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Original Research

Effects of Different Rhizobacterial Strains on Plant Growth and Yield of Use with Chemical Fertilizer Reduction in Cauliflower (*Brassica oleracea* var. *botrytis* L.)

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Abstract

In this study, application of different bacterial strains obtained from different ecosystems of Turkey with increasing doses of chemical fertilizers (NPK) was repeated for two years in field conditions in order to determine the effects on plant growth, yield and quality in cauliflower. Six PGPR strains (SA7, SB39, YÖ19, YÖ15, YÖ,41, SK72 107cfu/ml) from the trial subjects and a control group were added. Fertilizer applications were determined over the recommended dose; The rates of 0% NPK0, 50% NPK, 100% NPK and 200% NPK were applied. In the study, crown length, crown diameter, crown weight, leaf length, leaf diameter and marketable yield values were measured in sample plants selected on the basis of plots. Marketable yield values for 2021; NPK0 dose YÖ41, YÖ15 (2.55 ton ha^{-1}), 1/4NPK dose YÖ41 (2.98 ton ha^{-1}), 1/2NPK dose YÖ41, YÖ15 (4.57 ton ha^{-1}), NPK dose YÖ41 (4.74 ton ha^{-1}), 2NPK dose It was determined as YÖ41 (4.69 ton ha^{-1}). Marketable yield values for 2022; NPK0 dose YÖ41 (2.16 ton ha^{-1}), 1/4NPK dose SA7 (3.26 ton ha^{-1}), 1/2NPK dose YÖ41 (4.73 ton ha^{-1}), NPK dose YÖ41 (5.03 ton ha^{-1}), 2NPK dose YÖ41 (5.11 ton ha^{-1}) was determined. As a result of the research, it was determined that the effects of bacterial applications on the growth of the cauliflower plant are important. When the effects of applied bacterial strains on plant growth were examined, YÖ41, YÖ15 bacterial strains came to the fore, while other bacterial strains had a positive effect on all parameters.

Keywords: cauliflower, yield and quality, bacterial strains, reduced NPK

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Introduction

The word cauliflower (*Brassica oleracea* var. *botrytis* L.) derives from the Latin words "Caulis" meaning stem and "floris" meaning flower [1]. Cauliflower is grown year-round for its white and soft flower bed, and the success or failure of Cauliflower production has been reported to be largely dependent on climate, particularly temperature [2].

The great increase in chemical fertilizer inputs in the last 20 years has led to a great increase in vegetable yield [3, 4]. However, the increase in the cost of chemical fertilizers and its incorrect application caused a decrease in the yield and quality of vegetables as a result of the deterioration of the balance of the soil environment [5-7]. Balanced correct fertilization strategies can increase crop yield and reduce fertilizer waste [8]. Excessive and incorrect use of chemical fertilizers and pesticides applied in agricultural areas adversely affect the populations of all macro and micro organisms, thus reducing soil fertility. The use of synthetic chemical fertilizers alone limits the possibilities of sustainable agriculture. For this reason, it has become mandatory to use biological agents (biopesticides and microbial fertilizers) that can contribute to the regulation of the physical, chemical and biological structure of soils, protection of human health and prevention of environmental pollution in agricultural production [9]. The use of bacteria as biofertilizer or control agent in agriculture started to become widespread after the 1990s, the definition of biological fertilizer has been expanded in recent years and the conscious use of rhizobacteria, which are used as free-living organisms, has started. The use of biological warfare agents or biological fertilizers that provide plant growth has become common. Some bacteria commonly used in agriculture: Serratia, Pseudomonas, Burkholderia, Agrobacterium, Erwinia, Xanthomonas, Azospirillum, Bacillus, Enterobacter, Rhizobium, Alcanigenes, Arthrobacter, Acetobacter, Acinetobacter, Achromobacter, Aerobacter, Artrobacter, Artrobacter, Artrobacter, Artrobacter, Artrobacter, Artrobacter, Artrobacter, Artrobacter, Microcillus, Rhodospirrilum and Flavobacterium strains [10]. Researchers, who are aware of the damage caused by chemicals in agricultural production to all kinds of soil, food and the environment, have been searching for alternative solutions to chemicals for years in order to increase the yield and quality of agricultural products. Researchers considering reducing the use of chemical inputs have conducted different studies. When the scope of studies conducted in recent years is examined, the production and use of PGPRs has become widespread due to the positive contribution of PGPRs to plant growth, their effectiveness in disease control and also their positive effects on systemic resistance. Microorganisms in the rhizosphere of the soil affect a number of physicochemical events in the soil. Bacteria constitute the largest part of the microorganisms living in the soil. It has been determined as a result of research that some bacteria living in the rhizosphere support plant growth in many ways due to their different mechanisms of action. These beneficial bacteria are defined as PGPR (Plant Growth Promoting Rhizobacteria) and are also defined as "Probiotic Rhizobacteria" due to the many benefits they provide to the plant [11]. In the study, was used in cauliflower cultivation to determine the activities of new bacterial strains isolated from the plant and soil in order to reduce the use of chemical fertilizers that have harmful effects on the plant and soil when used in excessive quantities.

