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Yield and quality of Guava is Influenced by Plant Growth Promoting Microbial Isolates

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ABSTRACT: A field experiment was conducted to evaluate the effect of plant growth promoting microbial isolates on yield and quality of guava, during *kharif* season of 2019 and 2020 on Vertisol. The experiment was laid out in randomized block design with eleven treatments (Ten microbial isolate and one uninoculated control) and three replications. The laboratory stock cultures of microbial isolate (*Bacillus subtilis, Bacillus lecheniformis, Bacillus megaterium, Bacillus thuringiensis, Pseudomonas fluorescens, Pseudomonas striata, Trichoderma viride. Trichoderma herzenium, Azotobacter chroococcum and Azospirillum lipoferum*) selected and tested in field condition. Recommended dose of fertilizers is common for all treatments. In results it was observed that guava plant or row treated with treatment RDF+ *Pseudomonas striata* showed significant superiority in terms of number of fruits per plant, average fruit weight, yield and improved quality which was followed by RDF+ *Trichoderma viride* and RDF + *Bacillus megaterium*.

Keywords: Field experiment, PGPR, yield and quality of guava.

INTRODUCTION

Guava (*Psidium guajava* L.) is a member of the large Myrtaceae family, believed to be originated in Central America and the southern part of Mexico (Somogyi *et al.*,1996). Guava fruit has a characteristic flavour, which its acidity is range from pH 4.0 to 5.2 (Jagtiani *et al.*,1988). It is the fourth most important fruit in terms of area and production after mango, banana and citrus. India rank first in the production of guava in the world (Jagtiani *et al.* 1998). It has been in cultivated in India since early from 17th century and gradually became a crop of commercial importance. It is available throughout the year (except during the summer season). Guava fruit is known for its 'vitamin-C' content, rich in minerals like calcium, iron and phosphorous with pleasant aroma and flavour (Dhaliwal and Dhillon 2003). Guava is quite hardy, prolific bearer and highly remunerative even without much care. Guava leaf tip is commonly used as a medicine against gastroenteritis (dysentery). Keeping in the view these problems and economic importance of guava in developing economy of Maharashtra. However, thorough investigation is needed to study their growth behavior, flowering, fruit setting and quality and its response to plant growth promoting microbial inoculation. It is widely grown all over the tropics and sub-tropics including India *viz.*, Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, West Bengal, Assam, Orissa, Karnataka, Kerala, Rajasthan and many more states. Prominent varieties of guava grown in India are Lucknow- 49, Allahabad Safeda, Pant Prabhat, Lalit and Sangam.

Intensive farming practices are to old, that warrant high yield and quality, require extensive use of chemical fertilizers, which are costly and create environmental problems. Therefore, more recently there has been a resurgence of interest in eco-friendly, sustainable and organic agricultural practices (Esitken *et al.*, 2005). Organic agricultural is a production system, which avoids or largely excludes the use of synthetically compounded fertilizers (Including nano fertilizers), pesticides, herbicides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic agricultural systems rely upon bio-fertilization, crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity. However, yield reduction is an important problem in organic production system (Lind *et al.*, 2003). Use of biofertilizers containing beneficial microorganisms instead of synthetic chemical are known to improve plant growth through supply of plant nutrients and may help to sustain environmental health and soil productivity (O'Connell, 1992). So far, considerable number of bacterial species mostly associated with the plant rhizosphere, have been tested and found to be beneficial for plant growth, yield and crop quality. They have been called 'plant growth promoting rhizobacteria (PGPR)' including the strains in the genera A*cinetobacter, Alcaligenes, Arthrobacter, Azospirillium, Azotobacter, Bacillus, Beijerinckia, Burkholderia, Enterobacter, Erwinia, Flavobacterium, Rhizobium and Serratia* (Rodriguez and Fraga 1999; Sturz and Nowak, 2000; Sudhakar et al., 2000). In previous studies, it was found that PGPR could stimulate growth and increase yield in apple, citrus, high bush blueberry, mulberry and apricot (Kloepper, 1994; De Silva *et al*., 2000; Sudhakar *et al*., 2000; Esitken *et al*., 2002, 2003). The restricted availability of major nutrients like nitrogen and phosphorus limits plant growth and yield. Bio-fertilizers including microorganisms may add nitrogen to the soil by symbiotic or asymbiotic N2 fixation. On a worldwide basis, it is estimated that about 175 million tons of nitrogen per year is added to soil through biological nitrogen fixation. Meanwhile super-phosphate fertilizer is expensive and in short supply, but bio-fertilizers can bridge the gap. There are several microorganisms, which can also solubilize the cheaper sources of phosphorus, such as rock phosphate. Bacteria like Pseudomonas and Bacillus are widely used in organic production system and also important phosphorus solubilizing microorganisms, resulting in improved growth and yield of crops (Dobereiner, 1997). The direct promotion by PGPR entails either providing the plant with a plant growth promoting substances that is synthesized by the bacterium or facilitating the uptake of certain plant nutrients from the environment. The indirect promotion of plant growth occurs when PGPR lessen or prevent the deleterious effect of one or more phytopathogenic micro-organisms.

