JUST AGRICULTURE
multidisciplinary e-Newsletter

Role of Biofertilizer on Productivity and Growth of Kharif Crops in West Bengal Red Soil Zone

[1]Pabitra Kumar Biswas, [2]Pathik Sutradhar
[1]Associate Professor, [2]Student
[1, 2]Department of Soil Science and Agricultural Chemistry
Palli Siksha Bhavana, Visva-Bharati, Sriniketan, India

ARTICLE ID: 42

Abstract

This study investigates the impact of biofertilizer application on the productivity and growth of Kharif crops in the red soil zone of West Bengal. Red soil, characterized by its low fertility and nutrient-holding capacity, poses a challenge for sustainable agriculture in the region. In response to the need for environmentally friendly and economically viable alternatives to synthetic fertilizers, this research focuses on assessing the efficacy of biofertilizers in enhancing crop yield and overall plant growth. The study employs a comprehensive experimental design, incorporating multiple Kharif crops commonly cultivated in the region, including rice, pulses etc. Biofertilizers containing nitrogen-fixing and phosphorus-solubilizing microorganisms are applied to the soil, and their effects on plant nutrient uptake, soil fertility, and crop yield are measured and compared with traditional fertilizer practices.

Keywords - Biofertilizer, Kharif crops, red soil, Soil fertility, Sustainable agriculture, West Bengal.

Introduction

Agriculture has been the backbone of human civilization, providing sustenance and prosperity for millennia. As we confront the challenges of a growing global population, climate change, and environmental degradation, the need for sustainable agricultural practices has never been more pressing. In this quest for ecological balance, biofertilizers have emerged as a beacon of hope, promising to revolutionize the cultivation of Kharif crops. Kharif crops, also known as monsoon crops, are an integral part of India's agriculture, with regions like West Bengal witnessing extensive cultivation of rice, pulses, and oilseeds during the Kharif season. Traditionally, chemical fertilizers have played a significant role in augmenting soil fertility and increasing crop yields. However, their excessive and indiscriminate use has led to various environmental issues, including soil degradation, water pollution, and a decline in beneficial soil microorganisms. Continuous application of chemical fertilization leads to the decay of soil quality and fertility and might lead to the collection of heavy metals in plant tissues, affecting the fruit nutritional value and edibility (*Farnia and Hasanpoor, 2015*).

Hence, in the recent years, many organic fertilizers have been introduced that act as natural stimulators for plant growth. A particular group of organic fertilizers includes outcomes based on plant growth-promoting microorganisms identified as 'Biofertilizers'. These biofertilizers comprised efficient strains of nitrogen fixing or phosphate solubilizing microorganism. Organic farming has appeared as a prime concern area globally in aspect of the growing demand for safe and healthy food, durable sustainability and issue on environmental pollution associated with random use of agrochemicals (*Ghany et al., 2013*).

Red soil zone of West Bengal mainly comprised of Bankura, Purba Bardhaman (East Bardhaman), Paschim Bardhaman (West Bardhaman), Birbhum, Midnapore, some regions of Malda and Dinajpur districts. Due to the presence of ferrous oxide makes the soil red, reddis-brown, or red-black in colour. This soil is poor in Nitrogen(N) and Phosphate(P), but it has a high amount of potash and lime. Additionally, it has low water holding capacity. This soil is mildly acidic in nature and requires nitrogenous and phosphatic manuring. This soil is infertile in nature. Agriculture in this soil executed with the help of irrigation. Paddy is the primary crop grown in this soil.

Biofertilizers used in this red soil zone are beneficial because red soils are generally rich in iron and aluminum oxides but may lack essential nutrients like nitrogen, phosphorus. Biofertilizers, especially nitrogen-fixing bacteria, can help address this nutrient deficiency by fixing atmospheric nitrogen and making it available to plants. The microorganisms present in biofertilizers help in breaking down organic matter, releasing essential nutrients, and improving the overall fertility of the soil.