Materials and Methods

The Herbal Material Used in the Experiment

Mervan F1 cauliflower variety (*Brassica oleracea* L. var.) was used as plant material in the study. It can be harvested approximately 90 days after planting. Average head weight is between 1.5-2.5 kg, crown color is white, hard and tight. It is upright in the evening above the ground and the leaves cover the crown very well and provide a good endurance period for the variety.

Table 1. Bacteria used in the experiment and their properties.

SA7	Erwinia chrysanthemi biotype II: MIS similarity index (%) is 86, Nitrogen fixation feature is strong positive, phosphorus solubility feature is positive. Turgenia Latifolia was isolated from the soil surrounding the plant roots.
YÖ15	Pseudomonas fluorescens biotype F: MIS similarity index (%) is 63, Nitrogen fixation is positive, phosphorus solubility is weakly positive. Thymus vulgaris was isolated from plant roots.
YÖ19	Virgibacillus pantothenticus: MIS similarity index (%) 56, Nitrogen fixing and phosphorus dissolving properties are strongly positive. Thymus vulgaris isolated from plant roots.
YÖ41	Bacillus cereus GC subgroup A: MIS similarity index (%) is 78, Nitrogen fixing properties are strong, phosphorus dissolving properties are strongly positive. Thymus vulgaris was isolated from plant roots.
SB39	Bacillus pumilus GC subgroup B: MIS similarity index (%) 72 Nitrogen fixing and phosphorus dissolving properties are positive. It was isolated from the soil surrounding the roots of the Chenopodium album plant.
SK72	Bacillus subtilis: MIS similarity index (%) is 70, Nitrogen fixing and phosphorus dissolving properties are positive. *Kochia* sp. It was isolated from the leaf parts of the plant.

Table 2. Some climate data (2020-2021) of the Silifke center where the experimental area is located.

Months	1	2	3	4	5	6	7	8	9	10	11	12	Average.
Max. temp. ºC	24,6	26,3	30,3	35,0	28,3	41,3	42,4	42,4	40,0	37,0	31,9	28,5	34,8
Min. temp. ºC	-1,4	-1,9	-0,3	2,8	9,4	13,0	18,0	18,0	12,8	7,8	1,8	0,7	6,4
Avg. temp. ºC	10.2	10,9	13,7	17,3	21,4	25,4	28,1	28,1	25,6	21,5	15,5	11,6	19,1
Avg. moisture(%)	56.8	57,5	63,1	63,1	64,6	64,5	64,6	64,6	58,5	54,6	55,1	57,3	60,2
Avg. rains. (mm)	106.6	81,0	31,3	31,3	24,5	8,1	2,2	0,9	5,2	36,7	84,6	120,1	534,26*

*: Annual total

Preparation of Solutions of PGPR Strains

After the bacterial strains used in the study were stored at -80ºC, they were inoculated from stock cultures to NA medium by streaking. The cultivated petri dishes were incubated for 48 hours in an incubator set at 27ºC for bacterial growth and a loop was taken from the developing bacterial cultures and transferred to NB medium. Bacteria inoculated broths were incubated overnight on a shaker at 140 rpm. The concentration of the obtained bacterial solution was adjusted to 107 cfu/ml with sdH_2O.

Soil Properties of the Trial Area

Soil properties of the experimental area are given in Table 3.

Table 3. Soil properties of trial areas.

Parameters	Values
pH	6,96
Lime (%)	35,1
Salt (%)	0,44
Clay	11,2
Sand	41
Organic matter	2,2
TotalN (%)	0,118
P (mg kg^{-1})	2,04
K (mg kg^{-1})	395,2
Ca (mg kg^{-1})	3952
Mg (mg kg^{-1})	384
Fe (mg kg^{-1})	3,84
Mn (mg kg^{-1})	3,11
Zn (mg kg^{-1})	3,89
Cu (mg kg^{-1})	1,71

Fertilizer Materials Used in the Research

In the study, $(NH_4)_2SO_4$ was used as nitrogen fertilizer, P_2O_5 as phosphorus source fertilizer, and K_2SO_4 as potassium fertilizer source. According to the results of soil analysis, 50% reduced amounts of the fertilizer doses determined as 220 kg/ha N, 150 kg/ha P,240 kg/ha (110 kg.ha^{-1} N, 75 kg.ha^{-1} P and 120 kg.ha^{-1} K) was used.

