INNOVARE JOURNAL OF AGRICULTURAL SCIENCE

INNOVARE ACADEMIC SCIENCES Knowledge to Innovation

Vol 9, Issue 1, 2021 ISSN- 2321-6832

Review Article

BIOFERTILIZERS: BETTER APPROACH TOWARD FORMING

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Received: 14 November 2020, Revised and Accepted: 20 December 2020

ABSTRACT

In the present scenario, chemical fertilizers are seem to be a good source of inorganic nutrients to fulfill the need of increasing demand of crop production. Although, with respect to the time, so many adverse effects of chemical fertilizers on human health, natural microflora of soil and on the ecosystem have been reported which are not stoppable. On the other hand, in our nature, a great number of useful soil micro-organisms are found that can help plants to absorb nutrients. A bio-fertilizer is a substance which contains beneficial living microorganisms and used as a modernized form of organic fertilizer. From few decades, biofertlilizers are reported to exhibit similar beneficial and lesser harmful impacts on the ecosystem. Hence, as an alternative of chemical fertilizers, biofertlilizers are broadly used as a healthier and sustainable method for agriculture. In this review, we will discuss about the adverse effects of chemical fertilizers on different parts of environment in contrast to the benefits of biofertlilizers along with the brief history and mechanism of action of bacterial biofertlilizers.

Keywords: Inorganic fertilizers, Biofertlilizers, Adverse effects, Ecosystem, Beneficial micro-organisms, Biological nitrogen fixation.

 DOI: http://dx.doi.org/10.22159/ijags.2021v9i1.42675. Journal homepage: https://innovareacademics.in/journals/index.php/ijags

INTRODUCTION

In the past decades, the use of inorganic fertilizers has become very popular throughout the world as they are effortlessly affordable and showed rapid action due to their prompt release of nutrients [1]. Although, the use of chemical fertilizers and pesticides has helped lot in increase in the crop productivity the same has also a cause of subsequent deterioration of soil health, cause biomagnification, increase in microbial resistance, increase in soil salinity, etc. [2,3].

A number of researches on the adverse effects of inorganic fertilizers have revealed that their harmful activities cannot be overlooked. Such as use of chemicals is a great cause of increased level of salts and minerals in soil, in water bodies as well as in soil micro-organisms [4]. Apart from this, the same has also seen to associate with the low quality of harvested crops. Various studies on the human and other animals also indicated a number of negative impacts of chemicals used as fertilizers, such as impairment in their physiology; abnormal functioning of respiratory system, nervous system, and reproductive system. Long-term uptake of such agriculture products have observed to be connected with the serious malfunction of human life cycle [1-5]. Hence, awareness toward the excessive use of chemicals fertilizers has been taken to various spheres. Eco-friendly practices of agriculture are challenge for present time of great demand of foods and limited natural resources [6-8].

In nature, a number of beneficial and harmful microbes have been recognized and categorized. Out of these, some of the soil microbes have ability to increase mineral and nutrients in soil by different mechanisms [9]. These microbes with some special types of organic compounds are commonly using to enhance productivity of plant in the place of chemical fertilizers. Such, substances are called biofertlilizers. To fulfill the need of growth nutrients, biofertilizers are proved to be a better option. Many scientific data revealed that the biofertilizer has numerous advantages over chemical fertilizers [10-12].

Biofertlilizers are not only cost effective, eco-friendly, and secure for animal body but they also serve as a renewable source of plant nutrients. In addition to this, the same have capacity to work as important components of integrated nutrient management [1,5,13]. In this review article we have mentioned a brief description on various harmful effects of chemical fertilizers on different components of environment like soil, water, air, animals, plants, etc., has been given along with pollution caused due to their excessive application [14]. Here, we have also summarized the beneficial effects of biofertlilizers over inorganic fertilizers [15,16].

