International Journal of Agriculture, Environment and Food Sciences

e-ISSN: 2618-5946 https://dergipark.org.tr/jaefs

DOI: https://doi.org/10.31015/jaefs.2024.3.6 Int. J. Agric. Environ. Food Sci. 2024; 8(3): 531-540

The use of biofertilizer contribution to plant development and yield in greenhouse broccoli cultivation

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Article History
Received: May 24, 2024
Revised: August 13, 2024
Accepted: August 16, 2024
Published Online: September 01, 2024
Final Version: September 29, 2024

Article Info
Article Type: Research Article
Article Subject: Vegetable Growing and Treatment

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Available at
https://dergipark.org.tr/jaefs/issue/86361/1488945

Abstract

In this study, the effects of chemical fertilizers and fertilizers containing microorganisms on broccoli yield were examined. It is aimed to reduce the amount of chemical fertilizer by using microorganisms. Mundo F1 Broccoli variety was used as plant material. The research was established according to the randomized block trial design with 3 treatments and 3 replications, and 20 plants were used in each replication. Applications: 1. Control: 100% chemical fertilization (U1), 2. Treatment II: 70% chemical fertilization + Microorganisms (U2), 3. Treatment II: 100% chemical fertilization + Microorganisms (U3). The aim of the study is the effects of chemical fertilizers and microorganisms on plant growth and development; To examine the effect of plant height, stem diameter, number of leaves and yield. It was concluded that the number of leaves, plant height and stem diameter generally increased in the plots where microorganisms were applied. When the results were evaluated in terms of yield compared to the control treatment, U2 treatment increased yield by 20% and U1 treatment increased yield by 15%.

Keywords: *Brassica oleracea* var. *italica*, Chemical fertilizer, Fertilizer, Microorganism

Cite this article as: Altuntas, O., Kucuk, R. (2024). The use of biofertilizer contribution to plant development and yield in greenhouse broccoli cultivation. International Journal of Agriculture, Environment and Food Sciences, 8(3), 531-540. https://doi.org/10.31015/jaefs.2024.3.6

INTRODUCTION

As a result of the population increase in the world, it is clear that agricultural production must increase in order to meet the need for food, and fertilizer use, which is the most important input to increase the amount of production, will increase. As a result of the rapid increase in the world population, food and feed production will necessarily reach 3 billion tons in 2050. In this case, the most emphasized issue today is the decrease in natural resource reserves despite population growth and economic development (Karaçal & Tüfenkçi, 2019). In crop production, fertilizers are used intensively to achieve high yields and maximum growth. In vegetables, inorganic fertilizers are given more than necessary by producers in order to increase growth and development and consequently to obtain high yields (Badr & Fekry, 1998; Arisha & Bardisi, 1999; Dauda et al., 2008). However, although chemical fertilizers increase the amount of production, they pollute the soil and groundwater resources.

Living organisms have an important place in the natural structure of soil. These are divided into two as soil flora and soil fauna. Soil flora, i.e. plant organisms, ranks first in terms of activity. This group includes bacteria, fungi, actinomycetes and algae. Each of these has different benefits in terms of soil productivity. Dwindling fertilizer resources and expensive production costs in the world indicate that we will experience serious yield problems in crop production in the next 50 years (Ortas & Lal, 2011). For this reason, the use of these microorganisms, which reduce the demand for chemical fertilizers, are friendly to nature and the environment, and are from the ecology's own natural resources, in agricultural production is becoming increasingly important. In recent years, the interest of researchers has been directed towards studies to ensure agricultural sustainability by using beneficial microorganisms instead of chemical fertilizers and pesticides.

Preparations called "biofertilizers", which contain some bacteria, fungi and algae species, have started to be preferred by producers in recent years due to the benefits they provide. When used in cultivation, biofertilizers improve the soil by increasing biological activity and have a positive effect on the physical, chemical and biological structure of the soil. Apart from that, they help nutrient uptake and provide tolerance against environmental stresses by increasing the availability and usefulness of plant nutrients through nitrogen fixation, phosphate and potassium solubilization or mineralization, release of plant growth regulators, antibiotic production and biodegradation of organic matter in the soil (Sinha et al., 2014; Sivakumar et al., 2013). As a result; it also increases yield and product quality by promoting plant growth and development. Biofertilizers differ from chemical and organic fertilizers in that they do not provide any direct nutrients to plants in agricultural production and are special cultures of bacteria and fungi, relatively simple and low installation costs.

