# Response of Wheat to Biofertiliser and Nitrogen treatments - A Review

**Abstract:** Productivity of wheat under late sown condition can be increased through the application of suitable fertilizer level 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 economise the nitrogen dose for late sown wheat. While use of biofertilizer inoculation is one way to save the nitrogen level in wheat and it will help in reducing the cost of production as biofertilizer is a cheap source of nitrogen.

**Key Words:** Wheat, 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 solublizing bacteria* (PSB) can solublize 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 sp. of microbes which can solubilise residual phosphates, iron, magnesium etc. from soil making them more easily available to plants. It 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 had 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.

**Discussion:**

**Effect of biofertilizers**

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.

## 1.1 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.

## 1.2 Yield and yield attributes

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* compliment each other and result 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 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 metre compared to without inoculation treatment in wheat. Interaction effects of biofertilizers and N sources were significant in respect of spike per square metre. Maximum kernel weight was found in *Azotobacter* and *Azotobacter* + Micorrhiyza (Bahrani *et al.,* 2010). Milošević *et al.* (2012) reported that in *A. 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.

## 1.3 Quality parameters

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.

## 1.4 NPK content and uptake

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.

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.

**Effect of nitrogen levels**

### 2.1 Growth parameters

Ram *et al.* (2005) revealed that increase in nitrogen level up to 120 kg $ha^{-1}$ caused a significant increase in growth parameters like plant height, leaf area index and dry matter accumulation in wheat. The growth is significantly higher with the application of 10 t organic manure + 90 kg N $ha^{-1}$ over 120 kg N $ha^{-1}$ but remained at par with 150 kg N $ha^{-1}$. Hussain *et al*. (2006) showed that different nitrogen levels had significant effects on wheat plant height, total number of plants $m^{-2}$. Maximum plant height and total number of plants $m^{-2}$ were observed at 200 kg N $ha^{-1}$.

Kachroo and Razdan (2006) reported that each unit increase in N level led to significant increase in growth in wheat. Kumar *et al.* (2007) reported that increasing nitrogen levels increased the plant height, tiller numbers $m^{-1}$, leaf number $plant^{-1}$ and dry matter accumulation in wheat up to 200 kg N $ha^{-1}$ which was significantly higher than control.

Patel *et al*. (2012) reported that amongst nitrogen levels, the maximum nitrogen fertilized wheat crop (120 kg N $ha^{-1}$) had higher value of growth attributes *viz.*, plant height and number of leaves $plant^{-1}$ than lower nitrogen levels. Kaur *et al.* (2015) reported that physiological parameters namely plant height and tiller number increased with increase in nitrogen dose (150 kg N $ha^{-1}$) in wheat.

### 2.2 Yield and yield attributes

Increase in nitrogen levels up to 120 kg $ha^{-1}$ caused a significant increase in grain yield in wheat. The grain yields were significantly higher with the application of 10 t organic manure + 90 kg N $ha^{-1}$ over 120 kg N $ha^{-1}$ but remained at par with 150 kg N $ha^{-1}$ (Ram *et al.*, 2005). Patel *et al.* (2012) reported that amongst nitrogen levels, the maximum nitrogen fertilized wheat crop

(120 kg N ha$^{-1}$) had higher value of yield attributes *viz*., number of grains spike$^{-1}$, spike length and yield *viz*., grain, straw and biological yields than lower nitrogen levels. Similarly, Singh *et al.* (2013) reported that application of 120 kg N ha$^{-1}$ increased the growth, yield attributes and yield of wheat. The mean grain yield increased by 8.1 and 22.4% with the application of 120 kg N ha$^{-1}$ compared with 90 and 60 kg N ha$^{-1}$, respectively. These findings in wheat crop are in consonance with those of Kaur *et al*. (2016) who reported that the yield attributes and grain yield of wheat were highest under 150 kg N ha$^{-1}$. With increase in nitrogen level up to 120 kg N ha$^{-1}$, there was significant increase in grain yield which was statistically on par with 150 kg N ha$^{-1}$.

Different nitrogen levels had significant effect on number of grains spike$^{-1}$, number of spike m$^{-2}$, spike weight, biological yield, grain yield and grain protein content of wheat. Maximum number of spikes m$^{-2}$, spike weight, biological yield and grain protein content were observed at 200 kg N ha$^{-1}$ (Hussain *et al*., 2006; Kumar *et al.*, 2007). Kachroo and Razdan (2006) reported that each unit increase in N level led to significant increase in yield-attributing characters and yield of wheat. The maximum grain yield (53.55 q ha$^{-1}$) was recorded with highest N level. Pandey *et al.* (2014) reported that significantly higher number of effective tillers m.r.l$^{-1}$, spike length, grain spike$^{-1}$, grain yield and straw yield of wheat were recorded due to application of 150 kg N ha$^{-1}$. Similarly, Kaur *et al.* (2015) reported that physiological parameters namely spikelet number, grain yield, thousand grain weight and biomass of wheat increased with increase in nitrogen dose.

