Plant growth promoting rhizobacteria bio capsules: wide potential in ginger for growth and yield improvement

Abstract

The trial was conducted at the turmeric research station, Kammarpally for the continuous of three years from 2018-19 to 2020-21 to assess the potential of plant growth promoting rhizobacteria (PGPR) capsules developed by Indian Institute of Spices Research in ginger cultivation. PGPRs associated with plant growth processes such as nitrogen fixation, phosphate solubilization, and hormone secretion. PGPR has multiple ecological and practical functions in the soil's rhizosphere. One of PGPR's various roles in agro ecosystems is to increase the synthesis of phytohormones and other metabolites, which have a direct impact on plant growth. A field experiment has been conducted to study different PGPRs in ginger with three varieties V1-Mahima, V2-Maran, V3-Local type and five different PGPR combinations T1-POP + *Trichoderma* (Talc formulations) + GRB 35 (Talc formulations), T2- POP + *Trichoderma* capsules + GRB 35 capsule, T3- POP + *Trichoderma* capsules, T4- POP + GRB 35 capsule, T5-POP (Recommended package of practices). The maximum mean fresh rhizome yield per plot (6.28 kg/plot) and maximum mean fresh rhizome yield per hectare (21.53 t/ha) have been observed with T4V1- POP + GRB 35 capsule with Mahima variety followed by T4V2- POP + GRB 35 capsule with Maran variety which recorded fresh rhizome yield per plot (6.16 kg/plot) and mean fresh rhizome yield per hectare (20.15 t/ha).

Key words: Trichoderma, GRB-35, PGPR, Fresh rhizome yield, Talc formulation

Introduction

Ginger (Zingiber officinale Rosc.) belongs to the family Zingiberaceae is a perennial herbaceous monocotyledon plant that is commercially cultivated as an annual crop for its rhizomes. It has been cultivated in the country since ancient times and is a significant commercial spice crop. It is a high-value tropical rhizomatous spice crop grown in tropical and subtropical climates. Despite being grown in numerous countries, it thrives best in humid, tropical climates. Ginger has a long history that goes back more than 5000 years. It is a South East Asian native, but over the years, it has spread across several regions of the world, including Africa The countries like UK, the USA, and Saudi Arabia import the majority of the harvest. Nigeria is the greatest amount of ginger growing country (56.23% of the world's total area), followed by Bangladesh, India, China, and Indonesia, which have approximately 23.6, 4.7, and 3.4 per cent of the total area under ginger, respectively Ginger is used for various kinds of purposes in India, including pickles, food additives, confections, and traditional remedies for stomach aches. It is a powerful antioxidant and has been used to treat all kinds of nausea, including those brought on by motion sickness, pregnancy, surgery, and nausea following chemotherapy. Traditional and modern medications both employ ginger as a common raw ingredient. This is due to the volatile oleoresin and volatile oil found in ginger.

Sustainable agriculture has become increasingly important in recent times due to its focus on long-term environmental and social benefits. Recognizing the importance of sustainable farming practices is crucial for meeting the future economic needs of the world, as they can help reduce the use of artificial pesticides and fertilizers while improving plant health and soil quality (De Andrade *et al*, 2023). To secure long-term environmental health worldwide and produce adequate food for future generations, sustainable agriculture must preserve the soil's inherent diversity (Kumar, 2017). Thus, eco-friendly alternatives, including the sustainable use of beneficial microorganisms, are crucial for alleviating environmental stress. Bacteria, known as PGPR, are the most important of all the soil microbes. The benefits for the crop are achieved in many ways, such as fixing nitrogen, breaking down phosphate, getting rid of heavy metals, making phytohormones (like auxin, gibberellins, cytokinin, etc.), breaking down crop residue, and stopping phytopathogens from growing (Pantigoso *et al*, 2019). Researchers have thoroughly studied the positive impacts of PGPR, a naturally occurring soil bacterium, on plant vitality and output. In addition to protecting plants from pathogens and harsh conditions, they can also boost nutrient availability, spur plant growth, fortify root development. Several different mechanisms are involved in how PGPR helps plants. Some PGPR form auxins, cytokinins, and gibberellins, which encourage root and shoot growth (VanPeer *et al*. 2018). PGPRs can easily use the process of "fixation" to convert nitrogen in the air into a plant-available form, thereby augmenting the plant's nitrogen needs. PGPRs solubilize phosphorus and other mineral nutrients, increasing their availability to plants. PGPR competes with dangerous microbes for oxygen, food, and room by colonizing the rhizosphere, which lowers the danger of pathogen invasion and boosts plant health in general. PGPR improves plant resistance by activating defensive systems and enhancing tolerance to a wide range of environmental factors, including dryness, salinity, and extreme heat. Soil has many different kinds of bacteria and viruses.

