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Influence of biofertilizers on millet production

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Abstract
In recent years, food security, livelihood security, water security, environmental conservation, and preservation of natural resources have all become severe issues. Developing countries are grappling with these challenges while also dealing with the dual costs of climate change and globalisation. Increased food demand as a result of the world's rising population has spurred the worldwide use of fertilisers. Biofertilizers have a major impact on soil fertility and plant growth. Solubilize insoluble soil phosphates into soluble phosphates by fixing atmospheric nitrogen both with and without plants, improving phosphorus availability and secreting growth stimulating chemicals and supplies to inoculated plants. Inoculation of biofertilizers contributes to a reduction in the requirement for chemical fertilisers and can therefore optimise plant growth, yields and production quality. Inoculation of biofertilizers contributes to a reduction in the requirement for chemical fertilizers and can therefore optimize plant growth, yields and production quality. Biofertilizers *viz*. Nitrogen fixers, P solubilizers, bacteria releasing K, and mobilizers of nutrients were used. Hence, each aspect of the biofertilizer technology relevant to the sustained production of millets should be placed under scrutiny before its extensive use. Thus, the present review explains the biofertilizers generally used in millets, along with their impact on soil productivity and sustained fertility.

Keywords: Millets, biofertilizers, chemical fertilizers, sustained, soil productivity

Introduction
Millets are major crops in Asia and Africa's semi-arid tropics (particularly in India, Mali, Nigeria, and Niger), accounting for 97 percent of millet production. Under dry, high-temperature conditions, the crop is chosen due to its yield and short growing season. Millets are native to many different places of the planet. Pearl millet is the most widely grown millet, and it is an important crop in India and parts of Africa. Finger millet, proso millet, and foxtail millet are also important agricultural species. Millets are small-grained, annual, warm-weather cereals of the Poaceae (grasses) family. They are drought and other extreme weather resistant, and their nutrient content is comparable to that of other huge cereals.
The term'millet' refers to a variety of grass crops whose seeds are extracted for human consumption or animal feed. Sorghum is known as millet in several parts of Asia and Africa, and broomcorn is known as broom millet in Australia. Millets, as compared to other cereal grains, are often adapted to less fertile soils and inferior growing circumstances, such as severe heat and low rainfall. Millets are used to make a variety of beverages in India. Millet is also used as a foundation component in distilled liquor.
Foxtail (*Setaria italica*), pearl or cattail millet (*Pennisetum glaucum*), proso (*Panicum miliaceum*), Japanese barnyard millet (*Echinochloa crusgalli*), finger millet (*Eleusine coracana*), browntop millet (*Panicum ramosum*), Koda (*Paspalum scrobiculatum*), and teff millet (*Eragrostis tef*) are the most significant cultivated millet species.
In many essential ecosystem processes, soil microbes play an important role, including nutrient cycling and homeostasis, organic matter decomposition, as well as supporting plant health and bio-fertilization growth. Biological N2-fixation is only partially the product of the capacity of these bacteria to contribute to crop yields. The processes involved have a major potential for plant-growth promotion. Economic and ecological benefits may comprise improved income from reduced fertilizer cost, lowered leaching of NO3-, N to groundwater and reduced emission of N2O greenhouse gas, the effect global warming of which is 300 times more than carbon dioxide. A numerous variety bacteria promote plant growth, including Azotobacter sp., Azospirillum sp., Pseudomonas sp., Bacillus sp. Acetobacter sp.

Biofertilizers responsible for millets

Biofertilizers are living microorganisms that can fix atmospheric nitrogen either by living in the soil freely or by being symbiotically associated with plants.

Pearl millet

Azotobacter biofertilizer increases yields of wheat, maize, cotton and mustard by 0-30 percent over control, and reduces the amount of chemical fertilizer required for maize and millet by 50 percent without reducing yield. By inoculating nitrogen- fixing and phosphate solubilizing microorganisms by themselves or in combination with diazotrophic bacteria, *Pseudomonas fluorescens*, *Azotobacter chroococcum*, *Azospirillum lipoferum and Acetobacter diazotrophicus*, along with *Trichoderma viride*, nitrogen-fixing and phosphate solubilizing performance significantly improves the plant height, dry weight, ear length, grain and stover yield in pearl millet. Pearl millet and sorghum inoculated with azotobacter or Azospirillum showed an increase of 11-12 percent in yield due to inoculation. Inoculation of nitrogen-fixing and phosphate-solubilizing microbes alone or in combination with pearl millet improved yields (Swami, S. 2020).

