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Influence of Solid and Liquid Red California Vermicompost (*Eisenia foetida*) on Growth and Yield of Lettuce (*Lactuca sativa* var. *crispa* L.)

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ABSTRACT
The intensive use of chemical inputs in the agricultural field has reduced soil fertility as well as affected human health and the environment. To overcome these problems, environmentally friendly alternatives such as vermicompost applications should be used. Vermicomposting is an eco-friendly way in which earthworms convert organic residues into compost and contribute to plant growth and development. This is the first study of two forms of vermicompost applied as solid and liquid on plant growth and fungicide tolerance in lettuce. In this study, barnyard manure was composted with the Red California earthworm *Eisenia foetida* (Lumbricidae). The effects of different doses (0, 10, 20 and 30 %) of solid vermicompost and commercial liquid vermicompost were investigated on some growth and yield parameters (leaf length, leaf width, SPAD chlorophyll amount, number of marketable leaves, number of discarded leaves, leaf pH, leaf nitrogen content and fungicide residue values) of lettuce (*Lactuca sativa* var. *crispa* L.) grown under greenhouse conditions. The parameters were statistically significant for vermicompost type and dose for all results except leaf pH, number of discarded leaves and fungicide residue analysis. The results of solid vermicompost application were higher than control and commercial liquid vermicompost in terms of all parameters. The highest leaf length and width values were determined at a 20% dose of solid vermicompost, while the highest SPAD chlorophyll value and leaf nitrogen values were determined at a 30% dose. The number of marketable leaves was higher in all doses of solid vermicompost application. However, there was no statistically significant difference in fungicide residue analyses in terms of vermicompost types, dose, and vermicompost type-dose interactions. Fungicide residue levels were detected above the MRL (maximum residue limits) in all samples.

Keywords: Earthworm, Growth, Fungicide residue, Fungicide tolerance, Sustainable agriculture

1. Introduction

Rapid human population growth leads to increased demand for food (Nauman et al. 2020). To meet this demand, the use of fertilization and pesticide in agriculture are among the most widely used methods. It is known that mindless and excessive chemical fertilization can *adversely affect* pH, organic matter, nutrients, and structure of soil (Gill & Garg 2014; Bisen et al. 2015). However, it is necessary to add the substances to the soil to ensure the continuity of the development of the plants (Li & Marschner 2019). This concern has increased research on reducing the use of chemicals in agriculture and developing alternative methods. Vermicompost process is a biological oxidation method in which fermented waste is converted into a peat-like product with beneficial microbial activity, which provides high aeration, a high-water retention rate (Dominguez & Edwards 2011). Vermicomposting is an important production system that avoids the use of inorganic fertilizers and pesticides (Yatoo et al. 2021). Different forms of vermicompost have the potential to be used for plant growth, yield, disease, and pest control (Öztürkci & Akköprü 2021). Many studies about solid and liquid forms of vermicompost have indicated that this application can convert plant nutrients into forms beneficial to the plant (Olle 2019; Gül et al. 2021; Öztürkci & Akköprü 2021; Ducasse at al. 2022).

It has been reported that the application of organic fertilizers to the soil at regular intervals will improve the physical and chemical properties of the soil (Al-Amin et al. 2017). Compost applications obtained from organic residues/wastes of plant and animal origin in agricultural production have become widespread in recent years (Hussain et al. 2017). Fermenting organic wastes and turning them into compost, vermicompost, which is formed by adding earthworms to this processing, is an important soil conditioner (Wang et al. 2001; Garg & Gupta 2009; Sharma & Garg 2018). Earthworms have very useful tasks for natural ecosystems and improve the quality of soil by breaking down organic matter into inorganic (Nurhidayati et al. 2018). Vermicompost has an important place in eliminating the negative effects of organic wastes, recycling wastes, and sustainable agriculture methods (Ludibeth et al. 2012; Manyuchi et al. 2013; Bhat et al. 2018). Vermicomposting with a high potential for crop production has been widely used in solid and liquid forms as soil conditioners for the last two decades (Panth et al. 2009;

Yatoo et al. 2021). However, differences in the chemical and microbial properties of the liquid and solid forms of vermicompost may affect its effectiveness (Bademkıran et al. 2018; Franke-Whittle et al. 2019).

Arancon et al. (2020) reported that vermicompost application has shown plant disease suppression. It has been reported that fungal diseases such as *Rhizoctonia, Pythium* and *Verticillium* are significantly reduced in plants growing in environments with vermicompost extracts. It has been stated that this may be related to the presence of biological suppressive agents in vermicompost (Edwards et al. 2004; Datta et al. 2016; Öztürkci & Akköprü 2021). However, it has also been reported that inhibition can be caused by the activation of mechanisms such as competition, antibiosis, hyperparasitism and induced plant resistance (Sarma et al. 2010; Simsek-Ersahin 2011).

Lettuce (*Lactuca sativa* L.), a temperate climate plant of the Asteraceae family, is produced in many countries of the world. Fresh lettuce leaves are an important product in trade (Jimenez-Arias et al. 2019). Lettuce grows quickly in soils rich in organic matter (Zandvakili et al. 2019). Because the intensive application of nitrogen-containing fertilizers can cause harmful effects on humans by causing nitrate accumulation in the plant, it is necessary to pay attention to fertilization when growing lettuce (Santamari 2006).