Here, in the present studies our idea is to study effect of PGPR on yield and quality of guava. We will try to understand how PGPR increasing soil nutrient availability and yield.Thus, keeping this, in the view present study was undertaken for "Yield and quality of guava is influenced by plant growth promoting microbial isolates".

MATERIAL AND METHODS

Experimental details. The field experiments were conducted in 2019 and 2020 years at the farmer's orchard situated near Parbhani, in which inoculation of different promising microbial isolates and determination of their effect on yield and quality of guava.The yield of guava was estimated and recorded during picking or harvesting. For quality estimation fruits sample from each picking tested and evaluated in laboratory for TSS (%) using Anthrone reagent method (Ranganna, 1977), Titratable acidity (%), Vit C (mg 100^{-1})by using Iodin titration method (Sautntornsuk *et al.*,2002), Fruit diameter(cm), reducing sugar(%), nonreducing sugar (%) and Total sugar (%) by method given by Ranganna, 1977.The data obtained was statistically analysed and appropriately interpreted as per the methods described in "Statistical Methods for Agricultural Workers" by Panse and Sukhatme.

Treatment details. The dose of fertilizer with FYM was applied through soil application after 1st irrigation orinitial stage of flowering by ring method in both year and season equal for all treatments. The experiment was carried out with eleven treatment (Ten microbial isolates and one uninoculated control) and three replications and the design of experiment is randomized block design. The laboratory stock cultures (T_2-*Bacillus subtilis*, T_3- *Bacillus lecheniformis*, T_4- *Bacillus megaterium*, T_5-*Bacillus thuringiensis*,T_6-*Pseudomonas fluorescens*, T_7-*Pseudomonas striata*, T_8-*Trichoderma viride*. T_9-*Trichoderma herzenium*, T_{10}-*Azotobacter chroococcum and* T_{11} -*Azospirillumlipoferum*) were selected basedon the previous performaceand procured from All India Network Project on Soil Biodiversity-Biofertilizers, Vasantrao Naik Marathwada KrishiVidyapeeth, Parbhani and T_1 is control.

RESULTS AND DISCUSSION

Yield parameters. Plant growth promoting rhizobacterial agents significantly influenced the yield and quality of guava. The enhancement of yield and quality of guava observed in treatment having inoculation of promising microbial strains as compare to uninoculated control.

Number of fruits plant^{-1}. Number of fruits per plant of guava was positively and significantly influenced with inoculation of promising microbial agents. The guava plant or row treated with treatment T_7i.e. receiving RDF+ *Pseudomonas striata* shows higher number of fruits plant^{-1} (82.09 fruits plant^{-1}), which was followed by treatment T_8 i.e. inoculation RDF+ *Trichoderma viride*(82.09 fruits plant^{-1}), T_4 RDF+ *Bacillus megaterium*(77.37 fruits plant^{-1}) and T_{10} RDF+ *Azotobacter chroococcum*(75. 14 fruits per plant). These treatments were superior over other treatment and at par with each other.

Average fruit weight. Significantly higher value of average fruit weight was found with inoculation treatment T_4 receiving RDF+ *Bacillus megaterium*(147.78 g) followed by treatment T_7i.e. RDF+ *Pseudomonas striata*(143.82 g) and *Trichoderma viride* (141.75 g). These treatments were found superior over other treatment and at par with each other.

