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Effect of co inoculation of potassium solubilizing, mobilizing and phosphorus solubilizing bacteria on growth, yield and nutrient uptake of radish (*Raphanus sativus* L).

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Abstract

Pot experiments were carried out to evaluate the influence of application of coinoculation of potassium solubilizing, mobilizing and phosphorus solubilizing bacteria on growth and nutrient uptake of radish under greenhouse condition. Co-inoculation of potassium solubilizers, mobilizers and phosphate solubilizers together has significantly influenced the growth parameters and nutrient uptake in radish. All the growth parameters *viz*., shoot length, root length, no of leaves, fresh weight and dry weight was significantly enhanced by the application of biofertilizers. Among six treatments, consortia of potassium solubilizing isolates, potassium mobilizers and phosphorus solubilizing bacteria (T_3) and single inoculation of potassium mobilizer (T_6) recorded significantly highest growth parameters i.e. total biomass, no of leaves, shoot length, tuber weight, tuber diameter. Nutrient uptake was also recorded highest in T_3 followed by T_6 and T_2 respectively. Secondary nutrients calcium and magnesium was recorded highest in T_3 and T_9, whereas, tertiary nutrients *viz*., iron was significantly recorded highest in T_3 followed by T_6, copper was recorded maximum in T_3 and T_6, zinc content was also observed highest in T_3. Therefore, the study reveals that application of consortia of potassium solubilizers, mobilizers and phosphate solubilizers has highly enhanced the growth and nutrient uptake of radish under greenhouse condition.

Keywords: Potassium solubilizers, phosphate solubilizer, consortia, radish, secondary nutrient, tertiary nutrient.

Introduction

Radish (*Raphanus sativus* L), a cruciferous root vegetable is an excellent source of antioxidants, dietary fiber, minerals and vitamins. It is a low calorie vegetable with numerous health benefits. It is also rich in minerals like Ca, K, P, Zinc and vitamin C, which plays an important role in body metabolism. Sulforaphane an isothiocyanate antioxidant compound which is abundant in radish is known to have properties of antiproliferative activity against breast cancer (Anna Pawlik *et. al*., 2017).

Organic agriculture are gaining more and more importance in recent era due to its sustainability. Application of biofertilizers are one of the integral part of organic agriculture. Soil microorganisms mainly rhizospheric microorganisms are beneficial for plant growth and yield.

Potassium solubilizers and phosphate solubilizers are diverse group of microorganisms which are involved in solubilization process of both potassium and phosphorus from insoluble form respectively.

These microorganisms have the capability to breakdown the complex form of potassium and phosphorus by producing various organic acids which leads to the dissolution of mineral K and P resulted in exchangeable form (Kirkby, 2010). This soluble form of K and P can be easily absorbed by plants for their growth.

Phosphorus is an important macronutrient required by plants for its growth and development. Mainly it is involved in major metabolic process like cell division, photosynthesis, root development, energy transfer, signal transduction, biosynthesis of macromolecules and respiration (Khan *et. al.*, 2010). Though Indian soils are rich in phosphorus but the use of phosphorus is restricted. Most of the soil phosphorus is available in insoluble mineral complex form of iron, aluminum and calcium which are not readily available for uptake of plants (Sharma *et. al.*, 2013). Phosphate solubilizing bacteria are rhizospheric beneficial microorganism which are capable of hydrolyzing the insoluble form of mineral P into soluble organic form by their microbial activity. The solubilization process of mineral P undergoes through several mechanism by PSB. The phosphate solubilizing bacteria produces several organic acids by their activity which leads to lowering the soil pH or releasing of protons (Kumar *et. al.*, 2018, Satyaprakash *et. al.*, 2017). During the breaking down of mineral P complexes, PSB also solubilizes the secondary and tertiary nutrients like Ca, Mg, Zn (McNear. Jr., 2013). PSB not only mineralize the soil organic P by producing phosphatases, but also produces phytohormones *viz.*, auxins, gibberellins and cytokinins which promotes the plant growth (Mittal *et. al.*, 2008, Vikram and Hamzehzarghani, 2008). There are several reports stating that, application of PSB as biofertilizer are effective in promoting plant growth and development as well as increases bioavailability of P in soil.

