KSÜ Tarım ve Doğa Derg 25 (Ek Sayı 2): 430-440, 2022
KSU J. Agric Nat 25 (Suppl 2): 430-440, 2022
https://doi.org/10.18016/ksutarimdoga.vi.1047470

Influence of Different Vermicompost Doses on Growth, Quality and Element Contents in Curly Lettuce (*Lactuca sativa* L. var. *crispa*)

Serap KARADEMİR[1], Beyhan KİBAR[2]
[1,2]Bolu Abant İzzet Baysal University, Faculty of Agriculture, Department of Horticulture, Bolu, Türkiye
[1]https://orcid.org/0000-0001-5864-9193, [2]https://orcid.org/0000-0001-9253-5747
✉: beyhan.kibar@ibu.edu.tr

ABSTRACT

This study was conducted to determine the effects of different vermicompost doses on plant growth, quality properties and element contents in curly lettuce (*Lactuca sativa* L. var. *crispa*). The research was carried out in pots under plastic greenhouse conditions in Karabük province. In the study, 6 applications as 4 different doses of vermicompost (V), chemical fertilizer (CF) and control were examined. The applications were as follows: 1) Control (100% soil), 2) V1 (97.5% soil + 2.5% vermicompost, w/w), 3) V2 (95% soil + 5% vermicompost, w/w), 4) V3 (90% soil + 10% vermicompost, w/w), 5) V4 (80% soil + 20% vermicompost, w/w) and 6) CF (100% soil + chemical fertilizer). The experiment was established in completely randomized design with 3 replications. According to the research findings, vermicompost applications significantly increased plant height, plant fresh weight, plant dry weight, number of marketable leaves, chlorophyll, nitrogen, phosphorus, potassium, magnesium, calcium, sodium, iron, copper, and zinc contents of the plant compared with the control. When compared to the control, V1 application increased plant fresh weight by 13.25% and phosphorus content by 44.07%; V2 application increased potassium content by 24.29%; V3 application increased plant height by 13.77%, chlorophyll content by 22.30% and nitrogen content by 53.23%; V4 application increased magnesium content by 48.46%, calcium content by 14.36% and zinc content by 16.19%. It was detected that vermicompost had positive effects on plant growth, quality properties and element contents in curly lettuce. As a result, vermicompost can be used successfully as an alternative organic fertilizer for sustainable agriculture in curly lettuce cultivation.

Horticulture

Research Article

Article History
Received : 26.12.2021
Accepted : 24.05.2022

Keywords
Lactuca sativa
Organic fertilizer
Plant growth
Quality properties
Elements

Farklı Vermikompost Dozlarının Kıvırcık Marulda (*Lactuca sativa* L. var. *crispa*) Büyüme, Kalite ve Element İçerikleri Üzerine Etkisi

ÖZET

Bu çalışma, farklı vermikompost dozlarının kıvırcık marulda (*Lactuca sativa* L. var. *crispa*) bitki gelişimi, kalite özellikleri ve element içerikleri üzerine etkilerini belirlemek amacıyla yapılmıştır. Araştırma, Karabük ilinde plastik sera koşullarında saksılarda yürütülmüştür. Çalışmada, vermikompostun (V) 4 farklı dozu, kimyasal gübre (CF) ve kontrol olmak üzere 6 uygulama incelenmiştir. Uygulamalar aşağıdaki gibidir: 1) Kontrol (%100 toprak), 2) V1 (%97.5 toprak + %2.5 vermikompost, w/w), 3) V2 (%95 toprak + %5 vermikompost, w/w), 4) V3 (%90 toprak + %10 vermikompost, w/w), 5) V4 (%80 toprak + %20 vermikompost, w/w) ve 6) CF (%100 toprak + kimyasal gübre). Çalışma tesadüf parselleri deneme desenine göre 3 tekerrürlü olarak kurulmuştur. Araştırma bulgularına göre, vermikompost uygulamaları kontrole göre bitki boyu, bitki yaş ağırlığı, bitki kuru ağırlığı, pazarlanabilir yaprak sayısı, klorofil, azot, fosfor, potasyum, magnezyum, kalsiyum, sodyum, demir, bakır ve çinko içeriğini önemli ölçüde artırmıştır.

Bahçe Bitkileri

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 26.12.2021
Kabul Tarihi : 24.05.2022

Anahtar Kelimeler
Lactuca sativa
Organik gübre
Bitki gelişimi
Kalite özellikleri
Elementler

Kontrol ile karşılaştırıldığında, V1 uygulaması bitki yaş ağırlığını %13.25 ve fosfor içeriğini %44.07 oranında; V2 uygulaması potasyum içeriğini %24.29 oranında; V3 uygulaması bitki boyunu %13.77, klorofil içeriğini %22.30 ve azot içeriğini %53.23 oranında; V4 uygulaması magnezyum içeriğini %48.46, kalsiyum içeriğini %14.36 ve çinko içeriğini %16.19 oranında artırmıştır. Vermikompostun kıvırcık marulda bitki gelişimi, kalite özellikleri ve element içerikleri üzerine olumlu etkilerinin olduğu saptanmıştır. Sonuç olarak, vermikompost kıvırcık marul yetiştiriciliğinde sürdürülebilir tarım için alternatif bir organik gübre olarak başarılı bir şekilde kullanılabilir.

To Cite : Karademir S, Kibar B 2022. Influence of Different Vermicompost Doses on Growth, Quality and Element Contents in Curly Lettuce (*Lactuca sativa* L. var. *crispa*). KSÜ Tarım ve Doğa Derg 25 (Suppl 2): 430-440. https://doi.org/10.18016/ksutarimdoga.vi.1047470.

Atıf Şekli : Karademir S, Kibar B 2022. Farklı Vermikompost Dozlarının Kıvırcuk Marulda (*Lactuca sativa* L. var. crispa) Büyüme, Kalite ve Element İçerikleri Üzerine Etkisi. KSÜ Tarım ve Doğa Derg 25 (Ek Sayı 2): 430-440. https://doi.org/10.18016/ksutarimdoga.vi.1047470.

INTRODUCTION

Fertilization is one of the most important factors determining yield and quality in agricultural production. Nowadays, it is known that human health and sustainability of soils are adversely affected because of excessive and unconscious chemical fertilization to obtain high yield from vegetables. On the other hand, it is reported that continuous use of chemical (inorganic) fertilizers causes pollution of soil and water, soil salinity, decline in organic matter content of soil, heavy metal accumulation, decrease in microbial activities of soil, nitrate accumulation, decrease in soil fertility, poor product quality and serious health problems (Savcı, 2012). For this reason, recently, organic fertilizers have gained great importance as an alternative to chemical fertilizers used in agricultural production all over the world with the new understanding focused on ensuring sustainability in agriculture due to the adverse effects of chemical fertilizers.

