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Assessment of PGPR effects of wheat rhizosphere actinomycetes on tomato seedlings

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Abstract

Plant growth-promoting microbes (PGPMs) play a crucial role in sustainable agriculture. This study aims to isolate and characterize rhizospheric actinomycetes for their potential in promoting tomato plant growth. Five isolates were obtained and screened for their morphological and biochemical characteristics, exhibiting significant variations. These isolates were identified using polyphasic taxonomy and assessed for various plant growth-promoting activities. Phosphate solubilization and siderophore production were observed in the ranges of 11-24 mm and 9-10 mm in diameter, respectively. All isolates produced ammonia, though none showed HCN production. These promising actinomycetes were tested for their plant growth-promoting (PGPR) activity on tomato seedlings *in vivo*. The MKT5 isolate exhibited the highest plant growth-promoting traits, surpassing all other isolates in enhancing various plant parameters compared to the uninoculated control. Given its remarkable performance in pot trials with tomato seedlings, MKT5 can be considered a potential biofertilizer for various crops. Tomato seeds treated with the MKT5 isolate demonstrated a significant increase in plant growth compared to the control and can be explored for plant growth promoting attributes. These most promising actinomycetes were examined for their plant growth promoting (PGPR) activity on tomato seedlings *in vivo*.

Keywords: PGPR activity, actinomycetes, rhizospheric soil, pot trials, tomato seedlings

1. Introduction

Wheat (*Triticum aestivum*) is the dominant crop in India and grown all over the world. Wheat belongs to family Gramineae and it is the most important staple food of about two billion people (36% of the world population). Wheat's domestication produced larger grains and a more productive crop, which could not have survived in the wild and required continued intervention of farmers intentionally planting it. It is used for human food and livestock. Wheat (*Triticum species*) is a crop of global significance and grown in diversified environments. Approximately one-sixth of the total arable land in the world is cultivated with wheat. The rhizosphere is the narrow zone of soil specifically influenced by the root system (Dobbelaere *et al.* 2003) ^[13]. This zone is rich in nutrients when compared with the bulk soil due to the accumulation of a variety of plant exudates, such as amino acids and sugars, providing a rich source of energy and nutrients for bacteria (Gray and Smith, 2005) ^[22]. In the context of increasing international concern for food and environment quality, the use of PGPR for reducing chemical inputs in agriculture is a potentially important issue. PGPR have been applied to various crops to enhance growth, seed emergence and crop yield, and (Dey *et al.*, 2004; Minorsky, 2008) ^[11, 28]. Plant growth promoting rhizobacteria (PGPR) is a group of bacteria that can be found in the rhizosphere (Ahmed *et al.* 2008) ^[2], that colonize the roots of plants that enhance the plant growth.

Actinomycetes are filamentous, Gram-positive, a diverse group of heterotrophic prokaryotes forming hyphae at some stage of their growth, hence referred to as filamentous prokaryotes. They are widely distributed in soils, especially in dry soils, slightly acidic soils and rich in organic matter represent a high proportion of biomass (Saadoun *et al.* 2015) ^[38]. Among all the actinomycetes, *Streptomyces* is the predominant genus followed by *Actinomadura*, *Microbiospora*, *Micromonospora*, *Nocardia*, *Nonomurea*, *Mycobacterium*, *Frankia*, *Actinoplanes*, *Saccharopolyspora* and *Verrucosipora* (Martinez-Hidalgo *et al.* 2014;

Vijayabharathi *et al.* 2016) [27, 44]. Actinobacteria also employ both direct and in-direct mechanisms to influence the plant growth and protection. The direct mechanisms involve the production of vital factors for crop growth such as growth hormones and the assistive actions on nitrogen fixation, phosphate solubilization, and iron acquisition. Plant growth promoting actinobacteria indirectly influence the plant growth by controlling and minimizing the deleterious effects of external stresses of either biotic or abiotic sources through the following modes: competition for nutrients, production of low molecular inhibitory substances such as ammonia, cyanogens, alcohols, aldehydes, sulfides, and ketones, cell-wall degrading enzymes, and secondary metabolites with biocidal properties, in which the latter, two are the key phenomenon deployed by the actinobacterial community (El- Tarabily and Sivasithamparam, 2006; Glick, 2012; Bouizgarne, 2013; Dey *et al.* 2014) [14, 17, 7, 12]. Actinomycetes are used to develop commercial biocontrol and plant growth-promoting products. It is crucial to recognize the specific challenges they present. To begin with, the interaction between PGPR species and their plant symbionts appears to be specific, even within a crop or cultivar (Chanway *et al.* 1988; Glick, 1995; Lazarovits and Nowak, 1997) [8, 16, 26]. Therefore, the aim of my research was to explore the diversity of actinomycetes associated with wheat rhizosphere and their impact on tomato seedlings. This investigation holds significant implications for analyzing plant growth promoting abilities of actinomycetes and their role in enhancing plant growth.

