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Research Article

Impact of Vermicompost and Different Plant Activators on Yield and Some Quality Parameters in Pumpkin (*Cucurbita pepo* L.)

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Abstract: In addition to being used as a snack, pumpkin seeds are an industrial product. It also has the potential to be used in the food, pharmaceutical, and cosmetic industries. Seed yield and quality are traits of economic importance. This study aims to determine the effect of vermicompost and different plant activators on the yield and some parameters of the pumpkin's quality. For this purpose, three plant activators [(ISR-2000 (I), Symbion-Vam (S), and Green-Miracle (G)] together with vermicompost (V) have been used. The experiment was conducted in the field of the Cukurova University Pozantı Agricultural Research and Application Center, Turkey. A total of 8 applications were made. Conventional fertilizer (CF) application was determined as the control group. The results showed that the applications increased the snack pumpkin's fruit, seed yield, and quality. The highest fruit and seed yield was obtained from CF (37.2 t ha^{-1}, 101.42 $g^{-1}m^2$) application, followed by V+I (27.1 t ha $^{-1}$, 80.09 $g^{-1}m^2$) application. Additionally, CF applications resulted in the highest fruit width (14.82 cm), length (23.31 cm), seed width (10.21 mm), and length (20.66 mm) of internal weight (74.33 %) measurements. Regarding mineral element and phenolic content, higher results were obtained when vermicompost and plant activators were combined. According to the study results, different doses of vermicompost may be recommended as an alternative to conventional fertilizer application in future studies.

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1. Introduction

Cucurbitaceae is a prominent family of vegetable and fruit crops containing approximately 125 genera and 960 species. Vegetables of the *Cucurbitaceae* family are section ancient medicine and culinary traditions (Mukherjee et al., 2022). Pumpkins (Cucurbita spp.) are a substantial economic crop in the Cucurbita. The most commonly cultivated species of the *Cucurbitaceae* family in Turkey are the *Citrullus lanatus* Thunb., *Cucumis flexuosus* L., *Cucumis sativus* L., *C. maxima* Duch., *C. moschata* Duch. and *C. pepo* L (Ermiş and Yanmaz, 2022). Pumpkin, an essential part of human nutrition, is an edible vegetable (Prommaban et al., 2021). Each piece of the pumpkin vegetable has been correlated with one or more applications in food and health (Sharma et al., 2020). Pumpkin seeds are produced from fruit processing as a by-product containing different phytochemicals such as phenolic compounds, polyunsaturated fatty acids, vitamins, minerals, and carotenoids (Noroozi et al., 2021). Also, it is an excellent source of both oil and protein. When the amount of snack pumpkin confectionery production in Turkey between 2018-2022 is examined, there has been instability in production (TUIK, 2023). Plant nutrition and fertilization are essential in cultivating snack pumpkins to increase the amount of product to be taken from the unit area and obtain quality products. Therefore, it was stated that organic fertilizer applications should be included in addition to chemical fertilizer applications. Using organic fertilizers, like compost and vermicompost, is an efficient way to increase and protect the soil's organic matter and provide the valuable nutrients necessary for the plants (Amiri et al., 2017). Vermicompost is derived from organic wastes with the help of earthworms (Yatoo et al., 2021). Vermicompost is used in agricultural applications to increase plant yield and quality in plants (Aksu et al., 2017), suppress diseases and pests (Yatoo et al., 2021), and improve soil properties (Ding et al., 2021). Plant activators are used to increase yield and quality (Göktekin and Ünlü, 2016), increase resistance to diseases and pests (Aysan et al., 2019), and act as soil conditioners (Artyszak and Gozdowski, 2020). This study aims to determine the effect on the yield and some quality parameters of snack pumpkin fruit and seed in the case of vermicompost and plant activators.

2. Material and Methods

2.1. Trial area and climate data

The field trial was conducted at the Cukurova University Pozantı Agricultural Research and Application Center (Adana, Türkiye). Soil characteristics of the trial area: At the beginning of the study, soil samples were collected in April 2019 and analyzed in the Cukurova University Faculty of Agriculture, Department of Soil Science and Plant Nutrition laboratory. It was determined that the soil used in the field contained a salt-free organic matter content of 1.8%, a pH of 7.16, and some macro and microelements in specific amounts (Table 1). After analysis of the soil samples taken from the field, the content and quantity of conventional fertilizer application were determined.