The rhizosphere of a plant is home to helpful microorganisms called plant growth promoting rhizobacteria (PGPR), which play a crucial role in promoting plant growth and development. The significance of PGPR for long-term agricultural viability is outlined in this review. Increased plant tolerance to biotic and abiotic stress, reduced use of chemical fertilizers and pesticides, and enhanced nutrient availability, soil fertility, and absorption are all mentioned as potential benefits of PGPR. Phytopathogens can be stopped in their tracks, a plant's natural defenses can be bolstered, and so on. PGPR also helps clean up the soil through a process called bioremediation. The PGPR's many functions include indole acetic acid (IAA) production, ammonia (NH3) production, hydrogen cyanide (HCN) production, catalase production, and more. In addition to aiding in nutrient uptake, PGPR controls the production of a hormone that increases root size and strength. Improving crop yield, decreasing environmental pollution, and guaranteeing food security are only some of the ecological and economic benefits of employing PGPR for sustainable agriculture.

Material and methods

The field experiment was conducted to study the effect of different PGPR biocapsules and talc formulations on growth and yield of turmeric at Turmeric research station, Kammarpally, Nizamabad district, Telangana during 3 consecutive years from 2018-19 to 2020-21. The experimental initial soil status was less alkaline pH (7.65), electric conductivity 0.15 dS m-1 , low organic carbon with medium available nitrogen (250 kg ha-1), high available phosphorus (32.57 kg ha-1) and high available potassium (332.7 kg ha-1).

This experiment was laid in a randomized block design with three replications. This experiment is formulated with three varieties V1-Mahima, V2-Maran, V3-Local type and five different PGPR combinations T1-POP + *Trichoderma* (Talc formulations) + GRB 35 (Talc formulations), T2- POP + *Trichoderma* capsules + GRB 35 capsule, T3- POP + *Trichoderma* capsules, T4- POP + GRB 35 capsule, T5- POP (Recommended package of practices). Generally, the seed was sown in the month of June and harvested after completion of 8 months in the month of March during the experimental years.

Recommended cultural practices were adopted for all treatments. Growth parameters *viz.,* plant height, number of tillers, number of leaves, petiole length, leaf length, leaf width recorded in the second week of January month. Yield parameters data was recorded at harvesting time. In case of growth and yield parameters data was recorded from five plants from each replication and the means are used for statistical analysis (Panse and Sukhatme 1957)

Results and Discussion

Growth characters:

