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Conjugation of Biofertilizers with Different Sources of Chemical Fertilizers in Wheat: A Review

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ABSTRACT

Plants nutrients are necessary in increasing production and productivity of crops and healthy food for the world's ever increasing population. Today, soil management strategies are mainly dependent on inorganic chemical-based fertilizers, which cause a serious threat to human health and the environment. Bio-fertilizer has been identified as an alternative for increasing soil fertility and crop production in sustainable farming. The exploitation of beneficial microbes as bio-fertilizers has become of paramount importance in agricultural sector due to their potential role in food safety and sustainable crop production. Bio-fertilizer can be an important component of integrated nutrients management. Microorganisms that are commonly used as bio-fertilizer components include; nitrogen fixers (N-fixer), potassium and phosphorus solubilizers, growth promoting rhizobacteria (PGPRs), endo and ecto mycorrhizal fungi, cyanobacteria and other useful microscopic organisms. The use of bio-fertilizers leads to improved nutrients and water uptake, plant growth and plant tolerance to abiotic and biotic factors. In wheat, non-symbiotic spp. like Azotobacter and streptomyces may be used as a potential source of plant growth promoter and also can reduce chemical fertilizer up to 25% with compromising yield. Thus, these potential biological fertilizers would play a key role in productivity and sustainability of soil and also in protecting the environment as eco-friendly and cost effective inputs for the farmers. This review will overview the importance of biofertilizers with different sources of chemical fertilizers in wheat.

Key words: Bio-fertilizers, Environment, Nutrients, Production, Productivity.

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Wheat (*Triticum aestivum* L.) is an annual plant of poaceae family and one of the most important and strategic crops in the world contributing nearly about 30% of global cereal production with an area of 306 m ha and average productivity of 3.21 t ha^{-1} (FAO 2017) . Wheat grain is the major food of people and supply roughly 70% calories and 80% protein of human diet. It contains 12% protein which is higher than other cereals (Kumar *et al.* 2011). It acts as a staple food especially for north and north western part of India and rank fourth in production after Russia, USA and China and produced 101.20 m t of wheat from an area of 29.55 m ha with an average yield of 34.24 q ha^{-1} in 2018-19. Bio-fertilizer can be an important component of integrated nutrients management. Microorganisms that are commonly used as bio-fertilizer components include; nitrogen fixers (N-fixer), potassium and phosphorus solubilizers, growth promoting rhizobacteria (PGPRs), endo and ecto mycorrhizal fungi, cyanobacteria and other useful microscopic organisms. The use of bio-fertilizers leads to improved nutrients and water uptake, plant growth and plant tolerance to abiotic and biotic factors. These potential biological fertilizers would play a key role in productivity and sustainability of soil and also in protecting the environment as eco-friendly and cost effective inputs for the farmers.Rice-wheat is predominant cropping system in India that requires high dose of fertilizers which affects environment and soil health (Rai *et al.* 2014). Nitrogen and phosphorus are considered to be essential nutrients to increase the growth of plant, germination rate, they also improve seedling emergence and protect plants from different stresses. But use of synthetic chemical fertilizers is not considered as economically and ecologically suitable. They cause air and ground water pollution by eutrophication of water bodies. Conventional, chemically processed fertilizers also subvert the soil ecology, disrupt environment, degrade soil fertility and consequently shows harmful effects on human health (Suhag 2016). Hence, the practice of chemical farming put the long-run sustainability of agriculture at risk. There is need to develop and adopt production system that would be productive, sustainable and least burdensome on the environment. Among the accessible alternatives to chemical fertilizers are organic fertilizers, bio fertilizers and plant growth promoting rhizobacteria (PGPRs) are the important ones (Sharma *et al.* 2011). Beneficial rhizosphere microorganisms can boost plant growth via multiple regulatory biochemical pathways (categorized as direct and indirect mechanisms) that includes manipulating the plant hormonal signaling, preventing pathogenic microbial strains and increasing the bioavailability of soil-borne nutrients (Bargaz *et al.* 2018). An integrated approach

for use of biofertilizers with chemical fertilizers is considered as the need of hour as biofertilizers are not replacement of fertilizers but can supplement their requirement (Patra and Singh 2018).

Biofertilizers are living cell containing microbes which improve the uptake and solubility of plant nutrients by increasing root surface area through colonization of plant rhizosphere and facilitates nutrient. These are considered as precious constituent of sustainable agriculture in integrated plant nutrient management as well as holding enormous pledge in increasing the yield of crop plants (Narula *et al.* 2005). Biofertilizers play a significant role in improving soil fertility by fixing atmospheric nitrogen both in association with plant roots and without it, solublise insoluble soil phosphates and produces plant growth substances in the soil. They are in fact being promoted to harvest the naturally available, biological system of nutrient mobilization. It has been perceived that the soil contain free living microscopic organisms which are able to fix nitrogen non-symbiotically.

The non-symbiotic nitrogen fixer *Azotobactor sp*. has found to be beneficial for a wide range of crops due to its ability to fix atmospheric nitrogen, production of Indole Acetic Acid and fixation of atmospheric nitrogen, antibiotic production, siderophore production.

