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Mini Review

Biofertilizer: A Next Generation Fertilizer for Sustainable Rice Production

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Abstract

Adequate supply of nutrient is required for optimum crop production; the present scenario of crop production rely on chemical fertilizer. Synthetic fertilizer has prodigious amount of threats to environment and healthy food production. Nepal is importing chemical fertilizers thus Nepalese farmers are facing many problems for timely supply of chemical fertilizers. More than sixty percent of Nepal comprises of hilly regions, transportation in a hill is difficult and expensive due to lack of well-developed road networks. Chemical fertilizers reduce productivity and fertility of soil in long term and cause serious threats to human health and environment. Biofertilizers are biologically active cells or strains of latent cell which upon inoculation improves nutrient fixation and absorption. Biofertilizer has gigantic potential for improving plant nutrition by substituting chemical fertilizers. Biofertilizers are eco-friendly and has tremendous positive impact in yield of crops. Multiplication and distribution of biofertilizer do not require sophisticated infrastructure, multiplication is possible even at farmer's level. Biofertilizers (BGA, *Azolla-anabaena,* Mycorrhiza and Plant Growth Promoting Rhizobacteria) could be alternative to chemical fertilizer as it increases productivity, soil health and fertility. This review has highlighted the role of bio fertilizers in improving physical and chemical properties of soil in rice field, improving yield of rice by increasing nutrient fixation and absorption.

Keywords: Biofertilizer; BGA; *Azolla-anabanae; Mycorrhiza;* Plant Growth Promoting Rhizobacteria

Introduction

Rice (*Oryza sativa L*) is staple crop of about one-third population of the world and it is the most important cereal crop of Nepal. Rice is one of the most important cereal crops of world and its consumption and demand is increasing tremendously. It is cultivated in 55% of the world (Paudel *et al*., 2012). Area production and yield of rice in Nepal is 1,362,908 hectares, 967,067 metric tons and 2,359kg/ha respectively (MoAD, 2015-2016). Chemical fertilizer gives quick response but they are expensive thus it is unrealistic to advice farmers to apply fertilizer they can hardly afford (Tuladhar, 2003). Excessive use of chemical fertilizer has generated many problems like acidification of water, ozone layer depletion and greenhouse effect; this can be managed by the use of Biofertilizers (Choudhury and kennedy, 2005). Non- availability of chemical fertilizer and fluctuation in price is a major constraint in sustainable crop production (Shakeel *et al*., 2015). Supplying adequate quantity of chemical fertilizer is great challenge to government and it has been political commodity in Nepal (Shrestha, 2011) thus biofertilizer could be alternative option to it. *Azolla-anabanae*, Plant Growth Promoting Rhizobacteria (*Azospirillum*, *pseudomonas* etc), *Mycorrhiza* are used as biofertilizer in rice. *Azolla* is heterogeneous fern with seven species having endosymbiont *Anabaena azollae* a nitrogen fixing cyanobacteria (Bocchi and Malgioglio, 2010). Several species of *Azolla* is found in Nepal but *Azolla pinnaata* is dominant (Bhattrai, 1987). Blue Green Algae (BGA) can fix nitrogen in anaerobic environment due to specialized cell called heterocyst which compromise of 5-10% of the cell in filament (Fleming and Hasekorn, 1993). It has been used from centuries in rice field of china and Vietnam (Watanable, 1984). *Mycorrhizal* fungi are cosmopolitan in distribution and form symbiotic

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relationship with roots of many terrestrial plants (Linderman, 1986). *Mycorrhiza* increase nutrient uptake by increasing absorptive surface area of roots (Marschner and Dell, 1994). Flooding condition in rice field may inhibit the *mycorrhizal* association but not colonization in root. An anaerobic condition either delays the extension of external mycelium or promotes the adherence of high amount of hyphae to roots (Fernandez *et al*., 2011). *Mycorrhizal* association is found in roots of upland rice (Ammani *et al*., 1985) and lowland rice (Shivaprasad *et al*., 1990).

Plant Growth and Yield Improvement

Productivity of rice is related to availability of nitrogenous fertilizers, biofertilizer application results crop yield improvement due to increased uptake of N, P, K (Matheus *et al*., 2006). Research carried out in Bangladesh showed that 80% of the recommended dose of nitrogen along with BM9 or BM12 strain of *Azospirillium* is found to increase grain yield straw yield and all three yield governing parameters (Islam *et al*., 2012). An experiment carried out in Los Banos, Philippines suggested that the use of biofertilizer when combined with chemical fertilizer shows significant grain yield increment, among various fertilizer *Azospirillium* based bio fertilizer gives better yield increment (0.2 to 0.5 t/ha) (Banyo *et al*., 2012). Yield parameters of rice without synthetic ammonia is shown in Table 1.

