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# Development and Evaluation of Native Plant Growth Promoting Rhizomicrobial Consortia on Growth Parameters of Sweet Corn (*Zea mays* convar. *saccharata* var. *rugosa*)

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**A B S T R A C T**

An attempt was made to isolate, screen, and evaluate the different Plant Growth Promoting Rhizomicrobial consortia on growth parameters of sweet corn (*Zea mays convar. saccharata var. rugosa*). In the course of the study, as many as five *Acetobacter*, four phosphate solubilizing bacteria and four potassium solubilizing bacterial isolates were isolated from the rhizosphere soils of Malnad regions. Further all the isolates were screened under *in vitro* condition. Out of five *Acetobacter* isolates, Aceto-5 fixed a maximum of 4.8mg of nitrogen/g of carbon source. Hence Aceto-5 was selected for further studies. Similarly, Out of four PSB isolates the maximum inorganic phosphorus was released by PSB-3, hence it was selected and with reference to potassium solubilization, the KSB 3 was efficient. Hence all the efficient isolates *viz.*, Aceto-5, PSB-3 and KSB-3 were selected. Further the effective native Plant Growth Promoting Rhizomicrobial consortia carrier based formulations was developed and evaluated on growth parameters of sweet corn. With respect to germination percentage, number of leaves, chlorophyll content and plant height, the triple inoculation treatment resulted better than other treatment imposed indicating the combined inoculation of PGPR is having an impact on sweet corn. Finally, the treatment where *Acetobacter*-5, phosphate solubilizing bacteria-3 and potassium solubilizing bacteria-3showed maximum accumulation of NPK content in leaves after 90 days and the same treatment also showed increased residual nitrogen, phosphorus and potassium level in the soil.

## Introduction

As we enter the third millennium with more than six billion people, we are confronted with a herculean task of providing environmental and food security to the expanding population particularly in the developing countries. This calls for the reorientation of strategies to minimize the use of external inputs in agriculture and depend more on eco-friendly approaches to sustain food production without causing disruption to the fragile agro-ecosystem. Now a day the biological means of production is gaining lot of importance. Among the biological means, microorganisms being an integral component of soil ecosystem

which play a prestigious role by making the soil truly living. These organisms have the direct impact on growth and yield of plants by many mechanisms, such as nutrient availability, diseases and pest suppression and also production of plant growth promoting hormones *viz.,* Ethylene, Gibberellins, IAA, Auxin *etc.* In this contest there is a growing interest to concentrate much on plant growth promoting rhizomicroorganisms in agriculture.

On the other hand, soil is dynamic systems with multiple interactions between organic and inorganic soil components and these interactions in soil are important for the microorganisms and availability of mineral nutrients. Numerous microorganisms are especially those associated with roots have the ability to increase the plant growth by solubilizing or releasing the unavailable mineral nutrients and also increase soil fertility (Ledin *et al.,* 1996). In ecosystem with low inputs and without any fertilization or soil amendments by humans, the nutrients available to plants come from atmospheric inputs and weathering of soil minerals (Christophe *et al.,* 2006).

The microorganisms being soil engineers play a diverse role in organic sweet corn production by converting unavailable nutrients to available form and also used in suppression of many of the pests and diseases. Among the different microorganisms used in sweet corn cultivation, the nitrogen fixing microorganisms like *Acetobacter*, phosphorous solubilizing bacteria and potassium solubilizing bacteria are used extensively in single, double and triple inoculant formulation however the native efficient isolates are not concentrated much in sweet corn production.

Madhaiyan *et al.,* (2004) have reported the occurrence of *Gluconoacetobacter diazotrophicus* in tropical and subtropical plants of Western Ghats of India. Further they isolated *Gluconoacetobacter diazotrophicus* from different crops like maize, beetroot and carrot capable of nitrogen fixation and phosphorous solubilization. Sarita and Bhattacharya (2000) isolated *Acetobacter diazotrophicus* capable of solubilizing potassium from the different soil samples collectedfrom different sugary crops like sweet sorghum, maize, sugarcane and beetroot. Samina Mehnaz *et al.,* (2006) studied the inoculation effects of *Pseudomonas putida, Gluconoacetobacter azotocaptans*, and *Azospirillum lipoferum* on corn plant growth under greenhouse conditions.

