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***Research***
***(Araştırma)***

# Effects of plant growth-promoting rhizobacteria (PGPR) and different fertilizer combinations on yield and quality properties in cauliflower (*Brassica oleracea* L. var. *botrytis*)*

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*This paper is dedicated to the memory of my dear PhD student Cüneyt CIVELEK, who passed away before this paper was submitted to the journal. Our thoughts and condolences are extended to Cüneyt's family, friends and many colleagues.

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## Abstract

**Purpose:** This study was carried out to determine the influence of plant growth promoting rhizobacteria (PGPR) (*Paenibacillus polymyxa* RC14, *Bacillus subtilis* RC63 and *Pseudomonas fluorescens* RC77), organic chicken manure (OCM) (4000 kg/da), 3 levels of mineral fertilizer [(NPK1 (80 kg/ha N+50 kg/ha P+80 kg/ha K), NPK2 (160 kg/ha N+75 kg/ha P+160 kg/ha K) and NPK3 (200 kg/ha N+100 kg/ha P+200 kg/ha K)] and combination of these applications on growth, yield and quality of cauliflower under field conditions.

**Materials and Methods:** Field experiments were conducted in randomized complete block design with four replications. Treatments were 1. Control (No Fertilizer Application; 0 kg /ha NPK), 2. NPK1 (80-50-80 kg / ha NPK), 3. NPK2 (160-75-160 kg /ha NPK), 4. NPK3 (200-100-200 kg /ha NPK), 5. PGPR, 6. Organic Chicken Manure (OCM), 7. PGPR + OCM, 8. NPK1+PGPR, 9. NPK2+PGPR, 10. NPK3+PGPR, 11. NPK1+ OCM, 12. NPK2+ OCM, 13. NPK3+ OCM, 14. NPK1+PGPR+ OCM, 15. NPK2+PGPR+ OCM, 16. NPK3+PGPR+ OCM

**Results:** The highest curd weight and marketable yield were observed in NPK2+ OCM in 2014 while in NPK1+PGPR+OCM and NPK2+PGPR+OCM in 2015. NPK2+ OCM elevated the curd weight and marketable yield by 300% compared to the control in 2014. NPK1+PGPR+OCM increased the curd weight and marketable yield by 200% compared to the control in 2015. The highest TSS was observed in the control in 2014 whereas NPK1+PGPR+OCM gave the highest value. NPK treatments elevated the NO3 content of cauliflower curds. In 2014 the highest ascorbic acid content was determined in PGPR while the control gave the highest content in 2015. The highest oxalic acid contents were observed in NPK treatments. Furthermore, PGPR and OCM treatments generally reduced the oxalic acid contents of the cauliflower.

**Conclusion:** NPK with OCM and PGPR applications could be advisable for the yield and quality parameters of cauliflower. Furthermore, the PGPRxOCM combination was advisable for efficiently using in organic agricultural production.

**Keywords:** Cauliflower, PGPR, Plant Growth, Yield, Quality

## Bitki gelişimini destekleyici rhizobacteria (PGPR) ve farklı gübre kombinasyonlarının karnabaharda (B*rassica oleracea* l. var. *botrytis*) verim ve kalite özelliklerine etkisi

## Öz

**Amaç:** Karnabahar (*Brassica oleracea* var. *botrytis* L.), yüksek verim için önemli miktarlarda azot (N) gübresine ihtiyaç gösterir. Bu çalışma, tarla koşullarında bitki gelişimini teşvik eden rizobakterilerin (PGPR) (*Paenibacillus polymyxa*

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RC14, *Bacillus subtilis* RC63 ve *Pseudomonas fluorescens* RC77), organik tavuk gübresi (OCM) (4000 kg/da), 3 seviye mineral gübre [(NPK1 (80 kg/ha N+50 kg/ha P+80 kg/ha K), NPK2 (160 kg/ha N+75 kg/ha P+160 kg/ha K) ve NPK3 (200 kg /ha N+100 kg/ha P+200 kg/ha K)] ve bunların farklı karışımlarının karnabaharda büyüme, verim ve kalitesi üzerine etkisini belirlemek amacıyla yürütülmüştür.

**Materyal ve Yöntem:** Arazi denemeleri tesadüf blokları deneme desenine göre dört tekerrürlü olarak yürütülmüştür. Uygulamalar; 1. Kontrol (Gübresiz; 0 kg/ha NPK), 2. NPK1 (80-50-80 kg/ha NPK), 3. NPK2 (160-75-160 kg/ha NPK), 4. NPK3 (200-100-200 kg /ha NPK), 5. PGPR, 6. Organik Tavuk Gübresi (OCM), 7. PGPR + OCM, 8. NPK1+PGPR, 9. NPK2+PGPR, 10. NPK3+PGPR, 11 NPK1+ OCM, 12. NPK2+ OCM, 13. NPK3+ OCM, 14. NPK1+PGPR+ OCM, 15. NPK2+PGPR+ OCM, 16. NPK3+PGPR+ OCM.