Effect of nitrogen

Nitrogen (N) has been recognized as one of the important element in plant nutrition. It is a major nutrient required for proper metabolism of the plants. N is often most limiting nutrient for development and plant growth (Andrews *et al.,* 2004). It is an essential element of all the amino acids in plant structures which are the building blocks of plant proteins, important in the growth and development of vital plant tissues and cells like the cell membranes and chlorophyll. It is a component of nucleic acid that forms DNA a genetic material significant in the transfer of certain crop traits and characteristics that aid in plant survival. It also helps hold the genetic code in the plant nucleus. Chlorophyll being an organelle essential for carbohydrate formation by photosynthesis and a substance that gives the plant their green color, nitrogen is a component in it that aids in enhancing these features. Nitrogen is essential in plant processes such as photosynthesis. Thus, plants with sufficient nitrogen will experience high rates of photosynthesis and typically exhibit vigorous plant growth and development. With the deficiency of the N, plant shows yellowing of leaf, stunted growth and sometime death of the plants.

Effect on growth and development

Plant height was significantly affected by application of various levels. Maximum height was obtained by application of N @ 150 kg ha^{-1} which was statistically at par with 120 kg ha^{-1} (Kousar *et al* 2015).

Statistically higher plant height, root length, leaf number, leaf area were found in treatment where *Azotobacter* + 120:80:80 NPK ha^{-1} were applied in wheat (Mahato and Kafle 2018).

Umesha *et al.* (2014) observed non-significant influence of RDF + Bio on germination of maize but maximum germination (96.90%) was recorded in combined application of RDF with biofertilizers. This is due to improved soil condition by application of organic and bio fertilizers.

Effect on yield and yield attributes

Kousar *et al.* (2015) conducted experiment to study the effect of various Nitrogen levels on the yield and yield component of wheat. The experiment includes different treatments of Nitrogen levels *i.e*, 0, 30, 60, 90, 120 and 150 kg ha^{-1}. The results shows that yield parameters were significantly affected by various N levels and maximum were obtained in 120 and 150 kg ha^{-1}. Fertile tillers, spike length (17.75), number of spikelet per spike, number of grains per spike, 1000 grain weight (44.25) and grain yield (4885 kg ha^{-1}) were maximum in treatments where 120 and 150 kg ha^{-1} N applied.

Sugar *et al.* (2016) studied the effect of N fertilization on the yield, yield components, of winter wheat in a long-term experiment in Hungary. The effect of N fertilization on the yield was significant in all the years.In all the years, the yield was lowest in treatment N_0 (averaging 5.45 t ha^{-1}), with a significant increase in the N_{80} (6.45 and 7.99 t ha^{-1}, respectively) and in the N160 treatment (7.44 t ha^{-1}). Higher N doses had no further significant yield-increase. Grain yield was found to be highest in 80 and 160 kg ha^{-1} N treatments, the higher N rate did not lead to a further yield increase in any of the years.

Stephen *et al.* (2015) conducted experiment to know the effect fertilizer nitrogen application practices on grain yield components and grain yields of wheat *(Triticum aestivum)*. Variation of either N application time or mode of application had little effect on wheat grain yield. It was concluded that with single application of a moderate rate of fertilizer N (not exceeding 90-100 kg N ha^{-1}) are sufficient for the successful cultivation of autumn sown wheat in Canterbury, New Zealand.

Effect on grain quality

Yang *et al.* (2018) conducted experiments for better understanding the affect of N availability end-use quality of wheat. Four N rates (*i.e.*, zero, low, medium and high) were applied. Grain hardiness was found to be higher under the high N rate than the low and zero rates. Nitrogen availability above the low rate (168 kg N ha^{-1}) failed to further improve most end-use quality traits in either cultivar. These results indicate that excessive N fertilization offers minimal enhancement in end-use quality of wheat.

Luo *et al.* (2000) conducted experiment to know the effect of nitrogen and sulphur fertilization on wheat glutenins and quality parameters. He concluded that nitrogen application significantly increases the white flour protein percentage, hardiness, mid line peak value.

Litke *et al.* (2018) conducted experiment to investigate the effect of nitrogen fertilization on winter wheat yield and quality of wheat. Grain crude protein (CP) content is the most important indicator of wheat grain quality. CP content ranged from 8.7 to 13.7% on average per all trial years

depending on nitrogen fertilizer rate. He concluded that the nitrogen fertilizer significantly affect the CP content in grain. Similarly to CP content, also gluten content in grain increased significantly affected by nitrogen fertilizer rate N_{180} and the next significant increase was secured by N_{240}. The lowest border of food demand of gluten content was obtained when nitrogen fertilizer rate N_{180} was used. It means increase in nitrogen fertilizer rate significantly affected the winter wheat grain quality indices, except starch.

Effect of phosphorus

Phosphorus is a vital nutrient both as part of key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants. Phosphorus has its great important especially for its role in capturing and converting the sun's energy into useful plant compounds. Phosphorus is an essential component of DNA, the genetic "memory unit" of all living things. It is also a component of RNA, the compound that reads the DNA genetic code to build proteins and other compounds essential for plant structure, seed yield and genetic transfer. The structures of both DNA and RNA in plants are linked together by phosphorus bonds.