ADVERSE EFFECTS OF CHEMICAL FERTILIZERS

Chemical fertilizers are synthetic compounds created specifically to increase crop yield. These are rich sources of nitrogen, potassium, phosphate, etc. They may be single nutrient based (potassium, urea) or may be complex or blended having a mix of more than two nutrients such as ammonium phosphate, nitrophosphate, potassium chloride, and other nutrients. For example, ammonium nitrate is a good source of soluble nitrogen and ammonium ions for plants [17-19]. The main role of fertilizers is to add nutrients to the soil, but chemical fertilizers cannot add anything else other than inorganic ions to plants [20-23]. Although, chemical fertilizers are very helpful to enhance the crop yield their negative impacts and drawbacks cannot be neglected. Most of the inorganic fertilizers do not contain micronutrients which are essential for plant growth [24-26]. The same are unable to add organic content to the soil. Some studies have revealed that the synthetic fertilizers do not support microbiological lives in the soil which are essential to maintain soil quality [14,17,26].

Although, every chemical fertilizer need to be applied in their specific limited amounts but in most of the cases these are seen to be over applied that reported to cause root burn, exo-osmosis and found to create toxic concentration of salts [27-29]. Some findings revealed that most of the chemical fertilizers release their nutrients too quickly which results an abnormal plant growth. Many times, this kind of plants are weak, more prone for disease, with less fruiting. In addition to this, because of easy solubility and uncontrolled availability synthetic fertilizers often leach deep down in soil that serve as a source of underground water pollution [21,29].

A number of chemical fertilizers considered to serve as a potential source of natural radionuclide and heavy metals. A large majority of the heavy metals such as Hg, Cd, As, Pb, Cu, Ni, and Cu; natural radionuclide such as 238U, 232Th, and 210Po have been reported as a component or adulteration in the same [30]. Due to a long history of use of these fertilizers accumulation of heavy metals in soil and plant system is common and the same have been reported to enter in food chain through plants and soil eaters [31]. As many inorganic fertilizers are non-biodegradable, their long-term use results in accumulation of harmful substances, increased salinity and acidification of the soil thereby degrading soil fertility [32]. More accumulation and leaching have also been a great danger for water bodies and soil itself [33,34].

In addition to this, excessive use of chemical fertilizers in agriculture also linked with a number of other environmental problems too. For example, use of nitrogen fertilizer is directly proportional to the presence of nitrates and to carcinogen nitrosamines in aquatic bodies [35,36]. Plants such as lettuce and spinach showed higher accumulation of nitrates and nitrites in their leaves [37-39]. Water pollution, decrease in water oxygen, water odor, decrease in aquatic fauna and flora, and ultimately eutrophication are wide spread problem caused by chemicals used as fertilizers [40].

Continuous use of acid-forming nitrogen fertilizers causes a decrease in soil pH again destroy micro-environment of that soil, particularly sodium, potassium, and phosphorous in abnormally higher concentration exhibit negative impact on soil pH, soil structure, composition, and microbes of soil [41-43]. Moreover, excessive Ca and Fe with Zn disrupt the balance of soil nutrients may result in decrease plant growth as well as soil pollution. Soil nitrates, nitrites, and other nitrogen salts are reduced by denitrifying microbes which cause increase atmospheric nitrogen oxides as some report demonstrated that atmospheric N2O increases from 0.2 to 0.3% each year. Similarly ammonia emission from fertilized soil damages vegetation [33,44]. In addition to this, decomposition of chemical fertilizer may result in increased level of carbon dioxide, hydrogen sulfides, methane, and chloro-fluoro-carbon which together with other oxides causes greenhouse effect. Hence, indirectly too much use of inorganic fertilizers cause disturbs in whole ecosystem [45,46].

Studies on different vegetations also revealed a great number of negative effects of chemical fertilizers on plants themselves. Such as, these have seen to cause the early decay of harvested yam tubers [47]. The ions released from nitrates, nitrites, phosphates, sulfates, etc., exhibited unwanted physiological interactions resulting low quality products with less flavor, taste, and aroma than those cultivated without non-organic fertilizers. In some cases, higher concentration of these fertilizers has been found to be linked with the salt burn and even death of young plants [39,48-50].