Biofertilizers are considered as a idealistic and sustainable selected strains of beneficial soil microorganisms cultured in the laboratory and packed in a suitable carrier. They can be used either for seed treatment or soil application to increase crop productivity, stimulate plant growth, improve and restore soil fertility, reduce production costs and the environmental impact associated with chemical fertilization. Biofertilizers accelerate microbial processes which augment the availability of nutrients that can be easily assimilated by plants *(Subhash et al., 2016)*

Effect of Biofertilizer on Kharif Crops

In West Bengal red soil zone during kharif season paddy is major crops and also the staple food. Beside paddy, pulses like arhar, blackgram, greengram are cultivated. Maize also cultivated is some region during kharif season. In case of vegetable like pumpkin, ridge gourd, okra and cucurbits are also cultivated.

A. *Effect of Biofertilizer in Paddy*

Rice contributes to the major dietary energy for body. The nutrient content of rice contains proteins (6.81 g/100 g), lipids (0.55 g/100 g), carbohydrates (81.68 g/100 g), fiber (2.8 g/100 g), energy (370 kcal) and water (10.46 g/100 g) *(Rohman et al., 2014)*. Rice can be used as a source of staple food, starch, rice bran, rice bran oil, flaked rice, puffed rice, parched rice and rice husk. Rice is excellent source of complex carbohydrates with low fat, low salt and no cholesterol. It is also a great source of proteins, vitamins and minerals *(Chaudhari et al., 2018; Pawar et al., 2021)*.

Plant height: The effect of nutrient levels with biofertilizers was significant on plant height at all the growth stages. According to (Rama Kant Singh et al ,2015) highest plant height was observed to that plant which are continuous supply of nutrients through all growth stages with beneficial association between chemical fertilizers and biofertilizers (azotobactor and phosphobacteria). Leaching losses of nutrients must have been minimized by use of biofertilizers, which have an ability to mobilize nutritionally important elements from non-usable form to usable forms. According to (Tien et al. ,1979), in addition to its high N fixation, Azotobactor is known to synthesize growth substances such as IAA and other auxines and vitamins B which might have also helped in increasing the plant height. (Govindan and Bagyaraj ,1995) also conduct the field experiment of rice with biofertilizers inoculation and reported that biofertilizers inoculation enhanced shoot and root growth. Similar results are found by Rodriguez and Fraga (1999).

Number of Grain per Panicle: The number of grains per panicle difference significantly with respect to levels of biofertilizers. Kumari et al. (2000) reported that the increase in number of grain due to bio fertilizers inoculants may not be solely due to N fixation or phosphate solubilization, but because of several other factors such as release of growth promoting substances, control of plant pathogens, proliferation of beneficial organisms in the rhizosphere. Solubilizers of inorganic phosphates in the soil (PSB) make them available to the crop and resulted in better number of grains per panicle. It also produced a phytohormone. IAA which increased its capacity of nutrient extraction from the soil. These findings were in accordance with Datta et al. (1982).

Grain Yield: Grain yield of rice was significantly influenced with different treatment combinations of chemicals fertilizers with biofertilizers. The effect of biofertilizers had significant influence on grain yield at production increased 12 per cent over farmer practices. Kumari et al. (2000) reported that increase N level brought about significant increase in grain yield. The grain yield of rice was also increased by inoculation of biofertilizers (Gopalswamy and Vidhyasekaran, 1988) and Jayaraman (1990). The increase in yield due to biofertilizers inoculates may not be solely due to N fixation or phosphate solubilization, but because of several other factors such as release of growth promoting substances, control of plant pathogen, proliferation of beneficial organism in the azotobactor and PSB. These findings are in accordance with Kundu and Gaur (1984). Solubilizations of inorganic phosphate in the soil (PSB) make them available to the crop and resulted in better yield. It also produced a phytohormone (IAA) which increased its nutrient absorption capacity from the soil. These findings were in accordance with Datta et al. (1982) and Mudenoor (2002). The response to mixed culture inoculation was more than that for single culture, showing the synergistic effect of two types of organism. The significant response was mainly due to the supply of two major nutrients N and P. Rao et al. (1983) observed a statistically significant positive yield response with biofertilizers and N fertilizers.