Phosphorus is an important component of ATP which is the "energy unit" of plants. ATP manufactured during photosynthesis, has phosphorus in its structure and processes from the beginning of seedling growth through to the formation of grain and maturity.

Thus, phosphorus has important role in maintaining health and vigor of all plants. Some precise growth factors that have been linked with phosphorus are: Regulate root development, improve stalk and stem strength, increased flower formation and seed production, uniform and earlier crop maturity, increased N-fixing capacity of legumes, improvement in crop quality, increased plant diseases resistance, P support the development throughout entire life cycle of the plant.

Deficiency of P is more difficult to recognize under field condition as in case of Nitrogen it is easily recognized. Crops show stunting of the plants in early period of crop but by the time it can be visualized and it should be very late for application of fertilizers. The plants are typically dark bluish-green in color with leaves and stem become purplish. The intensity of purplish color is influenced by the genetic makeup of the plant, with some hybrids viewing much greater discoloration than others. The purplish color is due to increase of sugars that favors the synthesis of anthocyanin (a purplish-colored pigment), which is present in the leaves of the plant.

Effect on growth and development

Islam *et al.* (2016) conducted experiment on impact of various levels of phosphorus on wheat. The experiment includes different levels of P *i.e.* 0, 45, 60, 75 and 90 kg ha^{-1}. Leaf area, days to heading, days to physiological maturity, plant height, considerably ($p \leq 0.05$) affected by various levels of phosphorus. Phosphorus at the rate of 90 kg ha^{-1} produced maximum plant height (92.6 cm), biological yield (13056 kg ha^{-1}), So they concluded that with P application at the rate of 90 kg ha^{-1} showed best performance.

Mumtaz *et al.* (2014) conducted experiment to know the effect of different P levels on growth and yield of wheat. Five different phosphorus levels (P = 0, 30, 60, 90, 120 kg ha^{-1}) were applied to check the effects on growth and yield of wheat. They concluded that plant height was increased with increasing phosphorus application rate. Highest plant height (92 cm) was observed in well irrigated field conditions with the application of 120 kg ha^{-1} phosphorus. This application rate also showed better plant height in water stress at vegetative + reproductive stage (87 cm) and reproductive stages (90 cm). Increased application of phosphorus with optimum irrigation showed significant effect on growth of wheat. Higher application of P compensates the effect of water stress conditions both at vegetative and reproductive stage. Lower P application with water stress caused maximum reduction in plant height. On overall performance, application of phosphorus at the rate of 120 kg ha^{-1} showed better results under water stress conditions as compared to other phosphorus levels.

Singh and Ahlawat (2007) reported that application of phosphorous at the rate of 17.2 kg ha^{-1} rate in combination with PSB through seed treatment was at par with application of phosphorous at 34.4 kg ha^{-1} rate alone in plant height, number of tillers $meter^{-1}$ row length.

Effect on yield and yield attributes

Kaleem *et al.* (2009) conducted field experiment to determine the sensible use of phosphorus to find out the result of best phosphorus level on wheat. Five different fertilizer levels *i.e.* 32, 42, 84, 96 and128 kg P ha^{-1} keeping 128 kg N ha^{-1} constant, were studied to appraise their effect on number of fertile tillers m^{-2}, 1000 grain weight, number of grains $spike^{-1}$ and grain yield ha^{-1} of the crop. The result showed that maximum wheat yield of 3557 kg ha^{-1} was obtained in the plots where NP ratio was 1:1 *i.e.* 128-128 kg ha^{-1} indicating consequence of phosphorus at its highest dose in achieving maximum wheat productivity.

Jat *et al.* (2018) concluded that application of phosphorus up to 40 kg P_2O_5 ha^{-1} significantly increased the grain, straw and biological yields beyond which it increased non-significantly and found that a mean increase of 26.2, 30.6 and 28.8 per cent, respectively over control.

Results of the field experiment carried out by Idapuganti and Ahlawat (2007) also showed that application of phosphorus at 34.4 kg ha^{-1} through SSP with PSB inoculation recorded significantly more number of spikes m^{-1} row length, numberof grains per spike, 1000 grain weight, grain and straw yield of wheat compared to theapplication of phosphorous at 34.4 kg ha^{-1} alone.

Effect on grain quality

Higher phosphorus content in grain due to P fertilization resulted in higher crude protein content as nitrogen is an integral part of protein. Such increase in protein content is due to the reduction of nitrates to ammonia by the activities

of complex enzymes resulting in production of more amino acids which are main constituents of protein while did not affect sugar and crude fibre content of wheat. Application of phosphorus @ 40 kg P_2O_5 ha^{-1}, 3 kg Zn ha^{-1} and 6 kg Fe ha^{-1} significantly increased the protein content of grains in wheat during both the years of investigations and in pooled analysis (Jat *et al.* 2018).

Effect of biofertilizers

Biofertilizers are substances which improve the soil nutrient status with microorganisms. They are of different types like Nitrogen fixer, P fixer and some fix the micronutrient in the soil. These have not any negative effect on crops like chemical fertilizers. They are taken from the microbial mixtures. Microorganisms are used to improve the nutrients in the plants. They help the plant to grow in natural and healthy environment. They are ecofriendly and don't cause any type of pollution. Bio-fertilizers replace the chemical fertilizers to some extent as chemical fertilizers are not beneficial to plants. Some bio fertilizers have capacity to cure the diseases of plants. They are available at low cost to the farmers.

