Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 7, S. 110-117, 9, 2023

Araştırma Makalesi

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 7, pp. 110-117, 9, 2023

Research Article

Potential Status of Microbial Fertilizer Applications in Turkey

Nihal Ahıskalıoğlu*, Nurcihan Hacıoğlu Doğru[2]

[1]*Department of Biology/School of Graduate Studies, Çanakkale Onsekiz MartUniversity, Türkiye*
[2]*Department of Biology/Faculty of Science, Çanakkale Onsekiz MartUniversity, Türkiye*

(bjk.nihal61@hotmail.com)

(Received: 22 September 2023, Accepted: 05 October 2023)

(3rd International Conference on Innovative Academic Studies ICIAS 2023, September 26-28, 2023)

ATIF/REFERENCE: Ahıskalıoğlu, N. & Doğru, N. H. (2023). Potential Status of Microbial Fertilizer Applications in Turkey. *International Journal of Advanced Natural Sciences and Engineering Researches*, 7(9), 110-117.

Abstract – With the world's population expanding and available agricultural land dwindling, agriculture is undergoing significant changes. The traditional focus on maximizing food production through intensive chemical input usage has given way to a 21st-century emphasis on "quality production" that aims to balance food production with environmental sustainability. This shift has been driven by the adverse environmental effects of indiscriminate chemical input usage and the potential genetic consequences of genetic science applications in agriculture. Organic farming has gained traction as a more environmentally friendly alternative, banning chemical inputs and promoting natural farming methods. Furthermore, biofertilizers have emerged as a promising solution to enhance soil fertility and crop productivity in a sustainable manner. These biofertilizers are reported to not only reduce the need for chemical fertilizers but also mitigate environmental pollution. However, despite their potential benefits, the commercialization of biofertilizers faces practical challenges, including mass production, shelf life, and variability in performance across different soil and crop types. As the world seeks sustainable agricultural practices to meet growing food demands, biofertilizers represent a promising avenue but require further research and development to realize their full potential.

Keywords – Agriculture, Sustainable, Microorganisms, Biofertilizers, Environmental Sustainability

I. INTRODUCTION

As the available agricultural land for cultivation continues to decrease around the world due to increasing population, there has been a growing need for higher food production. This has led to the necessity of obtaining more produce from each unit of land, resulting in a significant increase in the use of chemical inputs in agriculture. This intensive input usage has indeed increased productivity and production in agricultural areas. However, it has also posed a threat to sustainable soil fertility and natural balances [1].

In addition to this, the agricultural approach known as the "Green Revolution," which aimed to maximize production in the 1960s and 70s, has now given way to the "quality production" approach, which is becoming dominant in 21st-century crop production [2]. According to this perspective, the most ideal approach is to produce a quantity of high-quality food that meets the current population's needs without harming natural balances.

In summary, the increasing need for food production due to a growing population has led to the intensification of agricultural practices, including the increased use of chemical inputs. However, there is a shift towards a focus on quality production that considers the sustainability of natural resources and ecosystems in the 21st century.

Synthetic chemical fertilizers and pesticides, which are constantly evolving with new products introduced every day, have been used extensively in an indiscriminate manner to achieve increased crop yields. This reckless use has turned agriculture, especially modern production methods, into a cause of environmental pollution. Furthermore, it has not been economically sustainable in the long term, especially from the perspective of agricultural product prices [3].

In addition to this, over time, all the technologies of genetic science have been employed. The DNA structures of plants and animals have been altered and even hybridization and cloning methods have been applied. As a result, ecological balance is disrupted, natural flavors of foods change, and the use of synthetic chemical substances can lead to genetic diseases in organisms.

However, efforts are being made to develop technologies and methods that improve soil health, do not harm natural balances, are not detrimental to health, and enhance both the quantity and quality of agricultural products.