Vermicompost is the most popular among organic fertilizers in recent years due to its positive effects on plant growth, yield and soil properties. Additionally, vermicompost is intensely applied as a reliable, economical, and sustainable method in the processing and evaluation of solid organic wastes, which has become a major environmental problem (Shetinina et al., 2019). Vermicompost, which is obtained by composting organic wastes during digestion by earthworms, is an organic product with high economic value (Karmakar et al., 2012). It is also referred to as biohumus (Shetinina et al., 2019). The production and use of vermicompost have been increasing in recent years. Vermicompost is a type of fertilizer that contributes to the use of organic wastes and their recycling. Many organic wastes (plant wastes, animal manure, food wastes, urban solid waste, waste paper, sawdust, etc.) can be used in vermicompost production (Karmakar et al., 2012). Vermicompost is a well stabilized, finely divided peat-like material produced through a non-thermophilic process involving the biodegradation and stabilization of organic materials by interactions between earthworms and microorganisms. Vermicompost can be directly applied to the soil without any other treatment. Vermicompost has very high porosity, aeration, drainage, water holding capacity and microbial activity, and a low C:N ratio (Kumar and Topal, 2015). Vermicompost is very rich in macro and micronutrients, beneficial soil microorganisms, various enzymes, vitamins, humic acid, organic matter, and growth hormones (Özkan et al., 2016). Vermicompost is a highly nutritive organic fertilizer rich in nitrogen (N), phosphorus (P) and potassium (K). In addition, 97% of the plant nutrients (especially N, P and K) in the vermicompost are in forms that are readily taken up by the plants. Vermicompost has a vast surface area, providing strong absorbability and retention of nutrients. Vermicompost may influence plant growth directly via the supply of plant growth regulating substances (PGRs). Vermicompost has a wide range of uses as organic fertilizer and soil conditioner in both organic and conventional agriculture because of its advantageous properties like promoting plant growth, increasing the physical, chemical, and biological properties of soil, restoring and improving natural fertility of soil without polluting the environment (Shetinina et al., 2019). Vermicompost is a good and ideal organic fertilizer that reduces environmental pollution and restricts the use of chemical fertilizers for sustainable agriculture. Therefore, vermicompost is considered as a promising alternative to inorganic fertilizers used in agriculture and growing media used in the greenhouse (Mahmoud and Gad, 2020). Vermicompost plays a major role in improving growth and yield of different field crops, vegetables, fruits, and flowers. It was determined that growth, yield and quality of many vegetables increased with the application of vermicompost (Kashem et al., 2015; Degwale, 2016;

Durak et al., 2017; Adiloğlu et al., 2018; Kenea and Gedamu, 2018; Rekha et al., 2018). Vermicompost has a significant positive influence on seed germination, seedling vigor, plant growth, flowering, fruiting, root development, leaf length, number of leaves, colour, shelf-life and quality of vegetables (Peyvast et al., 2008). Vermicompost can also suppress plant diseases, pests, and plant parasitic nematodes. In addition, it was reported that vermicompost improved the physical, chemical, and biological properties of the soil and increased the nutrient content of the soil (Özkan et al., 2016).

As in the whole world, chemical fertilizers are mostly used in fertilization to increase the yield in vegetable growing in Turkey. To provide a sustainable agriculture system that protects human health, environment, and natural resources in the long term in vegetable growing where the use of chemical fertilizers is excessive, it is necessary to expand the use of organic fertilizers such as vermicompost instead of chemical fertilizers. The use of vermicompost fertilizer in vegetable growing is an agricultural activity that has become widespread in Turkey with the increase in environmental awareness and the adoption of high-quality product consumption in recent years, though it is widely used in many countries for many years. In addition, many agricultural wastes in Turkey are either incinerated or thrown away. The use of vermicompost is one of the best ways to evaluate agricultural wastes in the country. For this reason, it is of great importance to produce vermicompost, to promote the use, to conduct studies on its benefits and to share the obtained results with the producers in Turkey.

Lettuce (*Lactuca sativa* L.) belongs to the Compositae family and is an annual winter vegetable. Lettuce, which has been cultivated and consumed fondly for many years in the world, can be found in markets throughout the year. Lettuce, whose fresh leaves are used as vegetable, is among the species of high commercial importance. It is one of the most produced and consumed winter vegetables in Turkey and it has high economic value. It can be grown in the open field or greenhouse conditions using different cultivars all year round almost all over the country. The vegetation period of lettuce is short, and it can be grown in 2-3 months. In Turkey, lettuce was grown in an area of 21821 ha with a production of 520151 tons in 2020 (TÜİK, 2021). Lettuce develops rapidly in soils rich in organic matter and comes to harvest maturity in a short time. As with other vegetables, lettuce is usually grown using inorganic fertilizers. On the other hand, fertilization in lettuce must be performed carefully because it is a leafy vegetable and consumed uncooked. Lettuce is quite sensitive to N fertilization. However, excessive and unconsciously used chemical N fertilizers increase the nitrate accumulation in the plant, which is harmful to human health. Lettuce is one of the vegetables with the highest nitrate accumulation. Therefore, the use of organic fertilizers in lettuce cultivation should be expanded.

It is very important to examine the effects of vermicompost on soil and plant productivity to increase yield and quality, improve the physical and chemical structure of the soil and prevent environmental pollution in lettuce cultivation. Although there are many studies showing the effects of vermicompost on plant growth and yield, it has been found that these effects are not general or constant and show great variability. The variability in the effects of vermicompost may depend on the cultivation conditions, plant species and variety, physical, chemical, and biological properties of vermicompost, earthworm species used and age of vermicompost (Warman and AngLopez, 2010). Generally, it is known that vermicompost positively affects the soil properties, plant growth and health. However, there are not enough academic studies about how much the most suitable dose should be for which vegetable. Accordingly, knowledge and experience of producers on this issue is lacking. In this context, determining of optimum vermicompost doses for plant growth, quality and nutrient content of lettuce is necessary, and it will provide important contributions to further studies.

The objective of this study was to investigate the effects of different vermicompost doses on growth parameters, quality properties and element contents of curly lettuce. In addition, a comparison of vermicompost with chemical fertilizer was made.

MATERIAL and METHOD

The research was carried out in pots under plastic greenhouse conditions in Karabük province of Turkey (lat. 41°07' N, long. 32°41' E, alt. 311 m) during the autumn growing season of 2017. Curly lettuce (*Lactuca sativa* L. var. *crispa* cv. Maritima) was used as plant material in the study.

The soil used in the experiment was clay-loam, pH value of 7.4, organic matter content of 2.73%, lime ratio of 13.16% and EC value of 0.67 dS m^{-1}. The N, P and K contents of the soil were 0.16%, 7.70 mg kg^{-1} and 385.00 mg kg^{-1}, respectively. The vermicompost used in the experiment was pH value of 6.9, organic matter content of 20%, EC value of 3.7 dS $^{m-1}$, N content of 1.20%, P content of 1.09% and K content of 3.51%.

