IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
Research Paper , Journal Volume 11, Iss 10, 2022

Role of Plant Growth Promoting Rhizobacteria in Sericulture

Lakshmi Rupa Das[1*], Gitanjali Biswas[2]
[1]Department of Botany, Gauhati University, Guwahati, Assam, India
[2]Department of Botany, Barkhetri College, Mukalmua, Nalbari, Assam, India
***Corresponding author:** Lakshmi Rupa Das, Department of Botany, Gauhati University, Guwahati, Assam, India, E-mail id: lakshmidas9990@gmail.com, Contact no: 6000601194

ABSTRACT

Sericulture, an agro-based farming practice, involves rearing silk worms to produce mulberry and non-mulberry silk. These sericigenous insects rely on primary and secondary host plants for their growth and development, with some being monophagous and others polyphagous. Host plants are crucial in sericulture as they serve as the sole food source for these insects, which ultimately produce silk of high commercial value. Given the continuous feeding nature of the insects, large-scale production of host plants is necessary. However, host plants are susceptible to various diseases, necessitating the use of inorganic fertilizers for quality and quantity enhancement, albeit at the expense of environmental degradation. To mitigate these issues, biofertilizers have emerged as an alternative in agriculture, reducing reliance on chemical fertilizers. Plant Growth Promoting Rhizobacteria (PGPR) are beneficial bacterial communities thriving in the rhizosphere, stimulating plant growth through various mechanisms. Strains such as *Pseudomonas*, *Bacillus*, *Micrococcus*, and *Azospirillum* have shown efficacy in enhancing the growth and development of numerous plants. PGPR also play a crucial role in sericulture by improving the quality and quantity of host plants, thereby increasing silk worm productivity and cocoon yield. For optimal productivity of sericigenous insects, a comprehensive understanding of host plants and their biology is essential. This paper reviews the role of PGPR and their potentiality in sericulture, highlighting their significance in improving host plant productivity and ultimately enhancing silk worm yield. Such insights contribute to sustainable sericulture practices, ensuring continued silk production while minimizing environmental impact.
Keywords: Sericulture, host plant, PGPR, silkworm

INTRODUCTION

Sericulture is a branch of science which focuses on the cultivation of silkworms for the purpose of silk production, commonly referred to as silk farming. This practice involves the exploitation of silk worms for commercial endeavours, yielding two primary types of silk: mulberry silk and non-mulberry silk. Mulberry silk is predominantly produced by the silk worm species *Bombyx mori*. Non-mulberry silk encompasses three distinct varieties: Muga silk, Eri silk, and Tassar silk, each contributing to the diverse landscape of silk production. The production of different types of silk—Muga silk by the silk worm *Antheraea assamensis*, Eri silk by *Samia ricini*, and Tassar silk *by Antheraea mylitta*—is reliant upon a diverse range of host plants crucial for the survival and development of these sericigenous insects. The growth, development, and economic traits of these silkworms are predominantly influenced by the nutritional content provided by their host plants (Shifa *et al.*, 1980). These sericigenous insects exhibit a broad dietary spectrum, feeding not only on primary host plants but also on secondary and tertiary food sources. For instance, the Muga silkworm *Antheraea*

IJFANS International Journal of Food And Nutritional Sciences

ISSN PRINT 2319 1775 Online 2320 7876
, Journal Volume 11, Iss 10, 2022

assamensis Helfer. primarily thrives on *Persea bombycina* Kost. (Som plant) and *Litsea monopetala* (Roxb.) Pers (Soalu plant), while the Eri silkworm *Samia Cynthia ricini* relies on *Riccinus communis* L (Castor plant) and *Heteropanax fragrans* Roxb. (Kesseru plant) as its main dietary sources. In contrast, the Tassar silkworm *Antheraea mylitta* finds sustenance in *Terminalia arjuna* (Roxb.)Wight & Arn. (Arjun), *Terminalia tomentosa* (Roxb.) Wight & Arn. (Asan) and , *Shorea robusta* Gaertn. (Sal) as its primary host plants. Lastly, the mulberry silkworm *Bombyx mori* predominantly feeds on *Morus* L., the mulberry plant (Tikader, 2010). Understanding the intricate relationship between these sericigenous insects and their host plants is crucial for optimizing silk production practices, ensuring the quality and quantity of silk output while maintaining ecological sustainability.