Mycorrhizae inoculation in upland rice showed 50% increase in shoot weight than non-inoculated in early season but shows not much difference in late season (Olawatomiwa and Awodun, 2014). *Rizobium* and Mycorrhiza inoculation in upland rice shows that plant height is less in early season than controlled but the result is reverse in late season. Under same experiment number of tillers, chlorophyll content and NPK content of leaf is more than non-inoculated in both of the seasons. (Olawatomiwa and Awodun, 2014). Under saline condition rice plant inoculated with AMF has shown significantly better growth than control (Fernandez *et al*,. 2011). Highest nutrient uptake in rice was seen in combined application of lower dose of chemical fertilizer and biofertilizer (*mycorrhiza* and bacteria) but the interesting point is reduced dose of chemical fertilizer has increased nutrient use efficiency (Hoseinzade *et al*. 2016). Inoculation of mycorrhizal fungi (*G. Mosseae*) and endophytic bacteria (*H. seropedicae*) significantly increase yield by 35% and 20% respectively (Hoseinzade *et al*., 2016).

Reduced dose of NPK with BGA gives higher value of grain yield, straw yield and other yield parameters. Grain yield and rice yield are found to be increased up to 7-20.9% and 7.2-18.1% when BGA is inoculated with rice (Paudel *et al*., 2012). *Azolla* increase grain yield of rice and curbing NH_3 volatilization by keeping PH value of flood water low and decreasing diurnal cycle of photosynthesis and respiratory activities of *Azoll*a (Vlek *et al*., 1995). Research conducted under greenhouse condition in khumultar found that 19% increase in yield in rice is due to *Azolla* application (Bhattrai, 1987). For better result *Azolla* should not be overcrowded and must not be grown in phosphorous deficit soil (Watanable *et al*., 1991). Cynobacteria application has increased rice root length by 66%, plant height by 53%, Fresh weight by 69% and dry weight by 137.5% (Saadantia and Riahi, 2009). Individually both cyanobacteria and *Azolla* gave better plant performance but the effect was best when half of dose of urea was applied along with *Azolla* and cyanobacteria (Yanni, 1992) (Table 2).

Table 1: Yield parameters of rice without synthetic ammonia

Treatments	Dry Weight (Gm)	N Uptake (Gm)	Spikelet (Number)	Filled Grains (Number)	Grain Filling Rate (%)	Grain Wt/Plant
None	32.3	206	614	307	22	2.64
Pseudomonas	34	227	805[a]	286[a]	35[a]	6.62[a]
Azospirrilum	43.5	219	720	307[a]	42[a]	5.7[a]

Source: (Watanable & Lin, 2012)

Table 2: Performance of rice under different biofertilizer and chemical fertilizer

Treatments	Tiller/m^2	Grain yield(ton/ha)	straw yield(ton/ha)
Azolla+72kg/ha N	574	6.4	6.69
Cynobacteria+72kg/ha N	621	8.52	6.35
Azolla+cynobacteria+ 72kg/ha N	652	7.54	6.77

Source: (Yanni, 1992)

Improvement of Soil Health

Loss of nitrogen in the form of NH_3 reduce Nitrogen Use Efficiency, *Azolla* treatment effectively lowered loss of NH_3 (Zao *et al*. 2018). Nitrogen in *Azolla* is obtained by rice only after decomposition in soil, under laboratory condition *Azolla* decomposition positively correlated with its N content (Watanabe, 1987). Basically mineralization of *Azolla* is slow and it will be slower in phosphorous deficient soils (Watanable *et al*., 2012). *Azolla* improves physical, chemical properties of soil (Table 3). It decreases bulk density but increases porosity and salt level in soil (Bhuvaneswori and Kumar, 2013). *Azolla* application maintains nearly neutral pH, increases organic matter content, primary and secondary nutrients (Bhuvaneswori and Kumar, 2013). *Azolla* is affordable and does not cause eutrophication and perturbation of soil (Scherr, 1999). Nitrogen uptake is higher from *Azolla* than urea. The *Azolla* applied plot contains higher organic carbon than in the plot where chemical fertilizers were applied (Singh and Singh, 1986).