In the study, 6 applications as 4 different doses of vermicompost (V), chemical fertilizer (CF) and control were examined. The applications were as follows: 1) Control (100% soil), 2) V1 (97.5% soil + 2.5% vermicompost, w/w), 3) V2 (95% soil + 5%

vermicompost, w/w), 4) V3 (90% soil + 10% vermicompost, w/w) 5) V4 (80% soil + 20% vermicompost, w/w) and 6) CF (100% soil + chemical fertilizer). The experiment was performed in completely randomized design with 3 replications. There were 5 pots in each replication and 15 pots in each application. In total, 90 pots (6 x 3 x 5) were used, and 90 plants were grown in the greenhouse. In CF application, ammonium sulphate, triple superphosphate and potassium sulphate fertilizers as commercial fertilizer were applied at 15 kg N da^{-1}, 10 kg P_2O_5 da^{-1} and 15 kg K_2O da^{-1}. All of P and K fertilizers and half of the N fertilizer were given at the time of planting, while the other half of the N fertilizer was given two weeks after planting. No fertilizer was added to the control application.

The curly lettuce seedlings were grown in plastic greenhouse according to standard procedures. The curly lettuce seeds were sown in multi-pot plastic trays consist of 45 pots (4 × 4 × 4 cm), containing a mixture of peat and perlite (3:1, v/v) on 17 August, 2017. To grow plants, each plastic pot (26 x 24 x 17 cm) was filled with 5 kg of growing medium prepared with different doses of soil, vermicompost or chemical fertilizer. Twenty seven days after sowing, seedlings were transplanted into pots at the 4-5 true leaf stage on 13 September, 2017. Life water was given immediately after planting the seedling. All necessary cultural practices were carried out regularly until harvest. No plant protection product was used during the experiment. The plants were harvested 53 days after planting on 5 November, 2017. During the experiment, the temperature and relative humidity values in the greenhouse were recorded using a temperature and humidity recorder (Onset HOBO UX100-003 Data Logger, USA) (Figure 1). Necessary measurements and analyzes of the harvested plants were made in the laboratory of Bolu Abant Izzet Baysal University, Faculty of Agriculture, Department of Horticulture.

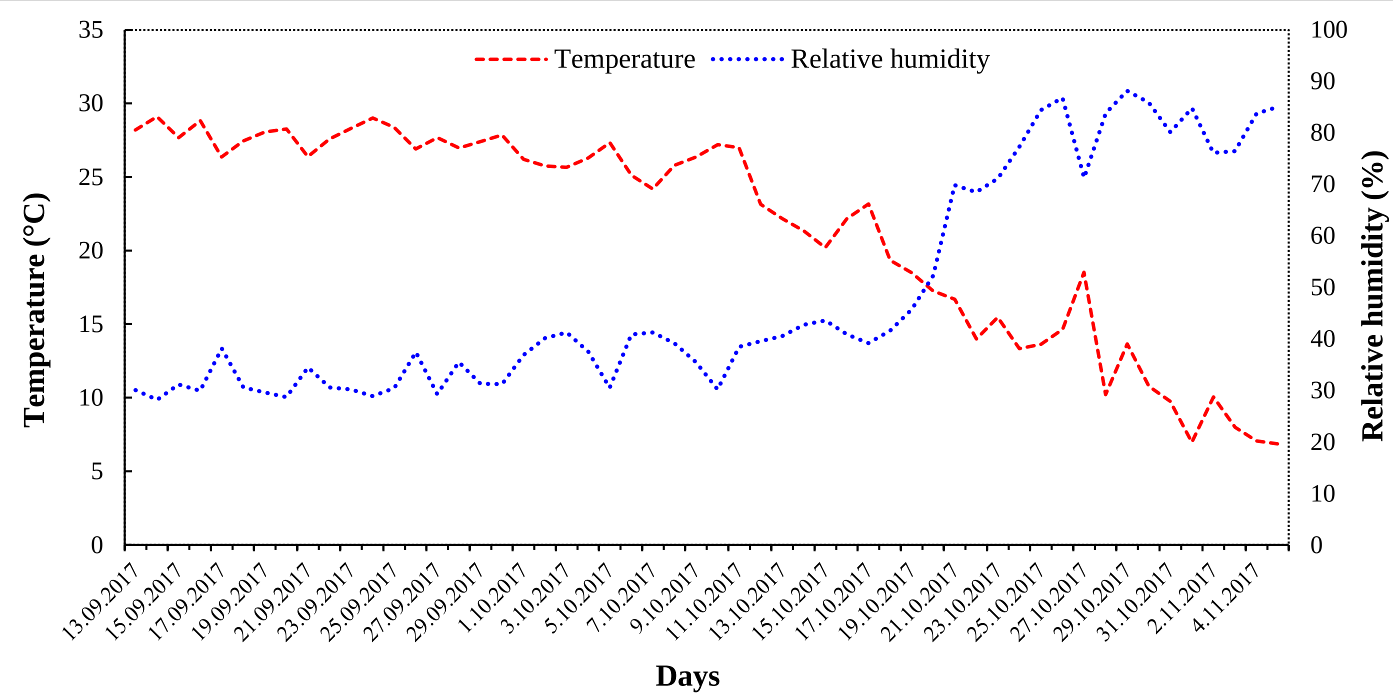

Figure 1. Temperature and relative humidity values measured in the greenhouse during the experiment

Şekil 1. Deneme süresince sera içerisinde ölçülen sıcaklık ve nispi nem değerleri

In this study, 23 properties related to plant growth and quality and 24 elements were determined. Plant height (cm), plant diameter (cm), root length (cm), leaf length (cm) and leaf width (cm) were determined by measuring with a ruler. Plant fresh weight (g), root fresh weight (g) and discard leaf weight (g) were detected by weighing with a precision balance. Plant dry weight (g) and root dry weight (g) were determined by weighing with a precision balance the samples after drying in an oven at 65 °C until they reach a constant weight. The number of marketable leaves (number plant^{-1}) was determined by counting the marketable leaves and the number of discard leaves was detected by counting the discard leaves. The root collar diameter (mm) was measured with a digital caliper. The dry matter content (%) was determined by using the procedures of AOAC (1990). The pH values of the samples were measured using a digital pH meter (Thermo Scientific, Orion Star A111). Total soluble solid content (%) was measured with a hand-held refractometer (ATC-1, Atago, Japan). The colour properties of the leaves (L*, a*, b*, C* and h°) were measured using a colorimeter (3NH NR60CP). The chlorophyll content of the leaves (spad) was determined with a chlorophyll meter (Apogee Chlorophyll Concentration Meter, MC-100). The nitrate and P contents of the samples (mg kg^{-1}) were determined using UV-visible spectrophotometer (UV-1800, Shimadzu, Japan). The N and sulphur (S) contents of the samples (%) were detected using Elemental Analyzer CHNS-O (Thermo Scientific, Flash 2000). To determine element (aluminum-Al, arsenic-As, barium-Ba, boron-B, cadmium-Cd, calcium-Ca, chrome-Cr, cobalt-Co, copper-Cu, iron-Fe, lead-Pb, magnesium-Mg, manganese-Mn, mercury-Hg, nickel-Ni, potassium-K, selenium-Se, sodium-Na, thallium-Tl, tinnen-Sn and zinc-Zn) contents of the samples (mg kg^{-1}), dried samples were firstly ground by using a grinder (MC23200, Siemens, Germany) and then prepared for analysis according to the microwave digestion method. Element contents of the samples were detected using inductively coupled plasma-mass spectrometry ICP-MS X Series (Thermo Scientific, UK).