Conceptual design is important in developing new technologies and also utilization of different beneficial plant growth promoting rhizomicroorganisms for sustainable vegetable production. The basis of conceptual design is simply to first convince a model and then to devise a strategy and method for achieving the reality. However, it is necessary to carefully co-ordinate the minerals, the environment and the technologies constituting the methods. Moreover one should adapt a philosophical attitude in applying microbial technology to corn production and also for soil health management. Based on the past work done by different researchers and in a view of greater need for developing Plant Growth Promoting Rhizomicroorganisms (PGPR) consortia for healthy sweet corn production the present investigation was undertaken to isolate, screen, and evaluate the different plant growth promoting rhizomicrobial consortia on growth parameters of sweet corn.

## Materials and Methods

### Collections of soil samples

A total of 20 different soil samples were collected from different sugary crop

rhizosphere like beetroot, carrot, sorghum and maize for isolation of different plant growth promoting rhizomicroorganisms.

## Isolation of Plant Growth Promoting Rhizomicroorganisms (PGPRs)

Fresh soil samples of different sugary crops collected were serially diluted and plated on the glucose yeast extract peptone media supplemented with Bromothymol blue (Kadere *et al.,* 2008) and for the phosphate solubilizing microorganisms were isolated from the pooled soil using Pikovaskay's agar media (Pikovaskay, 1948) and the same soil samples were used to isolate potassium solubilizing microorganisms using Alexandrove's media (Hu *et al.,* 2006).

## Identification and characterization of PGPR isolates

The nitrogen fixing *Acetobacter,* phosphorus and potassium solubilizing bacteria were identified and characterized based on various morphological and biochemical characteristics. Bacterial strains isolated were examined for colony morphology, pigmentation, cell shape and Gram's staining as per the standard procedure given by Anon (1957) and Barthalomew and Mittewer (1950).

## *In vitro* screening of plant growth promoting rhizomicroorganisms for the plant growth promoting activity

## *In vitro* screening of *Acetobacter* isolates for their nitrogen fixing ability

## Qualitative test for $N_2$-fixing ability of *Acetobacter* isolates

All the *Acetobacter* isolates were inoculated to the nitrogen free GYP medium and incubated for 5 days and after 5 days of incubation, 1 ml broth cultures of each tube was centrifuged at 8000 rpm for 5 min. The supernatant was discarded and the pellet was resuspended in sterile distilled water. The washing was repeated thrice to remove the traces of the medium and the pellet was suspended in one ml sterile distilled water. Five micro liters each of the suspension was spotted on N free medium. The plates were incubated at $28\pm2^0$C and observations on growth were recorded at 24 hours interval for 5 days and good grown colonies were subjected for quantitative estimation of nitrogen.

## Quantitative estimation of nitrogen by *Acetobacter*

To 250 ml conical flasks, 100 ml of the N free GYP medium was dispensed for all flasks and autoclaved. One ml of culture was inoculated to each flask. The flasks were incubated at $37^0$ C for seven days.

After seven days of incubation the culture was homogenized and 10 ml was digested with 5 ml of concentrated $H_2SO_4$ along with 0.2 g digestion catalyst mixture $K_2SO_4$ : $CuSO_4$ : Selenium (100:10:1). After cooling, volume was made up to 100 ml with distilled water. Later, 10 ml of aliquot was transferred to microkjeldhal distillation unit, for which 20 ml of 40 per cent NaOH was added and distilled.

Ammonia evolved was trapped in 4 per cent boric acid mixed indicator (Bromocresal green 0.066 g and methyl red 0.033 g in 100 ml methanol) till the solution turned from pink to green and then titrated against 0.05 N $H_2SO_4$till the green colour is turned to pink and total nitrogen content of the culture was determined and results were expressed as mg of N fixed per g of glucose.

$$\text{Percent N} = \frac{\text{Titre value} \times 0.014 \times \text{N of } H_2SO_4 \times \text{vol. made}}{\text{Volume of sample used}} \times 100$$

### *In vitro* screening of phosphorus solubilizing bacteria

### Agar plate method

All the phosphorus solubilizing bacterial isolates were spotted on Sperber's media for analyzing the phosphate solubilizing potentiality of each isolates. Based on the zone of solubilization of phosphorus on the media the phosphate solubilizing potentiality was interpreted (Gaur, 1990).

### Chemical method

Isolates of the phosphate solubilizing bacteria (10 ml of the overnight culture were inoculated to 100 ml of Pikovskaya's broth in 250 ml flask with equal number of uninoculated controls. The flasks were incubated on a mechanical shaker at $28^0$ C for 10 days. The amount of pi released in the broth in flasks was estimated at 10 days after inoculation. The broth cultures of bacteria were centrifuged at 9000 rpm for 20 minutes in a centrifuge to separate the supernatant from the cell growth and insoluble phosphate. The available pi content in the supernatant/filtrate was estimated by phosphomolybdic blue colour method (Jackson, 1973).

