Effect of Inoculation of Plant Growth Promoting Rhizobacteria (PGPR) Mix I Formulations on Plant Growth, Yield, Disease Incidence and Disease Severity of *Rhizoctonia* Leaf Blight of Amaranthus (*Amaranthus tricolor* L.)

A.R. Resmi, B. Lovely, A. Jayapal, G. Suja, N. Chitra

**ABSTRACT**

**Background:** Amaranthus is the most popular and commercially cultivated leafy vegetable in the Southern part of India, especially Tamil Nadu and Kerala which is susceptible to a number of diseases. Among the different diseases affecting amaranth, foliar blight caused by Rhizoctonia solani Kuhn, is considered as the most serious disease in Kerala.

**Methods:** A field experiment was taken up at Onattukara Regional Agricultural Research Station (O.R.A.R.S), Kayamkulam, Alappuzha, Kerala during December 2019 to February 2020 to assess the influence of dust and liquid formulations of Plant Growth Promoting Rhizobacteria (PGPR) mix I on growth, yield and disease incidence (*Rhizoctonia* leaf blight) in amaranth.

**Result:** The results of the study reveal that maximum number of leaves, number of branches per plant and yield were produced by the plants that were subjected to seedling root dip with 5% talc formulation followed by drenching with 5% talc solution at 30 DAT and 45 DAT. Regardless of talc or liquid formulation of PGPR mix I (2%) seedling dip followed by drenching at 15, 30 and 45 DAT provided the least disease incidence and disease severity in amaranthus at Onattukara condition. Hence use of PGPR mix I is a prerequisite for effective growth, yield and management of leaf blight of amaranthus at Onattukara.

**Key words:** Amaranthus, Disease incidence, Disease severity, PGPR mix I, *Rhizoctonia* leaf blight.

**INTRODUCTION**

Amaranthus is the most popular and commercially cultivated leafy vegetable in the Southern part of India, especially Tamil Nadu and Kerala. Amaranthus (*Amaranthus tricolor* L.), belonging to the family Amaranthaceae is a highly nutritious leafy vegetable and is hence known as ‘poor man’s spinach.’ The leaves are rich source of proteins, vitamins, minerals and dietary fibre.

Plant Growth Promoting Rhizobacteria (PGPR) are a group of bacteria that colonizes plant roots and enhances plant growth and yield by producing plant growth promoting substances. Bacteria of diverse genera were identified as PGPR of which *Bacillus* and *Pseudomonas* spp. are predominant. PGPR exert a direct effect on plant growth by production of phytohormones, solubilization of inorganic phosphates, increased iron nutrition through iron-chelating siderophores and volatile compounds that affect the plant signalling pathways. Cassan *et al.* (2014) discussed about the biosynthesis, metabolism, regulation, physiological role and agronomical impact of phytohormones produced by the model plant-growth-promoting rhizobacteria (PGPR) belonging to the genus *Azospirillum*, considered to be one of the most representative PGPR. Lenin and Jayanthi (2012) revealed that, among the plant growth promoting bacteria, *P. fluorescens* CRPS2 secreted highest amount of both catechol and salicylate type of siderophores followed by *Bacillus*, *Azospirillum* and *Azotobacter* isolates. Additionally, by antibiosis, competition for space and nutrients and induction of systemic resistance in plants against a broad-spectrum of root and foliar pathogens, PGPR reduce the populations of root pathogens and other deleterious microorganisms in the rhizosphere, thus benefiting the plant growth. Nair and Anith (2009) reported reduction in disease severity due to PGPR induced systemic resistance against *R. solani* in a susceptible amaranth variety, ‘Arun’.