**Araştırma Bulguları:** En yüksek baş ağırlığı ve pazarlanabilir verim 2014 yılında NPK2+ OCM'de, 2015 yılında ise NPK1+PGPR+OCM ve NPK2+PGPR+OCM'de gözlendi. NPK2+ OCM, 2014 yılında kontrole göre baş ağırlığını ve pazarlanabilir verimi %300 artırdı. NPK1 +PGPR+OCM, baş ağırlığını ve pazarlanabilir verimi 2015 yılında kontrole göre %200 artırmıştır. En yüksek TSS 2014 yılında kontrolde görülürken, NPK1+PGPR+OCM en yüksek değeri vermiştir. NPK uygulamaları karnabahar başlarında NO3 içeriğini yükseltmiştir. En yüksek askorbik asit içeriği 2014 yılında PGPR'de belirlenirken, kontrol en yüksek içeriği 2015 yılında vermiştir. En yüksek oksalik asit içeriği NPK uygulamalarında gözlenmiştir. Ayrıca, PGPR ve OCM uygulamaları genellikle karnabaharın oksalik asit içeriğini azaltmıştır.

**Sonuç:** Karnabahar verim ve kalite parametreleri için OCM ve PGPR uygulamaları ile NPK önerilebilir. Ayrıca PGPRxOCM kombinasyonunun organik tarımsal üretimde kullanılması önerilmiştir.

**Anahtar Kelimeler:** Karnabahar, PGPR, bitki büyümesi, verim, kalite

## Introduction

Adequate, regular and balanced inputs such as irrigation, fertilization are essential for vegetable production and quality. Chemical and organic fertilizer applications are one of the most effective means of increasing yield and quality of vegetable crops. With the rapid population growth, the pollution of the environment makes living conditions difficult. It is getting impossible to find clean water, air and soil for living things and people. In monoculture and commercial agriculture, environmental problems arise with the use of high chemical and external inputs. The use of chemical fertilizers and pesticides in crop production and the control of pests ultimately lead to the deterioration of soil health, and environmental pollution (Zhang et al., 2018).

Sustainability in agriculture cannot be achieved by the over-use of agricultural chemicals in the amount that ecosystems cannot handle. Today, there are many toxic and hazardous chemical residues in agricultural ecosystems (Kılıç and Korkmaz, 2012). There is a growing concern that food supply in sufficient quantity and quality in the world cannot be achieved by exploiting and polluting agriculture. The rapid increase in agricultural production due to the use of chemicals is now decreasing. Exploiting and inappropriate agricultural methods have the characteristics of reducing soil fertility, loss of nutrients and soil organic matter in agricultural areas (Lal, 2015).

The unconscious and excessive usage of synthetic agricultural chemicals used in intensive farming reduces soil, water and food quality and has harmful effects on human and environmental safety. The results of a survey conducted in Europe showed the negative effects of excess nitrogen accumulation in nature, including climate change and the destruction of biodiversity, are reported to be € 70 - 320 billion (Euro) per year (Sutton et al., 2011). Among the main causes of this pollution are the chemicals used in agricultural production.

Cauliflower (*Brassica oleracea* L. var. botrytis) is an important cool-season vegetable crop and belongs to Brassicaceae family. Cauliflower is one of the vegetables consumed widely in the world and Turkey. It is known that species belonging to Brassicaceae family are especially effective in preventing digestive tract cancers and are used in alternative medicine. Cauliflower contains a sulphurous substance called sulphoraphan and this substance has an anticarcinogenic effect. In addition, cauliflower acts as a disinfectant and has an antibiotic effect thanks to the sulfur it contains. For these reasons, the consumption of cauliflower is very important for human health (Şalk et al., 2008).

Cauliflower requires large amounts of nitrogen (N) fertilizer to produce high yields. Nitrogen (N) significantly affects the crop productivity as well as quality attributes. The optimum supply of N enhances plant growth and crop productivity (Blumenthal et al., 2008). However, the excessive and overuse of N fertilization may increase the accumulation of compounds such as nitrates and non-protein nitrogen in the edible parts, which may be harmful to human health. Pervious investigations have showed that curd yield and quality of cauliflower are greatly influenced by N application. To obtain high yield and curd quality, this crop consistently requires a generous supply of nitrogen (N) to achieve a soil availability of 250–300 kg N $ha^{-1}$ (Everaarts, 1993; Everaarts et al., 1996). Cauliflower has higher demand micronutrients than others and should be applied at optimum rates.

PGPR's are used as biological fertilizers because of the advantages such as increasing the fertilizer usage efficiency of the plants, ensuring that the nutrients can be taken more easily by the plants, increasing the nitrogen binding to the soil and positively affect the plant development (Turan et al., 2014). On the other hand, these bacteria are used to support the defense mechanisms of plants in the fight against plant diseases (Zhuang et al., 2007).