Yield plant^{-1} and yield ha^{-1}. The plant growth promoting microbial inoculants significantly affect the yield of guava crop as compared to uninoculated control treatment (only RDF)

Significantly higher yield was observed in treatment T_7i.e. inoculation of RDF+ *Pseudomonas striata*(10.38 kg plant^{-1} or 21.98 Mg ha^{-1}), which was followed by treatment T_8 i.e. RDF+ *Trichoderma viride* (21.75 Mg ha^{-1}), T_4 *Bacillus megaterium* (9.71 kg plant^{-1} or 20.89 Mg ha^{-1}) and T_{10} i.e. RDF+ *Azotobacter chroococcum*(9.49 kg plant^{-1} or 20.42 Mg ha^{-1}). These treatments were found better over other treatment and at par with each other. Whereas significantly lowest yield was observed in T_1 uninoculated control treatment.

However, percent increase in yield per hector over control was found higher with treatments T_7i.e. receiving RDF+ *Pseudomonas striata* (35.93 %)which was followed treatments T_8 i.e. inoculation RDF+ *Trichoderma viride*(34.51 %), T_4 RDF+ *Bacillus megaterium*(29.19%)and T_{10} RDF+ *Azotobacter chroococcum*(26.28).

The increase in yield of guava due to drenching of strain *Pseudomonas striata, Trichoderma viride, Bacillus megaterium* and *Azotobacter chroococcum* might be due to their higher plant growth promoting activity i.e. nitrogen fixation, phosphorus solubilization, zinc solubilization, siderophore production and IAA production, which improve nutrient content and enzymatic activity in soil. Present exploration is full conformity with those reported in the past Dutta *et al.* (2009) reported that increased in fruit retention and yield with bio-fertilizer may be due to the buildup of colonies of the applied bio-fertilizer inoculates and their growth promoting effects including the synthesis of plant growth promoting substances to enhance photosynthetic activity.

Table 1: Effect of promising microbial growth promoting agents on number of fruits plant $^{-1}$, average fruit weight (g) and yield of guava.

Treatment	Yield Parameter					
	Fruits Plant^{-1}	Avg. fruit weight(g)	Exp. Yield Plant^{-1}	Act.Yield Plant^{-1}	Yield Mg ha^{-1}	% Increase in yield over control
T_1- Uninoculated control (only RDF)	54.28	113.4	6.15	7.52	16.17	---
T_2 -RDF + *Bacillus subtilis*	65.1	123.87	8.24	8.45	18.18	12.43
T_3-RDF +*Bacillus licheniformis*	68.35	129.88	9.1	8.56	18.42	13.91
T_4-RDF +*Bacillus megaterium*	77.37	147.78	11.65	9.71	20.89	29.19
T_5-RDF +*Bacillusthuringiensis*	61.04	125.5	7.84	8.18	17.6	8.84
T_6 -RDF +*Pseudomonas fluorescens*	70.4	134.84	9.69	9.22	19.84	22.70
T_7-RDF +*Pseudomonas striata*	82.09	143.82	12.07	10.38	21.98	35.93
T_8 -RDF +*Trichoderma viride*	79.85	141.75	11.54	10.11	21.75	34.51
T_9-RDF +*Trichoderma herzenium*	60.75	125.13	7.85	8.1	17.42	7.73
T_{10} -RDF +*Azotobactorchroococcum*	75.14	137	10.42	9.49	20.42	26.28
T_{11}-RDF +*Azospirillumlipoferum*	64.8	126.26	8.41	8.63	18.57	14.84
S.Em.±	2.55	4.17	0.49	0.36	0.76	-
CD @ 5%	7.26	11.85	1.39	1.01	2.17	-

*Exp. Yield Plant^{-1} :Average fruit weight × Number of fruits Plant^{-1} ;

*Act. Yield Plant^{-1} : Yield obtained by to daily picking measurement in orchard