### In vitro screening of potassium solubilizing bacteria for K released from insoluble K bearing mineral

### Agar plate method

All the potassium solubilizing bacterial isolates were spotted on Alexandrov's media containing mica for analyzing the potassium solubilizing potentiality of each isolates. Based on the zone of solubilization of potassium (mica) on the media the potassium solubilizing potentiality of the potassium solubilizing bacteria was interpreted.

### Chemical method

The isolates showing zone of solubilization on Alexandrov's agar were further examined for their ability to release K from broth media (supplemented with 1 per cent muscovite mica). One ml of overnight culture of each isolate was inoculated to 25 ml of Alexandrov's broth (Hu *et al.*, 2006) in replicates. All the inoculated flasks were incubated for two weeks at 28±2°C. The amount of K released in the broth was estimated at 7, 15 and 20 days of incubation from triplicate flasks at each stage in comparison with a set of uninoculated controls. The broth cultures were centrifuged at 10,000 rpm for 10 minutes in the remi microcentrifuge to separate the supernatant from the cell growth and insoluble potassium. The available K content in the supernatant was determined by flame photometry (Sugumaran and Janarthanam, 2007).

### Development and evaluation of PGPR microbial consortia on growth and yield of sweet corn

### Compatibility analysis of efficient PGPR isolates

The efficient N fixing, P and K Solubilizing isolates were purified and streaked on the Nutrient agar medium for testing their compatibility. Based on the compatibility results the PGPR carrier (talc based) formulation was prepared for green house evaluation.

### Evaluation of PGPR consortia on growth of sweet corn

### Preparation of carrier based formulations of PGPR consortia

The efficient PGPR isolates were mixed with talc to produce the carrier based formulation

as given by Sireesha (2000) separately and based on the amount of Nitrogen fixed by *Acetobacter*, inorganic phosphorous and potassium released by the PSB and KSB isolates and also based on the compatibility analysis the developed PGPR microbial consortia, were evaluated for its influence on plant growth under greenhouse condition using sweet corn as test crop and the inoculation were made as single, dual and triple combination to the sweet corn pots (plate - 1).

## Treatment details of the pot experiment

$T_1$ = Control (RDF)

$T_2$ = RDF + *Acetobacter (Aceto - 5)*

$T_3$ = RDF + PSB - 3

$T_4$ = RDF + KSB - 3

$T_5$ = RDF + *Acetobacter (Aceto - 5)* + PSB - 3

$T_6$ = RDF + PSB – 3 + KSB - 3

$T_7$ = RDF+ *Acetobacter (Aceto - 5)* + KSB - 3

$T_8$ = RDF + *Acetobacter (Aceto - 5) + PSB – 3* + KSB – 3

## Results and Discussion

## Isolation of plant growth promoting microorganisms

As many as 5 *Acetobacte*r were obtained from the soil samples collected and for further studies they were named as Aceto-1, Aceto-2, Aceto-3, Aceto-4 and Aceto-5. Based on the zone of solubilization of phosphorus on Sperber's media, four phosphate solubilizing bacterial isolates were obtained from the rhizosphere soil samples and all the PSB isolates named as PSB-1, PSB-2, PSB-3, and PSB-4. Unlike phosphorus solubilizing bacterial bacteria, the potassium solubilizing bacteria were also isolated using the specific Alexandrove's media. Four potassium solubilizing microbial isolates (KSB-1, KSB-2, KSB-3, and KSB-4) were isolated based on the ability of the KSB isolates to solubilize the mica in Alexandrove's media (plate -2).

The results are in agreement with the findings of Gaur *et al.,* (1976) who isolated three strains of *Bacillus* species from the soil samples of Mussoriee rock phosphate capable of solubilizing tri-calcium phosphate.

In support of Gaur *et al.,* (1976) Cavalcanteand Dobreiner (1998) isolated *Gluconoacetobacter diazotrophicus* from the rhizosphere of sugar cane. Similarly Hu *et al.,* (2006) also isolated potassium solubilizing microorganism from the different soils using Alexandrove's media.

## *In vitro* screening of plant growth promoting microorganisms for their plant growth promotional activity

Statistically highest nitrogen fixing ability was observed in Aceto - 5 isolate (4.8mg of nitrogen/g of carbon source) followed by Aceto-4 (4.10mg of nitrogen/g of carbon source) respectively. However, the Aceto-1, Aceto-2 and Aceto -3 also showed the nitrogen fixing ability but comparatively low to with Aceto-5 (Table 1). Similar findings were also reported by Fuentes *et al.,* (1993) who isolated and screened 18 strains of *Acetobacter diazotrophicus* isolates from thirteen cane rhizosphere cultivars of Mexico.