Planning and Production Phase of the Trial Area

This study was repeated in different locations in the same soil conditions in 2021-2022 on a two-year leased field from a farmer. First year seed sowing: 15.07.2021, seedling planting was done on 01.09.2021. Seed sowing in the second year: 15.07.2022, seedling planting was done on 01.09.2022. In the experiment, 6 bacterial strains and one control, 5 fertilization doses, including four replications, 35 parcels in each block, 140 parcels in each block, 4 rows in each parcel and 6 seedling in each row. Planting distances 50x50 cm^2 was applied. Measurements and observations were made on medium plants that do not have edge effects. The seedlings, which were grown in accordance with the seed management method, were planted in viols with a 2:1 ratio of peat: perlite. The study was terminated after approximately 90 days. The irrigation water used in the research was applied as drip irrigation, which was taken from the Silifke DSI irrigation canal with a pump. The trial was terminated after approximately 120 days. PGPR applications were carried out in the form of seed coating.

Data Analysis

Statistical analysis. The data obtained in the study, which was organized in four replication plans according to the randomized blocks trial design, were evaluated according to the analysis of variance (ANOVA) test using the demo version of the "IBM SPSS statistics 28" statistical program. Duncan ($p = 0.05$) multiple comparison test was used to compare the differences between the means.

Result and Discussion

Effect of Rhizobacteria on Unfertilized (NPK 0) Plots

Crown length, crown diameter, crown weight, marketable yield, leaf length and leaf diameter values representing the vegetative growth characteristics of cauliflower treated with different bacterial strains at different NPK doses are given in the tables presented (Tables 4-5). According to the data of 2021-2022, when the plants inoculated with bacteria in NPK0 (without fertilizer) conditions are compared with the plants in the control plots; YÖ41 bacterial strain, which had the highest value in the effect of applications on plant crown length in both years, showed an increase of 16.2% in 2021 and 17.4% in 2022 compared to the control application. According to studies with similar results to our study, In a study; Biofertilized plants from bacterial colonization showed higher vegetative growth parameters (plant height, number of leaves, number of branches, as well as fresh and dry weight of leaves and stems) than untreated plants. Kumaraswami and Madalgeri [12].

According to the results of the two-year study; YO41 bacterial strain, which had the highest value increase in plant crown diameter, increased between 21.1% and 24% compared to the control application, increased by 33.3% in plant head weight, increased between 34.4% and 35.6%, in marketable yield. Leaf length increased between 7.9-8.3% and leaf diameter increased by 10.1%-14.8%. In a study, P. vulgaris inoculated with selected microbial consortia showed an increase in fruit yield in 75% chemical fertilization applications compared to the control; Similar grain yield and plant growth were obtained in applications with 100% chemical fertilization [14].

Effect of Rhizobacteria on Plots with 1/4 NPK Fertilizer Applied

Measurement results on plant samples belonging to the plots where different bacterial strains were applied at 1/4 NPK dose in 2021-2022 are given

Table 4. Effects of different bacterial applications on plant growth and yield factors under NPK_0 (No Fertilizer) conditions (year 2021).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	11.7+-0.3b	12.8+-0.2b	0.9+-0b	19.1+-0.1b	45.4+-1.6b	18.8 +-0.4b
SA7	13.2+-0.3a	15.1+-0.2a	1.2+-0a	24.8+-0.1a	48.3+-0.4a	20.4+-0.5a
YÖ9	13+-0.4a	14.9+-0.2a	1.1+-0.1a	25.2+-0.2a	47.9+-0.5a	20.2+-0.2a
YÖ15	13.1+-0.3a	14.9+-0.3a	1.1+-0.1a	25.9+-0.1a	48.8+-0.3a	20.3+-0.3a
YÖ41	13.6+-0.2a	15.5 +-0.3a	1.2+-0a	25.5+-0.1a	49+-0.5a	20.7+-0.2a
SB39	13.4+-0.4a	14.6+-0.5a	1.2+-0a	23.8+-0a	48.7+-0.4a	20.2+-0a
SK72	12.9+-0.2a	15.5+-0.6a	1.2+-0.1a	23.6+-0a	48.2+-0.4a	20.4+-0.2a
Average	12.98	14.75	1.12	23.9	48	20.14

