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Review Article

USE OF NITROGEN BASED BACTERIAL BIOFERTILISERS ON AGRICULTURAL CROP PRODUCTIVITY

[a]M.F. Baqual, [a]Saqib Farooq, [a]Azra Qayoom, [a]Shabir Ahmed Wani and [b]Huma Habib
[a]College of Temperate Sericulture, Sher-e Kashmir University of Agricultural Sciences and Technology of Kashmir, Mirgund.
[b]Department of Biochemistry, Islamia College of Science and commerce, Srinagar.

ABSTRACT
The unprecedented use of various agrochemicals for increased agricultural productivity has posed a tremendous challenge upon all forms of life as they are badly involved in the deleterious effects posed by their excessive and unabated use. Due to increased health awareness the use of these chemicals is reduced in major agricultural crops and efforts are on to look into possibility of their further curtailment through supplementation of biofertilizers without hampering the soil fertility for sustainable agriculture. Nitrogen being essential input required by various crops and its application is generally meted out through urea or in rare cases di-ammonium phosphate etc is used. However the use of various forms and strains of nitrogen fixing bacteria *viz*., *Azotobacter*, *Azospirrillum* and *Rhizobium* has proven to be very promising in crop use either singly or in consortium which not only improves the yield but also holds a greater promise for effective control against various plant diseases. Further their use is not only ecofriendly but economically sound as well. The use of these nitrogenous based bio-fertilizers is reviewed.

KEY WORDS: nitrogenous biofertilisers, agricultural crops, *Azotobacter*, *Azospirrillum.*

INTRODUCTION
Soil microorganisms are important components of integrated nutrient management and soil biodiversity system. They play a crucial role in the plant growth and development. In recent years, it is being noticed that excessive exposure to chemical fertilizers and pesticides not only deteriorate soil health but also create several environmental impacts which pose global threat. Beneficial microorganisms offer the potential to meet our agricultural needs through increased productivity and thus are better alternatives for sustainable agriculture practices. As compared to the synthetic fertilizers, biofertilizers are safer with reduced environmental damage with more targeted activity and are also effective in lesser quantities. Moreover, use of bio fertilisers or microbial inoculants is less likely to induce resistance in the pathogens and pests. Bio-fertilizers are products containing living cells of different types of microorganisms which when, applied to seed, plant surface or soil, colonize the rhizosphere or the interior of the plant and promote growth by converting nutritionally important elements (nitrogen, phosphorus) from unavailable to available form through biological process such as nitrogen fixation and solubilisation *etc* (Rokhzadi *et al.,* 2008). These potential biological fertilizers would play key role in productivity and sustainability of soil and also protect the environment as eco-friendly and cost effective inputs for the farmers (El-Yazeid *et al.,* 2007). Fixed nitrogen is a limiting nutrient in most environments, with the main reserve of nitrogen in the biosphere being molecular nitrogen which cannot be directly assimilated by plants, but becomes available through the biological nitrogen fixation process. For many years, a limited number of bacterial species were believed to be nitrogen fixers, but in the last 30 years nitrogen fixation has been shown to be a property with representatives in most of the phyla of bacteria. They are grouped into free living bacteria (*Azotobacter* and *Azospirillium*) and the blue green algae and symbionts such as *Rhizobium*, *Frankia* and *Azolla*. Although many genera and species of N_2-fixing bacteria are isolated from the rhizosphere of various cereals, mainly members of *Azotobacter* and *Azospirillum* genera have been widely tested to increase yield of cereals and legumes under field condition.

Bacterial biofertilisers in action

Anantha *et al.* (2007) while working on the influence of *Azotobacter chroococcum* strains on growth and biomass of *Adathoda vasica* reported that *Adathoda vasica* plants inoculated with different isolates of *A. chroococcum* revealed significantly increased nitrogen content in shoot compared to the control plants. It was also reported that the root nitrogen content was also significantly higher in *A. chroococcum* inoculated plants compared to control plants.

Dhamangaonkar (2009) while studying the effect of *Azotobacter chroococcum* (PGPR) on the growth of Bamboo (*Bambusa vulgaris*) and Maize (*Zea mays*) plants found that *A. chroococcum* at concentration of 108 cfu ml^{-1} increased seed germination and also have a significant promoting effect on growth parameters like root, shoot length and dry mass of bamboo and maize seedlings in *invitro* and in pot experiments.