2. Materials and Methods

2.1 Isolation of actinomycetes from the rhizospheric soil of wheat plant

2.1.1 Collection of rhizospheric soil sample

The rhizospheric soil samples were collected from Sri Muktsar Sahib, Punjab, total Five soil samples were collected from five different plant rhizosphere of wheat and mixed, to make it one composite sample. Similarly, four composite samples were taken from two different sites in Sri Muktsar Sahib district, Punjab. The rhizospheric soil sample along with roots pieces was collected around 10 cm apart and upto 1 - 2 feet in depth. Composite soil samples were collected and brought to the laboratory in sterile polythene bags and stored at 4°C for further studies. Before isolation, all the twelve composite samples were dried for 4-5 days at 28°C. Isolation was carried out by using serial dilution method using KenKnight agar and Starch Casein agar plate (Williams and Davies, 1965) [45]. Ten grams of each pretreated soil sample were mixed and shaken in 90 ml sterile distilled water for isolation. Pour plate technique was used for the isolation of actinomycetes, plates were incubated at $28 \pm 2^\circ\text{C}$ for 7-10 days. The total actinomycetes count was expressed as colony forming unit per gram (cfu/g soil) of each soil sample. The colonies were streaked for purification and further observations of colony morphological characterization.

2.1.2 Identification of actinomycetes isolates by morphological and biochemical characterization

All indigenous isolates were characterized by polyphasic taxonomy as per Bergy's manual. Isolates were examined for colony morphology (*viz.*, form, elevation, margin etc) colony pigmentation, gram staining and various biochemical reactions as per standard procedures *viz.*, Catalase, oxidase, indole production, MRVP, citrate utilization, starch hydrolysis, lysine decarboxylase, nitrate reduction, hydrogen sulphide production and gelatin liquification tests.

2.2 In vitro screening of actinomycetes isolates for multifarious plant growth promoting (PGP) activities

2.3.1 Phosphate solubilization (Pikovskaya, 1948)

Cultivate the actinomycetes culture in nutrient broth and incubated at 28°C for 72 h. 100µl of cell free culture supernatant was added to Pikovskaya's agar wells and plates were incubated at 28°C for 24-48 h. Observe yellow zones produced around bit after incubation.

2.3.2 Siderophores Production (Schwyn and Neilands, 1987)

Siderophores production has been done by two ways quantitative and qualitative. Siderophores production was detected qualitatively by chrome azurol-S (CAS) plate assay method. Sterilized blue agar was prepared by mixing chrome azurol-S (CAS) (60.5 mg / 50 ml distilled water) with 10 ml iron solution (1 mM $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ in 10 mM HCl). This solution was slowly added to Hexadecyl-trimethyl ammonium bromide (HDTMA) (72.9 mg / 40 ml distilled water). Nutrient agar was prepared and autoclaved separately. It was mixed with chrome azurol - S (CAS) (100 ml) (above) and plates were poured. The cell-free supernatant was added to CAS plate wells, which were pre-cut using a sterilized cork borer. The plates were then observed for yellow/orange zones around the wells, measured in mm of diameter. Quantitative estimation of siderophores, chrome azurol-S (CAS) liquid assay method was used as demonstrated by Schwyn and Neilands, 1987, 0.5 ml of 72 h old cell free supernatant of each isolate was mixed with 0.5 ml CAS assay solution in each separate tube.

CAS assay solution Mix 1.5 ml of 1mM $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ in 10 mM HCl with 7.5 ml of 2mM CAS stock solution (0.121g chrome azurol-S in 100 ml water) and 50 ml of Hexadecyltrimethyl Ammonium Bromide (HDTMA) solution (0.0219 g in 50 ml water). Add 30 ml of piperazine solution (4.307 g in 30 ml water, pH 5.6) and adjust the final volume to 100 ml with distilled water. Add 10 µl of 0.2M 5-sulfosalicylic acid (shuttle solution). The tubes were incubated at room temperature for 10 minutes. Color intensity was measured at 630 nm, with siderophore production indicated by a reduction in blue color, expressed as percent siderophore units (% SU).

2.3.3 Ammonia production

Detection of ammonia production was carried out as described by Lata and Saxena, (2003), 48 h old culture were inoculated in 5 ml of peptone water in each test tube and incubated for 72h at 28°C. After incubation 0.5 ml of Nessler's reagent was added in test tubes. Presence of very light brown color (+) indicates small amount of ammonia production and light brown (++) to orange brown color (+++++) indicates large amount of ammonia production.

2.3.4 HCN Production

This has been done by following Bakker and Schippers, 1987 method, streak actinomycetes cultures in King's B medium plates amended with glycine (4g/L). Place Whatman Filter paper No.1 already soaked in 2% sodium carbonate and then in 0.5% picric acid inside the top of the plate. Seal plates with parafilm and incubate at 28 °C for 4 days and after incubation observe the change in colour of filter paper

2.3.5 Protease Test

Prepare Skim milk agar plate by adding separately sterilized 1% skim milk to nutrient agar. Add 100µl of 72 h old culture supernatant to the 7mm well already cut on the skim milk agar

plates. Incubate the plates at 28°C and observe for production of clear zone around the well (Kaur *et al.* 1989) ^[24].

2.3.6. Chitinase Test

Prepare chitin-nutrient agar plates contain 1% colloidal chitin, place 72 h old culture supernatant in the well already cut on the plate with the help of cork borer and incubate the plates at 28°C for 2-7 days. After incubation flood the iodine on chitin-nutrient agar plates and observe the plates for production of clear zone around the well (Robert and Selitrennikoff, 1988) ^[36].

