Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 1, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

ENVIRONMENTAL ADVANTAGES OF THE USE OF BIOFERTILIZERS IN THE AGROECOSYSTEM - A REVIEW

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Abstract

The agricultural industry is becoming a viable component of a healthy ecosystem. This paper aims to present the environmental advantages of the use of biofertilizers in the agroecosystem. The paper discusses some of the types of biofertilizers that are based on biological nitrogen fixation, PGPR, EM, and their benefits to the soil environment and growing crops. There is now a need to adopt a more environmentally friendly approach by applying biofertilizers to aid better nutrient uptake by plants, to stimulate their growth, and increase the population of beneficial microorganisms in the rhizosphere, thereby increasing crop yields, and stabilizing soil fertility, thus ensuring a healthy environment. The application of biofertilizers has an impact on the formation of larger plant biomass, as it increases the mass and improves the number of fruits per plant, increases the standard yield, and improves the quality of the production. Scientific developments in different parts of Europe, America, Africa and Australia present the efficiency of biofertilizers in crops that are typical for these regions - fruits, vegetables, cereals, essential oil crops, etc.

Key words*: agroecosystem, biofertilizers, organic farming, PGPR.*

INTRODUCTION

In order to meet the food needs of a growing global population, conventional agriculture plays a very important role, which necessarily leads to the increased use of chemical fertilizers and pesticides (Santos et al., 2012; Bhardwaj et al., 2014), which are the two main factors required for greater agricultural production (Muraleedharan et al., 2010; Barman et al., 2017). When farmland is managed through an intensive monoculture system, in which only chemical fertilizers are actively used, aggressive soil use is observed, together with rapid nutrient leaching (Adejobi et al., 2013; Filho et al., 2017), with a slow decline in productivity and with significant deterioration in environmental quality (Rahim, 2002). A number of publications, such as those of Mahajan & Gupta (2009), Khare & Arora, (2015), have reported that increased use of chemical fertilizers leads to soil deterioration due to the lack of organic matter and loss of fertility, while other authors, such as Gupta & Singh (2008), add that both adverse impact on soil microflora and fauna and reduction in crop yields have been reported.

Both synthetic fertilizers and environmental pollution pose a threat to sustainable agriculture (Agarwal et al., 2018). The problem of nutrient depletion contributes to soil degradation (Graham & Vance, 2003; Sutton et al., 2013), as environmental protection requires a research into new sustainable technologies (García et al., 2004) that use ecological sources of organic matter to maintain soil fertility (Stanhill, 1990; Van Bruggen, 1995) and one such alternative cropping system is organic farming (Bettiol et al., 2004).

This paper aims to present the environmental benefits of application of biofertilizers in the agroecosystem.

MATERIALS AND METHODS

This is a scientific publication overview which focuses on the alternative role of biofertilizers that ensure the sustainability of soil fertility in the agroecosystem. The paper discusses some of the types of biofertilizers that are based on biological nitrogen fixation, PGPR, EM, and their benefits to the soil environment, growing crops, and stimulation of the diversity of beneficial microorganisms in the rhizosphere. The beneficial role of mycorrhizal fungi in agricultural systems is pointed out with a focus on the innovative nature of biofertilizers when it comes to improving soil environment, vegetative growth, yield and quality of the resulting produce.

RESULTS AND DISCUSSIONS

The rhizosphere is the part of the soil as the zone of maximum microbial activity that is influenced by plant roots and their exudates (García-Fraile et al., 2015), which function as a source of nutrients for microbial growth, and in this zone the microbial population is significantly more active and different as compared to that in the surrounding environment (Weller & Thomashow, 1994; Burdman et al., 2000).