Simlarly Shukla *et al.* (2014) reported that application of treatment *Azotobacter* + PSM + *T. herzenium* + organic mulching show significant improved yield(fruit length, fruit diameter, fruit weight and yield ha^{-1}). Increasing productivity of various crops for utilization of organic fertilizer could be better preposition for improving biological attributes of soil, which in turn may increase productivity of guava crops (Allen *et al.*, 2002). Similar finding was also reported by Das *et al.* (2017) revealed that different sources of bio-fertilizers significantly influenced the fruit retention of guava. Highest fruit retention, yield, fruit length, fruit weight, core weight and pulp weight of guavawas recorded from the combination of *A. brasilense*+ AMF. Also Kumar *et al.* (2017) studied the impact of inorganic and biofertilizers with different spacing on yield of guava and reported that inoculation of *Azotobacter* (20g) + PSB (20g) + vermicompost (10g) + 50% recommended NPK show significantly high number of fruits plant^{-1} and fruit yield ha^{-1}, Application of treatment 50% NPK + 25 kg FYM + *Trichoderma spp.* + *Pseudomonas spp.* show significant increase in guavafruit tree^{-1}, fruit weight, fruit yield tree^{-1} and fruit yield ha^{-1} (Dwivedi and Agnihotri,2018). Similarly, Singh *et al.* (2020) studied the effect of biofertilizers on growth yield of guava and reported that where maximum number of fruits per tree, yield per tree and yield ha^{-1} was recorded in the tree treated with treatment 100 % RDF + *Azotobacter* (250 gtree^{-1}) + PSB (200 g/tree) + VAM (200 gtree^{-1}) however minimum number of fruits per tree, yield per tree, yield per hectare was recorded in the tree treated control (100 % RDF).

Quality attributes. Total soluble solid. The significantly higher of TSS in fruit of guava was found in treatment T_4i.e. inoculation of RDF+ *Bacillus megaterium* (8.93 % and 9.10%),followed by treatment T_7 i.e. RDF+ *Pseudomonas striata* (9.37%). The treatment T_8 receiving RDF+ *Trichoderma viride* (8.53%, 9.05% and 9.08%) was found at par with treatment T_4 and T_7 in both year and pooled mean data.

Titratable acidity. The titratable acidity was also positively and significantly influenced with inoculation of plant growth promoting microbial agents and observed that treatment T_4i.e. RDF+ *Bacillus megaterium* shows lowest titratable acidity in both season (0.339%) which was followed by treatment T_7 receiving RDF+ *Pseudomonas striata* (0.351%) and treatment T_8 i.e. receiving RDF+ *Trichoderma viride* ((0.372). These treatments were found superior over other treatments and at par with each other.

Ascorbic acid content. The ascorbic acid content in guava fruits was positively and significantly influence with inoculation plant growth promoting rhizobacterial agents found that values of Vitamin C was s significantly influenced with treatment T_7 i.e. inoculation RDF+ *Pseudomonas striata* and showed higher content of Vitamin C (143.78 mg 100g^{-1}).

Table 2: Effect of promising microbial growth promoting agents on TSS, Titratable acidity, Vit. C and fruit diameter of guava fruit.

Treatment	Pooled			
	TSS (%)	Titratable acidity (%)	Vit- C mg 100 g $^{-1}$	Fruit diameter (mm)
T_1- Uninoculated control (only RDF)	8.06	0.392	135.96	60.915
T_2 -RDF + *Bacillus subtilis*	8.16	0.409	135.23	62.010
T_3-RDF +*Bacillus licheniformis*	8.25	0.384	136.27	63.686
T_4 -RDF +*Bacillus megaterium*	9.10	0.339	142.17	70.259
T_5-RDF +*Bacillus thuringiensis*	8.23	0.389	136.20	60.622
T_6 -RDF +*Pseudomonas fluorescens*	8.37	0.385	139.76	65.543
T_7 -RDF +*Pseudomonas striata*	9.08	0.351	143.78	69.484
T_8 -RDF +*Trichoderma viride*	8.71	0.372	141.00	66.603
T_9-RDF +*Trichoderma herzenium*	8.03	0.409	133.41	62.062
T_{10} -RDF +*Azotobactorchroococcum*	8.42	0.378	138.14	65.494
T_{11}-RDF +*Azospirillumlipoferum*	8.17	0.390	135.30	62.343
S.Em. ±	0.16	0.008	2.68	1.336
CD @ 5%	0.44	0.024	NS	3.799
CV	4.55	5.410	4.75	5.060

Table 3: Effect of promising microbial growth promoting agents on reducing sugar, non-reducing sugar and total sugar content in guava fruit.

