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Mamatha K
Department of Agronomy, Department of Plant Pathology, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Pal KK
Department of Microbiology, ICAR-DGR, Junagadh, Gujarat, India

Sravanti K
Department of Genetics and Plant Breeding, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Reddy VR
Department of Genetics and Plant Breeding, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Reddy VD
Department of Genetics and Plant Breeding, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Sujatha M
Department of Genetics and Plant Breeding, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Damodar CH
Department of Genetics and Plant Breeding, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Corresponding Author:
Mamatha K
Department of Agronomy, Department of Plant Pathology, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

A study on the effect of endophytic bacteria on water saving and disease incidence in groundnut under limited irrigation conditions through frontline demonstrations

Mamatha K, Pal KK, Sravanti K, Reddy VR, Reddy VD, Sujatha M and Damodar CH

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Abstract
A study on the effect of endophytic bacteria on yield and disease incidence in groundnut under limited irrigation conditions through frontline demonstrations was carried out in the farmer's fields in the year *rabi* 2021-22. The study was conducted in the Uppununtala mandal of Nagarkurnool district focusing on the areas under canal command areas. The soil of the demonstrated area is light sandy soil and requires 8-10 irrigations through sprinkler irrigation. 10 demonstrations were conducted with two treatments T_1 (Farmers Practice) and T_2 (Demonstration / Seed Treatment with Endophytic bacteria Bacillus firmus). The data was analyzed using a two-sample T-test. The two treatments were demonstrated in the same farmer's field for accurate data. During this study, there was a long interval in the release of water from the project and the study area was under the tail end part of the project. The farmers of the tail-end region were able to provide only 6 irrigations in the entire Crop Growth Period (CGP). Data on the disease incidence like collar rot & leaf spot were also recorded 3 times during the CGP. The study revealed that seed treatment with endophytic bacteria reduced the number of irrigations (3) to the crop, recorded low disease incidence i.e., collar rot (3.8%) and late leaf spot (22.3%) to the crop saving cost of cultivation of the pesticides over farmers practice (9.6% and 82.5% respectively) and recorded higher productivity (9.8%) over farmers practice.

Keywords: Groundnut, endophytic bacteria, water saving, irrigation, disease incidence

Introduction
Climate change is an important threat among the serious emerging problems that got global attention in the last few decades. Globally, crop production has been seriously affected by drought stress and limited irrigation access. In this regard, various technologies including traditional breeding and genetic engineering are used to cope with limited water availability. However, the interaction between plants and endophytic bacteria emerged as an interesting era of knowledge that can be used for novel agriculture practices. Endophytic bacteria which survive within plant tissues are among the most appropriate technologies for improving plant growth and yield under drought conditions. These endophytic bacteria live within plant tissues and release various phytochemicals that assist plants to withstand harsh environmental conditions, i.e., drought stress and can be isolated from almost all parts of the plant like roots, leaves, stems, fruits, seeds, flowers etc. These microbes were found to help the host plant in disease management and environmental stress tolerance and also help the plant in its growth and development.

Groundnut (*Arachis hypogaea* L.) is an important legume and oilseed crop of tropical and sub-tropical areas cultivated in about 25 million hectares of land in more than 90 countries in the world under different agroclimatic regions where rainfall during the growing season exceeds 500 mm. India occupies first in terms of area and second in terms of production in the world. In India. The country has exported 680,698.61 MT of Groundnuts to the world for the worth of Rs. 7,135.35 Crores/ 860.68 USD Million during the year 2023-24 Indonesia, Vietnam, Philippines, Malaysia and Thailand as Major Export Destinations. (APEDA, 2023-24). Indian groundnuts are available in different varieties: Bold, Java, and Red Natal. In addition to raw edible peanuts, India also supplies blanched peanuts, roasted salted peanuts, dry roasted peanuts, peanut butter, and various peanut-based products (IOPEPC).