Gharib *et al.* (2009)while working on the influence of *Rhizobium* inoculation combined with *Azotobacter chroococcum* and *Bacillus megaterium* var *phosphaticum* on growth, nodulation, yield and quality of two snap bean (*Phasealus vulgaris* L.) cultivars studied the effect of some bacterial inoculation with *Rhizobium leguminosarum* bv. *phaseoli* (ARC 301) (Rh) and two strains of *Azotobacter chroococcum* (AZ1) and *Bacillus megaterium* var *phosphaticum* (BM3) as a biofertilizers and reported that the highest values were recorded with mixed inoculation treatment of Rh + AZ1 + BM3 in the presence of 25% from the recommended dose of chemical NPK fertilizers while as the best interaction treatments regarding plant growth and chlorophyll leaf content was inoculation *cv. Paulista* with Rh + BM3 + 25% NPK.

Hamid (2008) while studying *Azotobacter chroococcum* inoculation on yield and post harvest quality of wheat (*Triticum aestivum*) reported that wheat yield was affected when cultivars were inoculated with *Azotobacter chroococcum* and the inoculation resulted in improving post harvest seed germination and nitrogen content of the seed.

Huerta *et al.* (2007) while evaluating the effects of biofertilizers and earthworms on maize and bean growth reported that the treatments that combined earthworms and biofertilizers promoted the highest growth of *P. vulgaris* (earthworms with *Azotobacter chroococcum*), the highest dry plant mass was enhanced by *Azospirillum brasiliensis for Zea mays*, and the highest yield production for *Z. mays* was enhanced with the presence of earthworms (earthworms with *A. chroococcum* and earthworms with *Bacillus megaterium*), 4-fold higher than control.

Irfan *et al.* (2010) while studying the effect of nitrogen fixing bacteria on plant growth and yield of *Brassica juncea* reported that application of both the bacteria recorded higher plant growth and yield in *Brassica juncea*. Also it was reported that *Azospirillum* inoculation resulted in higher growth and yield parameters in comparison to *Azotobacter* inoculation. However, the combination of half dose of both the bacteria proved best in improving plant growth and yield in comparison to individual inoculation.

Mahato *et al.* (2009) while studying the effect of *Azotobacter* and nitrogen on seed germination and early seedling growth in tomato concluded that *Azotobacter* as biofertilizer reported better than inorganic fertilizer in relation to seed germination and all plant growth parameters.

Ridvan (2008) while evaluating the yield response and nitrogen concentrations of spring wheat (*Triticum aestivum*) inoculated with *Azotobacter chroococcum* strains reported that inoculation of seeds of wheat (*Triticum Aestivum*) with 11 bacterial strains of *A.chroococcum*, showed that all *A. chroococcum* strains had positive effect on the yield and N concentrations of wheat .

Govindan *et al.* (2009) while studying the response of ginger (*Zingiber officinale*) to *Azospirillum* inoculant at different levels of nitrogen application reported that the *Azospirillum*, has been found associated with the rhizosphere of ginger and the inoculated as well as uninoculated treatment recorded the stimulation in root growth but with a great difference as evident from the fact that the mean root length for inoculated plants was 16.9 cm only while the corresponding figures for non-inoculated plants was 2.1 cm.

Darzi *et al*. (2012) while studying the effects of the application of vermicompost and nitrogen fixing bacteria on quantity and quality of the essential oil in dill (*Anethum graveolens*) reported that vermicompost and nitrogen fixing bacteria have stimulatory effects on the quantity and quality of the essential oil in dill and thus have considerable potential for providing nutritional elements in essential oil production of dill, especially for the sustainable production systems.

Khan *et al*. (2012) while working on the effect of N-fixing biofertilizers on growth, yield and quality of chilli (*Capsicum annuum* L.) concluded that application of the bio-fertilizer to the crop is beneficial for higher crop production and maintenance of soil health as well and between the two bio-fertilizers, application of *Azospirillum* in combination with N 75% and full dose of P and K may give the highest return from cultivation of chilli in Gangetic Alluvial Plains of West Bengal.

Afzal (2006) while studying the effect of *Rhizobium, PSB* with different fertility levels on green gram under temperate conditions of Kashmir found that seed and straw yield of green gram increased significantly up to single inoculation with *Rhizobium* under 20 kg N + 45 kg P_2O_5 ha^{-1} fertility level.