2.3.7. Auxins production

Auxins production was carried out by inoculate the test organism in nutrient broth and incubate for 72 hours. Prepare supernatant by centrifugation of cultures at 10,000 rpm for 20 min. Now 3 ml of supernatant was pipette into test tube, add 2-3 drops of orthophosphoric acid to 3 ml supernatant followed by 2 ml of salper reagent (1ml of 0.5M FeCl₃ in 50 ml of 35% HClO₄). Development of pink colour confirmed the production of IAA (Gorden and paleg, 1957) ^[19].

2.4. Estimation of PGPR activity screened actinomycetes by pot trial

Pot trials were conducted to assess the impact of PGPR activity from rhizospheric actinomycetes on tomato seedlings. Tomato seeds were inoculated with actinomycete isolates (MKT1, MKT2, MKT3, MKT4, and MKT5). The experiment comprised two sets of treatments: (i) seeds inoculated with actinomycetes (treated), and (ii) seeds without inoculation (control). Seeds were sown in protrays for germination, and seed germination was recorded on the 15th day after sowing. Subsequently, seedlings were transplanted into pots. The experiment followed a completely randomized block design with each treatment replicated four times. Sixty days after sowing, plants from each replication were harvested to evaluate the effects of actinomycetes on leaf number, root and shoot length, root and shoot fresh weight, and root and shoot dry weight (Plate 8).

2.4.1. Effect of liquid formulations on tomato seedlings

Tomato seeds were procurement from local market of Chunni Kalan (Fatehgarh Sahib). Inoculum preparation was done by 48h old culture of different actinomycetes isolates was prepared in SCA broth. The population density that resulted in the formation of 10⁸cfu/ml of actinomycetes isolates was used for preparation of liquid formulation. Subsequently seed sterilization were done by surface sterilization or treated with 70% ethanol for four minutes followed by 2% of HCl for one minute. After that washed several times with sterilized distilled water and blot dry the seeds with blotting paper.

• Seed Bacterization

Sterilized tomato seeds were soaked in liquid cultures of different bacterial formulations in flasks and after 2hrs the seeds were sown in pots. Soil was collected from natural habitat and made suitable for growing media preparation after removal of stones and other plant debris. The soil was then mixed with sand and cocopeat thoroughly in ratio (1:1:1).

• Experimental details

The following treatments were applied in pot assay in four replications of each treatment as T₁: Uninoculated control(C),

T₂: Inoculation with MKT₁, T₃: Inoculation with MKT₂, T₄: Inoculation with MKT₃, T₅: Inoculation with MKT₄, T₆: Inoculation with MKT₅.

All the treatments and replications were observed and evaluated using a Completely Randomized Design (CRD).

• Sowing of seeds

Seedling production of tomato was completed with cocopeat using protrays, seedling of tomato was raised and transplanted in a pots. Cocopeat was used as a growing media, as it reduces incidence of seedling disease and contains appropriate amount of moisture in it. The seedling tray (protray) was filled with the growing medium (cocopeat). A small depression (0.5cm) was made with finger tip in the centre of the cell of protray for sowing. One seed per cell was sown and covered with medium. Cocopeat with 300 to 400 percent moisture were used and have no immediate irrigation was required until germination.

• Transplanting

The plants were transplanted in pots containing well prepared growing media. After planting the medium around the stem of the plant was pressed gently with the help of hand. Thorough watering was done immediately after planting. The intercultural operations were carried out including irrigation, hoeing and weeding, spraying against insect pest and disease.

3.5 Analysis of Plant Parameter

The plant parameters that have been analyzed and calculated were number of leaves, shoot length and root length after sixty days in centimeters. Shoot or root biomass was done by measuring the fresh weight of shoot or root biomass and excess of water was wiped out by placing it between the folds of filter paper. Then the roots were cut at collar with secateurs and dried in oven at 60°C. Then dry weight was taken and expressed in g/plant. Root: shoot ratio was calculated as

Root shoot ratio= Dried root weight/ Dried shoot weight

3. Results and discussion

3.1 Isolation and identification of actinomycetes

In this study, five isolates namely MKT₁, MKT₂, MKT₃, MKT₄ and MKT₅ were isolated from two sites of Shri Muktsar Sahib district. Similarly, Saadaoui *et al.* (2024) ^[37] isolated 14 endophytic actinomycete from wheat roots using Starch casein agar. Gopinath *et al.* (2018) ^[18] isolated and screened the effective antibiotic producing actinomycetes from rhizospheric soil of *Cipadessa baccifera* and *Clausena dentate*. Sharma *et al.* (2024) ^[41] isolated *Streptomyces bluensis* from the apple rhizosphere and evaluate their effect on plant growth parameters.

3.2 Identification of actinomycetes

Morphological characteristics of all five isolates from wheat rhizosphere were found to be circular to irregular, raised (elevation), entire (margin), whitish, greyish and dark greyish in colour on the SCA medium (Table 1 and Fig 1). Similar result was found by Dar and Ahmed, (2024) ^[10] observed that the actinomycetes colonies grow on Starch casein agar in the powdery form and show different shape and colour. Thapa *et al.* (2024) ^[43] found that the actinomycetes colonies grown in the form of vegetative or mycelium hyphae, which penetrate into the agar.