In many countries, particularly in high-income nations, both producers and consumers have started to prefer agricultural products produced using methods that do not have toxic effects on humans and do not harm the environment. To achieve this goal, organic farming has emerged as a production method that includes environmentally friendly production systems, bans the use of chemical fertilizers and pesticides, recommends organic and green manure application, crop rotation, and the utilization of natural sources such as parasites and predators. It also aims to improve product quality [4].

Furthermore, organic farming practices are gaining increasing importance as time goes by. Products produced using organic fertilizers and without pesticide applications are highly sought after in global markets. These preferences highlight the need for more detailed research into the possibilities of using various organic materials in agriculture [5]. One of these methods is the use of biological alternatives in fertilizer application.

The source of both plant and animal food is the soil. The fertility of the soil depends on the presence of an adequate amount of essential nutrients within it [6]. The most crucial factor limiting agricultural production is low soil fertility. To improve soil fertility, the essential nutrient elements required for plant growth need to be added to the soil through fertilization. The negative effects caused by the inputs used for this purpose, such as fertilizers, were initially observed in developed countries where intensive inputs were used. In the early 20th century, these adverse effects began to be examined, leading to the exploration of alternative agricultural and fertilization techniques. With advancements in biological agriculture, biofertilizers have been developed as alternatives to chemical fertilizers, and various studies have shown their ability to increase crop productivity and soil fertility in sustainable agricultural systems. Biofertilizers have been increasingly produced and applied, particularly in agricultural lands where the use of chemical fertilizers is limited or absent. They have become widespread in some African countries with such soil characteristics, like Sudan [7].

Investments in biofertilizers worldwide have been on the rise since the 1980s. At the National Specialized Conference held in Beijing on October 30-31, 1995, it was reported that biofertilizers increase crop yield, enhance soil fertility and bioavailability, reduce the need for chemical fertilizers, break down organic waste materials to release nutrients, and consequently reduce environmental pollution. It was also reported that their use in ecological farming is more economical compared to other fertilizers, making them ideal for crops consumed as greens. The conference took decisions to promote the use of biofertilizers, leading to their increased adoption [8]. Research has shown that biofertilizers can increase crop yield by approximately 10-25% [9].

The commercial history of biofertilizers dates back to the work of Nobbe and Hiltner on Rhizobium sp. in the late 1950s. In the late 1950s, several studies involving arbuscular mycorrhizal fungal inoculants reported positive plant growth-promoting (PGP) effects through increased phosphorus (P) uptake. However, despite numerous advantages and cost-effectiveness, the commercialization of biofertilizers is not widespread. The reasons limiting their use are mainly related to practical aspects such as mass production, shelf life, appropriate recommendations, and ease of use for farmers, as well as inconsistent responses on different soils, crops, and environmental conditions.

II. TYPES OF BIOFERTILIZERS AND THEIR CONTENT

Biofertilizers are environmentally friendly and economically viable solutions that promote sustainable agriculture by improving soil fertility, enhancing plant growth, and reducing the need for chemical inputs while posing no harm to plants or the environment [10].

Biofertilizers are typically used as fertilizers by returning them to the environment where they were isolated, which means their living conditions will remain relatively constant, except for seasonal variations. However, the form in which they are used as fertilizer can also affect their lifespan and impact on the soil. Biofertilizers are not always applied directly to the soil or plants in their pure form. To enhance their effectiveness, they are sometimes mixed with different types of biofertilizers, chemical fertilizers, or mineral fertilizers. In such cases, information about the content, quality, and shelf life of the biofertilizer product becomes even more crucial. This ensures that the desired beneficial microorganisms are present in the right quantities and remain viable when combined with other fertilizers or soil amendments for maximum effectiveness in promoting plant growth and nutrient uptake.