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

Table 5. Effects of different bacterial applications on plant growth and yield factors under NPK_0 (No Fertilizer) conditions (year 2022).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	11.5+-0.3b	13.5+-0.4a	09 +-0b	19.6+-0.1d	45.4 +-1.6a	18.2+-0.1b
SA7	13.4+-0.4a	15.7+-0.9a	1.2+-0a	25. 8+-0.1a	48.7 +-0.4a	20.7+-0.4a
YÖ9	13.2+-0.5a	15+-0.2a	1.2+-0a	23.3+-0.1c	47.6 +-0.4a	20.4+-0.1a
YÖ15	12.9+-0.3a	15.2+-0.2a	1.2+-0a	25. 8+-0.1a	48.6+-0.2a	20.7+-0.3a
YÖ41	13.5+-0.4a	15.6+-0.3a	1.2+-0a	26.1 +-0.1a	49.2+-0.5a	20.9+-0.3a
SB39	13.1+-0.2a	15.4+-0.4a	1.2+-0a	25. 2+-0.1ab	48.8+-0.3a	20.6+-0.3a
SK72	13,1+-0.3a	15.4+-0.3a	1.2+-0.1a	23. 6+-0.1bc	48.6+-0.4a	20.4+-0.1a
Average	12.95	15.11	1.16	247.7	48.39	20.27

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

(Table 6-7). As a result of the measurements made for both years, the effect of bacteria on plant growth and yield parameters was found to be significant. For both years, SA7 bacterial strain came to the fore in the effect of bacterial strains on plant crown length and there was an increase between 17.4% and 19.3% compared to the control application. SA7 bacterial strain, which had the highest effect on plant crown diameter, was 15.5%-17.9% compared to the control application. SA7, YÖ41 bacterial strains, which have the highest effect on plant crown weight, increased between 43% and 44.9% compared to the control application. [15] reported that crown weight increased as the amount of fertilizer increased in their study on cauliflower at three different NP levels (50%, 75% and 100% of the recommended dose) It increased SA7, YÖ41, YÖ15 bacterial strains with the highest marketable yield increased between 27.8-30.4% compared to the control application. According to studies with similar results to our study, the use of bio-inocculants may have promoted the growth of soil microflora and increased the effectiveness of fertilizers and fertilizers applied [16]. The ability of Azotobacter to not only fix nitrogen but also release certain phytochromes such as GA3, IAA and Cytokinins, they promote plant growth and increase their solubility, increasing the availability of nutrients for plant roots [17]. Regarding the promotion of plant growth under greenhouse conditions, plants inoculated with the autochthonous yellow cultivar and H48 hybrid bacteria consortium showed significant improvements compared to the control group. Positive results of vegetative growth parameters; possibly due to the ability of bacteria to produce indoles, dissolve phosphates, and produce siderophores [18].

Effect of Rhizobacteria on Plots with 1/2 NPK Fertilizer Application

According to the data of 2021-202, the measurement results of the plots where different bacterial strains were applied at 1/2 NPK dose are given (Tables 8-9). The effects of YÖ41 bacterial strain, which had the highest effect on plant crown length for both years. Compared to the control application, it increased between 21.7%

Table 6. The effects of different bacterial applications on plant growth and yield factors in ¼ NPK dose (2021).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	13.2+-0.2c	14.8+-0.6c	1.06+-0b	23.3+-0.2b	45.2+-0.9b	18.6 +-0.4b
SA7	14.8+-0.2a	16.7+-0.5ab	1.54+-0.1a	29.4+-0.2a	50+-0.7a	20.4+-0.5a
YÖ9	14.4+-0.5ab	15.8+-0.2bc	1.43+-0a	28.8+-0.1a	49.2+-0.5ab	20.2+-0.2a
YÖ15	14.2+-0.5abc	15.7+-0.3bc	1.46+-0.1a	29.6+-0a	49.6+-0.7a	20.3+-0.3a
YÖ41	14.6+-0.2ab	17.1 +-0.3a	1.52+-0.1a	29.8+-0.1a	49.2+-0.6ab	20.7+-0.2a
SB39	14.1+-0.4abc	15.9+-0.1bc	1.42+-0a	28.9+-0.1a	49.7+-0.4a	20.2+-0a
SK72	13.6+-0.2bc	16.3+-0.3ab	1.41+-0.1a	27.6+-0.1a	48.7+-0.5ab	20.4+-0.2a
Average	14.12	16.04	1.37	27.9	49.11	20.11