Soil microorganisms are involved in many chemical changes in the soil and are important elements of soil fertility as they are involved in the cycling of nutrients necessary for plant growth, for example nitrogen and carbon. The beneficial microorganisms in bio-fertilizers promote plant growth directly and indirectly by establishing colonies in the rhizosphere and endorhizosphere of the plant (Saxena et al., 2005).

By asymbiotic nitrogen fixation, increasing the solubility of inorganic phosphorus and mineralization of organic phosphorus compounds, increasing the uptake of iron through siderophore production and some other trace elements through organic acid production, beneficial bacteria can improve the mineral nutrition of plants and promote growth. In addition, plant growth can be directly enhanced through the production of plant hormones such as auxins, gibberellins, cytokinins, inhibition of ethylene synthesis through 1-Aminocyclopropane-1-carboxylate (ACC) deaminase enzyme activity, reduction of environmental stress; harmony in the bacteria-plant relationship, vitamin synthesis, and increased root permeability (Esitken et al, 2005; Şahin et al., 2004; Zahir et al., 2004; Canbolat et al., 2006; Fuentes-Ramirez and Caballero Mellado, 2006; Aslantas et al., 2007; Çakmakçı et al., 2007 a; Cakmakci et al., 2007 b; Akgül and Mirik, 2008; Yildirim et al., 2011; Cakmakci et al., 2009). They stimulate the development of plant organs through cell division and expansion (Taiz and Zeiger, 2002) or by improving nutrient uptake (Chabot et al., 1996; Yanni et al., 1997). Through these mechanisms, plant growth-promoting bacteria benefit plant growth by increasing germination rate, root growth, yield, leaf area, chlorophyll content, Mg, N content, protein, hydraulic activity, drought resistance, shoot and root weights and delaying the formation of the abscission layer in leaves (Lucy et al., 2004).

Bacteria such as *Rhizobium*, *Bradyrhizobium*, *Azotobacter*, *Azospirillum*, *Pseudomonas* and *Bacillus* have been reported to be present in India from desert ecosystems to acidic soils, saline soils to alkaline soils (Selvakumar et al., 2009, Upadhyay et al., 2009). The adaptation of microorganisms to different stress factors has occurred through many complex processes (Srivastava et al., 2008). While in some species that can survive under extreme environmental conditions (thermophiles and halophiles) the optimum conditions for metabolic activities such as enzymatic activities may be high temperature and salinity, other microorganisms have developed different adaptation mechanisms to cope with stress. Some bacteria, such as *Pseudomonas*, can survive under stress conditions because they produce exopolysaccharide (EPS). EPS protects microorganisms against water stress and flooding (Sandhya et al., 2009). Exopolysaccharide has a unique ability to retain and bind water and has important effects in regulating the structure and balance of soil aggregates and in the transport of nutrients dissolved in water to the plant root zone (Roberson and Firestone 1992; Tisdall and Oadea 1982).

Furthermore, microorganisms can play an important role in stress management due to their tolerance to unusual conditions and their ability to exist in many different climatic and soil conditions for the same reason. These organisms can also be used as an important model to unravel the mechanism of tolerance to different stressors. In this way, tolerance mechanisms against stressors such as cold damage, salinity, heavy metal damage and high temperature can also be developed. In the last century, it has been proven that bacteria belonging to different genera such as *Rhizobium, Bacillus, Pseudomonas, Pantoea, Paenibacillus, Burkholderia, Achromobacter, Azospirillum, Microbacterium, Methylobacterium, Variovorax, Enterobacter*, etc. increase the tolerance of host plants to different abiotic stress factors (Grover et al., 2011). These bacteria exert these effects through ACC deaminase enzyme activity. Polymeric ACC deaminase linked to pyridoxal 5-phosphate (PLP) was first studied with Pseudomonas by researchers, and especially the studies were directed towards the promotion of plant growth under stress conditions and the reduction of the negative effects of stress (Mayak et al., 2004; Madhaiyan et al., 2006).