Biofertilizers showed a considerable improvement in growth parameters over control, according to Rathore and Gautam (2003). They also found that using biofertilizers with low doses of N and P, i.e., 40 kg N + 30 kg P2O5 ha-1 + biofertilizers boosted growth characters equivalent to larger doses of N and P, i.e., 60 kg N + 45 kg P2O5 ha-1 + biofertilizers.

According to Choudhary *et al.*, (2007), applying 60+40 kg/ha of N + P2O5 combined with 10 t FYM/ha and biofertilizer resulted in considerably yield enhancement and N, P uptake by pearl millet than using control and FYM (5 or 10 t/ha) + biofertilizers.s

The combined inoculation resulted in considerable enhancement in all of the growth and yield indices studied. Thus, the results demonstrated the usefulness of these bio-inoculants (*Azotobacter chroococcum*, *Azospirillum lifoferum*, *Acetobacter sp.*, and phosphate solubilizer *Bacillus megaterium*) in enhancing pearl millet for crop growth and yield (Latake *et al.*, 2009).

Inoculation with nitrogen-fixing and phosphate-solubilizing microorganisms, either alone or in the mixture, promotes crop growth and development. When the diazotrophic bacteria *Pseudomonas fluorescens*, *Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Acetobacter diazotrophicus* were combined with the fungi *Trichoderma viride*, the plant height, dry weight, ear length, grain and stover yield, grain quality (58.9 percent protein and 17 percent carbohydrate), nitrogen uptake (grain 59.03 and stover 79.76 kg ha-1) Phosphorus uptake (grain 9.21 and stover 8.73 Kg/ha) and B: C ratio over control and single inoculation of pearl millet crop (Singh *et al.*, 2017).

During the 2016-17 academic year, Rekha DLM *et al.*, (2018) performed a pot culture investigation at the Agriculture Research Station in Amravati. In this study, two microbial consortia (MC1 and MC2) comprised of nitrogen fixers Azospirillum and Azotobacter were treated alone and with prescribed amounts of FYM to soil treated with varying amounts of chemical fertilizer. When compared to other treatments, the treatments which are treated with microbial consortium MC1 combined with the prescribed dose of FYM and 75 percent chemical.
RDF showed maximum yield characteristics like seed yield and straw yield of Bajra and soil health parameters like available N, P, K in soil. This research convincingly demonstrated that when bio-fertilizers were used in conjunction with the recommended amount of FYM, the soil's nutritional status improved. This experiment demonstrates the possibility of reducing the use of chemical fertilizers by biofertilizers.

In sandy loam soils of Rajendra Nagar, Hyderabad, Divya *et al.*, (2017) found that the treatment with 75% RDF + biofertilizer @ 5 kg ha-1 incubated with vermicompost @ 500 kg ha-1 showed the highest dry matter accumulation, number of tillers m-2, leaf area index (LAI), days to 50% flowering, number of grains per ear head of pearl millet than the RDF with 100% and 75% along with 25% nitrogen through vermicompost.

Sorghum

The impact of nitrogen and biofertilizer inoculation on forage sorghum production potential and protein content. Green forage and dry matter yields, as well as crude protein content, were significantly greater than the control and indicated quantities at N 100 kg ha-1. With 100 kg N ha-1, the largest gross and net monetary returns, as well as the best benefit: cost ratio, were achieved. Azotobacter or Azospirillum seed inoculation produced much greater gross and net returns and benefits: cost ratios than uninoculated regulation, in addition to a notable improvement in forage yield and crude protein (Singh *et al.*, 2005).

Green and dry fodder yields of sorghum were maximum when the crop gained RDF of 60 kg N + 30 kg P2O5 ha-1, according to Ramanjaneyulu *et al.*, (2010), but green and dry fodder yields were significant compared when the crop received 50 percent of RDF (30 kg N + 15kg P2O5 ha-1) + FYM + biofertilizers (Azotobacter +PSB), which increased dry fodder yield in both treatments by 45.8 and 41.2% over control.