Result: Biofertilizers such as Azospirillum brasilense, Bacillus megaterium and Pseudomonas fluorescens show positive impact on growth parameters of paddy. The highest crop performance was recorded in the combined biofertilizer application. The results indicated that use of biofertilizer would be a great substitute of the inorganic fertilizers. The study recommends that biofertilizers from microorganisms can replace chemical fertilizers to increase crop production.In principle, biofertilizers are less expensive and are more environmentally-friendly than chemical fertilizers. Application of combination of biofertilizers in intensive agricultural practices may witness the great increases in crop yields and food production in developed countries. It is also clear that due to application of biofertilizers the fertility status of soil is going to be improved as well as the soil physicochemical status. Similar finding was reported by Chakraborty et al. (2010). Kumar and Balasubramanian (1989) also reported that 25 to 50 kg N/ha can be saved by biofrtilizers inoculation in rice cultivation.

B. Biofertilizers used in Pulse Production

The production of pulse crop mainly depends on the formation of nodules mostly by Rhizobium strains which helps in fixation of Nitrogen. The strains of Rhizobium create a symbiotic relationship between them and host plants to fix the Biological Nitrogen from atmosphere. With the formation of root nodules helps for plants to uptake of Nitrogen. Normally for pulse crops different species shows different host and bacteria relationship hence only by using suitable species may be beneficial to a certain pulse crop. Rhizobium is well used biofertilizer for N uptake and accelerates yield in pulses. In addition to Rhizobium, the other supportive microbes such as phosphobacteria, PGPRs, AM fungi and many other cooperative microorganisms are known for improved symbiotic capacity, nutrient absorption, better growth and helps the development in the direction of biotic and abiotic stresses. PGPRs such as Azotobacter, Azospirillum, Rhizobium are intended in ready-to-use 'live-formulations'. Which can be directly used to seeds, root or soil to improve their growth and yield of crop plants. PGPRs themselves do not supply any type of nutrients to crops, but their interactions can improve the nutrient supplement to crops. Fixation of Nitrogen is done by Rhizobium and the fixation of Phosphorous is done by Phosphate solubilizing bacteria (PSB) includes namely Aspergillus, Bacillus and Pseudomonas. PSBs are responsible for production of bioactive molecules and organic compounds which helps in the uptake of Phosphorus, PSBs also plays a crucial role in phytate activity which is production of Phosphorus by the phytate mineralization (*Idriss et al.,2002*). Not only PSBs but fungi like VAM (Vascular Arbuscular Mycorrhiza) may help in spreading of hyphal growth in rootzone for simulating absorption of Phosphorus (*Smith and Smith,1990*).

Different Types of Biofertilizer that are used in Pulse Crops

Symbiotic nitrogen fixing bacteria

It includes the species of Rhizobium which have a symbiotic relationship whit host which helps in fixation of nitrogen. It includes-

1. ***Rhizobium leguminosarum*: It is a species of Rhizobium which helps in the fixation of nitrogen in Pea groups (includes All types of Pea, Lentil, and some Beans)
2. ***Rhizobium japonicum***: this type of Rhizobium is observed in the soybean crop which helps in the nitrogen fixation.
3. ***Rhizobium phaseoli***: this species of Rhizobium helps in the fixation of nitrogen in the crops of Kidney beans and Garden beans.
4. ***Rhizobium meliloti***: the species of Rhizobium is observed in the Alfalfa groups of pulses where mainly is seen in lucerne.