Broccoli (*Brassica oleracea* var. *italica*), which is consumed raw or cooked as small green tubers, is among the vegetables of the *Brassicaceae* (*Cruciferae* family). In broccoli, it is important for market quality that the flower stalks do not open, the crown color maintains its green color when it reaches the harvest width and has a smooth shape. According to 2023 data, our broccoli production is 120 549 tons. Broccoli, which is grown in large areas in Europe and America and consumed fondly, has been rapidly increasing in production and consumption in our country in recent years. Especially its positive effects on health increase the demand for broccoli. Broccoli (*Brassica oleracea* var. *italica*) is widely consumed worldwide due to its high nutritional value (e.g., rich in vitamins A, B2, C, minerals (Anonymous, 2018; Glaser & Lehr, 2019), fiber and low calories (Anonymous, 2017). It is beneficial for health due to its high content in antioxidants and bioactive compounds such as atocopherol, β-carotene and isothiocyanates (Babalola, 2010). It has also been found to have anticancer properties in recent studies, especially in relation to specific phytochemicals such as organosulfuric compounds, sulforaphane and glucosinolates (Cruz et al., 1993;Yadav & Sarkar, 2019; Zia et al., 2021). The increase in the living standards of people, the awareness of consumers, the importance of "healthy" and "high quality" food as well as being satisfying, and the emphasis on the effect of adequate and balanced nutrition on human health and development have caused producers to be more attentive during cultivation and to take many measures. With the development of technology, excessive use of fertilizers or pesticides has increased in intensive agricultural areas, which has negatively affected human health and environmental health. In vegetable cultivation, the use of fertilizers is more intensive due to the reasons such as more plants per unit area, especially the high yield of the varieties bred in recent years, thus removing more plant nutrients from the soil, and obtaining several times more yield from the unit area compared to open cultivation, especially in greenhouse cultivation. For this reason, research on practices that reduce the use of chemical fertilizers in vegetable production or products of organic origin that can be used in the nutrition of plants such as chemical fertilizers has been quite high in recent years. Especially due to the pandemic, healthy nutrition and products that strengthen the immune system have come to the forefront, and the importance of practices that will not adversely affect the environment and human health has increased even more.

In our research, a commercial biofertilizer containing many beneficial microorganisms was used in the cultivation of broccoli, a vegetable that stands out with the above-mentioned characteristics and is in constant demand in the market. No research has been conducted on broccoli under Malatya conditions before and the producers in the region are far from broccoli cultivation. Therefore, it was thought that the research would contribute to the producers of the region. The aim of the study was to determine whether the biofertilizer used in the experiment saves chemical fertilizer fertilizer in broccoli cultivation and its effect on plant growth and yield. In addition to being a fertilizer for plants exposed to different abiotic stresses in crop production due to climate change in recent years, the use of biofertilizers is also important to provide resistance against stress. Here, we used a biofertilizer that can be found commercially by the producers in the market, so that the results can be directly recommended to the producers.

MATERIALS AND METHODS

This study was conducted in a plastic greenhouse (270 m^2) belonging to the Faculty of Agriculture of Malatya Turgut Özal University between October/March 2020-2021 (Figure 1).

Figure 1. Appearance of broccoli plants planted in the experimental greenhouse.

Plant Material

Mundo F$_1$ (Asgen Tarım Tic. A.Ş.) Broccoli variety was used as plant material in the research. This variety is a medium late, 80-85 days old variety. It has a very tight head structure, dark green in color and round. The side heads after the top is cut are of the same quality. It is suitable for spring, fall and summer planting.

