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Effect of Microbial Consortia as Basal Application and Foliar Spray of *Gluconacetobacter diazotropicus* on Growth, Yield and Nutrient Uptake by Maize

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ABSTRACT

The experiment on Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus* on maize *(Zea maize)* was carried out during Kharif 2018 in the experimental field under Department of Soil Science & Agricultural Chemistry. The experiment was laid out under randomized block design (RBD) with 3 replications having 18 treatments of microbial consortia of *Arthrobacter* sp., phosphate solubilizing bacteria (*Bacillus* sp.) and potash solubilizing bacteria (*Fraturia aurentia)* as seed treatment and additionally, *Gluconacetobacter diazotrophicus* was applied as foliar application at 25, 45 and 65 DAS of the crop growth stages. The crop was supplemented with recommended dose of fertilizers 120:60:40 ($N:P_2O_5:K_2O$ kg/ha) at basal application. Besides these, two types of control plots were maintined as fertilized uninoculated control (FUI) and unfertilized uninoculated control (UFUI Regarding findings towards study of growth, yield and nutrient uptake by maize, the treatment combinations of F+*G. diazotropicus*+*Arthro*+PSB+KSB increased plant height by 75.5, 42.8 and 26.7%, plant biomass (fresh and dry) by 87.3, 26.3 and 36.6%, and 8.72, 41.9 and 28.1%, respectively and leaf chlorophyll content by 49.6, 48.5 and 16.6% at 35, 55 and 75 DAS. The same treat combination yielded maximum grain and stover at harvest by 33.4 and 77.9%, respectively over the control (2146 and 6029 kg ha^{-1}) with major nutrient contents by 17.5, 14.7 and 18.9% more in N, P and K, respectively. These were all the positive influence of *G. diazotropicus* and *Arthrobacter* when crop was supplemented with sufficient available nutrient particularly phosphorus with PSB, as the soil was moderately deficient of phosphorus. However, response of KSB was not evident since the soil was sufficient with potash.

Keywords

Maize, *G. diazotrophicus*, Arthrobacter, PSB, KSB, Yeild, FUI

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Introduction

Maize (*Zea mays* L.) is the most widely distributed cereal crop of the world. India occupies fifth place in acreage and ranks 10^{th} in production and is the third after wheat and rice in total food grain production. In our country, more than 50% of maize produce is being used as animal feed. The state of Madhya Pradesh occupies 13% of the total maize area and contributing equally to the total maize production in the country. Nutritionally, maize contains 60 to 68% starch, 1.2 to 5.7% edible oil and 7 to 15% protein. In India, maize is grown in an area of 7.18 million hectares contributing 14.1

million tonnes of production with a productivity of 1959 kg ha^{-1} (Agriculture Statistics at a glance, 2016).

Gluconacetobacter diazotrophicus is a gram-negative, flagellated bacilli, darkish brown or orange colonies under a microscope, aerobic, obligate endophytic (an endosymbiont), and nitrogen-fixing endophytes in non-leguminous plants, **(**Sevilla *et al.,* 2001**).** Nitrogen fixing bacterium originally found in monocotyledon sugarcane plants in which the bacterium actively fixes atmosphere N and provides significant amounts of N to plants. Ever since it was first isolated from the phyllosphere as well as the rhizosphere of inter-cellular spaces of sugarcane. It may actually fix up to 70% of their N requirements. Using seedlings grown aseptically in sucrose-containing culture media, it has been shown that inoculation with very low numbers of *G. diazotrophicus* results in extensive intracellular colonization of roots and progressive systemic intracellular root colonization, enabling non-nodular endosymbiotic N fixation from the atmosphere. Amazingly, the bacterium is capable of affecting a very wide range of plants.

Additionally, it possesses many other characteristics potentially valuable in the area of agriculture viz., plant growth promotion, sugar metabolism pathways, secretion of organic acids, promotes an increase in the solubility of phosphate as well as zinc (Saravanan *et al.,* 2007), synthesis of auxin, antifungal-antibacterial properties and the occurrence of bacteriocins (proteinaceous toxins inhibiting the growth of closely related bacterial strains). The bacterium is less plant/crop specific and found in a number of unrelated plant species. *G. diazotrophicus* requires a large amount of sucrose for adequate growth (Dong *et al.,* 1994). It was being recommended as a biofertilizer for sugar crops. *G. diazotrophicus* has potentials to fix atmospheric nitrogen up to 300 kg ha^{-1}. In addition to fixing N_2, it has the ability to produce significant amounts of plant growth hormones like IAA (Indole Acetic Acid) and gibberellins in culture (Bastian *et al*., 1999).