Organic-based agricultural wastes and natural-origin organic materials, which are used to partially meet the nutrient needs of plants in agricultural production and formed as a result of various agricultural activities, are important soil conditioners. The high organic matter content of the organic fertilizers used for this purpose is important in terms of soil sustainability. Enrichment of soil organic matter content indirectly increases soil fertility. With organic fertilizer applications, the aeration and water holding capacity of the soils and physical properties such as warming and permeability are improved. In addition, organic fertilizer applications affect the chemical properties of the soil positively by ensuring that the nutrients are absorbed in the soil and become useful. Organic fertilizers applied to the soil have a positive effect not only on the physicochemical properties of the soil, but also on the microorganism activities that affect their biological properties.

Because of the importance of biological fertilizer for sustainable agriculture and the cost and environmental damages of chemical fertilization, adaptation of environmentally acceptable biological alternatives to fertilizer nitrogen has been raised and research has gained momentum. People have started to use production systems such as organic plant production and good agricultural practices for health reasons, with the increasing demand for such products in recent years. In the production system called organic, ecological or biological agriculture, no synthetic chemicals are used in any of the agricultural production stages. Instead, green fertilizers, organic fertilizers, pesticides and biological agents are used. In the case of good agricultural practices, chemicals other than harmful chemicals are used in specified sizes and have no residues (Assefa and Tadesa, 2019).

The correct use of organic fertilizers and inorganic nitrogen fertilizers is important not only to achieve high yields and quality, but also to maintain soil health and sustainability for a longer period (Rani and Mallareddy, 2007). Little information is available on the integrated use of organic and inorganic N fertilization on cauliflower curd yield and quality (TTS, oxalic acid as well as ascorbic acid and nitrate content). Thus, we have focused on the impact of PGPR and different fertilizer combinations on yield and quality properties in cauliflower.

## Materials and Methods

Cauliflower (*Brassica oleracea* var. Botrytis cv. Tetris F1) was used as plant material. The field experiments were conducted in Bozok University, Yozgat, Turkey (39.85° N latitude and 34.46° E longitude) during 2014 and 2015. The study area (Yozgat) is located on the Plateau of Bozok in the Central Anatolia Region in Turkey (1300 m above sea levels). The total rainfall was 97.8 mm for 2014 and 85.2 m for 2015 for the growing period. The average temperature ranged between 11.6 and 21.5 °C in the growing season of 2014, and between 12.6 and 22.0 °C in 2015.

The field experiments were initiated in late May 2014 and repeated in 2015. The experiment area in both years was not cultivated before. Before planting, samples consisting of approximately twenty cores were taken across the diagonal of the soil layers 0–20 and 20–40 cm of the experimental field. The chemical properties of soil in 2014 and 2015 are shown in Table 1.

Seeds were sown into 216 celled plastic trays filled with peat + perlite mixture 1/1 (v / v) at the end of May in each two years (2014-2015). Thirty day-

Table 1. Some chemical characteristics of experimental area soil

| Depth | pH 2:1 (S:W) | Organic matter | $CaCO_3$ | Salinity | N | $P_2O_5$ | $K_2O$ | Fe | Zn | Mn | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ---------------------%------------------ | | | | -----kg/da---- | | ----------------ppm-------------- | | | | |
| **2014** | | | | | | | | | | | | |
| **0-20** | 7.67 | 1.47 | 4.04 | 0.03 | 0.07 | 5.83 | 79.48 | 1.67 | 0.24 | 4.42 | 7.82 | 221 |
| **20-40** | 7.70 | 1.29 | 5.25 | 0.03 | 0.06 | 1.95 | 62.13 | 1.20 | 0.13 | 3.56 | 8.16 | 221 |
| **2015** | | | | | | | | | | | | |
| **0-20** | 7.48 | 1.69 | 3.74 | 0.04 | 0.08 | 5.48 | 78.44 | 2.04 | 0.19 | 4.45 | 7.43 | 175 |
| **20-40** | 7.16 | 1.16 | 3.48 | 0.03 | 0.07 | 1.79 | 59.87 | 1.46 | 0.09 | 3.48 | 6.59 | 156 |

seedlings were planted to the experiment plots in distance as 0.70 m and intra row spacing of 0.60 m. mid-July. The plots were tilled twice with a tractor at the end of April and made suitable for planting and divided subsequently into sub plots according to the treatments plan with a net plot size of 3.5 × 3.0 m. Necessary cultural processes were made during the study period. Weeds were removed by manual. Irrigation in all the plots in the experiment was done by the drip irrigation method to maintain field capacity. The same plots were used for same treatments for each year.