Fertilizers used in the study and their application

Sufficient studies have been carried out with single strains of bacteria isolated and propagated from the laboratory environment, and the benefits of the bacteria to the plant in single use have been reported by researchers. What needs to be done in the future is to bring together their combined use and the benefits they provide to the plant in different aspects. The biofertilizer we used in our study here is from Japanese oak and is a biofertilizer that can be easily supplied by commercial producers. It contains beneficial microorganism species for which research and development studies have been carried out and which will not be a problem in terms of production in the same solution.

Bio-fertilizer; Saion EM with its commercial name, contains beneficial microorganisms *Pseudomonas fluorescens, Rhizobium leguminosarum, Azotobacter chroococcum, Bacillus subtilis, Serratia aquatilis, Aspergillus oryzae*, *Penicillium chrysogenum* Biofertilizer application was done as recommended by the company. The number of live microorganisms guaranteed by the company: $1x10^7$ kob/ml. Liquid biofertilizer containing active microorganisms was started to be applied 13 days after planting. This process continued at 10-day intervals until the end of harvest. In this application, 3 liters/da was given to the plants.

Commercial fertilizers; commercial fertilizers used in conventional cultivation were given during the growing season at the doses recommended for broccoli cultivation according to the results of soil analysis. Commercial fertilizers used in the experiment were Triple Super Phosphate, Potassium Nitrate, Ammonium Sulphate. In addition, elemental sulfur was given to reduce soil pH and during seedling planting. Fertilization was calculated as 15 kg N, 20 kg P_2O_5 and 20 kg K_2O per decare and applied to the plots.

The research was established according to the randomized block design with 3 treatments and 3 replications, and 20 plants were used in each replicate. Broccoli seedlings were planted in the greenhouse on October 1 with 100 cm between rows and 30 cm above rows. Before planting, basic fertilization was given to all treatments during soil preparation. In order to determine the effect of the use of microorganisms on fertilizer saving, a treatment in which commercial fertilizers were reduced by 30% was also included in the experiment. All cultural operations were carried out regularly from planting to harvest.

Treatments;

1. Control: Plots where all recommended fertilizer amounts were applied in broccoli production (100% chemical fertilization). This is the type of fertilization used by producers in broccoli production in conventional cultivation.
2. Treatment I: Plots with 30% reduced rates of recommended fertilizer amounts and active microorganisms in broccoli production (70% chemical fertilization + Microorganisms). It is a treatment to reduce the use of chemical fertilizers in conventional farming and to improve the soil with the use of beneficial microorganisms.
3. Treatment II: Plots where all recommended fertilizer amounts and effective microorganisms were applied in broccoli production (100% chemical fertilization + Microorganisms). This application was made to see the contribution of using biofertilizers in addition to chemical fertilizers in conventional production without reducing chemical fertilizers to the soil and plants.

Measurements on plants

Plant growth and development measurements (plant height, stem diameter and number of leaves) started one month after planting the seedlings in the greenhouse and were carried out four times at four-week intervals. In addition, root length, root, stem, stem, leaf fresh and dry weights were taken on the plants that were uprooted twice during the young plant period (December 09) and at the end of the experiment (March 24). Broccoli heads of the expected size could not be obtained during the cold period in the unheated plastic greenhouse. Harvesting started on March 11 and ended on March 30, and a total of 4 harvests were made. The first harvest values of the treatments were evaluated as early yield and the effect of microorganism application on early yield was determined. Then, all harvest values were summed and total yield was obtained.

RESULTS AND DISCUSSION

Plant Growth Parameters: The results of plant growth parameters on broccoli plants on 4 different dates are presented in Table 1. When we look at the results of plant height; although there was no significant difference in the first measurements in the treatments using microorganisms, it was determined that microorganism treatments increased the plant height by 8-9% at the last measurement date. Plant height in plots with 30% fertilizer reduction (U1) was almost the same as in plots with 100% fertilizer + microorganisms (U2). The difference between the treatments was found to be statistically significant at the last measurement date. When we examined the stem diameter values, the stem diameter values of the plants in the plots where microorganisms were applied were higher on the first measurement date, and the stem diameters of the plants in the plots where 30% fertilizer was reduced (U1) were higher than the plots where 100% fertilizer + microorganisms were applied (U2) in the last measurements except the first two measurement dates. There was a statistically significant difference between the treatments only on the 3rd measurement date. At the last measurement date, microorganism application provided an increase of 7-11% in stem diameter. When we look at the number of leaves; it is seen that the plants formed more leaves in the plots where 20-30% microorganisms were applied in the first two measurement dates. Even the difference determined on the 2nd measurement date is at the level of statistical significance. In the following measurement dates, the lower old leaves were pruned as the plants grew and the number of leaves in all treatments were found to be close to each other.

