A review: Usage of Biofertilizer in Cereal crops

[1]Bishnupriya Patra, [2]Jagdev Singh

Department of Agronomy, [1]Orrissa university of agriculture and technology,

[2]CCS Haryana Agricultural University, Hisar, India

E-mail:bishnupriya11patra@gmail.com

Abstract: Productivity of crops under various abiotic stress conditions can be increased through the application of suitable fertilizer levels along with biofertilizers. Nitrogen is one of the most important mineral nutrients for plants, influencing growth but the application of increased doses of N increases cost of production. Thus, there is a need to economies the nitrogen dose for various crops. While the use of biofertilizer inoculation is one way to save the nitrogen level in crops and it will help in reducing the cost of production as biofertilizer is a cheap source of nitrogen.

Key Words: Biofertilizers, Nitrogen, Growth, Yield, Quality, Economics

Introduction: Biofertilizer is a substance which contains living microorganisms which on application promotes growth of plant by increasing the availability of nutrients. These micro-organisms serve as a viable alternative to nitrogenous fertilizers and involve comparatively less cost. However, the productivity of wheat under late sown condition can be increased through the application of suitable fertilizer level along with biofertilizers. *Azotobactor*, a non symbiotic bio-fertilizer contributes about 20-25 kg N ha^{-1} in crop like wheat, maize, cotton and other crops under favorable conditions. *Phosphorus solubilizing bacteria* (PSB) can solubilize 20-30 per cent of insoluble phosphate and increase yield up to 20 per cent. If these two microorganisms interact favorably they may show synergistic effect to produce even better result than expected separately. Biofertilizers being cheaper, effective and environmental friendly are gaining importance for use in crop production (Kachroo and Razdan, 2006). Nitrogen-fixing bacteria such as *Azospirillum*, Vesicular arbuscular mycorrhizal (VAM) fungi improve plant growth through increased uptake of relatively immobile nutrients such as P, Zn, Cu etc. (Tarafdar and Rao., 1997). Other beneficial effects of VAM is their role in biological control of root pathogens, hormone production and greater ability to withstand water stress. *Azotobacter* is a free-living nitrogen fixing bacterium fixes annually 60-90 kg N ha^{-1}. Biomix is a unique blend of selected species of microbes which can solubilize residual phosphates, iron, magnesium etc. from soil making them more easily available to plants. Which stimulates sprouting and helps to increase water holding capacity of soil.

Nitrogen is one of the most important mineral nutrients for plants influencing growth, development, yield and protein content of grains (Heydari Sharifabad, 2012). It promotes shoot elongation, tillering and regeneration after defoliation and governs to considerable degree, the utilization of phosphorus, potassium and other elements in the plant. Nitrogen is the most limiting factor for high crop productivity but its use efficiency is low. Studies have shown that increasing nitrogen fertilizer application and frequent nitrogen top-dressing during the wheat-growing season are effective ways of improving wheat yield (Borghi *et al*., 1997). Increasing nitrogen fertilization is a common strategy to increase grain protein concentration in spring wheat (Van Herwaarden *et al.,* 1998; Guttieri *et al*., 2005) and winter wheat (Brown and Petrie, 2006).

But the excessive use of chemical fertilizers has some adverse effect on soil health and environment. Therefore, to achieve improved and sustainable soil fertility and crop yield, balanced and integrated application of chemical, biological and organic fertilizers should be a key factor.

Biofertilizers: Biofertiliser are the low cost source of plant nutrients, eco-friendly and have supplementary role with chemical fertilizers. Recently, the Potash mobilisers like Frateuria aurentia, Zinc & Sulphur solubilisers like thiobacillus species and manganese solubiliser fungal culture like pencillium citrinum have also been identified for commercial operations.

The bio-fertilizers were initially identified by a Dutch scientist in 1888 and thereafter 'Nobbe & Hiltner' produced for the first time under the trade name "Nitragin" in 1895 in USA. There has been a continuous effort made by various scientists, Govt. agencies & extension agencies after the first study on legume-Rhizobium symbiosis by NV Joshi in India as well. The usage was observed in Tamil- Nadu (1956) and among Soybean growers in Madhya Pradesh (1964).

