A COMPARATIVE STUDY ON THE EFFECTS OF DIFFERENT CONVENTIONAL, ORGANIC AND BIO-FERTILIZERS ON BROCCOLI YIELD AND QUALITY

ALTUNTAŞ, Ö.

Department of Horticulture, Faculty of Agriculture, Inonu University, Malatya, Turkey
(e-mail: ozlem.altuntas@inonu.edu.tr; phone: +90-541-896-4029)

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Abstract. In this study, we evaluated the effects of fertilizers of different origin on broccoli yield and some characteristics. For this purpose, 9 different fertilizers were used. The different fertilizers used in the study were; NT**;** Control (No Treatment), FM**;** Farm Manure (approximate 2-4% N) CF; Chemical Fertilizer (46% N, 46% P_2O_5, 51% K_2SO_4), HA; Humic Acid, AA; Amino Acid, HFA; Humic and Fulvic Acid, ALG; Microalgea, ART; *Arthrobacter sp.*, BAS; *Bacillus subtilis* strain QST 713. During the vegetation period, the plant growth parameters were measured twice in the growth season. The first measurement was performed after 40 days of planting, while the second was done after 70 days. Two plants were harvested from each replication in order to determine the plant growth parameters of shoot fresh weight, root fresh weight, plant height, root length, shoot and root dry weight and the number of the leaves. At the end of the experiment, mineral contents of leaves, total yield and ascorbic acid contents of broccoli heads were determined. As a result, it was determined that some organic fertilizers and biofertilizers increased the yield, various plant growth parameters, nutrient uptake of broccoli and ascorbic acid contents of broccoli heads at a significant level.
Keywords: *organic farming, eco-friendly, broccoli, biofertilizer, yield, quality, nutrient elements*

Introduction

Many agricultural soil types lack at least one essential nutrient element that is necessary for plants. Soil degradation can occur due to acidity, alkalinity, salinity, anthropogenic processes and erosion. Maximum nutrient and yield are only possible by adding fertilizers to the soil in agriculture. In general terms, less efficiency counts for chemical fertilizers causing that only a small part of the fertilizer is used by plants (Arisha and Bardisi, 1999). In previous studies conducted on the efficiency of the fertilizers revealed that the efficiency was less than 50% in N, less than 10% in P, and around 40% for K in mineral fertilizers. These values are even lower in manure. When plants absorb the nutrients in an efficient manner, the costs of inputs are reduced and loss of nutrients is decreased in the ecosystem (Baligar et al., 2001).

One way to optimize the efficiency of fertilizers is managing the fertilizers in an efficient manner, which means applying them at the right time, rate and place. This is true both for conventional and organic agriculture. Optimal crop productivity and optimal nutrient use efficiency must be in balance (Roberts, 2008). Applying agricultural activities for the purpose of obtaining high yield and quality requires chemical fertilizers be applied in a frequent manner. This causes extra costs and environmental problems. The biogeochemical cycle is a complex system and is frequently influenced in a negative manner when chemical fertilizers are used too often to promote soil fertility and crop yield. For instance, applying fertilizers gives rise to leaching and nutrient runoff (especially P, and N). This has causes that there appeared an environmental degradation. Therefore, organic agriculture has attracted attention more in recent years (Esitken et al., 2005).

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When chemical fertilizers are not used in an efficient manner, one possible way to reduce negative effects is inoculation with Plant Growth Promoting Rhizobacteria (PGPR), which have useful effects on plant growth. For this reason, these bacteria may be used for agricultural activities as bio-fertilizers (Baligar et al., 2001). Some bacteria species were tested, and it was concluded that they were useful for plant yield, growth and quality improvement. These bacteria can enhance yield of organic systems and help control pollution. Faster breakdown of organic substance, improved nutrient availability and soil characteristics are among the positive effects of biofertilizers. It is possible to explain these positive effects by metabolite release, which enhances growth. Although full mechanism has not been fully resolved, PGPR acts in the following mechanisms; producing plant growth hormones (like auxin, cytokinin, gibberellin); ethylene production inhibition; fixation of symbiotic N_2; inorganic phosphate solubilization; organic phosphate and/or other nutrients mineralization; acting as an antagonist to phytopathogenic microorganisms (by siderophores production); antibiotic, enzyme and fungi compound synthesis; and competition with detrimental microorganisms (Mellada et al., 2007).