All chemical analyses were performed with three replications. Measurements for morphological properties carried out with ten replications. Mean values and standard errors were calculated, and the data were expressed as mean ± standard error. Data obtained in the study were subjected to analysis of variance (ANOVA) using SPSS statistical software (Version 23.0). Differences among means were evaluated by Duncan's multiple range test and the significance was accepted at $P < 0.05$ level.

RESULTS and DISCUSSION

Effects of the applications evaluated in the study on plant height, plant diameter, plant fresh weight and plant dry weight in curly lettuce are given in Table 1. The difference among the applications in terms of plant height, plant diameter and plant fresh weight was significant at the $P < 0.05$ level, while the difference among the applications in terms of plant dry weight was significant at the $P < 0.01$ level. Plant height, plant diameter, plant fresh weight and plant dry weight depending on the applications ranged from 19.02 to 21.64 cm, 27.14 to 30.64 cm, 187.46 to 235.11 g and 12.67 to 17.97 g, respectively. Among the applications, the highest plant height was determined in V3 application, and it was followed by CF, V4, V2 and V1 applications. The highest plant diameter was found in CF application closely followed by V4 application. Plant fresh weight is the most important yield parameter in curly lettuce. CF and V1 applications which there was no statistically significant difference between them possessed the highest plant fresh weight. In parallel with plant fresh weight, the highest plant dry weight was also observed in CF application followed by V3 and V1 applications. However, the lowest values in terms of plant properties mentioned above were observed in the control. In the present study, the higher values in terms of plant height, plant fresh weight and plant dry weight were obtained from all vermicompost applications (V1, V2, V3 and V4) in comparison with the control application. When compared to the control, V3 application increased plant height by 13.77% and plant dry weight by 32.68%. In addition, it was determined that V1 application increased plant fresh weight by 13.25% compared with the control (Table 1).

Table 1. Effect of different applications on plant height, plant diameter, plant fresh weight and plant dry weight in curly lettuce

Çizelge 1. Kıvırcık marulda farklı uygulamaların bitki boyu, bitki çapı, bitki yaş ağırlığı ve bitki kuru ağırlığı üzerine etkisi

Application	Plant height (cm)	Plant diameter(cm)	Plant fresh weight(g)	Plant dry weight(g)
Control	19.02±0.46b*	27.14±0.46b*	187.46±10.66b*	12.67±1.36d**
V1	19.41±0.59ab	27.44±0.90b	212.30±11.88ab	16.05±0.74abc
V2	19.47±1.54ab	26.73±0.68b	194.47±13.14b	14.64±0.81bcd
V3	21.64±0.96a	28.08±1.14b	199.84±9.60b	16.81±0.74ab
V4	20.05±0.69ab	28.64±0.93ab	194.46±7.54b	13.45±0.76cd
CF	21.46±0.35ab	30.64±0.44a	235.11±14.49a	17.97±0.89a

Means followed by different letters within the same columns are statistically different according to Duncan's multiple range test. *: significant at $P < 0.05$, **: Significant at $P < 0.01$.

Similar to the results in this study, Hernandez et al. (2010) investigated effect of vermicompost and compost on lettuce production and the highest plant fresh weight was determined in inorganic fertilizer. In another study, Durak et al. (2017) stated that yield and growth parameters in lettuce were improved by vermicompost application when compared to control and conventional fertilization. Likewise, Özkan and Müftüoğlu (2016) investigated the effects of different doses of vermicompost on lettuce and reported that vermicompost increased plant growth and yield. In the study conducted by Adiloğlu et al. (2018) on lettuce, significant increases in vermicompost applications were found in terms of plant height, plant diameter and plant fresh weight as compared with the control, which was agreed with the findings in this study.

According to Table 2, there were significant differences ($P < 0.05$) in terms of root length and root collar diameter among the applications. On the other hand, no statistically significant difference was found among the applications in terms of root fresh weight and root dry weight. In the control application, the root length was found to be the highest with 12.41 cm, and it was followed by V4 and V1 applications which were not statistically different. However, the lowest values for root length was detected in CF, V3 and V2 applications. Root collar diameter varied from 12.74 (V4 application) to 16.79 mm (V3 application) depending on the applications (Table 2).

In a study conducted in lettuce, there was no significant difference in terms of root length among control and vermicompost applications (Adiloğlu et al., 2018). Getnet and Raja (2013) reported that vermicompost applications increased root length compared to control in cabbage, which was not compatible with the results of this study. In the study carried out by Özkan et al. (2016) in spinach, the root fresh weight in vermicompost applications was found to be significantly higher than the control, and the root fresh weight increased as the amount of vermicompost increased. Likewise, Kashem et al. (2015) reported that vermicompost applications significantly increased root dry weight as compared with the control in tomato. In another study, it was determined that vermicompost applications significantly increased root length, root fresh and dry weight compared to the control in eggplant (Kumari et al., 2017).

Table 2. Effect of different applications on root length, root collar diameter, root fresh weight and root dry weight in curly lettuce

Çizelge 2. Kıcırcık marulda farklı uygulamaların kök uzunluğu, kök boğazı çapı, kök yaş ağırlığı ve kök kuru ağırlığı üzerine etkisi

Application	Root length (cm)	Root collar diameter (mm)	Root fresh weight (g)	Root dry weight (g)
Control	12.41±0.52a*	15.31±1.21ab*	17.04±1.63^{ns}	4.65±0.79^{ns}
V1	11.70±0.30ab	16.12±1.53a	20.36±1.17	3.97±0.68
V2	11.29±0.43b	15.44±1.53ab	16.83±1.15	3.31±0.43
V3	11.24±0.32b	16.79±1.52a	16.28±0.99	3.57±0.14
V4	11.84±0.34ab	12.74±1.50b	17.44±0.89	3.10±0.28
CF	10.80±0.23b	14.30±1.38ab	17.50±2.07	4.25±0.71

Means followed by different letters within the same columns are statistically different according to Duncan's multiple range test. *: significant at $P < 0.05$, ns: non-significant.

The analysis of variance showed that there were significant differences ($P < 0.05$) among the applications in terms of all leaf properties examined except for leaf width and number of discard leaves. Among the applications, the highest leaf length was determined in CF application with 18.08 cm, and it was closely followed by V1, V3, control and V2 applications which were statistically in the same group with CF. However, the lowest leaf length was observed in V4 application with 16.62 cm. As in leaf length, the highest number of marketable leaves was found in CF application (25.58) followed by V1, V4, V3 and V2 applications, while the lowest number of marketable leaves was recorded in control application (21.67). Discard leaf weight ranged from 9.84 (V1 application) to 19.47 g (CF application). The lower values in terms of discard leaf weight were obtained from the vermicompost applications in comparison with control and CF. The lower number and weight of discard leaves is very important in terms of market value and quality in lettuce. With respect to number of marketable leaves, the higher values were obtained from vermicompost applications than the control application. It was determined that V1 application increased number of marketable leaves by 12.28% compared to the control (Table 3).