The effective activity of microorganisms occurs only under suitable and optimal conditions for them to metabolize their substrates. Some of these conditions include: Adequate water and oxygen (depending on whether microorganisms are aerobic or anaerobic), pH levels, and environmental temperature, such as around 15 ^{o}C. Today, thanks to new technologies, a wide variety of microbial cultures and inoculation materials are commercially available in the market. Microorganisms are becoming more widespread in use in natural farming and organic agriculture due to their potential as alternatives to solve the problems caused by chemical fertilizers and pesticides [11].

According to the general classification in the FAO's 2006 report titled "Plant Nutrition for Food Security," biofertilizers can be divided into four main categories:

N-Fixing Biofertilizers: These include bacteria like *Rhizobium*, *Azotobacter*, *Azospirillum*, *Clostridium*, and *Acetobacter*. Additionally, blue-green algae (cyanobacteria) and the fern Azolla, which work in conjunction with cyanobacteria, fall into this category.

P-Solubilizing/Mobilizing Biofertilizers: These comprise phosphate-solubilizing bacteria (PSB) and phosphate-solubilizing microorganisms (PSMs), such as *Bacillus*, *Pseudomonas*, and *Aspergillus*. Mycorrhizae are nutrient mobilizing fungi and are also known as vesicular arbuscular mycorrhiza (VAM).

Compost Accelerators: These include cellulolytic (e.g., *Trichoderma*) and lignolytic (e.g., Humicola) microorganisms that help in the decomposition of organic matter.

Plant Growth-Promoting Rhizobacteria (PGPR): This category includes species like Pseudomonas, which do not provide plant nutrients but enhance plant growth and performance.

These categories reflect the different functions and benefits of biofertilizers in agriculture, such as nitrogen fixation, phosphorus solubilization, organic matter decomposition, and promotion of plant growth.

In Turkey, the use of biofertilizers in agriculture has become more widespread since the 1990s [12]. Compared to the EU, Turkey has a clearer definition of biofertilizers and a more established regulatory framework for their use. In recent years, the scope of biological fertilization has expanded. Research has focused on the use of rhizobacteria (PGPR) and biological control agents, especially those that promote plant growth and are free-living in the soil. These bacteria include various strains of *Serratia*, *Pseudomonas*, *Burkholderia*, *Agrobacterium*, *Erwinia*, *Xanthomonas*, *Azospirillum*, *Bacillus*, *Enterobacter*, *Rhizobium*, *Alcanigenes*, *Arthrobacter*, *Acetobacter*, *Acinetobacter*, *Achromobacter*, *Aerobacter*, *Artrobacter*, *Azotobacter*, *Clostridium*, *Klebsiella*, *Micrococcus*, *Rhodobacter*, *Rhodospirillum*, and *Flavobacterium* spp. Additionally, research has been conducted on fungal isolates from *Chaetomium*, *Trichoderma*, *Gliocladium*, mycorrhizal fungi (ectomycorrhiza and arbuscular mycorrhizae), *Glomus*, *Aspergillus*, and *Penicillium* species for use as biological fertilizers [12]. Due to the rising production costs and environmental concerns associated with chemical fertilizers in crop production, there is growing interest in biological fertilizers. Comprehensive studies are being conducted to support agricultural sustainability, reduce chemical usage to protect natural resources and the environment, and identify new PGPR strains that can be used in biological fertilizer formulations.

Some studies in Turkey have revealed that certain tested PGPR strains have characteristics such as the production of plant hormones like auxin, cytokinin, gibberellin, and ethylene; nitrogen fixation in an asymbiotic manner; enhancement of plant enzyme activity; organic and inorganic mineral solubilization; reduction of the negative effects of salt stress on plant growth and nutrition; and the production of vitamins, siderophores, antibiotics, enzymes, and antimicrobial compounds [12].

Apart from accepted rhizobacteria in Turkey, other types of biofertilizers are also available and are specified in the relevant regulations.