Potassium is third essential and vital macronutrient required by plants for their growth and development. Like phosphorus, potassium is also involved in many metabolic and physiological processes including enzyme activation and stomatal activity, photosynthesis, transportation of sugars and building of proteins. Inadequate supply of potassium leads to stunted growth, increased susceptibility to diseases and reduced crop yield (McAfee, 2008, Meena *et.al.*, 2014).Total number of potassium are abundant in Indian soil, however, major portion of potassium containing minerals *viz*., muscovite, orthoclase, biotite, feldspar, illite, mica are present in the soil as a fixed form which are not directly taken up by the plant and thus very small amount of potassium are available to the plants. Depending on soil type, approximately 90-98 % of total soil K is found in non-exchangeable form. In nature, soil has limited potassium and expensive synthetic fertilizers along with its adverse effects leads to the substitution of potassium. Therefore, emerging importance of potassium solubilizing bacteria is increasing in sustainable agriculture. Potassium solubilizing bacteria are rhizospheric microorganisms which are able to release potassium from insoluble potash minerals (Basak and Biswas, 2012, Sugumaran and Janarthanam, 2007, Parmar and Sindhu, 2013).

Therefore, the present study was taken up to evaluate the effect of co inoculation of both potassium solubilizing and mobilizing bacteria and phosphorus solubilizing bacteria on growth promotion and nutrient uptake in radish.

Materials and Methods

Preparation of pots for greenhouse experiment

Pot experiment was carried out under greenhouse condition at Department of Agricultural Microbiology, UAS, GKVK, Bengaluru. The experiment consisted of 7 treatments in single and consortia and one uninoculated kept as control. Three replications were kept for each treatment and the experiment was designed in randomized block design.

The pots containing 10 kg of soil was selected for the experiment. Red soil, vermicompost and sand were mixed into 2:1:1 ratio and pots were filled.

Seeds of radish were soaked overnight in a petri plate containing filter paper before sowing. 4-5 seeds were placed in each pot. During sowing, broth cultures of PSB, KMB and KSB isolates were applied @ 30ml per pot. After 4-5 days of sowing, seeds were found sprouted with two leaf stage. Seedlings were watered in regular intervals depending upon the moisture content in the pot. Once the seedlings were in four to five leaf stages, thinning was done in each pot.

Culture preparation

All the cultures were maintained in regular intervals in their respective media. Bacterial culture of *Bacillus megaterium* as phosphorus solubilizing bacteria (PSB) was selected and grown on Pikovskaya media,

whereas, *Frateuria aurentia* was selected as potassium mobilizing bacteria (KMB) was grown and maintained on GYCA (Glucose yeast extract calcium carbonate agar) media. Potassium solubilizing bacterial (KSB) isolates was isolated from two different potassium bearing minerals on Aleksandrov medium and maintained on the same.

Seed variety

Radish variety "Arka Nishanth" was procured from IIHR, Hessaraghatta for the pot trial experiments under greenhouse condition.

Treatment details

Experiments were carried out in replicated randomized block designed with three replications for each treatments. PSB, KMB and KSB bacterial isolates were applied individually and in consortia. Control has been kept as uninoculated. Total six treatments were applied to the plants.

Treatments were given during sowing and at 15th day of plant growth and the plants were harvested at 45th day.

Growth parameters studied:

The following parameters were recorded after harvest. Plant growth and biomass was recorded for each replication of the treatments. Growth parameters *viz*., shoot length, root length, number of leaves, fresh weight, tuber weight and tuber diameter were recorded.

Nutrient content

Nutrients content *viz.*, macronutrients nitrogen, phosphorus, potassium, secondary nutrients calcium and magnesium and tertiary nutrients iron, copper, zinc were recorded.

Ascorbic acid and fiber content was also estimated.

Results and Discussion

Growth parameters:

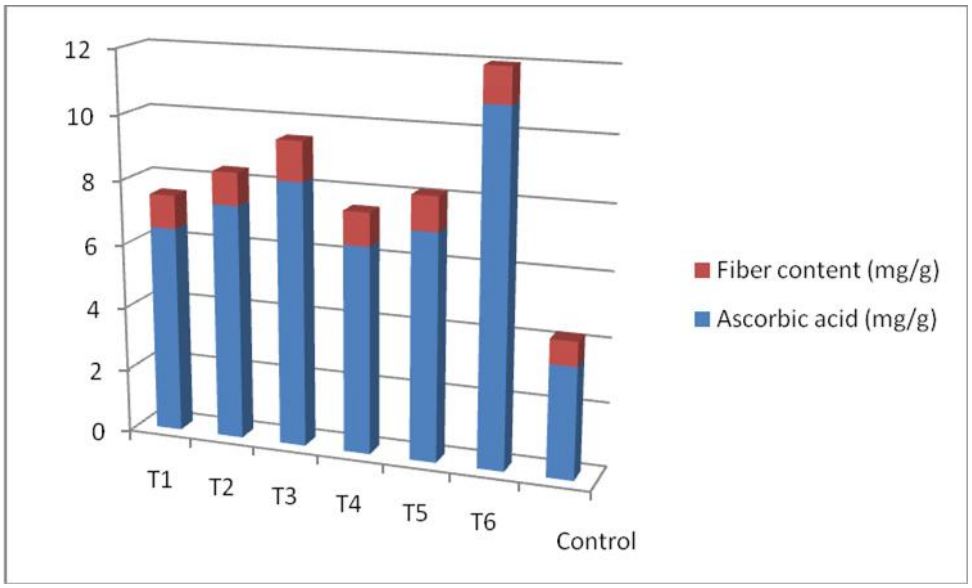
Application of different biofertilizer has profusely influenced the growth and yield of radish. Compare to individual application, consortia of PSB, KMB and KSB recorded significant growth and yield. The data pertaining to growth parameters are presented in Table 1.