Treatment	Pooled		
	Reducing sugar (%)	Non reducing sugar (%)	Total sugar
T_1- Uninoculated control (only RDF)	3.355	2.068	5.423
T_2 -RDF + *Bacillus subtilis*	3.543	2.110	5.653
T_3-RDF +*Bacillus licheniformis*	3.436	2.142	5.578
T_4 -RDF +*Bacillus megaterium*	3.973	2.424	6.397
T_5-RDF +*Bacillus thuringiensis*	3.454	1.983	5.436
T_6 -RDF +*Pseudomonas fluorescens*	3.715	2.192	5.906
T_7 -RDF +*Pseudomonas striata*	4.414	2.529	6.943
T_8 -RDF +*Trichoderma viride*	4.162	2.357	6.520
T_9-RDF +*Trichoderma herzenium*	3.436	2.099	5.535
T_{10} -RDF +*Azotobactorchroococcum*	3.854	2.267	6.122
T_{11}-RDF +*Azospirillumlipoferum*	3.588	2.089	5.677
S.Em. ±	0.123	0.059	0.142
CD @ 5%	0.349	0.167	0.404
CV	8.080	6.530	5.880

Fruit diameter. Significantly highest fruit diameter was found in treatment T_4i.e. inoculation RDF+ *Bacillus megaterium*(70.259 mm) which was at par with treatment T_7receiving RDF+ *Pseudomonas striata* (69.48 mm) and treatment T_8 i.e. RDF+ *Trichoderma viride*(66.603 mm). These treatments were found superior to other treatment and at par with each other.

Reducing, Non-Reducing and Total Sugar. Sugar concentration in guava fruit was significantly influenced with inoculation of plant growth promoting microbial agents. The treatment T_7 i.e., inoculation of RDF+ *Pseudomonas striata* was found significantly superior over other treatments in reducing, non-reducing and total sugar content of guava fruit(4.41% 2.52% and 6.943%). Which was followed by treatment T_8receiving RDF+ *Trichoderma viride* (4.162%, 2.357% and 6.520 %) and treatment T_4 i.e. RDF + *Bacillus megaterium* (3.77 %, 2.42 % and 6.39 %) reducing, non-reducing and total sugar content in guava fruit. These treatments were superior over other treatment and at par with each other.

Improvement in quality of guava fruits due to inoculation of tested microbial isolates might be due to their plant growth promoting activity which causing more accumulation food material in the tree lead to an efficient utilization same for fruit development. Our results are also corroborated with finding of Godage *et al.* (2013) recorded significantly higher fruit diameter (10.07 cm), fruit weight (215.06 g) and maximum pulp weight (193.44 g) with the treatment 75% N + 100% P_2O_5 + 100% K_2O + *Azotobacter* 5ml tree^{-1} + PSB 5mltree^{-1}. They further stated that improvement in quality is might be due to optimum supply nutrients through applied treatment resulting high photosynthesis and higher accumulation of carbohydrate in fruit thereby increasing fruit diameter and weight. Similarly, Shukla *et al.* (2014) observed that treatment *Azotobacter* + PSM + *T. herzenium* + organic mulching show significant improvement in quality parameter (TSS, titratable acidity, total sugar and ascorbic acid content). Das *et al.* (2017) revealed that. highest fruit length, fruit weight, core weight and pulp weight of guavawas recorded from the combination of *A. brasilense*+ AMF and this was followed by *A. brasilense*+ *B. megatherium*,whilefruit length, fruit weight, core weight and pulp weight of guava from control was recorded minimum. Other quality parameters like non reducing sugar, ascorbic acid and titrable acidity of fruit were significantly influenced by different treatments of bio-fertilizers. The improved fruit quality may be attributed to better vegetative growth of the treated plants, which resulted in higher quantities of photosynthates (starch, carbohydrates etc.) and the translocation to the fruits thus increasing the contents of various fruits quality parameters (Naik & Haribabu 2007).