Table 1. Physical and chemical properties of soil used in the study

Soil Characteristics	Value
K (kg ha^{-1})	4770 ± 1.7
P (kg ha^{-1})	18.3 ± 0.13
Fe (mg kg^{-1})	10.61 ± 0.38
Mn (mg kg^{-1})	16.41 ± 0.86
Zn (mg kg^{-1})	1.47 ± 0.13
Cu (mg kg^{-1})	3.91 ± 0.01
Organic Matter (%)	1.8
pH	7.16 ± 0.04
EC (mS cm^{-1})	0.18 ± 0.00
CaCO3 (%)	0.70 ± 0.01
Sand (%)	18.1
Clay (%)	31.9
Silt (%)	63.0

Climate data for the experimental field are presented in Table 2. The highest average temperature in 2019 was recorded in August, and the highest in 2020 was recorded in July. The average humidity was highest in April "(67.84) in 2019 and March (65.60%) in 2020. "Total precipitation was highest in March in both years" (Table 2).

Table 2. Climatic characteristics of the experiment area for the year 2019-2020

Year	Month	Minimum Temperature (⁰C)	Maximum Temperature (°C)	Average Temperature (°C)	Average Relative Humidity (%)	Total Precipitation (mm)
2019	March	1.92	12.89	6.80	63.58	2.56
	April	5.17	15.66	9.66	67.84	2.27
	May	11.09	25.26	17.93	52.14	0.57
	June	15.75	29.24	21.62	59.20	1.77
	July	17.72	31.27	24.13	44.14	0.02
	August	18.83	32.65	25.11	44.32	0.03
	September	14.16	28.28	20.62	46.38	0.64
2020	March	2.63	13.95	8.09	65.60	3.50
	April	5.67	18.51	11.67	60.17	1.69
	May	10.93	23.44	16.77	54.26	1.30
	June	14.45	27.61	19.93	57.32	1.59
	July	18.42	34.16	26.36	42.75	0.01
	August	18.77	33.15	25.54	31.74	0.32
	September	15.53	33.08	24.32	44.45	0.01

2.2. Plant materials and experimental treatments

The current study used the Çağlayan pumpkin cultivar (Obtained from Ahmet Erkan Company located in Turkey; http://erkantarim.com/) as the plant material. ISR-2000 (I), Green Miracle (G), and mycorrhiza (Symbion-Vam) (S) were used as plant activators. In addition, vermicompost (V) and conventional fertilizer applications (CF) were included within the scope of this study.

2.3. Vermicompost and plant activator description

The vermicompost used in this experiment was made of organic plant materials, changing the physical and chemical structures of *Lumbricus rubellis* and *Eisenia foetida* earthworm species. Some chemical properties of vermicompost were determined: humidity, 72.05 (%); organic matter, 61.11 (%); nitrogen, 1.95 (%); C/N, 18.18 (%); lime, 8.7 (%); pH, 7.54; Electrical conductivity, 3.29 (mS cm^{-1}).

I: Contains *Lactobacillus acidophilus*, yeast extract, Yucca plant extract, and benzo-(1,2,3)-thiadiazole-7-carbothioic acid S-methyl ester (BTH). When ISR-2000 is applied, the receptors on the plant send a signal as if they have detected the presence of a pathogen, activating the defense system to resist attacks. It is a plant activator that provides natural resistance against disease factors and stress conditions in herbal production, stimulates and activates the natural defense system of the plant with its components, and is commercially produced (Çıngı Tarım, Türkiye).

G: Contains 80% vegetable fatty acids and is commercially available as an emulsion concentration (EC) (Agrobest, Türkiye). It is a highly effective plant activator in liquid form. It is a reflection-type antitranspirant and a surface coating agent that prevents sweating, heating, and water loss in plants. It is a balanced combination of vegetable fatty acids, amino acids, surface tension reducers (surfactants), and organic biological stimulants.