Effect of *Azotobacter* sp.

Nitrogen fixing bacteria are tried in cereals with significant success. These microorganisms provide as a viable substitute to chemical fertilizers and involved comparatively less cost. Several workers have reported significantly increase in yield of wheat in various crops with the use of *Azotobacter*.

Effect on growth and development

Many field experiments were conducted in India as well as whole world to know the importance of *Azotobacter* as microbial inoculants. Azotobacter inoculation enhanced seed germination of wheat seeds as compared to control. 100% germination was reported when seeds were incolulated with Azotobacter within 48 hours (Singh 2006). *A. chroococcum* strains isolated from a chernozem soil has showed that these strains have the ability to produce auxins, gibberelins and phenols and in association with the tomato plant, increase effect of inoculation on dehydrogenase activity (µg TPF/10 g of soil). Phytohormones (auxin, cytokinin and gibberellin) can stimulate root development. *A. chroococcum* produces an antibiotic which inhibits the growth of several pathogenic fungi in rhizosphere thereby seedling mortality. Incidence of some diseases of mustard and rapeseeds could be reduced by inoculating with *Azotobacter*.

In soils, *Azotobacter* have capacity to fix about 60-90 kg N ha^{-1} and it may be used in next crop as an alternate for a portion of mineral nitrogen fertilizers. *Azotobacter* fixes molecular nitrogen as well as assimilates inorganic form of nitrogen. It has been found that nitrogen assimilated by *Azotobacter* is released in the form of amino acids, proteins and ammonium ions and therefore results in better growth of plants. Gonzales *et al.* (1991) reported that *Azotobacter chroococcum* produces gibberellins, auxins and cytokinins.

Bindia *et al.* (2005) reported that seed inoculation of *Azotobacter* in wheat significantly increased the plant height (90.43 cm) of wheat. Subbarao *et al.* (2001) reported that *Azotobacter chroococcum* produce an antibiotic which reduces the growth of several pathogenic fungi in rhizosphere thereby seedling mortality. Only small amounts of IAA produced in old cultures of *Azotobacter* to which no tryptophan was added. Bacteria of the genus *Azotobacter* produce auxins, cytokinins and GA-like substances and these growth materials are the major substance controlling the enhanced growth of tomato (Azcorn and Barea (1975). These hormonal substance which instigate from the rhizosphere or root surface, affect the growth of the closely associated higher plants.

Effect on yield and yield attributes

Kakraliya *et al.* (2017) conducted a field experiment to find out the effect of organic and inorganic fertilizers on grain yield, fertilizer use efficiency and grain quality of wheat crop. Result showed that the treatment RDF + VC at 2.5 t ha^{-1} + FYM at 5 t ha^{-1} + *Azotobacter* produced higher grain yield than the other treatments. Wheat yield with synthetic fertilizer (NPK) was 42% more compared with control and further increased with layering of organic and inorganic fertilizers along with bio-fertilizers. The increase in grain and straw yields might be due to adequate quantities and balanced proportions of plant nutrients supplied to the crop as per need during the growth period resulting in favourable increase in yield attributing characters.

Zaidi and Khan (2005) found that seed inoculation with *Azotobacter* in association with *P. straita* in wheat enhanced grain and straw yields by 20% and 50% in comparison to the control. The effect of microbial inoculations on the number of tillers per plant followed similar trend that obtained with grain and straw production of wheat.

Ram *et al.* (2005) reported that inoculation of wheat seeds with *Azotobacter* strains significantly increased the grain yield. The strain Mac-27, AC-4 and Ac-5 increased grain yield, by 7.7, 4.2 and 6.6 per cent, over uninoculated control, respectively. The increase in grain yields have been attributed to improved growthparameters following *Azotobacter* inoculation.

Deelip and Ravinder (2006) observed that grain and straw yield of wheat significantly increased due to seed inoculation of biofertilizers and maximum grain yield was recorded with combined inoculation of *Azotobacter* + *Azospirillum,* being significantly higher over the individual application of *Azotobacter* and *Azospirillum* and uninoculated control.

Sirafy *et al.* (2006) evaluated the effect of seed inoculation with biofertilizers products like phosphorein containing P solubilizing bacteria and nitrobein containing *Azotobacter* on Egyptian winter wheat (*Triticum aestivum* L.) and reported increases in grain and straw yields of winter wheat when biofertilizers products were applied with chemical fertilizers.

Sarma *et al.* (2007) conducted a field experiment to find out a suitable combination of biofertilizers along with chemical fertilizers in wheat. The application of 187.5 kg N/ ha + FYM (10 t ha^{-1}) + *Azotobacter* was found statistically at par with 187.5 kg N ha^{-1} + FYM (10 t ha^{-1}), however, treatment of 150 kg N ha^{-1} + FYM (10 t ha^{-1}) + *Azotobacter* recorded significantly more spike length m^{-1} row length, grains per spike and grain and straw yields of wheat over recommended dose of N (150 kg ha^{-1}) and absolute control.