Types of Biofertilizers: Biofertilizers include the following types:

1. Symbiotic Nitrogen Fixers Rhizobium spp.
2. Asymbiotic Free Nitrogen Fixers (Azotobacter)

3. Azospirillum

4. Algae Biofertilizers (Blue Green Algae or BGA in association with Azolla).

5. Phosphate Solubilising Bacteria.

6. Mycorrhizae.

Nitrogen fixing biofertilizers:

Freeliving- *Azotobacter, Beijerinickia, Clostridium, Klebsiella, Anabena, Nostoc.*

Symbiotic- *Rhizobium, Frankia, Anabena azollae*

Associative: *Azospirillum*

P Solubilizing Biofertilizers:

Bacteria: *Bacillus Circulans, B. subtilis, B. megathecium var. phosphaticum, Pseudomonas striata*

Fungi- *Penicillium sp., Aspergillus awamori*

P-Mobilizing Biofertilizers

Arbuscular mycorrhiza- *Glomus sp. Gigaspora sp. Sclerocysis sp.*

Ectomycorrhiza- *Loccaria sp., Pisolithus sp., Boletus sp., Amaniata sp.*

Ericoid mycorrhiza- *Pezizella ericae*

Orchid myccorhiza- *Rhizoctonia solani*

Micronutrient solubilizers:

Silicate & Zinc solubilizers- *Bacillus sp.*

Plant growth promoting Rhizobacteria: Pseudomonas fluoroscens.

Source: Entrepreurial Training Manual, The Professor and Head Department of Microbiology Tamil Nadu Agricultural University, Coimbatore-3

Discussion:

Effect of biofertilizers on biology and fertility of crop:

Biofertilizers are found to have positive contribution to soil fertility, resulting in an increase in crop yield without causing any environmental, water or soil pollution hazards. Nitrogen fixing and Phosphorus solubilizing bacteria play an important role in nitrogen mobilization and phosphorus solubilization for the benefit of plant growth.

Agrawal *et al.* (2004) reported that at 80 DAS, about 72.03% increase in nitrogen uptake over the control was recorded due to *Azotobacter* inoculation and it was at par with the addition of 20 kg N ha^{-1} alone. *Azotobacter* alone and 20 kg N ha^{-1} were statistically at par in affecting the nitrogen content in straw as well as in grain. Inoculation alone increased about 37.97, 39.17 and 37.37% phosphorus uptake over the control in the yields of straw, grain and total yield, respectively, whereas, potassium uptake was 95.25, 43.23 and 44.81%, respectively. Kachroo and Razdan (2006) reported that nitrogen use efficiency values were higher with combined inoculation of *Azotobacter* + *Azospirillum* in 1:1 in wheat. Grain N content of wheat increased in response to increasing rates of nitrogen application (Campbell *et al*., 1993). Similarly, Kader *et al.* (2002) reported that the highest N uptake (23.2 mg $plant^{-1}$) was recorded with the treatment having 168 kg N ha^{-1} + cowdung + *Azotobacter* and the lowest with the control (11.03 mg $plant^{-1}$) in wheat.

Higher N (33.6 mg $plant^{-1}$) and P (67.8 mg $plant^{-1}$) content in wheat plants were observed with the co-inoculation of *A. chroococcum* with *Bacillus sp.* and *G. fasciculatum* (Khan and Zaidi, 2007). Suri and Choudhary (2010) reported that inoculation with TERI VAM culture *(Glomus intraradices)* showed its superiority over other two VAM cultures in terms of productivity and nutrient uptake in wheat though differences were non-significant amongst the VAM cultures alone or at each P level. Patil *et al*. (2015) reported that plants inoculated with AM fungi and PSB in sterilized soil significantly increased P uptake in shoot and root in sorghum. Nishant *et al.* (2016) reported that addition of 100% NPK (RDF-recommended dose of fertilizer i.e 120:60:40 kg NPK ha^{-1} recorded significantly higher value of nutrient uptake and nitrogen, phosphorous and potash content in wheat grain which was at par with the 75% NPK + 1 t ha^{-1} vermicompost + *Azosprillium*. Integration of 75% NPK + 1 t ha^{-1} vermicompost + *Azosprillium* found more productive as it maintains or improves the soil health.