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

Table 7. The effects of different bacterial applications on plant growth and yield factors in 1/4 NPK dose (2022).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	12.4+-0.4b	13.4+-0.5b	1.07+-0.1b	24. 3+-0d	44.8 +-0.7b	19.1+-0.8b
SA7	15+-0.3a	15.7+-0.9a	1.55+-0.1a	31.6 +-0.1a	49.8 +-0.8a	21.3+-0.2a
YÖ9	14.8+-0.3a	15+-0.2ab	1.48+-0a	29.2 +-0.1abc	48.8 +-0.2a	20.8+-0.2ab
YÖ15	14.3+-0.4a	15.2+-0.2ab	1.52+-0a	30. 4+-0.1ab	49.5+-0.7a	21.1+-0.3a
YÖ41	14.8+-0.2a	15.8+-0.3a	1.54+-0a	30. 8+-0.1ab	50,4+-0.4a	21.5+-0.4a
SB39	14.2+-0.4a	15.4+-0.4a	1.45+-0a	28.4 +-0.1bc	49.4+-0.6a	21.1+-0.4a
SK72	14+-0.3a	15.4+-0.3a	1.43+-0.1a	27.1 +-0.1c	49.6+-0.3a	20.9+-0.2ab
Average	14.21	15.16	1.14	28.9	49.41	20.9

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

and 29.4%, increased the plant crown diameter by 19.7-24.8%, increased the plant crown weight between 30.4-31.4%, increased the marketable yield between 32.8-34.4%, It increased the leaf length by 11.5%-18.9%, and the leaf diameter increased by 12-13%. According to studies with similar results to our study, The increase in yield characteristics due to inoculation with Azotobacter may be due to better root proliferation, nutrient and water uptake, higher leaf number and areas responsible for effective photosynthesis, and improved food accumulation [19]. The yield of cabbage increases as a result of adequate nutrient supplementation, and the yield has increased significantly as a result of the application of bio-fertilizer (Pseudomonas fluorescens and Azotobacter chroococcum), which plays an important role in enhancing the growth of cabbage plant [20].

Effect of Rhizobacteria on NPK (Recommended Dose) Fertilizer Applied Plots

According to the 2021-2022 data, the results of the measurements made in the plots where different bacterial strains were applied at the full dose of NPK are given (Tables 10-11). When the effects of YO41 bacterial strain, which is prominent in the vegetative growth parameters of these applications on both years basis, are compared with the control application; YÖ41 bacterial strain, which has the highest effect on plant crown length, increased between 16.6% and 23.8%, increased plant crown diameter by 19.8-22.3%, increased plant crown weight by 24.3-25.2%, marketable yield by 22.5-25.4%. There was an increase between 8.2% and 8.8% in leaf length, and an increase in leaf diameter between 9.2-10.4% compared to. In 2022, there was an increase of 7.2 %. The genus Massilia has been frequently reported as a rhizosphere and endorhizal colonizer. Furthermore, Massilia was reported to promote plant growth by producing auxin and siderophore, and by antagonizing the growth of Phytophthora infestans in vitro [21]. As a result of the applications of different bacterial strains and 2NPK fertilizer doses in two growing seasons in 2021-2022. According to the measurements made in the plots, the effects of applications on crown

Table 8. The effects of different bacterial applications on plant growth and yield factors in 1/2 NPK dose (2021).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	leaf Length (cm)	Leaf diameter (cm)
Control	14.3+-0.3c	15.7+-0.4c	1.8+-0.1c	34.4+-0.1c	47.8 +-1.1c	18.9 +-0.6b
SA7	16.3+-0.2b	18.1+-0.5ab	2.6+-0.1ab	44.8+-0ab	52.5+-0.3ab	23.1+-0.3a
YÖ9	15.8+-0.3b	17.6+-0.4ab	2.5+-0b	43.5+-0.1b	51.6+-0.5ab	21.6+-0.4a
YÖ15	16.2+-0.3b	17.4+-0.4b	2.6+-0ab	45.2+-0.1ab	52.1+-0.3ab	21.4+-0.7a
YÖ41	17.4+-0.3a	18.8+-0.6a	2.7+-0a	45.7+-0.1a	53.3+-0.2a	21.8-0.6a
SB39	16.5+-0.4b	17.2+-0.2b	2.6.+-0ab	43.9+-0.1b	51.1+-0.5b	21.6+-0.5a
SK72	15.9+-0.3b	16.8+-0.3bc	2.6+-0.1ab	44.5+-0.1ab	51.7+-0.4ab	21.3+-0.6a
Average	16.05	17.33	2.48	43.4	314.6	21.35