Host plants are susceptible to various diseases, impacting both the quality and quantity of leaf production. To address this, inorganic fertilizers are commonly employed, but they pose environmental risks such as soil fertility degradation and pollution. Thus, the use of biofertilizers is increasingly favoured in Sericulture, as they offer cost-effective and environmentally friendly alternatives to chemical fertilizers. Among the range of biofertilizers utilized in Sericulture, plant growth-promoting rhizobacteria (PGPR) stand out for their ability to enhance host plant growth and confer disease resistance.

Plant Growth Promoting Rhizobacteria

Soil serves as a thriving habitat for a diverse array of microorganisms, including bacteria, fungi, and protozoa, with bacteria being the most abundant among them in soil ecosystems. The richness of soil nutrients is a key factor driving the proliferation of soil microbiota. The composition and fertility of soil dictate the structure of the rhizobacterial community, which significantly impacts plant growth and development. Numerous biotic and abiotic factors influence plant growth in soil, with soil microorganisms playing a pivotal role in enhancing plant productivity. The rhizosphere, the region surrounding plant roots, is particularly active and teeming with microorganisms. This zone is enriched with nutrients such as sugars, amino acids, and various organic compounds, making it an ideal niche for microbial colonization. Given the predominance of bacteria in the rhizosphere, they exert a substantial influence on plant physiology. The presence of rhizobacteria in the soil can have various effects on the plant which can be neutral, detrimental or beneficial. These soil bacteria which help in the plants growth and development by producing various growth regulators, enhancing the availability of nutrients or by controlling pathogens are called as the Plant Growth Promoting Rhizobacteria (PGPR). Among these bacteria, Plant Growth Promoting Rhizobacteria (PGPR) plays crucial role in fostering plant growth and development through diverse mechanisms. In other terms, it can be said that the Plant Growth Promoting Rhizobacteria are the free living beneficial rhizospheric bacteria which colonizes the plant roots and stimulates its growth and development by a number of mechanisms. Large number of rhizospheric bacteria like *Pseudomonas*, *Bacillus*, *Azotobacter*, *Burkholderia*, *Serratia*, *Klebsiella* are reported to enhance the plant growth and development (Joseph *et al*., 2007). Based on their site of occurrence, PGPR are divided into two types- extracellular PGPR and intracellular PGPR. (Viveros *et al*., 2010). The extracellular PGPR are those which are found to occur in the rhizosphere in regions between the root cortical cells. On the other hand, intracellular ones are those which are found to occur in the form of nodules in the roots. The extracellular PGPR includes bacteria belonging to the genera *Pseudomonas*, *Micrococcus* ,

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

Agrobacterium, Arthrobacter, Azotobacter, Flavobacterium, Azospirillum, Burkholderia, Erwinia, Bacillus , Caulobacter, Chromobacterium and *Serratia* (Gray and Smith 2005) whereas intracellular PGPR includes the endophytes and *Frankia* species (Verma *et al*., 2010). Furthermore, PGPR can be also divided into two types based on their relation with plants- symbiotic bacteria and free living rhizobacteria (Kundan *et al*., 2015).