Emergence, phenology and plant growth parameters:

Azotobacter inoculation enhanced seed germination, growth and development of cereal crops. The nitrogen requirement of cereal crops could be reduced by *Azotobacter* inoculation (Singh, 2006). Kushare *et al*. (2009) and Singh *et al*. (2016) reported that *Azotobacter* and PSB inoculation, being at par caused significant improvement in the growth and yield attributes over control. Co-inoculation of both the biofertilizers further increased the growth and yield attributes over individual inoculation in wheat.

Minaxi *et al.* (2013) reported that significant increase in growth, yield and nutrient uptake of wheat plants was noticed by both strains of PSB (BAM-4, BAM-12) interacted positively with AM fungi towards all growth parameters. A remarkable enhancement of seed yield was recorded notably by 92.8%. Singh *et al.* (2013) reported that seed inoculation with *Azotobacter* and *Azospirillum* significantly increased the plant height, dry matter of wheat over no inoculation. However, both were at par with respect to above-mentioned parameters.

Patil *et al*. (2015) reported that plants inoculated with AM fungi and PSB in sterilized soil produced significantly higher growth, dry matter, increased per cent root colonization, chlorophyll content in leaves. A synergistic effect was recorded with increased plant dry matter, per cent root colonization in *Sorghum vulgare* Pers. plants with both the inoculants in sterilized soil compared to unsterilized soil.

Effect of Biofertilizers on use of Commercial fertilizers

Integrated treatments with biofertilizer and nitrogen showed better performance in terms of shoot length by 31.9% compared to separate treatments in wheat (Saber *et al.,* 2012). Singh *et al.* (2013) observed that combination of *Azotobacter* strain (Azo-8) along with urea (60 kg N ha^{-1}), FYM (40 kg N ha^{-1}), resulted in more than 23 and 36% increase in shoot fresh and dry weight, 26 and 38% increase in root fresh and dry weight of wheat crop over control regularly.

Mane *et al.* (2014) reported that the application of 125% RDF (80:40:40 kg NPK ha^{-1}) + *Azotobacter* + PSB recorded significantly higher plant height, number of effective tillers per plant of wheat than all other treatments. Khandare (2015) reported that soil application of carrier biofertilizer at 10 kg ha^{-1} and liquid biofertilizer at 0.625 and 1.25 L ha^{-1} in combination with 75% NP gave significantly more plant height in wheat over 75% NP alone at different intervals. These treatments were at par with 100% NP alone in plant height.

Combined application of biofertilizer and nitrogen increased grain number per spike and tiller number by 35.57 and 35.1% compared to separate treatments, respectively (Saber *et al.*, 2012). Beheraa and Rautaray (2010) reported that biofertilizers + 50% NPK increased grain yield of wheat marginally (2–6%) compared to the 50% NPK. However, straw yields were significantly higher under the former treatment. Singh *et al.* (2013) observed that combination of *Azotobacter* strain (Azo-8) along with urea (60 kg N ha^{-1}), FYM (40 kg N ha^{-1}), resulted in 39% increase in test weight of seeds and 27% increase in yield of wheat crop over control.

Mane *et al.* (2014) reported that the application of 125% RDF (80:40:40 kg NPK ha^{-1}) + *Azotobacter* + PSB recorded significantly higher panicle length, dry matter per plant, number of spikelets per panicle, number of grains per panicle, weight of grains per panicle, grain yield, straw yield and biological yield of wheat than all other treatments. Khandare (2015) reported that soil application of carrier biofertilizer at 10 kg ha^{-1} and liquid biofertilizer at 0.625 and 1.25 L ha^{-1} in combination with 75% NP gave significantly more grain and straw yields in wheat. The trend observed in grain and straw yields was also observed in various yield attributes *viz.*, total tillers, effective tillers, ear length, and number of spikelet/ear, number of grains/ear and 1000 grain weight.

Nitrogen saving: Kader *et al.* (2002) reported that *Azotobacter* alone or in combination with urea nitrogen had some beneficial effect on the yield of wheat, which amounted to saving about 20% of urea N. Agrawal *et al.* (2004) reported that inoculation of *Azotobacter* could save about 20 kg fertilizer nitrogen in wheat crop. Kushare *et al.* (2009) reported that 25% saving in nitrogen and phosphorus application could be possible with combined inoculation of *Azotobacter* + PSB in wheat.