Significant differences were observed with the growth parameters plant height, number of shoots, height of shoot, leaf length, leaf width. The maximum mean plant height (56.0 cm), number of shoots (12.95), height of shoot (24.75), leaf length (20.72 cm), leaf width (1.79 cm) were recorded with T4- POP + GRB 35 capsule with Mahima variety which may be due to the the direct mechanisms observed in PGPR include N2 -fixation, mobilization of nutrients via production of phosphatases, siderophores, or organic acids, and production of phytohormones and enzymes which trigger the growth of the turmeric plants (V. Jeyanthi *et al*., 2018). Many scientists reported that plant growth promoting rhizobacteria might enhance plant height and productivity by synthesizing phytohormones (Prokryl *et al*, 2000, Burd et al, 2000, Gravel, 2007). The beneficial effects of PGPR involve boosting key physiological processes, including water and nutrient uptake, photosynthesis, and source-sink relationships that promote growth and development (Illangumaran and Smith, 2017). One of the mechanisms by which bacteria are adsorbed onto soil particles is by ion exchange. A soil is said to be naturally fertile when the soil organisms are releasing inorganic nutrients from the organic reserves at a rate sufficient to sustain rapid plant growth (Goswami *et al*., 2016). Gray and Smith (2005) have shown that the PGPR associations range in the degree of bacterial proximity to the root and intimacy of association. The three distinct characteristics of PGPR are they must be able to colonize the root, they must survive and multiply in microhabitats associated with the root surface, in competition with other microbiota, at least for the time needed to express their plant promotion/ protection activities and they must promote plant growth (Kloepper, 1994; Lucy et al., 2004). Phytohormones are responsible for plant growth development and allow plants to tolerate different stress conditions (Shaterian *et al*., 2005). Some rhizobacteria are able to produce phytohormones, including cytokinins, auxins, gibberellins, ethylene, and abscisic acid (ABA), which play a role in different growth processes in plants, including cell multiplication, which results in increased cell and root expansion (Glick, 2014; Kaur et al., 2016). However, the production of ABA by rhizobacteria is considered an indirect way of promoting plant growth. Several bacteria that have the ability to produce IAA and have positive effects on shoot and root weight and nutrient uptake on maize plants. Besides, activities like phosphorus solubilization, or even other non-evaluated PGPR traits that stimulate plant growth. PGPR may promote growth directly, e.g. through fixation of atmospheric nitrogen, solubilization of minerals (phosphorus and potassium), production of siderophores that solubilize and sequester iron, or production of plant growth regulating hormones (Grover et al. 2009).

Yield characters:

The maximum mean fresh rhizome yield per plot (6.28 kg/plot) and maximum mean fresh rhizome yield per hectare (21.53 t/ha) have been observed with T4V1- POP + GRB 35 capsule with Mahima variety followed by T4V2- POP + GRB 35 capsule with Maran variety which recorded fresh rhizome yield per plot (6.16 kg/plot) and mean fresh rhizome yield per hectare (20.15 t/ha). The results are in conformity with Kuan et al. (2016) who reported that plant growth-promoting bacteria may provide a biological alternative to fix atmospheric N2 and delay N remobilization in maize plant to increase crop yield based on an understanding that plant-N remobilization is directly correlated to its plant senescence promoting high up to 30.9% with reduced fertilizer-N input. Di Salvo et al. (2018) reported that PGPR used as inoculants of cereal crops including maize can improve their growth and grain yield. The crops responses to inoculation are complex because are defined by plant-microorganisms interactions, many of them still unknown. Thus, it is necessary to improve the knowledge about the microbial ecology of the rhizosphere of crops under different agricultural practices. Various processes, such as the mineralization of organic matter, nutrient immobilization, phosphate solubilization, nitrogen nitrification, and phytohormone production, combine to enhance soil fertility and crop productivity (Van Peer *et al* 1989). Plant growth promoting rhizobacteria in rhizosphere soil is highly dynamic, more versatile in transforming, mobilizing and solubilising the nutrients. Therefore, the rhizobacteria are the dominant deriving forces in recycling the soil nutrients and consequently, they are crucial for soil fertility. They may be extensively used in plant growth promotion as it acts as a plant nourishment and enrichment source which would replenish the nutrient cycle between the soil and plant roots , exhibits detoxifying potential, controls phytopathogen thereby exerts a positive influence on crop productivity and ecosystem functioning, hence can be implemented in agriculture (V. Jeyanthi, 2018)

Conclusion

Application of GRB 35 capsules along with package of practices is proved to improve growth and fresh rhizome yield in ginger. In case of varieties Mahima found to give higher growth and fresh rhizome yield followed by Maran. Hence the use of GRB-35 capsules recommended in ginger cultivation for higher yield

Future scope:

Further field research and testing must be conducted to completely discover the potential of PGPR and develop feasible, widespread applications. Eco-friendly PGPR approaches that significantly enhance plant growth and increase crop yields are now achievable due to these improvements.