In order to increase the population of beneficial microorganisms in the rhizosphere (Okur, 2018), it is necessary to adopt a more environmentally friendly approach by applying biofertilizers (Vessey, 2003). Biofertilizers are an outstanding alternative to agrochemicals (Bhardwaj et al., 2014), as their use cannot replace chemical fertilizers completely, but can significantly reduce the use of chemical fertilizers (Subashini et al., 2007). The innovative view of agricultural production is based on the growing demand for bio-based organic fertilizers (Raja, 2013; Bhardwaj et al., 2014), biofertilizers and other microbial products (Rahim, 2002) that improve soil quality, ensure long-term soil fertility to achieve the sustainability of farming systems, and make the agricultural area a viable component of a healthy ecosystem (Bhardwaj et al., 2014). Biofertilizers are preparations containing live or latent cells of effective strains of microorganisms that fix nitrogen, dissolve phosphate and certain elements, produce plant growth substances, and prevent certain soil diseases (Okur, 2018). Biofertilizers maintain the richness of soil environment in all types of micro- and macroelements by fixing nitrogen, dissolving or mineralizing phosphate and potassium, releasing substances that regulate plant growth, producing antibiotics, and biodegrading soil organic matter (Sinha et al., 2014). They are valuable to the environment (Mazid & Khan, 2014) and have a potential role in sustainable agriculture (Barman et al., 2017). Application of biofertilizers promotes better nutrient uptake by plants (Vessey, 2003; Hart & Trevors, 2005; Chen, 2006), stimulates their growth (Das et al., 2007; Khan et al., 2018), increases crop productivity (Kaewchai et al., 2009; Malusá & Vassilev, 2014; García-Fraile et al., 2015) and also stabilizes soil fertility (Mazid & Khan, 2014). Biological fertilization aims to accelerate microbial processes, which increase the availability of nutrients that are readily assimilable by plants and increase the number of beneficial microorganisms in the soil (Mahdi et al., 2010), thus maintaining and gradually building the microbial population, which helps maintain soil fertility (Choudhury & Kennedy, 2004; Malik et al., 2011).

Various field studies have shown that biofertilizers are effective and inexpensive inputs into the agroecosystem without any environmental hazards (Ghosh, 2004; Sahoo et al., 2014; Borkar, 2015) and are environmentally friendly, productive, efficient and affordable for farmers (Agarwal et al., 2018). Biofertilizers are produced in liquid, powder and granular form and applied to soil, compost, seeds, seedlings and foliar on plants and all types of crops grown under different agro-ecological conditions can benefit from the effectiveness of biofertilizers (Amutha, 2011; Masso et al., 2015).

Biofertilizers provide plants with nutrients that are naturally present in the soil and atmosphere (Barman et al., 2017). Wani et al. (2013) and Borkar (2015) pointed out that biofertilizers could fix atmospheric nitrogen through the process of biological nitrogen fixation (BNF) and dissolve plant nutrients such as phosphate, potassium; in addition, they stimulated plant growth through the synthesis of various growth-promoting substances and had a C:N ratio of 20:1, thus indicating their stability. Masso et al. (2015) reported that biological nitrogen fixation (BNF) was enhanced by inoculation, and Gupta et al. (2007) and Olivares et al. (2013) specified that it was through biological nitrogen fixation that excessive application of chemical nitrogen fertilizers could be reduced, thereby reducing their negative impact on the environment.

Plant growth-promoting rhizobacteria (PGPR) are a group of bacteria that occur in the rhizosphere (Ahmad et al., 2008) and colonise plant roots, hence improving their growth, productivity, immunity (García-Fraile et al.,