Phosphate solubilizing bacteria (PSB) have attracted the attention of agriculturists as soil inoculums to improve the plant growth and yield. Phosphorus besides directly providing vital energy package to plant system, also creates for a balanced nutrient utilization and absorption by all living system including diazotrophic microbes and PGPR. Simple inoculation of seeds with PSB gives crop yield responses equivalent to 30 kg P_2O_5 /ha or 50 percent of the need for phosphatic fertilizers. Many different species of bacteria have been identified as PSB like *Bacillus phosphaticus*, *B. megatherium*, *Pseudomonas putida.* PSB are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compounds. P-solubilization ability of rhizosphere microorganisms is considered to be one of the most important traits associated with plant phosphate nutrition. It is generally accepted that the mechanism of mineral phosphate solubilization by PSB strains is associated with the release of low molecular weight organic acids, through which their hydroxyl and carboxyl groups chelate the cations bound to phosphate, thereby converting it into soluble forms. PSB have been introduced to the Agricultural community as phosphate biofertilizer.

After nitrogen (N) and phosphorus (P), potassium (K) is the most important plant nutrient that has a key role in the growth, metabolism and development of plants. In addition to increasing plant resistance to diseases, pests, and abiotic stresses. Depending on soil type, from 90 to 98% of soil K is mineral K and most of this K is unavailable for plant uptake (Sparks and

Huang, 1985). It was reported that some beneficial soil microorganisms, a wide range of saprophytic bacteria including *Farteuria aurentia*, fungal strains and actinomycetes, could solubilize the insoluble K to soluble forms of K by various mechanisms including "(i) by lowering the pH; (ii) by enhancing chelation of the cations bound to K; and (iii) acidolysis of the surrounding area of microorganism". *Frateuria aurantia* is a species of Proteobacteria. The cells are mostly straight rods.

Co-inoculation of the beneficial microorganisms improves growth attributes, yields of maize and nutrient status in plant (Awasthi *et al.*, 2011).

Materials and Methods

The experiment was carried out during Kharif at the Research field Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur. The recommended dose of fertilizer 120:60:40 ($N:P_2O_5:K_2O$ kg/ha) for maize crop was applied in the form of urea, single super phosphate (SSP) and murate of potash (MOP) as basal applications to each plot as per recommendation.

Seed treatment (basal application) of microbial consortium containing Potash solubilizing bacteria- *Fraturia aurentia*, phosphate solubilizing bacteria (*Bacillus* sp.) and *Arthrobacter* sp. In addition, *Gluconacetobacter diazotrophicus* was applied as foliar application at 25, 45 and 65 DAS of the crop growth stages.

Plant height

Plant height was measured at 35, 55 and 75 DAS. Three plants from each plot were taken under observation and their heights were measured.

Total chlorophyll content

The total chlorophyll content was estimated following the method of Arnon (1949) and expressed as mg g^{-1} fresh weight.

Plant biomass

Plant fresh weight

At 45 DAS, the root portion of three plants was cut off and fresh plant biomass was recorded in g $plant^{-1}$.

Plant dry biomass

After recording the fresh plant biomass, plants were dried in hot air oven at $60^{o}C$ for 3 - 4 days (till constant weight) to record the dried plant biomass in g $plant^{-1}$.

Germination percentage

Germination percentage of seed was recorded at 4^{th} and 6^{th} days after sowing with help of formula.

$$\text{Germination \%} = \frac{\text{Number of seed germinated}}{\text{Number of seed sown}} \times 100$$

Digestion of plant samples

The plants samples were subjected to wet digestion for estimation of various nutrients in grain and straw Mixture of HNO3 and HClO4 was added in 2.5:1 ratio (v/v) for estimation of major nutrients.