PGPR as biofertilizers

The term biofertilizer refers to microbial inoculants, which are preparations of live microorganisms such as bacteria and fungi. These inoculants, when applied to plant surfaces, soil, or seeds, colonize the rhizosphere or plant interiors, thereby enhancing plant growth and productivity for sustainable agriculture. The term biofertilizer refers to the microbial inoculants which are the preparation of live microorganisms like bacteria, fungi which, on applying to the plant surfaces, soil, or seeds colonizes the rhizosphere or plant interiors thereby increasing the plant growth and productivity for sustainable agriculture (Vessey, 2003). The use of inorganic fertilizers also leads to serious issues in the environment like degrading the fertility of the soil. So, application of biofertilizers in the field of agriculture minimizes the use of chemical fertilizers. Among the biofertilizers, the plant growth promoting rhizobacteria plays a major role in the agriculture systems because of their potential to reduce the use of chemical fertilizers as because the chemical fertilizers are harmful to human beings as well as the animals and also cause a lot of pollution to the environment. PGPR plays a major role as biofertilizers not only in the field of agriculture but also in horticulture, forestry and environmental protection. The use of PGPR as biofertilizers can increase the plant growth and development by inducing various plant growth promoting traits. It helps in increasing the plant height, dry matter production of root and shoots, controlling from pathogens, root size, yield etc. Noteworthy PGPR strains such as *Allorhizobium*, *Azorhizobium*, *Bradyrhizobium*, *Mesorhizobium*, *Rhizobium*, and *Sinorhizobium* have been identified as potent biofertilizers (Vessey, 2003). PGPR not only promote plant growth and development but also confer resistance to various pathogens, making them integral components of biofertilizer formulations (Vejan, 2016). Over the last few decades, the application of PGPR in agriculture for sustainable development has significantly increased worldwide. The use of PGPR to control plant pathogens was pioneered in the Soviet Union in 1958, although selecting potent PGPR strains was challenging during that period (Suslow *et al*., 1979). Studies have demonstrated the positive impact of PGPR on crop growth and yield. For instance, the application of PGPR in rice fields led to substantial growth and yield increases (Ashrafuzzaman *et al*., 2009). Similarly, in Mongolia, the application of the PGPR strain *Bacillus pumilus* 8N-4 resulted in increased crop yield in wheat variety Orkhon (Hafeez *et al*., 2006). Moreover, PGPR have been shown to enhance growth and yield in various other plants, including maize, pea, canola, lentils, cucumber, radish, soybean, black pepper, and cotton.

Mechanisms of PGPR

There are a number of mechanisms by which the plant growth promoting rhizobacteria enhances the plants growth and also increases crop productivity being less harmful to the environment. Based on their working mechanism, PGPR can be divided into two types- direct

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

mechanism and indirect mechanism. It stimulates the plant growth directly or indirectly by producing and secreting various phytoregulators in close proximity to the rhizosphere.

Direct Mechanisms

PGPR directly influence plant growth by producing and secreting specific compounds, including phytohormones and growth regulators, which directly affect plant physiology and development. Some of the key direct mechanisms include:

Phytohormone Production: PGPR synthesize and release phytohormones such as auxins, cytokinins, and gibberellins, which regulate various aspects of plant growth and development. For example, auxins promote root elongation and lateral root formation, while cytokinins stimulate cell division and shoot growth (Lwin *et al*., 2012; Morris, 1986).

Nitrogen Fixation: Certain PGPR, such as species of *Azotobacter* and *Azospirillum*, have the ability to fix atmospheric nitrogen into a form that plants can readily utilize (Tilak *et al*., 2005). This provides an additional source of nitrogen for plant growth, reducing the need for synthetic fertilizers and promoting sustainable agricultural practices.

Phosphate Solubilization: Some PGPR produce enzymes and organic acids that solubilize insoluble phosphorus in the soil, making it more available to plants. This enhances phosphorus uptake by the roots, which is essential for energy transfer, photosynthesis, and overall plant growth (Richardson, 2001).

Iron Chelation: Certain PGPR produce siderophores, which are chelating agents that bind to iron in the soil, making it more accessible to plants. Improved iron uptake enhances chlorophyll synthesis and photosynthetic activity, leading to increased plant vigor and productivity (Schippers *et al*., 1987).

Indirect mechanisms

PGPR also exert indirect effects on plant growth by modulating soil properties, nutrient availability, and plant-microbe interactions within the rhizosphere. These indirect mechanisms include:

Biocontrol of Pathogens: Some PGPR produce antimicrobial compounds, lytic enzymes, or siderophores that suppress the growth of soil-borne pathogens, thereby protecting plants from diseases. This biocontrol activity promotes plant health and reduces the need for chemical pesticides (Tariq *et al*., 2017).