Malik *et al.* (2005) conducted experiment with two efficient strains of *Azotobacter* W-5 (standard culture) and DA-2 (newly identified culture for wheat) was tested on wheat varieties of hexaploid and tetraploid group. The basal dose of 60 kg N and 60 kg P_2O_5 per hectare were applied and thereafter there were no top dressing of nitrogenous fertilizer. The data on grain yield, biomass, harvest index, 1000-grain weight and tillers m^2 were generated. The grain yield, its attributing traits, varieties and the treatments (W-5 and DA-2) differed significantly, indicating diversity in varieties and the inoculants used in the experiment. The inoculants enhanced grain yield and biomass significantly over the control. The grain yield of the *Azotobacter* sp. inoculated plots was increased due to increase in *tillering* capacity and the ear size producing higher number of grains.

Effect on grain quality

Wani *et al.* (2012) conducted experiment under eight greenhouse conditions and concluded that inoculation of *Azotobacter chroococcum* recorded a significant N and P uptake in both seed and stover in Brown sarson over the control.

Singh *et al.* (2007) concluded that *Azotobacter* sp. decrease the lysine content and increase the starch content in wheat. Free living bacteria *i.e Azotobacter* sp. fix atmospheric nitrogen in the soil. It also has some properties which are beneficial for crop growth and some of them are ammonia production, vitamins, growth substances which increase the seed germination.

Kakraliya *et al.* (2017) concluded that the highest grain protein content was obtained from the application of organic and inorganic fertilizer along with *Azotobacter* and lowest from control as well as NPK fertilizer alone.

Kader *et al.* (2002) reported the highest N uptake (23.17 mg $plant^{-1}$) by wheat with the application of *Azotobacter* in combination with chemical fertilizers and the lowest with the absolute control (11.03 mg $plant^{-1}$). The total N uptake increased ranging from 36 to 109% over the control due to different biofertilizers treatments with chemical fertilizer. *Azotobacter* either alone or in combination with urea N had some beneficial effects on the yield of wheat, which amounted to saving about 20% of urea N.

Singh *et al.* (2008) reported the maximum N and P uptake by wheat with the application of FYM @ 7.5 t ha^{-1} + 50% RDF + biofertilizer (PSB + *Azotobacter*) followed by 100% RDF and FYM @ 15 t ha^{-1}, being significantly higher than control.

Koushic and Singha (2008) studied the residual effect of vermicompost, chemical fertilizer and biofertilizer (*Azotobacter* + PSB) in wheat on succeeding fodder cowpea. Their results revealed that the dual inoculation of biofertilizers significantly enhanced N uptake by 4.85, 7.17 and 9.54% and P uptake by 9.53, 15.98 and 21.44% over *Azotobacter* alone, PSB alone and no inoculation, respectively.

Kizikaya (2008) evaluated the effect of indigenous and non-indigenous A.*chroococcum* strains on yield response and N concentrations in spring wheat. Results revealed that all *A. chroococcum* strains had positive effects on yield and nitrogen concentration of wheat. In pot trial, the nitrogen concentration in grain ranged between 1.54 (*Azotobacter* RK 38) to 2.11% (Beijerinck1901), while in wheat straw concentration of N ranged from 0.41% (*Azotobacter* strain RK 49) to 0.50% (*Azotobacter* strain RK 38).

Effect of *Streptomyces badius*

Streptomyces is a kind of Gram-positive bacteria that grows in various environments and its shape resembles filamentous fungi. In *Streptomyces* morphological differentiation involves the formation of a layer of hyphae that can differentiate into a chain of spores. *Streptomyces* have ability to produce bioactive secondary metabolites, such as antifungals, antivirals, antitumorals, anti-hypertensives, immunosuppressants and especially antibiotics. The production of most antibiotics is species specific and these secondary metabolites are important for *Streptomyces* species in order to compete with other microorganisms that come in contact, even within the same genre. Despite the success of the discovery of antibiotics and advances in the techniques of their production, infectious diseases still remain the second leading cause of death worldwide and bacterial infections cause approximately 17 million deaths annually, affecting mainly children and the elderly. Self-medication and overuse of antibiotics is another important factor that contributes to resistance, reducing the lifetime of the antibiotic, thus causing the constant need for research and development of new antibiotics (Procopio *et al.* 2012).

Effect on growth and development

Naqeeb *et al.* (2018) conducted experiment to know the effect of biofertilizers on growth and yield of bread wheat. He concluded that three spray of EM-1 enhanced plant height, increased an incidence of elongation and division of cells in all vegetative organs. According to the response of wheat cultivars toward spraying of biofertilizer, he recommended frequent spraying of biofertilizer at tillering, stem elongation and booting stages.

With the discovery of streptothricin in 1942, the history of antibiotics derived from *Streptomyces* began and with the discovery of streptomycin two years later, scientists intensified the search for antibiotics within the genus. Today, 80% of the antibiotics are sourced from the genus *Streptomyces*, actinomycetes being the most important.