Total nitrogen

The nitrogen content of soybean plant was estimated on dry weight basis by microkjeldahl method as per procedure suggested by AOAC (1995).

Total phosphorus and potassium

The phosphorus contents in grain and straw of soybean were estimated on dry weight basis by vanado-molybdate yellow colour method as suggested by Bhargava and Raghupathi (1984). The potassium content in the digested material was directly estimated. Nutrients uptake by soybean was calculated in kg ha-1 in relation to dry with a flame photometer using the procedure of Bhargava and Raghupathi (1984).matter production by using the following formula.

$$\text{Nutrient uptake (kg ha-1)} = \frac{\text{Content (\%) x yield (kg ha–1)}}{100}$$

Results and Discussion

Plant height

Table 1 presents data on plant height at 35, 55 and 75 DAS of the crop. The data on plant height at 35 DAS varied from 39.2 to 19.9 cm plant^{-1}. Among all the treatments, the treatment combination of F+*G. diazotropicus* +*Arthro*+PSB+KSB increased the plant height at the maximum by 75.7%, followed by, F+*G. diazotropicus*+ *Arthro*+PSB, F+ *Arthro*+PSB+KSB, F+*G. diazotropicus*+ *Arthro*+KSB with 68.1, 58.7 and 56.1% response, respectively over the control (22.3 cm plant^{-1}).

The data on plant height at 55 DAS ranged from 90.7 to 57.1 cm plant^{-1}.). Among all the treatments, the treatment combination of F+*G. diazotropicus*+*Arthro*+ PSB+KSB performed the best by 42.8%, followed by F+*G. diazotropicus*+*Arthro*+PSB, F+*Arthro*+ PSB+KSB and F+*G. diazotropicus*+ *Arthro*+ KSB with 35.9, 32.3 and 21.4% response, respectively over the control (63.3 cm plant^{-1}). The data on plant height 75 DAS varied from 217 to 168 cm plant^{-1}. the treatment combination of F+*G. diazotropicus*+*Arthro*+PSB+KSB responded the best by 12.4%, followed by F+*G. diazotropicus*+*Arthro,* F+*G. diazotropicus* + *Arthro*+PSB *and* F+*G. diazotropicus*+KSB by 9.32, 8.88 and 7.25% response, respectively over the control (193 cm plant^{-1}) Similarly, studied that the effectiveness of inoculation of *Acetobacter diazotrophicus* to corn plant was beneficial in growth of plant. Triplett (1996).

Plant biomass (fresh and dry)

Table 2 represents the data on biomass (fresh and dry) production of maize plants at 35, 55 and 75 DAS. The fresh weight at 35 DAS ranged from 19.67 to 9.07 g plant^{-1}. Among all the treatments, F+*G. diazotropicus*+ *Arthro*+PSB+KSB responded the best followed by F+*G. diazotropicus*+*Arthro*+ PSB, F+*Arthro*+PSB+KSB *and* F+*G. diazotropicus*+*Arthro+KSB* respectively over FUI (10.5 g plant^{-1}).

The fresh weight at 55 DAS ranged from 177 to 89.0 g plant^{-1}. Among all the treatments, F+*G. diazotropicus*+*Arthro*+PSB+KSB responded the best by 25.8% followed by F+*G. diazotropicus*+*Arthro*+PSB, F+*Arthro*+ PSB+KSB and F+*G. diazotropicus*+ *Arthro+KSB* by 25.4, 23.6, and 20.4% respectively over FUI (93.0 g plant^{-1}).

The fresh weight at 75 DAS ranged from 147 to 107 g plant^{-1}. Among all the treatments, F+*G. diazotropicus*+*Arthro*+PSB+KSB responded the best by 28.9% followed by F+ *G. diazotropicus*+*Arthro*+PSB, F+*G. diazotropicus*+*Arthro* and F+*G. diazotropicus* + PSB by 26.3, 26.1 and 24.5% respectively over FUI (114 g plant^{-1}). The data on dry weight at 35 DAS varied from 3.53 to 13.8 g plant^{-1} leaf. Among all the treatments, F+*G. diazotropicus*+*Arthro*+PSB+KSB responded the best followed by F+*G. diazotropicus*