It was found that vermicompost applications increased leaf length, leaf width and number of leaves as compared with the control in lettuce and leaf width also increased as the dose of vermicompost increased (Özkan and Müftüoğlu, 2016). Similarly, it was reported that vermicompost applications significantly increased leaf length, leaf width and number of leaves compared to the control in cabbage (Getnet and Raja, 2013), spinach (Özkan et al., 2016) and lettuce (Adiloğlu et al., 2018). Kenea and Gedamu (2018) found that vermicompost applications increased leaf length in comparison with control in garlic. Rekha et al. (2018) reported that vermicompost application increased number of leaves compared to the control in pepper. In addition to, it was reported that the number of leaves increased as the dose of vermicompost increased in tomato (Kashem et al., 2015) and garlic (Degwale, 2016).

Significant differences ($P < 0.01$) were found among the applications with regards to chlorophyll content, dry matter content, total soluble solid content and nitrate content. However, no statistically significant difference was found among the applications in terms of pH value. The chlorophyll content in curly lettuce plants belonging to different applications varied from 19.69 to 24.08 spad. The highest values with regard to chlorophyll content were found in V3, V2, V4 and V1 applications, while the lowest value were observed in the control application. The maximum and minimum dry matter contents were obtained from V3 (8.45%) and V1 (6.51%) applications, respectively. When the total soluble solid content is examined, the highest values were found in control, V3 and V2 applications (3.10, 3.08 and 2.98%, respectively). Whereas, the lowest total soluble solid content was detected in V1 application (2.39%). There was a wide range variation in nitrate content of the plants. The nitrate content varied between 516.78 and 2694.33 mg kg^{-1} depending on the applications. In the current study, V3, V2, V4 and CF applications had the highest nitrate contents, and they were statistically in the same group. Conversely, the lowest nitrate contents were observed in control and V1 applications. The nitrate content in the control were considerably lower than those of other applications. It was determined that vermicompost applications generally provide an increase in chlorophyll content when compared to control and CF. In the present study, V3 application increased chlorophyll content by 22.30% compared with the control (Table 4).

Table 3. Effect of different applications on leaf length, leaf width, number of marketable leaves, number of discard leaves and discard leaf weight in curly lettuce

Çizelge 3. Kıcırcık marulda farklı uygulamaların yaprak uzunluğu, yaprak genişliği, pazarlanabilir yaprak sayısı, ıskarta yaprak sayısı ve ıskarta yaprak ağırlığı üzerine etkisi

Application	Leaf length (cm)	Leaf width (cm)	Number of marketable leaves (number $plant^{-1}$)	Number of discard leaves (number $plant^{-1}$)	Discard leaf weight (g)
Control	17.04±0.38ab*	17.72±0.42^{ns}	21.67±0.53b*	2.83±0.51^{ns}	16.78±3.33ab*
V1	17.29±0.43ab	18.35±0.32	24.33±1.30ab	2.58±0.38	9.84±1.59c
V2	16.98±0.53ab	18.09±0.63	22.75±0.87ab	2.67±0.26	14.07±1.57abc
V3	17.16±0.41ab	17.98±0.40	23.58±0.82ab	3.42±0.43	16.16±1.71abc
V4	16.62±0.45b	17.81±0.34	24.17±1.30ab	2.42±0.38	10.70±2.10bc
CF	18.08±0.41a	18.41±0.46	25.58±1.03a	3.00±0.28	19.47±1.96a

Means followed by different letters within the same columns are statistically different according to Duncan's multiple range test. *: significant at $P < 0.05$, ns: non-significant.

Table 4. Effect of different applications on chlorophyll content, dry matter content, pH, total soluble solid content and nitrate content in curly lettuce

Çizelge 4. Kıcırcık marulda farklı uygulamaların klorofil içeriği, kuru madde içeriği, pH, suda çözünebilir kuru madde miktarı ve nitrat içeriği üzerine etkisi

Application	Chlorophyll content (spad)	Dry matter content (%)	pH	Total soluble solid content (%)	Nitrate content (mg kg^{-1})
Control	19.69±0.87c**	7.77±0.37ab**	5.99±0.02^{ns}	3.10±0.17a**	516.78±60.96b**
V1	21.68±0.61abc	6.51±0.30c	6.00±0.02	2.39±0.07c	1189.89±266.35b
V2	23.10±0.64ab	7.39±0.15b	6.01±0.02	2.98±0.04ab	2210.44±129.55a
V3	24.08±0.58a	8.45±0.48a	6.05±0.02	3.08±0.21a	2694.33±239.43a
V4	22.61±1.17ab	6.93±0.12bc	6.00±0.02	2.66±0.12bc	2130.89±178.86a
CF	20.67±0.85bc	7.37±0.27b	6.06±0.03	2.70±0.06bc	2054.56±437.44a

Means followed by different letters within the same columns are statistically different according to Duncan's multiple range test. **: Significant at $P < 0.01$, ns: non-significant.

In the study carried out by Baliah and Muthulakshmi (2017) in okra, the chlorophyll content in vermicompost applications was found to be higher than control, which was consistent with the findings in this study. Degwale (2016) determined that vermicompost increased dry matter content as compared with the control in garlic. Tavalı et al. (2014) reported that there was no significant difference in terms of pH value among control, chemical fertilization and vermicompost applications in cauliflower and cabbage, respectively, which was agreed with the findings in this study. Aminifard and Bayat (2016) observed that no significant difference was found for total soluble solids between control and vermicompost treatments in pepper. In the present study, the higher nitrate content detected in vermicompost applications compared to the control may be due to the high N content of vermicompost. In the study conducted by Vigardt (2012) on spinach, higher nitrate content in vermicompost application was found as compared with the control, and it was noted that the nitrate content also increased as the dose of vermicompost increased, which was consistent with the findings in this study. It was determined that the nitrate content determined in this study does not exceed the limit value reported for lettuce by the Türk Gıda Kodeksi (2008).

As seen in Table 5, effects of different applications on b* and C* (Chroma) colour values of curly lettuce were statistically significant ($P < 0.05$). On the other hand, there was no statistically significant difference among the applications with respect to L*, a* and h° (Hue angle) colour values. The b* and C* colour values of the curly lettuce samples varied from 26.02 to 29.99 and 28.56 to 31.93, respectively. The higher values in terms of b* and C* colour properties were obtained from the control compared to other applications. On the contrary, the lowest b* and C* values were recorded in V1 application. An apparent effect of vermicompost applications on the colour properties of curly lettuce was not observed (Table 5).

Colour is one of the most important factors in terms of quality in lettuce. Similar to the results in this study, in the study carried out by Özen (2018) in lettuce, the effect of different organic materials (waste mushroom compost, leonardite and vermicompost) and their different doses on colour was found to be insignificant.