Table 1. General scope of microbial fertilizer products accepted in Turkey [6]

Product type name	Microbial fertilizer	Product contents	Product pH and other information	The mandatory content to be declared on the label
Fertilizer containing microorganisms	They are commercial formulations of microorganisms that play a role in providing the essential nutrients necessary for the growth and development of plants.	They consist of bacteria, algae, and fungi. For bacteria; The number of living organisms For other microorganisms; Chlorophyll a. Dry cell weight (gr/kg or g/L) The number of spores (per gram or per milliliter)	The required pH and temperature values for microorganisms -Names of organism species -Activity trial report -applicability status, including pathogen testing, for foliar application	-Names of microorganisms used -Quantity of live microorganisms -Appropriate storage conditions (temperature, humidity, light) and duration to maintain the viability of the used microorganism -Usage time, dosage, and method -The product's effect on soil pH, soil temperature, and soil structure

In the study conducted by [13] biofertilizer formulations of *Pseudomonas putida* strain 18/1K and *Bacillus subtilis* strain 66/3 PGPR isolates that yielded successful results in terms of plant growth and yield in greenhouse vegetable cultivation were produced. In vitro and in vivo irrigation simulation tests were conducted to determine the performance of biofertilizer formulations under irrigation conditions. These tests showed that the viability on substrates was successfully maintained, and in the greenhouse trial with plants, colonization in the root zone reached 10^6 cfu/g for all preparations. Shelf-life studies, an important aspect of the practical application of biofertilizer formulations, were also conducted, and the formulations were successful in maintaining viability levels of 10^5-10^6 cfu/g on the 90th day.

Sezen (2012) conducted a study in which a total of 180 bacteria were isolated from soils belonging to different plant rhizospheres in the regions of Erzurum and Kırşehir. These bacteria were tested for their nitrogen-fixing and phosphate-solubilizing capabilities. It was determined that 16 of the isolates had both nitrogen-fixing and phosphate-solubilizing capabilities at various levels. After harvesting, measurements were taken for parameters like root and stem lengths, leaf dry weights, and protein contents of the plants. Inoculation with the isolates was found to significantly ($p < 0.05$) affect growth parameters in chickpea plants. The most effective strains were found to be AS-8, AS-10, AS-2, and AS-13 in terms of root length, stem length, leaf dry weight, and leaf protein content, respectively [14].

Günbenzer (2012) investigated the effects of different concentrations of NaCl, KCl, glucose, sucrose, and mannitol on biomass, total protein, total carbohydrate, and chlorophyll-a content in *Anabaena* sp., *Gloethece* sp., and *Synechocystis* sp. In the study, it was observed that the growth of some cyanobacteria was inhibited under NaCl stress, while the growth of others was stimulated by the initial NaCl concentration. As a result of the study, *Anabaena* sp. GO1 showed the best response to different salt and osmotic stresses. This culture exhibited high nitrogenase activity and demonstrated the best performance in terms of nitrogenase activity and tolerance to stress conditions, making it a suitable candidate for biofertilizer [15].

Çelikten et al. (2018) conducted a study in Hatay Province, where wheat is cultivated in 9 different fields, and collected wheat root samples. A total of 84 bacterial isolates were purified from these samples using MALDI-TOF for identification. The results showed that at the genus level, Pseudomonas was the most abundant genus with 32 isolates, followed by *Bacillus* with 29 isolates, *Micrococcus* with 7 isolates, *Arthrobacter* with 5 isolates, *Microbacterium* with 3 isolates, and single isolates of *Paenibacillus*, *Clostridium*, *Weeksella*, *Exiguobacterium*, *Acinetobacter*, *Brevundimonas*, *Providencia*, and *Corynobacterium*. Germination tests were conducted to determine the effects of these isolates on root and shoot growth of wheat seeds compared to a control treatment. The trial results revealed that 73 bacterial isolates had a positive effect on root development, increasing it by 7.1% to 70.6%, while 4 isolates resulted in lower root growth compared to the control [16].