Arshad *et al*. (2010) while studying the growth, nodulation and yield response of soybean to biofertilizers and organic manures concluded that soybean yield can be significantly enhanced by the application of *Bradyrhizobium japonicum* and effective microorganism in farmyard manure amendment.

Rajaee *et al*. (2007) while working on the effect of plant growth promoting potentials of *Azotobacter chroococcum* native strains on growth, yield and uptake of nutrients in wheat reported that free-living nitrogen fixing micro-organisms, such as *Azotobacter* and *Azospirillum*, enhanced root-development, increased water and mineral uptake, and produced plant hormones that might be responsible for growth of chilli plant.

S. Ravikumar *et al*. (2007) while studying the growth of *Avicennia marina* and *Ceriops decandra* seedlings inoculated with halophilic *Azotobacters* concluded that, inoculation of A. beijerinckii preferably at 30 and 35 gl^{-1} salinity would be more beneficial for raising vigorous seedlings in nursery for *C. decandra* and *A. marina*.

Rueda *et al*. (2016) while working on the effect of effect of *Azospirillum* spp. and *Azotobacter* spp. on the growth and yield of strawberry (*Fragaria vesca*) in hydroponic system under different nitrogen levels reported that the biofertilizers *Azospirillum* spp. and *Azotobacter* spp. enhance the presence of nitrogen in leaf of strawberries var. *Albion*.

Das and Saha (2007) while working on the effect of diazotrophs on mineralization of organic nitrogen in the rhizosphere soils of rice (*Oryza sativa* L.) reported that combined inoculation of *Azotobacter, Azospirillium* along with diazotrophs increased grain and straw yield of rice by 4.5 and 8.5 kg ha^{-1} respectively.

Kamil *et al*. (2008) while studying the plant growth promotional effect of *Azotobacter chroococcum*, *Piriformospora indica* and vermicompost on rice plant reported that the dual inoculation of *A. chroococcum* and *P. indica* had beneficiary response on shoot length, root length, fresh shoot and root weight, dry shoot and root weight, and panicle number that affect growth of rice plant. Sandeep *et al.* (2011) while studying the growth response of *Amaranthus gangeticus* to *Azotobacter chroococcum* isolated from different agro climatic revealed that there is better growth response of *Azotobacter* inoculated plants as compared to non-inoculated control plants.

Salhia (2013) while studying the effect of *Azotobacter chrococcum* as nitrogen biofertilizer on the growth and yield of *Cucumis sativus* reported that *Azotobacter* inoculants have a significant promoting effect on growth parameters like root, shoot length and dry mass of bamboo and maize seedlings in vitro and in pot experiments.

Wani (2012) while evaluating the effect of balanced N,P,K,S, biofertilizer (*Azotobacter*) and vermicompost on the yield and quality of brown sarson (*Brassica rapa* L.) reported that under green house conditions plant height, leaf number/plant, number of primary and secondary branches/ plant, fresh and dry weight of whole plant, number of siliqua/plant, seeds/siliqua of brown sarson increased significantly with *Azotobacter* inoculation than no inoculation with seed and stover yield of 10.107 g pot $^{-1}$ and 22.400 g pot $^{-1}$ respectively.

Naseri *et al.* (2013) while studying the effect of *Azotobacter chroococcum* and *Azospirillum brasilense* on grain yield, yield components of maize (S.C.704) as a second cropping in western Iran indicated that the dual inoculation with *Azotobacter and Azospirillum* on plant height, number of grain per row, 1000-grain weight, grain yield, biological yield and protein content was significant.

Estiyar *et al.* (2014) while studying the effect of nitrogen biofertilizer on yield and yield components of white bean (Phaseolus *vulgaris* cv. Dorsa) reported that number of branches, pod per plant and 1000 grain weight also increased with *Azotobacter* application.

Yasari *et al.* (2008) reported that treating canola (*Brassica napus* L.) with *Azotobacter* and *Azospirillum* inoculants resulted in maximum number of pods/plant and helped in obtaining maximum seed yield.

Yasari and Patwardhan (2007) reported that the combined inoculation of *Azotobacter chrococcum*, *Azospirillum brasiliense* and *Azospirillum lipoferum* helped in increasing the yield by 21.17 % over the control, increased the number of pods per plant (16.05%), number of branches (11.78%), weight of 1000 grains (2.92%) and the oil content of seeds (1.73%) of canola (*Brassica napus* L.) cv. Hyola 401 hybrid.