Table 1. Effect of biofertilizer treatment on some growth parameters of broccoli measured at different dates

Date of Measurement	Treatments	Plant Height (cm)	Stem Diameter (mm)	Number of Leaves (number)
3 November (32 days after planting)	Control	37.36	10.66	10.39
	U-1	38.13	13.12	12.76
	U-2	38.29	11.52	13.73
	Std sp.	00.41	01.02	01.40
21 November (60 days after planting)	Control	51.59	23.23	14.15 b
	U-1	55.63	22.82	18.79 a
	U-2	52.93	22.16	18.66 a
	Std sp.	01.68	00.44	02.15
9 December (88 days after planting)	Control	57.53	23.76 b	21.49
	U-1	60.59	24.62 a	24.13
	U-2	58.46	25.66 a	21.43
	Std sp.	01.28	00.77	01.25
25 December (116 days after planting)	Control	61.63 b	23.92	24.76
	U-1	66.93 a	25.66	26.63
	U-2	66.46 a	26.65	24.56
	Std sp.	02.39	01.12	00.93

In addition to the measurements made on the plants in the greenhouse, the plants were uprooted on the measurement date on December 9, 88 days after planting, and some of the plant growth parameters were measured in the uprooted plants (Table 2). The effects of treatments on root length, root, stem and leaf fresh and dry weights were analyzed. The difference in leaf fresh weight was statistically significant except for the root and stem dry weight parameters. In the young period, microorganisms are more effective in plant growth. On December 9, when we examined the results of the plant uprooting, we found that the root length in the plots with 30% reduced fertilizer + microorganisms (U1) was about 20% longer than the control plant roots, and the plant roots in the plots with 100% fertilizer + microorganisms (U2) were about 47% longer. In parallel with these results, root dry weight values were 66% and 56% higher in the plots treated with microorganisms compared to the control plots. Root development was quite good in the plots treated with microorganisms and this was reflected positively on the above-ground parts. When we take stem+leaf dry weight values, 85% more dry matter accumulation was found in plots with 30% reduced fertilizer + microorganism (U1) and 50% more in plots with 100% fertilizer + microorganism (U2).

Table 2. Some measurement results of broccoli plants uprooted 88 days after planting (December 9)

Treatments	Root Length (cm)	Root Fresh Weight (g)	Leaves Fresh Weight (g)	Stem Fresh Weight (g)	Root Dry Weight (g)	Leaves Dry Weight (g)	Stem Dry Weight (g)
Control	23.66	42.16	346.94	89.11	12.54	37.55	24.14
U-1	25.83	44.99	324.52	70.96	11.49	22.57	21.80
U-2	34.66	48.02	315.47	107.59	10.17	32.75	22.78
Std sp.	04.76	02.39	13.23	14.95	00.97	6.25	00.96

The boosting effect of biofertilizers may be due to the fact that microorganisms increase root activity in the rhizosphere, initiate hormonal activity and thus increase the uptake of plant nutrients (Vessey, 2003; Itelima et al., 2018; Kamal et al., 2021). Many studies have reported the supportive effects of biofertilizers on plant growth. Rather et al. (2018) found that *Azotobacter* and *Azospirillum* bacteria increased the amount of IAA and root length, enhanced cytokinin formation and root branching, thus increasing nutrient uptake from the soil and accelerating plant growth.