Broccoli (*Brassica oleracea* L. var. *italica*) is considered as a Brassicaceae family member. It is a wild form belonging to this family, and is spread in the Mediterranean region (Decoteau, 2000) Broccoli is an important vegetable because of its high nutritional as well as commercial value (Yoldas et al., 2008). In general, more than necessary inorganic fertilizers are given to vegetables for the purpose of achieving higher yields and maximum growth value (Badr and Fekry, 1998; Arisha and Bardisi, 1999; Dauda et al., 2009) On the other hand, using inorganic fertilizers solely can lead to several problems for human health and the environment (Arisha and Bardisi, 1999). For the purpose of improving soil structure (Dauda et al., 2009), and microbial biomass an alternative to mineral fertilizers is organic manure (Naeem et al., 2006). For this reason, using locally produced manure in agricultural activities might increase crop yield, and thus, less chemical fertilizers will be used. Nowadays, consumers prefer organic foods than ever because there is a widespread belief that organic foods are healthier and more environmental-friendly. However, an important drawback of organic agriculture is the fact that most organic fertilizers have low nutrient contents (Mengel and Kirkby, 1987) which mostly depends on the source and moisture content. Another problem is the difficulties to assess the value of organic fertilizers by using direct total quantity of plant nutrients analysis. For this reason, further studies are necessary to define the availability of the nutrient elements and the efficiency of many organic fertilizers. During the decomposition of organic materials, a slow and variable release of nutrients occurs. By increasing the mineral and organic fertilizer efficiency, it is possible to use biofertilizers to increase soil productivity and plant growth in sustainable agriculture activities (Arisha and Bardisi, 1999). For this reason, the study was designed to examine the effects of organic fertilizers that have different contents on plant growth parameters, nutrient uptake, and yield of broccoli in comparison with mineral fertilizer application under field conditions.

Materials and methods

Plant material

Broccoli 'Marathon F1' (*Brassica oleracea* L. var. *italica*) plant (middle season variety was used as plant material in the present study.

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Experimental design

The study was designed and applied in high plastic tunnels at Cukurova University, Karaisali Vocational School, Adana, which is located in the southern part of Turkey. The study was applied in 2011 and 2012 growth period. In the first year, broccoli was grown in the southern region in a limited time period, which is between September and February. In the second year of the study, the application was made in the same period. *Table 1* shows some of the physical and chemical characteristics of the soil in the study area. According to soil analysis; phosphorus content is low, potassium, magnesium, calcium is high, zinc is medium, and other micro elements are sufficient.

Table 1. *Analysis results of the soil used in the study*

Nutrient	Concentration	Unit
Phosphorus (P)	107	kg/ha
Potassium (K)	768	kg/ha
Magnesium (Mg)	2630	kg/ha
Calcium (Ca)	20600	kg/ha
Sulphur (S)	94	kg/ha
Boron (B)	3	kg/ha
Zinc (Zn)	7	kg/ha
Manganese (Mn)	189	kg/ha
Iron (Fe)	153	kg/ha
Copper (Cu)	6	kg/ha
Salt	0.8	mmhos/cm
Organic Matter	2.34	%
Lime	28.4	%
pH	7.6	-

Broccoli (Marathon F1 cultivar) was planted in high plastic tunnels in the 3rd week of September (in the 1st year on 22.09.2011; and in the 2nd year on 19.09.2012). The selected variety is a high value for marketing that can be adapted to different climatic conditions including extreme winter colds, harvested in 75 days after planting and has a strong plant structure. It can be harvested all season. A distance of 0.80 m was given between the seedlings with an intrarow spacing of 0.60 m. A randomized complete block design was used in the study area with three replications. There were 10 plants in each plot. The applications were as follows; **NT;** Control (No Treatment), **FM;** Farm Manure (approximate 2-4% N) **CF;** Chemical Fertilizer (46% N, 46% P_2O_5, 51% K_2SO_4), **HA;** Humic Acid (Humic A), **AA;** Amino Acid (Pattrone), **HFA;** Humic and Fulvic Acid (Ekoflora), **ALG;** Microalgea (Allgrow), **ART;** *Arthrobacter sp.* (Roa Natura), **BAS;** *Bacillus subtilis* strain QST 713 (Serenade ASO). *Table 2* shows the doses applied in each treatment.

Treatments time

Organic and biofertilizer doses were added to the soil 3 times; 1st time: Before planting. 2nd time: 30 days after planting. 3rd time: 60 days after planting.

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Table 2. *Organic and bio fertilizer contents and application doses*

Treatments	Ingredients	Doses
NT	Control (No Treatment)	-
FM	Farm Manure (approximate 2-4% N)	3 ton da^{-1}
CF	Chemical Fertilizer; 46% N, 46% P_2O_5, 51% K_2SO_4	20 kg N da^{-1}, 15 kg P_2O_5 da^{-1}, 25 kg P_2O_5 da^{-1}
HA	Humic Acid 50%, Amino Acid 10%, N 16%, K_2O 1%, P_2O_5 2%, Humidity 1%, pH 3-5.	5 kg da^{-1}
AA	Free Amino Acid, 45.43%, 10.21% Organic N	3 kg da^{-1}
HFA	Humic + Fulvic acid 28.2%, K_2O 2%, P_2O_5 2%, MgO_2 1.1%, Fe_2O, 0.24%, Zinc 129 ppm, Manganese 90 ppm, pH 6-8	150 kg da^{-1}
ALG	Algea, 660 ppm N, 27 ppm NA, 5.6 ppm F, 184 ppm P 17 ppm Mn, 15 ppm Ca, 722 ppm K, 0.49 ppm Co, 0.89 ppmV, 3.7 ppmCu, 8.5 ppm Zn, 0.28 ppm Mo, 310 ppm S, 44 ppm B, 21 ppm	2 l da^{-1}
ART	*Arthrobacter sp.*	2 l da^{-1}
BAS	*Bacillus subtilis* strain QST 713	1 l da^{-1}