Thumar *et al.* (2013) noticed that 70% RDF + 2t ha^{-1} vermicompost + *Azotobacter* + *Azospirillium* + *PSB* significantly was gave higher yield parameter *viz.* flower yield per plant and flower yield per hectare in marigold whereas, quality parameters *viz.* shelf life of flower was significantly highest in treatment 200 kg N/ha + 100 kg P_2O_5/ha + 100 kg K_2O/ha + 15 t ha^{-1} FYM.

Paritosh Patra (2013) observed that inoculation of biofertilizers and sulphur have significant effect on yield and yield attributes of sunflower. However, *PSB* + *VAM* + *Azotobacter*, as well as application of sulphur @40 kg ha^{-1} may be considered as the best treatment for sunflower, with respect to height, total chlorophyll content, thalamus diameter, weight of thalamus, filled seeds capitulum^{-1} and 100 seed weight, grain yield, stalk yield, biological yield, harvest index and oil content.

Subashini *et al*. (2007) while studying the effect of biofertilizers (N fixers) on yield of rice varieties in parts of Pondicherry proved that biofertilizers play a major role in increasing the soil fertility, improve soil biota thereby increasing the crop yield and minimize the use of chemical fertilizers.

Studies on generation of bivoltine seed cocoons by integrated ecofriendly technology package by Jagadesh *et al.* (2005) revealed that integrated organic manures package of practices which include *Azotobacter*, VAM, Vermicompost application to V-1 mulberry and in turn feeding to CSR-2 and CSR-4 silkworm breeds resulted in improved rearing and grainage parameters of silkworm.

Studies on effect of VAM and bacterial biofertilizer on mulberry leaf quality and silkworm cocoon characters under semi-arid conditions by Ram Rao *et al.* (2007) prove that the dual inoculation of VAM and *Azotobacter* proved economical and beneficial with regard to saving 50% cost of chemical fertilizers and improvement in soil fertility, leaf quality and cocoon parameters.

Singh *et al.* (2009) while observing the influence of nitrogen doses on growth and green pod yield parameters of French bean varieties during Kharif season under subtropical area of Jammu region revealed that (*Rhizobium* + PSB + FYM) treatment recorded lowest days (40 days) to marketable maturity.

Sharma *et al.* (2008) stated that minimum days to sprouting, maximum plant height and number of leaves per plant were recorded when plants received recommended dose of NPK along with vermicompost and dual inoculation of *Azotobacter* and PSB in Gladiolus.

Selvakumar *et al.* (2009) while studying the response of biofertilizers on the growth and yield of black gram (*Vigna mungo* L.) reported that addition of the combination inoculation of *Rhizobium* + *Phosphobacteria* significantly increased growth and yield of black gram as compared to the control (without biofertilizers).

Sarwa *et al.* (2014) found that application of *Azospirillum* + *Azotobacter* + 100% recommended dose of NPK had noted significant effect on plant height and number of leaves, when compared to control in *Petunia*.

Saikia *et al*. (2007) observed Azospirillum biofertilizer in sweet potato: growth, yield and economics reported that the dry weight of sweet potato increased with the combined application of organic and inorganic fertilizers.

S. Umesha *et al*. (2014) while studying the comparative effect of organics and biofertilizers on growth and yield of maize (*Zea Mays* L.) reported that combined application of *Azotobacter chroococcum*, *Bacillus megaterium* and *Pseudomonas fluorescence* along with recommended dose of NPK and enriched compost has resulted in obtaining highest plant growth, crop yields and dry matter production.

Razie and Anas (2008) while studying the effect of *Azotobacter* and *Azospirilium* on growth and yield of rice grown on tidal swamp rice fields in south Kalimantan reported that inoculation of rice seedlings with *Azotobacter* and *Azospirilium* species was able to substitute for the application of inorganic nitrogen fertilizer and that technology enabled rice yield of 39-64 t/ha.

Rana *et al*. (2006) while studying the effect of *Rhizobium* culture in combination with organic and chemical fertilizers on Rajmash under dry temperate conditions of Himachal Pradesh reported that seed inoculation with *Rhizobium* significantly increased plant height.

Raja *et al.* (2009) conducted a field experiment to study the effect of VAM fungi and its interaction with other beneficial microbial inoculants, *Azospirillum spp*., *Azotobacter spp.* and phosphate solubilising bacteria on plant biomass, nutrients and biochemical constituents in *Jatropha curcas*. Application of combined microbial inoculants has significantly enhanced the fresh biomass, total soluble protein and phenols as well as relative water content over other treatments and uninoculated control.