Rathore (2016) reported with the application of 75% recommended dose of nitrogen in the chemical fertilizer form and rest 25% of nitrogen through vermicompost and seeds are treated with PSB and Azospirillum, that leads to the maximum plant height (244.33 cm), dry matter accumulation (138.86 g plant-1), highest length of the ear head (34.47 cm), number of grains (2812) per ear head, test weight (39.33 g), grain yield (3914 kg ha-1), stover yield (14125 kg ha-1), gross returns (Rs. 86,965 ha-1) net returns (Rs. 59,971 ha-1), B: C ratio (3.22), total uptake of NPK were obtained as N (135.15 Kg N ha-1), P (27.78 Kg ha-1) and K (220.71 Kg ha-1).

According to Shinde *et al.*, (2017), the application of RDF 75% + 5 t FYM ha-1 + ZnSO4 25 kg ha-1 resulted in significantly higher yield attributes such as grain weight per ear head (131.78g), dry grain yield (21.83 q ha-1), and dry fodder yield (137.71 q ha-1) than the application of RDF 100% + ZnSO4 25 kg ha-1.

Ashwani and Rajesh (2017) experimented on sorghum at Crop Research Farm, Naini Agricultural Institute, SHUATS, Allahabad. The experimental results showed that with the application of 100% nitrogen through chemical fertilizer along with Azospirillum recorded maximum grain yield (2.53 t ha-1), stover yield (5.74 t ha-1), length of ear head (24.7 cm), test weight (14.38 g), highest protein content (12.02%), gross return (Rs. 79300 ha-1), net returns (Rs. 49490 ha-1) and B: C ratio (2.66) of sorghum were significantly superior to other treatments.

At Bapatla Agricultural College Farm, Goutami *et al.*, (2015) experimented on sorghum to know how chemical fertilizers, bio-fertilizers, and FYM applied to rice-fallow sorghum affected soil properties and biological activity. The results showed that application of 150 kg N ha-1 +FYM+ bio-fertilizers resulted in the highest bacterial and fungal population (10.6 x106, 5 x104 CFU /gm of soil, respectively),

In a field experiment in Akola, Maharashtra, Nemade *et al.*, (2013) discovered that applying 75 percent RDF (60:30:30 kg NPK ha-1) + 5 t FYM ha-1, Azospirillum, and PSB enhanced soil fertility status with higher Organic carbon (6.33 g kg-1), available N (283 kg ha-1), P2O5 (25.00 kg ha-1), and K2O (424 kg ha-1) than rest of the treatments.

Rani *et al.*, (2019) found that seed treatment with Azospirillum @ 4ml + PSPB @ 4ml kg-1 seed drastically enhanced plant height (195.3 cm), no. of plants m-2 (14 plants m-2), biomass (8.1 t/ha), test weight (3.8 g), grain yield (2.33 t/ha), straw yield (5.79 t/ha), net returns (Rs. 51,217/ha), B:C ratio, and net returns (2.10).

Finger millet

According to Ramamoorthy *et al.*, (2002), 50 percent RDF + 50 percent FYM + biofertilizer inoculation of Azospirillum and Aspergillus @ 25 g/kg seed was shown to be comparable to biofertilizer + 100 percent RDF (60:30:30 kg NPK/ha) and finger lengths of 11.5 and 10.8 cm in finger millet.

At the College of Agriculture, Phule, Patil *et al.*, (2006) investigated various nutrient management systems and noticed that seed treatment with 50 percent RDF (50 kg N/ha + 25 kg P2O5/ha) + FYM @ 2.5 t/ha + biofertilizer significantly increased grain (20.11 q/ha) and fodder yield (28.17 q/ha) in finger millet. Trichoderma spp. is a type of free-living fungus or virulent plant symbiont that is usually found in soil, or root habitats. The effects of a biofertilizer (Trichoderma) and a chemical fertilizer (urea) on photosynthesis, chlorophyll fluorescence, and yield characteristics in *Eleusine coracana* were investigated in isolation and combination.

The recommended dose of NPK + FYM at 7.5 t ha-1 + PGPR at 2 kg ha-1 + vermicompost and Frond compost both at 3.75 t ha-1 as top-dressing at 25 DAT was found by Thimmaiah *et al.*, (2016). In finger millet grown on red sandy loam soils of Shivamogga, Karnataka, higher plant height (145.27 cm), total dry matter accumulation (59.13 g plant-1), number of tillers (4.07 plant-1), leaf area (1177.30 cm-2 plant-1), grain yield (63.50 q ha-1), straw yield (86.67 q ha-1), and gross returns (Rs. 1,03,000 ha-1) were recorded.

