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The Efficiency of Plant Growth Promoting Rhizobacteria for The Enhancement of Rice Production

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ABSTRACT

Numerous bacteria encourage the growth of plants, and numerous microbial products that encourage plant growth have been commercialized. In this review, we focus only on bacteria that originate from the root and have this impact on it. These microorganisms are frequently referred to as PGPRs (plant-growth-promoting rhizobacteria). These rhizobacteria's beneficial impacts on Direct or indirect plant growth are possible. The use of plant growth-promoting rhizobacteria (PGPR) for agricultural purposes is becoming more and more popular on a global scale, and it appears that this will be the future trend. PGPR are bioresources that have the potential to revolutionize agriculture by offering significant advantages. These advantageous, free-living microorganisms promote emergence, colonize roots, encourage growth, and increase yield. Many plant diseases are reported to be resistant to PGPR in a variety of crops, including cereals, pulses, ornamentals, vegetables, plantation crops, spices, and some trees. The majority of studies have focused on the investigation and possible advantages of PGPR in horticulture, forestry, and agriculture. Although well-documented, the possible mechanisms used by these rhizobacteria in growth promotion and resistance have not yet been extensively investigated. When many mechanisms are combined through the application of PGPR, their positive properties are increased. Due to inconsistent performance and little commercialization outside of a few industrialized nations, their use hasn't been maximized. The benefits and drawbacks of using PGPR as bioinoculants, biofertilizers, and biocontrol agents, as well as their practical potential for bettering agriculture, are also covered. The goal of the study was to describe plant growth-promoting rhizobacteria (PGPR) for growth enhancement and stress tolerance features as well as their effectiveness on early establishment of rice seedlings. Out of 30 PGPR isolates, 18 fixed nitrogen, 17 solubilized tricalcium phosphate, and 29 and 17 generated IAA with or without the presence of L-tryptophane, according to in vitro growth boosting features When it came to stress tolerance, PGPR isolates were tolerant of pH levels between 5 and 10, NaCl levels between 1 and 6%, and polyethylene glycol (PEG) levels between 10 and 40%, respectively. With PIRG values ranging from 7 to 68%, they demonstrated antagonistic action against Pyriculariaoryzae.To maintain the development and yield of rice plants that are stressed by drought, it may be useful and environmentally benign to inoculate them with plant growth-promoting rhizobacteria (PGPR).

Keywords: Rice, Growth Promotion, Plants, Rhizobacteria

INTRODUCTION

More than half of the world's food needs are met by the cereal crop known as rice. More than 700× 106 tonnes of rice were produced worldwide in one year from 167 million tonnes of rice. Irrigated lowland rice provides more than 75% of the world's total rice production. In general, rice has been produced in flooded fields with a constant water depth of 5 to 10 cm. Lowland rice is often directly seeded or transplanted on puddled soils by harrowing and leveling management after plowing under saturated water conditions [1-3]. A significant irrigation water supply is needed in flooded areas, which is employed both as a management tool during rice cultivation and to meet the water requirements for the growth and development of rice plants [4]. It is well recognized that plants can benefit from plant growth-promoting rhizobacteria (PGPR) through a variety of direct and indirect processes, including biological nitrogen fixation, phosphate and potassium solubilization, synthesis of plant growth regulators, siderophore, hydrolyzing enzymes, and many more processes. By creating systemic resistance in plants, these helpful microbes also function as biocontrol agents against pests and diseases [5]. Despite the overwhelmingly positive results, there are varying problems when using PGPR on rice plants. Since rice agriculture requires a large amount of N-fertilizer, the biological nitrogen fixation (BNF) process, which can reduce the use of chemical or inorganic N-fertilizer, is what has the greatest positive impact. According to estimates, rice crops remove 19.4 kg of nitrogen for every tonne of rice grain produced. Additionally, the regularly used N-fertilizer urea has a low plant uptake efficiency, frequently at only 40%. Despite the energy-intensive manufacturing procedures that use the non-renewable resource natural gas [6].

