

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

Abstract

The study aimed to assess the impact of plant growth promoting rhizobacteria capsules on the growth and yield of ginger across three consecutive years (2018-2021) 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 known for their role associated with plant growth processes such as nitrogen fixation, phosphate solubilization, and hormone secretion, were tested in combination with three ginger varieties: 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 combination treatments 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 treatment T₄V₁ (POP + GRB 35 capsule with Mahima variety), The maximum mean produced the highest fresh rhizome yield per plot with (6.28 kg/plot and) and maximum mean fresh rhizome yield per hectare (21.53 t/ha), have been observed with T₄V₂ (POP + GRB 35 capsule with Maran variety) which recorded fresh rhizome yield per plot at (6.16 kg/plot) and mean fresh rhizome yield per hectare (20.15 t/ha). These results suggest that GRB 35 capsules significantly enhance ginger yield, offering a sustainable approach to ginger cultivation.

Key words: Plant growth promoting rhizobacteria; bio capsules; ginger; yield enhancement; *Trichoderma*, GRB 35, PGPR, Fresh rhizome yield, Talc formulation

Introduction

Ginger (*Zingiber officinale* Rosc.) belongs to the family Zingiberaceae family, is a perennial herbaceous monocotyledon plant that is commercially cultivated commercially as an annual crop for its rhizomes. It is traditionally grown as an annual crop 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 where, it thrives best under humid conditions, tropical climates. Ginger has been grown for over a long history that goes back more than 5000 years, with its origin in It is a South East Asia, native, Although it is now cultivated in various regions, 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. Major

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ginger producing countries include Nigeria, is the greatest amount of ginger growing country (which accounts for 56.23% of the world's production total area), followed by Bangladesh, India, China, and Indonesia, which have contribute approximately 23.6, 4.7, and 3.4 per cent of the total area of ginger cultivation, respectively. In India, ginger is widely used in for various kinds of purposes in India, including pickles, food additives, confections, and traditional remedies for stomach aches. Its medicinal properties, such as is a powerful antioxidant effects and the ability to alleviate has been used to treat all kinds of nausea from various causes, including those brought on by motion sickness, pregnancy, surgery, and nausea following chemotherapy make it a valuable ingredient in both. Traditional and modern medicine both employ ginger as a common raw ingredient. This is due to the volatile oleoresin and volatile oil found in ginger.

The importance of sustainable agriculture has become increasingly important grown in recent yearstimes due to its focus on long-term environmental and social benefits. Recognizing the importance of sustainable farming practices are crucial for reducing reliance on 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 maintaining soil quality (De Andrade *et al*, 2023). Preserving soil diversity and employing eco-friendly practices To secure are critical for ensuring long-term environmental health worldwide and food security produce adequate food for future generations, sustainable agriculture must preserve the soil's inherent diversity (Kumar, 2017). Plant growth promoting rhizobacteria (PGPR) represent a key component. Thus, eco friendly alternatives, including the sustainable of sustainable agriculture. These use of beneficial microorganisms enhance plant growth through various mechanisms including, 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 fixation, phosphorous solubilization, breaking down phosphate, getting rid of heavy metals, making and production of phytohormones such as (like auxins, gibberellins, and cytokinins, 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 also improves soil health by competing with harmful microbes, thereby reducing pathogen invasion and enhancing plant resistance by activating defensive systems and enhancing tolerance to a wide range of to environmental factors like, including droughtyness, salinity, and extreme temperaturesheat. Soil has many different kinds of bacteria and viruses.

The rhizosphere of a plant is home to helpful microorganisms called numerous plant growth promoting rhizobacteria (PGPR), thatwhich play a crucial role in promoting plant

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growth and development. They contribute to increased The significance of PGPR for long-term agricultural viability is outlined in this review. Increased plant tolerance to biotic and abiotic stress, reduced need for use of chemical inputs fertilizers and pesticides, and enhanced nutrient availability, soil fertility, and nutrient uptake. Additionally PGPR can aid in soil bioremediation and enhance crop yield, making them a valuable tool for promoting sustainable agricultural practices 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. This study aims to explore the role of PGPR biocapsules in enhancing ginger growth and yield, highlighting their potential benefits and contributions to 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 conditions status included a slightly was less alkaline pH of (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:

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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 (phosphoric 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

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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

~~The a~~Application of GRB 35 capsules, ~~along combined~~ with ~~recommended package of practices, - is proved to significantly~~ improves ~~ginger~~ growth and ~~fresh rhizome yield in ginger~~. ~~In case of~~~~Among the ginger~~ varieties ~~tested, 'Mahima' found to give higher~~~~exhibited the highest~~ growth and ~~fresh rhizome~~ yield, followed by 'Maran'. ~~In order to increase yields and improve crop performance overall, it is suggested to use and~~~~Hence incorporate the use of~~ GRB -35 capsules ~~into ginger cultivation practices, 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.

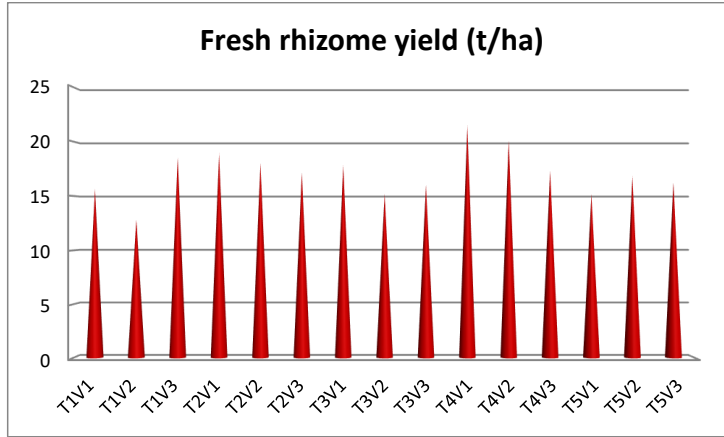


Fig 1: Effect of plant growth promoting rhizobacteria bio capsules on growth and yield characteristics of ginger

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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

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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 [PareteePractice](#))

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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)

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