+PSB+KSB, F+*Arthro*+ PSB+KSB, F+*G. diazotropicus*+*Arthro*+ PSB, respectively over FUI (4.47 g plant^{-1}). The data on dry weight at 55 DAS varied from 63.6 to 41.1 g plant $^{-1}$ leaf. Among all the treatments, F+*G. diazotropicus*+*Arthro*+ PSB+KSB responded the best by 41.9% followed by F+*Arthro*+PSB, F+*G. diazotropicus*+*Arthro*+ KSB and F+*G. diazotropicus*+ *Arthro*+PSB by 34.1, 29.6 and 29.0% respectively over FUI (44.8 g plant^{-1}).

The data on dry weight at 75 DAS varied from 95.2 to 72.2 g plant $^{-1}$ leaf. Among all the treatments, F+*G. diazotropicus*+*Arthro*+ PSB+KSB responded the best by 28.1% followed by F+*Arthro*+PSB+KSB, F+*G. diazotropicus*+PSB+KSB, F+*G. diazotropicus*+*Arthro*+PSB by 24.8, 17.6 and 17.3% respectively over FUI (74.3 g plant^{-1}).

Jambukar (2003) also confirmed the finding that among the different treatments tested, the treatment T_8 (*Azotobacter*+*Acetobacter*+75 % N) showed significant improvement in fresh weight, dry weight, number of leaves per plant of beet root. Linu (2009) reported that seed inoculation of cowpea by phosphate solublizers improved nodulation, root and shoot biomass, straw and grain yield and phosphorous and nitrogen uptake of crop.

Chlorophyll content

Table 3 exhibits the data on total chlorophyll content in leaf at 35, 55 and 75 DAS. The data on chlorophyll content at 35 DAS varied from 1.96 to 1.01 mg g^{-1} leaf. The treatment combination of F+*G. diazotropicus*+ *Arthro*+PSB+KSB , among all the treatments, increased leaf chlorophyll content by 49.6%, followed by F+*G. diazotropicus* +PSB+KSB, F+*Arthro*+PSB+KSB and F+*G. diazotropicus* +*Arthro*+PSB by 43.5, 37.4 and 37.3%, respectively over the control (1.34mg g^{-1} leaf). The data on chlorophyll content at 55 DAS varied from 1.99 to 1.19 mg g^{-1} leaf with the mean value of 1.60 mg g^{-1} leaf. The treatment combination of F+*G. diazotropicus*+*Arthro*+PSB+KSB , among all the treatments, increased leaf chlorophyll content by 48.5%, followed by F+*Arthro*+ PSB+KSB, F+ *G.diazotropicus*+*Arthro*+PSB and F+*G. diazotropicus*+KSB+PSB by 42.5, 38.0 and 54.6%, respectively over the control (1.19mg g^{-1} leaf).

The data on chlorophyll content at 75 DAS varied from 1.90 to 1.27 mg g^{-1} leaf with the mean value of 1.64 mg g^{-1} leaf. The treatment combination of F+*G. diazotropicus*+ *Arthro*+PSB+KSB, among all the treatments, increased leaf chlorophyll content by 16.5%, followed by F+*Arthro*+PSB+KSB, F+ *G.diazotropicus* +*Arthro*+PSB and F+ *G.diazotropicus*+KSB +PSB by 14.7, 9.20 and 8.58%, respectively over the control (1.6mg g^{-1} leaf). Madhaiyan *et al.*, (2004). also observed higher photosynthetic activity by enhancing the number of stomata, chlorophyll concentration and maleic acid content of crops.

Germination percent

Table 4 presents data on germination percent at 4th and 6th DAS after sowing of the crop. The data on plant height at 4th DAS varied from 53.7 to 39.0%. Among all the treatments, the treatment combination of F+*Arthro*+KSB, increase the Germination % at the maximum by 19.3%, followed by F+PSB + KSB, F+*G. diazotropicus*+KSB and F+*G. diazotropicus*+*Arthro*+PSB+KSB with 14.1,13.3 and 13.0% response, respectively over the control (45.0%). The data on plant height at 6th DAS ranged from 72.7 to 56.3%. Among all the treatments, the treatment combination of F+*G. diazotropicus*+*Arthro*+ PSB+KSB performed the best by 18.4%, followed by F+*G. diazotropicus*+PSB+KSB, F+*Arthro* +PSB+KSB, F+*G. diazotropicus+ Arthro+KSB* and F+*Arthro* with 15.8, 15.1 and 12.5% response, respectively over the control (61.3%).