Montario *et al.* (2017) conducted experiment to know the evaluation of the antifungal activity of *streptomyces* sp

on growth promotion of wheat. Growth-promoting efficiency of wheat seedlings were tested using *in vivo* assays in a greenhouse. *Streptomyces* sp. R18 (6). *Streptomyces* sp. 6(4) produced auxin, siderophores, fixed nitrogen and solubilized phosphate, whereas R18 (6) did not produce siderophores. In the greenhouse assays, strain R18(6) show statistical differences in shoot dry mass and root dry mass compared with those of strain 6(4) in the presence of the phytopathogen ($P \leq 0.05$) and these results were more evident when the environmental temperature was higher.

Effect on yield and yield attributes

Gopalkrishan *el al.* (2015) conducted experiment to know the effect of *Streptomyces* sp. strains in chickpea. He obtained enhanced nodule number, nodule weight, root weight and shoot weight at 30 days after sowing (DAS) and pod number, pod weight, leaf area, leaf weight and stem weight at 60 DAS in both seasons over the un-inoculated control. At crop maturity the *Streptomyces* strains had enhanced stover yield, grain yield, total dry matter and seed number plant^{-1} in both seasons over the un-inoculated control.

Tahvonen *et al.* (1994) conducted experiment to know the effect of seed dressing treatment of *Streptomyces griseoviridis* on barley and spring wheat in field experiment. He obtained considerable yield increase in wheat and barley with application of *Streptomyces griseoviridis*.

Statistically higher panicle length and 1000 grain weight were obtained with application of BCA-698 strains of streptomyces which significantly influence the grain and straw yield of wheat (Alekhya and Gopalakrishna 2016).

Effect on grain quality

Alekhya and Gopalakrishnan (2016) reported that 60% of the biological active compounds in agriculture such as antifungal, antibacterial and PGP substances were produced by streptomyces and it have potential to produce PGP and biocontrol traits such as IAA, Siderophore, lipase, cellulose, protease, glucanase and chitinase.

Endophytic *streptomyces* was a source of metabolites which decrease the disease incidence and they have ability to perform antibiosis, competition and parasitism which indirectly improve the quality of plants (Vurukponda *et al.,* 2018).

Effect of biofertilizers on soil health

Biofertilizers, the gift of modern agricultural sciences retard the nitrification for sufficiently longer time and improve the soil fertility. Growing crops using bio-fertilizers is advantageous in protecting the soil from degradation.

Effect on soil pH and organic carbon

Illmer and Schinner (1995) proposed that acidification of rhizosphere could be through liberation of organic acids by proton extrusion mechanism. However, this shift in the pH to 7.8 from 8.5 was relatively marked in the soil wherein Azophos in combination with mycorrhiza was applied followed by phosphobacteria, Azophos and mycorrhiza. There was also an improvement in the organic carbon content in the biofertilizer treated rhizosphere soil. It was 0.30 per cent initial. The highest organic carbon (0.38 %) was recorded in the treatment with Azophos and mycorrhiza at 120 DAS. Any increase in the organic carbon content also will result in increased nutrient availability to the plant by augmenting soil biological activity, thereby enhancing nutrient use efficiency. *Azotobacter chroococcum* appered to be the ideal soil microorganisms for high level of indole acetic acid production.

Tejera *et al.* (2005) assessed growth rates of *Azotobacter sp*. at different initial pH values (4-9) and showed that a lower number of isolates grew on N-free media at pH value as high as 8-7.

Ramlakshmi *et al.* (2008) conducted experiment to know the effect of biofertilizers on pH and OC of the soil. The initial pH of the soil in the experimental plots was 8.5. There was only a small variation in the pH due to biofertilizer application. The biofertilizer inoculation resulted in the shift in the pH reducing the alkalinity slightly.

Effect on nutrients

There was significant improvement in the soil available N, P and K in the biofertilizer inoculated plots over the uninoculated control. The available nitrogen was higher in the coinoculation of Azophos and mycorrhiza with 153, 181, 184 and 182 kg ha^{-1} at 30, 60, 90 and 120 DAS, respectively. A similar increase in soil nitrogen was observed in the treatment of *Azospirillum* almost paralleling the Azophos and mycorrhiza combination at all intervals of sampling. Mertens and Hess (1984) reported that inoculation of *Azospirillum* in wheat increased available nitrogen in soil.

Effect on soil biological properties

The effects of biofertilizers application on total bacteria, fungi and actinomycetes in black cotton soil during the cropping period were significant. The bacterial population increased during the crop growth. The bacterial population was 47.6 × 106 g^{-1} at initial stage and subsequently increased at 30 DAS. Microbial inoculation improve the nutritional absorption of plant (total N, P and K) and improved soil properties, such as organic matter content and total N in soil (Wu *et al.,* 2005). The biofertilizer may act as alternative for NPK fertilization that slows down the release of nutrients in soil, favoring longterm soil fertility. Application of either organic amendments or biofertilizer as individual or in mixture improves fertility status of the soil as well as, the seed yields of wheat and peanut. These include Increasing available N, P and K of the treated soil and increased OM content in treated soil. Mixing soil conditioners with organic amendments and biofertilizer was more efficient in improving chemical properties of the soil than applying each of them alone. In this context, the maximum content of available NPK were (22.64, 13.23 and 68.41 mg kg^{-1} soil) and (24.14, 13.71 and 70.46 mg kg^{-1} soil) for N, P and K in the soil after wheat and peanut harvesting, respectively, resulted from the high rate of compost (7.5 ton fed^{-1}) combined with biofertilizers. It was also noticed that yields significantly increased by