Induced Systemic Resistance (ISR): PGPR can trigger the plant's innate defence mechanisms, leading to the induction of systemic resistance against pathogens. This priming effect enhances the plant's ability to withstand disease pressure and promotes overall resilience (Pieterse *et al*., 2003; Jeyanthi and Kanimozhi 2018).

Enhanced Nutrient Uptake: PGPR can enhance nutrient uptake by solubilizing minerals, mobilizing nutrients in the soil, or promoting root growth and branching. By improving nutrient acquisition efficiency, PGPR help plants maintain optimal growth and yield even under nutrient-limiting conditions.

Drought and Salinity Tolerance: Some PGPR produce osmolytes, which help plants tolerate drought and salinity stress (Ayub, 2020). Additionally, PGPR can promote root elongation and water uptake, enhancing plant resilience to water scarcity.

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

PGPR in Sericulture

The susceptibility of host plants to foliar diseases poses a significant challenge in Sericulture, as it directly impacts the quality and quantity of leaves available for silk production (Thangavelu *et al*., 1988; Das *et al*., 2003). Controlling these diseases with chemical agents is a delicate task, as their indiscriminate use may harm beneficial insects crucial to the ecosystem (Gamo and Hirobe, 1977). In light of these challenges, biological control methods have emerged as promising alternatives, particularly through the application of beneficial rhizospheric microorganisms, which possess antimicrobial properties against foliar fungal pathogens. Research efforts in Sericulture have focused on harnessing the potential of plant growth-promoting rhizobacteria (PGPR) as biological control agents. These microorganisms, residing in the root zone of plants, have been found to enhance plant growth and confer resistance against various pathogens. By bolstering the health of host plants, PGPR contribute to increased silkworm productivity and cocoon yield, aligning with sustainable practices in silk production. Several studies, as documented in Table 1, have explored the efficacy of PGPR strains in combating foliar diseases and improving overall plant health in Sericulture. These research endeavours typically involve the isolation and characterization of potent PGPR strains from the rhizosphere of host plants. These strains are then evaluated for their ability to suppress foliar fungal pathogens through various mechanisms, including competition for resources, production of antimicrobial compounds, and induction of systemic resistance in plants. Furthermore, field trials are conducted to assess the practical application of PGPR-based biocontrol strategies in real-world Sericulture settings. These trials involve the inoculation of PGPR strains onto host plants either through seed treatments, soil drenching, or foliar applications. The impact of PGPR inoculation on disease incidence, leaf quality, and ultimately silk production is carefully monitored and evaluated. Overall, research on PGPR-based biocontrol in Sericulture holds immense potential for effectively managing foliar diseases while minimizing the environmental risks associated with chemical interventions. By leveraging the natural antimicrobial properties of beneficial rhizospheric microorganisms, Sericulture practices can achieve sustainable disease management strategies, thereby ensuring consistent and high-quality silk production.

CONCLUSION

Plant growth-promoting rhizobacteria (PGPR) play a crucial role in advancing the field of Sericulture. Host plants utilized in Sericulture serve as the primary nutrition source for sericigenous insects, and the application of PGPR leads to a notable enhancement in both the quality and quantity of leaf production. Given that silkworms rely solely on their host plants for sustenance, ensuring a robust and ample supply of disease-free host plants is imperative for their survival. Traditional practices involving the use of chemical fertilizers pose significant environmental risks, including pollution and soil degradation. In contrast, PGPR offer a promising solution by reducing reliance on inorganic fertilizers. Their cost-effectiveness and eco-friendly nature make them a viable alternative to chemical fertilizers, thereby mitigating environmental threats associated with conventional agricultural practices. PGPR serves as a pivotal tool in Sericulture by effectively diminishing the need for chemical fertilizers. Inoculating potent strains of PGPR as bioinoculants or bioformulations holds immense potential in augmenting plant growth and development, thus fostering the

ISSN PRINT 2319 1775 Online 2320 7876
, **Journal Volume 11, Iss 10, 2022**

production of healthier, disease-resistant host plants. The application of PGPR in Sericulture not only enhances the production of disease-free host plants but also significantly boosts the productivity of silkworms. This, in turn, leads to marked improvements in the quality and quantity of silk produced. Therefore, the integration of PGPR in Sericulture practices promises to yield substantial benefits, paving the way for sustainable development within the industry and establishing PGPR as a renewable and indispensable tool in silk production.