Similarly, studied that the response of sweet sorghum to *A. diazotrophicus*, *Azospirillum brasilense*, *Azotobacter chroococcum, Glomus leptoticum* and interaction of these diazotrophic bacteria with the VAM fungus in respect to plant growth parameters.In this experiment they recorded more per cent germination, seedling vigour index, all growth parameters (number of leaves, length of shoot and root, stem girth) and dry weight of shoot and root of sweet sorghum. Bhowmik and Konde (1999).

NPK contents in plant

Table 5 and 6 presents the data on contents of nitrogen, phosphorus and potassium in grain and stover. The data on nitrogen content in grain varied from 1.16 to 1.41 % N. Among all the treatment combinations, F+*G. diazotropicus+Arthro*+PSB+KSB responded the best by 21% increase, followed by F+*Arthro*+PSB+KSB, F+*G. diazotropicus+ Arthro+KSB* and F+*G. diazotropicus*+ PSB+KSB by 20.6, 19.8 and 18.9% increase, respectively over the control (1.16 % N).

The data on phosphorus content in grain varied from 0.32 to 0.39 % P with the mean value 0.35 % P. Among all the treatment combinations, F+*G. diazotropicus+ Arthro*+PSB+KSB responded the best by 21.8% increase, followed by, F+*G. diazotropicus+Arthro+KSB,* F+*Arthro*+ PSB+KSB and F+*G. diazotropicus*+PSB+ KSB by 18.7, 15.6 and 12.5 % increase, respectively over the control (0.32 % P).

The data on potassium content in grain varied from 0.56 to 0.69 % K with the mean value 0.62% K. Among all the treatment combinations, F+*G. diazotropicus+ Arthro*+PSB+KSB responded the best by 23.2% increase, followed by F+*G. diazotropicus*+PSB+KSB, F+*G. diazotropicus+Arthro+KSB* and F+*G. diazotropicus+ Arthro*+PSB by 21.4, 19.6 and 17.8 % increase, respectively over the control (0.56 % K).

The data on nitrogen content in stover varied from 0.90 to 1.05 % N. Among all the treatment combinations, F+*G. diazotropicus+ Arthro*+PSB+KSB responded the best by 16% increase, followed by F+*Arthro*+PSB+ KSB, F+*G. diazotropicus+Arthro+KSB* and F+*G. diazotropicus*+PSB+KSB by 15.5, 14.4 and 13.3% increase, respectively over the control (0.90% N).

The data on phosphorus content in stover varied from 0.23 to 0.29 % P. Among all the treatment combinations, F+*G. diazotropicus +Arthro*+PSB+KSB responded the best by 26.08% increase, followed by, F+*G. diazotropicus*+PSB+KSB, F+*G. diazotropicus+Arthro*+PSB and F+*Arthro* +PSB+KSB by 21.7, 17.3 and 17.0% increase, respectively over the control (0.23% P). Similarly, potassium content in stover varied from 0.81 to 0.92 % K. Among all the treatment combinations, F+*G. diazotropicus+Arthro*+PSB+KSB responded the best by 15.00 % increase, followed by F+*G. diazotropicus+Arthro*+PSB, F+*G. diazotrophicus+Arthro*+KSB and F+*Arthro* +PSB+KSB by 12.3, 11.1 and 9.87% increase, respectively over the control (0.81% K) which has been supported by the findings of Vessey (2003) reported that the potential improving K and P nutrition by application of PGPR including phosphate and potash solubilizing bacteria (PSB and KSB) as biofertilizers as a sustainable solution to improve plant nutrient status and production.