The results obtained on the zone of solubilization of phosphorus on Sperber's media and percentage of inorganic phosphate released by the phosphate solubilizing microbial isolates is furnished in Table 2. The highest zone of solubilization (1.5cm) and maximum inorganic phosphate released was observed in PSB - 3 Isolate at $10^{th}$ day after

the inoculation. Similarly, with reference to potassium solubilization by potassium solubilizing isolates, the isolate number KSB-3 is more efficient in releasing available potassium and maximum zone of solubilization of mica in Alexandrove's agar at the 10th day after inoculation (44.49mg/ml and 1.45cm, respectively) (Table 3).

The results are in agreement with the findings of Gaind and Gaur (1981), who isolated and screened *Bacillus megaterium*, *Bacillus brevis*, *Bacillussubtilis* from the rhizosphere of Oat and Arhar. Similarly, Murulikannan (1986) isolated and screened silicate solubilizing bacteria from rice rhizospheres. Similarly Kannan and Raj (1998) also screened 17 *Bacillus* species for their potassium solubilizing ability.

## Identification of efficient plant growth promoting rhizomicroorganisms

Since, Aceto-5, PSB-3 and KSB-3 were found to be the efficient plant growth promoting rhizomicrobial isolates. All the three isolates were selected for further studies and was tentatively identified and confirmed as *Acetobacter*, phosphate solubilizing *Bacillus sp.* and potassium solubilizing *Bacillus sp.* based on morphological and biochemical tests (Table 4).

**Table.1** Nitrogen fixing potential of *Acetobacter* under *in vitro* condition

| Sl.No. | *Acetobacter* isolates | Nitrogen (mg/g of carbon source) |
|---|---|---|
| 1 | Control | 0.50$^{(e)}$ |
| 2 | Aceto - 01 | 3.93$^{(c)}$ |
| 3 | Aceto - 02 | 3.97$^{(c)}$ |
| 4 | Aceto - 03 | 3.40$^{(d)}$ |
| 5 | Aceto - 04 | 4.10$^{(b)}$ |
| 6 | Aceto - 05 | 4.80$^{(a)}$ |
| | SEM ± | 0.62 |
| | CD @ 1% | 1.79 |

Note: Means followed by the same letters do not differ significantly.

**Table.2** Percent inorganic phosphorus released by phosphorous solubilizing bacterial isolates under *in vitro* condition

| Sl. No | PSB Isolates | Zone of solubilization on Sperber's media | Inorganic phosphorus released(%) at 10th day after inoculation |
|---|---|---|---|
| 1 | Control | 0.00 | 3.10$^{(e)}$ |
| 2 | PSB-1 | 0.95 | 4.10$^{(d)}$ |
| 3 | PSB-2 | 1.00 | 5.30$^{(c)}$ |
| 4 | PSB-3 | 1.50 | 7.80$^{(a)}$ |
| 5 | PSB-4 | 1.10 | 6.50$^{(b)}$ |
| | | SEM ± | 0.16 |
| | | CD @ 1% | 0.46 |

Note: Means followed by the same letters do not differ significantly

**Table.3** Amount of Potassium released (mg/ml) by potassium solubilizing bacterial isolates under *in vitro* condition

| Sl.No | KSB isolates | Zone of solubilization on Alexandrove's media | Amount of potassium released (mg/ml)at 10th day after inoculation |
|---|---|---|---|
| 1 | Control | 0.00 | 0.07(e) |
| 2 | KSB-1 | 0.60 | 8.12(d) |
| 3 | KSB-2 | 0.90 | 23.00(c) |
| 4 | KSB-3 | 1.45 | 44.49(a) |
| 5 | KSB-4 | 1.35 | 37.07(b) |
| | | SEM ± | 0.18 |
| | | CD @ 1% | 0.67 |