AUTHOR CONTRIBUTION

LRD: Manuscript writing, Data collection and compilation, reviewing and editing.

GB: Data collection and compilation, reviewing and editing.

CONFLICT OF INTEREST

The author declares there is no conflict of interest.

Table 1: Plant Growth Promoting Rhizobacteria and their application in Sericulture

Sl. No.	*Plant Growth Promoting Rhizobacteria (PGPR)*	*Host plant*	*Mode of application*	*Reference*
1.	*Pseudomonas fluorescens, Bacillus subtilis*	*Morus alba* (Mulberry plant)	Bioformulations of two isolates of *Pseudomonas fluorescens* and one isolate of *Bacillus subtilis* was found to protect mulberry plants from root rot disease caused by *Macrophomina phaseolina.*	Ganeshmoorthi *et al.,* 2008
2.	*Bacillus pumilus* BRHS/C1, BRHS/T82, *B. altitudinus* BRHS/P22, BRHS/S73, *Paenibacillus lentimorbus*	*Litsea monopetala* (Soalu)	Foliar application improved the quality and quantity of leaves.	Acharya *et al.*, 2013
3.	*Pseudomonas aeruginosa* MAJ PIA03	*Ricinus communis* (Castor plant)	Bio-formulation of *Pseudomonas aeruginosa* with reduced inorganic NPK increased the growth and leaf nutritional content in Castor plant.	Sandilya *et al*., 2017
4.	*Pseudomonas fluorescens*	*Morus alba* (Mulberry plant)	Liquid bioformulation of *Pseudomonas fluorescens* sprayed twice daily showed a significant increase in leaf yield.	Tewary *et al*., 2014
5.	*Bacillus pumilus* strain BRHS-C1	*Persea bombycina* (Som plant)	Application of *Bacillus pumilus* strain BRHS-C1 along with arbuscular mycorrhizal fungi increased growth of the plant.	Chakraborty *et al*., 2014
6.	*Azotobacter*	*Morus alba* (Mulberry	A combination of *Azotobacter* along with	Chakraborty and Kundu 2015

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

		plant)	organic manure and reduced doses of inorganic fertilizer caused an increase in the growth and leaf quality of mulberry plants.	
7.	*Pseudomonas sp.* GUDBPKA301	*Persea bombycina* (Som plant)	Application of *Pseudomonas* strain (GUDBPKA301) causes an increase in shoot length, number of leaves and branches of Som plant.	Rabha *et al.*, 2014
8	*Bacillus cereus* and *Pseudomonas rhodesiae* (MTCC 8299 AND 8300)	*Persea bombycina* (Som plant)	Bioformulations prepared from the *Bacillus cereus* and two strains of *Pseudomonas rhodesiae* (MTCC 8299 AND 8300) showed an increase in shoot length, leaf number, biomass of leaves.	Kalita *et al.*, 2015
9.	*Bacillus* spp., *Streptomyces* spp., *Pseudomonas* spp., *Chromobacterium* spp.	*Persea bombycina* (Som plant)	Maximum increase in the growth of Som plants and fibre quality and quantity in muga silk worm.	Unni *et al.* 2008
10	*Azotobacter chroococcum* strain Azc-3, *Bacillus megaterium* strain Bm-1 and *Pseudomonas fluorescens* strain Psf-4	*Morus alba* (Mulberry plant)	Bioformulation of three strains of PGPR namely, *Azotobacter chroococcum* (Azc-3), *Bacillus megaterium* (Bm-1) and *Pseudomonas fluorescens* (Psf-4), along with plant activators namely acetyl-salicylic acid, sodium salicylate and 4-amino-n-butyric acid induces resistance against *Cercospora moricola* which causes brown leaf spot or *Cerotelium fici* that cause leaf rust in mulberry plant.	Gupta *et al.*, 2008
11	*Pseudomonas fluorescens*	*Morus alba*	An invitro and pot culture experiment was	Narayanan *et al.*, 2015