Table 5. Effect of different applications on colour properties of the leaves (L*, a*, b*, C* and h°) in curly lettuce
Çizelge 5. Kıcırcık marulda Marulda farklı uygulamaların yaprakların renk özellikleri (L, a*, b*, C* ve h°) üzerine etkisi*

Application	L*	a*	b*	C*	h°
Control	52.97±1.00^{ns}	-12.30±0.52^{ns}	29.99±0.91a*	31.93±0.94a*	112.29±0.42^{ns}
V1	53.36±1.27	-11.34±0.54	26.02±0.94b	28.56±1.02b	113.14±0.55
V2	52.70±1.53	-12.70±0.53	28.52±0.97ab	31.23±1.09ab	113.79±0.35
V3	51.64±1.24	-12.29±0.51	28.28±0.63ab	30.92±0.68ab	113.35±0.54
V4	53.03±1.70	-12.17±0.64	27.63±0.88ab	30.22±1.04ab	110.77±2.87
CF	53.83±1.23	-12.10±0.66	27.70±1.17ab	30.29±1.33ab	110.63±2.79

Means followed by different letters within the same columns are statistically different according to Duncan's multiple range test. *: significant at $P < 0.05$, ns: non-significant.

Effects of different applications on element contents of curly lettuce are shown in Table 6. The difference among the applications in terms of Al, Cd, Co, Cr, Cu, K, Mg, N, Na, Ni, P, S and Sn contents was significant at the $P < 0.01$ level, while the difference among the applications in terms of As, Ca, Fe, Mn, Pb and Zn contents was significant at the $P < 0.05$ level. On the other hand, no statistically significant difference was found among the applications in terms of B, Ba and Se contents. In addition to, it was determined that Hg and Tl contents in curly lettuce plants were not detected because of below the detection limits (Table 6).

In the present study, a considerable variation in terms of element contents was observed among the applications. K, Mg, Ca, P, Na, N and S contents depending on the applications varied from 18163.67 to 22574.78 mg kg^{-1}, 7846.83 to 11649.49 mg kg^{-1}, 4033.78 to 4880.33 mg kg^{-1}, 2253.33 to 3681.22 mg kg^{-1}, 1110.00 to 2910.00 mg kg^{-1}, 4.49 to 6.88% and 3.32 to 7.04%, respectively. Among the applications, the lowest values in terms of K, Mg, P, Na and N were observed in the control. The highest K content was obtained from all vermicompost applications (V1, V2, V3 and V4) and CF which were statistically in the same group. The plants in V4 application possessed the highest Mg content. Likewise, the highest Ca content was also found in V4 application, and it was closely followed by V3 application. The highest values regarding P and S contents were recorded in CF application. The highest N content was observed in V3 application followed by V1 application. Regarding Na content, the highest values were determined in V4, V3 and V2 applications which were not statistically different. The lowest values for Ca content were observed in V1, control, V2 and CF applications. V1 and V2 applications had the lowest S content. It was determined that vermicompost applications generally increased essential mineral contents such as K, Mg, Ca, P, Na and N in the plant compared with the control. When compared to the control, V4 application increased Mg content by 48.46%, Ca content by 14.36% and Na content by 162.16%. It was determined that V1 application increased P content by 44.07% compared to the control. V2 application increased K content by 24.29% as compared with the control. In addition to, it was found that V3 application increased N content by 53.23% compared to the control. On the contrary, the lower values in terms of S content were obtained from vermicompost applications in comparison with control and CF. In applications containing vermicompost (V1, V2, V3 and V4), Ca and Na contents increased as the dose of vermicompost increased (Table 6).

Fe, Zn, Mn, Cu and Se contents depending on the applications varied from 703.89 to 848.45 mg kg^{-1}, 49.11 to 79.79 mg kg^{-1}, 60.30 to 70.66 mg kg^{-1}, 14.53 to 21.88 mg kg^{-1} and 0.20 to 0.27 mg kg^{-1}, respectively. When the Fe content was examined, it was determined that there was no statistically significant difference among V4, CF, V3, V2 and control applications and they had the highest Fe content. However, the lowest Fe content was observed in V1 application. The highest Zn content was obtained in V4, V3, control, V1 and V2 applications which were not statistically different. Conversely, Zn content in CF application was found to be considerably lower than those of other applications examined in the study. Mn content was the highest in V3 application followed by CF, V4 and control applications, while it was the lowest in V1 and V2 applications. The highest values in terms of Cu content were determined in vermicompost applications (V1, V2, V3 and V4) which were statistically in the same group, whereas the lowest Cu content was observed in the control. In applications containing vermicompost (V1, V2, V3 and V4), Fe content increased as the dose of vermicompost increased. Cu content in vermicompost applications was found to be higher than control and chemical fertilizer (CF). When compared to the control, V4 application increased Zn content by 16.19% and Fe content by 8.72%. V3 application increased Mn content by 8.77% as compared with the control. Additionally, V1 application increased Cu content by 50.58% compared to the control (Table 6).

Table 6. Effect of different applications on element contents in curly lettuce
Çizelge 6. Kıcırcık marulda farklı uygulamaların element içerikleri üzerine etkisi