Under pot culture for rice inoculated with Cyanobacteria, it has been reported that 20% increase in soil moisture, 28% increase in soil porosity, 9.8% decrease in soil bulk density, 4.8% decrease in particle density (Saadantia and Riahi, 2009). Soil with low bulk density and high porosity makes soil environment better for crop growth. Cyanobacteria improves availability of phosphorous by solublilizing and mobilizing the insoluble organic phosphate present in soil. They solubilize insoluble forms of $Ca_3 (po_4)_2$, $FePo_4$ and hydroxyapatite in soils and sediments (Bose *et al*., 1971; Cameron and Julian, 1988). Extra –matrical hyphae of VAM fungi exudates substances that cause soil and organic fraction to aggregate which helps to increase absorptive surface and helps to uptake nutrients from the soil especially non mobile elements (P, Zn and Cu) and mobile elements like S, Ca, K, Mg, Mn, Cl, Br and N (Linderman, 1986). Glomalin is a glycoprotein produced by AMF, glue the hyphae and has special role in soil aggregate stabilization by sloughing off hyphae onto the surrounding organic matter, binding to clay and providing a hydrophobic coating (Pal and Pandey, 2014). Glomalin are positively correlated with aggregate stability and with carbon sequestration in the soil by protecting soil organic matter physically within aggregates (Riling *et al*., 1999). The glomalin protein produced by AMF has primary effect on improved nutrients management in soil are increase plant productivity, soil organic carbon and Biological activity of soil (Subbian *et al*., 2000). Chemical condition of soil after harvest of rice studied by Oladele & Awodan (2014) is shown in Table 4.

Phosphate solubilizing bacteria produces organic and inorganic acids like gulconic acid and ketogulconic acid which solubilize phosphorous (Nahas, 1996). Gluconic acid produces carboxyl and hydroxyl group these group will function as a chelating Fe^{2+}, Al^{3+} and Ca^{2+} this will lower the soil pH (Stephen *et al*., 2015). There is positive interaction between *Gluconacetobacter spp* and *Barkholderia spp* for increasing dehydrogenase activity in soil, dehygrogenages are involve in oxidation process of soil and good indicator of soil microbial activity (Stephen *et al*. 2015). It is the endo cellular enzyme which catalyzes organic matter present in soil (Pascual *et al*., 1998). *Azospirillum* improves soil biological properties by improving dehydrogenase activity (Singh, *et al*., 2015). Urease activity has been found to be increased by 2.8 folds over dark control (soil coated with polyvinyl chloride), dehygrogenase activity and phosphatase activity is increased by BGA inoculated soil which increase mineralization of organic matter in soil (Rao and Burns, 1990).

Table 3: Chemical analysis of soil inoculated *Azolla*

Days	pH	N%	P(ppm)	K(cmol/kg)	Ca%	mg%	Na(mol/kg)	OM%
zero	6.31	2.41	0.15	0.49	0.18	0.33	0.58	2.42
30 days	6.59	3.57	0.32	0.58	0.99	0.56	0.68	3.56
90 days	6.21	3.69	0.47	0.64	1.37	0.93	0.7	3.69

Source: (Bhuvaneswori & Kumar, 2013)

Table 4: Chemical condition of soil after harvest of rice

Treatments	N%	OM%	K(cmol/kg)	P(cmol/kg)	Mg9Cmol/kg)	Ca(cmol/kg)	Na(cmol/kg)	pH
Mycorrhiza	0.7	5.13	0.03	3.89	2	4.03	0.17	6.04
Rhizobium	0.83	5.48	0.02	4.69	1.2	2.3	0.04	5.55
Non inoculation	0.63	2.3	0.005	2.73	0.8	1.7	0.02	5.27

Source: (Oladele & Awodan, 2014)

Conclusion

Chemical fertilizer creates serious threats to environment and sustainable rice production. Our dependence upon foreign country for chemical fertilizer has traumatized rice producing farmers. This study spectacle that, biofertilizer improves yield, eco-friendly and maintain better soil health for sustainable rice production. They improve soil condition of rice field by maintaining chemical, physical and biological properties at its optimum level. Biofertilizer are cheaper and accessible to farmers, thus we recommend Government of Nepal and other concerned authorized body to make policy regarding mass multiplication and distribution of biofertilizer. This recommends Nepalese rice producing farmers to adopt the new technology.

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