Narula *et al.* (2005) reported that a net saving of 25–30 kg nitrogen by using chosen bio-inoculants (*Azotobacter*) in wheat crop. Saber *et al.* (2012) reported that biofertilizers significantly reduced P and N fertilizer application without any reduction in yield related parameters of wheat. Yadav *et al.* (2014) revealed that application of inorganic N fertilizer may be reduced by 66.7% with integrated use of 40 kg N + 5 t FYM + 5 kg biofertilizer ha^{-1} in late sown wheat crop. Kaur *et al*. (2016) reported that agronomic use efficiency was significantly similar at 120 and 150 kg N ha^{-1} than other nitrogen levels. Therefore, there is need to save nitrogen fertilizers in soils with low nitrogen availability.

Contribution of biofertilizers on crop yield and Economics:

Inoculation of AM fungi and AM fungi + *Azotobacter* led to increase in peduncle length, flag leaf area, number of grains $spike^{-1}$, 250 grain weight, grain and biological yields $plant^{-1}$ in wheat. AMF and *Azotobacter* complement each other and resulted in improved plant growth

(Behl *et al.,* 2003). Kader *et al.* (2002) reported that there was 18% increase in grain yield in wheat due to *Azotobacter* inoculants over the control. Suri and Choudhary (2010) reported that inoculation with either of 3 VAM cultures with increasing P levels from 50 to 75% of recommended phosphorus dose resulted in consistent and significant improvement in grain protein content, grain and straw yield and nutrient uptake in wheat.

In wheat crop, combined inoculation of *Azotobacter* + *Azospirillum* in 1:1 ratio increased the growth, yield attributes and yield significantly (Kachroo and Razdan, 2006; Singh *et al.,* 2013). Khan and Zaidi (2007) reported that the triple inoculation of *Azotobacter chroococcum* with *Bacillus* and *Glomus fasciculatum* significantly increased the dry matter by 2.6-fold above the control, grain yield of plants 2-fold higher, increased N and P concentrations, and quality of wheat grains than that of non-inoculated plants.

Single application of *Azotobacter* and Mycorrhiza inoculation and in combination to each other increased significantly spike per square meter compared to without inoculation treatment in wheat. Interaction effects of biofertilizers and N sources were significant in respect of spike per square meter. Maximum kernel weight was found in *Azotobacter* and *Azotobacter* + Micorrhiyza (Bahrani *et al.,* 2010). Milošević *et al.* (2012) reported that in *Azotobacter chroococcum* treatment, depending on variety of wheat and fertilizer treatment, increased the energy of germination by 1 to 9% and seed viability by 2 to 8%. The largest increase in 1000-seed weight was obtained in case of the cultivar Renesansa, in the variant without N application (16%). The highest yield increase (74%) was registered in the case of the cultivar Zlatka when inoculated and treated with 50 kg ha^{-1} of urea.

Application of biofertilizers increased grain yield of wheat and harvest index as much as 46.6 and 48.8% compared to control, respectively (Saber *et al.,* 2012). Narula *et al.* (2005) reported impact of *Azotobacter* in improving yield, dry weight, plant growth under field conditions. Pronounced effects were seen by the use of bio-inoculants in wheat crop. Singh *et al*. (2016) reported that *Azotobacter* and PSB inoculation, being at par, caused significant improvement in the growth and yield attributes over control in wheat.

The crude protein content increased and total carbohydrate content decreased significantly in seed with the application of nitrogen + *Azotobacter* in all the cultivars of wheat. The highest protein content was found with 100 kg N ha^{-1} + 1 kg *Azotobacter* treatment (Sharma and Bhatnagar, 2005). Khan and Zaidi (2007) reported that the multiple inoculations with plant growth promoting rhizobacteria showed maximum increase in grain protein (255.2 mg g^{-1}) in wheat plants. Bahrani *et al.* (2010) reported that *Azotobacter* + Micorrhiyza treatment increased grain protein by 13% than control. Nishant *et al.* (2016) reported that addition of 100% NPK (RDF-recommended dose of fertilizer i.e 120: 60: 40 kg NPK ha^{-1} recorded significantly higher yield in wheat in terms of biological yield and grain yield (q ha^{-1}), followed by 75% NPK + 1 t ha^{-1} vermicompost + *Azosprillium*.