Application	Al(mg kg^{-1})	As(mg kg^{-1})	B(mg kg^{-1})	Ba(mg kg^{-1})	Ca(mg kg^{-1})
Control	355.08±26.07bc**	0.41±0.02b*	59.35±2.32^{ns}	27.95±1.84^{ns}	4267.56±215.17b*
V1	311.89±15.74cd	0.39±0.03b	59.88±4.65	25.21±2.13	4033.78±89.90b
V2	365.69±49.54bc	0.40±0.03b	60.29±4.19	28.12±2.27	4303.89±286.71b
V3	268.14±45.36d	0.47±0.02ab	58.45±2.37	27.84±2.36	4514.78±151.20ab
V4	381.46±16.46b	0.49±0.02a	59.36±1.93	27.32±1.24	4880.33±125.59a
CF	454.22±19.51a	0.44±0.04ab	63.96±2.50	25.03±1.71	4322.33±127.79b
Application	Cd (mg kg^{-1})	Co (mg kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})
Control	0.63±0.02a**	0.34±0.01a**	1.90±0.16b**	14.53±0.32c**	780.41±51.50ab*
V1	0.47±0.03b	0.23±0.01d	1.87±0.04b	21.88±1.53a	703.89±11.92b
V2	0.51±0.05b	0.26±0.02cd	1.91±0.22b	19.01±0.99ab	788.06±61.35ab
V3	0.56±0.02ab	0.30±0.02abc	2.12±0.08b	19.05±0.84ab	798.69±46.87a
V4	0.55±0.03ab	0.29±0.01bc	2.25±0.12b	19.88±0.81ab	848.45±23.98a
CF	0.62±0.04a	0.31±0.01ab	3.02±0.48a	17.68±0.89b	844.06±10.89a
Application	Hg (mg kg^{-1})	K (mg kg^{-1})	Mg (mg kg^{-1})	Mn (mg kg^{-1})	N (%)
Control	nd	18163.67±503.14b**	7846.83±441.82d**	64.96±2.44ab*	4.49±0.04e**
V1	nd	21379.11±478.36a	9233.55±266.72bc	60.30±1.72b	6.86±0.03ab
V2	nd	22574.78±474.96a	8670.50±217.08cd	61.83±3.41b	6.77±0.05b
V3	nd	22023.56±902.81a	10116.68±234.49b	70.66±4.09a	6.88±0.03a
V4	nd	22073.67±556.00a	11649.49±655.51a	66.91±2.39ab	5.15±0.03d
CF	nd	21078.11±760.67a	8730.34±227.44cd	68.05±1.24ab	5.79±0.03c
Application	Na (mg kg^{-1})	Ni (mg kg^{-1})	P (mg kg^{-1})	Pb (mg kg^{-1})	S (%)
Control	1110.00±155.44d**	4.95±0.85a**	2253.33±9.37e**	2.39±0.09a*	5.39±0.12b**
V1	1839.56±140.20bc	2.94±0.51b	3246.33±9.90b	1.82±0.22b	3.33±0.03e
V2	2229.44±183.17ab	3.07±0.60b	2525.11±52.93c	2.19±0.23ab	3.32±0.02e
V3	2414.33±276.03ab	2.81±0.27b	2400.78±13.58d	2.43±0.10a	4.33±0.02c
V4	2910.00±388.83a	3.25±0.22b	2545.78±9.30c	2.09±0.05ab	3.53±0.04d
CF	1386.33±137.75cd	4.95±0.32a	3681.22±7.60a	2.09±0.14ab	7.04±0.06a
Application	Se (mg kg^{-1})	Sn (mg kg^{-1})	Tl (mg kg^{-1})	Zn (mg kg^{-1})	
Control	0.26±0.03^{ns}	0.94±0.14b**	nd	68.67±10.48ab*	
V1	0.22±0.01	1.27±0.27b	nd	68.46±5.26ab	
V2	0.20±0.01	0.65±0.02b	nd	59.67±5.44ab	
V3	0.21±0.02	0.86±0.10b	nd	76.04±12.78a	
V4	0.25±0.03	2.05±0.69b	nd	79.79±5.11a	
CF	0.27±0.02	5.57±1.86a	nd	49.11±2.60b	

Means followed by different letters within the same columns are statistically different according to Duncan's multiple range test. *: Significant at $P < 0.05$, **: Significant at $P < 0.01$, ns: non-significant, nd: not detected.

The Al contents of plants showed a wide range of variation from 268.14 to 454.22 mg kg-1. The minimum and maximum values for Al were determined in V3 and CF applications, respectively. The highest As content was found in V4, V3 and CF applications which were not statistically different, whereas the lowest As content was determined in V1, V2 and control applications. Cd content was found to between 0.47 (V1 application) and 0.63 mg kg^{-1} (control). Co content was in the range from 0.23 (V1 application) to 0.34 mg kg^{-1} (control). In the current study, Sn and Cr contents in the CF application (5.57 and 3.02 mg kg^{-1}, respectively) were considerably higher than those of other applications examined in the study. On the other hand, Sn and Cr contents were determined at the lowest level in control, V1, V2, V3 and V4 applications. The highest Ni content was found in control and chemical fertilizer (CF) applications with 4.95 mg kg^{-1}. On the contrary, Ni content was the lowest in vermicompost applications

(V1, V2, V3 and V4). The lowest value in terms of Pb content was obtained in V1 application, though the highest values were observed in V3, control, V2, V4 and CF applications which were not statistically different. In applications containing vermicompost (V1, V2, V3 and V4), As and Cr contents also increased as the dose of vermicompost increased. The Cd, Co, and Ni contents in vermicompost applications were found to be lower than control and CF. Additionally, Al, Cr and Sn contents in vermicompost applications were lower than that of chemical fertilizer (Table 6). This is very important considering that Cd, Co, Ni, Al, As, Pb, Cr and Sn are heavy metals.

It is thought that the K (3.51%), N (1.20%) and P (1.09%) contents of vermicompost used in the experiment is effective in the increase K, N and P contents of plant in vermicompost applications compared to the control in this study. Similar to the results in this study, Hernandez et al. (2010) reported that the highest Ca, Mg, Fe, Cu, and Mn contents in lettuce were determined in vermicompost among vermicompost, compost and inorganic fertilizer applications. In addition to, highest P content in the plant was found in inorganic fertilizer, which was also compatible with the results of this study. Durak et al. (2017) determined that Mg, P, Fe, Mn, Zn and Cu contents in vermicompost applications were higher than the control in lettuce. Researchers also reported that K, Ca, Fe and Mn contents in vermicompost applications were higher than the conventional fertilization. In another study carried out in lettuce, there was no significant difference in terms of K, Mg, P, Ca and N contents among control and vermicompost applications (Adiloğlu et al., 2018). In the study conducted by Özen (2018) on lettuce, it was determined that Na and Fe contents increased as the dose of vermicompost increased, which was compatible with the results of this study. In the previous studies, it was determined that vermicompost applications increased K, Ca, Mg, N, P, Fe, Mn, Zn, and Cu contents in the plant compared to the control in different vegetables (Peyvast et al., 2008; Tavalı et al., 2014). Tavalı et al. (2014) found that there was no significant difference in terms of Fe, Zn and Cu contents among control, chemical fertilizer and vermicompost applications in cabbage.

CONCLUSIONS

Nowadays, in parallel with the importance given to environment, the use of organic fertilizers such as vermicompost is becoming increasingly important. As in the whole world, the use of vermicompost in vegetable growing has been increasing in recent years in Turkey. According to findings obtained from the present study, the applications evaluated in the study significantly affected the plant growth, quality properties and element contents in curly lettuce. The results indicated that vermicompost applications generally increased plant height, plant fresh weight, plant dry weight, number of marketable leaves, chlorophyll, N, P, K, Mg, Ca, Na, Fe, Cu, and Zn contents of the plant compared to control application. In addition, as the dose of vermicompost increased in vermicompost applications, Ca, Na and Fe contents increased. In terms of heavy metals such as Cd, Co and Ni, vermicompost applications showed lower values than control and chemical fertilizer. Likewise, heavy metal contents such as Al, Cr and Sn in vermicompost applications were lower than that of chemical fertilizer. Consequently, all vermicompost applications (V1, V2, V3 and V4) in terms of plant height, number of marketable leaves, chlorophyll, K and Zn contents; V1 application in terms of plant fresh weight and P content; V1 and V3 applications in terms of plant dry weight and N content; V3 and V4 applications in terms of Ca and Mn contents; V4 application in terms of Mg content; V2, V3 and V4 applications in terms of Fe content were found to be the most successful vermicompost applications. It was concluded that vermicompost can be used successfully as an alternative organic fertilizer for curly lettuce cultivation. The results of this study will be beneficial in terms of raising the awareness of producers, reducing the use of chemical fertilizers in agricultural production, contributing to the widespread use of vermicompost, obtaining healthier and higher quality agricultural products in Turkey. Nevertheless, conducting of this study, which was carried out as a pot experiment in the greenhouse, under field conditions will reveal clearer results.