Plant growth parameters

Plant growth parameters were measured twice in the growth season; 1st time: 40 days after planting (10 days after 1st fertilizer application). 2nd time: 70 days after planting (10 days after 2nd fertilizer application). Two plants were harvested from each replication. The parameters like growth variables (fresh weight of the shoot, fresh weight of the root, height of the plant, length of the root, dry weight of the shoot, dry weight of the root, and the number of the leaves) were recorded. Roots and shoots were separated from the surface of the soil. Plant roots were cleaned of soil with water. For the purpose of determining the dry matter amount, shoots (including the leaves and the stem) and root samples were dried at 70 °C in an oven until the humidity was evaporated.

Physical properties and the yield of the broccoli heads

The broccoli that was not mature and marketable were harvested between December and February in both years. Heads with stems were cut into 15 cm pieces. The yield per decare was computed. To define the physical properties (for example, the weight of the head), 15 broccoli heads (per treatment – 3 replicates of 5 heads) were measured. The heads were sampled from each application. The weight of the heads was computed as the mean value of 15 heads. In order to measure the head diameter, the widest part of the head was used.

Determination of mineral contents in leaves

For the purpose of determining the relation between the broccoli nutrient content and soil nutrient pools, the measurements were made when the heading process started (Jones, 1981; Mengel and Kirkby, 1987). In this respect, during the heading process,

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leave samples were taken (five of the youngest leaves). These samples were then dried at oven at 70 °C for 48 h. After the drying process, they were weighed. Then they were placed in ash at 550 °C for nearly 10 h. The ash was dissolved in 3.3% HCL. Atomic Absorption Spectrometry was used to determine the K, Ca, Mg, Fe, Mn, Zn, Cu concentrations in the leaves. The nitrogen amount of the leaves was determined by using the Kjeldahl method.

Vitamin C analysis

The head samples were taken in the 4th harvest to analyze the Vitamin C content. 5 g of broccoli head was homogenized with 50 ml meta-phosphoric acid (HPO_3) solution and then filtered to analyze Vitamin C. After this process, 10 ml filtrate was titrated by using 2.6 dichlorophenolindophenol solution to obtain a pale pink color. Vitamin C content was computed after 2.6 dichlorophenolindophenol solution was calibrated by using L-Ascorbic Acid (Uggla, 2004).

Data analysis

The experiment was repeated in 2 years. For the purpose of analyzing the data, the IBM SPSS Statistics 20 Software was used. The mean values for each parameter were compared by a multiple comparison Duncan test to investigate the grouping (at P = 0.05). No significant interactions were detected by year. For this reason, the data were pooled.

Results and discussion

As a result of the study, it was determined that some organic fertilizers and biofertilizers increase the yield, various plant growth parameters, and nutrient intake of broccoli at a significant level. (Naeem et al., 2006) conducted a study and reported the following positive outcomes of the Plant Growth Promoting Rhizobacterias; fixation of nitrogen, reducing ethylene levels by ACC Deaminase enzyme activity, siderophores and phytohormones production (like oxins), pathogen resistance induction and nutrient solubilization. The growth and development of plants may be influenced by Plant Growth Promoting Rhizobacterias in two ways, either directly or indirectly. Direct effects are as follows; production of ACC deaminase for the purpose of reducing the ethylene levels in the plant roots (Dey et al., 2004) production of plant growth regulators like Indole Acetic Acid (IAA) gibberellic acid (Narula et al., 2006) cytokinins (Dey et al., 2004) and ethylene, (Ortiz-Castro et al., 2008) asymbiotic nitrogen fixation exhibition of antagonistic activity against phytopathogenic microorganisms by producing siderophores (b-1.3-glucanase, chitinases, antibiotics, fluorescent pigment and cyanide) and solubilization of mineral phosphates and other nutrient elements (Dauda et al., 2009). There are more than one mechanism used by PGPR for the purpose of improving plant growth. According to several studies, stimulation of plant growth is the clear result of multiple mechanisms, which might be activated simultaneously (Martinez-Viveros et al., 2010). Indirect stimulation is related with biocontrol – including production of antibiotics, chelation of available Fe in the rhizosphere, extracellular enzyme synthesis for the purpose of hydrolyzing the fungal cell wall and competition for niches in the rhizosphere (Uggla, 2004). Blue green algae are the diverse group of photosynthetic prokaryotes, which are known to fix