2015) and having a positive effect on the control of phytopathogenic microorganisms (Vejan et al., 2016). Kumar et al. (2015) cited Shishido et al. (1999) reporting that PGPR had to colonize the rhizosphere around the roots, the root surface or within root tissues, and added that Verma et al. (2013) indicated that the plant growth-promoting mechanisms were extracellular PGPR (ePGPR) which existed in the rhizosphere or in the spaces between root cortex cells, and intracellular PGPR (iPGPR) that existed inside root cells. Vocciante et al. (2022) presented the complex and efficient network of functional interactions established by PGPR to maintain the performance of cultivated plants under adverse environmental conditions and abiotic stress. Khalid et al. (2009) pointed out that PGPR not only ensure the availability of essential nutrients to plants but also increased nutrient use efficiency, hence being potential tools for sustainable agriculture and receiving recognition over the years for their benefits in agriculture. Depending on their interactions with plants, plant growth promoting rhizobacteria (PGPR) can be divided into symbiotic bacteria, which live in plants and exchange metabolites with them directly and free-living rhizobacteria living outside plant cells (Gray & Smith, 2005). According to Qureshi et al. (2009), inoculation of legumes with rhizobium has been practiced in agricultural systems for more than a century (Mulongoy et al., 1992; Masso et al., 2015). Root colonization is essential to promote plant growth by rhizobacteria (Kloepper & Beauchamp, 1992; Ikeda et al., 1998; García et al., 2004). García-Fraile et al. (2012) cited authors pointing out that the ability of rhizobia to stimulate growth was well-known both in cereal crops such as maize, barley and rice (Chabot et al., 1996; Gutiérrez-Zamora et al., 2001; Peix et al., 2001; Yanni et al., 2001; Mishra et al., 2006), and in plants whose seeds were used to produce edible oils such as rapeseed or sunflower (Noel et al., 1996; Alami et al., 2000). Barman et al. (2017) cited Panda, (2011) who reported that *Rhizobium* and blue-green algae (BGA) could be considered established biofertilizers, while *Azolla*, *Azospirillum* and *Azotobacter* were at an intermediate stage. Hence, as reported by Lima et al. (2010), it is necessary to mix stone biofertilizers and a mixture of earthworms inoculated with selected free-living diazotrophic bacteria, which are effective when it comes to enriching nitrogen through the process of biological nitrogen fixation (BNF) (Oliveira et al., 2017). In their article, Khalid et al. (2009) referred to a large number of authors (Naiman et al., 2009) reporting a significant increase established by them in crop growth and yield of agricultural crops in response to microbial (PGPR) inoculants under greenhouse and field conditions.

Kaewchai et al. (2009) cited authors pointing out that mycorrhizal fungi were in relationship with the roots of 90% of plants and supported nutrient and water absorption (Gaur & Adholeya, 2004; Das et al., 2007; Rinaldi et al., 2008), and improved soil structure (Rola, 2000; Zhao et al., 2003; Chandanie et al., 2006; Rinaldi et al., 2008), crop productivity and its fertility (Malik et al., 2005). Agarwal et al. (2018) added that according to Rather et al. (2010) mycorrhizal fungi increased resistance to pests and pathogens, and increased survival at high temperatures. Plants colonized by mycorrhizal fungi grow better than those without them (Singh et al., 2008) and are useful in natural and agricultural systems (Adholeya et al., 2005; Marin, 2006).

Effective microorganisms according to Joshi et al. (2019) are mixed cultures of beneficial naturally occurring organisms that can be applied as inoculants to increase the microbial diversity in the soil ecosystem, and according to Formowitz et al. (2007) effective microorganisms (EM) are a mixture of supposedly beneficial microorganisms that are claimed to enhance microbial turnover in compost and soil. Olle & Williams (2013) cite Higa (2012), who reported the concept of Effective Microorganisms for the first time in 1986 at an IFOAM conference and Subadiyasa (1997), described the technology of Effective Microorganisms as a technique that supported "natural farming". Effective microorganisms (EM) consist of mixed cultures of beneficial microorganisms such as photosynthetic bacteria (e.g. *Rhodopseudomonas palustris*, *Rhodobacter sphaeroides*), lactobacilli (e.g. *Lactobacillus plantarum*, L. *casei* and *Streptococcus lactis*), yeasts (e.g. *Saccharomyces* spp.) and actinomycetes

(*Streptomyces* spp.) (Nayak et al., 2020). Microbial inoculants (EM) consist of about 70 species of microorganisms (Valarini et al., 2003; Okorski et al., 2008). The application of EM has a beneficial effect on soil structure and quality (Khaliq et al., 2006; Okorski et al., 2008; Allahverdiev et al., 2015) and has beneficial potential for plant development (Teixeira et al., 2017; Avila et al., 2021). Khaliq et al. (2006) cited authors (Hussain et al., 1999) showing that the inoculating of agroecosystems of effective microorganisms cultures could improve both soil quality and crop quality. Nosheen et al. (2021) presented a classification of biofertilizers, indicating their mechanism of action and examples of different groups of them, Suhag (2016) and Chaudhary et al. (2022) presented the types of biofertilizers, their characteristics and microorganisms. Ammar et al. (2023) cited Ammar et al. (2022) and Aioub et al.(2022) where many species of soil bacteria and fungi, which lived in beneficial associations, acted as ecofriendly soil fertilizers. Cyanobacteria such as *Nostoc* sp., *Anabaena* sp., and *Oscillatoria angustissima* are potential sources of biofertilizers.