The experimental design was randomized complete block design with four replications. Treatments were 1. Control (No Fertilizer Application), 2. NPK1 (80-50-80 kg / ha NPK), 3. NPK2 (160-75-160 kg /ha NPK), 4. NPK3 (200-100-200 kg /ha NPK), 5. PGPR, 6. Organic Chicken Manure (OCM), 7. PGPR + OCM, 8. NPK1+PGPR, 9. NPK2+PGPR, 10. NPK3+PGPR, 11. NPK1+ OCM, 12. NPK2+ OCM, 13. NPK3+ OCM, 14. NPK1+PGPR+ OCM, 15. NPK2+PGPR+ OCM, 16. NPK3+PGPR+ OCM

Half of the nitrogen fertilizer (urea), and all of the potassium (dipotassium oxide) and phosphorus fertilizer (triple super phosphate) were applied to the plots just before the seedling planting. Organic chicken manure (OCM) was applied to the soil before planting with an account of 4000 kg per hectare. In this study, as PGPR treatment, the combination of three different bacterial strains (*Pseudomonas putida* RC14, *Bacillus subtilis* RC63 and *Pseudomonas fluorescens* RC77), which are isolated from the rhizosphere of different plants and have nitrogen fixation and phosphate solubilization properties, were used. Seedlings roots were dipped into the bacterial suspensions (at the concentration of $10^8$ cfu $mL^{-1}$ in sterile water) for 60 min prior to transplanting (Turan et al., 2014).

In order to determine the yield and quality in plants; plant weight, curd (head) weight, curd diameter, curd height, leaf number, leaf weight, marketable yield, chlorophyll reading value (CRV) and leaf area were determined.

Marketable cauliflower curds were harvested in late October 2014 and 2015. Inner rows were used for sampling and harvest. Plants were harvested at the ground level and weighed. Plants were then cut below the curd. Curd diameter was measured across the widest part of head. Leaf number and weight, curd height, curd weight, and marketable yield were also determined.

A portable chlorophyll meter (SPAD-502, Konica Minolta Sensing, Inc., Japan) was used to measure leaf greenness.

The leaf areas formed in randomly selected plants from each plot during the harvest period were measured with the ADC AM300 leaf area measuring device (ADC BioScientific, Hoddesdon, Herts EN11 0NT, UK) and the average leaf area per plant was determined.

TSS was measured with the Hanna HI 96801 digital refractometer. The nitrate content of curds was determined by Liquid Chromatography according to Chou et al. (2003). Oxalic acid was determined by HPLC according to Gancedo and Luh (1986). Ascorbic acid (Vitamin C) was determined with a Merck reflectometer set (Merck RQflex).

Data were subjected to analysis of variance (ANOVA) using SPSS 18 (PASW Statistics 18) (SPSS Inc 2010) statistical program. The differences between years were significant, thus means were shown for each year.

The differences among the means were compared using the least significant difference test (LSD, $P < 0.05$).

## Results

The application of different fertilizers significantly affected the growth properties of cauliflower (Table 2 and Table 3). Growth characteristics, i.e., plant weight, leaf weight, leaf number, leaf area and chlorophyll reading value (CRV) showed a significantly higher response to NPK applications compared to those of the control. Maximum values were generally observed when NPK treatments were applied with or without OCM and PGPR. The greatest CRV (73.29) was observed in NPK3+ OCM in 2014 while there were no significant differences between applications. NPK2+PGPR+OCM gave the greatest CRV (66.08) in 2015. The greatest leaf number and leaf area per plant were obtained from NPK3+OCM in both years.

Effects of different fertilizer treatments significantly affected curd weight, marketable yield, curd diameter and curd height of cauliflower. The highest curd weight (1.367 kg) and marketable yield (45.58 kg/t) were observed in NPK2+ OCM in 2014 while in NPK1+PGPR+OCM (1.824 kg-60.78 kg/t) and NPK2+PGPR+OCM (1.749 kg-58.30 kg/t) in 2015. NPK2+ OCM elevated the curd weight and marketable yield by 300% compared to the control in 2014. NPK1+PGPR+OCM increased the curdweight and marketable yield by 200% compared to the control in 2015. Fertilizer applications also increased generally curd diameter and curd height in both years (Table 3).

Table 4 shows effects of different fertilizer treatments on TSS, $NO_3$, ascorbic acid and oxalic acid of cauliflower. Different fertilizer treatments significantly affected these parameters. The highest TSS (8.83 %) was observed in the control in 2014 whereas NPK1+PGPR+OCM (10.70 %) gave the highest value in 2015. NPK treatments elevated the $NO_3$ content of cauliflower curds. The lowest $NO_3$ contents were obtained from the control (20 ppm) and PGPR (20 ppm) treatments. In 2014 the highest ascorbic acid content (104.35 ppm) was determined in PGPR while the control (60.63 ppm) gave the highest content in 2015. The highest oxalic acid contents were observed in NPK treatments. Furthermore, PGPR and OCM treatments generally reduced the oxalic acid contents of the cauliflower.