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atmospheric nitrogen and to convert insoluble phosphorus into soluble form (Irisarri et al., 2001). Cyanobacteria play an important role in maintenance and build-up of soil fertility, consequently increasing rice growth and yield as a natural biofertilizer (Song et al., 2005) The acts of these algae include: (1) Increase in soil pores with having filamentous structure and production of adhesive substances. (2) Excretion of growth-promoting substances such as hormones (auxin, gibberellin), vitamins, amino acids (Roger and Reynaud, 1982; Rodriguez et al., 1982). (3) Increase in water-holding capacity through their jelly structure. (4) Increase in soil biomass after their death and decomposition. (5) Decrease in soil salinity. (6) Preventing weeds growth. (7) Increase in soil phosphate by excretion of organic acids (Wilson, 2006). After water, nitrogen is the second limiting factor for plant growth in many fields and deficiency of this element is met by fertilizers (Malik et al., 2001).

Humic substances, play a vital role in soil fertility and plant nutrition. Plants grown on soils which contain adequate humin, humic adds, and fulvic adds are less subject to stress, are healthier, produce higher yields; and the nutritional quality of harvested foods and feeds are superior. The value of humic substances in soil fertility and plant nutrition relates to the many functions these complex organic compounds perform as a part of the life cycle on earth. The life death cycle involves a recycling of the carbon containing structural components of plants and animals through the soil and air and back into the living plant. As a result humic acids function as important ion exchange and metal complexing (chelating) systems. Because of the relatively small size of fulvic acid molecules they can readily enter plant roots, stems, and leaves. As they enter these plant parts they carry trace minerals from plant surfaces into plant tissues. Fulvic acids are key ingredients of high quality foliar fertilizers. Plant grow is influenced indirectly and directly by humic substances. Positive correlations between the humus content of the soil, plant yields and product quality have been published in many different scientific journals (Petit, 2004).

Root length, fresh and dry root weight

The results of these parameters are given in *Tables 3* and *4*. When the root development parameters were analyzed, it was determined that the farm manure and organic fertilizers were more effective in the root length. In the first measurement date, in the root length rank, the *Arthrobacter sp.*(ART), which is one of the biofertilizers, came after HFA and AA, which are organic fertilizers, and after FM, which is a farm fertilizer (*Table 3*). In the second measurement date, the longest root was measured in *Arthrobacter sp.* (ART) application, and HFA, FM, AA, BAS followed it respectively. When the fresh and dry weight of the roots were analyzed, it was determined that biofertilizers are more influential unlike the organic fertilizers in root length. It was determined that eave-formation is more intense and this is reflected to fresh and dry root weight (*Table 4*). Especially the biofertilizers that include algae (ALG) and *Bacillus subtilis* (BAS) were determined to be the highest ones in terms of dry root weight in both measurement dates. Chemical fertilizer application (CF) and Control (NT) groups were left behind in root development.

It was determined that biofertilizer treatment improves the radical system in broccoli. Dry root weight and root length were detected to be increased at a significant level in the plants which received bio fertilizers (47% *Arthrobacter sp*. (ART), and 30% *Bacillus subtilis* (BAS), respectively) when compared with the Control Group (NT). Plant nutrient facilitation may be the mechanism with which biofertilizer improves the

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crop yield and head size, because the nutritional plant status is improved with the increased availability of nutrients in the rhizosphere (Bar-Ness et al., 1992) According to the findings, inoculants may be used to allow reduction in the current high fertilizer rates and to eliminate relevant problems (Shaharoona et al., 2008; Dauda et al., 2009) without compromising the productivity of the plants.

Fresh and dry weight of shoot

In terms of the fresh weight of the shoot, although the biofertilizer that included *Bacillus subtilis* (BAS) had the highest value in both measurement dates in terms of dry weight of the shoot, (AA), which was rich in amino acid content and organic N content among the organic fertilizers, was detected to be ahead of the biofertilizers in both measurement dates. (ALG) biofertilizer, which contained algae + macro and micro elements, followed this application (*Tables 3* and *4*). The applications that had better root development rather than root length, and therefore higher root weights, affected the development of the shoot in a positive manner. In general, in both measurement dates, it was determined that the fresh and dry weight of the shoot was increased by biofertilizer applications. It is possible to claim that biofertilizers play active roles in the root development of the plants, and depending on this, in nutrient intake, and therefore, in the development of broccoli (*Tables 3* and *4*).

Plant height and number of the leaves

When the results obtained about the plant height were analyzed, it was determined that organic fertilizers came to the forefront in the first measurement date AA, HFA, HA, respectively. Organic fertilizer applications were followed by chemical fertilizer application (CF) with algae + macro and micro element (ALG) and *Bacillus subtilis*-containing (BAS) biofertilizers (*Table 3*).