	and *Bacillus subtilis*	(Mulberry plant)	carried out using 3 antagonists namely *Trichoderma viride*, *Pseudomonas fluorescens* and *Bacillus subtilis* and six fungicides viz., carbendazim, mancozeb, zineb, copper oxy chloride, tebuconazole and pre-mixture fungicide (carbendazim 75% and mancozeb 25%) against mulberry wilt pathogen, *Fusarium solani* which significantly reduced the mycelial growth of the pathogen.	
12	*Beijerinckia indica*, *Azotobacter chroococcum* and *Azospirillum brasilense*	*Morus alba* (Mulberry plant)	Foliar spray application reduced the powdery mildew caused by *Phyllactinia corylea*, black leaf spot caused by *Pseudocercospora mori*, black leaf rust caused by *Cerotelium fici* and bacterial leaf blight caused by *Pseudomonas mori* in Mulberry plant.	Sudhakar *et al*. 2000
13	*Burkholderia cepacia*	*Morus alba* (Mulberry plant)	*Burkholderia cepacia* strains were reported to be useful antagonists of plant pests like *Colletotrichum dematium*, which causes Anthracnose which is a serious threat to the production and quality of mulberry leaves.	Ji *et al*., 2000
14.	*Pseudomonas fluorescens*	*Morus alba* (Mulberry plant)	A combination of *P. fluorescens* and *T.viride* was effective in reducing the *Meloidogyne incognita* numbers in soil and root and also	Muthulakshmi and Devrajan, 2015

ISSN PRINT 2319 1775 Online 2320 7876
, Journal Volume 11, Iss 10, 2022

			in suppressing the root-gall disease of mulberry.	
15.	*Burkholderia* spp.	*Terminalia arjuna* (Tassar plant)	*Burkholderia* species can be used for the induction and enhancement of growth in *T. arjuna* and also for the control of bacterial diseases of tropical tassar silkworm.	Madhusudhan *et al.*, 2015

REFERENCES

Acharya, A., Chakraborty, U., Chakraborty, B. 2013. Improvement of Health Status of *Litsea monopetala* using Plant Growth Promoting Rhizobacteria. *International Journal of Bioresource and Stress management* **4(2)**: 187-191.

Ashrafuzzaman, M., Hossen, F.A., Razi Ismail, M., Hoque, M.A., Islam, M.Z., Shahidullah, S.M., Meon, S. 2009. Efficiency of plant growth-promoting rhizobacteria (PGPR) for the enhancement of rice growth. *African Journal of Biotechnology* **8**: 1247-52.

Ayub, M.A., Ahmad, H.R., Ali, M., Rizwan, M., Ali, S., ur Rehman, M.Z., & Waris, A.A. 2020. Salinity and its tolerance strategies in plants. In: *Plant life under changing environment*, Academic Press, (pp. 47-76).

Chakraborty, B., Acharya, A., Chakraborty, U., Jha, D. K., Rabha, J., Sharma, H. K. 2014. Growth promotion and induction of defense enzymes in *Persea bombycina* following application of AMF and PGPR against *Colletrotrichum gloeosporiodes* causing leaf blight disease. *Journal of Mycology and Plant Pathology* **44(3)**: 249-256.

Chakraborty, B., Kundu, M. 2015. Effect of biofertilizer in combination with organic manures on growth and foliar constituents of mulberry under rainfed lateritic soil condition. *The International Journal of Engineering and Science* **4(3)**: 16-20.

Das, R., Das, K., Benchamin, K. V. 2003. Diseases of muga food plant som. *Indian Silk* **41**: 23-24.