Amaranthus is susceptible to a number of diseases. Among the different diseases affecting amaranth, foliar blight caused by *Rhizoctonia solani* Kuhn, is considered as the most serious disease in Kerala (Nayar *et al.*, 1996). *Rhizoctonia solani* Kühn (teleomorph: *Thanatephorus cucumeris* [A.B. Frank] Donk.) is a soil-borne fungus that causes disease on many economically important crop plants...
Effect of Inoculation of Plant Growth Promoting Rhizobacteria (PGPR) Mix I Formulations on Plant Growth, Yield...
at 15, 30 and 45 DAT (Table 1). The lowest leaf number was recorded by the control plot during the entire period of study. PGPR mix I is a consortium of biofertilizers which can enhance NPK uptake by plants. It was also found to impart disease resistance to vegetable seedlings mainly through improvement in growth (Soumya et al., 2020). A significant enhancement in leaves was observed in plants which were treated with a combination of *Pseudomonas* consortium, 50% fertilizer and micronutrients. The application of PGPR mix I did not have any significant influence on the number of branches per plant throughout the study. However more number of branches were produced by plants from the control plots (T_0) at 15 days after transplanting and at 30 and 45 DAT, the plants treated with 5% talc formulation of PGPR mix I produced more number of branches (17.05 and 18.05 respectively). Observation from Table 1 indicate that the days needed for flowering was not at all influenced by any of the treatments as there was no significant difference among them. On an average the plants flowered between 45th and 50th days under the study. However, Bandopadhyay (2015) had reported that flowering of amaranthus occurred after 21 days of dual inoculation of plant growth promoting rhizobacteria.

Maximum yield was produced from T_3 (1.193 kg m\(^{-2}\)) when the plants were treated with 5% talc formulation of PGPR mix I. But this was found to be on par with T_1 and T_3 (2% talc and 2% liquid formulation respectively). Thus economic yield in amaranthus is possible even with 2% formulation (talc or liquid). This is in accordance with the studies of Gopi and Meenakumari (2020) who revealed that liquid formulation of PGPR mix I is equally effective as talc based formulation of PGPR mix I in enhancing yield and other biometric parameters of amaranthus. The lowest yield was obtained from the treatment with 5% liquid formulation of PGPR mix I (T_1 0.62 kg m\(^{-2}\)).

### Disease incidence

The field experiment revealed that observations on disease incidence and disease severity exhibited significant differences between the treatments (Table 2). In plots that received the treatments, number of days taken for first appearance of *Rhizoctonia* leaf blight symptom in amaranthus ranged from 26 to 35 days after transplanting. But for the plants in the plot T_0 (absolute control), at the time of observation (15 DAT) there was 4.37% disease incidence which means that the symptoms of the disease had appeared much earlier. This is in agreement with the findings of Gireesh and Radhakrishnan (2016) who reported that the number of days taken for first symptom appearance of *Rhizoctonia* leaf blight in amaranthus plots ranged from 13 to 14 days after transplanting. Throughout the period of study the percentage of disease incidence was found to be the least in T_1 and T_3 when the seedlings were given a root dip followed by drenching with 2% solution using talc or liquid formulations. Thus regardless of talc or liquid formulation of PGPR mix I (2%) seedling dip and drenching at 15, 30 and 45 DAT provide the least disease expression in amaranthus at Onattukara condition. Even at 45 DAT percentage disease

### Table 1: Effect of PGPR Mix I on plant growth and yield of amaranthus.

| Treatment | Plant height (cm) | Number of leaves per plant | Number of branches per plant | Days to flowering | Number of plants flowered per plot | Yield (kg m\(^{-2}\)) |
|-----------|------------------|-----------------------------|-----------------------------|------------------|-----------------------------------|---------------------|
| T_1       | 45.85            | 81.25                       | 113.65                      | 29.9             | 73.45                             | 77.65               | 11.65                  | 14.6                  | 15.85                  | 47.75                 | 4.5                   | 1.058                 |
| T_2       | 44.15            | 88.2                        | 104.35                      | 21.8             | 77.28                             | 83.5                | 11.05                  | 17.05                 | 18.05                  | 48.5                  | 4                     | 1.193                 |
| T_3       | 51.4             | 86.7                        | 91.8                        | 32.35            | 75.7                              | 81.8                | 10.65                  | 16.35                 | 17.2                   | 49.75                 | 3.5                   | 0.935                 |
| T_4       | 45               | 90.5                        | 94.95                       | 25.1             | 70.2                              | 75.3                | 11.15                  | 15.35                 | 17.05                  | 45.75                 | 5.5                   | 0.62                  |
| C.D.      | 2.902            | 3.25                        | 3.496                       | 3.654            | 3.535                             | 3.702               | N/A                    | 1.202                 | 1.267                  | N/A                   | 1.064                 | 0.397                 |
| SE(m)     | 0.932            | 1.043                       | 1.122                       | 1.173            | 1.135                             | 1.188               | 0.393                  | 0.386                 | 0.407                  | 1.191                 | 0.342                 | 0.127                 |
| C.V.      | 3.862            | 2.378                       | 2.16                        | 9.056            | 3.192                             | 3.084               | 6.898                  | 4.845                 | 4.754                  | 4.958                 | 14.232                | 28.041                |