Non symbiotic nitrogen fixing bacteria

1. **Azatobacter:** these are aerobic microbes which helps in fixation of Nitrogen works well in neutral soils and sensitive to inadequacy of phosphate.
2. **Clostridium:** these are anaerobic bacteria helps in fixation of nitrogen but fixes less in compare to Azatobacter .
3. **Mycorrhizae:** it is a symbiotic association of fungi and roots of higher plants. It is of two types-
   a. **Endomycorhizae group** are called vesicular arbuscular mycorrhizae [VAM] improves uptake of phosphorus imparts resistance against drought and certain root infecting fungus. Ectomycorrhizae grown on surface layers of roots.
   b. **Frankia:** it is an association between actinomycetes and plants, Actinomycetes are interim between bacteria and fungi, these are responsible for the smell of earth when it rains which is caused by the breakdown of compounds like gaosmin.
4. **Phosphorus solubilizing bacteria (PSB):** Most of the phosphorus sources are gets fixed in soil and becomes unavailable to plants so availability and absorption of phosphorus is induced by the utilization of phosphorus solubilizing microbes such as aspergillus, pseudomonas, bacillus, and mycorrhizal fungus.

Table1: Recommended Biofertilizers for different Pulses

Crop	Recommended Biofertilizers	Capacity of nitrogen fixation (kg/ha)
Chickpea	*Mesorhizobium sp., Ensifer meliloti*	5 - 140
Pea	*Rhizobium leguminosarum*	17 - 245

JUST AGRICULTURE
multidisciplinary e-Newsletter

Red gram	*Bradyrhizobium sp., Sinorhizobium fredii*	7 - 234
Green gram	*Bradyrhizobium sp.*	10 - 112
Black gram	*Rhizobium leguminosarum bv. viceae*	21 - 140
Common bean	*Rhizobium gallicum*	0 - 125
Lentil	*Rhizobium leguminosarum*	10 - 190

Effect on plant growth, symbiotic traits and productivity

In plants, nitrogen and phosphorus play an important role in growth, development and finally determine the yield of the crops. Nitrogen is an important nutrient to plant growth and development as it is building blocks of protein. Phosphorus is a fundamental component of the substances that are building blocks of genes and chromosomes. Application of biofertilizers positively affects the plant growth, nodule number, nodule weight and grain yield. Biofertilizers make available nitrogen and phosphorus to the plants, as discussed above and thereby influence the plants.

Soil Fertility

All the living diazotrophs fix atmospheric nitrogen in the soil and lower the C:N ratio, which in turn enhances mineralization of N. Several biofertilizers containing microorganisms secrete growth promoting substances like IAA, gibberellic acid (GA), cytokinin etc. Single or dual inoculations of bacterial strains (Pseudomonas fluorescens BAM-4, Burkholderia cepcia BAM-6 and Burkholderia cepcia (BAM-12) were able to solubilize the insoluble inorganic phosphorus in mungbean (Jha et al., 2012a).

Seed inoculation with biofertilizers significantly influences the available N and P in the soil. Seed inoculation with Rhizobium+PSB+PGPR and Rhizobium alone recorded significantly higher available N in the soil over seed inoculation with PSB alone and uninoculated control (*Goud and Kale, 2010*). Biofertilizers enhance soil fertility by solubilizing unavailable sources of elemental nitrogen and bound phosphate into available forms in order to facilitate the plant to absorb them (Singh and Yadav, 2008). *Khan et al. (2013)* reported that seed inoculation of cowpea with Rhizobium and PSB significantly increased organic carbon, available nitrogen, available phosphorus and available potassium than uninoculated control. In chickpea, microbial inoculant Anabaena laxa biofilm formulation increased nitrogen fixation and soil available nitrogen (*Bidyarani et al., 2016*).