Dılman used the Stoneville 468 cotton variety as plant material to determine the effects of biofertilizer applications on cotton yield, growth, and technological characteristics. Two biofertilizers, namely Coton Plus and Mega Flu, were applied to investigate their effects on cotton yield and technological characteristics. Coton Plus is a microbial mixed fertilizer containing B. subtilis and *Paenibacillus azotofixans*, while Mega Flu contains three different types of bacteria: B. *megaterium*, *P. agglomerans*, and *P. fluorescens*. The results of the study showed significant differences among treatments in terms of mass cotton yield, lint yield, ginning percentage, and boll number. However, there were no significant differences in terms of fiber quality criteria except for fiber elongation [17].

Koçak isolated and purified 12 different cyanobacterial species from 5 different geothermal areas in Çanakkale province, Turkey. These species were evaluated based on their nutritional content, and some of them stood out. P. foveolarum had high carbohydrate content, N. azollae, A. affinis, and S. platensis had high protein contents, and *Synechocystis* sp. had a high lipid content. These cyanobacteria were found to be rich in macroelements, with N. azollae having high N and S content, *C. parienta* having high Mg content, and *Synechococcus* sp. having high K content. After evaluating their toxic properties, it was suggested that these cyanobacteria could be used as feed additives for small ruminants, a direct nutrient source in aquaculture, or as biofertilizers in agricultural soils [18].

Altınok and Çiftçi conducted a study to investigate the effects of PGPR applications on the control of downy mildew disease in eggplants. They found that PGPR applications, both individually and in combinations of three isolates, increased the activity of proline, catalase, and peroxidase enzymes in eggplants. PGPRs also had a partial antibiosis effect, contributing to increased plant biomass [19].

Altunlu et al. assessed the potential of a commercial microbial fertilizer containing Endomycorrhiza, Trichoderma spp., Bacillus subtilis, and Bacillus megaterium on the growth and yield of sweet corn (*Zea mays* L. var. *saccharata*). The results indicated that increasing the doses of microbial fertilizer led to improvements in plant growth, cob weight, and benefits [20].

Mutlu et al. studied a microbial fertilizer containing *B. megaterium*, *P. agglomerans*, and *P. fluorescens* for potential use as an alternative to conventional fertilizers in turfgrass areas. The results indicated that microbial fertilizers could have significant potential for sustainable turfgrass management, affecting parameters such as establishment rate, turf quality, color, density, thatch source, and root weight [21].

Tekeli aimed to isolate *Azotobacter* species from the soil and optimize their biomass production for use in commercial biofertilizer formulations. In this regard, they isolated 191 strains of *Azotobacter* from 33 soil samples collected from various agricultural areas in Antalya, İzmir, Bursa, Manisa. The strains were evaluated for biomass production under different carbon and nitrogen sources. The results showed that the best results for biomass production were obtained using potato starch as a carbon source and soybean flour as a nitrogen source [22].

Çakır et al. conducted a study on Jeromine apple variety to investigate the effects of PGPR, algae extract (*Chara* sp.), and vermicompost fertilizer applications on tree growth, quality, and biochemical content. They applied these growth-promoting substances to the trees in the form of PGPR (3%), algae extract (15%), and vermicompost (10 kg per tree). Comprehensive applications were found to enhance quality characteristics and have a positive impact on biochemical content in fruits when compared to the control treatment [23].

Çağlayan obtained 103 potential *Pseudomonas* isolates from different soil and mushroom compost samples. Among these isolates, 17 were found to produce siderophores, and 9 produced HCN using qualitative methods. The *P. chlororaphis* P-106 strain, which exhibited the best PGPR properties, was selected, and laboratory-scale production optimization was carried out to achieve high biomass production. Statistical experimental design was used to examine the effects of readily available, low-cost carbon sources (molasses and glycerol) and nitrogen sources on production medium optimization. The trials resulted in identifying an economical production medium for achieving high biomass production [24].