increasing rate of organic fertilizer. If biofertilizer supplemented with poultry manure improved soil properties, such as organic matter, NPK content and concentration of the micronutrients Fe, Mn, Cu and Zn. The application of biofertilizer increased the efficiency of both organic and mineral N fertilizer but alone was ineffective in increasing yield. Thus, biofertilizers could be used as value-added soil amendments by supplementing organic and low chemical fertilizer rates for improving soil fertility and sustaining crop productivity. All bacterial inoculations, especially mixed inoculation, significantly increased uptake of macro-nutrients (N, P, K, Ca, Mg and S) and micro-nutrients (Fe, Mn, Zn and Cu) of grain, leaf and straw part of the plant (Kumar and Urmila 2018).

Combined effect of biofertilizers with different sources of nutrients

Soil characteristics like pH, available N, P and K status, O C, microbial biomass and dehydrogenase activity were significantly influenced by the combined application of biofertilizers and inorganic fertilizers. Application of PSB along with SSP significantly increased the available P status in soil compared to uninoculated plots. More availability of P under PSB treatment can be attributed to the production of organic acids. These acid acts as chelating agent and form stable complexes with Fe and Al abundantly available in acid soil and thereby release P to the soil solution making it available for more uptake by plants (Gogoi *et al.,* 2004).

Dhiman and Dubey (2017) conducted an experiment with wheat-maize cropping system. They observed an increase in number of tillers per plant, number of grains per spike, grains per cobs, number of cobs per plant, diameter of cob were recorded highest in the treatment (T_{12}) where inoculation with nitrogen fixer and phosphate solubilizers +125% of RDF of nitrogen+75% of RDF of phosphorus was done. Grain yield and straw yield were also increased in the treatment (T_{12}) where inoculation with nitrogen fixer and phosphate solubilizers+125% of RDF of nitrogen+75% of RDF of phosphorus sources were applied. Quality parameters (protein and carbohydrate content) were also highest in treatment (T_{12}).

Rana *et al* (2012) conducted a pot experiment under net house conditions, with three rhizobacterial strains AW1 (*Bacillus* sp.), AW5 (*Providencia* sp.) and AW7 (*Brevundimonas* sp.), applied along with 2/3 recommended dose of nitrogen (N) and full dose of phosphorus (P) and potassium (K) fertilizers ($N_{90}P_{60}K_{60}$). Enrichment in plant biometric parameters up to 14-34% and in micronutrient content up to 60% was recorded in combinations of treatment involving AW1 and AW5 strains, as compared to full dose of fertilizer application. The treatment involving inoculation with AW5 and AW7 recorded highest values of % P and N, (two-fold enhancement in phosphorus and 66.7% increase in N content) over full dose application of P and K fertilizers. A significant relationship was recorded between plant biomass, panicle weight, grain weight, N, P and iron (Fe) with acetylene decline activity, representing the significance of N fixation in overall crop productivity. The grain yield recorded in the PGPR inoculated treatments was superior and statistically at par with treatment incurring full dose NPK and (2/3N + Full dose of PK treatments).

Singh and Parsad (2011) conducted two year experiment and studied the effectiveness of bio fertilizer on growth and productivity of wheat. They concluded that the grain yield was highest when chemical fertilizers were combined with bio fertilizer. This is due to additive effect of various yield attributing characters like ear m^{-2}, no. of grains ear^{-1} and test weight.

Desai *et al.* (2015) studied the effect of INM on wheat and observed that combined application of inorganic fertilizer along with FYM, bio fertilizer and sulphur have significant effect on spike per m^2, spike length, number of grains $spike^{-1}$ and grain yield. The percentage enhance in number of spike m^{-2},row length, length of spike and number of grains per m^2 were 34.4%, 28% and 31% respectively over treatments receiving recommended dose fertilizer. This might be result of positive effect of FYM and inoculation of *Azotobecter* sp. and PSB along with S on all other essential nutrients availability.

Meena *et al.* (2016) studied on integrated nutrient management in wheat. The treatments consist of the planting system and 10 fertilizer treatments. The yield contributing characters of wheat *viz.*, number of spikes $plant^{-1}$ and number of grains $spike^{-1}$ were recorded considerably superior when the crop was supplied with joint application of RDF or 75% RDF along with FYM, bio fertilizer and zinc over control and treatment getting RDF only. In case of wheat yield, 10.8 and 11.3 per cent higher yield were registered with FIRB planting system over conventional system. However in case of integrated nutrient management, RDF + FYM + BF + Zn treatment produced 50.39 and 52.73 q ha^{-1} wheat yield respectively. The grain and straw yields increased significantly with treatment RDF + FYM + Zn over control and RDF alone. The increase in grain yield with application of RDF + FYM + BF + Zn over RDF alone was 16.8 and 14.1%, respectively.