## Discussion

In the study, the effects of different levels of synthetic fertilizer (NPK1-NPK2- NPK3), PGPR, organic fertilizer, and their combinations on growth, yield and quality of cauliflower were investigated (Table 2, 3, 4). Treatments of varying levels of NPK applied alone or in combination with OCM and PGPR significantly affected the morphological characteristics of cauliflower.

The highest yield in the first year was detected in NPK2xOCM, NPK3xOCM and NPK applications, respectively, while in the second year, NPK1xPGPRxOCM, NPK2xPGPRxOCM and NPK2xOCM applications, respectively. As can be seen, in the study OCM and PGPR treatments with NPK generally positively affected the growth characteristics of the cauliflower in both years. PGPR seems to be more effective in the second year of the trial. This may be due to the higher PGPR population in the soil in the second year. Oztekin et al., (2020) reported that organic fertilizers improved the quality and growth parameters of the cauliflower varieties. Similarly, it has been reported that the combined use of nitrogen and PGPR increased plant growth and yield of cauliflower (Bashyal, 2011). Kaniszewski and Rumpel (1998) reported that the nitrogen in the form of nitrate increased the curd weight up to 600 kg/ha, and that the curd weights decreased again with nitrogen applications at higher amounts than this level. Kaushal et al. (2011) applied three different bacterial isolates at three different NP levels (50%, 75% and 100% of the recommended dose) in their study on cauliflower and reported that the curd weight increased as the fertilizer level increased. Gunes et al. (2014) in lettuce and Inal et al. (2015) in bean and maize determined the application of chicken manure enhanced growth and yield. Increasing plant growth with the application of organic fertilizer usually results in the availability of plant nutrients (Glaser et al., 2002, Lehman et al., 2003, Gaskin et al., 2010), improvement of soil microbiology (Biederman and Harpole, 2013, Thies and Rillig, 2009) and reduction of some toxic elements (Glaser et al., 2002, Steiner et al., 2007).

Increasing the production and quality of vegetables is possible with adequate, regular and balanced use of inputs such as fertilization, irrigation, agricultural struggle and quality seeds. As the intensive use of these inputs will increase the unit cost, it decreases the profitability level of the grower. Excessive and unconscious use of chemical fertilizers brings with it some important negative effects as well as economic losses. Chemical fertilizers not only disrupt the physical, chemical and biological properties of the soil, but also affect the parameters such as the quality of the plant, its storage durability, resistance

Table 2. Effects of different fertilizer treatments on plant weight, leaf weight, leaf number, leaf area and Chlorophyll Reading Value (CRV) of cauliflower

| Treatments | Plant weight (kg/plant) | Leaf weight (kg/plant) | Leaf number | Leaf Area ($m^2$/plant) | CRV (SPAD) |
|---|---|---|---|---|---|
| | **2014** | | | | |
| **Control** | 1.275 e | 0.591 d | 30 ad | 1.26 ce | 70.54 ab |
| **PGPR** | 1.793 ce | 0.912 bd | 35 ac | 1.23 de | 73.36 ab |
| **OCM** | 1.718 de | 0.712 cd | 29 bd | 1.49 be | 70.34 ab |
| **PGPR+ OCM** | 2.813 ab | 1.445 ab | 37 ab | 1.29 ce | 72.40 ab |
| **NPK1** | 2.983 ab | 1.571 a | 26 d | 1.71 bd | 72.18 ab |
| **NPK2** | 3.055 ab | 1.562 a | 34 ac | 1.75 bc | 74.38 ab |
| **NPK3** | 2.983 ab | 1.484 a | 33 ad | 1.11 e | 71.20 ab |
| **NPK1+PGPR** | 2.170 be | 1.127 ac | 32 ad | 1.52 be | 70.69 ab |
| **NPK2+PGPR** | 2.193 be | 1.116 ad | 31 ad | 1.45 be | 71.27 ab |
| **NPK3+PGPR** | 1.818 ce | 0.947 bd | 30 ad | 1.38 ce | 72.41 ab |
| **NPK1+ OCM** | 2.203 de | 1.147 ac | 33 ad | 1.19 e | 71.07 ab |
| **NPK2+ OCM** | 3.158 a | 1.541 a | 32 ad | 1.89 b | 73.29 ab |
| **NPK3+ OCM** | 2.683 ac | 1.293 ab | 38 a | 2.33 a | 76.07 a |
| **NPK1+PGPR+OCM** | 2.275 ad | 1.043 ad | 34 ad | 1.30 ce | 71.18 ab |
| **NPK2+PGPR+OCM** | 2.400 ad | 1.183 ac | 33 ad | 1.43 be | 73.03 ab |
| **NPK3+PGPR+OCM** | 1.525 de | 0.695 cd | 28 cd | 1.35 ce | 69.94 b |
| | **2015** | | | | |
| **Control** | 2.908 bc | 1.945 ab | 21 c | 1.21 ef | 60.71 c |
| **PGPR** | 3.510 ab | 1.915 ab | 21 c | 1.02 f | 63.14 ac |
| **OCM** | 2.520 c | 1.458 bc | 22 bc | 1.21 ef | 62.12 bc |
| **PGPR+ OCM** | 2.820 bc | 1.735 ac | 22 bc | 1.28 e | 62.22 bc |
| **NPK1** | 2.915 bc | 1.928 ab | 23 bc | 1.73 bc | 65.17 ab |
| **NPK2** | 3.480 ab | 1.688 ac | 21 c | 1.35 de | 64.07 ab |
| **NPK3** | 4.078 a | 2.198 a | 23 bc | 1.88 b | 65.11 ab |
| **NPK1+PGPR** | 3.173 ac | 1.388 bc | 21 c | 1.35 de | 63.06 ac |
| **NPK2+PGPR** | 2.865 bc | 1.425 bc | 21 c | 1.39 de | 64.36 ab |
| **NPK3+PGPR** | 3.500 ab | 1.618 bc | 23 bc | 1.85 b | 64.02 ab |
| **NPK1+ OCM** | 3.168 ac | 1.450 bc | 22 bc | 1.54 cd | 62.13 bc |
| **NPK2+ OCM** | 3.333 ac | 1.545 bc | 21 c | 1.01 f | 63.86 ab |
| **NPK3+ OCM** | 2.668 bc | 1.280 c | 27 a | 2.50 a | 64.04 ab |
| **NPK1+PGPR+OCM** | 3.928 a | 1.893 ab | 26 ab | 1.55 cd | 64.63 ab |
| **NPK2+PGPR+OCM** | 3.950 a | 1.793 ac | 23 bc | 1.93 b | 66.08 a |
| **NPK3+PGPR+OCM** | 3.568 ab | 1.675 ac | 23 bc | 1.35 de | 64.46 ab |