Kushare *et al.* (2009) reported that application of 60:30 kg N:P ha^{-1} (75% RDF) coupled with combined inoculation registered significantly higher grain yield (30.96 q ha^{-1}) of wheat with higher net profit, B:C than those with 80:40 kg N:P ha^{-1} (100% RDF) (30 q ha^{-1} grain yield) without biofertilizer inoculation. Chand *et al.* (2014) revealed that the application of NPK at 120:60:40 kg ha^{-1} with seed treatment of *Azotobactor* at 200 g kg $seed^{-1}$ and PSB at 2.5 kg mix with 60 kg FYM applied in the soil before sowing improved the grain yield of wheat by 29.3% followed by 18.1% in application of NPK at 120:60:40 kg ha^{-1} with seed treatment of *Azotobactor* at 200 g 10 kg $seed^{-1}$ over Farmers practice (control). The corresponding values of net returns were Rs. 50390 ha^{-1} and Rs. 43650 ha^{-1} as compared to Rs. 32865 ha^{-1} in control and also the B:C were more as compared to control. Yadav *et al.* (2014) revealed that integrated use of 40 kg N ha^{-1}+ 5 t ha^{-1} FYM + 5 kg ha^{-1} biofertilizer (*Azotobacter*) produced highest grain yield (36.29 q ha^{-1}) in wheat and earned maximum net income (Rs. 24641 ha^{-1}) and it was at par with integration of 40 kg N ha^{-1} + 5 t ha^{-1} FYM + 5 kg ha^{-1} *Azospirilium* (35.66 q ha^{-1} grain yield and Rs. 23864 ha^{-1} net income) followed by application of 120 kg N ha^{-1} (34.89 q ha^{-1} grain yield and Rs. 23173 ha^{-1} net income).

Verma *et al*. (2015) reported that plots receiving recommended dose of fertilizer (RDF) + vermicompost 5 t ha^{-1} + *Azotobacter* and PSB as seed treatment of wheat and spraying at first and second irrigation recorded maximum grain yield (5.67 and 5.73 t ha^{-1}), straw yield (7.29 and 8.87 t ha^{-1}), gross income (Rs. 87443 and 97127 ha^{-1}) and net income (Rs. 37001 and 45462 ha^{-1}) during 2011-12 and 2012-13, respectively. Kumar *et al*. (2016) reported that application of half of the recommended dose of N and P_2O_5 i.e., 60 kg N along with 30 kg P_2O_5 ha^{-1} supplemented with seed treatment of wheat by *Azotobactor* and phosphate culture, produces a mean wheat yield of 39.10 q ha^{-1} which is much more economical (2.69 kg grain rupee $invested^{-1}$) in terms of grain produced per rupee invested in fertilizers with bio-fertilizers as compared to the plot where recommended dose of fertilizers (1.65 kg grains rupee invested^{-1}) were applied in the form of chemical fertilizers only in both the years.

Jilani *et al.* (2007) revealed that integration of half dose of NP fertilizer with Biopower+Biological potassium fertiliser/ Effective Microorganisms can give similar crop yield as with full rate of NP fertilizer; and through reduced use of fertilizers the production cost is minimized and the net return maximized. G. Barrett and S. Marsh ()Biofertiliser has the potential to increase rice yield and decrease the use of chemical fertilisers. Farmers in Ha Tay province reported yield increases of up to 20% in field trials using biofertiliser, as compared to conventional chemical fertiliser treatment. This practice increased average farm income substantially

Limitation of Bio-Fertilizer :

- Unavailability of suitable strain due to lack of availability of specific strain
- Unavailability of suitable carrier: As per suitability, the order is peat, lignite, charcoal, farmyard manure, soil, rice bran.
- Lack of awareness among farmers: They are unaware of the damages caused on the ecosystem by continuous application of inorganic fertilizer.
- Inadequate human resources and inexperienced staff
- bio-fertilizer is their nutrient content when compared to inorganic fertilizers. This might result to deficiency symptoms in plants grown with the bio-fertilizer.
- Environmental constraints: Soil characteristics like salinity, acidity, drought; water logging affects the use of bio-fertilizers.