The legume-rhizobia symbiosis, in which the bacteria fix atmospheric nitrogen as endosymbionts inside root nodules in a nutrient-rich and oxygen-controlled microenvironment, has received the greatest attention from investigations of N2 -fixing plant-microorganism interactions [7-8]. Rhizobia only modulates one host species during this symbiotic relationship, and there are hardly any cross-inoculations. Researchers have recently experimented with the idea of inoculating rhizobia on non-legumes like rice, and there have been sporadic reports of success, specifically through the improvement of rice seedling growth and grain output. The mechanisms, however, are yet unknown, and it was not the development of root nodules like in the rhizobia-legume symbiosis [9-10]. The researchers have hypothesized that this may be because rhizobia behaves and functions similarly to PGPR in delivering positive benefits such as phytohormone synthesis, phosphate solubilization, and an improvement in soil N assimilation [11]. Naturally contains a photosynthetic Bradyrhizobium sp. strain, which was isolated. Acetylene reduction assay (ARA) and greenhouse studies revealed that this strain produced a significant level of N2 fixing activity with 20% increases in shoot and grain yields. Contrarily, several other researchers who used ARA and 15N dilution methodologies in their experiments concluded that rhizobial inoculation had positive effects on rice that were more closely related to physiological adjustments in rice development and root shape than to BNF [12-13]. The use of PGPR and rhizobial strains as multiple-strain inocula for crops to profit from their various advantageous properties has recently attracted a lot of interest. A significant quantity of N-fertilizer can be replaced by BNF produced by several diazotrophic bacteria, such as Azotobacter, Clostridium, Azospirillum, Herbaspirillum, and Burkholderia, whereas Rhizobium can enhance the physiological growth or root morphology of rice plants [14-15]. This multi-strain biofertilizer inoculum is hypothesized to support plant growth and rice grain yield through BNF in addition to other known positive effects of PGPR and rhizobia [16].

This will increase the development and yield of the rice plants while reducing the need for artificial N-fertilizer. As a result, there will be a decrease in production costs, less environmental impact, and promotion of environmentally friendly and sustainable agriculture. The goal of the current study was to compare the effects of locally isolated PGPR and native rhizobia multi-strain biofertilizers on rice plant development and nitrogen fixation activities. Rice is regarded as a significant food and has an average yield of 4.5 t ha-1 every season, self-sufficiency is only about 75% [17-20]. Rice output needs to be raised by roughly 7 ha-1 per season to keep up with the rising demand. However, rice-based agricultural systems are susceptible to climate change. Over 65% of the world's rice demand is met by vast stretches of rice cultivation in dangerous places, mostly along South and Southeast Asia's coastlines [21-22]. Climate change causes the sea level to increase, resulting in flooding and the incursion of saltwater into inland areas. According to reports, more than 50% of arable land will be in danger by 2050 as a result of soil salinization, a side effect of climate change, incorrect irrigation methods, overuse of chemical fertilizers, and a lack of adequate drainage systems. Additionally, it is anticipated that by 2056, salt stress will damage around 100,000 ha of rice-growing regions [23].

Salinity negatively disrupts the physical and chemical qualities of soil and more severely influences crop growth. Beneficial microorganisms called plant growth-promoting rhizobacteria (PGPR) may be crucial in reducing the severity of this condition [24]. A beneficial substitute for inorganic fertilizers and pesticides, this species of rhizospheric bacteria can colonize plant roots and preserve soil fertility.PGPR is beneficial in boosting the development of a variety of crops when they are exposed to salt stress in prior studies. It has been reported that local strains are more effective at boosting plant resistance to salinity stress than PGPR derived from the non-saline ecosystem in salinity mitigation. The preliminary selection of locally-isolated salt-tolerant PGPR is crucial to ensure its effectiveness. Exopolysaccharide (EPS), an extracellular polymeric molecule that guarantees the survival of these beneficial microorganisms under unfavorable soil conditions, is one of the strategies these microbes use to mitigate salt stress [25-27].

Exopolysaccharides are also necessary for the growth of bacteria that aggregate or flocculate, which is accomplished by the specific adsorption of the polymeric segment and the formation of polymer bridges between the cells. Additionally, EPS is useful for enhancing bacterial interaction and forming bacterial biofilms on plant root surfaces [28-29]. According to earlier research, several bacterial taxa, including Pseudomonas, Bacillus, Burkholderia, Enterobacter, Microbacterium, Planococcus, and Halomonas, are capable of producing EPS in conditions of salt stress. Additionally, PGPR can produce a variety of plant growth-promoting qualities, including the production of indole acetic acid, biological nitrogen fixation, the solubilization of soil phosphorus (P) and potassium (K), the production of siderophores, and the hydrolyzing of enzymes in salt-stressed conditions [30-32].

It has long been known that PGPR and plants go together. As endophytes that provide the plant host with growth-promoting traits, improve osmolyte, antioxidant, and phytohormonal signaling, and improve plant nutrient uptake efficiency, PGPR may also have some other potential mechanisms for coping with salinity. Not all PGPR can enter the plant host as endophytes, thus there are still more methods to investigate [33]. Rice output in Malaysia could be significantly increased by the use of salt-tolerant PGPR, particularly in the coastline region, which is subject to saltwater intrusion [34]. We postulate that choosing appropriate native and local bacterial strains and isolating them to reduce salt stress in rice plants through their several advantageous features would be a climate-smart agricultural practice and to characterize, identify, and ascertain the impact of salt-tolerant PGPR isolated from the saline rice field on crop growth and yield, the current study was carried out.

Technologies for Enhancing Rice Production

Production in Paddy Field: For the rice crop in paddy fields, several technologies have been created to reduce input costs and increase resource utilization efficiency. Some of these technologies are described since their use can increase yield while using less water.