The yield and plant growth improvement effects of the bacteria used in this study can be explained by their N_2-fixing and P-solubilization capacities. The positive effects of biofertilizers on yield and growth parameters (such as apricot, tomato, sugar beet and barley) are explained by their N_2-fixing ability, phosphate solubilizing capacity, indole acetic acid and antimicrobial production (Esitken et al., 2005; Rodríguez et al., 2006; Wilsion, 2006; Malik et al., 2001). In general, improvements in macro/micro nutrient contents were found to be higher in PGPR treatments. The increase in mineral uptake by plants is due to the contribution of biofertilizers to the plant. They reported that the use of N_2-fixing and P-solubilizing PGPR in barley (Rodríguez et al., 2006), tomato (Caballero-Mellado et al., 2007), and lettuce (Bar-Ness et al., 1992), increased macro-micro nutrient uptake in plants. According to the results of Valverde et al. (2015), the application of biofertilizer containing Azospirillum + Azotobacter (50% each) to broccoli during transplanting by root dipping method increased the yield as well as the functional biomolecules in the plant. Singh et al. (2014) and Choudhary & Paliwal (2017), showed that the integration of bio-organic and mineral fertilizers showed a significant effect in maximizing broccoli yield.

Total Yield: When the total yield values (Figure 2) were analyzed; similar results were obtained for plant growth parameters. Yield in plots treated with microorganisms was higher than the control. Yield in plots with 100% fertilization and microorganisms (U2) was 20% higher than the control and yield in plots with 30% reduced fertilization + microorganisms (U1) was 15% higher than the control.

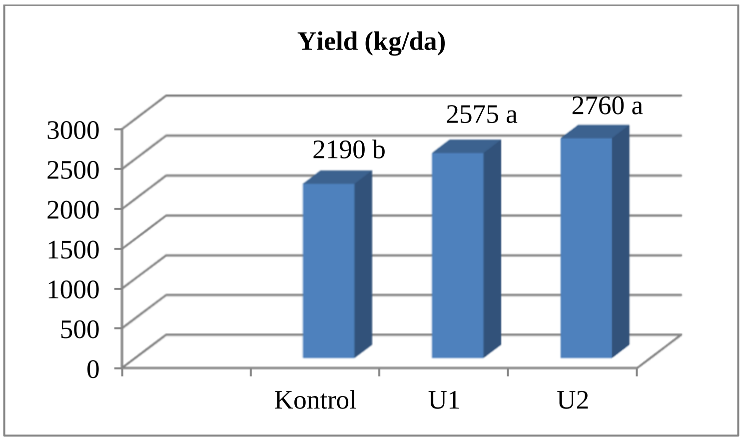

Figure 2. Effect of biofertilizer treatments on broccoli yield (std sp.: 237.42)

As in other cultivated plants, yield is the most important criterion in vegetable cultivation. Although it is a known practice to increase yield with chemical fertilization, the effective use of biofertilizers and the reduction of chemical fertilizer applications may necessitate the updating of fertilization practices. With this result in the yield parameter, environmental and economic gains can be achieved by reducing the use of chemical fertilizers. It can be said that this situation is due to the activity of microorganisms in the soil. Various studies have reported an increase in productivity and a decrease in the use of chemical fertilizers thanks to biofertilizers. Panda (2011) and Berg (2009) reported that biofertilizers have an effect on yield in the range of 35-65%. Some researchers have also determined that NPK use can be reduced with the use of microbial fertilizers (Chauhan and Bagyaraj, 2015; Yıldırım et al., 2011).

Some bacteria, such as *Bacillus* and *Azotobacter*, can synthesize organic acids and phosphates that convert the unavailable form of phosphorus into a usable form for plants (Tošić et al. 2016), while *Pseudomonas*, *Bacillus* and *Rhizobium* bacteria are known to be the most powerful phosphate solubilizing bacteria (Rodríguez and Fraga, 1999). Among the phosphorus-solubilizing microorganisms, phosphate-solubilizing bacteria have the potential to solubilize 1-50% of phosphorus (Chen et al., 2006) and phosphate-solubilizing bacteria secrete phosphate organic acid metabolites containing hydroxyl and carboxyl group chelates and convert them into a usable form by binding with cation bonds (Sagoe et al., 1998).