Table 1: Colony morphological characteristics of actinomycetes isolates from rhizospheric soil of wheat

Isolates	Colony shape	Margin	Elevation	Pigment
MKT ₁	Circular	Entire	Raised	Whitish
MKT ₂	Circular	Entire	Raised	Dark greyish
MKT ₃	Irregular	Entire	Raised	Greyish
MKT ₄	Circular	Entire	Raised	Greyish
MKT ₅	Circular	Entire	Raised	Dark greyish

Actinomycetes isolates were found to be Gram positive and exhibits great variations among biochemical tests. All the isolates showcase positive results for catalase, citrate utilization, starch hydrolysis, nitrate reduction tests and negative for indole production, lysine decarboxylase, hydrogen sulphide tests (Table 2 and Fig 2). Our findings was consistent with the finding by Sapkota *et al.* (2020) ^[39]; Mondal and Thomas, (2022) ^[29]; Somasundaram *et al.* (2024) ^[42] and Corral *et al.* (2022) ^[9].

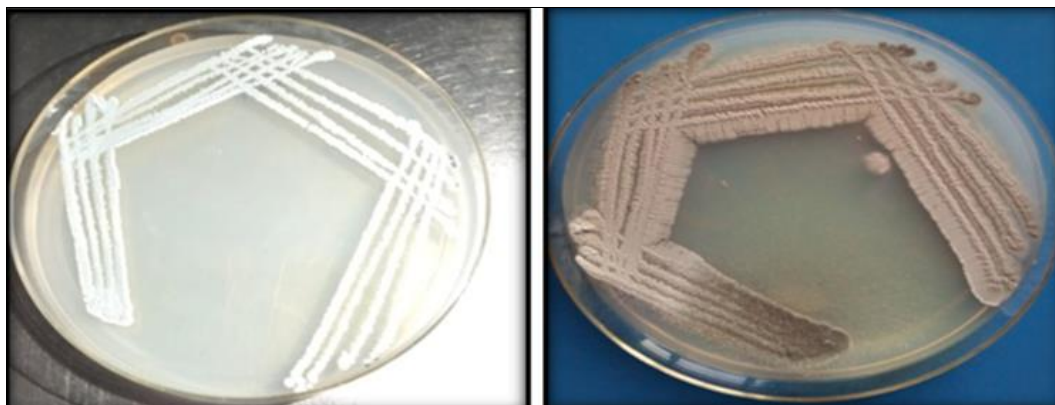
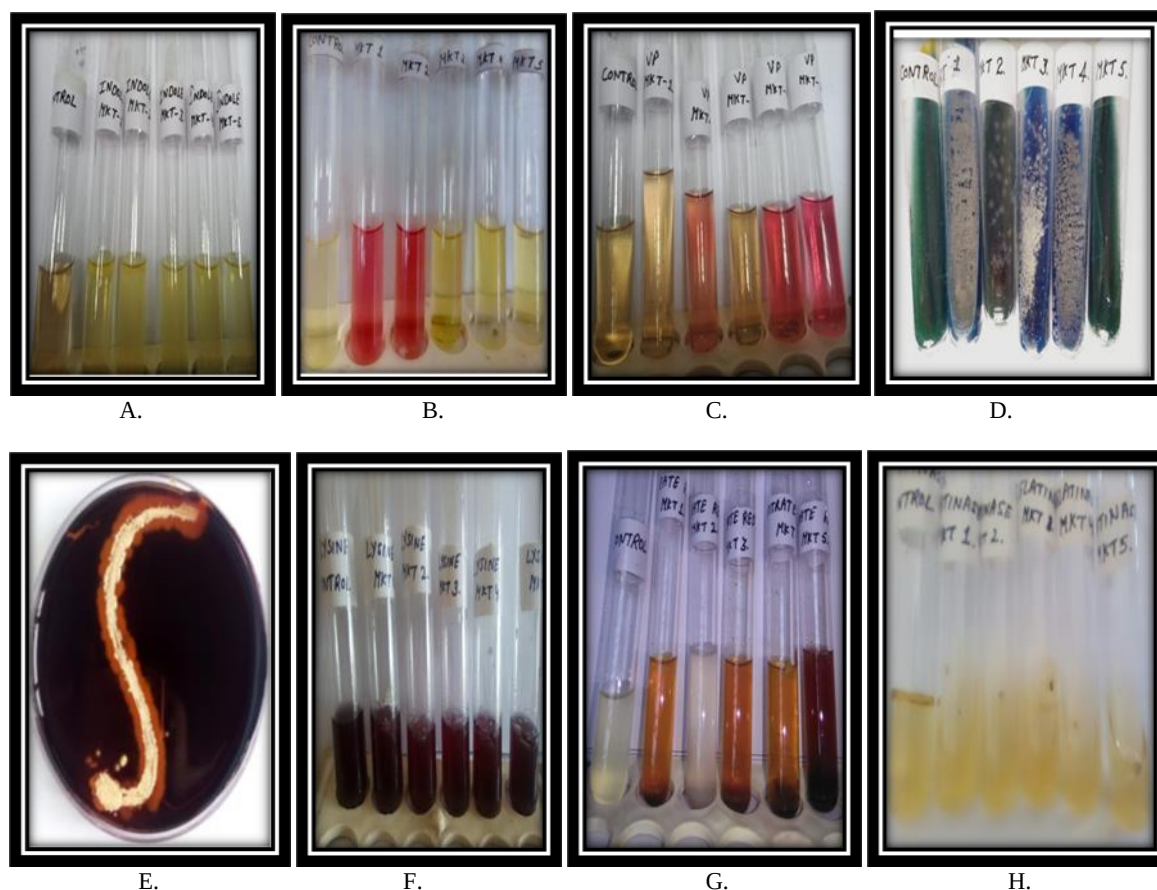
**Fig 1:** Actinomycetes culture**Fig 2:** Biochemical characterization of actinomycetes isolates (A) Indole test (B) Methyl red test (C) Voges- Proskauer test (D) Citrate utilization test (E) Starch hydrolysis (F) Lysine decarboxylase (G)Nitrate reduction test (H)Gelatin liquification test