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

Table 9. The effects of different bacterial applications on plant growth and yield factors in 1/2NPK dose (2022).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	13.6+-0.5b	16.1+-0.6c	2.1+-0.1c	35.2 +-0.1c	50.6 +-0.3b	20.7+-0.4b
SA7	16.9+-0.4a	18.3+-0.6a	2.65+-0ab	46. 4+-0.2ab	52.4 +-0.2a	22.9+-0.2a
YÖ9	16.5+-0.4a	19.6+-0.4ab	2.63+-0.1b	46.2 +-0.1ab	52.2 +-0.2a	22.6+-0.2ab
YÖ15	16.8+-0.4a	18.2+-0.5b	2.66+-0b	45.9+-0.1ab	52.3+-0.2a	22.7+-0.4a
YÖ41	17.6+-0.5a	20.1+-0.5a	2.74+-0a	47.3+-0.1a	52.8+-0.4a	23.4+-0.2a
SB39	16.4+-0.5a	18.1+-0.4b	2.7+-0.1ab	44.7+-0ab	52.4+-0.4a	22.6+-0.2ab
SK72	16.4+-0.4a	18+-0.3b	2.62+-0ab	43.8+-0.1b	52.1+-0.2a	22.4+-0.2ab
Average	16.3	18.34	2.56	43.9	52.11	22.4

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

length, crown diameter, crown weight, marketable yield, leaf length and leaf diameter were found to be statistically insignificant. According to the results of our study, it was determined that the effect of bacterial strains on NPK subjects in excessive doses was insignificant Tables (12-13).

Table 10. The effects of different bacterial applications on plant growth and yield factors in NPK dose (2021).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	14.3+-0.6c	15.7+-0.4c	2.26+-0.1c	38.7+-0.1c	48.7+-0.3b-	19.8 +-0.5b
SA7	17.1+-0.6ab	18.1+-0.5ab	2.74+-0.1ab	45.6+-0.1ab	52.6+-0.3a	22.8+-0.2a
YÖ9	16.4+-0.2b	17.6+-0.4ab	2.64+-0b	43.9+-0.1b	52.3+-0.6ab	22.5+-0.3a
YÖ15	16.2+-0.3b	17.4+-0.4b	2.63+-0.1b	45.3+-0.1ab	52.4+-0.3ab	22.6+-0.4a
YÖ41	17.8 +-0.2a	18.8+-0.6a	2.81+-0.1a	47.4+-0.1a	52.7+-0.5a	22.8+-0.a
SB39	16.7+-0.5ab	17.2+-0.2b	2.65.+-0.1ab	45.2+-0.1ab	52.2+-0.2ab	21.8+-0.5a
SK72	16+-0.3b	16.8+-0.3bc	2.64+-0.1b	44.1+-0.1b	52.1+-0.4ab	21.3+-0.6a
Average	16.35	17.37	2.61	44.6	52.2	21.94

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan ($p = 0.05$) test.

Table 11. The effects of different bacterial applications on plant growth and yield factors in NPK dose (2022).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	15.6+-0.4c	16.6+-0.4c	2.22+-0.1b	40 .1+-0.1c	48.6 +-0.4b	21.6+-0.3b
SA7	17.7+-0.5ab	18.9+-0.3b	2.76+-0.1a	47.4 +-0.1ab	52.4 +-0.2ab	23.3+-0.2ab
YÖ9	16.5+-0.5bc	18.4+-0.4b	2.69+-0ab	46.3 +-0.1bc	52.6 +-0.6ab	22.9+-0.3ab
YÖ15	16.1+-0.4c	18.6+-0.4b	2.75+-0ab	45.8+-0.1bc	52.6+-0.1ab	22.8+-0.1ab
YÖ41	18.2+-0.3a	20.3+-0.7a	2.78+-0.1a	50.3+-0.1a	52.9+-0.3a	23.6+-0.4a
SB39	16.3+-0.6bc	18.5+-0.5b	2.76+-0.1ab	45.9+-0bc	52.7+-0.5ab	22.8+-0.3ab
SK72	16.3+-0.4bc	18.5+-0.3b	2.67+-0ab	45.6+-0.1bc	52.3+-0.2ab	22.5+-0.2ab
Average	16.67	18.54	2.62	46.5	52.4	22.84

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan ($p = 0.05$) test.