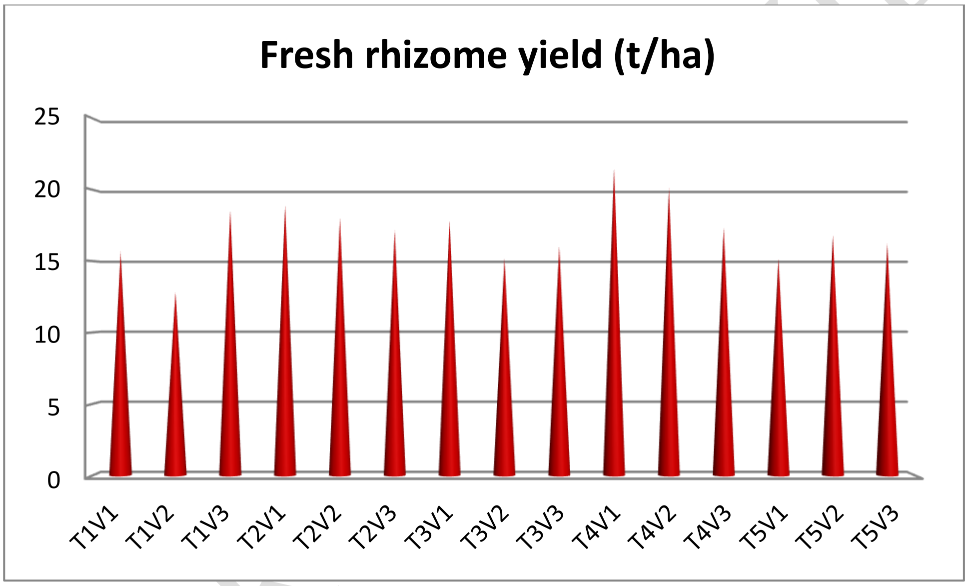

Fig 1: Effect of plant growth promoting rhizobacteria bio capsules on growth and yield characteristics of ginger

Table 1: Effect of plant growth promoting rhizobacteria bio capsules on growth and yield characteristics of ginger

	Plant height (cm)			Number of shoots			Height of shoot (cm)			Leaf length (cm)		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
T1V1	40.85	40.5	40.675	10.32	10.36	10.34	21.17	20.8	20.985	15.65	15.4	15.525
T1V2	53.65	50.8	52.225	8.65	8.69	8.67	20.2	19.2	19.7	15.95	16.3	16.125
T1V3	44.52	43.8	44.16	9.54	10.21	9.875	22.22	21.4	21.81	15.9	17.2	16.55
T2V1	44.05	43.0	43.525	10.36	9.65	10.005	15.42	16.4	15.91	17.52	18.4	17.96
T2V2	42.52	42.6	42.56	10.23	11.23	10.73	16.87	17.4	17.135	16.3	16.6	16.45
T2V3	37.17	38.5	37.835	7.69	8.54	8.115	20	20.1	20.05	14.21	16.34	15.275
T3V1	35.25	36.0	35.625	8.54	7.36	7.95	18.92	20.7	19.81	15.5	15.4	15.45
T3V2	46.3	45.4	45.85	9.63	10.25	9.94	18.45	20.7	19.575	14.27	15.1	14.685
T3V3	45.27	45.3	45.285	11.21	10.45	10.83	20.57	1.4	10.985	16.52	15.21	15.865
T4V1	55.23	56.78	56.005	13.21	12.69	12.95	25.36	24.15	24.75	20.12	21.33	20.725
T4V2	54.36	53.96	54.16	12.56	12.36	12.46	23.31	24.21	23.76	19.36	20.45	19.905
T4V3	45.65	49.0	47.325	10.36	9.21	9.785	22	21.6	21.8	16.75	18.1	17.425
T5V1	49.07	48.3	48.685	8.52	7.63	8.075	19.8	21.3	20.55	12.31	13.45	12.88
T5V2	44.45	35.2	39.825	7.65	8.12	7.885	21.25	20.1	20.675	16.3	16.4	16.35
T5V3	41.5	42.7	42.1	9.21	10.36	9.785	16.97	16.5	16.735	14.55	16.4	15.475
SE(m)	1.251	1.070	1.128	0.538	0.636	0.563	0.566	0.525	0.542	0.556	0.548	0.521
CD (5%)	3.584	3.065	3.345	1.540	1.823	1.634	1.622	1.505	1.534	1.593	1.569	1.563
CV %	5.682	4.927	5.178	6.175	7.282	7.165	5.851	5.434	5.634	6.634	6.388	6.513