Gamo, T., Hirobe, T. 1977. Effects of insecticides and Fungicides upon the hereditary characters of the silkworm, *Bombyx mori* , *Japanese Journal of Applied Entomology and Zoology* **21**: 47-49.

Ganeshmoorthi, P, Anand, T., Prakasan, V., Bharani, M., Ragupathi, N., Samiyappan, R. 2008. Plant growth promoting rhizobacterial (PGPR) bioconsortia mediates induction of defense-related proteins against infection of root rot pathogen in mulberry plants. *Journal of Plant Interactions* **3**: 233-244.

Gupta, V. P., Mishra, S., Chowdary, N. B., Vindhya, G. S., Rajan R. K. 2008. Integration of plant growth-promoting rhizobacteria and chemical elicitors for induction of systemic resistance in mulberry against multiple diseases. *Archives of Phytopathology and Plant Protection* **41(3)**: 198-206.

Hafeez, F., Yasmin, S., Ariani, D., Rahman, M., Zafar, Y., Malik, K. 2006. Plant growth-promoting bacteria as biofertilizer. *Agronomy for Sustainable Development* **26**: 143-150.

Ji, X., Lu, G., Gai, Y., Gao, H., Lu, B., Kong, L., Mu, Z. 2010. Colonization of *Morus alba* L. by the plant-growth-promoting and antagonistic bacterium *Burkholderia cepacia* strain Lu10-1. *BMC Microbiology* **10**: 243.

Jeyanthi, V., Kanimozhi, S. 2017. Plant Growth Promoting Rhizobacteria (PGPR) – Prospective and Mechanisms: A Review. *Journal of Pure and Applied Microbiology* **12(2)**: 733-749.

Joseph, B., Patra, R.R, Lawrence, R. 2007. Characterization of plant growth promoting Rhizobacteria associated with chickpea (*Cicer arietinum* L). *International Journal of Plant Production* **1(2)**: 141-152.

Kalita, M., Bharadwaz, M., Dey, T., Gogoi, K., Dowarah, P., Unni,., Ozah, D., Saikia, I., 2015. Developing novel bacterial based bioformulation having PGPR properties for enhanced production of agricultural crops. *Indian Journal of Experimental Biology* **53**: 56-60.

Kundan, R., Pant, G., Jado. N., Agrawal, P.K. 2015. Plant growth promoting rhizobacteria: mechanism and current prospective. *Journal of Fertilizers & Pesticides* **6**: 2.

Lwin, K.M., Myint, M.M., Tar, T., Aung, W.Z. 2012. Isolation of plant hormone (indole-3-acetic acid-IAA) producing rhizobacteria and study on their effects on maize seedling. *Engineering Journal* **16**: 137-144.

Madhusudhan, K. N., Minz, Prerana., Sinha, Ajit., Deka, M., Yadav, Harendra., Kumar, Kiran., Gargi, K., Gupta, V., Naqvi, A., Sahay, A. 2014. Screening of *Rhizobacterium, Burkholderia* for biocontrol of bacterial pathogens of tropical Tasar silkworm, *Antheraea Mylitta* D. and induction of growth in silkworm host plant, *Terminalia arjuna*. *Journal of Chemical, Biological and Physical Sciences* **5**: 450-456.

Morris, R.O. 1986 Genes specifying auxin and cytokinin biosynthesis in phytopathogens. Annual Review of Plant Physiology. **37**: 509-538.

Muthulakshmi, M., Devrajan, K. 2015. Management of *Meloidogyne incognita* by *Pseudomonas fluorescens* and *Trichoderma viride* in mulberry. *International Journal of Plant Protection* **8(1)**, 1-6.

Narayanan, P., Vanitha, S., Rajalakshmi, J., Parthasarathy, S., Arunkumar, K., Nagendran, K., Karthikeyan, G. 2015. Efficacy of Bio-Control Agents and Fungicides in Management of Mulberry Wilt Caused by *Fusarium solani. Journal of Biological Control* **29(2)**.