Table 12. The effects of different bacterial applications on plant growth and yield factors in 2NPK dose (2021).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	14.3+-0.4b	17.8+-0.7b	2.6+-0b	45.1+-0.1b	52+-0.2a	21.1+-0.3a
SA7	17.6+-0.4a	18.8+-0.4ab	2.7+-0.1a	46.4+-0.1ab	52.5+-0.3a	23.2+-0.4a
YÖ9	16.3+-0.4a	18.1+-0.3ab	2.6+-0b	45.8+-0.1ab	52.6+-0.2a	23 +-0.3a
YÖ15	16.5+-0.4a	17.9+-0.3ab	2.6+-0b	46.3+-0ab	52.4+-0.4a	23.3+-0.5a
YÖ41	17.7+-0.6a	19.3+-0.5a	2.9+-0a	46.9+-0a	52.5+-0.4a	23.3+-0.2a
SB39	16.6+-0.5a	17.7+-0.5b	2.6+-0b	46.1+-0ab	52.3+-0.3a	22.9+-0.3a
SK72	16.4+-0.5a	17.4+-0.3b	2.6+-0b	46.2+-0ab	52 +-0.2a	22.9+-0.1a
Average	16.94	18.14	2.66	46.1	52.3	23.1

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan ($p = 0.05$) test.

Table 13. The effects of different bacterial applications on plant growth and yield factors in 2NPK dose (2022).

PGPR Name	Crown length (cm)	Crown diameter (cm)	Crown weight (kg)	Marketable yield (ton ha^{-1})	Leaf length (cm)	Leaf diameter (cm)
Control	17.2+-0.4a	18.1+-0.2b	2.6+-0d	46.2+-0c	52.3+-0.3a	23+-0.3a
SA7	17.4+-0.5a	19.2+-0.2ab	2.7+-0ab	48.3+-0.1b	52.5+-0.3a	23.4+-0.5a
YÖ9	17+-0.6a	18.+-0.4b	2.6+-0.1cd	46.1+-0.1c	52.8+-0.4a	23.1+-0.3a
YÖ15	17.5.1+-0.4a	18.6+-0.4b	2.7+-0abc	46.3+-0c	52.7+-0.4a	22.9+-0.2a
YÖ41	16.9+-0.3a	19.9+-0.5a	2.8+-0a	51.1+-0.1a	53 +-0.6a	23.5+-0.2a
SB39	16.9+-0.4a	18.6+-0.5b	2.7+-0ab	46.6+-0.1c	52.8+-0.2a	22.8+-0.3a
SK72	16.8+-0.6a	18.5+-0.4b	2.7+-0bc	46.4+-0.1c	52.4 +-0.4a	22.6+-0.1a
Average	17.1	18.7	2.69	47.3	52.64	23

When the columns are examined from top to bottom, the averages containing the same letter are not statistically different according to the Duncan (p = 0.05) test.

Conclusions

In this study, which was carried out as an open field experiment, the effects of bacterial strains isolated from different regions and plants on the vegetative growth, yield and plant nutrition of cauliflower were tested at varying NPK doses. When the results of our study were evaluated, it was not observed that the same rate of increase in the vegetative growth and yield criteria was observed in the plots where the increased NPK dose was doubled. When the increase in nitrogen dose was doubled, bacterial strains could not show their effect sufficiently. It is thought that the differences in bacterial colonization due to changes in climate and soil conditions are effective in obtaining different results in parameter measurements on the basis of years. While bacterial strains such as YÖ41 and YÖ15 were prominent among the bacterial strains tested in the study, all bacterial strains showed significant effects on yield and yield components compared to the control application. There is a serious need for widespread testing of newly isolated bacterial strains from the Turkish ecosystems, which has a wide genetic diversity, in different climates, soils and plant species.

Conflict of Interest

The authors declare no conflict of interest.