Note: Means followed by the same letters do not differ significantly

**Table.4** Morphological and biochemical characterization of efficient microbial isolates

| Sl. No. | Isolates | Morphological tests | | Biochemical tests | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ES | CS | CT | $H_2S$ | IP | NR | MR | VP | CH | CU | UA | SH | GL | A | G | PG |
| | | Colony morphology | Gram's reaction and cell shape | | | | | | | | | | | | | | | | |
| 1 | Aceto-5 | Yellowish color Smooth colony | Gram negative Small rods | - | + | + | - | + | + | - | - | + | + | + | + | - | + | + | *Acetobacter* |
| 2 | PSB-3 | Creamy white Smooth colony | Gram positive Rods | + | + | + | + | + | - | - | + | - | + | - | + | + | - | + | *Bacillus* |
| 3 | KSB-3 | Creamy white Smooth colony | Gram positive Rods | + | + | + | + | + | - | - | + | - | + | - | + | + | - | + | *Bacillus* |

Note:

ES - Endospore Staining,
CS – Crystal Staining
CT – Catalase Test
$H_2S$ – Hydrogen Sulphide production
IP – Indole Production
NR – Nitrate Reduction
MR – Methyl Red
VP – Voges Proskauer's
CH – Casein Hydrolysis
CU – Citrate utilization
UA – Urease Activity
SH – Starch Hydrolysis
GL – Gelatin Liquefaction
A – Acid Production
G – Gas Production
PG – Probable Genera

**Table.5** Effect of PGPR consortia on germination percentage and Number of leaves of sweet corn

| Sl.No | Treatments | Germination (%) | Number of leaves | | |
|---|---|---|---|---|---|
| | | | 30days | 60days | 90days |
| 1 | Control | 95 | 8.50$^{(de)}$ | 13.00$^{(bc)}$ | 17$^{(d)}$ |
| 2 | RDF + *Acetobacter* (Aceto-5) | 95 | 8.00$^{(d)}$ | 14.00$^{(b)}$ | 19$^{(b)}$ |
| 3 | RDF + *Bacillus* (PSB-3) | 96 | 7.50$^{(e)}$ | 11.00$^{(e)}$ | 15$^{(f)}$ |
| 4 | RDF + *Bacillus* (KSB-3) | 96 | 9.00$^{(c)}$ | 14.00$^{(b)}$ | 17$^{(d)}$ |
| 5 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (PSB-3) | 98 | 10.00$^{(b)}$ | 13.00$^{(bc)}$ | 16$^{(e)}$ |
| 6 | RDF + *Bacillus* (KSB-3) + *Bacillus* (PSB-3) | 95 | 8.50$^{(d)}$ | 12.00$^{(d)}$ | 18$^{(e)}$ |
| 7 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (KSB-3) | 100 | 9.0$^{(c)}$ | 12.00$^{(d)}$ | 19$^{(b)}$ |
| 8 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (KSB-3) + *Bacillus* (PSB-3) | 100 | 11.0$^{(a)}$ | 16.00$^{(a)}$ | 22$^{(a)}$ |
| | SEM ± | 0.48 | 2.607 | 6.186 | 6.139 |
| | CD @ 1% | 1.79 | 0.907 | 1.592 | 1.586 |

Note:
Absolute Control = Only Soil without compost or fertilizer treatment
RDF = Recommended Dose of Fertilizer
Means followed by the same letters do not differ significantly

**Table.6** Influence of PGPR Consortia on Total Chlorophyll Content and Plant height of Sweet Corn

| Sl.No. | Treatments | Chlorophyll (mg/g of tissue) | Plant height or Shoot Length(cm) | | |
|---|---|---|---|---|---|
| | | | 30days | 60days | 90days |
| 1 | Control | 0.87$^{(h)}$ | 40.60 | 50.00 | 75.00 |
| 2 | RDF + *Acetobacter* (Aceto-5) | 1.96$^{(cd)}$ | 42.00 | 55.00 | 74.00 |
| 3 | RDF + *Bacillus* (PSB-3) | 1.16$^{(g)}$ | 44.00 | 56.00 | 76.00 |
| 4 | RDF + *Bacillus* (KSB-3) | 1.81$^{(e)}$ | 38.00 | 51.00 | 84.00 |
| 5 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (PSB-3) | 2.00$^{(b)}$ | 44.00 | 54.00 | 83.00 |
| 6 | RDF + *Bacillus* (KSB-3) + *Bacillus* (PSB-3) | 1.98$^{(c)}$ | 41.00 | 52.00 | 81.00 |
| 7 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (KSB-3) | 1.70$^{(f)}$ | 39.00 | 53.00 | 80.00 |
| 8 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (KSB-3) + *Bacillus* (PSB-3) | 2.54$^{(a)}$ | 45.00 | 61.00 | 88.00 |
| | SEM ± | 0.08 | 0.03 | 0.21 | 0.56 |
| | CD @ 1% | 0.01 | 0.10 | 1.57 | 1.72 |