Mahimairaja *et al.* (2008) stated that the addition of phosphorus to wastes makes the bio-fertilizer more balanced and reduces nitrogen losses. Again storage of bio-fertilizer goes a long way in affecting its efficacy. Even though bio-fertilizer has many positive aspects, its use can sometimes not lead to the expected positive results and this could be because of exposure to high temperature or hostile conditions before usage. Bio-fertilizer should be stored at room temperature or in cold storage conditions away from heat or direct sunlight and polythene bags used in packaging bio-fertilizer should be of low density grade with a thickness of about 50 –75 microns (Mishra *et al*., 2010). Other constraints limiting the use of biofertilizer technology may be environmental, human resource, unawareness, unavailability of suitable strains, and unavailability of suitable carrier and so on (Ritika et al., 2014). Short shelf life, lack of suitable carrier material, susceptibility to high temperature, problem in transportation, and storage are biofertilizers bottlenecks that still need to be solved in order to obtain effective inoculation (Chen, 2006).

Conclusion: Biofertilizers are found to have positive contribution to soil fertility, resulting in an increase in crop yield without causing any environmental, water or soil pollution hazards. Nitrogen occupies a conspicuous place in plant metabolism because adequate supply of this nutrient associated with high photosynthetic activity, vigorous vegetative growth and a dark green color among cereal crops. From this review it was known that biofertilizer along with nitrogen will meet the increasing demand of this growing world, also biofertiliser will reduce the hazards due to excess use of inorganic fertilizers.

References:

Agrawal, N., Singh, H.P. and Savita, U.S. Effect of *Azotobacter* inoculation and graded doses of nitrogen on the content, uptake and yield of wheat in a mollisol. Indian Journal of Agricultural Research. 2004;**38** (4): 288-292.

Bahrani, A., Pourreza, J. and Hagh Joo, M. Response of winter wheat to co-inoculation with *Azotobacter* and *Arboscular Mycorrhizal Fungi* (AMF) under different sources of nitrogen fertilizer. American-Eurasian Journal of Agriculture & Environmental Science. 2010; **8** (1): 95-103.

Barrett, G. and Marsh, S. An economic analysis of inoculant biofertiliser production and use in Vietnam. Biofertilisers in action., A report for the Rural Industries Research and Development Corporation. 2002:102-111

Beheraa, U.K. and Rautaray, S.K. Effect of biofertilizers and chemical fertilizers on productivity and quality parameters of durum wheat (*Triticum turgidum*) on a Vertisol of Central India. Archives of Agronomy and Soil Science. 2010; 56 (1): 65-72.

Behl, R.K., Sharma, H., Kumar, V. and Singh, K.P. Effect of dual inoculation of VAM and *Azotobacter chroococcum* on above flag leaf characters in wheat. Archives of Agronomy and Soil Science.2003*;* 49 **:** 25-31.

Borghi, B., Corbellini, M., Minoia, C., Palumbo, M., Difonzo, N. and Perenzin, M. (1997) Effects of mediterranean climate on wheat bread-making quality. *Eur J Agron.* **6**: 145-154.

Brown, B.D. and Petrie, S. (2006) Irrigated hard winter wheat response to fall spring and late season applied nitrogen. *Field Crops Res.* **96**:260-268.

Chen J. The combined use of chemical and organic fertilizer and or bio-fertilizer for crop growth and soil fertility. International Workshop on sustained management of the Soil-rhizosphere system for efficient crop production and fertilizer use. 2006;37-43.

Ezigbo U. Studies on the production of biogas from droppings and cow dung. Unpublished B.Sc. Thesis Department of Botany. University of Jos. 2005;110-26.

Guttieri, M.J., McLean, R. and Souza, E. Managing irrigation and nitrogen fertility of hard spring wheat for optimum bread and noodle quality. Crop Science. 2005;45: 2049-2059.

Heydari, Sharifabad H. (2012) Crop physiology. Mashhad: Astan Quds Razavi (Behnashr).

Jackson, M.L. Soil chemical analysis.Prentice Hall of India Pvt. Ltd., New Delhi. 1973; 214-221.