Grain and stover yields

Table 6 and 7 exhibits the data on yields of grain and stover. The data on grain yield ranged from 1348 to 2863 kg ha^{-1}. Among all the treatment combinations, responded the best F+*G. diazotropicus*+*Arthro*+PSB+KSB by 33.4%, followed by the treatment combinations F+*G. diazotropicus*+ *Arthro*+PSB, F+*G. diazotropicus*+ *Arthro*+*KSB* and F+*Arthro*+PSB, by 30.1, 28.3 and 25.4%, respectively over the control (1348 kg ha^{-1}) which has been supported by the findings of Jain *et al.,* (1999) conducted field experiment to study the effect of PSB and biofertilizer *Rhizobium* on growth, yield attributes of chickpea in sandy loam soil. Inoculation of *Rhizobium* and PSB alone or in combination with 30, 45 and 60 kg P_2O_5 ha^{-1}markedly enhanced the seed yield, stover yield and protein content over its independent application of`P'.

Table.1 Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus* at different growth stages on plant height of maize

Treatments	Plant height (cm plant^{-1})		
	35 DAS	55 DAS	75 DAS
G. diazotropicus	20.0	58.6	185
F+*G. diazotropicus*	26.5	66.9	206
F+*Arthro*	28.1	70.2	194
F+PSB	25.1	69.7	210
F+KSB	23.6	72.0	211
F+*G. diazotropicus*+Arthro	31.1	73.2	202
F+*G. diazotropicus* + PSB	29.3	73.8	196
F+*G. diazotropicus*+KSB	27.6	68.0	210
F + *Arthro* + PSB	32.7	72.7	204
F+*Arthro*+KSB	25.5	65.0	207
F+PSB + KSB	24.2	75.0	207
F+*G. diazotropicus* + *Arthro* + PSB	37.5	86.3	210
F+*G. diazotropicus* + *Arthro* + *KSB*	34.8	77.1	204
F+*G. diazotropicus* + PSB + KSB	30.4	71.7	198
F + *Arthro* + PSB + KSB	35.4	84.0	205
F+*G. diazotropicus* + *Arthro* + PSB + KSB	39.2	90.7	217
FUI	22.3	63.5	193
UFUI	19.9	57.1	168
SE_m±	1.16	2.83	5.31
$CD_{5\%}$	3.42	8.35	15.6
CV (%)	8.14	9.63	11.5

Table.2 Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus at different growth stages* on plant biomass of maize

Treatments	Fresh wt. (mg/ plant)			Dry wt. (mg/ plant)		
	35D AS	55 DAS	75D AS	35D AS	55D AS	75D AS
G. diazotropicus	10.3	90.0	128	5.67	43.9	73.7
F+*G. diazotropicus*	13.3	112	138	8.03	51.0	84.2
F+*Arthro*	15.2	111	135	8.07	52.9	83.1
F+PSB	13.0	112	135	6.00	55.2	78.8
F+KSB	18.7	107	128	5.87	55.4	77.0
F+*G. diazotropicus+Arthro*	17.6	102	144	10.4	54.4	84.4
F+*G. diazotropicus* + PSB	12.8	108	142	7.87	54.5	84.9
F+*G. diazotropicus*+KSB	17.8	117	141	6.53	53.2	86.3
F + *Arthro* + PSB	16.7	109	141	12.0	60.1	89.4
F+*Arthro*+KSB	15.2	110	138	6.43	55.2	84.4
F+PSB + KSB	14.9	103	140	5.77	55.7	80.6
F+*G. diazotropicus* + *Arthro* + PSB	18.4	112	144	12.3	57.8	87.2
F+*G. diazotropicus* + *Arthro* + *KSB*	17.7	108	141	12.2	56.5	86.3
F+*G. diazotropicus* + PSB + KSB	12.8	108	139	13.0	58.1	87.4
F + *Arthro* + PSB + KSB	18.3	115	141	12.7	57.5	92.8
F+*G. diazotropicus* + *Arthro* + PSB + KSB	19.6	117	147	13.8	63.6	95.2
FUI	10.5	93.0	114	4.47	44.8	74.3
UFUI	9.07	89.0	107	13.8	41.1	72.3
$CD_{5\%}$	3.36	10.9	9.67	2.00	2.47	4.39
CV (%)	10.4	9.57	12.4	8.52	8.01	9.65

Table.3 Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus* on total chlorophyll content at different stages of crop growth