Note:
Absolute Control = Only Soil without compost or fertilizer treatment
RDF = Recommended Dose of Fertilizer
Means followed by the same letters do not differ significantly

**Table.7** Effect of PGPR consortia on NPK content of plant and soil at the time of harvest

| Sl.No | Treatments | Nutrient (mg/plant) | | | Nutrient (mg/ha) | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | N | P | K |
| 1 | Control | 254.33$^{(e)}$ | 190.33$^{(g)}$ | 166.33$^{(h)}$ | 215.00$^{(h)}$ | 23.00$^{(g)}$ | 144.67$^{(g)}$ |
| 2 | RDF + *Acetobacter* (Aceto-5) | 289.33$^{(b)}$ | 191.00$^{(g)}$ | 196.00$^{(g)}$ | 363.33$^{(b)}$ | 33.67$^{(d)}$ | 180.33$^{(b)}$ |
| 3 | RDF + *Bacillus* (PSB-3) | 232.33$^{(f)}$ | 204.00$^{(e)}$ | 215.00$^{(f)}$ | 227.00$^{(f)}$ | 27.83$^{(f)}$ | 176.00$^{(c)}$ |
| 4 | RDF + *Bacillus* (KSB-3) | 233.33$^{(f)}$ | 263.33$^{(b)}$ | 240.00$^{(d)}$ | 219.66$^{(g)}$ | 35.50$^{(b)}$ | 158.00$^{(e)}$ |
| 5 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (PSB-3) | 285.33$^{(c)}$ | 241.33$^{(d)}$ | 232.33$^{(e)}$ | 352.00$^{(c)}$ | 34.50 $^{(c)}$ | 156.33$^{(f)}$ |
| 6 | RDF + *Bacillus* (KSB-3) + *Bacillus* (PSB-3) | 191.00$^{(a)}$ | 195.33$^{(f)}$ | 246.00$^{(c)}$ | 231.33$^{(e)}$ | 31.33$^{(e)}$ | 162.00$^{(d)}$ |
| 7 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (KSB-3) | 266.33$^{(d)}$ | 254.66$^{(c)}$ | 257.00$^{(b)}$ | 295.33$^{(d)}$ | 33.67$^{(d)}$ | 180.67$^{(b)}$ |
| 8 | RDF + *Acetobacter* (Aceto-5) + *Bacillus* (KSB-3) + *Bacillus* (PSB-3) | 297.33$^{(a)}$ | 285.00$^{(a)}$ | 259.00$^{(a)}$ | 372.33$^{(a)}$ | 38.00$^{(a)}$ | 191.33$^{(a)}$ |
| | **SEM ±** | 18.01 | 16.52 | 13.32 | 12.51 | 0.52 | 18.03 |
| | **CD @ 0.05%** | 2.61 | 2.54 | 2.42 | 2.30 | 1.89 | 3.00 |

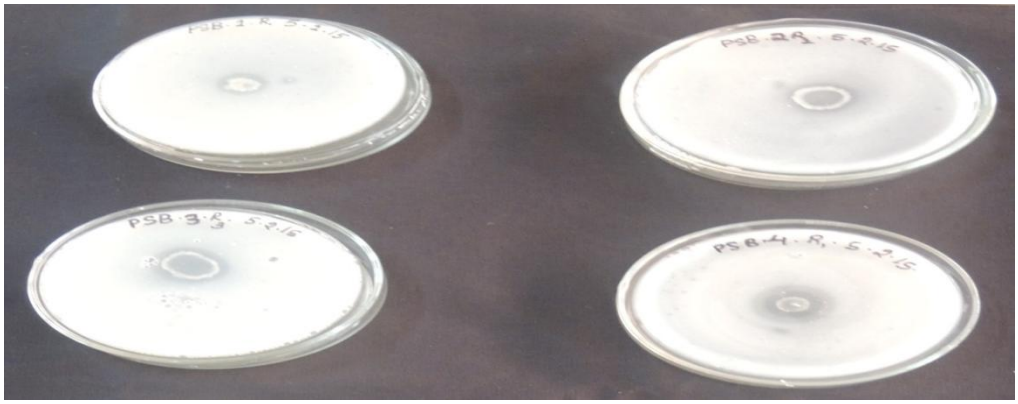
Note:
Absolute Control = Only Soil without compost or fertilizer treatment
RDF = Recommended Dose of Fertilizer
Means followed by the same letters do not differ significantly