Jakhar, P. Effect of planting methods, biofertilizers and nitrogen levels on wheat. MSc. Thesis submitted to CCS HAU, Hisar 2004.

Jilani, G., Akram, A., Ali, R.M., Hafeez, F.Y., Shamsi, I.H., Chaudhry, A.N., Chaudhry, A.G., Enhancing crop growth, nutrients availability, economics and beneficial rhizosphere microflora through organic and biofertilizers. Annals of Microbiology, 2007, 57(2):177–184

Kachroo, D. and Razdan, R. Growth, nutrient uptake and yield of wheat (*Triticum aestivum*) as influenced by biofertilizers and nitrogen. Indian Journal of Agronomy. 2006;51 (1): 37-39.

Kader, M.A., Milan, M.H. and Hoque, M.S. Effects of *Azotobacter* innoculant on the yield and nitrogen uptake by wheat. Online Journal of Biological Science. 2002;2 (4): 259-261.

Khan, M.S. and Zaidi, A. Synergistic effects of the inoculation with plant growth-promoting rhizobacteria and an arbuscular mycorrhizal fungus on the performance of wheat. Turkish Journal of Agriculture. 2007;31: 355-362.

Khandare, R.N., Chandra, R., Pareek, N. and Raverkar, K.P. Effect of varying rates and methods of carrier based and liquid *Azotobacter* and PSB biofertilizers on yield and nutrient uptake by wheat (*Triticum aestivum* L.) and soil properties. Journal of Indian Society of Soil Science. 2015;63 (4): 436-441.

Kumar, A., Singh C.B. and Raj, R. Biofertilizer a potent supplement of N and P fertilizers in economical and sustainable wheat cultivation in NEPZ. Journal of Community Mobilization and Sustainable Development. 2016;11(1): 122-126.

Kushare, B.M., Kushare, Y.M. and Sandhan, V.S. Effect of N and P levels and biofertilizers on the growth and yield of wheat under late sown irrigated conditions. International. Journal of Agricultural Science. 2009; 5(2): 424-427.

Mahimaraja S, Dooraisamy P, Lakshmanan A, et al. Composting technology and organic waste utilization. Journal of Science. 2008;1(3):332-560.

Mane, A.R., Karanjikar, P.N. and Wayase, K.P. Performance of late sown wheat (*Triticum aestivum* L.) as influenced by different levels of fertilizers along with biofertilizers. Advance Research Journal of Crop Improvment. 2014;5 (2): 197-199.

Milošević, N., Tintor, B. and Cvijanović, G. Effect of inoculation with *Azotobacter chroococcum* on wheat yield and seed quality. International conference: conventional and molecular breeding of field and vegetable crops. Romanian Biotechnological Letters. 2012; 17(3): 7352-7357.

Minaxi, Saxena, J., Chandra, S. and Nain, L. Synergistic effect of phosphate solubilizing rhizobacteria and arbuscular mycorrhiza on growth and yield of wheat plants. Journal of Soil Science & Plant Nutrition. 2013; 13(2), http://dx.doi.org/10.4067/S0718-95162013005000040.

Mishra BK, Dadhick SK. Methodology of Nitrogen bio-fertilizer production unpublished B.Sc. Thesis. Department of Molecular and Biotechnology RCA Udaipur. 2010;4-16.

Narula, N., Kumar, V., Singh, B., Bhatia, R. and Lakshminarayana, K. Impact of biofertilizers on grain yield in spring wheat under varying fertility conditions and wheat-cotton rotation. Archives of Agronomy & Soil Science. 2005; 1(1): 79-89.

Nishant, Vivek; Singh, V., Sharma, D.K. and Raju Influence of organic and inorganic sources on nutrient uptake and yield of wheat (*Triticum aestivum* l.) in western Uttar pradesh. Progressive Agriculture. 2016; 16 (2): 223-228.

Patil, G.B., Lakshman, H.C. and Puttaradder, J. Synergistic effect between phosphate solubilising bacteria and Arbuscular Mycorrhizal Fungi on growth and P uptake in *Sorghum vulgare* Pers. International Journal of Research in Engineering and Applied Science. 2015; 5, ISSUE 10.

Ram, T., Yadav, S.K. and Sheoran, R.S. Growth analysis of wheat *(Triticum aestivum* l.) under varying fertility levels and *Azotobacter* strains. *Indian* Journal of Agricultural Research. 2005; 39 (4): 295-298.