Increase in physicochemical parameters of fruits might be on account of influential role of bio-fertilizer in higher nitrogen fixation and uptake of nitrogen thereby stimulating the catalytic activity number of enzymes in the physiological processes and increasing production of sugars and amino acids that ultimately increase the total soluble solid, sugar and ascorbic acid content of the fruits (Dutta & Kundu 2012). Also, Singh *et al*. (2020) reported that significantly high TSS, ascorbic acid content and minimum titratable acidity were recorded in plants subjected to biofertilizers in combination, i.e treatment 100 % RDF + *Azotobacter* (250 gtree^{-1}) + PSB (200 g/tree) + VAM (200 g tree^{-1}) however minimum number of TSS, ascorbic acid content maximum titratable acidity was recorded in the tree treated control (100 % RDF).

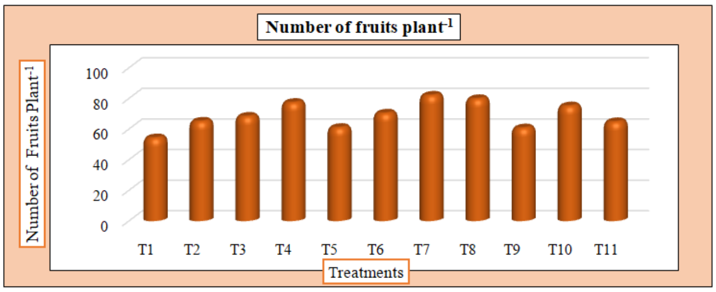

Fig. 1. Effect of different promising microbial growth promoting agents on number of fruits per plant.

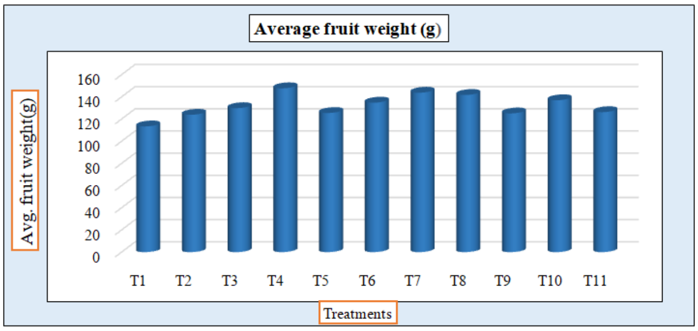

Fig. 2. Effect of different promising microbial growth promoting agents on average fruit weight.

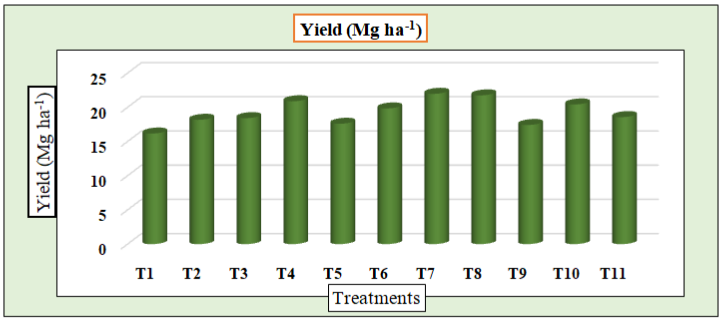

Fig. 3. Effect of different promising microbial growth promoting agents on yield.

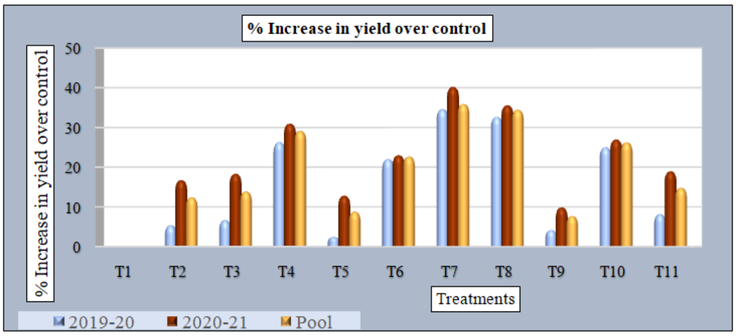

Fig. 4. Effect of different promising microbial growth promoting agents on percent increase yield over control.