Uysal aimed to utilize rose oil processing wastewater, which has no economic value, as a nutrient for *Acutodesmus obliquus* microalgae in channel-type pond cultivation systems. The study focused on nutrient removal, microalgal biomass production, and biodiesel, biofertilizer, and biochar potentials. The highest COD (Chemical Oxygen Demand) removal was achieved with a rate of 94.9% in the R2-3 application. Water footprint (WF) calculations were also conducted within the scope of the study. The R2 application, which used 50% of rose oil processing wastewater, was found to be suitable for chemical load removal and biomass yield, carbon dioxide removal, biodiesel, biofertilizer, and biochar production [25].

Yolcu conducted a study in Van's ecological conditions to determine the effects of biofertilizer applications and inorganic fertilization on some agronomic, quality, and biochemical characteristics of safflower (*Carthamus tinctorius* L.) during the summer growing seasons of 2020 and 2021 under irrigated conditions. Parameters such as plant height, first branch height, number of branches per plant, number of heads per plant, head diameter, seed count per head, thousand-seed weight, seed yield, leaf yield, crude oil content, crude oil yield, total coloring matter content, total phenolic content, total flavonoid content, and total antioxidant activity were examined. The results showed that the highest seed yield of 260.22 kg/da was obtained from the plots where the NP100 fertilizer dose and B1 bacterial application were applied, while the lowest seed yield of 112.40 kg/da was observed in the NP0 × B0 interaction according to the average of combined years [26].

III. RESULTS AND DISCUSSION

In Turkey, the use of biofertilizers in agriculture has become more widespread since the 1990s. Compared to the EU, Turkey has a clearer definition of biofertilizers and a more established regulatory framework for their use. In recent years, the scope of biological fertilization has expanded. Research has focused on the use of rhizobacteria (PGPR) and biological control agents, especially those that promote plant growth and are free-living in the soil. These bacteria include various strains of *Serratia*, *Pseudomonas*, *Burkholderia*, *Agrobacterium*, *Erwinia*, *Xanthomonas*, *Azospirillum*, *Bacillus*, *Enterobacter*, *Rhizobium*, *Alcanigenes*, *Arthrobacter*, *Acetobacter*, *Acinetobacter*, *Achromobacter*, *Aerobacter*, *Artrobacter*, *Azotobacter*, *Clostridium*, *Klebsiella*, *Micrococcus*, *Rhodobacter*, *Rhodospirillum*, and *Flavobacterium* spp. Additionally, research has been conducted on fungal isolates from *Chaetomium*, *Trichoderma*, *Gliocladium*, mycorrhizal fungi (ectomycorrhiza and arbuscular mycorrhizae), *Glomus*, *Aspergillus*, and *Penicillium* species for use as biological fertilizers. Due to the rising production costs and environmental concerns associated with chemical fertilizers in crop production, there is growing interest in biological fertilizers. Comprehensive studies are being conducted to support agricultural sustainability, reduce chemical usage to protect natural resources and the environment, and identify new PGPR strains that can be used in biological fertilizer formulations.

Some studies in Turkey have revealed that certain tested PGPR strains have characteristics such as the production of plant hormones like auxin, cytokinin, gibberellin, and ethylene; nitrogen fixation in an asymbiotic manner; enhancement of plant enzyme activity; organic and inorganic mineral solubilization; reduction of the negative effects of salt stress on plant growth and nutrition; and the production of vitamins, siderophores, antibiotics, enzymes, and antimicrobial compounds [12].

Apart from accepted rhizobacteria in Turkey, other types of biofertilizers are also available and are specified in the relevant regulations.

IV. CONCLUSION

The potential status of microbial fertilizer applications in Turkey is gaining importance with developments in the agricultural sector, increasing environmental awareness, and the growth of sustainable agricultural practices. Microbial fertilizers are organic materials used to enhance soil biological activity, improve nutrient uptake by plants, and increase their resistance to diseases. an assessment of the potential status:

Increasing Conscious Farmers: Farmers in Turkey are becoming more interested in sustainable agricultural practices, which are boosting the demand for microbial fertilizers.