**DAT-** days after transplanting.

### Table 2: Effect of PGPR Mix I on disease incidence and disease severity of *Rhizoctonia* leaf blight of amaranthus.

| Treatment | Disease incidence (%) | Disease severity (%) |
|-----------|-----------------------|----------------------|
| T_1       | 0                     | 0                    | 0.67                  | 0.0                  | 3.6                   |
| T_2       | 1.07                  | 1.96                 | 6.08                  | 2.25                 | 3.75                  | 26.5                  |
| T_3       | 0                     | 0                    | 1.81                  | 0.0                  | 0.0                   | 15.88                 |
| T_4       | 0.68                  | 1.91                 | 5.01                  | 2.6                  | 3.93                  | 14.34                 |
| T_5       | 4.37                  | 5.91                 | 9.79                  | 23.58                | 38.88                 | 51.15                 |
| C.D.      | 1.86                  | 2.92                 | 3.45                  | 3.95                 | 3.57                  | 4.698                 |
| SE(m)     | 0.598                 | 0.94                 | 1.109                 | 1.268                | 1.14                  | 1.508                 |
| C.V.      | 97.722                | 95.941               | 47.482                | 44.598               | 24.582                | 13.53                 |
incidence was found to be very less in T₀ and T₁ (< 2% incidence) compared to plants from absolute plot where there was 9.79% disease incidence. Similar reports of reduced incidence of leaf blight in *A. tricolor* with PGPR mix I was reported earlier by Nair and Anith (2009). They revealed that a native isolate, *P. fluorescens* PN026R was particularly effective in suppressing the disease and promoting plant growth. Uppala *et al.* (2010) isolated 63 endophytes and evaluated their effect against *R. solani* and observed that six endophytic bacteria and one endophytic fungus were antagonistic against the pathogen. *Azotobacter chroococcum*, *Azospirillum* sp. and *Glucanoacetobacter diazotrophicus* were found to be inhibitory against *R. solani* in cotton and rice and *F. oxysporum* in tomato. (Chauhan *et al.*, 2012). They also reported the production of antifungal substances by *A. chroococcum*.

The trend followed in disease incidence was continued in the percentage of disease severity also (Table 2). The least disease severity percentage was recorded in plants from T₀ plots throughout the study. Even at 45 DAT, the plants expressed only 3.6% disease severity. The next best was from T₀ when the plants did not express any symptom till 30 DAT, but recorded 15.88% at 45 DAT. The treatment T₀ was found to be on a par with T₁ at 15 DAT and at 45 DAT. The highest disease severity was recorded from T₁ (absolute control) which recorded maximum damage compared to other treatments at all stages of crop growth. At harvest more than half the population from T₀ was damaged due to diseased leaves and were found to be unmarketable. This suggests that a seedling dip followed by drenching of 2% PGPR mix I formulation (regardless of talc or liquid) is sufficient to provide desirable disease suppression in *amaranthus* at Onattukara condition.

**CONCLUSION**

The results of the study reveal that amaranthus is greatly influenced by the application of PGPR mix I treatments. Even though taller plants were produced by the plots which did not receive any treatments, maximum number of leaves and number of branches per plant were produced by the plants that were subjected to seedling root dip with 5% talc formulation followed by drenching with 5% talc solution at 30 DAT and 45 DAT. Days to flowering was not influenced by any of the treatments. The highest yield was obtained by seedling dip of 5% talc formulation followed by drenching with the same at 15, 30 and 45 DAT. But yield was not much affected even when the dosage was reduced to 2% formulation (talc or liquid) suggesting the sufficiency of 2% dosage for profitable yielding in amaranthus. In plots that received the treatments took about a month to develop the first disease symptom. Regardless of talc or liquid formulation of PGPR mix I (2%) seedling dip followed by drenching at 15, 30 and 45 DAT provided the least disease incidence and disease severity in *amaranthus* at Onattukara condition. The plants that did not receive any treatment expressed disease symptoms even before 15 days after transplanting. Hence it can be concluded that use of PGPR Mix I is a prerequisite for effective growth, yield and management of leaf blight of amaranthus at Onattukara.