Rahul Khatkar *et al.* (2007) while working on the effect of biofertilizers and sulphur levels on growth and yield of black gram (*Vigna mungo* L.) reported that application of sulphur @ 20 kg ha^{-1}+ dual inoculation with *Rhizobium* and PSB significantly increased the growth characters and yield of black gram.

Prasad *et al*. (2009) while working on the effect of bio-fertilizers and nitrogen on growth and yield attributes of bitter gourd (*Momordica charantia* L.) reported that application of nitrogen @ 20 kg/ha through inorganic sources combined with the inoculation of *Azotobacter* and PSB for highest fruit yield of bitter gourd.

Poonia *et al*. (2014) reported while working the effect of organic, inorganic and biofertilizers on productivity and economics of groundnut-pigeon pea relay intercropping system in *vertisols* of Gujarat that from the view point of economics, application of 50% RDF + 5 ton FYM/ha + *Rhizobium* + PSB to groundnut provided an alternate best option of nutrient management in groundnut-pigeon pea relay intercropping system.

Mostafa *et al.* (2012) while studying the effect of bio and chemical fertilization on growth of Sunflower (*Helianthus annuus* L.) at South Valley Area revealed that biofertilization treatments of *Azospirillum*+ *Bacillus* plus 100% chemical fertilizers produced the highest values in all growth and yield parameters compared with the control.

Moorthi M. *et al*. (2016) while studying the effect of biofertilizer *Azotobacter Chroococcum* on the growth of mulberry crop *Morus Indica* L. and the yield of *Bombyx mori* L.reported that the use of biofertilizer *A. chrococcum* has reduced man power and time duration and also showed increasing trends in silk filament length, cocoon weight ,shell weight ,shell ratio and ERR.

Moghadam and Shoor (2013) studied the effect of vermicompost and two biofertilizer applications on growth, yield and quality of petunia *(Petunia hybrida)* The treatment receiving *Azospirillum* + *Phosphate solubilising* bacterium + Vermicompost + NPK (25% of recommended dose) recorded the highest plant height, number of branches, plant spread, leaf area index and dry matter accumulation.

Mirzakhani *et al.* (2009) found that inoculating seeds of spring safflower (*Carthamus tinctorius* L.) with *Azotobacter* and *Glomus intraradices* under different levels of nitrogen and phosphorus fertilizers resulted in the improvement of yield and oil content. *Azotobacter* inoculation has significantly increased the grain yield whereas *mycorrhiza* could affect significantly on characters such as harvest index, root dry weight, root mycorrhizal colonization.

Megawer and Mahfouz (2010) determined the effect of *Azotobacter* and *Azospirillum* as free living nitrogen fixers and *Trichoderma* as phosphate solubilising fungi in combination with mineral N fertilizer (50%, 100%) on yield and quality of two canola (*Brassica napus* L.) lines (L6 and H2). The highest productivity was recorded in (N2 + *Trichoderma* + *Azotobacter*), (N2 + *Azotobacter* + *Azospirillum*) and (N2 + *Azotobacter*) which out-yielded the corresponding control by 39.3, 31.8 and 23% respectively thus helped in saving 50% of the recommended dose of N- fertilizer.

Manisha Basu and Bhadoria (2008) reported that the combined application of *Rhizobium* and phosphobacterium (*Bacillus polymyxa*) inoculants and cobalt applied at the rate of 0.21 kg ha^{-1} has significantly increased the yield and uptake of N, P and K in groundnut compared to single application of either inoculants or cobalt. The beneficial effects of application of microbial inoculants and cobalt were also reflected on the soil fertility status.

Lawje *et al.* (2005) while studying the effect of *Rhizobium* and phosphorus solubilizers on nodulation, dry matter, seed protein, oil and yield of soybean reported that total nitrogen content of fenugreek seeds under two biofertilizer treatments was maximum in *Azospirillum* treatment and this might be due to the fact that inoculation helps in more synthesis and utilization of the atmospheric nitrogen resulting in the increase.

Latake *et al.* (2009) reported that the inoculation of bio inoculants *viz. Azotobacter chrococcum, Azospirillum lipoferum, Acetobacter sp.* and phosphate solubilizers *Bacillus megaterium* alone or in combination increased plant height, number of tillers and ultimately the yield of pearl millet.