The area under *rabi* groundnut in Telangana increased tremendously during the *rabi* season with productivity ranging from 2261-2330 kg ha^{-1}. In India, 24.4 percent of rabi season Groundnut is cultivated in Telangana State. In the state lion share of area and production are contributed from Wanaparthy, Nagarkurnool and Gadwal districts (72,030 ha). The average yield (2047 kg ha^{-1}) of groundnut in Telangana is higher than the national average (1,486 kg ha^{-1}) because of the season, suitable soils, weather, 90% of groundnut area under sprinkler system of irrigation combined with partial mechanization (All India crop situation *rabi*, 2019-20, GOI). The *rabi* groundnut crop is cultivated under irrigated situations under borewells and canal irrigation water. Declining groundwater and late release of irrigation project water during critical phases of the crop lead to a decline in productivity.

Endophytic bacteria enhance drought tolerance with different mechanisms in plants including, plant growth-promoting characteristics of endophytic bacteria like nitrogen fixation, phosphate solubilization, mineral uptake, production of siderophore, 1-aminocyclopropane-1- carboxylate (ACC) deaminase improve root length and density to cope with osmotic and oxidative stresses which leads to enhanced drought tolerance. Plant–endophytic bacteria assist plants to withstand drought stress by producing drought-tolerant substances like Abscisic acid, Indole-3-acetic acid and ACC deaminase. Endophytic bacteria also improve osmotic adjustment, relative water content and antioxidant activity. To cope with drought stress, plants show various morpho-physiological, biochemical, and molecular responses, and these processes are altered by endophytic bacteria to improve drought tolerance in plants. Endophytic bacteria-inoculated plants showed higher root and shoot biomass compared to non-inoculated plants under drought stress. In addition, a higher yield of inoculated plants was also recorded. Endophytic bacteria have been reported to increase compatible solutes, such as sugars and proline content under drought stress. The production reactive oxygen species can be decreased in the plants by the application of endophytic bacteria under drought stress as reported (Khan *et al*. 2016) [2]. Endophytic bacteria release various substances including plant growth regulators at very low concentrations causing physiological, biochemical, and molecular changes related to drought tolerance in plants that improve drought tolerance capability of the associated plant. The production of IAA is mostly synthesized by plant-associated microbes. IAA is generally produced by numerous rhizobacteria, but its production is widespread among endophytes. By inoculating plants with endophytic bacteria, an increase in the lateral roots and root hairs was observed which leads to the increased surface area and consequently enhanced moisture and mineral uptake from the soil. Abscisic acid is also involved in plant responses to several abiotic stress (extreme temperature, drought, and salinity) responses and adaptations. endophytic bacteria have also been found to produce ABA. Various environmental stresses, including drought stress, lead to enhanced ethylene production and might reach the inhibitory levels of plant growth. Endophytic bacteria producing ACC deaminase reduce the ethylene level and protect plants from being damaged by abiotic stress.

The disease resistance in groundnut crop was also observed. In particular, less incidence of collar rot and late leaf spots were observed. Plant priming with endophytic bacteria induces a faster defence reaction of the plant towards bacterial, fungal or viral infections and environmental stresses (Pavlo, 2011) [4]. Priming defence responses is energetically more expedient than constitutive defence, as plants need to defend themselves only during pathogen attack or abiotic stress.

Endophytic bacteria colonize the plant tissue without harming the host (Rosenblueth and Martínez-Romero, 2006) [7]. A group of endophytes likely have established mutualistic relationship with the host by promoting plant growth and by inducing resistance against biotic and abiotic stressors (Kumar *et al*., 2021) [6]. Endophytic bacteria are good candidates for biofertilizers and biocontrol agents, as they are better protected from environmental stressors compared to rhizospheric bacteria, and, unlike rhizospheric bacteria, can be transferred between plant generations (Rosenblueth and Martínez-Romero, 2006) [7].

Materials and Methods

The study was conducted by AICRP on Groundnut Supporting Centre at the RARS, Palem. A total of 10 farmers were selected for the study. The study was conducted in Uppunutala village of Uppununtala Mandal, Nagarkurnool District during *rabi* season, 2021-22. The study area located near tail-end region of the canal. The soils of the demonstrated area are light-textured sandy and sandy loam soils having low available nitrogen, medium in available phosphorus and high in available potash contents. The demonstrated area has canals as the source of irrigation facilities.

The study was formulated in association with the Directorate of Groundnut Research, Junagadh, Gujarat to find out the efficacy of endophytic bacteria in minimizing the number of irrigations and disease incidence in irrigated groundnut.