Table 2: Biochemical characterization of actinomycetes isolates

Characteristics	MKT ₁	MKT ₂	MKT ₃	MKT ₄	MKT ₅
Gram staining	+	+	+	+	+
Catalase	+	+	+	+	+
Oxidase	+	+	-	+	+
Indole production test	-	-	-	-	-
Methyl Red test	+	+	-	-	-
Voges Proskauer test	-	+	-	+	+
Citrate utilization test	+	+	+	+	-
Starch hydrolysis	+	+	+	+	+
Lysine Decarboxylase test	-	-	-	-	-
Urease production test	+	+	-	+	+
Hydrogen sulphide test	-	-	-	-	-
Nitrate reduction test	+	+	+	+	+
Gelatin liquification test	+	+	-	+	+

All the isolates were found to be Gram positive. (-) Negativity of test (+) positivity of test

3.3 Characterization of actinomycetes isolates for plant growth promoting traits

All the five actinomycetes isolates were screened out for plant growth promoting activities i.e. all the isolates exhibited variation of different plant growth promoting traits.

Among all the five isolates, the maximum phosphate solubilization was shown by MKT₅ (24 mm) and minimum activity was shown by MKT₂ (11 mm) produced yellow zone of solubilization, around the well after two days of incubation on Pikovaskaya's medium. MKT₁ did not show phosphate solubilization (Table 3 and Fig 3). The majority of the phosphorus present in soil in insoluble form which is difficult to intake by plants (Pradhan and Shukla, 2005) [33]. The ability of bacteria to solubilize mineral phosphate has been of interest of agricultural microbiologists as it can increase the availability of phosphorous and iron for plant growth (Panwar *et al.* 2018) [31]. Endophytic actinomycetes isolated from the roots of eight distinct medicinal plants showed great variation in phosphate solubilization activity on Pikovasaya agar (Hassan *et al.* 2023) [23]. Out of five isolates, only two isolates i.e. MKT₃ (10 mm) and MKT₂ (9 mm) were found to be positive for siderophore production in the plate assay. The results (Table 3) were obtained qualitatively in the form of yellowish/ orange coloured zone (mm diameter) produced around the well on chrome azurol-S (CAS) agar plate. In quantitative assay (liquid assay), maximum siderophore activity was shown by MKT₂ (33.8%), followed by MKT₃ (28.4%). Microorganisms release siderophores, high-affinity ferric iron-chelating compounds, when iron is absent, which transport Fe³⁺ into microbial cells Ghosh *et al.* (2020) [15]. Out of six actinomycetes isolates from rhizospheric soil of apple orchards five isolates exhibits siderophore production on chrome azurol-S agar plates in the range of 10-18mm (Sharma *et al.* 2024) [41]. Auxins production was showcase by three isolates MKT₂, MKT₄ and MKT₅. This

test is performed to check the ability of microorganism to produce IAA which is a chief phytohormone. IAA producing bacteria are known to promote root elongation and plant growth (Patten and Glick, 2002) [30]. Indole acetic acid is a main auxin in the plants is known to control many important physiological processes of plants such as cell enlargement, cell division, root initiation, growth rate, and apical dominance, results are show a great agreement with results were found by Anwar *et al.* (2016) [14]; Batool *et al.* (2017) [6].

HCN production was not exhibited by any isolate (Table 5 and Plate 6 A). Actinomycete isolates from groundnut rhizospheric did not exhibits HCN production (Rani *et al.* 2023) [35]. In the present study all the isolates were found to be positive for ammonia production as all tubes showed colour change in broth from yellow to brown. Ammonia is considered as one of the substances produced by microorganisms that promotes growth and has antimicrobial properties. It helps in disease supression of plants. Zhao *et al.* (2023) [46] found that all the actinomycetes exhibits ammonia production from different cultures such as manures, humus layer, field soil etc. Isolates were also analyzed for enzyme activity of lytic enzymes such as protease and chitinase test. Enzyme activity was expressed in terms of mm diameter of clear zone produced around the well at 28°C after 48 h. Maximum proteolytic activity was shown by MKT₃ (25mm) followed by MKT₅ (22mm) and minimum proteolytic activity were shown by remaining isolates i.e. MKT₁, MKT₂ and MKT₄ (20mm). Our findings are in the line with Rahma *et al.* (2023) [34]; Sharma *et al.* (2014) [41]; MKT₃ showed maximum chitinolytic activity (20mm) and MKT₁ and MKT₄ was represents minimum chitinolytic activity (15mm) whereas MKT₅ were found to be negative for chitinase test (Table 3 and Fig 3). Comparable results were reported by Alloun *et al.* (2024) [3], in which out of thirteen isolates of actinobacteria from wheat only three isolates has shown the positive result.