Kumar *et al.* (2013) conducted an experiment on integrated nutrient management in Gladiolus and revealed that the treatment 80% R.D. of NPK (96 kg N, 80 kg P and 80 kg K/ha) + vermicompost (128 q/ha) + *Azotobacter* (5.28 kg/ha) showed better response to plant height, number of leaves and other growth parameters.

Kavitha *et al.* (2013) while working on the individual and combined effect of biofertilizer, chemical fertilizer and vermicompost on *Amaranthus Tristis* reported that the combined application of vermicompost, *Azospirillum* and chemical fertilizer is superior in enhancing the growth and development of the green leafy vegetable, *Amaranthus tristis.*

Katiyar *et al.* (2011) while working on the effect of *Azotobacter* and nitrogen levels on yield and quality of wheat reported that when the wheat seed is inoculated with *Azotobacter,* it increases the yield up to 1.92 – 2.0 % as compared to non-inoculated seed.

Kashap S.K. *et al.* (2016) while working on the effect of biofertilizers with different levels of nitrogen and phosphorus on growth and flower yield of gladiolus (*Gladiolus grandiflorus* L.) reported that the *Azotobacter* and PSB improved vegetative growth, flowering, flower quality, number of spike and corms and cormels yield.

Kadlage *et al.* (2007) while studying the yield and quality of tomato fruits as influenced by biofertilizer recorded higher yield with *Azotobacter* application. The increase in yield might be due to increased fruit set per plant, fruit length and fruit width as well as berry weight with nitrogen fixers.

Hegde and Sudhakara Babu (2009) reported that dual inoculation of *Azospirillum* and *Azotobacter* could be able to substitute up to 50 % of the N requirement in sunflower under rainfed conditions.

Hadwani *et al.* (2013) reported application of FYM @ 30 t/ha +PSB @ 2g/m^2 +*Azotobacter* @ 2g/m^2 took minimum days to sprouting whereas, maximum plant height and plant spread at E-W and N-S were recorded in treatment ½ RDF +NC @ 1 t/ha +PSB @ 1g/m^2 + *Azotobacter* @ 1 g/m^2.

Godse *et al.* (2006) revealed that plants receiving vermicompost 8 t ha^{-1}+ *Azotobacter* and PSB @ 25 kg ha^{-1} each + 80% RDF significantly increased yield and quality attributes of Gladiolus viz., number of spikes ha-1, length of spike and number of florets spike^{-1} when compared with RDF and other treatments.

Gangwar and Dubey (2012) in the study on Chickpea (*Cicer arietinum* L.) root nodulation and yield as affected by micronutrients application and *Rhizobium* inoculation concluded that combined inoculation of *Rhizobium* and PSB significantly increased yield and the number of pods per plant, straw yield, net monetary returns and pod length .

Baqual and Das (2012) while working on the effect of inoculation with *Azotobacte*r and PSM on mulberry reported that the dual inoculation of mulberry with PSM like *Bacillus megaterium*, *Aspergillus awamori* and NFB like *Azotobacter chrococcum* under varying levels and sources of P and N revealed significant beneficial effect on fresh root biomass, total above ground biomass *etc*. of the saplings of V1 and S36 mulberry varieties.

Baqual (2013) while working on the economics of using biofertilizers and their influence on certain quantitative traits of mulberry reported that it is possible to curtail the application of N and P in mulberry cultivation to an extent of 25-50% without any adverse effect on leaf yield and quality by supplementing N & P through use of *Azotobacter* and PSB.

Anop Kumari *et al.* (2014) conducted an experiment in the screen-house to investigate the effect of different levels of nitrogen (0, 10, 20 and 30 g/m^2) and biofertilizers (*Azotobacter* and *Azospirillum*) on growth, yield and nutrient content of *Chrysanthemum* and revealed that interaction effect of different levels of nitrogen and biofertilizers on number of branches per plant was found to be non significant. The maximum fresh weight of plant (102.36g) was noticed with the application of *Azospirillum* along with nitrogen 20 g/m^2, whereas, in second year, it was maximum (103.45g) with the application of *Azospirillum* in combination of nitrogen 30 g/m^2. The maximum dry weight of plant (10.52 and 10.50 g) was observed in the application of *Azospirillum* along with nitrogen 20 g/m^2, which was at par with *Azospirillum* along with nitrogen 30 g/m^2 (10.06 and 10.40 g).

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