S: Include *Glomus fasciculatum*, *Glomus intraradices*, *Glomus mosses*, nitrogen bacteria (*Azotabacter*), phosphorus bacteria (*Bacillus megaterium*), and potassium bacteria (*Frateuria aurantia*), which are sold commercially. They play essential roles in plant root growth (Agrobest, Türkiye). It eliminates the problems caused by factors that limit plant nutrition in the soil, such as high pH and excessive salinity. It increases the plant's defense mechanism and resistance against the adverse effects that undesirable climate conditions, such as excessive heat and excessive cold, will create on the plant. It stores additional water and nutrients for the plant. Application doses of vermicompost and plant activators were made according to the recommendations of the companies.

CF: NPK (N:100 kg ha^{-1} P_2O_5: 50 kg ha^{-1} K_2O: 200 kg ha^{-1}) fertilized the plants. CF application was determined as the control group.

Vermicompost and plant activator in their combination as follows:

V+I: 100 g $plant^{-1}$ +1 L / 100 L

V+S: 100 g $plant^{-1}$+ 10 kg ha^{-1}

V+G: 100 g $plant^{-1}$ + 200 ml/100 L

V+G+S: 100 g $plant^{-1}$ + 200 ml/100 L+10 kg ha^{-1}

V+G+I: 100 g $plant^{-1}$ +200 ml/100 L+ 1 L/100 L

V+I+S: 100 g $plant^{-1}$ + 1 L / 100 L +10 kg ha^{-1}

V+I+S+G: 100 g $plant^{-1}$ +1 L / 100 L+10 kg ha^{-1} +200 ml/100L

V: 100 g $plant^{-1}$

CF: N:100 kg ha^{-1} P_2O_5: 50 kg ha^{-1} K_2O: 200 kg ha^{-1}

The experiment was conducted in a randomized complete block design with four replications of each treatment. Çağlayan pumpkin cultivar was sown the second week of May with plant-plant and row-row distances of 70 cm and 70 cm, respectively. The size of each treatment was 6.86 m^2. Seedling planting was carried out on 22 May 2019 and 29 April 2020.

2.4. Morphological measurements

The fruit was harvested on 15 August 2019 and 13 August 2020. After harvesting, their weights were taken, and then morphological measurements were made. After completing the measurements on the fruit, the seeds were removed from the fruit and dried (for approximately ten days), and both morphological measurements were made on the seeds. Finally, biochemical analyses were carried out on the seeds.

Fruit and yield per treatment: The data was recorded in grams with the help of scale and then converted into kg per hectare. Fruit weight, width, and length as "cm" were inscribed. For measurement purposes, five fruits were randomly selected from each application. Seed width and length were recorded as "mm." For fruit measurement purposes, five fruits were randomly selected from each application. Seed width and length were recorded as "mm." For seed measurement, fifty seeds from four replications were chosen randomly. The seed's internal weight was measured as %.

2.5. Chemical analysis in seed

Seed samples were dried in an oven at 50 - 55 °C for approximately a week. After drying, the samples were ground to powder. The samples were kept in the muffle furnace at 550 °C for approximately 7-8 hours. According to Kacar (1972), solutions were obtained from the samples taken from the furnace. Macroelements (Potassium (K), Phosphorus (P), Magnesium (Mg), and Calcium (Ca) and microelements (Zinc (Zn), Manganese (Mn), Iron (Fe), and Copper (Cu) concentrations were measured using Inductively Coupled Plasma (ICP) devices. Total phenolic content: First, fat was extracted from the seeds. The phenolic content was determined using a spectrophotometer according to the Folin-Ciocalteu method made by (Ayaz et al., 2017).

Statistical Analysis: The data obtained were analyzed using the JMP package program. They were subjected to variance analysis, and the statistical differences between the averages were grouped at a 5% significance level by the LSD test, and correlation analysis was performed.