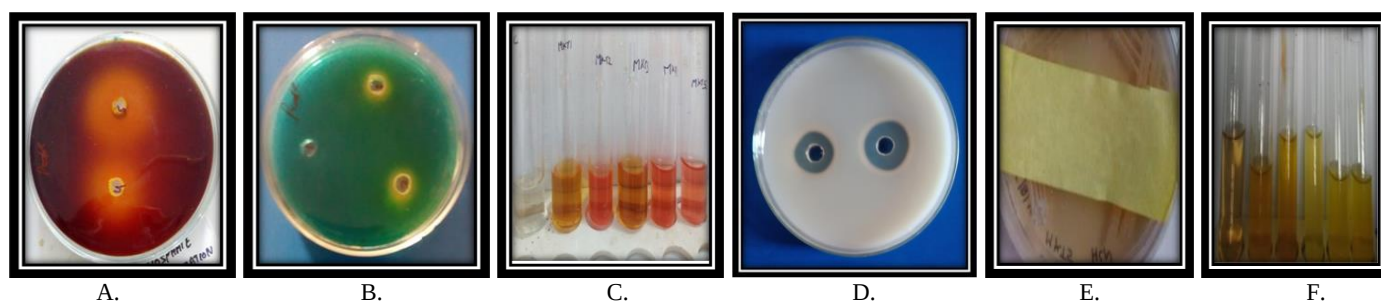


Fig 3: Plant growth promoting traits shown by actinomycetes isolates activities (A) Phosphate solubilization (B) Siderophore production (plate assay) (C) Auxins production (D) Protease (E) HCN (F) Ammonia production

Table 3: Plant growth promoting attributes of actinomycetes isolates from rhizospheric soil of wheat

Isolates	Phosphate solubilization plate (mm dia)	Siderophore		IAA	HCN (Paper strip colour change yellow to brown)	Ammonia (Culture broth)	Lytic enzyme (zone dia. in mm)	
		Qualitative	Quantitative				Protease	Chitinase
		Plate (mm dia)	% SU					
MKT ₁	-	-	-	-	-	++	20	15
MKT ₂	11	9	28.4	+	-	++	20	-
MKT ₃	21	10	33.8	-	-	+	25	20
MKT ₄	20	-	-	+	-	+	20	15
MKT ₅	24	-	-	+	-	+	22	-
(++) show the maximum production, (+) show the minimum production and (-) for the negativity of the test								

3.4 Impact of plant growth promoting rhizospheric actinomycetes on tomato seedlings using pot trials

Pot trials were conducted to assess the effect of PGPR activity of actinomycetes on tomato seedlings. Effect of actinomycetes liquid formulations on plant parameters of tomato were accessed under pot trial studies. The effects of PGPR activity of actinomycetes were examined by monitoring the root, shoot length and number of leaves presented, results shown in Table 4. The current study revealed that the maximum root length (8cm) was recorded with treatment (T₅) represented by MKT₅ isolate, followed by (7.75cm) was observed with treatment (T₄) (MKT₄) isolate. While, minimum root length (2cm) was recorded in T₆ (uninoculated control plants) (Fig. 4). At the same time as in case of shoot length, the maximum 60.50 cm shoot length was recorded with treatment T₅ (MKT₅) isolate followed by (59.25cm) (T₄) (MKT₄) isolate was observed. Minimum shoot length (51.25cm) was recorded in T₆ (uninoculated control)

results shown in Fig 5. Maximum number of leaves (82.25) was recorded by (T₅) (MKT₅) isolate followed by (T₄) (MKT₄) isolate i.e. (72.00) and minimum (64.00) was recorded in T₆ (uninoculated control) and results shown in Fig 6. Data appended in Table 5 illustrated that the maximum root and shoot ratio (0.103) observed with T₅ inoculated with MKT₅ isolate followed by (0.085) T₄ inoculated with MKT₄ isolate was observed and minimum (0.049) was recorded in T₆ that was uninoculated control Fig 7. Goudjal *et al.* (2016) ^[21] confirm the similar results with our pot trial that the actinomycetes show the positive effect on the growth of the tomato plant. Hamada *et al.* (2020) proved that the actinomycetes enhance the plant growth as biofertilizer. Statistical analysis using analysis of variance (ANOVA) was performed to determine the significance levels. The results indicated that all parameters were significantly influenced by seed inoculation with actinomycetes

Table 4: Effect of actinomycetes liquid formulation on plant parameters of tomato (*Solanum lycopersicum*) under pot assay (60 days)

Treatment	Root length (cm)	Shoot length (cm)	No. of leaves
T ₁ : MKT ₁	4.87	53.50	67.25
T ₂ : MKT ₂	5.42	53.75	69.25
T ₃ : MKT ₃	6.50	58.50	71.00
T ₄ : MKT ₄	7.75	59.25	72.00
T ₅ : MKT ₅	8.00	60.50	82.25
T ₆ : Control	2.00	51.25	64.00
CD _{0.05}	2.89	4.80	9.66

Table 5: Effect of actinomycetes liquid formulation on the root and shoot weight of tomato (*Solanum lycopersicum*) under pot assay (60 days)