Table 3. *In the first measurement date, the effects of various organic and biofertilizers on plant growth parameters of broccoli*

Treatments	Plant height (cm)	Leaf number (number/plant)	Root length (cm)	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)
NT	28.21 b	16.5	20.46 b	45.48 c	600.45	8.65	54.15 c
FM	28.41 b	18.2	29.43 a	64.43 ab	705.12	12.65	70.54 bc
CF	30.17 ab	19.0	23.29 b	45.48 c	795.32	12.45	95.45 b
HA	32.37 ab	24.3	25.18 b	65.68 ab	880.41	15.65	79.23 bc
AA	35.34 a	25.2	30.15 a	69.52 a	884.65	15.45	164.95 a
HFA	35.12 a	24.2	31.11 a	75.41 a	800.64	15.75	72.42 bc
ALG	29.49 ab	22.3	24.48 b	60.65 b	765.41	13.65	110.65 ab
ART	28.61 b	18.5	27.61 a	75.23 a	845.14	17.45	98.45 b
BAS	29.23 ab	19.5	26.49 b	67.43 ab	970.25	18.45	103.35 ab

In the second measurement date, the bio fertilizers that contained microorganism showed positive effects on plant height, and the gap between the applications with

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significant differences in the first measurement were closed. In the second measurement date, the lowest value in terms of plant height, which were close to each other, was measured in the control application (*Table 4*). No clear differences were detected in terms of the number of the leaves between the applications in the first measurement date. The highest number of leaves were determined in the organic fertilizer applications AA, HA, HFA, respectively. This was followed by the biofertilizer that had algae in it ALG (*Table 3*). However, in the second measurement date, AA application surpassed the other applications at a significant level and was followed by microorganism applications ALG, ART, BAS, respectively (*Table 4*).

Table 4. *In the second measurement date, the effects of various organic and biofertilizers on plant growth parameters of broccoli*

Treatments	Plant height (cm)	Leaf number (number/plant)	Root length (cm)	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)
NT	40.45	24.25 c	32.18 b	125.45 d	1380.45 d	15.6 b	125.50 b
FM	45.25	27.25 bc	40.45 a	125.62 d	1560.12 d	24.81 a	185.85 ab
CF	45.45	29.20 bc	36.48 b	135.36 c	1915.58 c	24.70 a	183.27 ab
HA	45.25	31.25 b	33.58 b	135.35 c	1948.52 c	25.35 a	210.65 a
AA	47.65	42.00 a	40.35 a	145.42 b	2245.12 b	25.65 a	330.42 a
HFA	46.40	31.50 b	41.24 a	136.65 c	2485.04 a	26.54 a	230.32 a
ALG	48.45	33.30 b	39.45 ab	141.15 b	2460.15 a	28.41 a	240.52 a
ART	47.85	33.00 b	46.24 a	138.48 b	2345.65 ab	29.71 a	220.05 a
BAS	46.45	32.50 b	39.48 ab	164.18 a	2565.36 a	29.85 a	195.05 a

The plant nutrient element content in the leaves

When the results on the plant nutrient element in the leaves were analyzed it was determined that AA, which was rich in terms of amino acid content and organic N content as an organic fertilizer; ALG, which included algae + micro and macro elements as a biofertilizer; and BAS, which included *Bacillus subtilis* ranked the first (*Figs. 1* and *2*). In terms of macro elements, the highest nitrogen amount in the leaves was found in *Arthrobacter sp.* (ART) application, and the highest calcium amount was found in farm fertilizer (FM) application. AA application ranked the third in terms of Nitrogen amount, and ALG ranked the second in terms of calcium amount (*Fig. 1*). It was determined that broccoli plant made use of organic fertilizers in AA application in the most efficient way, and biofertilizers helped nutrient intake. This affected the head quality and yield in broccoli in a direct manner. It was determined that the control application (NT) was in the lowest level in terms of nutrient element (*Figs. 1* and *2*). Aside from the control application (NT), the lowest nutrient element contents were detected in farm fertilizer application (FM) in terms of N, Mg and Mn contents; the lowest K and Zn contents were determined in F8 application, the lowest Ca and Cu contents were determined in Chemical Fertilizer (CF) application; and the lowest Fe content was detected in HA application, which was rich in terms of humic acid (*Figs. 1* and *2*).

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Humic acid can influence mineral nutrient intake of plants in a positive way. For this, the permeability of the membranes must be increased in the root cells. Humic elements affect the plant growth in an indirect and direct manner. It was reported in previous studies that there is a positive correlation between the humus content and plant yield. Among the direct effects, there are the changes in plant metabolism after the intake of organic macromolecules (like humic acids and fulvic acids). After the compounds enter the cells of the plant, some biochemical changes happen in the membranes and in some cytoplasmic components of plant cells. Humic substances mediate the intake of major plant nutrients. The intake of major plant nutrients improves plant growth as a stimulative effect of humic substances; nitrogen (N) phosphorus (P), and potassium (K). If humic substances exist in the soil in sufficient amounts, the necessity for N, P, and K fertilizer applications decrease. The growth of plant roots is affected by humic substances. When the soil receives humic acid and/or fulvic acid, root initiation and increased root growth occur. In this way, humic and fulvic acids are considered as root simulators. The key role of PGPR may be described as plant hormone secreting activities. In previously conducted studies, it was reported that auxin-producing rhizobacteria affected root development and had a strong growth-promoting activity (Probanza et al., 1996) However, it was also reported that *Bacillus* OSU-142 is important on N2-fixation on sugar beet and barley, (Cakmakci et al., 2001; Sahin et al., 2004) tomatoes and pepper and apricot (Esitken et al., 2003) in field studies.