3. Results

According to the statistical analysis, the averages of 8 different applications made within the trial were to be significant. However, the applications increased both fruit and seed yields in snack pumpkins. The highest fruit and seed yield was obtained from CF application (37.2 t ha^{-1}, 101.42 $g^{-1}m^2$). This application was followed by the V+ I application (27.1 t ha^{-1}, 80.09 $g^{-1}m^2$). The highest measurement in fruit width, length, seed width, and length of internal weight measurements was taken from CF applications (Table 3).

Table 3. Findings of total fruit yield, fruit weight, fruit width (cm), fruit length (cm) and fruit circumference (cm), total seed yield ($g^{-1}m^2$), seed internal weight (%), seed width, seed length as a result of vermicompost and some plant activator applications regarding pumpkin

Applications	Total fruit yield (t ha $^{-1}$)	Fruit width (cm)	Fruit length (cm)	Fruit diameter (cm)	Total seed yield ($g^{-1}m^2$)	Seed internal weight (%)	Seed width (mm)	Seed length (mm)
V+I	27.1 b[1]	13.21 bc	20.87 b	42.9 bc	80.09 b[1]	73.15 ab	9.76 ab	19.97 ab
V+S	22.2 bcd	12.42 cd	19.47 bc	40.49 cd	52.28 c	70.78 ab	9.32 bc	18.54 cd
V+G	26.0 bc	13.73 b	19.85 bc	44.47 b	73.99 b	73.66 ab	9.21 c	19.76 abc
V+G+S	21.8 bcd	12.51 cd	19.11 c	40.55 cd	53.06 c	74.27 a	9.35 bc	19.01 bcd
V+G+I	20.7 cd	12.24 d	18.71 c	39.35 d	42.21 c	66.70 ab	9.03 c	18.30 d
V+I+S	22.9 bcd	12.73 cd	19.61 bc	41.29 bcd	53.61 c	66.35 b	9.18 c	18.69 bcd
V+I+S+G	19.3 d	11.89 d	18.71 c	38.39 d	40.61 c	73.61 ab	8.97 c	18.10 d
V	22.8 bcd	12.41 cd	19.28 c	40.45 cd	53.17 c	70.05 ab	9.31 bc	18.67 bcd
CF	37.2 a	14.82 a	23.31 a	48.92 a	101.42 a	74.33 a	10.21 a	20.66 a
$LSD_{0.05}$	0.22***	0.65***	1.74***	7.88***	256.48***	41.46*	0.19**	1.19*

V; Vermicompost, I; ISR-2000, S: Symbion-Vam, G; Green miracle, CF; Conventional fertilizer application.
Statistical differences between means shown with separate letters in the same column are significant.***: p < 0.001; **: p < 0.01; *: p < 0.05.

The difference between vermicompost and plant activator application averages was statistically significant regarding nutrient content in snack pumpkins. K, P, Mg, and Ca were dominant in nutrient element analyses. It was determined that the seed's K, P, and Mg contents were more effective in V+S application. The V+I application was more effective in Ca content. The lowest measurements of macro and microelements were generally taken from CF applications. Microelements have been dominant in different applications. As a result of the applications, the total phenol content in the confectionary pumpkin seeds showed a distribution between 20.08 and 31.65 (mg GAE g^{-1}). This distribution obtained the maximum total phenol content from the V+G+I application. The lowest total phenol content was obtained from the V+I+S application (Table 4).

Table 4. Macro and microelement, phenolic content (mg GAE g^{-1}) content obtained from the seed as a result of vermicompost and some plant activator applications (g mL $^{-1}$)