Ranwa, R.S. Studies on integrated nutrient management with vermicompost in wheat. Ph. D. Thesis submitted to CCS HAU, Hisar, 1997.

Ritika B, Uptal D. Bio-fertilizer a way towards organic agriculture: A Review. Academic Journals. 2014;8(24):2332-42.

Saber, Z., Pirdashti, H., Esmaeili, M., Abbasian, A. and Heidarzadeh, A. Response of wheat growth parameters to co-inoculation of plant growth promoting rhizobacteria (PGPR) and different levels of inorganic nitrogen and phosphorus. World Applied Science Journal. 2012; 16 (2): 213-219.

Sharma, J. and Bhatnagar, V.P. Effect of nitrogen levels along with A*zotobacter* on crude protein and carbohydrate contents in seed of wheat cultivars**.** Agriccultural Science Digest. 2005; 25 (3): 170-173.

Singh, M.P., Kumar, P., Kumar, A., Kumar, R., Diwedi, A., Gangwar, S., Kumar, V. and Sepat, N.K. Effect of NPK with biofertilizers on growth, yield and nutrient uptake of wheat (*Triticum aestivum* l.) in western Uttar pradesh condition. Progressive Agriculture. 2016; 16 (1): 83-87.

Singh, M.S. Cereal crops response to azotobacter - A review. Agricultural. reviews. 2006; 27 (3): 229-231.

Singh, N.K., Choudhary, F.K. and Patel, D.B. Effectiveness of Azotobacter bio-innoculant for wheat grown under dry land condition. Journal of Environmental Biology, 2013; 34: 927-932.

Singh, V., Singh, S.P., Singh, S. and Shivay, Y.S. Growth, yield and nutrient uptake by wheat (*Triticum aestivum*) as affected by biofertilizers, FYM and nitrogen. Indian Journal of Agricultural. Science. 2013; 83 (3): 331-4, March 2013/A

Singhal, S.K., Sharma, V.K. and Singh, R.D. Effect of inorganic and biofertilizers (vam and psb) on yield of maize and wheat cropping sequence and soil fertility. *Indian journal of agricultural. research.* 2012; **46** (2): 167-172.

Suri, V.K. and Choudhary, A.K. Comparative performance of va-mycorrhizal (vam) fungi and applied phosphorus in wheat under controlled environment in a phosphorus deficient acid alfisol. Progressive Agriculture. 2010; 10 (1): 23-28.

Sushila, R. and Giri, G. Influence of FYM, nitrogen and biofertilizers on microbial population, dry matter accumulation and nutrient uptake of wheat under limited water supply. Biofertiliser Newsletter. 2000; 7: 22-26.

Tarafdar, J.C. and Rao, A.V. Response of arid legumes of VAM fungal inoculation. Symbiosis, 1997; 22: 265-274.

Tulasa Ram. Performance of *Azotobacter* under different fertility levels in wheat (*Triticum aestivum* L.). Ph.D. thesis submitted to CCS HAU, Hisar, 1999.

Van Herwaarden, A.F., Farquhar, G.D. and Howe, G.N. Haying-off' the negative grain yield response of dryland wheat to nitrogen fertilizer. I Biomass grain yield and water use. Australia Journal of Agricultural Research. 1998; 49:1067-1081.

Verma, V.K., Singh, V., Chaudhary, S., Tripathi, A.K. and Srivastava, A.K. Effect of organic manures and microbial inoculants superimposed over inorganic fertilizers on production and profitability of wheat (*Triticum aestivum*). Current Advance in Agricultural Science.2015; 7(2): 129-132.

Woldeyesus Sinebo., Gretzmacher, R. and Edelbaue, A. Genotypic variation for nitrogen use efficiency in Ethiopian barley. Field Crops Research. 2004; 85: 43-60.

Yadav, S.M., Singh, R., Kumar, H., Khan, N., Verma, S.P., Shweta; Yadav, B.K. and Kumar, S. (2014) Response of late shown wheat (*Triticum aestivum*) to FYM, biofertilizers and inorganic N alone and in different combinations. Plant Archieves. 2014; 14 (2): 1127-1129.