Treatment	Total chlorophyll content (mg g^{-1} leaf)		
	35 DAS	55DAS	75DAS
G. diazotropicus	1.39	1.33	1.37
F+*G. diazotropicus*	1.60	1.65	1.64
F+*Arthro*	1.23	1.37	1.25
F+PSB	1.46	1.55	1.43
F+KSB	1.24	1.32	1.65
F+*G. diazotropicus*+*Arthro*	1.57	1.75	1.71
F+*G. diazotropicus* + PSB	1.70	1.74	1.70
F+*G. diazotropicus*+KSB	1.62	1.73	1.75
F + *Arthro* + PSB	1.67	1.68	1.71
F+*Arthro*+KSB	1.56	1.66	1.69
F+PSB + KSB	1.56	1.70	1.62
F+*G. diazotropicus* + *Arthro* + PSB	1.80	1.85	1.82
F+*G. diazotropicus* + *Arthro* + *KSB*	1.73	1.80	1.77
F+*G. diazotropicus* + PSB + KSB	1.79	1.84	1.78
F + *Arthro* + PSB + KSB	1.88	1.91	1.87
F+*G. diazotropicus* + *Arthro* + PSB + KSB	1.96	1.99	1.90
FUI	1.31	1.34	1.63
UFUI	1.01	1.19	1.27
$SE_m\pm$	0.18	0.15	0.07
$CD_{5\%}$	0.53	0.44	0.20
CV (%)	7.03	8.45	10.1

Table.4 Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus* at 4th and 6th DAS on germination of maize

Treatments	Germination (%)	
	4th DAS	6th DAS
G. diazotropicus	43.3	58.7
F+*G. diazotropicus*	49.3	69.0
F+*Arthro*	52.3	70.3
F+PSB	49.3	69.0
F+KSB	46.7	70.3
F+*G. diazotropicus*+*Arthro*	44.3	69.3
F+*G. diazotropicus* + PSB	47.0	70.0
F+*G. diazotropicus*+KSB	51.3	69.0
F + *Arthro* + PSB	50.7	67.0
F+*Arthro*+KSB	53.7	70.0
F+PSB + KSB	51.3	68.0
F+*G. diazotropicus* + *Arthro* + PSB	49.0	69.0
F+*G. diazotropicus* + *Arthro* + *KSB*	49.7	70.3
F+*G. diazotropicus* + PSB + KSB	49.3	71.0
F + *Arthro* + PSB + KSB	49.7	71.0
F+*G. diazotropicus* + *Arthro* + PSB + KSB	51.0	72.6
FUI	45.0	61.3
UFUI	39.0	56.3
$SE_m \pm$	1.78	1.84
$CD_{5\%}$	5.25	5.42
CV (%)	5.25	5.42

Table.5 Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus* on grain yield, NPK content and their uptake by grain

Treatment	Grain yield (kg ha^{-1})	Nutrient content (%)			Grain nutrient uptake (kg ha^{-1})		
		N	P	K	N	P	K
G. diazotropicus	1447	1.21	0.33	0.57	17.5	4.73	8.24
F+*G. diazotropicus*	2293	1.28	0.34	0.59	29.4	7.81	13.4
F+*Arthro*	2483	1.33	0.38	0.58	33.0	9.53	14.4
F+PSB	2281	1.33	0.36	0.58	30.4	8.22	13.1
F+KSB	2296	1.27	0.34	0.62	29.1	7.91	14.1
F+*G. diazotropicus+Arthro*	2639	1.29	0.34	0.60	34.1	8.85	15.8
F+*G. diazotropicus* + PSB	2762	1.34	0.33	0.60	37.1	9.15	16.6
F+*G. diazotropicus*+KSB	2538	1.32	0.36	0.63	33.4	9.18	15.9
F + *Arthro* + PSB	2749	1.35	0.34	0.63	37.0	9.42	17.4
F+*Arthro*+KSB	2366	1.37	0.35	0.63	32.3	8.19	14.9
F+PSB + KSB	2265	1.35	0.35	0.64	30.6	7.93	14.4
F+*G. diazotropicus* + *Arthro* + PSB	2794	1.36	0.35	0.66	38.1	9.87	18.5
F+*G. diazotropicus* + *Arthro* + *KSB*	2754	1.39	0.36	0.67	38.3	9.82	18.3
F+*G. diazotropicus* + PSB + KSB	2655	1.38	0.38	0.68	36.5	10.2	18.1
F + *Arthro* + PSB + KSB	2611	1.40	0.37	0.66	36.4	9.66	17.1
F+*G. diazotropicus* + *Arthro* + PSB + KSB	2863	1.41	0.39	0.69	40.3	11.3	19.7
FUI	2146	1.20	0.34	0.58	25.7	7.20	12.4
UFUI	1348	1.16	0.32	0.56	15.6	4.25	7.5
$SE_m\pm$	2404	1.32	0.35	0.62	31.9	8.50	15.1
$CD_{5\%}$	42.8	0.07	0.02	0.02	1.12	0.90	0.78
CV (%)	126.1	0.21	0.06	0.06	3.30	2.65	2.30