ACKNOWLEDGMENTS

The authors would like to thank Assoc. Prof. Dr. Ferit Sönmez for her support in the chemical analyses and Unit of Scientific Research Projects (2017.10.05.1194) of Bolu Abant Izzet Baysal University for the financial support. This article was produced from Serap Karademir's M.Sc thesis "Determination of the Effects of Vermicompost Applications at Different Rates on Plant Growth, Quality Properties and Nutrient Content in Lettuce".

Contribution Rate Declaration Summary of Researchers

The authors declare that they have contributed equally to the article.

Conflict of Interest Statement

The authors of the article declare that there is no conflict of interest between them.

REFERENCES

Adiloğlu S, Eryılmaz Açıkgöz F, Solmaz Y, Çaktü E, Adiloğlu A 2018. Effect of Vermicompost on the Growth and Yield of Lettuce Plant (*Lactuca sativa* L. var. *crispa*). International Journal of Plant & Soil Science 21(1): 1-5.

Aminifard MH, Bayat H 2016. Effect of Vermicompost on Fruit Yield and Quality of Bell Pepper. International Journal of Horticultural Science and Technology 3(2): 221-229.

AOAC 1990. Official methods of analysis. In: Association of Official Analytical Chemists (15th ed.), Washington, DC, USA.

Baliah TN, Muthulakshmi P 2017. Effect of Microbially Enriched Vermicompost on the Growth and Biochemical Characteristics of Okra (*Abelmoschus esculentus* (L.) Moench). Advances in Plants & Agriculture Research 6(5): 1-6.

Degwale A 2016. Effect of Vermicompost on Growth, Yield And Quality of Garlic (*Allium sativum* L.) in Enebse Sar Midir District, Northwestern Ethiopia. Journal of Natural Sciences Research 6(3): 51-63.

Durak A, Altuntaş Ö, Kutsal İK, Işık R, Karaat FE 2017. The Effects of Vermicompost on Yield and Some Growth Parameters of Lettuce. Turkish Journal of Agriculture-Food Science and Technology 5(12): 1566-1570.

Getnet M, Raja N 2013. Impact of Vermicompost on Growth and Development of Cabbage, *Brassica oleracea* Linn. and Their Sucking Pest, *Brevicoryne brassicae* Linn. (Homoptera: Aphididae). Research Journal of Environmental and Earth Sciences 5(3): 104-112.

Hernandez A, Castillo H, Ojeda D, Arras A, Lopez J, Sanchez E 2010. Effect of Vermicompost and Compost on Lettuce Production. Chilean Journal of Agricultural Research 70(4): 583-589.

Karmakar S, Brahmachari K, Gangopadhyay A, Choudhury, SR 2012. Recycling of Different Available Organic Wastes Through Vermicomposting. Journal of Chemistry 9(2): 801-806.

Kashem MA, Sarker A, Hossain I, Islam MS 2015. Comparison of the Effect of Vermicompost and Inorganic Fertilizers on Vegetative Growth and Fruit Production of tomato (*Solanum lycopersicum* L.). Open Journal of Soil Science 5: 53-58.

Kenea FT, Gedamu F 2018. Response of Garlic (*Allium sativum* L.) to Vermicompost and Mineral N Fertilizer Application at Haramaya, Eastern Ethiopia. African Journal of Agricultural Research 13(2): 27-35.

Kumar B, Topal D 2015. Comparative Study of Normal Soil and Vermicompost. International Journal of Novel Research in Life Science 2(2): 4-8.

Kumari N, Yadav BS, Peter JK 2017. Synergistic Effect of Vermicompost, Vermiwash, Bioaugmontation and Carrier Based Biofertilizer on Growth of *Solanum melongena L.* var. Silligudi 111 (Brinjal). International Journal of Multidisciplinary Research and Development 4(3): 6-70.

Mahmoud SO, Gad DAM 2020. Effect of Vermicompost as Fertilizer on Growth, Yield and Quality of Bean Plants (*Phaseolus vulgaris* L.). Middle East Journal of Agriculture Research 9(1): 220-226.

Özen N 2018. Marul Bitkisinin Verim ve Kalitesi Üzerine Farklı Mineralizasyon Oranlarına Sahip Organik Uygulamaların Etkileri. Akdeniz Üniversitesi Fen Bilimleri Enstitüsü Toprak Bilimi ve Bitki Besleme Anabilim Dalı, Yüksek Lisans Tezi, 142 sy.

Özkan N, Dağlıoğlu M, Ünser E, Müftüoğlu NM 2016. Vermikompostun Ispanak (*Spinacia oleracea* L.) Verimi ve Bazı Toprak Özellikleri Üzerine Etkisi. ÇOMÜ Ziraat Fakültesi Dergisi 4(1): 1-5.

Özkan N, Müftüoğlu NM 2016. Farklı Dozlardaki Vermikompostun Marul Verimi ve Bazı Toprak Özellikleri Üzerine Etkisi. Bahçe Dergisi 45: 121-124.

Peyvast G, Olfati JA, Madeni S, Forghani A 2008. Effect of Vermicompost on the Growth and Yield of Spinach (*Spinacia oleracea* L.). Journal of Food, Agriculture and Environment 6(1): 110-113.

Rekha GS, Kaleena PK, Elumalai D, Srikumaran MP, Maheswari, VN 2018. Effects of Vermicompost and Plant Growth Enhancers on the Exo-morphological Features of *Capsicum annum* (Linn.) Hepper. International Journal of Recycling of Organic Waste in Agriculture 7: 83-88.

Savcı S 2012. An Agricultural Pollutant: Chemical Fertilizer. International Journal of Environmental Science and Development 3(1): 77-80.

Shetinina E, Shetinina A, Potashova I 2019. Efficiency of Vermicompost Production and Use in Agriculture. E3S Web of Conferences 91: 06006.

Tavalı İE, Maltaş AŞ, Uz İ, Kaplan M 2014. Vermikompostun Beyaz Baş Lahananın (*Brassica oleracea* var. *alba*) Verim, Kalite ve Mineral Beslenme Durumu Üzerine Etkisi. Akdeniz Üniversitesi Ziraat Fakültesi Dergisi 27(1): 61-67.

TÜİK 2021. *Türkiye İstatistik Kurumu*. Bitkisel Üretim İstatistikleri. http://www.tuik.gov.tr. (Alınma Tarihi: 17.07.2021).

Türk Gıda Kodeksi (2008). Türk Gıda Kodeksi Yönetmeliği. Gıda Maddelerindeki Bulaşanların Maksimum Limitleri Hakkında Tebliğ, (Tebliğ No: 2008 / 26).

Vigardt A 2012. Influence of Coffee Vermicompost on Growth and Nutrient Quality of Greenhouse Spinach and Field Grown Green Bell Peppers. MSc Thesis, Southern Illinois University, Carbondale, USA, 52 p.

Warman PR, AngLopez MJ 2010. Vermicompost Derived from Different Feedstocks as a Plant Growth Medium. Bioresource Technology 101(12): 4479-4483.