**Plate.1** General view of pot experiment

**Plate.2** Plant growth promoting rhizomicrobial isolates isolated for different rhizosphere soils

**a)** ***Acetobacter***


***b) Potassium solubilizing bacteria***



***c) Phosphorus solubilizing bacteria***

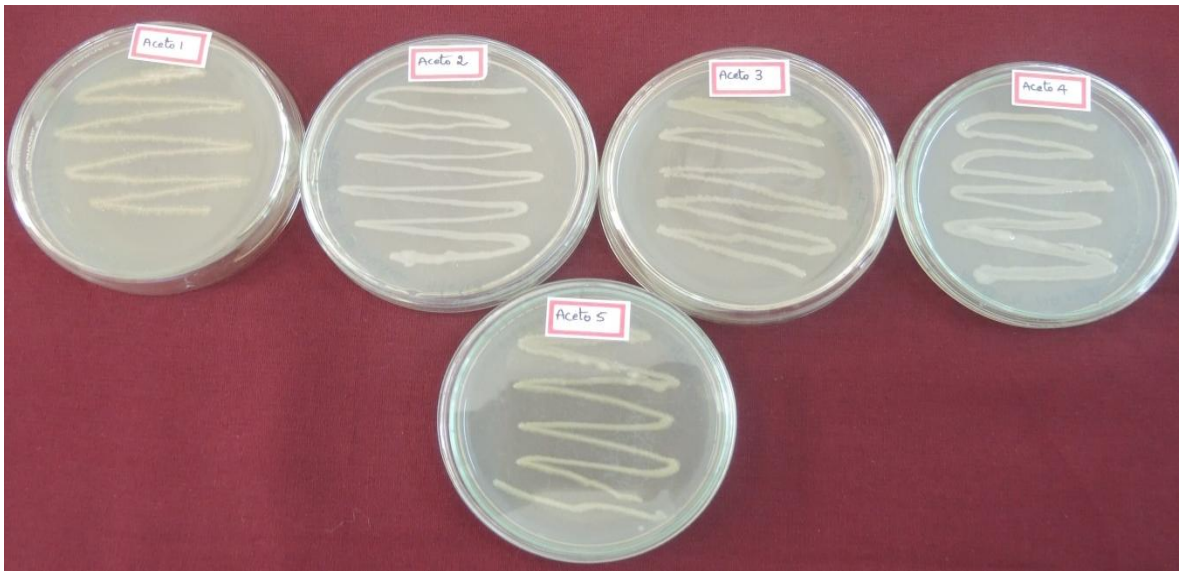
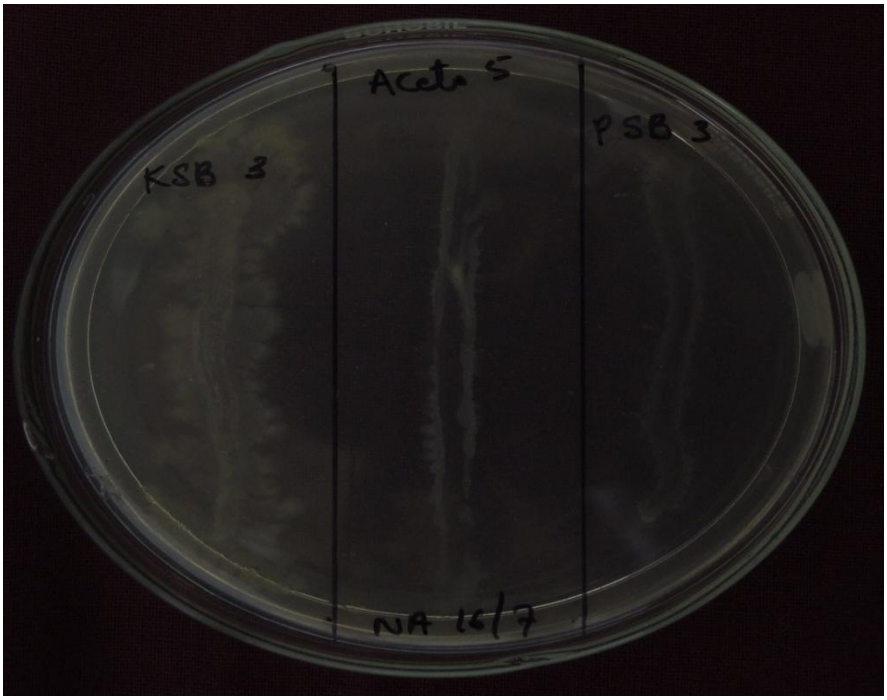


**Plate.3** Compatibility analysis of PGPR isolates




## Development and evaluation of efficient Plant growth promoting rhizomicrobial consortia on growth parameters of sweet corn

### Compatibility evaluation

It was observed from plate-3 that all these efficient Plant Growth Promoting Rhizomicrobial isolates are compatible to each other when they are grown in common media. Based on the compatibility evaluation, the consortial formulation was developed and further used for pot experiment studies.