The farmers of the study area were informed about this technology during the conduct of the training program "Improved Crop Management Practices to Enhance the Productivity of Groundnut". The selected farmers then allotted 0.4 ha of area for Seed treatment with endophytic bacteria and 0.4 ha for traditional practices.

The selected farmers have been demonstrated with the seed treatment with endophytic bacteria. The strain used for the study The recommended rate of endophytic bacteria is 200 grams per acre *i.e.* for 80 kg of groundnut seed. The seed was treated with endophytic bacteria along with around 100 ml of water. The seed was then mixed properly and shade-dried for 30 minutes before sowing. The recommended package of practices was demonstrated in the demo plot. The adjacent field near the demonstration plots of the same farmer was considered as farmers practice.

The data on socioeconomic characteristics, yield parameters, cost of cultivation and other parameters were collected and analyzed. The following formulas were used to analyze different parameters.

Gross Income (Rs.) = Economic yield (kg/ha) × Market Price (Rs/kg)………………(1)

Net Income (Rs.) = Gross Income -Cost of Cultivation………………………………(2)

B:C Ratio (Rs.) = Gross Returns/Cost of Cultivation…………………………………(3)

% increase in the yield = (Demonstrated yield-farmers yield/ Farmers yield ×100…...(4)

Technology Gap = Pi (Potential Yield)-Fi (Farmers Yield) …………………………..(5)

Extension Gap = Di (Demonstration Yield)-Fi (Farmers Yield)………………………(6)

Technology Index= (Potential Yield-Demonstration Yield)/(Potential Yield) ×100…..(7)

Impact of yield = (Yield of Demonstration Plot-Yield of Control Plot)/ (Yield of Control Plot)×100

Days of the first appearance of disease and collection of data: The first appearance of the collar rot was observed 10-15 days after sowing. Whereas, leaf spot disease was seen 45 days after sowing.

Percentage Disease Incidence (PDI): PDI is calculated using the formula

PDI= (Number of plants with collar rot/Total number of plants observed) × 100

Leaf Spot Score: For the estimation of disease incidence leaves were seen from each plot and the disease was recorded using a modified 9 point scale shown in table 2 (Subrahmanyam *et al.*, 1995) [8].

Table 1: Description of leaf spot rating scale (1-9) (Subrahmanyam *et al*., 1995) [8]

Leaf Spot Score	Description	Disease severity (%)
1	No Disease	0
2	Lesions largely on lower leaves, no defoliation	1-5
3	Lesions largely on lower leaves, very few lesions on middle leaves, defoliation of some leaflets evident on lower leaves	6-10
4	Lesions on lower and middle leaves, but severe on lower leaves, defoliation of some leaflets evident on lower leaves	11-20
5	Lesions on all lower and middle leaves; over 50% defoliation of lower leaves	21-30
6	Lesions severe on all lower and middle leaves; lesions on top of leaves but less severe; extensive defoliation of lower leaves; defoliation of some leaflets evident on middle leaves	31-40
7	Lesions on all leaves but less severe on top leaves; defoliation of all lower and middle leaves	41-60
8	Defoliation of all lower and middle leaves; lesions severe on top leaves and some defoliation of top leaves evident	61-80
9	Defoliation of almost all leaves leaving bare stems; some leaflets may be present, but severe leaf spots	81-100

The study has been conducted with the following objectives:

1. To increase water productivity or reduce the irrigation water used for the groundnut crop.
2. To increase disease resistance in groundnut crop thus reducing the Cost of Cultivation of the crop.
3. To enhance the productivity of the groundnut crop in Nagarkurnool District.

3. Results and Discussion

3.1 Yield Gap Analysis

Before implementing the frontline demonstrations, a yield gap analysis was conducted to study the gap between demonstration and farmer's practice. Technologies to be demonstrated were decided based on the presence of a gap. Depending on the priority endophytic bacteria were targeted through giving awareness and demonstrations.