Pieterse, C.M., Zamioudis, C., Berendsen, R.L., Weller, D.M., Van Wees, S.C., & Bakker, P.A. 2014. Induced systemic resistance by beneficial microbes. Annual Review of Phytopathology **52**: 347-375.

Rabha, J., Jha, D., Sarma, H., Acharya, A., Chakraborty, U., Chakraborty, B. 2014. Characterization of bacteria from the rhizosphere of *Persea bombycina* with multiple growth promoting traits. *Indian Phytopathology* **67(2)**: 126-133.

Richardson A.E. 2001. Prospects for using soil microorganisms to improve the acquisition of phosphorus by plants. *Functional Plant Biology* **28**: 897-906.

Sandilya, S.P., Bhuyan, P.M., Nageshappa, V., Gogoi, D.K., Kardong, D. 2017. Impact of *Pseudomonas aeruginosa* MAJPIA03 affecting the growth and phytonutrient

ISSN PRINT 2319 1775 Online 2320 7876
, Journal Volume 11, Iss 10, 2022

production of castor, a primary host-plant of *Samia ricini*. *Journal of Soil Science and Plant Nutrition* 17.

Schippers, B., Bakker, A. W., & Bakker, P.A.H.M. 1987. Interactions of Deleterious and Beneficial Rhizosphere Microorganisms and the Effect of Cropping Practices. *Annual Review of Phytopathology* **25(1)**: 339-358.

Shifa, K., Getu, E., Sori, W. 2014. Rearing performance of eri-silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) fed with different castor (*Ricinus communis* L.) genotypes. *Journal of Entomology* **11(1)**: 25-33.

Sudhakar, P., Gangwar, S.K., Satpathy, B., & Sahu, P.K., Ghosh, J.K., Beera, S. 2000. Evaluation of some nitrogen fixing bacteria for control of foliar diseases of mulberry (*Morus alba*). *Indian Journal of Sericulture* **39**: 9-11.

Suslow, T.V., Kloepper, J.W., Schroth, M.N., Burr, T.J. 1979. Beneficial bacteria enhance plant growth Rhizobacteria. *California's Agricultural* Experiment *Station* **33**: 15-17.

Tariq, M., Noman, M., Ahmed, T., Hameed, A., Manzoor, N., Zafar, M. 2017. Antagonistic features displayed by plant growth promoting rhizobacteria (PGPR): a review. *Journal of Plant Science and Phytopathology* **1**: 38-43.

Tewary, P. K., Misra, A. K., Kumar, S. N. 2014. Effect of plant growth promoting rhizobacteria (*Pseudomonas fluorescens*) strain on leaf quality and quantity improvement of mulberry. *Advances in Plant Sciences* **27(2)**: 531-533.

Thangavelu, K., Chakravarty, A.K., Bhagawati, A.K., Isa, M.D. 1988. Hand Book of Muga culture. CSB, Bangalore 9-11, pp. 102.

Tikader, A., Kamble C. 2010. Seri-biodiversity with reference to host plants in India. *The Asian and Australasian Journal of Plant Sciences and Biotechnology* **4(1)**, 1-11.

Unni, B. G., Bora, U., Singh, H., Kumar, B., Devi, B., Wann, S. B., Borah, A., Bhau, B., Neog, K., Chakravorty, R. 2008. High yield and quality silk fibre production by muga silkworm, *Antheraea assamicus* through application of plant growth promoting rhizobacteria. *Current Science* **94(6)**.

Unni, B.G., Devi, B., Kakoty, Y., Wann, S.B., Borah, A., Dowarah, P. 2012. Role of plant: Microbe interactions in the sustainable development of Muga Sericulture. In: Bacteria in Agrobiology: *Plant Probiotics*, pp. 213-225.

Vejan, P., Abdullah, R., Khadiran, T., Ismail, S., Nasrulhaq Boyce, A. 2016. Role of Plant Growth Promoting Rhizobacteria in Agricultural Sustainability—A Review. *Molecules* **21**: 573.

Vessey, J. 2003. Plant growth promoting rhizobacteria as biofertilizer. *Plant and Soil*. **255**: 571-586.