T1-POP + *Trichoderma* (Talc formulations) + GRB 35 (Talc formulations), **T2-** POP + *Trichoderma* capsules + GRB 35 capsule, **T3-** POP + *Trichoderma* capsules, **T4-** POP + GRB 35 capsule, **T5-** POP (Package of Parctice)

Table 2: Effect of plant growth promoting rhizobacteria bio capsules on growth and yield characteristics of ginger

	Leaf width (cm)			**Leaf petiole length (cm)**			**Fresh rhizome yield kg/plot**			**Fresh rhizome yield (t/ha)**		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
T1V1	1.72	1.55	1.63	1.7	1.6	1.65	4.8	4.6	4.7	16.0	15.33	15.66
T1V2	1.35	1.45	1.4	1.65	1.7	1.675	3.8	3.91	3.855	12.66	13.03	12.85
T1V3	1.65	1.65	1.65	1.77	1.7	1.735	5.6	5.56	5.58	18.66	18.53	18.6
T2V1	1.5	1.65	1.57	1.55	1.7	1.625	5.7	5.67	5.685	19.0	18.9	18.95
T2V2	1.6	1.55	1.57	1.8	1.9	1.85	5.5	5.34	5.42	18.33	17.8	18.06
T2V3	1.5	1.6	1.55	1.6	1.8	1.7	5.2	5.12	5.16	17.33	17.06	17.2
T3V1	1.65	1.55	1.6	1.8	1.8	1.8	5.4	5.32	5.36	18.0	17.73	17.86
T3V2	1.52	1.35	1.43	1.5	1.7	1.6	4.5	4.63	4.565	15.0	15.43	15.21
T3V3	1.65	1.65	1.65	1.77	1.6	1.685	4.9	4.75	4.825	16.33	15.83	16.08
T4V1	1.82	1.77	1.79	1.77	1.8	1.785	6.2	6.32	6.28	20.66	22.41	21.53
T4V2	1.4	1.35	1.37	2.1	2.1	2.1	5.9	6.42	6.16	19.66	20.65	20.15
T4V3	1.57	1.58	1.57	1.82	1.8	1.81	5.3	5.12	5.21	17.66	17.06	17.36
T5V1	1.67	1.62	1.64	1.75	1.8	1.775	4.6	4.53	4.565	15.33	15.1	15.21
T5V2	1.65	1.7	1.67	1.67	1.7	1.685	5.1	5.01	5.055	17.0	16.7	16.85
T5V3	1.65	1.65	1.65	1.5	1.6	1.55	4.9	4.87	4.885	16.33	16.23	16.28
SE(m)	0.122	0.126	0.116	0.132	0.090	0.108	0.437	0.340	0.397	1.16	0.906	0.964
CD (5%)	N.S.	N.S.	N.S	N.S.	N.S.	N.S	1.251	0.974	1.145	3.33	2.596	3.174
CV %	15.29	15.991	15.234	15.36	10.094	12.654	13.12	10.016	11.964	13.1	10.016	11.234

T1-POP + *Trichoderma* (Talc formulations) + GRB 35 (Talc formulations), **T2**- POP + *Trichoderma* capsules + GRB 35 capsule, **T3**- POP + *Trichoderma* capsules, **T4**- POP + GRB 35 capsule, **T5**- POP (Package of Parctice)

References

Aidin N, Sahiri, I. Madauna. The Effect of Rhizome Types and the Composition of Planting Media on The Growth of Red Ginger (Zingiber officinale Rosc.) (Pengaruh Jenis Rimpang dan Komposisi Media Tanam Terhadap Pertumbuhan Bibit Jahe Merah). J. Agrotekbis. 2016; 4(4): 394–402.

Burd GI, Dixon DG and BR Glick. Plant growth promoting rhizobacteria that decrease heavy metal toxicity in plants. Can.J.Microbiol. 2000; 33:237-245.

De Andrade LA, Santos CHB, Frezarin ET, Sales LR, Rigobelo EC. Plant growth-promoting rhizobacteria for sustainable agricultural production. Microorganisms 2023, 11, 1088.

Gohain N, Atibudhi HN, Kumar A. A study on economics of ginger cultivation in Assam–a case study of Tinsukia district. Plant Archives. 2020;20(2):2522 2526.