References

1. GOCHER P., SONİ A.K., MAHAWAR A.K., SİNGH S.P., SHARMA D., SİNGH B. Effect of NPK and sulphur on growth attributes and chlorophyll content of cauliflower (*Brassica oleracea* var. *botrytis* L.) variety pusa synthetic. Chemical Science Review and Letters **6** (23), 1544, **2017**.
2. HOSSAİN M.F., ARA N., UDDİN M.R., ISLAM M.R., AZAM M.G., Effect of sowing date and plant spacing on seed production of cauliflower. Bangladesh Journal of Agricultural Research **40** (3), 491, **2015**.
3. DAWSON C.J., And HİLTON J. Fertiliser availability in a resource-limited world: production and recycling of nitrogen and phosphorus. Food Policy **36**, S14, **2012**.
4. SOUZA C. JR., RİBEİRO V., MENDES M., SOARES P. H. Enhanced- Efficiency Phosphorous Fertilizer Impacts on Corn and Common Bean Crops and Soil Phosphorus Diffusion. J. Agric. Sci. **12**, 15, **2020**.
5. WANG H., HU R., CHEN X., ZHONG X., ZHENG Z., HUANG N., et al. Reduction in nitrogen fertilizer use results in increased rice yields and improved environmental protection. Int. J. Agric. Sustain. **15**, 681, doi: 10.1016/j, **2017**.
6. WESENBEECK C., KEYZER M.A., VEEN W., QİU H. Can China'soveruse of fertilizer be reduced without threatening food security and farm incomes?. Agric. Syst. **190**, 103093, **2021**.
7. YİN J., YUAN L., HUANG J. New Functions of Ceriporia lacerataHG: mobilization of Soil Nitrogen and Phosphorus and Enhancement of Yield and Quality of Ketchup-Processing Tomato. J. Agric. Food Chem. **69**, 4056, 4063. doi: 10.1021/acs. jafc.0c06783, **2021**.
8. LİN X., FENG Y., ZHANG H., CHEN R., WANG J., ZHANG J., et al. Long-Term Balanced Fertilization Decreases Arbuscular Mycorrhizal Fungal Diversity in an Arable Soil in North China Revealed by 454 Pyrosequencing. Environ. Sci. Technol. **46**, 5764, doi: 10.1021/es3001695, **2012**.
9. GOKCE A.Y., KOTAN R., Investigation of biological control possibilities under controlled conditions using PGPR and bioagent bacteria against Bipolaris sorokiniana (Sacc.), which causes wheat root rot, Plant Protection Bulletin, **56** (1), 49, **2016**.
10. KOTAN R., Use of beneficial bacteria in agriculture. HarmanTime, **11**, 44, **2014**.
11. KLOEPPER J.W., LEONG J., TEİNTZE M., SCROTCH M.N., Enhanced plant growth by sideroph-ores produced by plant growth-promoting rhizobacteria. Nature **286**, 885, **1980**.
12. SALİM H.A., AZİZ A.K., MAHDİ M.H., ALİ M.A., SALMAN M.H., HUSSEİN M.M., MOHAMMED L.K., AHMED M.S., KHALİL A.Y., HADİ T.A. Effect of Bio-Fertilizers Azotobacter chroococcum and Pseudomonas fluorescens on Growth of Broccoli (*Brassica oleracea* L.

var. *Italica*), Journal of Advances in Biology, **11** (01), 2236, **2018 a.**

13. ADRİANA Ş.I. Impact of Bacillus megaterium on fertilization with phosphogypsum, Journal of Engineering Studies and Research., **17** (3), 93, **2011**.
14. CHAUHAN H., BAGYARAJ D.J. Inoculation with selected microbial consortia not only enhances growth and yield of French bean but also reduces fertilizer application under field condition. Sci. Horticul. **197**, 441. doi: 10.1016/j.scienta.10.001, **2015**.
15. KAUSHAL M., KAUSHAL R., THAKUR B.S., SPEHİA R.S. Effect of plant growth-promoting rhizobacteria at varying levels of N and P fertilizers on growth and yield of cauliflower in mid hills of Himachal Pradesh. Journal of Farm Sciences, **1** (1), 19, **2011**.
16. KAUSHAL M., KAUSHAL R., THAKUR B.S., SPEHIA R.S. Effect of plant growth-promoting rhizobacteria at varyinglevels of N and P fertilizers on growth and yield of cauliflower in mid hills of Himachal Pradesh. J. Farm Sci. **1**, 19, **2011**.
17. IBRAHIM A.N., ABD EL-AZIZ I.M. Solubilization of rock phosphate by streptomycin. Agric. Talajton. **26**, 424, **1977**.
18. MOLINA-ROMERO D., BAEZ A., QUINTERO-HERNANDEZ V., CASTANEDA-LUCIO M.,FUENTES-RAMIREZ L.E., BUSTILLOS-CRISTALES M.D.R. Compatible bacterial mixture, tolerant to desiccation, improves maize plant growth. PLoS ONE 12:e0187913. doi: 10.1371/journal. pone.0187913, **2017**.
19. KUMARASWAMY D., MADALAGERI B.B. Effect of Azotobacter inoculation on tomato, South Indian Horticulture, **38** (6) 345, **2015**.
20. SALİM H.A., AZİZ A.K., MAHDİ M.H., ALİ A.F., ALİ M., SALMAN M.H., HUSSEİN M.M., MOHAMMED L.K., AHMED M.S., KHALİL A.Y., HADİ T.A. Efficacy of Bio-Fertilizers Pseudomonas fluorescens and Azotobacter chroococcum on Yield of Cabbage (*Brassica oleracea* L. Var. *Capitata*), Haya: Saudi J. Life Sci., **3** (8), 561, **2018b**.
21. OFEK M., HADAR Y., MİNZ D. Ecology of root colonizing Massilia (Oxalobacteraceae). PLoS One 7:e40117. doi: 10.1371/journal. pone.0040117, **2012**.