Selection of suitable period of crop plantation:
Rice farming recommendations included the following:
1. Plant during the rainy season and harvest after the season,
2. To determine the growing date for non-photoperiod sensitive types (110 to 120 days), the harvesting date should be determined after the rainy season,
3. Cropping schedules should be established according to the dry and wet seasons.

Increase yield per unit evapotranspiration

The new "IRRI varieties" have around a 3-fold increase in water productivity compared to the conventional kinds by boosting yield while concurrently reducing crop duration and the outflows of evapotranspiration, seepage, and percolation. New cultivars can be created and used to shorten agricultural seasons and use less input [35].

Laser leveling: Surface-irrigated fields have been leveled successfully using laser-guided machinery. It brings down the field's unevenness to around 2 cm, which improves water application and distribution efficiency, water productivity, fertilizer efficiency, and weed pressure. Up to 50% in savings on wheat, and 68% on rice. Therefore, the most useful innovation in agriculture is laser land leveling, notably for efficient and equitable input consumption for maximum output [36].

Direct seeding: When opposed to transplanting, direct seeding of rice saves time and energy. Dry soil seeding conserves water because there is no puddling and the entire time needed for plants to grow from seed to seed is cut down to roughly 10 days. The crops in the following rotation had higher yields and water efficiency. However, weed control in dry direct-seeded rice is more challenging than in puddled and transplanted rice. While typical transplanted rice on beds had a 15% reduction in total water input, direct-seeded rice had a reduction of 30% [37].

Better soil nutrient management: Although rice continues to require approximately the same quantity of water, better soil nutrient management leads to higher yields. Each kilogram of nitrogen fertilizer added to the soil could result in 10 to 15 kg more rice being produced [38].

Plant spacing: Each plant receives more room, air, and sunlight with broad spacing. Each plant thus produces more tillers. The roots would absorb more nutrients and develop robustly and widely. Since the plant is robust and vigorous, there will be more tillers [39]. The panicle contains more grains, and each grain weighs more as well 25×25 cm should be used as the row-to-row and plant-to-plant distances inside a row.

Weed control: Following the introduction of short-stature rice varieties and the practice of shallow water in the fields during the early stages, which created an ecological condition more conducive to their growth, weed management became even more difficult. A program for managing weeds that is both culturally and chemically sustainable is required. Chemicals and cultural practices by themselves cannot effectively manage weeds. Without weed control, yield loss is predicted to be as high as 90% at a yield level of 7 to 8 tonnes per hectare [40]. The productivity of water is also increased with proper weed control.

Mulching and green manure: To preserve and improve soil fertility, mulching, and green manure are key methods of supplying organic matter to the soil. Crop wastes or green manure crops can be used as mulch, which offers food for soil life and mineral nutrients for plants. When legumes are utilized as green manure, they can add up to 200 kg/ha of nitrogen to the soil, which can save 50–75% of the mineral fertilizer needed for rice [41]. Mulch is applied on the soil's surface to prevent weed development, save water, protect against wind and water erosion, and reduce evaporation.

Climate and climatic change: Extreme weather occurrences like prolonged droughts, very high precipitation, and high temperatures have increased in frequency and intensity during the past few decades. Systems for agricultural production are quite vulnerable to these changes. Crop water needs can help with climate change adaptation by strengthening agricultural cropping systems' resilience and reducing their susceptibility to unfavorable climatic conditions [42]. Together or independently, these cutting-edge solutions have a positive influence on crop productivity and water savings. These methods increase soil fertility while simultaneously increasing productivity.

CONCLUSIONS

Reviewing earlier studies reveals that PGPRs have improved plant growth and yield in the greenhouse and in vitro environments by raising plant tolerance to non-biological stressors. However, these PGPRs frequently fail to produce these advantageous effects when utilized in natural settings, such as fields, which are frequently caused by insufficient rhizosphere and endorhizal colonization. The plant development and yield of several crops may be improved with PGPR. Despite these, it can raise agricultural output without harming the land or the environment by improving the quality of the crop's produce. Using effective soil and rhizome microorganisms in a soil-plant-environmental system allows for an agricultural system that is environmentally friendly, economically viable, and long-lasting.

In addition to providing safe rice and maintaining the health of the soil, the Purple Nonsulfur Bacteria (PNSB) mixture and P fertilizer decreased the amount of chemical fertilizer required for the maximum grain output. These methods are successfully used under the concept of advanced agriculture in many agricultural systems around the world without having a negative environmental impact and are universally adaptable to obtain the greatest benefits. Combining these many cutting-edge techniques, such as mulching, improved soil nutrient management, and direct sowing, leads to greater crop productivity and soil fertility in addition to water savings. The findings indicate that the rhizosphere is a significant source of microorganisms that can stimulate plant growth. Because PGPR bacteria can grow and function in environments with high levels of heavy metals, they may reduce the toxicity of heavy metals to plants. Due to the high ion toxicity, this impact is especially important in industrial regions without natural cover.

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