Treatments	Root Weight		Shoot Weight		Root and Shoot Ratio
	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
T ₁ : MKT ₁	1.41	0.57	37.50	7.50	0.05
T ₂ : MKT ₂	1.50	0.58	40.00	7.75	0.05
T ₃ : MKT ₃	1.81	0.66	41.25	8.50	0.08
T ₄ : MKT ₄	1.90	0.66	45.00	9.50	0.08
T ₅ : MKT ₅	2.29	0.67	50.00	10.50	0.10
T ₆ : Control	0.62	0.43	31.25	6.50	0.04
CD _{0.05}	0.93	0.03	4.94	2.28	0.03

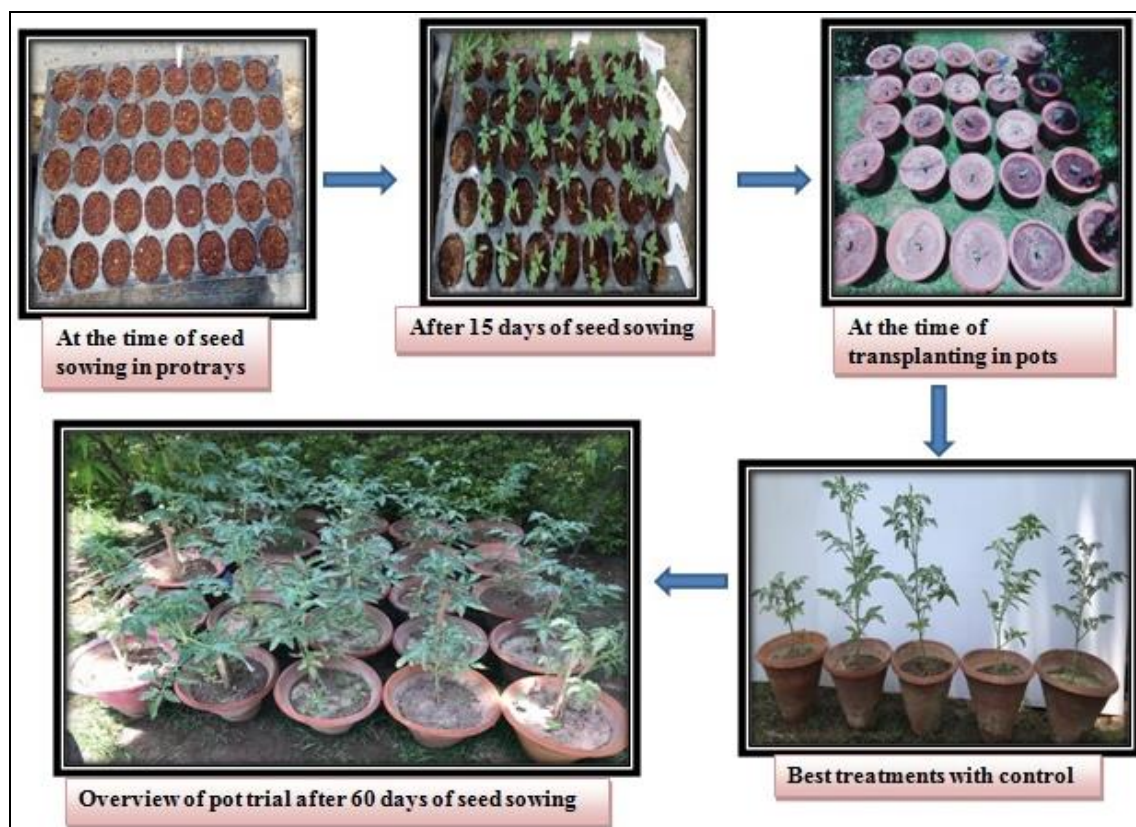


Fig 4: Overview of the pot trial

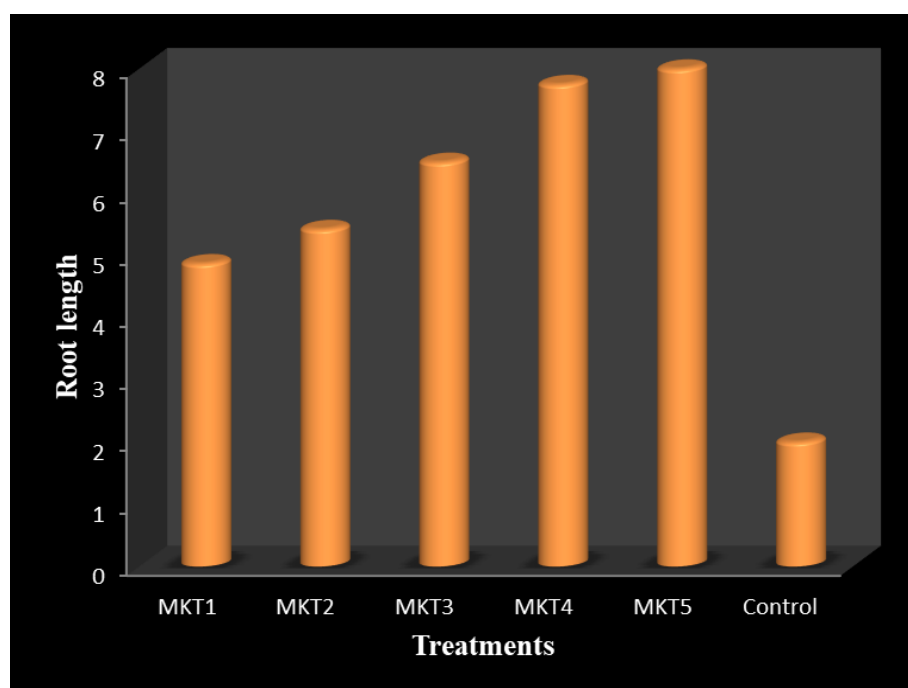


Fig 5: Effect of actinomycetes isolates on root length of tomato (*Solanum lycopersicum*) under pot assay (60 days)