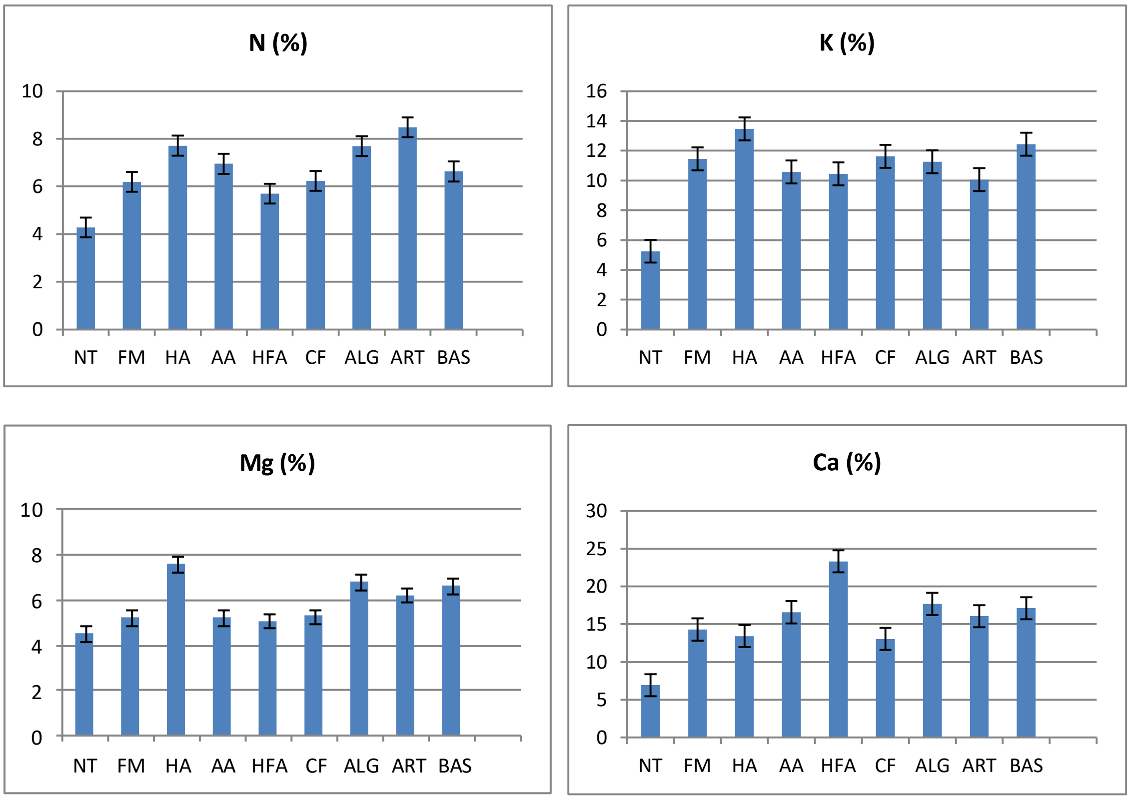

Figure 1. *The effects of different organic and biofertilizers on macro nutrient element contents of broccoli leaves*