Many studies revealed a number of adverse impacts of these fertilizers on human bodies. For example, the presence of nitrates in drinking water exert negative effects on salivary glands, intestine, immune systems, and as well as on endocrine system. Because of same, inflammation of urinary system and chronic kidney disease has also been reported [16,39,51].

Adverse effects of these agrochemicals were also reported to hinder the functioning of blood hemoglobin, interfere with the physiology of iron, and observed to be associated with acute health problems, such as abdominal pain, dizziness, headaches, irritation, nausea, vomiting, hair loss as well as skin and eye problems [34,46].

ADVANTAGEOUS EFFECTS OF BIOFERTILIZERS

Because food is compulsory for survival of all living beings so to fulfill this need we should have more natural, eco-friendly, non-hazardous, and degradable agricultural practices. Till now, bio-fertilizers are proved as a better choice to fulfill these demands [47,49]. These are cost effective, pollution free, natural, and renewable source of plant nutrients along with their short life span. As compared to the chemical fertilizers, excessive use of biofertlilizers does not cause much harm [52].

Chemical fertilizers can supply sufficient nutrients to the soil, but growing herbs need much more than just nutrients to survive. Plants also need organic matter and living organisms [27,44]. In contrast to the synthetic fertilizers biofertlilizers promote growth of soil microbes up to a significant percentage. These microbes are reported to enhance the decay of complex organic matter of soil that serve as a prominent source of plant nutrients. In this manner, these are responsible for improving soil quality and fertility in natural way [39,53].

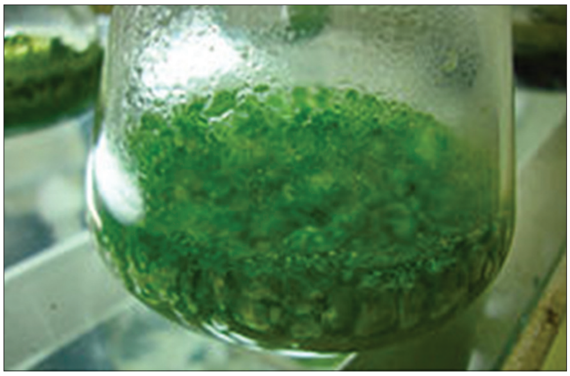

Fig. 1: Blue-green algae cultured in specific media used as Biofertilizer [12]

Bio-fertilizers contain an ample range of natural nutrients with trace elements which are not possible with inorganic fertilizers. Although, in biofertlilizers, a number of different microbial cells are used as source of nutrients so instead of greenhouse gases generation they utilized these gas and observed to work against global warming effect [39,46].

Increased application of ammonium salts in rice paddy fields has been found to linked with increased emission of methane gas that too serve a causing agent of global warming, when it replaced with biofertlilizers and composting of animal waste reverse effects were observed [28,38,53]. The methane gas is commonly utilized and reduced or oxidized by microbes and thus proved to be a better medium of fertilizers. In addition to this, the longevity of organic fertilizers is much more than inorganic and they can release nutrients slow and steady for more than one season is also made them a better choice as a fertilizer [54]. In many studies, the uses of biofertlilizers have been found to increase overall quality of soil and crop both [18,39,40].

Since, biofertlilizers are rich source of beneficial micro-organisms they also provide protection to the host plants from different pathogenic microbes by releasing growth inhibiting chemicals and showed competition for place and nutrients with pathogenic microbes [44]. For example, studies have showed that use of biofertlilizers has seen to associated with decreased cases of plant diseases such as pythium root rot, rhizoctonia root rot, chill wilt, and attack of parasitic nematodes [54]. Composts contain huge variety of microbes, many of which may be useful in controlling pathogens. Thus, beneficial microbes help to control plant pathogens. More than this, the constituent of biofertlilizers such as degraded tree barks and roots also helps to control growth of disease causing microbial cells as they also liberate some anti-pathogenic chemicals [35,55]. Antibiotics released from microbial cells also seen to be useful against pathogens. However, disease resistance gene activation in host plants by the symbiotic action of beneficial microbes again served as a strong tool against plant infection. In some cases, predation of harmful microbes by microbes used as biofertlilizers showed a great help. Sometimes, inorganic fertilizers may contain pathogens such as *Salmonella* Spp. which may cause plant infection, so instead of serving a growth nutrient the same may serve as source of contamination [8,26].