Scientific Research and Developments: Agricultural research institutes and universities in Turkey are conducting studies on the use of microbial fertilizers. These studies provide more information about the effects of such fertilizers.

Rise in Organic Farming: With the increase in organic farming practices in Turkey, microbial fertilizers are becoming an important component of organic agriculture.

Environmental Factors: The environmental impacts of chemical fertilizers and their negative effects on soil health could influence the preference for microbial fertilizers.

Regulations and Incentives: The Turkish government provides various incentives and support to promote sustainable agricultural practices, which could encourage the use of microbial fertilizers.

Awareness and Training Programs: Training programs for agricultural experts and farmers can promote the correct and effective use of microbial fertilizers.

In conclusion, the potential status of microbial fertilizer applications in Turkey is moving in a positive direction. However, increasing awareness in this field, supporting scientific research, and organizing educational programs for farmers can further promote the widespread use of microbial fertilizers. This, in turn, can contribute to the development of sustainable agricultural practices and the preservation of soil health.

Acknowledgment

This investigation is a part of Master thesis of Nihal AHISKALIOĞLU.

References

[1] Tortopoğlu, A.P. 2000. Ekolojik Tarım ve Geleceği, Hasad, Yıl: 16, Sayı: 182;38-41.

[2] Karaçal ve Tüfenkçi 2010. Bitki Beslemede Yeni Yaklaşımlar ve Gübre- Çevre İlişkisi. Ders Notları. Ankara.

[3] Elanwar H, Sheekh O, Naggar A, Saly F, 2010. Effect of two species of cyano bacteria as bio fertilizers on some metabolic activities, growth, and yield of pea plant. BiolFertil Soils (2010) 46:861–875.

[4] Akkaya, F. 1999. Ekolojik tarım gerçeği. Derim, 16(4): 180-190.

[5] İnal, A., Sözüdoğru, S. ve Erden, D., 1996. Tavuk Gübresinin İçeriği ve Gübre Değeri. Tarım Bilimleri Dergisi, 2 (3): 45-50.

[6] Anonymous, 2014. Mikrobiyolojik Gübreleme. http://www.bahcesel.net/forumsel/gubrebilgisi/23208-mikrobiyolojik-gubreleme

[7] Mahdi, A.A., Mohamed, Ahmed, T.H. 2002. Growth and Multiplication of *Rhizobium leguminosarum* bv. Viceae as affected by pH, Al and Ca. Sudan Journal of Scientific Research. (8)1: 59-72.

[8] Chen, C.Y., Xiong, S.G.1997. The present and development of microbial fertilizer. Journal of China Agricultural University (in Chinese) 2:12-15.

[9] Kholkute, R. 2013. Biofertilizers:Oppurtunuties and Challenges. Fertilizer&Agriculture. Issue 65. 40-43.

[10] Çakmakçı, R. 2014. Mikrobiyal Gübre Olarak Kullanılabilecek Mikroorganizmaların Etki Mekanizmaları ve Özellikleri. Mikrobiyal Gübre Çalıştayı. 5-18. Ankara.

[11] Yalçın, S.R. 2014. Mikrobiyal Gübreler ve Uygulama Yöntemleri. Mikrobiyal Gübre Çalıştayı. 75-86. Ankara.

[12] Kiper, M. 2013. Biyoteknoloji Sektörel İnovasyon Sistemi: Kavramlar, Dünyadan Örnekler, Türkiye'de Durum ve Çıkarımlar. Türkiye Teknoloji Geliştirme Vakfı. Ankara.

[13] Çakmakçı, R., 2005. Bitki Gelişimini Teşvik Eden Rizobakterilerin Tarımda Kullanımı. Ankara Üniversitesi Ziraat Fakültesi Dergisi.36 (I), 97-107. Ankara.