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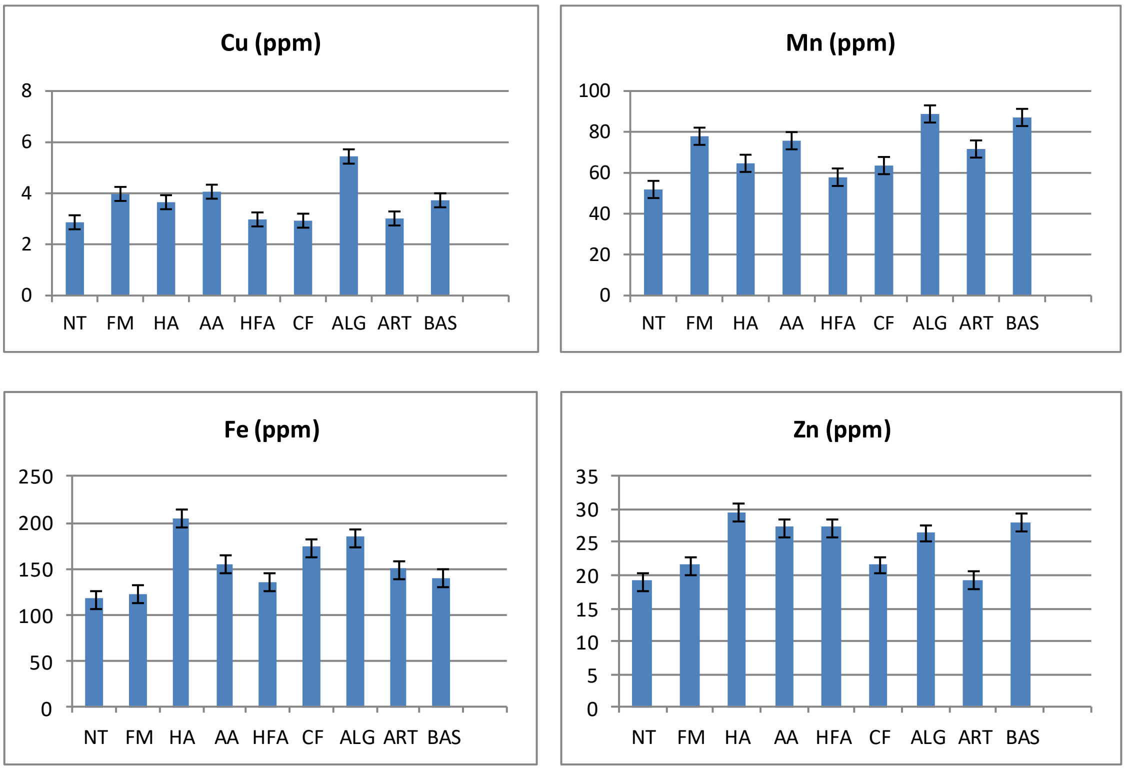

Figure 2. *The effects of different organic and biofertilizers on the micro nutrient element contents of broccoli leaves*

Broccoli head quality

It was determined in diameter and weight measurements of the heads of broccoli that biofertilizer applications gave better results (*Table 5*). The best result in terms of head diameter was determined at a statistically significant level in BAS, which included *Bacillus subtilis*, and the best results in terms of head weight were received at a statistically significant level in ALG application, which included algae + macro and micro elements. *Arthrobacter sp.* (ART), which was another biofertilizer application, followed these. Biofertilizers were more effective than the organic fertilizers in terms of main head diameter and weight. As a result of Vitamin C analyses in the heads of broccoli, it was determined that both the biofertilizers and organic fertilizers were found to be different from the control application at a significant level, and the results were close to each other aside from the control application. In terms of head quality, typical changes were detected in our results in all treatments in broccoli ripening, in other words, the head diameter increased (Elkoca et al., 2008) Although different fertilizers were given, the plants in the study showed higher Ascorbic acid values. BAS treatment was found to have the highest Ascorbic acid content when compared with other treatments (*Table 5*). Lai et al. (2008) indicated that yield (mean floret weight), total phenolic and flavonoid content in broccoli shows significant year on year variation, but is not significantly different in organic compared to conventional production systems.

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Table 5. *The effect of biofertilizer and organic fertilizer applications on diameter, weight and Vitamin C content in the heads of broccoli*

Treatments	Total yield (kg/da) (main head + lateral heads)	Main head diameter (cm)	Main head weight (g)	Ascorbic acid (mg 100 g^{-1})
NT	691.25 c	9.00 d	162.50 g	90.03 b
FM	1254.32 b	12.50 abc	205.00 efg	95.25 a
CF	1155.75 b	10.25 cd	272.50 de	95.41 a
HA	1057.08 b	11.50 bcd	205.00 efg	95.51 a
AA	1340.62 ab	11.50 bcd	233.75 def	95.66 a
HFA	1307.5 ab	11.00 bcd	266.00 de	95.56 a
ALG	1458.33 a	13.00 ab	452.50 a	96.63 a
ART	1348.25 ab	13.00 ab	301.25 cd	96.41 a
BAS	1445.68 a	14.50 a	378.75 b	96.66 a

Total yield

Together with the main and side-heads, in terms of yield values in biofertilizer applications, ALG application, which included algae + macro and micro elements, and BAS, which included *Bacillus subtilis*, were found to be different from all other applications at a statistically significant level. These applications were followed by *Arthrobacter sp.* (ART), and AA and HFA applications which were among organic fertilizer applications. It was determined that the yield in broccoli plants was higher in biofertilizers than in organic fertilizers, chemical fertilizers and control (*Table 5; Figure 3*). The yield and plant growth improvement effects of bacteria, which were used in the present study, may be explained with the N2-fixing and P-solubilizing capacity of bacteria. Positive influences of biofertilizers on yield and growth parameters (like apricot, tomatoes, sugar beet, and barley) are explained with N2-fixation ability, phosphate-solubilizing capacity, indole acetic acid, and antimicrobial substance production (Esitken et al., 2005; Rodrigues et al., 2006; Wilsion, 2006; Malik et al., 2001). In general, the improvements in macro/micronutrient contents were more emphasized in PGPR treatments. However, mineral fertilizer and control also resulted in significant nutrient increases in terms of plant leaf. It is expected that the improvement in mineral intake by plants results in and increased accumulation of minerals in the leaves of plants. Using N2-fixing and P-solubilizing PGPR in chickpea (Pettit, 2004) barley (Rodriguez et al., 2006) tomato (Caballero-Mellado et al., 2007) lettuce (Bar-Ness et al., 1992) stimulated macro- and micronutrient intake like N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu, which show consistency with our results. (Valverde et al., 2013) belong to the results showed that application of biofertlizera combination of Azospirillum + Azotobacter (50% of each) through root dipping method during transplanting is beneficial for yield enhancement as well as for the improvement of functional biomolecules present in broccoli. According to (Singh et al., 2014; Choudhary and Paliwal, 2017) study revealed that the integration of bio-organics and mineral nutrients had shown a marked effect in enhancing yield as well as productivity of broccoli with maximum net returns. On the basis of results, it could be concluded that