Beheraa and Rautaray (2010) reported that the grain and straw yields of wheat were higher under recommended fertilizer dose (100% NPK) than under 50% NPK. Narolia *et al.* (2016) reported that 125% RDF registered significantly higher growth and yield attributes, grain yield (4.04 t ha$^{-1}$), net returns (54,058 Rs. ha$^{-1}$) and all the efficiency indices of wheat. However, significant improvement in straw yield was observed up to 150% RDF. Maximum harvest index were found only with 100% RDF (RDF 120 kg ha$^{-1}$ N, 40 kg ha$^{-1}$ $P_2O_5$ and 30 kg ha$^{-1}$ K). Singh *et al*. (2016) reported that the growth and yield attributes showed an increase with increase in the NPK fertilizer levels. In wheat significantly highest grain yield (54.10 q ha$^{-1}$) and straw yield (79.69 q ha$^{-1}$) were recorded with 125% RDF. 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*.

## 2.3 Quality parameters

Hussain *et al*. (2006) showed that different nitrogen levels had significant effects on grain protein content. The grain protein content and yield of wheat increased significantly at 200 kg N $ha^{-1}$ compared to dose of 150 kg N $ha^{-1}$. Pandey *et al.* (2014) reported that significantly higher protein content (12.58%) was recorded due to application of 150 kg N $ha^{-1}$ in wheat. Similarly, Kaur *et al*. (2016) reported that the quality parameters of wheat were highest under 150 kg N $ha^{-1}$.

Beheraa and Rautaray (2010) reported that wheat protein and β-carotene contents were higher and the hectoliter weight was lower with 100% NPK as compared to 50% NPK. Yield, quality parameters and net returns were the lowest under the unfertilized control. Massoudifar *et al.* (2014) reported that nitrogen fertilization increased some quality characteristics of wheat.

## 2.4 NPK content and uptake

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. Woldeyesus *et al.* (2004) and Muurinen (2007) reported significant increase in straw nitrogen uptake with increased N rates in spring cereals. Singh *et al.* (2013) reported that the uptake of N, P and K by wheat grain and straw showed increasing tendency with the application of 120 kg N $ha^{-1}$ compared with 90 and 60 kg N $ha^{-1}$.

Pandey *et al.* (2014) reported that significantly higher uptake of N (123.34 kg $ha^{-1}$), P (22.81 kg $ha^{-1}$) and K (109.29 kg $ha^{-1}$) and higher agronomic use efficiency were recorded due to application of 150 kg N $ha^{-1}$ in wheat. Narolia *et al.* (2016) reported that 125% RDF registered significantly higher N, P and K uptake by grain and straw of wheat. 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.

**Integrated effect of biofertilizers and nitrogen levels**

## 3.1 Growth parameters

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 per cent 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.

## 3.2 Yield and yield attributes

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.

### 3.3 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.

### 3.4 Economics:

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 @ 120:60:40 kg $ha^{-1}$ with seed treatment of *Azotobactor* @ 200 g kg $seed^{-1}$ and PSB @ 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 @ 120:60:40 kg $ha^{-1}$ with seed treatment of *Azotobactor* @ 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.

**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 Biofertiliser along with nitrogen will meet the increasing demand of this growing world, also biofertiliser will reduce the hazards dueto excess use of inorganic fertilizers.

**References:**


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

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

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

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

Campbell, C., Selles, F., Zentner., R. and McConkey, B. (1993) Available water and nitrogen effects on yield components and grain nitrogen of zero-till spring wheat. *Agron. J.* **85**: 114-120.

Chand, M., Gupta, J. and Roy, N. (2014) Effect of integrated nutrient management module on wheat yield in bundelkhand zone of Uttar Pradesh. *Bhartiya Krishi Anushandhan Patrika,,* **29**(1): 01-04.

Gupta, Trilok Chand. (2002) Integrated nutrient management in wheat (*Triticum aestivum* L.). Ph. D. Thesis submitted to CCS HAU, Hisar.

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

Hussain, I., Khan, M.A. and Khan, E.A (2006) Bread wheat varieties as influenced by different nitrogen levels. *J. Zhejiang Univ. sci. B.* **7**(1): 70-78.

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

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

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

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

Kaur, G., Asthir, B. and Bains, N.S. (2015) Nitrogen levels effect on wheat nitrogen use efficiency and yield under field conditions. *Afr. J. Agric. Res.* **10** (23): 2372-2377.

Kaur, H., Ram, H., Sikka, R. and Kaur, H. (2016) Productivity, agronomic efficiency and quality of bread wheat [*Triticum aestivum* (L.)] cultivars in relation to nitrogen. *IJAEB*: **9**(1): 101-106.

Khan, M.S. and Zaidi, A. (2007) Synergistic effects of the inoculation with plant growth-promoting rhizobacteria and an arbuscular mycorrhizal fungus on the performance of wheat. *Turk. J. Agric.* **31**: 355-362.