Z numbers with the same letters are not statistically different according to the Duncan's Multiple Range Test ($P < 0.05$)

Table 3. Effects of different fertilizer treatments on curd weight, marketable yield, curd diameter and curd height of cauliflower

| Treatments | Curd weight (kg) | Marketable yield (t/ha) | Curd diameter (cm) | Curd height (cm) |
|---|---|---|---|---|
| | **2014** | | | |
| **Control** | 0.462 g | 15.40 g | 14.10 bc | 9.60 cd |
| **PGPR** | 0.617 eg | 20.55 eg | 14.30 bc | 9.03 d |
| **OCM** | 0.637 dg | 21.23 dg | 14.33 bc | 8.93 d |
| **PGPR+ OCM** | 1.033 ae | 34.40 ae | 14.93 bc | 10.90 cd |
| **NPK1** | 1.047 ad | 34.88 ad | 15.80 ac | 11.13 cd |
| **NPK2** | 1.100 ac | 36.65 ac | 18.80 a | 15.75 a |
| **NPK3** | 1.042 ad | 34.73 ad | 16.65 ac | 14.65 ab |
| **NPK1+PGPR** | 0.861 bg | 28.70 bg | 15.50 ac | 10.70 cd |
| **NPK2+PGPR** | 0.892 bf | 29.73 bf | 15.90 ac | 9.95 cd |
| **NPK3+PGPR** | 0.712 cg | 23.73 cg | 14.98 bc | 9.98 cd |
| **NPK1+ OCM** | 0.860 bg | 28.68 bg | 13.33 c | 9.55 cd |
| **NPK2+ OCM** | 1.367 a | 45.58 a | 17.53 ab | 12.05 bc |
| **NPK3+ OCM** | 1.177 ab | 39.23 ab | 18.65 a | 12.43 bc |
| **NPK1+PGPR+OCM** | 0.876 bg | 29.20 bg | 17.00 ab | 10.43 cd |
| **NPK2+PGPR+OCM** | 0.957 af | 31.90 af | 14.95 bc | 12.25 bc |
| **NPK3+PGPR+OCM** | 0.567 fg | 18.90 fg | 13.20 c | 9.03 d |
| | **2015** | | | |
| **Control** | 0.834 c | 27.80 c | 13.70 cd | 10.10 d |
| **PGPR** | 1.334 ac | 44.45 ac | 15.55 ad | 12.73 ab |
| **OCM** | 1.159 bc | 38.63 bc | 14.25 bd | 11.55 bd |
| **PGPR+ OCM** | 1.106 bc | 36.90 bc | 13.35 d | 10.68 cd |
| **NPK1** | 1.325 ac | 44.15 ac | 14.00 bd | 10.53 cd |
| **NPK2** | 1.340 ac | 44.65 ac | 16.38 ad | 12.00 ac |
| **NPK3** | 1.442 ab | 48.08 ab | 17.63 ab | 13.63 a |
| **NPK1+PGPR** | 1.475 ab | 49.20 ab | 17.75 ab | 13.25 ab |
| **NPK2+PGPR** | 1.161 bc | 38.73 bc | 15.13 ad | 11.50 bd |
| **NPK3+PGPR** | 1.458 ab | 48.60 ab | 17.25 ac | 12.63 ab |
| **NPK1+ OCM** | 1.361 ac | 45.40 ac | 16.50 ad | 12.25 ac |
| **NPK2+ OCM** | 1.499 ab | 49.95 ab | 18.75 a | 13.75 a |
| **NPK3+ OCM** | 1.103 bc | 36.75 bc | 15.10 ad | 11.58 bd |
| **NPK1+PGPR+OCM** | 1.824 a | 60.78 a | 16.95 ad | 12.25 ac |
| **NPK2+PGPR+OCM** | 1.749 a | 58.30 a | 18.45 a | 13.28 ab |
| **NPK3+PGPR+OCM** | 1.443 ab | 48.08 ab | 16.93 ad | 12.65 ab |