### Influence of efficient plant growth promoting rhizomicrobial consortia on growth parameters of sweet corn

### Germination percentage and number of leaves

An evaluation of efficient *Acetobacter*, Phosphorus solubilizing bacteria and potassium solubilizing isolates in single, double and triple inoculation combinations were evaluated to know their effect on germination percentage of sweet corn Statistically, highest germination percentage was observed in the treatment 7 (RDF + *Acetobacter* (Aceto-5) + *Bacillus* PSB 3) and treatment 8 (RDF +*Acetobacter* (Aceto 5) + *Bacillus*PSB-3 + *Bacillus* KSB-3) whereas least germination percentage of 95% was observed in treatment number 1 and 2 (Control and RDF + *Acetobacter* (Aceto-5). On the other hand, with reference to number of leaves the maximum number of leaves were observed in treatment number 8 (11,16 and 22 at 30, 60 and 90 days after sowing) followed by treatment number 7 that is 9, 12 and 19 at 30, 60 and 90 days indicating the effect of Plant Growth Promoting Rhizomicrobial consortia on number of leaves. The statistically less number of leaves were observed in treatment number 1 and 3(control and RDF + *Bacillus* PSB-3) (Table 5).

Similar findings were also reported by Sugumaran and Janarthanam, (2007) who studied the effect of potassium and phosphorus solubilizing bacteria on germination of sweet corn seeds. Similarly, Leyval and Berthelin (1991) also conducted the green house experiment using potassium solubilizing microorganism and ectomycorrhizal fungus to know the effect of the dual inoculation of KSB and *Mycorrhiza* growth on leaf number of pine.

## Total chlorophyll content and plant height

Statistically the highest chlorophyll content of 2.54 mg/g of tissue was observed in triple inoculation of Aceto-5, KSB-3 and PSB-3 followed by inoculation of Aceto-5 and KSB-3. Further, statistically on par results were obtained in treatment number 6 and 2. The least chlorophyll content of sweet corn leaves were observed in control treatment. However**,** It was observed from Table 6 that plant height of 45cm was in treatment number 8 followed by 5 and 3at 30 days. On the other hand, at 60 days the same trend was continued, however, at 90 days the maximum plant height was observed in triple inoculation of *Acetobacter*-5, PSB-3 and KSB-3. The perusal of Table 6 clearly indicates increase in the plant height due to the treatment of microbial consortia. The treatment number 8 (RDF + *Acetobacter* Aceto-5 + *Bacillus* KSB-3) showed increased plant height from 45-80 cm up to 90days. The results are in line with the findings of Han *et al.,* (2006) who reported the effect of co-inoculation of phosphorus and potassium solubilizing bacteria on growth of pepper and cucumber along with the Recommended Dose of Fertilizer.

## Influences of PGPR inoculants on NPK content of plant and soil

With reference to nitrogen and phosphorus level in plants, all the treatments showed good accumulation of nitrogen. However, statistically significant high nitrogen accumulation of 297.33 mg/plant was observed in the treatment 8, where the triple inoculation of all the efficient PGPR isolates were used along with the recommended dosage of fertilizers. Similarly, With reference to phosphorus the result showed increase in phosphorus content, where the consortial application of Aceto–5, PSB–3 and KSB–3 was used (285 mg/plant). Same trend of results reveled with respect to potassium, where the highest potassium content accumulation was recorded in consortial application of Aceto–5, PSB–3 and KSB–3(259 mg/plant).Similar results were obtained in the findings of Ishque *et al.,* (2009) who evaluated six different levels of nitrogen along with *Azospirillum* on growth, number of leaves, plant height and also nutrient status of the lettuce plant after harvest.

However, when the soil nutrient status was analyzed chemically, similar results were obtained where nitrogen, phosphorus and potassium content levels recorded high in the treatment where triple inoculation of PGPR was done along with the RDF. However, in the absolute control, the NPK level was very less with reference to N, P and K content. Maximum soil NPK was observed in the treatment number 8 and the least NPK was observed in treatment number 1(Absolute control) (Table 7). Similar findings were reported by Park *et al.,* (2003) which can prove the bacterial inoculation could improve phosphorus and potassium availability in the soils by producing organic and other chemicals by stimulating growth and mineral uptake of plants.

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