Luz *et al.* (2001) studied the effects of PGPBR on wheat and results showed the significant increase in germination of wheat and grain yield was higher as compared to non-treated control. Yield increase with PGPBRs varied from 18 to 28 percent.

Heidaryan and Feilinezhad (2015) concluded that sources of biological nitrogen fixation and phosphorous had significant effect on number of spike m^{-2} and grains $spike^{-1}$, no. of spikelets $spike^{-1}$ which ultimately resulted in significant increase in grain yield. Biological fertilizers have positive effect on leaf surface area and photosynthesis which in turn increases the growth of plant.

Chaudhary *et al.* (2013) studied the plant growth stimulation by inoculation of salinity tolerant *Azotobacter* strains and observed that there was significant increase in total nitrogen, biomass and grain yield of wheat on inoculation with selected salinity tolerant *Azotobacter* strains in wheat variety WH 157.

Yousefi and Barzegar (2014) in Iran also indicated that the combined application of *Azotobacter* and *Pseudomonas* increased grain yield, harvest index, biological yield and protein content compared to the control. *Azotobacter* and *Pseudomonas* inoculation plus fertilization reduced chemical fertilizers application up to 50% at farmer's field also as compared to conventional fertilization.

Omar *et al.* (1991) concluded that inoculation of seed with bio fertilizer save nitrogenous fertilizers upto 37.5 to 41.6%. Increase in nitrogen level significantly increased in plant height, test weight, harvest index and number of grains per spike.

Singh *et al.* (2007) concluded that *Azotobacter* sp. decrease the lysine content and increase the starch content in wheat. Free living bacteria *i.e*. *Azotobacter* sp. fix atmospheric nitrogen in the soil. It also has some properties which are beneficial for crop growth and some of them are ammonia production, vitamins, growth substances which increase the seed germination.

Mondal *et al.* (2017) conducted experiment to know the impact of reduced chemical fertilizers with vermicompost and biofertilizers on morphological and biochemical traits of mustard. They concluded that combined application of chemical fertilizer, biofertilizers and vermicompost reflects the variable morpho-physiological and biochemical response of mustard plants toward synthesis and accumulation of simple secondary metabolites and pigment content such as sugar, proline and chlorophyll respectively in leaves which therefore played a role in regulation of plant osmosis and crop plant metabolism leading to better crop growth and yield. Combined application of different fertilizers with biofertilizers and vermicompost has enhanced LAI, CGR, NAR, PR, LAD and HI of mustard crop plants.

Berger *et al.* (2013) conducted experiment to study the effectiveness of a mixed biofertilizer with phosphate and potash rocks (PK biofertilizer) combined with an earthworm compound inoculated with free living diazotrophic bacteria and Cunninghamella elegans, fungi that produces chitosan, on cowpea nodulation, biomass yield and nutrient uptake. The effects of some chemical attributes from an acidic soil of the Brazilian Northeast were also studied. The treatments were as follows: a) biofertilizer enriched in N by free living diazotrophic bacteria(NPKB), applying crustaceous chitosan (ChCru) at a rate 2 mg mL^{-1}; b) NPKB and ChCru at a rate 4 mg mL^{-1}; c) NPKB and ChCru at a rate 6 mg mL^{-1}; d) NPKB and fungi chitosan (ChFu, 2 mg mL^{-1}); e) NPKB+C. elegans (NPKP); f) NPKB without chitosan; g) mineral fertilizers (NPKF); and h) control without NPK fertilizer and chitosan. Biofertilizer treatments increased cowpea nodules biomass, shoot biomass and total N, P and K in the shoots. The biofertilizer may be an alternative for NPK fertilization that slows the release of nutrients, favoring longterm soil fertility.

Rekha *et al.* (2018) concluded that soil fertility level was influenced by use of bio fertilizers, which play an important role in fixing atmospheric nitrogen, solubilizing insoluble form of phosphorous and potash and mobilizes the immobile nutrients in soil. These processes enhance the nutrient status of soil. In this study, microbial consortium consisting of bio-fertilizers *viz.* nitrogen fixers, P solubilize, K releasing bacteria and nutrients mobilizers were used. There were two microbial consortia (MC1 and MC2) consisting of nitrogen fixers Azospirillum and *Azotobacter* were applied alone and with recommended dose of FYM to the soil treated with different doses of chemical fertilizers. The soil health parameters like soil available N, P, K were found to be maximum in the treatments with microbial consortia MC1 along with recommended dose of FYM and 75% recommended dose of chemical fertilizers compared to other treatments. Maximum yield parameters like seed yield and straw yield of Bajra were recorded in the treatments applied with microbial consortia MC1 along with recommended dose of FYM and 75% recommended dose of chemical fertilizers compared to other treatments. This study showed that the increased nutrient status of soil when the bio-fertilizers are applied along with recommended dose of FYM. This experiment shows that possibility of reduced use of chemical fertilizers with application of bio fertilizers.

CONCLUSION

Biofertilizer of *Azotobacter sp. and Streptomyces badius* found to escalate the growth and yield attributes of wheat. They may be used synergistically as a potential source of plant growth promotion and chemical fertilizer can be reduced up to 25% without compromising the yield. Thus, biofertilizer could play significant role in sustainable agriculture.

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