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the application of vermicompost @ 2.5 t ha^{-1} + FYM @ 5 t ha^{-1} + Azosprillium + PSB along with S @ 40 kg ha^{-1} + Zn @ 5 kg ha^{-1} + Boron @ 1.5 kg ha^{-1} were best for higher yield with maximum profit and had recommended for commercial production of broccoli.

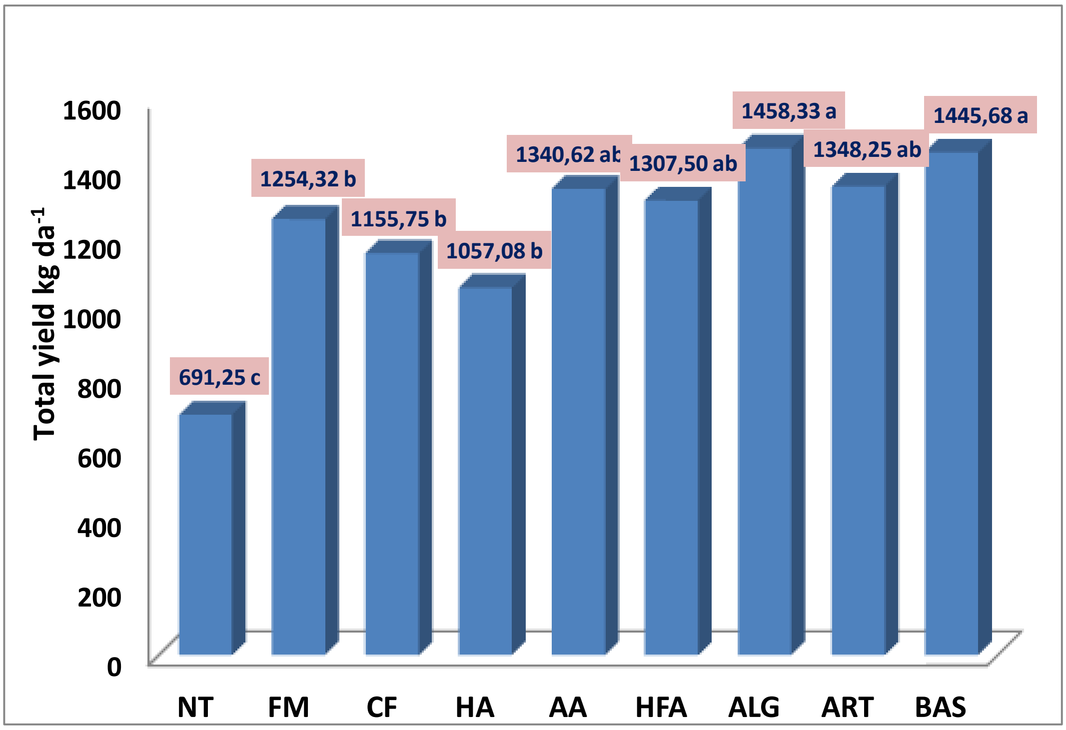

Figure 3. *Effects of different organic and biofertilizers on the total yield of broccoli*

Conclusion

As a conclusion, biofertilizers gave better results in broccoli cultivation than organic fertilizers, farm fertilizers and chemical fertilizers under plastic tunnels. If the biological activity is high in the soil, the nutrient intake, plant growth, yield and head quality are also high. An increase at a rate of 50% was determined in the yield with biofertilizers when compared with the control (ALG 53%, BAS 52%, ART 49%), and 20% increase was determined when compared with chemical fertilizer (ALG 21%, BAS 20%, ART 14%).

An increase at a rate of 47-48% (AA, HFA) was determined in the yield with organic fertilizers when compared with the control application; and at a rate of 14-12% when compared with chemical fertilizers (AA, HFA).

In organic agriculture; plant nutrition and plant protection are two important issues. In this research, plant nutrition sources of broccoli cultivation, which is a vegetable with both health and commercial preservation, are emphasized. While farmland is a traditional organic resource, it has always been sought to find the desired amount and the efficiency and quality of other resources due to transportation difficulty. In future studies, the impact of new organic resources can be examined.

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