App.	K	P	Ca	Mg	Cu	Fe	Mn	Zn	Total phenolic
V+I	75.44 c[1]	44.90 b	9.76 a	30.55 b	0.18 bc	1.07 a	0.60 b	1.24 ab	24.17 de[1]
V+S	84.90 a	52.05 a	8.44 b	32.77 a	0.12 c	0.94 bcd	0.70 a	1.25 ab	23.70 e
V+G	74.31 c	43.57 bc	7.82 bc	24.59 cd	0.15 c	0.95 bcd	0.54 bcd	1.17 b	25.04 cd
V+G+S	83.82 ab	47.05 b	8.21 b	26.40 c	0.25 ab	0.97 bc	0.52 bcd	1.25 ab	23.03 e
V+G+I	79.50 abc	43.41 bc	8.29 b	25.26 cd	0.32 a	0.94 bcd	0.51 cd	1.23 ab	31.65 a
V+I+S	83.65 ab	39.14 cd	6.86 c	23.98 d	0.32 a	1.00 ab	0.54 bcd	1.27 ab	20.08 f
V+I+S+G	76.22 c	37.62 d	7.25 bc	23.46 d	0.33 a	0.86 de	0.57 bc	1.34 a	28.97 b
V	77.80 bc	35.10 d	8.42 b	21.17 e	0.26 ab	0.90 cd	0.54 bcd	1.33 a	27.82 b
CF	56.51 d	18.35 e	7.95 bc	13.47 f	0.21 bc	0.81 e	0.47 d	1.19 b	25.45 c
$LSD_{0.05}$	26.96***	16.44***	2.59***	2.05***	0.00***	0.00***	0.00*	0.01***	1.04***

Statistical differences between means shown with separate letters in the same column are significant. ***: p < 0.001; **: p < 0.01; *: p < 0.05.

When the correlation between the yield and the quality parameters was evaluated (P < 0.01), it showed that total fruit yield (t ha $^{-1}$) had a significantly positive correlation with fruit width (cm) (r=0.96; P<0.0001), fruit length (cm) (r=0.85; P<0.0001), fruit diameter (cm) (r= 0.89; P< 0.0001), total seed yield ($g^{-1}m^2$) (r=0.70; P<0.0001), seed internal weight (%) (r=0.20; P=0.08), seed width (mm) (r=0.48; P<0.0001) and seed length (mm) (r=0.38; P<0.0007). However, a negative correlation was observed between total fruit yield and a negative correlation with some macro and microelements. Correlation and significance values between nutrients and total yield; K, (r=-0.14; P=0.21), Ca, (r=-0.07; P=0,54), P (r=-0.19; P=0.10), Mg (r=-0.15; P=0.18) Cu (r= -0.14; P=0.23), Fe (r= -0.06; P=0.58), Mn (r=-0.13; P=0.24).

Total seed yield was not correlated with K and Mg, but there was a positive correlation with Ca (r=0.16; P=0.15) and a negative correlation with P (r=-0.04; P=0.72). While total seed yield showed a positive correlation with Zn (r=0.12; P=0.50), Mn (r=0.06; P=0.60), and Fe (r=0.16, P=0.17), there was a negative correlation with Cu (r=-0.19; P=0.10). When the correlation relationship between the nutritional elements was evaluated, there was a positive and strong correlation between all elements except Cu. Total Phenolic content was negatively correlated with total fruit yield (r=-0.10; P=0.39) and positively correlated with total seed yield (r=0.04; P=0.69). The correlation with the nutrient elements was positive and strong with all the elements except Cu. This study observed significant positive correlations between total phenolic content and other mineral elements [K (r=0.74; P<0.0001), Ca (r=0.68; P<0.0001), P (r=0.73; P<0.0001), Mg (r=0.72; P<0.0001), Fe (r=0.79; P<0.0001), Mn (r=0.73; P<0.0001), Zn (r=0.83; P<0.0001)] except the Cu element (r=-0.11; P=0.34).

4. Discussion

As a result of the applications, there has been an increase in fruit and seed yield in snack pumpkins. The data obtained regarding fruit yield are consistent with those reported in previous studies (Altun, 2017; Günhan, 2020). However, these results differ from previous studies (Durukan et al., 2019; Rahimi et al., 2019; Üçok et al., 2019). The reason for this can be attributed to the plant material used, climatic conditions, different dosages and contents of vermicompost (Dayan and Sarı 2019), and the activities of microorganisms in the plant activators used in the study (Basu et al., 2022). The findings of some researchers (Saket et al., 2014; Santos et al., 2018; Sadegh et al., 2020) regarding seed yield support the conclusions of this study. However, other studies have obtained different results Ceritoglu and Erman (2020). This difference may be because the amount of vermicompost used in the current study was low, resulting in less translocation and accumulation of yield components such as proteins and carbohydrates in the reproductive organs (Saket et al., 2014). Also, vermicompost doses have a significant relationship with plant growth (Singh et al., 2012; Blouin et al., 2019).