**REFERENCES**

Anderson, N.A. (1982). The genetics and pathology of *Rhizoctonia solani*. Annual Review of Phytopathology. 20: 329-347.

Bandopadhyay, S. (2015). Effect of dual inoculation of plant growth promoting rhizobacteria on different non-leguminous plants under pot condition. Indian Journal of Microbiology Research. 2(1): 20-26.

Cassan, F., Vanderleyden, J. and Spaepen, S. (2014). Physiological and agronomical aspects of phytohormone production by model plant-growth-promoting rhizobacteria (PGPR) belonging to the genus *Azospirillum*. Journal of Plant Growth Regulation. 33: 440-459.

Chauhan, S., Wadhwa, K., Vasudeva, M. and Narula, N. (2012). Potential of *Azotobacter* ssp. as biocontrol agents against *Rhizoctonia solani* and *Fusarium oxysporum* in cotton (*Gossypium hirsutum*), guar (*Cyamopsis tetragonoloba*) and tomato (*Lycopersicum esculentum*). Archives of Agronomy and Soil Science. 58(12): 1365-1385.

Gireesh and Radhakrishnan, N.V. (2016). Eco-friendly management of *Rhizoctonia* leaf blight of *amaranthus*. International Journal of Applied and Pure Science and Agriculture. 2(8): 22-26.

Gokulapalan, C., Reghunath, P., Celine, V.A. and Ramachandran, N.S. (1999). Managing leaf blight on amaranth. Indian Horticulture. 44: 33.

Gokulapalan, C., Nayar, K. and Umamaheswaran, K. (2000). Foliar blight of *amaranthus* caused by *Rhizoctonia solani* Kuhn. Journal of Mycology and Plant Pathology. 30:101-102.

Gopi, G.K., Meenakumari, K.S., Anith, K.N., Nysanth, N.S. and Subha, P. (2020). Application of liquid formulation of a mixture of plant growth promoting rhizobacteria helps reduce the use of chemical fertilizers in *amaranthus* (*amaranthus tricolor* L.). Rhizosphere. 15.

KAU (Kerala Agricultural University) (1998). Management of important pests and diseases of *amaranthus*. Research Report. Kerala Horticulture Development Programme (R and D) Vellanikkara, Thrissur, Kerala, India. 33p.

Lenin, G. and Jayanthi, M. (2012). Indole Acetic Acid, Gibberellic acid, Siderophore production by PGPR isolates from Rhizospheric soils of Catharanthus roseus. International Journal of Pharmaceutical and Biological Archives. 3(4): 933-938

Nair, C. and Anith, K. (2009). Efficacy of acibenzolar-S-methyl and rhizobia for the management of foliar blight disease of *amaranthus*. Journal of Tropical Agriculture. 47: 43-47.

Nayar, K., Gokulapalan, C. and Nair, C. (1996). A new foliar blight of *amaranthus* caused by *Rhizoctonia solani*. Indian Phytopathology. 49(4): 407.

Ogoshi, A. (1987). Ecology and pathogenicity of anastomosis and interspecific groups of *Rhizoctonia solani* Kühn. Annual Review of Phytopathology. 25: 125-143.

Smitha, K.P. (2000). Management of foliar blight of *amaranthus* (*amaranthus tricolor* L.) caused by *Rhizoctonia solani*
Kuhn using Microbial antagonists. M.Sc. (Ag.) Thesis, Kerala Agricultural University, Thrissur. 74p.

Soumya, S., Sreeraj, S., Anusha, P., Swathy, B., Renikrishna, R., Saranya, S., Jisha, P., Radhakrishnan, E.K. and Remakanthan, A. (2020). Combined effect of Pseudomonas spp. Consortium and Fertilizer with Micronutrients on Enhanced yield of Amaranthus tricolor (L.). Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. DOI:10.1007/s4011-020-01179-x.

Uppala, S., Beena, S., Chapala, M. and Bowen, K.L. (2010). Bioefficacy of endophytes in the management of leaf blight disease of amaranth. Plant Growth Promotion by Rhizobacteria for Sustainable Agriculture. Scientific Publishers, India. 524-530 p.

Wheel er, B.E.J. (1969). An Introduction to Plant Diseases. John Wiley and Sons Ltd., London. 301p.