Glick B R.. The enhancement of plant growth by free living bacteria. Canadian Journal of Microbiology, 1995. 41: 109–14.

Goswami, D, Thakker JN, Dhandhukia PC. Portraying mechanics of plant growth promoting rhizobacteria (PGPR): *A review. Cogent Food Agric.*, 2016; 2:1-19.

Gravel V, Antoun H and Tweddell RJ. Growth stimulation and fruit yield improvement of greenhouse tomato plants by inoculation with Pseudomonas putida or Trichoderma atroviride: Possible role of indole acetic acid (IAA). *Soil. Biol. Biochem.* 2007; 39:1968–1977.

Gray EJ and Smith DL. Intracellular and extracellular PGPR commonalities and distinctions in the plant-bacterium signalling processes. *Soil Biol. Biochem.,* 2005; 37: 395–412.

Lucy M, Reed E, Glick BR. Applications of free living plant growth promoting rhizobacteria. Antonie Van Leeuwenhoek., 2004; 86 (1): 1–25.

Grover M, Pandey AK, Mishra BK, Lata and Roy RC. Sugarcane Crops: Plant Growth Promoting Bacteria in Growth, Yield and Productivity. (In) Sugar Beet Crops: Growth, fertilization and Yield, pp 135–51. Hertsburg Claus T (Eds). 2009. Nova Science Publishers Inc., New York.

He Y, Pantigoso HA, Wu Z, Vivanco JM. Co-inoculation of Bacillus sp. and Pseudomonas putida at different development stages acts as a biostimulant to promote growth, yield and nutrient uptake of tomato. *J. Appl. Microbiol.* 2019, 127, 196–207. [CrossRef] [PubMed]

Jeyanthi V and Kanimozhi S. Plant Growth Promoting Rhizobacteria (PGPR) - Prospective and Mechanisms: A Review-Journal of Pure and Applied Microbiology, June 2018. Vol. 12(2), p. 733-749

Kloepper JW and Schroth MN. Relationship of in vitro antibiosis of plant growth promoting rhizobacteria to plant growth and the displacement of root microflora. Phytopathology. 1981; 71:1020–1024.

Kuan KB, Othman R, Rahim KA, Shamsuddin ZH. Plant growth-promoting rhizobacteria inoculation to enhance vegetative growth, nitrogen fixation and nitrogen remobilisation of maize under greenhouse conditions. PLoS ONE 2016, 11, e0152478.

Kumar A, Maurya BR, Raghuwanshi R, Meena VS, Islam MT. Co-inoculation with Enterobacter and Rhizobacteria on Yield and Nutrient Uptake by Wheat (Triticum aestivum L.) in the Alluvial Soil Under Indo-Gangetic Plain of India. J. Plant Growth Regul. 2017, 36, 608–617.

Nair KP, Nair KP. The agronomy and economy of ginger. In: Turmeric (Curcuma longa L.) and Ginger (Zingiber officinale Rosc.)-World's Invaluable Medicinal Spices: The Agronomy and Economy of Turmeric and Ginger. 2019. pp. 245-315.

Prasad S, Tyagi AK. Ginger and its constituents: Role in prevention and treatment of gastrointestinal cancer. Gastroenterology Research and Practice; 2015. Available:https://doi.org/10.1155/2015/142 979

Prokryl Z, Vancura V, Wurst M. Auxin formation by rhizosphere bacteria as a factor of root growth. Biol. Plant. 1985; 27:159- 163

Salvo LPD, Cellucci GC, Carlino ME, de Salam IEG. Plant growth-promoting rhizobacteria inoculation and nitrogen fertilization increase maize (Zea mays L.) grain yield and modified rhizosphere microbial communities. Appl Soil Ecol (2018) 126: 113–120.

Soeparjono S. Pengaruh Komposisi Media Organik Terhadap Pertumbuhan, Hasil dan Kualitas Rimpang Tiga Varietas Jahe (Zingiber officinale Rosc.). Prosiding Seminar Ilmiah Perhorti. 2013;2013:613 618.

VanPeer R, Schippers B. Plant growth responses to bacterization with selected Pseudomonas spp. strains and rhizosphere microbial development in hydroponic cultures. Can. J. Microbiol. 1989, 35, 456–463.

****