Table 1. Growth parameters influenced by PSB, KMB and KSB isolates in radish

Treatments	Root length (cm)	Shoot length (cm)	No. of leaves	Fresh wt (g)	Tuber wt (g)	Tuber diameter (cm)
T_1	27.00ab	35.33a	18.66a	316.00c	126.66b	13.16ab
T_2	29.00a	39.66a	17.00a	700.00ab	202.33b	13.16ab
T_3	22.33abc	40.66a	17.66a	966.66a	760.00a	15.83a
T_4	22.66abc	37.66a	19.00a	258.66c	151.33b	11.83ab
T_5	19.33bc	35.33a	17.33a	229.33c	135.00b	11.33ab
T_6	21.33abc	44.33a	17.66a	355.00bc	115.00b	12.83ab
Control	14.00c	32.66a	14.33a	137.33c	71.66b	9.00b

Root length, shoot length, number of leaves was recorded highest in T_2 and$T_{3;}$ fresh weight, tuber weight and tuber diameter was also recorded significantly highest in T_3, The enhancement in growth parameters may be due to the availability and uptake of macro and micronutrients provided by the consortia of PSB, KMB and KSB isolates. Similar results were recorded by Shruthi *et. al.*, 2016 in radish.

Figure 1. Effect of biofertilizers on fiber content and ascorbic acid content of radish



Ascorbic acid content was recorded highest in T_6 i.e. single application of KMB. Fiber content was also found highest in T_3. Growth parameters, yield and the phytochemical components were significantly influenced by the microbial activities of PSB, KMB and KSB isolates. The result is supported by Shani *et.al.*, 2016. Ascorbic acid was found significantly highest with the application of KMB followed by consortia of PSB, KMB and KSB isolates and individual application of PSB respectively. Fiber content was also achieved highest in consortia of PSB, KMB and KSB isolates followed by KMB and PSB respectively.

Table 2 Nutrient uptake influenced by biofertilizers in radish

Treatments	Nitrogen (N %)	Phosphorus (P) (ppm)	Potassium (K) (ppm)	Calcium (Ca) (ppm)	Magnesium (Mg) (ppm)	Iron (Fe) (ppm)	Copper (Cu) (ppm)	Zinc (Zn) (ppm)
T_1	0.10bc	346.91c	2124.42d	209.81e	219.84c	12.16c	0.01b	1b
T_2	0.11ab	528.65b	3025.80c	313.83c	187.86d	18.54b	0.01b	1b
T_3	0.12a	649.06a	4834.44a	503.58a	233.48a	20.23a	0.02a	2a
T_4	0.09c	240.61d	1516.90e	322.03b	160.84e	8.51d	0.01b	1b
T_5	0.10ab	227.44e	1473.69e	255.40d	151.63f	7.00e	0.01b	1b
T_6	0.11bc	343.95c	3154.73b	502.58a	229.04b	8.66d	0.02a	1b
Control	0.04d	120.77f	441.65f	120.73f	105.16g	2.26f	0.001c	0.1c

Nutrient uptake was also highly influenced by the application of biofertilizers. The significant results were recorded with the application of consortia of PSB, KMB and KSB isolates followed by T_2 and T_5. Potassium content was found significantly highest in T_3 and all other treatments were par with each other though mean was recorded in control. Calcium and magnesium was also found highest in T_3 followed by T_6. KSB isolates and KMB has exceptionally influenced the uptake of secondary nutrients. In case of, tertiary nutrient uptake, iron, copper and zinc were recorded highest in T_3 and all other treatments are par with each other. This is may be due to the effect of microbial activities of biofertilizers applied.

Conclusion

Radish is a good source of ascorbic acid, dietary fiber and minerals like potassium, calcium and manganese. Biofertilizers PSB, KMB and KSB isolates has significantly influenced the mineral content, ascorbic acid and fiber content. In regard to yield attributes, biomass, tuber weight and fresh weight was highly effected by the application of biofertilizers. Consortia of PSB, KMB and KSB isolates remarkably effected the growth and yield. Tuber diameter, tuber length and tuber weight was notably highest with this application. Therefore, it can be concluded that these rhizospheric microorganisms have the ability to increase the growth and yield by solubilizing and mobilizing the nutrients and make readily available to the plants.

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