Fertilizers are among the most utilized substance in agriculture. Based on the production process, fertilizers are categorized into three types: chemical (inorganic), organic, and biofertilizers (Suliasih & Widawati, 2018). Organic fertilizers have an important role in maintaining soil sustainability and improve both soil physicochemical characteristics and microorganisms activity (Walia & Kler, 2009; Suliasih & Widawati, 2018). Organic fertilizers, i.e. cattle, chicken manure-compost, not only supply growing plants with nutrients, but also improve soil stricture, soil fertility, water holding capacity, physical and chemical properties, soil pH, microbial activity, etc. (Muhammad & Khattak 2009; Elsayed et al., 2020). Nosheen et al. (2021) quoted authors (Bumandalai & Tserennadmid, 2019) stating that after continuous use of biofertilizers for 3-4 years, another beneficial aspect was found, namely that they did not need to be re-applied because were sufficient for growth and multiplication as parental inocula.

Several studies reported the supportive effects of biofertilizers on plant growth (Demir et al., 2023; Wilson, 2023), increasing crop productivity (Vessey, 2003; Chen et al., 2006; Isfahani & Besharati, 2012; Saeed et al., 2015; Sharma et al., 2022; Wilson, 2023), improving its quality (Abd et al., 2023) enhancing the productivity of soil (Saeed et al., 2015), and improving soil fertility (Daniel et al., 2022; Ollio et al., 2024). Mahmud et al. (2021) cited Panda (2011) who documented that the impact of bio-fertilizers for yield improvement ranged between 35% to 65%. Biofertilizers enhanced crop yield by about 10 to 40% and increased proteins, vital amino acids, vitamins, and nitrogen fixation (Bhardwaj et al., 2014; Shahwar et al., 2023; Ammar et al., 2023).

The application of biofertilizers could be a probable approach towards improvng the soil microbial status that stimulates the natural soil microbiota, thus influencing nutrient accessibility and decomposition of organic matter (Chaudhary et al., 2021; Chaudhary et al., 2022). Mahmud et al. (2021) cited Sneha et al. (2018) who found that the use of biofertilizers enhanced the productivity per area in a comparatively short time, increased soil fertility, and encouraged antagonism and the biological control of phytopathogenic organisms. Schütz et al. (2018) reported that research teams (Lekberg & Koide, 2005; Berruti et al., 2016) analyzed the potential of arbuscular mycorrhizal fungi (AMF) as biofertilizers.

Liquid fertilizers are resistant to high temperatures and UV rays and can be applied in the field using hand sprayers, fertigation tanks, motor sprayers, etc. (Agarwal et al., 2018). Barman et al. (2017) cites authors Verma et al. (2011), Borkar (2015) who present the advantages of liquid over powdered biofertilizers which are that microorganisms have a longer shelf life of up to 2 years, usually bypass the effect of high temperature and survive better on seeds and soil, in addition liquid biofertilizers are easy to use, handle and store, the dosage is ten times less than that of the powder form.

Organic fertilizer can serve as an alternative practice to mineral fertilizers (Naeem et al., 2006) to improve soil structure (Dauda et al., 2008) and microbial biomass (Suresh et al., 2004; Fawzy et al., 2012). The use of organomineral biofertilizers in agriculture is an alternative for efficient fertilization (Oliveira et al., 2017), which has led to intensive research on the production of suitable organic materials (biofertilizers) that should be mostly locally produced and environmentally friendly (Filho et al., 2017). Microorganisms such as bacteria, fungi and blue-green algae go into the composition of biofertilizers, and to increase their shelf life are packaged in carrier materials such as peat and lignite powder (Agarwal et al., 2018). Authors point out that the most frequently used biofertilizer carrier in many countries is a local source of peat, which is insufficient upon developing commercial biofertilizers (Khavazi et al., 2007), as it is highly desirable to develop locally produced inoculants, for they are adapted to local conditions (Wang et al., 2015).