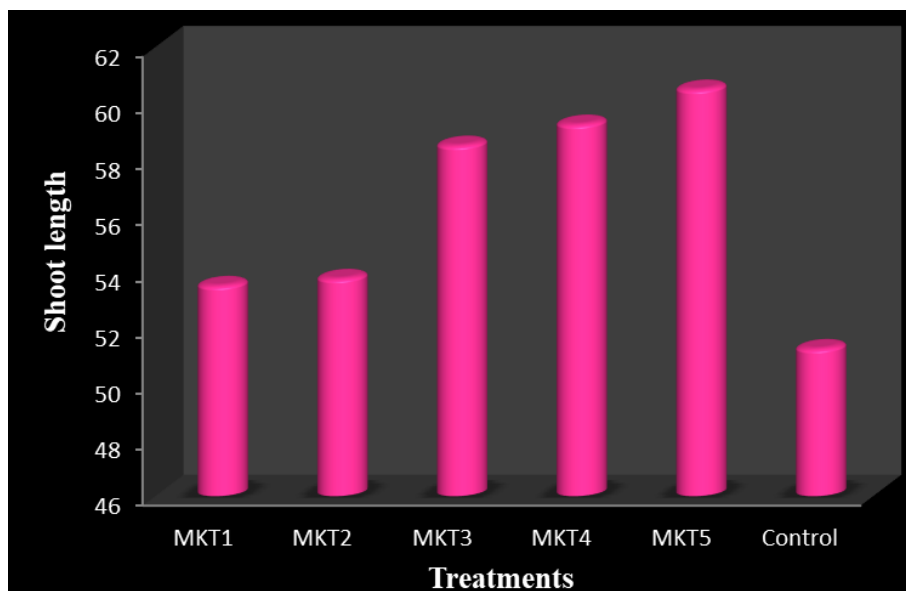


Fig 6: Effect of actinomycetes isolates on shoot length of tomato (*Solanum lycopersicum*) under pot assay (60 days)

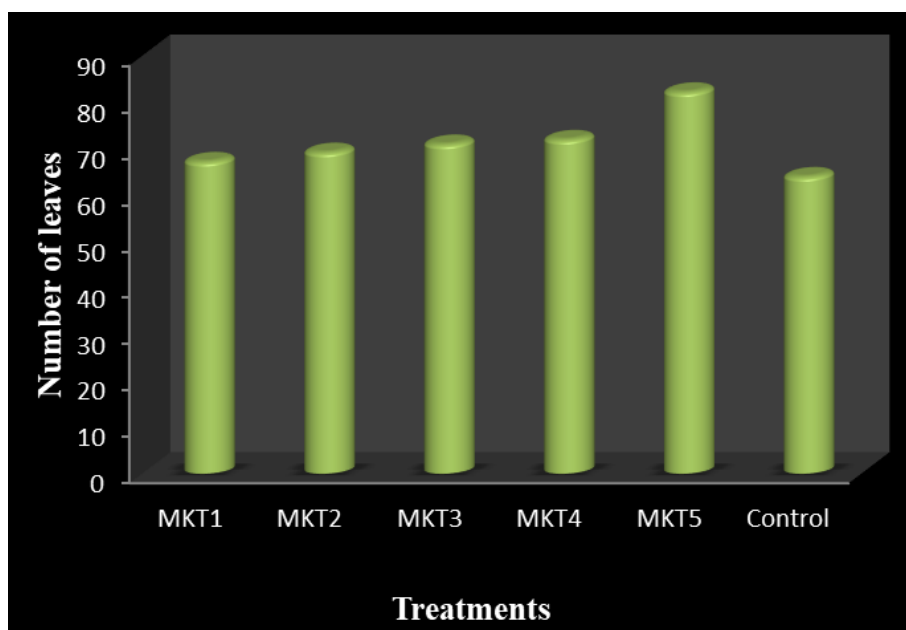


Fig 7: Effect of actinomycetes isolates on no. of leaves of tomato (*Solanum lycopersicum*) under pot assay (60 days)

4. Conclusion

The present study aimed to investigate the plant growth-promoting attributes of actinomycetes from the wheat rhizospheric habitat. Five actinomycete isolates were successfully obtained, each demonstrating excellent plant growth-promoting traits. These isolates were then applied in pot trials to assess their effectiveness. Among them, the isolate MKT5 showed remarkable potential, significantly enhancing root and shoot growth as well as producing a greater number of leaves. This indicates that MKT5 possesses significant plant growth-promoting capabilities compared to other actinomycetes. Therefore, it can be inferred that rhizospheric actinomycetes, such as MKT5, are a viable option for enhancing plant growth and can be utilized as biofertilizers and for other agricultural applications.

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6. Conflict of Interests

The authors have not declared any conflict of interests

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