Z numbers with the same letters are not statistically different according to the Duncan's Multiple Range Test ($P < 0.05$)

Table 4. Effects of different fertilizer treatments on TSS, NO3, ascorbic acid and oxalic acid of cauliflower

| Treatments | TSS (%) | $NO_3$ (ppm) | Ascorbic acid (ppm) | Oxalic Acid (ppm) |
|---|---|---|---|---|
| | **2014** | | | |
| **Control** | 8.83 a | 20 gh | 102.20 b | 27.77 j |
| **PGPR** | 7.85 ac | 20 gh | 104.35 a | 23.21 l |
| **OCM** | 8.28ab | 60 d | 102.88 ab | 26.83 k |
| **PGPR+ OCM** | 8.28 ab | 40 eg | 62.03 j | 27.79 j |
| **NPK1** | 7.65 ac | 53 df | 77.31 h | 35.45 d |
| **NPK2** | 6.25 d | 120 b | 94.20 e | 42.68 b |
| **NPK3** | 6.48 cd | 155 a | 97.96 cd | 45.02 a |
| **NPK1+PGPR** | 7.43 bd | 33 fh | 72.19 i | 32.41 f |
| **NPK2+PGPR** | 7.18 bd | 38 fh | 101.42 b | 32.39 f |
| **NPK3+PGPR** | 7.55 ad | 58 de | 81.03 g | 28.35 i |
| **NPK1+ OCM** | 7.58 ad | 37 fh | 97.42 d | 36.05 c |
| **NPK2+ OCM** | 7.45 ad | 52 df | 95.13 e | 31.57 g |
| **NPK3+ OCM** | 6.63 cd | 58 df | 99.35 c | 30.92 h |
| **NPK1+PGPR+OCM** | 8.23 ab | 25 gh | 87.89 f | 34.23 e |
| **NPK2+PGPR+OCM** | 7.10 bd | 30 gh | 86.76 f | 31.14 gh |
| **NPK3+PGPR+OCM** | 8.13 ab | 85 c | 98.20 cd | 31.48 g |
| | **2015** | | | |
| **Control** | 8.90 bc | 24 i | 60.63 a | 26.72 de |
| **PGPR** | 7.70 c | 35 h | 47.98 c | 23.30 fh |
| **OCM** | 7.83 c | 61 cd | 46.60 d | 21.86 gh |
| **PGPR+ OCM** | 8.00 c | 65 c | 24.60 n | 22.23 gh |
| **NPK1** | 7.80 c | 58 ce | 23.86 o | 30.74 c |
| **NPK2** | 7.80 c | 95 b | 28.90 l | 50.52 b |
| **NPK3** | 8.15 bc | 114 a | 31.00 k | 59.61 a |
| **NPK1+PGPR** | 8.55 bc | 57 cf | 35.70 i | 27.00 d |
| **NPK2+PGPR** | 8.83 bc | 61 cd | 41.41 g | 18.86 i |
| **NPK3+PGPR** | 8.50 bc | 90 b | 28.12 m | 21.64 h |
| **NPK1+ OCM** | 7.73 c | 43 gh | 46.04 d | 24.43 f |
| **NPK2+ OCM** | 9.88 ab | 48 eg | 44.51 f | 23.34 fh |
| **NPK3+ OCM** | 8.90 bc | 47 fg | 45.28 e | 24.13 f |
| **NPK1+PGPR+OCM** | 10.70 a | 48 eg | 53.64 b | 25.13 ef |
| **NPK2+PGPR+OCM** | 8.98 bc | 54 df | 34.81 j | 23.59 fg |
| **NPK3+PGPR+OCM** | 8.63 bc | 90 b | 39.91 h | 24.67 f |

Z numbers with the same letters are not statistically different according to the Duncan's Multiple Range Test ($P < 0.05$)

to diseases, nitrate content that affects human health. Chemical fertilizer production is dependent on the use of non-renewable resources and is a high-energy, unsustainable process (Jensen and Nielsen, 2003). Ulukapi and Sener (2018) investigated the effect of different organic fertilizers on plant growth and yield parameters of cauliflower grown in field and greenhouse conditions. They reported that organic fertilizers could compete with synthetic chemical fertilizers, and that organic fertilizer applications yield close to or higher than synthetic chemicals. Especially on soils with low organic matter content, organic fertilizers can be more effective by regulating the physical, chemical and biological properties of the soil. Previous studies have shown that PGPR increases the efficiency of fertilizer use in some plants and the amount of fertilizer used can be reduced (Yildirim et al., 2016). It has also been suggested in studies that nitrogen-fixing bacteria increase nitrogen uptake by the plant and that the increase in nitrogen content in the plant is due to the increase in nitrogen use efficiency, and that these bacteria can be used in integrated nutrient management systems (Adesemoye et al., 2008).