García et al. (2004) point out that in recent years there has been increased interest in soil microorganisms that can stimulate plant growth (Bashan, 1998) or help prevent attack by soilborne plant pathogens (Chanway, 1997; Van Loon et al., 1998). A number of different bacteria promote plant growth, including *Azotobacter* sp., *Azospirillum* sp., *Pseudomonas* sp., *Acetobacter* sp., *Burkholderia* sp. and *Bacillus* sp. (Probanza et al., 1996; Paulitz & Bélanger, 2001; Probanza et al., 2001; García et al., 2004). The main mechanisms of plant growth promotion are: production of growth-promoting phytohormones (Gutiérrez-Mañero et al., 2001); phosphate mobilization (Vázquez et al., 2000); production of siderophores (Raaska et al., 1993) production of antibiotics (Schnider et al., 1994); inhibition of plant ethylene synthesis (Glick et al., 1997); and induction of systemic plant resistance to pathogens (Ramamoorthy et al., 2001; García et al., 2004). Restoring the principles and mechanisms that operate in nature should be used as a substitute for the traditional process and can only be achieved if there is a broad base of knowledge about the complex relationships between organisms and their relationship to the environment (Ghini & Bettiol, 2000; Bettiol et al., 2004).

Many authors point out that the agro-meteorological conditions in Bulgaria are very suitable for organic farming and scientific trials of biofertilizers and bioproducts in many vegetable crops are being conducted (Panayotov, 2000; Boteva & Cholakov, 2011; Dintcheva, 2011). The increasing demand for vegetables with high ecological value is also associated with increasing number of researches on organic fertilizers and their impact on biological manifestations, productivity and quality of production (Vlahova & Popov, 2014; Boteva et al., 2016; Vlahova & Popov, 2018). The application of biofertilizers increases vegetative growth, yield, fruit quality, in vegetable crops, and also increases the number and mass of fruits (Aly, 2002; Berova et al., 2010; Shopova & Cholakov, 2014; Vlahova, 2014). Dintcheva (2013) points out that according to Tringovska & Naydenov (2003) microbial biofertilizers are involved in various biochemical processes related to soil fertility and plant nutrition, stimulating plant growth and increasing their yield. Dochev et al. (2016) cite authors (Raykov et al., 2011; Pachev, 2014) who indicate that the application of biofertilizers lead to yield rising and accelerate the growth and development of plants. Todorova & Djinovic (2017) point out the report of several researchers (Panayotov & Dimova, 2014; Todorova & Arnaudova, 2014) that both breeders and farmers need knowledge to evaluate new breeding lines and varieties in the organic farming system. Antonova et al. (2012) report that they have conducted a research to identify genotypes suitable for organic vegetable production.

The organic farming system applies biofertilizers authorised by Regulation (EC) No 889/2008, which protect geobionts and insect species that have a biological role in the agroecosystem (Kostadinova, 2017). There is a close relationship between the diversity of the vegetation cover and the representatives of the macrofauna that inhabit the soil environment, thereby contributing to the maintenance of soil fertility (Popov, 2013). Arthropods and worms are groups of invertebrates that are widespread and often play key roles in agroecosystems (Pfiffner & Mäder, 1997; Pfiffner et al., 2000; Popov et al., 2017; Vlahova et al., 2021), but conventional agro-technologies have a marked negative effect on earthworm populations (Popov et al., 2018), with pesticides being a major factor in reducing these populations and disrupting natural biodynamic processes in ecosystems (Velcheva et al., 1999; Velcheva et al., 2012; Kostadinova & Popov, 2015; Kostadinova et al., 2016; Qin et al., 2022).

CONCLUSIONS

The influence on soil biogenicity and its physical and chemical properties at the same time is an ecological benefit with a positive effect on the agroecosystem. The application of environmentally friendly biofertilisers aims to preserve soil fertility and to achieve the realisation of potentially feasible yields. There is now a need to adopt a more environmentally friendly approach by applying biofertilizers to aid better nutrient uptake by plants, stimulate their growth, increase the population of beneficial microorganisms in the rhizosphere, thereby increasing crop productivity, and stabilizing soil fertility, ensuring a healthy environment.

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