Table.6 Effect of microbial consortia as basal application and foliar spray of *G. diazotropicus* on stover yield NPK content and their uptake by stover

Treatment	Stover yield (kg ha^{-1})	Nutrient content (%)			Stover uptake of nutrient (kg ha^{-1})		
		N	P	K	N	P	K
G. diazotropicus	6010	0.97	0.24	0.78	58.5	14.6	46.8
F+ *G. diazotropicus*	9827	1.01	0.25	0.85	99.6	24.9	83.2
F+ *Arthro*	9981	1.01	0.26	0.83	101.1	26.2	82.5
F+PSB	8860	1.00	0.25	0.84	88.9	21.8	74.1
F+KSB	8737	1.02	0.24	0.86	89.1	20.9	74.8
F+ *G. diazotropicus* +*Arthro*	8667	1.00	0.25	0.84	86.7	21.3	72.8
F+ *G. diazotropicus* +PSB	8846	1.01	0.26	0.82	89.6	22.7	72.8
F+ *G. diazotropicus* +KSB	8755	1.01	0.25	0.85	88.4	21.5	74.4
F + *Arthro* + PSB	9857	1.00	0.25	0.86	98.9	24.3	84.7
F+*Arthro*+KSB	8933	1.01	0.25	0.86	90.5	22.0	76.8
F+PSB + KSB	8754	1.02	0.26	0.87	89.3	23.0	75.8
F+ *G. diazotropicus* +*Arthro*+PSB	10619	1.01	0.27	0.91	107	28.3	96.2
F+ *G. diazotropicus* +*Arthro*+KSB	10280	1.03	0.26	0.90	106	26.7	92.5
F+ *G. diazotropicus* +PSB + KSB	9942	1.02	0.28	0.88	101	27.5	87.1
F + *Arthro* + PSB + KSB	10493	1.04	0.27	0.89	109	28.3	93.0
F+*G. diazotropicus* + *Arthro* + PSB + KSB	10729	1.05	0.29	0.92	112	30.7	98.3
FUI	6029	0.92	0.24	0.83	55.5	14.2	50.2
UFUI	5618	0.90	0.23	0.81	50.6	12.7	45.6
$SE_m\pm$	8940	1.00	0.25	0.85	90.2	22.9	76.7
$CD_{5\%}$	143.9	0.02	0.04	0.03	0.95	1.21	1.02
CV (%)	424.1	0.05	0.13	0.09	2.78	3.58	2.99

Data on stover yield ranged from 10729 to 5618 kg ha^{-1}. Among all the treatment combinations, F+*G. diazotropicus*+*Arthro* +PSB+KSB responded the best by 77.9%, followed by, F+*G. diazotropicus*+ *Arthro*+PSB, F+*Arthro*+PSB+KSB and F+*G. diazotropicus*+*Arthro*+KSB by 76.0, 74.7 and 70.5%, respectively over the control (6029 kg ha^{-1}). Arangarasan *et al.*, (1998) studied rice inoculated with diazotrophic bacteria viz.,*Azospirillum lipoferum*, *Herbaspirillum seropedicae* and PSB *Bacillus megaterium*. In inoculated treatments with the two bacterial cultures, increase in shoot and root length, 1000 grain weight and grain yield were recorded over uninoculated control.

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