob weight (g)	Test weight (g)	Harvest Index	Shelling %	kernel yield (kg ha^{-1})	stover yield (kg ha^{-1})
T_1	14.13	27.80	392.84	134.54	228.03	33.93	0.48	59.03	7193	7886
T_2	14.03	30.43	427.43	146.08	229.82	33.87	0.50	63.56	7825	7888
T_3	14.60	32.30	474.78	162.81	243.14	34.20	0.52	67.25	8230	7904
T_4	14.60	31.80	464.48	161.90	261.02	34.53	0.51	63.66	8379	8062
T_5	14.20	28.03	398.07	136.51	228.04	33.97	0.47	59.90	6938	7879
T_6	14.23	28.90	411.34	141.06	229.83	33.97	0.47	61.42	7022	7928
T_7	14.37	30.23	434.60	149.88	229.82	34.17	0.51	65.60	8222	7988
T_8	14.73	31.70	467.11	162.87	249.32	35.10	0.52	65.33	8718	8100
T_9	14.20	27.60	391.19	134.09	227.96	33.93	0.47	58.84	7168	7901
T_{10}	15.30	27.67	425.34	145.71	229.75	33.93	0.50	63.44	7813	7886
T_{11}	13.40	30.60	409.57	141.76	229.74	34.27	0.48	62.32	7561	8045
T_{12}	14.50	31.27	452.90	159.24	249.24	34.83	0.51	63.91	8420	8027
T_{13}	13.13	25.73	337.25	109.43	205.14	32.10	0.48	53.59	6554	7063
S.Em ±	0.37	0.47	11.66	4.02	8.03	0.21	0.01	2.42	230	111
CD @ 5%	1.08	1.38	34.02	11.74	23.44	0.60	0.02	7.06	673	324

4. Conclusion

The application of 75, 100 and 125 per cent of recommended dose of phosphorus fertilizer along with PGPR II showed on par growth and yield parameters as well as improved nutrient status after harvest of the crop over the control. A consortia of *Bacillus megaterium, Pseudomonas fluorescens* and *Azospirillum brasilense* (PGPR II) can be effectively used for maize under irrigated conditions with a reduction of use in chemical phosphorus fertilizer to the tune of 25 per cent.

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