The K, P, Mg, and Ca contents were higher according to the data obtained from macro and micronutrient element analyses. The data obtained were compatible with the results of some researchers (Erdinç et al., 2018; Martinec et al., 2019). However, different results have been obtained in some studies regarding the amounts of these elements (Seymen et al., 2016; Devi et al., 2018). Different ecological conditions, genotypes, and soil and seed maturation periods are possible reasons for these different results. Studies have emphasized that leaf senescence plays a role in transferring macro- and micronutrients to seeds (Gregersen et al., 2013; Dass et al., 2022). While the result obtained was similar to the result of Meru et al. (2018), it was different from the findings of Seymen et al. (2016). The phenolic content obtained in this study was higher than those reported in other studies. Saavedra et al. (2015), 0.95 – 3.43 mg GAE g^{-1}; Boujemaa et al. (2020) total phenol content, 13.70 mg EAG g^{-1}; Peng et al. (2021), 2.44–3.82 mg GAE g^{-1}. In terms of phenolic content, the differences between the findings of the current research and the literature can be attributed to the climatic factors (Kabtni et al., 2020), extraction methods (Saavedra et al., 2015), and cultivar (Seymen et al., 2016).

Correlation analysis was performed to determine the relationship between the investigated parameters. Total fruit yield was positively correlated with fruit width, fruit length, fruit diameter, total seed yield, seed internal weight, seed width, and seed length. These findings from the current study were consistent with previous studies (Nagar et al., 2017; Seymen et al., 2019; Yetişir and Aydın 2019). Total seed yield analysis correlates positively with K, Mg, and Ca. But negative correlation with P. While total seed yield showed a positive correlation with Zn, Mn, and Fe, there was a negative correlation with Cu. These findings may be related to the ability to chelate ion metals by polyphenol compounds (Rehecho et al., 2011). The balance between the nutritional content of the applications made causes these applications. However, the concentration of nutrients can also be effective (Karaköy et al., 2012). It is necessary to conduct detailed research on the correlation between the elements and the yield of snack pumpkins. Total phenolic content was negatively correlated with total fruit yield and positively correlated with total seed yield, with the nutrient elements being positive and strong with all the elements except Cu. Present results demonstrated that current levels of mineral elements except Cu affected the total phenolic content as the correlations were primarily positive. These findings agree with our previously published result (Aras, 2022). However, these results differ from previous studies (Sulaiman et al., 2011; Ngamdee et al., 2016). It can be explained by the gene expression between nutrients and antioxidant compounds (Lillo et al., 2007).

Conclusion

Under the scope of the trial, the Çağlayan pumpkin cultivar was subjected to vermicompost and different plant activators. The applications made were practical in the snack pumpkin, and there was an increase in fruit and seed yield and quality. The highest measurement in fruit width, length, seed width, and length of internal weight measurements was taken from CF applications. The V+ I application followed this application. Better results were obtained from conventional fertilizer application than vermicompost application, possibly because the vermicompost dose used in the study was insufficient. K, P, Mg, and Ca were dominant nutrients in snack pumpkins. V+S application is more effective in increasing the seed's K, P, and Mg contents, while V+I application is more effective in boosting Ca content. On the other hand, different applications were practical in microelements. In general, CF applications produce the lowest measurements of macro and microelements the maximum total phenol content obtained from the V+G+I application.

Correlation studies indicated that yield was significantly and positively correlated with all the fruit and seed characters under study. However, there were both positive and negative correlations between total fruit yield, total seed yield, and total phenolic compounds and nutrients. From this study, depending on the producer's preference, the vermicompost and plant activator (I) combination can be used within the scope of sustainable agriculture as an alternative to conventional agriculture. According to the study results, the application of different doses of vermicompost may be recommended as an alternative to conventional fertilizer application in future studies.

Ethical Statement

Ethical approval is not required for this study.

Conflict of Interest

The author declares that there are no conflicts of interest.

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Author Contributions

All contributions to this article were made by the corresponding author.

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