Microorganisms work more efficiently if there is a lack of nutrients in the environment. In the light of previous studies, we can say that microorganisms increase nutrient uptake in the soil and consequently increase yield. Recent research has shown that *Rhizobium leguminosarum*, *Rhizobium* spp. and *Bradyrhizobium* spp. increased plant biomass, yield and chlorophyll content in plants compared to non-inoculated plants. The highest increase was recorded in IRBG strains, which showed a 14% increase compared to uninoculated plants (Verma et al., 2019). Similarly, some Rhizobia strains increased the surface area, photosynthetic rate, water uptake capacity, yield and stomatal conductance of inoculated plants (Enebe & Babalola, 2018). In addition, a bacterial mixture of *Pseudomonas*, *Bacillus lentus* and *Azospirillum brasilense* was reported to increase chlorophyll content and antioxidant enzymes in plants under stress conditions (Brahmaprakash et al., 2017). Khalid et al. (2017) found that biofertilizer application increased growth, chlorophyll content, antioxidant activity, yield and phenolic compounds in spinach. Total phenolic compounds were reported to be 58% higher than uninoculated spinach. Similarly, Arora et al. (2018) reported an increase in growth, yield, phenolic compounds, anthocyanins and carotenoid content of lettuce when inoculated with *Azotobacter chroococcum* and *Piriformospora indica*.

Hassen et al. (2016) reported an 80% increase in soybean yield when inoculated with nitrogen-fixing *Rhizobium* and *Bradyrhizobium.* Dicko et al. (2018) used plant growth-promoting bacteria in a study conducted by Dicko et al. (2018), which found that biofertilizer increased plant growth and yield, and increased corn yield. Recently, the effect of biofertilizer made from plant growth-promoting *Bacillus pumilus* strain TUAT-1 was evaluated on rice genotype, and it was revealed that biofertilizer made from Bacillus strain increased rice yield (Win et al., 2019). In the study conducted by Fathi (2017), in maize, biofertilizer containing phosphate solubilizing bacteria was used, and it was reported to increase maize growth and yield compared to the uninoculated control. Altuntaş (2018) reported that the highest total head yield was obtained by using Bacillus subtilis inoculations in broccoli. In addition to the increase in yield and crop quality in the use of biofertilizers, more importantly, soil nutrients are reduced as a result of different activities occurring in the soil, such as surface runoff, burning of crop residues and washing of agricultural soil. The nutrients in the soil travel through rain-induced runoff to the groundwater body, where they cause eutrophication and contamination of the groundwater body (Yu et al., 2019). This poses a major threat to the natural environment. Therefore, the application of nutrient-rich biofertilizers made from plant growth-promoting microorganisms with potentials such as nitrogen fixation, potassium solubilization and phosphate solubilization is essential in recovering soil nutrients to enhance plant growth and yield performance (Olanrewaju et al., 2019).

CONCLUSION

The use of microorganisms such as bacteria, fungi, actinomycetes and algae as biological fertilizers reduces the environmental risk in agricultural production. These preparations, which can be easily used in organic production, come to the forefront as an environmentally friendly technique with the fact that they do not cause environmental pollution, on the contrary, they improve the structure of the soil, in addition to the benefits they provide to plants in recent years when environmental awareness has developed. The results of our researches have revealed that the biofertilizer we use in broccoli cultivation positively affects plant growth and yield. Both the growth and development parameters of the plants in the greenhouse and the biomass measurements as a result of plant removal gave higher results in the applications using biofertilizer. In addition, the increase in yield (15% and 20%) shows that it is worth recommending the biofertilizer to the producer. Biofertilizer, which contains different microorganisms that enable plants to effectively utilize the given nutrients and contains different microorganisms in its content, is important both environmentally and economically with this increase in yield. Biofertilizer is used approximately 2.5 liters per decare during the production season. In this case, it is possible to improve the soil, especially biologically, and increase the yield with an environmentally friendly and cheap input. Recommending biofertilizers containing microoganisms in fertilizer recommendations in open and greenhouse vegetable cultivation will be beneficial in terms of plant development and soil improvement and increasing biological activity.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

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