II. Methods of Application of Biofertilizer

1. **Seed Treatment**

   Seed treatment is the most common method adopted for all types of inoculants. The seed treatment is effective and economic. For a small quantity of seeds (up to 5 kg), the coating can be done in a plastic bag. For this purpose, a plastic bag sized 21” x 10” or larger can be used. The bag should be filled with 2 kg of seeds or more. The bag should be closed in such a way so as to trap the air as much as possible. The bag should be squeezed for 2 minutes or more until all the seeds are uniformly wetted. Then the bag is opened, inflated again and shaken gently. The shaking should stop after each seed gets a uniform layer of culture coating. The bag is opened and the seeds are shade-dried for 20–30 minutes. For large amounts of seeds, coating can be done in a bucket and the inoculant can be mixed directly by hand. Seed treatment with Rhizobium, Azotobacter, Azospirillum, along with PSM can be done. The seed treatment can be done with any of two or more bacteria. There is no side (antagonistic) effect. The important things that have to be kept in mind are that the seeds must be coated first with Rhizobium, Azotobacter or Azospirillum. When each seed gets a layer of these bacteria, then the PSM inoculant has to be coated as an outer layer. This method will provide maximum cell counts of all bacteria required for better results. Treatments of seeds with any two bacteria will not provide a maximum number of bacteria on individual seeds.

2. **Root Dipping**

   This method is used for application of Azospirillum/ /PSM on paddy transplating/ vegetable crops. The required quantity of Azospirillum/ /PSM has to be mixed with 5–10 litres of water at one corner of the field and the roots of seedlings has to be dipped for a minimum of half an hour before transplantation. For rice crop, a bed is made in the field and filled with water. Recommended biofertilizers are mixed in this water and the roots of seedlings are dipped for 8-10 h and transplanted.

3. **Soil Treatment**

   Use 200 ml of PSM per acre. Mix PSM with 400 to 600 kg of cow dung farmyard manure along with ½ bag of rock phosphate, if available. The mixture of PSM, cow dung and rock phosphate have to be kept under any tree or in the shade overnight and 50% moisture should be maintained. The mixture is used for soil application in rows or during leveling of soil.

III. Benefits of Using Biofertilizer

1. Increasing harvest yields
2. An average increase in crop yields by 20 to 37 percent.
3. Algae-based fertilizers give improved yields in rice at rates ranging between 10 and 45 %.
4. Improving soil structure
5. The use of microbial biofertilizers improves the soil structure by influencing the aggregation of the soil particles.
6. Better water relation-
   a. Arbuscular mycorrhizal colonization induces drought tolerance in plants by:
      - Improving leaf water and turgor potential,
      - Maintaining stomatal functioning and transpiration,
      - Increasing root length and development.
7. Lowering production costs.
8. Made from easily obtained organic materials such as rice husks, soil, bamboo and vegetables etc.
9. Reduce the input expenses by replacing the cost of chemical fertilizers.
10. Providing protection against drought and some soil-borne diseases-
11. Aquatic cyanobacteria provide natural growth hormones, proteins, vitamins and minerals to the soil.
    - Azotobacter infuse the soil with antibiotic pesticide and inhibit the spread of soil-borne pathogens like Pythium and Phytophthora.
12. Suppressing the incidence of insect pests and plant diseases.

Biofertilizers strengthen the soil profile, leave water sources untainted and improve plant growth without detrimental side effects.

IV. **Factors Affecting Bio-Fertilizer Response**

1. Efficiency of any inoculant and micro-organisms to be determined by host plant and genotype.
2. Quality of inoculant largely influences its results in term of nitrogen fixation and solubilisation of particular
   nutrients.
3. Package of practices and management of crop alter results of bio- fertilizers.
4. Soil physical and chemical properties highly influence impact of different inoculants and micro-organisms.
5. Climatic conditions like temperature, relative humidity, rainfall and photoperiod affect response of biofertilizers significantly.