[14] Sezen, I., Kaymak, H.Ç., Aytatlı, B., Dönmez, M.F. and Ercişli, S. 2014. Inoculations With Plant Growth Promoting Rhizobacterıa (Pgpr) Stimulate Adventitious Root Formation On Semi-Hardwood Stem Cuttıngs of Ficus benjamina L. Propagation of Ornamental Plants, 14 (4),152-157.

[15] Günbenzer (2012), Bazı siyanobakterilerin biyogübre olarak kullanım potansiyellerinin belirlenmesi. Yüksek lisans tezi, Muğla Üniversitesi Fen Bilimleri Enstitüsü

[16] Çelikten, M. ve Bozkurt, İ. (2018). Buğday kök bölgesinden İzole edilen bakterilerin buğday gelişimine olan etkilerinin belirlenmesi. Mustafa Kemal Üniversitesi Ziraat Fakültesi Dergisi, 23: 33-48

[17] Dılman Osman (2018), Biyogübrelerin pamuk gelişimi, verimi ve teknolojik özelliklere etkisi. Yüksek lisans tezi. Siirt Üniversitesi / Fen Bilimleri Enstitüsü

[18] Koçak (2018), İç sularımızdan izole edilen bazı siyanobakterilerin biyogübre olarak kullanılabilme potansiyellerinin araştırılması. Yüksek lisans tezi. Atatürk Üniversitesi Fen Bilimleri Enstitüsü.

[19] Altınok, H. ve Çiftçi, G. 2019. Patlıcan Tohumlarında Bitki Büyüme Düzenleyici Rizobakteri Uygulamalarının Kurşuni Küf (Botrytis cinerea Pers.: Fr.) Hastalığına Etkileri. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 22 (3): 421-429.

[20] Altunlu, H., Demiral, O., Dursun, O., Sönmez, M., & Ergün, K. (2019). Mikrobiyal gübre uygulamasının tatlı mısır *(Zea mays L. var. saccharata*) yetiştiriciliğinde bitki gelişimi ve verim üzerine etkileri. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi*, *50*(1), 32-39.

[21] Mutlu, S.S., Sever, E., & Sönmez, S. (2019). Mikrobiyal gübre uygulamalarının *Lolium perenne* L. türünün çim performansı üzerine etkileri. *Mediterranean Agricultural Sciences*, *32*, 147-155.

[22] Tekeli (2022), Biyogübre olarak azotobacter türlerinin üretim optimizasyonu. Yüksek lisans tezi Ege Üniversitesi Fen Bilimleri Enstitüsü.

[23] Çakır, M., Yıldırım, A., Çelik, C., & Meltem, E. S. E. N. (2021). Farklı Bitki Büyümeyi Düzenleyici Maddelerin Jeromine Elma Çeşidinde Kalite ve Biyokimyasal İçerikleri Üzerine Etkisi. *Anadolu Tarım Bilimleri Dergisi*, *36*(3), 478-487.

[24] Çağlayan (2021). Biyogübre olarak pseudomonas türlerinin üretim optimizasyonu. Yüksek Lisans tezi. Ege Üniversitesi Fen Bilimleri Enstitüsü

[25] Uysal (2022), Gül yağı işleme atık suyunun *Acutodesmus obliquu*s ile arıtımı ve elde edilen mikroalgal kütleden biyodizel, biyokömür ve biyogübre üretim potansiyelinin araştırılması, süreçlerin su ayak izi ve enerji analizleri. Doktora tezi. Isparta Uygulamalı Bilimler Üniversitesi / Lisansüstü Eğitim Enstitüsü

[26] Yolcu (2022), Biyogübre uygulamaları ve inorganik gübrelemenin aspir (*Carthamus tinctorius* L.) bitkisinin bazı agronomik, kalite ve biyokimyasal özellikleri üzerine etkisi. Doktora tezi Van Yüzüncü Yıl Üniversitesi / Fen Bilimleri Enstitüsü