The combination of inorganic N with chicken manure enhanced curd quality of cauliflower cultivar (Abdel-Razzak et al., 2008). Nitrogen fertilizers have been considered to influence NO3 content in vegetables. NPK treatments elevated the $NO_3$ content of cauliflower curds (Table 4). Nitrates are naturally occurring compounds of nitrogen and the formation of nitrates is an integral part of the nitrogen cycle in the environment (Kmecl et al., 2017). $NO_3$ content without fertilization or with natural fertilizers was lower than with fertilization. Studies have been shown that $NO_3$ content of plants edible parts were influenced by fertilization amount and type (Liu et al., 2014). Nerdy et al., (2018) reported that $NO_3$ content of cauliflower elevated with increasing nitrogen ratio that incorporated into the soil.

NPK treatments generally reduced the ascorbic acid content of cauliflower (Table 4). Antonious (2018) applied biochar, chicken manure, sewage sludge, horse manure and garden waste compost to the tomato plant and the highest ascorbic acid content was reached in the plants applied chicken manure. Isuwan (2014), chicken manure application increased vitamin C by 60% in pineapple fruit. Jaipaula et al., (2011) investigated the effects of different organic fertilizers on the ascorbic acid content of red pepper and pea plants and the highest ascorbic acid content was found in NPK fertilizer applied integrated with 25.23 mg 100 $g^{-1}$ farm manure, followed by chicken manure and biological fertilizer (19.26). mg 100 $g^{-1}$) and farm manure + chicken manure + vermicompost + biological fertilizer (18.83 mg 100 $g^{-1}$) applications. Oztekin et al. (2020) reported that ascorbic acid content was the highest in organic fertilizer treatments. Toor and Savage (2006) and Xu et al., (2003) suggested that organic fertilizers enhance ascorbic acid content in vegetables.

The highest oxalic acid contents were observed in NPK treatments. Furthermore, PGPR and OCM treatments generally reduced the oxalic acid contents of the cauliflower (Table 4). Oxalates compounds are unwanted in vegetables because of their unfavorable effects on humans. The content of oxalates depends on species and cultivar, forms of fertilizers (especially nitric ones), phases of plant growth (Alessa et al., 2017).

The synthesis of oxalic acid by plants has been associated with the metabolic reduction of nitrate nitrogen as a mode to balance the cytoplasmic pH, being high when plants are fertilized with nitrogen in nitrate form. The oxalic acid may combine with calcium and iron, originating insoluble salts, commonly known as oxalates, hindering the availability of these minerals for humans, which can cause kidney stones and iron anemia Oxalate concentration in vegetables could be reduced by different agronomic management, for example using different nutrients (Castelli et al., 2010).

Chemical fertilizers, which contain plant nutrients in inorganic form, are kept in the soil depending on the soil properties, application dose and method and precipitation, or they may cause environmental pollution by moving away from the root zone of the plants. Organo-mineral fertilizers produced in the composition of inorganic fertilizers and organic matter by utilizing the positive effects of organic materials on soil fertility, on the one hand reduce the fixation of nutrients (Wang et al., 2012, Gunes et al., 2014), on the other hand, increase the efficiency of inorganic fertilizers and reduce the amount of use.

## Conclusion

75.6% of Turkey's soils are insufficient in terms of organic matter, 18.3% are medium and 6.1% are sufficient. Approximately 94% of Turkey's soils are insufficient in terms of organic matter coverage. In the study, the best values in terms of the parameters examined in terms of plant growth and yield were generally obtained from applications with NPK and organic chicken manure. We think that this study, in which we investigated the effects of separate and combined use of bacteria, organic chicken manure and synthetic fertilizer applications on yield and quality in cauliflower, will be beneficial for studies in the fields. In addition, we think that it will be useful to investigate the effects of the use of bacteria as biological fertilizers on the environment, especially on the soil.

## Conflict of interest

There is no conflict of interest between the authors

## Authors' Contributions

CC: contributed to the procurement of the materials required for the research, the establishment and conduct of the field trial, the acquisition and evaluation of the data, and the writing of the Master's Thesis. EY: contributed to the stages of planning the research, supplying the necessary materials for the research, establishing and conducting field trials, obtaining data and making statistical analyzes, writing the PhD Thesis and converting the thesis into an article.

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