V. **Constraints in Bio-Fertilizer Application**

1. There is lack of good quality of strain which efficiently provide required nutrients in soil.
2. Non- existence of storage facility makes it difficult to adopt bio- fertilizers.
3. Field conditions like extremely high or low pH, temperature, nutrients deficiency not only influence the response of inoculants u also limits heir benefits.

Conclusion

This review focused on the potential role of biofertilizers in kharif crops with respect to growth, nitrogen fixation, nutrient uptake, soil fertility and grain yield of kharif crops. The results from different studies showed that biofertilizer inoculation had positive effects on all parameters measured, suggesting the important role of biofertilizers in increasing crop and yield production especially on less fertile soil of West Bengal red soil zone. Therefore, use of biofertilizers(s) inoculants is the best option in improving crops yield, reducing dependence on chemical fertilizers and also for sustainable soil health and the environment.

Acknowledgement

In preparing this article, I had to take the help and guidelines of some respected persons, who deserve my greatest gratitude. I would like to extend my deep gratitude and regard to our respected teacher Dr. Pabitra Kumar Biswas (Department of Soil Science & Agricultural Chemistry, Palli Siksha Bhavana, Visva-Bharati) for his constant guidance and support in

completing my article on " Role of Biofertilizer on Productivity and Growth of Kharif Crops in West Bengal Red Soil Zone" which was meticulously planned and arranged.

References

Bidyarani, N., Prasanna, R., Babu, S., Hossain, F. and Saxena, K. (2016). Enhancement of plant growth and yields in Chickpea (Cicer arietinum L.) through novel cyanobacterial and biofilmed inoculants. Microbial Research. 188-189: 97- 105.

Chakraborty, B.N., Chakraborty, U., Saha, A., Sunar, K. and Dey, P.L. (2010). Evaluation of phosphate solubilizers from soils of North Bengal and their diversity analysis. World J. Agric. Sci., 6(2): 195-200.

condition of central India. Journal of Food Legumes, 23: 212-217.

Datta, M., Banik, S. and Guptha, P. K. (1982). Studies on efficiency of phytoharmone producing phosphate solubilizing Bacillus firmis in augmenting paddy yield in acid soils of Nagaland. Plant Soil, 69: 365-373.

Devasenamma, V., Reddy, M.R. and Rajan, M.S.S. (1999). Effect of varying levels of nitrogen on growth and nitrogen uptake of rice hybrids. Andhra Agric. J., 46: 124-125.

Fakir, M.A.I., Hasan, S.M.R. and Sattar, M.A. (2007). Growth and yield of rice as influenced by Azotobacter and Azospirillum inoculation in presence and absence of urea-N. J. Bangladesh Soc. Agril. Sci. & Technol., 4: 247-250.

Farnia A, Hasanpoor K (2015). Comparison between effect of chemical and biological fertilizers on yield and yield components in wheat (Triticum aestivum L.). Indian J. Nat. Sci. 5 (30): 7792-7800.

Ghany TMA et al (2013). Role of biofertilizers in agriculture: a brief review. Mycopath. 11 (2): 95-101.

Gopalswamy, G. and Vidhyasekaran, P. (1988). Efficiency of Azospirillum brasilense in increasing rice yield. Internat. Rice Res. Newsletter, 12(1) : 34.

Goud, V.V. and Kale, H.B. (2010). Productivity and profitability of pigeonpea under different sources of nutrients in rainfed

Govindan, N. and Bagyaraj, D.J. (1995). Field response of wetland rice to *Azospirillum noculation*. *J. Soil Biol. & Ecol.*, **15**(1): 17-22.

Idriss, E. E et al., (2002). Extracellular phytase activity of Bacillus amyloliquefaciens FZB45 contributes to its plant-growth-promoting effect. Microbiology 148: 2,097–2,109.

Jayaraman, S. (1990). Studies on comparative performance of different biofertilizers with sub-optimal level of nitrogen on rice. Andhra Agril. J., 37(4): 366-369.