Compost and organic material introduces beneficial microorganisms in soil. Microorganisms are normally found in soil and compost convert organic nitrogen into inorganic nitrogen, a process called mineralization. Plants may then take up these nutrients [56].

In general, most of the biofertlilizers are applied either to the soil or on seed or plant surfaces where they form their colonies called the rhizosphere [30,34,55]. Such group activity of microbes promotes growth of host plant by increasing the availability of nutrients to the host plant [49]. For large scale production, these inoculums are recognized, studied for their beneficial activities and then cultured in the laboratory and packed in suitable carriers. For example, the use of *Rhizobium* sp., *Azospirillum* sp., *Azotobacter* sp., and *Cyanobacteria* to increase crop production has long history [56]. Some of these oxidizing microbes accelerate the decomposition of soil organic residues, agricultural by-products, complex organic manure, etc., through various process and release simple organic and inorganic compounds which can be easily absorbed by host plants that result in healthy harvest of crops. While some microbes like the *Rhizobium* sp., acts by enhancing the activity of deaminase enzyme in pulses crops [33,56].

In dry and semi-dry areas water excessive water loss due to vaporization can be minimized with the use of bio-fertilizers as the organic components of the same serve as a good soil conditioner. These also help to bind soil particles preventing desertification and erosion. Earlier studies showed that with biofertlilizers water retention capacity of soil can be increased many times on the other hand; inorganic fertilizers do not show any water retention action [14,38,50]

In addition to this, certain diazotrophic bacteria exhibit symbiosis with some specific plant species and form root nodules and specifically fix atmospheric nitrogen for host plant. These symbioses are found between rhizobia and legumes and Frankia and actinorhizal plants [44].

Plants produce many growth hormones, which are organic molecules involved in several development processes. Broad spectrums of beneficial bacteria are known which produce phytohormones that are involved in plant-growth promotion [30]. For example, some bacterial strains secrete auxins, which act as signaling molecules for bacterial communication to coordinate activities. In *Solanun tuberosum* auxin-producing *Bacillus* spp. has been reported to exert a positive effect on plant growth and development [57].

Likewise endophytic *Streptomyces* in *Azadirachta indica* produce indole acetic acid and serve as a potential plant-growth promoter. Indole acetic acid secretion by *Rhizobial* strains also reported to improve the growth of several crops such as *Capsicum annuum*, *Solanum lycopersicum*, *Daucus carota,* and *Lactuca sativa*. [58].

Some bacterial species have been observed to secrete various types of cytokinins that are important plant physiological activities. Such as cytokinin secreted by *Azotobacter chroococcum* and *Bacillus megaterium* strains promote cucumber growth. The growth of red pepper plants observed to be increased by treatment with a *Bacillus cereus* strain producing gibberellins. Tomato plants inoculated with the gibberellin-producing *Sphingomonas* sp. LK11 strain showed significantly more production. Root-hair elongation in *Arabidopsis thaliana* was seen by ethelene producing activity of *Phyllobacterium brassicacearum* STM196 [37,48].

Specific enzymes of microbes used as fertilizers also help in plant physiology as bacterial enzyme, 1-aminocyclopropane-1-carboxylate, hydrolyze plant ACC, the precursor molecule of ethylene and reduce rate of aging. Furthermore, *Rhizobium leguminosarum* strains producing ACC-deaminase promoted pepper and tomato plant growth. Moreover, plant growth- promoting strains of *Azotobacter* have been reported to produce a large amount of B-group vitamins that again help to enhance gross productivity [56]. Microbial vitamin production enhances plant-rhizobial symbiosis and plant mycorrhization that exert positive effect on plant growth [57].