Khandare, R.N., Chandra, R., Pareek, N. and Raverkar, K.P. (2015) 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. *J. Indian Soc. Soil Sci.* **63** (4): 436-441.

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

Kumar, Rajesh. (2001) Effect of planting systems, seed rates and nitrogen levels on the wheat productivity (*Triticum aestivum* L.). Ph. D. Thesis submitted to CCS HAU, Hisar.

Kumar, S., Singh, K. and Jatav, A.L. (2007) Effect of nitrogen levels on growth and yield of recently released wheat variety malviya 468 under late sown condition. *Prog. Agric.* **7** (1/2): 25-27.

Kushare, B.M., Kushare, Y.M. and Sandhan, V.S. (2009) Effect of N and P levels and biofertilizers on the growth and yield of wheat under late sown irrigated conditions. *Intern. J. Agric. Sci.* **5**(2): 424-427.

Lindner, R.C. (1944) Rapid analytical methods for some of the more common inorganic constituents of plant tissues. *Plant Physiology,* **19,** 76-86.

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

Massoudifar, O., Kodjouri, F. D., Mohammadi, G. N. and Mirhadi, M. J. (2014) Effect of nitrogen fertilizer levels and irrigation on quality characteristics in bread wheat (*Triticum aestivum* L.). *Arch. Agron. and Soil Sci.* **60**(7): 925-934.

Milošević, N., Tintor, B. and Cvijanović, G. (2012) 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*. **17**(3): 7352-7357.

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

Muurinen, S. (2007) Nitrogen dynamics and nitrogen use efficiency of spring cereals under Finnish growing conditions. *Yliopistopaino,* **29**: 1-38.

Narolia, R.S., Meena, H., Singh, P., Meena, B.S. and Ram, B. (2016) Effect of irrigation scheduling and nutrient management on productivity, profitability and nutrient uptake of wheat (*Triticum aestivum*) grown under zero-tilled condition in south-eastern Rajasthan. *Indian J. Agron.* **61** (1): 53-58.

Narula, N., Kumar, V., Singh, B., Bhatia, R. and Lakshminarayana, K. (2005) Impact of biofertilizers on grain yield in spring wheat under varying fertility conditions and wheat-cotton rotation. *Archives Agron. Soil Sci.* **51**(1): 79-89.

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

Olsen, S.R., Cole, C.V., Watanabe, F.S. & Dean, L.A. (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circulation,* 939.

Pandey, A.K., Kureel, R.S., Shukla, U.N., Singh. S., Mishra, M.L. and Kumar, J. (2014). Effect of nitrogen doses and scheduling on yield, quality and uptake of NPK under late sown wheat. *Bioinfolet,* **11** (2A): 284-288.

Patel, C.B., Singh, R.S., Yadav, M.K., Singh, S.K., Singh, M.K., Singh, K.K. and Mall, R.K. (2012) Response of different wheat (*Triticum aestivum* L. emend Fiori & Paol.) genotypes to various nitrogen levels under late sown conditions of Eastern Uttar pradesh. *Env. & Ecology,* **30** (3C): 1192-1196.

Patil, G.B., Lakshman, H.C. and Puttaradder, J. (2015) Synergistic effect between phosphate solubilising bacteria and Arbuscular Mycorrhizal Fungi on growth and P uptake in *Sorghum vulgare* Pers. *International J. Res. in Eng. and Applied Sci.* **5**, ISSUE 10.

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

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

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

Saleem, A.N. (1987) Effect of nitrogen and seed rate on agronomic parameters of wheat. *J. Agri. Res.* **18**(2): 34-38.

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

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

Singh, M.S. (2006) Cereal crops response to azotobacter - *A review agric. rev*. **27** (3): 229-231.

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

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

Singh, N.K., Choudhary, F.K. and Patel, D.B. (2013) Effectiveness of Azotobacter bio-innoculant for wheat grown under dry land condition. *J. Env. Biology*, **34**: 927-932.

Subbiah, B.V. & Asija, A.K. (1956) A rapid procedure for the estimation of available nitrogen in soil. *Current Sci.* **24,** 259-260.

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

Sushila, R. and Giri, G. (2000) Influence of FYM, nitrogen and biofertilizers on microbial population, dry matter accumulation and nutrient uptake of wheat under limited water supply. *Biofert. Newsl.* **7**: 22-26.

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

Tiwana, U.S. and Narang, R.S. (1997) Crop productivity and soil nitrate nitrogen change in rice-wheat cropping sequence grown under maximum yield fertilization. *Indian J. Agron.* **42**(4): 559-563.

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

Van Herwaarden, A.F., Farquhar, G.D. and Howe, G.N. (1998) Haying-off' the negative grain yield response of dryland wheat to nitrogen fertilizer. I Biomass grain yield and water use. *Aust J Agric. Res.* **49**:1067-1081.

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

Woldeyesus Sinebo., Gretzmacher, R. and Edelbaue, A. (2004) Genotypic variation for nitrogen use efficiency in Ethiopian barley. *Field Crops Res.* **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 Arc.* **14** (2): 1127-1129.