Jha, M.N., Kumar, P. and Chourasia, S.K. (2012b). Hope, hype and reality of biofertilizer. Fertilizer Technology. 121: 448- 480.

Khan, V.M., Manohar, K.S., Kumawat, S.K. and Verma, H.P. (2013). Effect of vermicompost and biofertilizers on yield and

Kumar, K. and Balasubramanian, A. (1989). Evaluation of two methods of Azospirillum biofertilizer application in rice. Mysore J. Agril. Sci., 23: 1-5.

Kumari, M.B.G.S., Subbaiah, G., Veeraraghavaiah, R. and Rao, C.V.H. (2000). Effect of plant density and nitrogen levels on growth and yield of rice. Andhra Agric. J., 47: 188-190.

Kundu, B.S. and Gaur, A.C. (1984). Rice response to inoculation with N2 fixing and P-solubilizing microorganisms.Pl. Soil, 79: 227-234.

Mudenoor, M.G. (2002). Effect of micronutrient supplemented Azospirillumbiofertilizers on maize (Zea mays L.). M.Sc. (Ag.) Thesis, University of Agricultural Sciences, Dharwad, KARNATAKA (INDIA).

Nayak, D.N., Ladha, J.K. and Watanabe, I. (1986). The fate of marker *Azospirillum lipoferum* inoculated into rice and its effect on growth, yield and N2 fixation of plants studied by acetylene reduction N2 feeding and 15N dilution technique. *Biology & Fertility Soils*, **2:** 7-14.

Ngampimol, H. and V. Kunathigan, (2008). The study of shelf life for liquid biofertilizer from vegetable waste. AU JT. 11(4): 204-208. Web-sites: http://www.biotecharticles.com/Agriculture-Article/Biofertilizers-Types-Benefits-and Applications-172.html

Pawar Prabhakar R., Mhatre Ramesh P. and Supnekar Santosh P. (2021). Preliminary survey of major insect pests of rice (Oryza sativa L.) from Panvel, Navi Mumbai, India. Intern. J. Zool. Invest. 7 (1): 22-31. https://doi.org/10.33745/ijzi.2021.v07i01.003.

Prasad, J. and Singh, R.S. (1984). Effect of Azolla, seedling bacterization with Azotobacter and *Azospirillum*with and without nitrogen on paddy (*Oryza sativa*). *Indian J. Agril. Res.*, **18:** 63-67

Rao, V. R., Nayak, D. N., Charyulu, P.B.B.N. and Adhya, T.K. (1983). Yield responses of rice to root inoculation with Azospirillum. J. Agril. Sci. Cambridge, 106: 689-691.

Razie, F. and Anas, I. (2008). Effect of Azotobacter and Azospirillum on growth and yield of rice grown on tidal swamp rice fields in south Kalimantan. J. Tanah dan Lingkungan, 10: 41-45.

Rodriguez, H. and Fraga, R. (1999). Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnol. Adv.*, **17**(4-5): 319-339.

Singh, R.S. and Yadav, M.K. (2008). Effect of phosphorus and biofertilizers on growth, yield and nutrient uptake of long duration pigeonpea under rainfed condition. Journal of Food Legumes. 21: 46-48.

Smith, S.E., and Smith, F.A. (1990). Structure and function of the interfaces in biotrophic symbioses as they relate to nutrient transport. New Phytologist 114: 1–38.

soil nutrient status after harvest of cowpea [Vigna unguiculata (L.) W.]. Agriculture and Sustainable Development. 1: 79-81.

Subhash R., S. Triveni & K. Damodarachari. (2016). Biofertilizers for Sustainable Production in Oil Seed Crops. Journal of Agriculture and Veterinary Sciences. 3(6): 435-444

Tien, T.M., Gaskins, M.H. and Hubbel, D.H. (1979). Plant growth substances produced by Azospirillum brasilese and their effect on growth of pearl millet (Pennisetum americanum L.). Applied Env. Microbiol., 37: 1016-1024.