Some studies described that impact of abiotic stress can also be decreased with biofertilizers for example, *Pseudomonas* strains enhancing asparagus seedling growth and seed germination under water-stress conditions. Commercial species of *Pseudomonas putida* promotes cotton seedling grown under salt stress [22,49]. It helps to increase germination rates and protect against salt stress by escalating the absorption of Mg2+, K+ and Ca2+, decreasing Na+ uptake, and improving the production of endogenous indole acetic acid. Similarly, *Pseudomonas fluorescens* species MSP-393 acts as a Plant Growth Promoting Rhizobacteria for many crops grown in the saline soils of coastal ecosystems [58].

In addition to above mentioned activities some antibiotic producing bacterial and fungal species indirectly influence plant growth as they inhibit growth of pathogenic microbes. For instance, Pseudomonas sp. produces antibiotics that inhibit *Gaeumannomyces graminis* var. tritici that cause infection in wheat. Antibiotics produced by *Bacillus* sp. seen to be active against many Gram-positive and Gram-negative bacteria, as well as many pathogenic fungi [24,59]. Bacterial enzymes such as chitinases and β-glucanases inhibit fungal growth. In a similar way, the same enzymes secreted by *Pseudomonas* sp. destroy *Rhizoctonia solani* and *Phytophthora capsici*, two of the most destructive crop pathogens in the world [17,28,59].

Although, here a number of positive aspects of biofertilizers have been seen but actually there are much more left. For example, as compare to chemical fertilizers biofertilizers are cost effective [60]. Since, these can be produced from cheap waste materials, self-growing microbial cells which are abundant in each country [3,18,32,57].

DISCUSSION

Hence, reviewing all these consequences we need to accept practice of minimum use of inorganic fertilizers and use of biofertilizer as an alternate of chemicals fertilizers. We have already mentioned the acidification, salinity, imbalance in soil pH etc caused due to excessive application of inorganic fertilized [22,28,60]. This problem can be easily counteracted by the use of bio-fertilizers as they do not change pH of soil; instead they help to maintain soil pH to make it more optimum for plant growth [35,61].

Microbial cells used in biofertilizers have capacity of fix nutrients in soil by their natural physiological mechanisms. Some examples of free-living nitrogen-fixing organisms are Azospirillum, commonly associated with cereals in temperate zones and reported to improve rice crop yields; Azotobacter, shown to play an important role in nitrogen fixation in rice crops and can also be used for wheat, barley, oat, rice, sunflowers, maize, beetroot, tobacco, tea, coffee and coconuts production as biofertilizer [46,51,61]. Some genera of bacteria like Gluconacetobacter, Azospirillum and Herbaspirillum are endophytes of sugarcane and play a significant contribution in nitrogen fixation [49,62].

Comparative study of chemical verses biofertilizer demonstrated more weight and size of fruits treating with biofertilizer than chemical fertilizer [48,55,63]. Since, too much use of inorganic fertilizer in agriculture causes environmental problems including soil, physical destruction, and nutrient imbalance and disrupts food chain biofertilizers seemed to be better option [36,39,62].

Environmental point of view, the main advantage of use of bio-fertilizer is that it does not cause soil pollution and also does not show any negative effect on human health [64-67]. Although, in some cases biofertilizers are not successful but this problem can be overcome either by giving combine treatment chemical fertilizers containing nitrogen with some other nutrients or by adopting different agricultural approach like mixed farming, vermin-composting etc. [68]. But there is a strong need to prefer chemical free forming to protect environment from pollution [69]. Though, biofertilizers are safe and natural nutrient suppliers and showed a great number of advantages over chemical fertilizers but along with this much more researches are needed in this direction.

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