Table 2: Details of the Front-Line Demonstration Technology

S. No.	Particulars	Demonstration	Farmers practice	Gap
1.	Seed Treatment	Seed Treatment with endophytic bacteria	No seed treatment	Full Gap
2.	No. of irrigations required	Irrigation with sprinkler irrigation system (6 irrigations)	Irrigation with sprinkler irrigation system (8-10)	Moderate Gap
3.	Pest Management	Early diagnosis and timely spraying of effective low-dose chemicals	Higher concentration chemicals after pest outbreak	Moderate Gap
4.	Use of Biofertilizers and Biopesticides	Yes	No	Full Gap
5.	Disease resistance mechanisms	Yes	No	Full Gap

3.2 Yield Parameters

The perusal of the yield data (Table 2) indicates that due to the demonstration, groundnut yields have been improved significantly ranging from 2600 to 3200 kg ha^{-1} against farmer's practice ranging from 1900 to 2450 kg ha^{-1} with a yield increment of 9.8%. An average yield of 2800 kg ha^{-1} was obtained under the demonstration plot as compared to the control plot of 2550 kg ha^{-1}. The yield increment observed in groundnut cultivation in 2021-22 was 9.8% due to multifarious mechanisms of endophytic bacteria. These findings are similar to Shree *et al*., (2023) [1] and Pavlo *et al*., (2011) [4].

Table 3: Effect of seed treatment with endophytic bacteria on productivity of groundnut over Farmers Practice

Year	No. of Farmers	Area (ha)	Yield (kg/ha)			% increase in yields
			Potential Yield	Demonstration Yield	Framers Yield	
2021-22	10	4	3000	2800	2550	9.8%

Table 4: Technology gap, technology index and extension gap in Front Line Demonstration over Farmers Practice

Extension gap (kg/ha)	Technology gap (kg/ha)	Technology Index
250 kg ha^{-1}	450 kg ha^{-1}	6.6

3.3 Economic Parameters: The data on the economic parameters of the study indicate that, in terms of the cost of cultivation, the demo could save Rs. 7,510/- hectare due to reduced pesticide applications for collar rot and late leaf spots . Higher gross returns were observed with the demo plot (Rs.1,82,000/-) over the demo plot (1,65,000/-). A similar trend was followed for net returns. Higher benefit: cost ratio was observed with demo plot (2.65) over control plot (2.16). The results are in line with shree *et al*., (2023) [1] and Kumar *et al*., (2021) [6].

Table 5: Economic Parameters of the Front Line Demonstration

S. No.	Parameter	Demo/Check	(Rs/ha)
1.	Cost of Cultivation (Rs/ha)	Demo	Rs. 68,590/-
		Check	Rs. 76,100/-
2.	Gross Returns (Rs/ha)	Demo	Rs. 1,82,000/-
		Check	Rs. 1,65,000/-
3.	Net Returns (Rs/ha)	Demo	Rs. 1,13,410/-
		Check	Rs. 88,900/-
4.	B: C Ratio	Demo	2.65
		Check	2.16

Percent Disease Index: Table 6 reveals that the application of endophytic bacteria influenced the collar rot and late leaf spot. The demo plot PDI for collar rot is 3.8% whereas the check recorded 9.6%. PDI for the late leaf spot for the demo plot is recorded to be 22.3% whereas the check recorded 82.5%. Studies conducted by olga *et al*., 2023 [5], K.KPal *et al*., 2021 [13], Rosenblueth *et al*., 2006 [7] and Pavlo *et al*., (2011) [4] support the results.

Table 6: Effect of seed treatment with endophytic bacteria Percent disease index (&) and leaf spot score

Treatment	Collar Rot PDI (%)	Late Leaf Spot PDI (%)	Leaf Spot Score (1-9)
Check	9.6%	82.5	9
Demo	3.8%	22.3	5

Conclusion
Seed treatment with endophytic bacteria in groundnut crop enhanced yield up to 9.8%, water saving up to 3 irrigations, reduced collar rot and late leaf spot resistance which reduced the cost of pesticide spray. Use of bio-inoculants is a low cost input and sustainable management approach.

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Authors Contribution
Authors K. Mamatha conducted the trial. Author Dr. K.K. Pal provided the endophytic bacteria material, Dr. V.R. Reddy and other authors provided their valuable suggestions in effective conduct of the trial.

Disclaimer
I declare that NO generative AI technologies such as large language models and text-to-image generators have been used during the writing or editing of this manuscript.

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