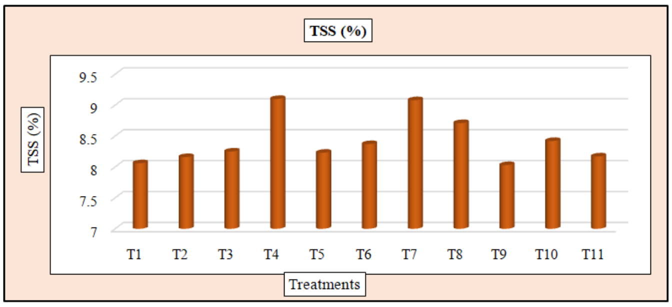

Fig. 5. Effect of different promising microbial growth promoting agents on total soluble solids.

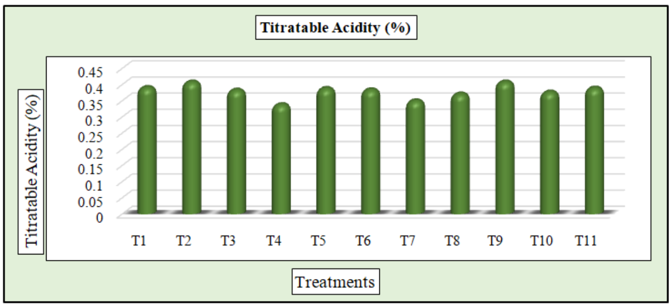

Fig. 6. Effect of different promising microbial growth promoting agents on titratable acidity.

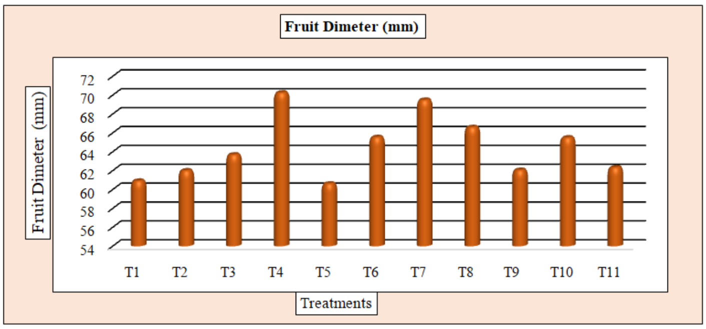

Fig. 7. Effect of different promising microbial growth promoting agents on fruit dimeter.

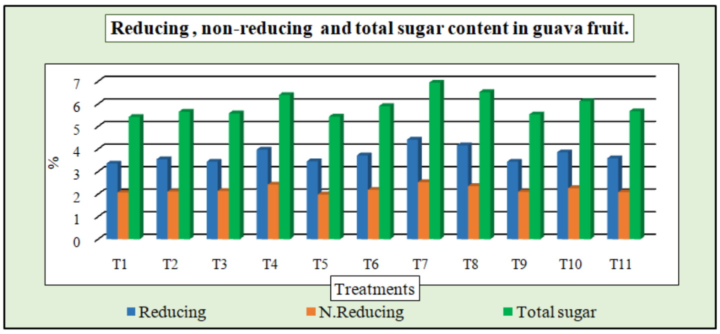

Fig. 8. Effect of different promising microbial growth promoting agents on reducing, non-reducing and total sugar in fruit.

General view of experimental plot.

CONCLUSIONS

It is evident from the above Results discussion that the plant growth promoting microorganisms (bacteria or fungi) plays an important role in enhancing the crop productivity by various direct as well as indirect mechanisms. The effect of these microorganisms has been shown by various workers either using singly or in consortium of more than one type of microorganism and predicted that the dual inoculation of PGPR has showed better results as compared with the single inoculations. The present study with plant growth promoting isolates and guava crop revealed that inoculation with *Pseudomonas striata* along with RDF of NPK followed by *Trichoderma viride* and *Bacillus megaterium* were found considerably effective in enhancing growth, yield and maintaining quality of guava crop. These microbial isolates can be explored as bioinput for improving plant growth and also to correct the nutrients deficiency in guava.

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Appendix A. Supplementary Data. Supplementary data to this article can be found online ahttp://krishikosh.egranth.ac.in/ handle/1/5810070599

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