During Kharif Roy *et al.*, (2018) conducted experiments in Ranchi on finger millet based on the application of chemical and organic and biofertilizers revealed maximum grain yield (3773 kg ha-1), straw yield (7695 kg ha-1) with the combination of FYM (10 t ha-1) + Biofertilizer + ZnSO4 (12.5 kg ha-1) + Borax (5 kg ha-1) + 75% RDF followed by application of FYM (10 t ha-1) + Biofertilizers + ZnSO4 (12.5 kg ha-1) + Borax (5 kg ha-1) + 100% RDF (3542 kg ha-1) and significantly superior to rest of the treatments.

Kiran *et al.*, (2017) stated that in highest grain yield (2200 kg ha-1), straw yield (4550kg ha-1), maximum uptake of nitrogen, phosphorus and potassium 47.4 kg ha-1 N, 8.6 kg ha-1 P, 10.3 kg ha-1 K in the grain of finger millet were noticed with combined application of 50% RDP+ FYM @7.5 t ha-1 + PSB @ 5 kg ha-1.

Foxtail millet

Rhizobacteria are biofertilizers that help plants grow and produce. The purpose of this study was to evaluate the productivity improvement potential of rhizobacteria and the nutritional level of foxtail millet (*Setaria italica*). Bacillus sp. and Rhizobium sp. were isolated from a local crop's rhizosphere and root nodules (*Macrotyloma uniflorum*). The best bio-inoculant was chosen, implying that Rhizobium sp. might be used as a powerful biofertilizer for foxtail millet. Rhizobium sp. outperforms the control in terms of the total dry weight of the plants (122.78%) and grain yield (76.29%). In a conclusion, there is potential for the creation of bio-inoculants for nutrient-poor soils, which could aid in increasing the production and nutritional value of foxtail millet (Khatri *et al.*, 2016).

In shallow alfisols of Hanumanamathi, Dharwad, Basavarajappa *et al.*, (2002) reported a substantial rise in plant height of foxtail millet with enhanced FYM + Azospirilllum @ 10 kg ha-1 (86.35 cm) above individual application of enriched FYM (84.16 cm) and gliricidia GLM (81.93 cm).

Monisha *et al.*, (2019) discovered that the application of 50 percent RDF + 25 percent Poultry manure N Based + 25 percent Biofertilizer resulted in the highest number of productive tillers m-2, maximum panicle length (17.8 cm), grain weight (2.73 g), maximum yield (2385 kg ha-1) and greater straw yield (4293 kg ha-1) in red soils of Madurai, followed by 50 percent RDF + 25 percent Poultry manure.

Marwein *et al.*, (2019) did an experiment on foxtail millet at Prayagraj, Uttar Pradesh and discovered that incorporating 75 percent RDN through Urea + 25 percent N through poultry manure + Azospirillum Seed Inoculation contributed the highest grain yield (2.31 t ha-1).

Nonsymbiotic nitrogen-fixing bacteria

Azotobacter: aerobic microbes which thrive well in neutral soils and are susceptible to deficiency of phosphate.

Clostridium: Anaerobic fixes less amount of nitrogen fixation than azotobacter.

Mycorrhizae: it is a mutually beneficial association between fungi and roots of higher plants It is divided into two groups The Endo-mycorrhizae group is called vesicular arbuscular mycorrhizae [VAM] improves uptake of phosphorus imparts resistance against drought and certain root infecting fungus. Ecto-mycorrhizae has grown on surface layers of roots.

Frankia: Association of actinomycetes and plants. Actinomycetes are transitional between bacteria and fungi, producing a smell of earth which we feel initial raindrops after falling on earth called geosmin. Breakdowns recalcitrant compounds.

Phosphorus solubilizing bacteria: Most of the phosphorus sources are gets fixed in the soil become unavailable to plants so availability and absorption of phosphorus are induced by the utilization of phosphorus solubilizing microbes such as aspergillus, pseudomonas, bacillus and mycorrhizal fungus.

Conclusion

Biofertilizers play a crucial role in enhancing food crop production to fill the required ranges of requirements for population growth without endangering natural resources. Implementation of biofertilizers results in increased production of crops with increased sustainable and environmentally friendly productivity and soil fertility. Institutional training to popularize biofertilizer technology for staff, students, farmers and distribution through mass media, publications and bulletins, etc. Appropriate and specific strains for n fixing and other nutrient solubilizing microbes are recognized to increase nutrient availability, thereby increasing crop production.

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