To our knowledge, although there are separate studies on the effects of solid and liquid vermicompost on the yield of lettuce plants grown in greenhouses, there is no study comparing them together. Moreover, the influence of fungicides on lettuce of solid and liquid worm application has not been explored. Therefore, we compared the effect of solid and liquid vermicompost application on the growth and development of lettuce plant and the amount of fungicide residue in this study. We thought that the resistance that vermicompost application may provide to the plant may influence the amount of fungicide residue.

2. Material and Methods

2.1. Materials

Plant

The Maritima lettuce (*Lactuca sativa* L. var. *crispa*) variety produced by Istanbul Seed Inc. was used in the study. Lettuce is an annual temperate zone plant belonging to the genus *Lactuca* of the family Compositae (Asteraceae). The plant reaches maturity in 2–3 months and grows rapidly in soils rich in organic matter.

Vermicompost

In the study, solid vermicompost was obtained from *Eisenia foetida* (Red California earthworm) from cow manure (separator) placed in 2 × 1.20 m cases (Figure 1a, b). The humidity requirement of the medium was kept between 65-75% with meter device. The solid vermicompost, harvested after about 6 months, was made ready for use after drying and sieving. (Figure 1c). Solid vermicompost analyses were carried out at the Laboratory of Central Research Institute of Soil, Fertilizer and Water Resources of the Ministry of Agriculture and Forestry. Soil analysis was performed at the Tekirdağ Commodity Exchange Analysis Laboratory.

Analysis results of solid vermicompost are given Table 1. According to the analysis of vermicompost formed by composting cow manure, it was determined that solid vermicompost was rich in organic matter, nitrogen, phosphorus, and potassium. The solid vermicompost used in this study had neutral pH, 6% humidity, 50.94% organic matter, 5.94 EC (dS/m) electrical conductivity, 2.02% nitrogen, 1.56% potassium, 1.10% phosphorus, 736.00 ppm calcium, 138.00 ppm magnesium and 196.00 ppm iron. The liquid vermicompost used in the experiment was purchased from Solomcan organic fertilizer company. It was stated that liquid vermicompost had a pH range of 8–9, 8% organic matter, and 1% nitrogen.

Table 1- Analysis results of solid vermicompost

Solid vermicompost	*Results*
pH	7.05
Humidity (%)	60.12
Organic matter (%)	50.94
EC (dS/m)	5.94
Total nitrogen (N)(%)	2.02
Total potassium (K)(%)	1.56
Total phosphorus (P)(%)	1.10
Total calcium (Ca)(ppm)	736.00
Total magnesium (Mg) (ppm)	138.00
Total iron (Fe) (ppm)	196.00

a b c

Figure 1- a) Solid vermicompost case, b) *E. foetida* (Red California Worm) c) Vermicompost

Fungicide

Commercially purchased Captan 50 WP (Wettable Powder) fungicide, which is a form of wettable powder used in lettuce mildew and belongs to the phthalimide class of pesticides, was used in the present study. It is a trichloromethyl sulfonyl-containing fungicide. The recommended dose of fungicide is 300 grams per 100 liters of water.

2.2. Experimental design

Lettuce seeds were sown with 2–3 seeds in each section of the viols prepared by mixing peat and perlite in a ratio 3:1 ratio. The first germination was seen 3–4 days after the seeds were sown. After about 30 days, the healthy seedlings were planted to 3-kg pots filled with soil. The study was carried out in a plastic greenhouse. The floor of the greenhouse is covered with a tarp to prevent the viol and pots from contact with the soil. 48 pots were used, and a seedling was planted in each pot. No fertilization was applied in the study other than vermicompost application. Vermicompost was applied to 48 pots except the control group (0%). 24 of the 48 pots were used to examine the yield characteristics of the plant, and the other 24 were used to determine the fungicide effect. Three different doses (10, 20 and 30) of solid and liquid vermicompost were applied to all pots. At the beginning of the experiment, 300-600-900 g of solid vermicompost was added to 24 pots of 3 kg used in the study at doses of 10, 20 and 30 % and completed to 3 kg. Liquid vermicompost was prepared by adding 0.1 mL to 900 mL water, 0.2 mL to 800 ml water, 0.3 mL to 700 mL water in accordance with the company's recommendation. Liquid vermicompost was applied two times in total, with an interval of one months. The study was carried out in three replications.

All pots were watered two times a week. Watering was performed by spraying five times using a spray bottle. Common tap water was used for irrigation. Lettuce was harvested 60 days after planting in pots. Fungicide (Captan 50 WP) was applied three times by using spray, according to the dosage recommended by the manufacturer. The plants were harvested 7 days after fungicide application.

2.3. Plant measure and analysis

Leaf length and width were measured with a ruler on the harvested plants. The number of discarded leaves was determined by counting the outermost yellowed, spoiled, and rotten leaves. The number of marketable leaves was determined by removing the discarded leaves from the harvested plants and counting the edible leaves. After the plant leaves were ground, the pH of the water obtained from the leaves was measured with a Hachlange HQ40d Multimeter. The chlorophyll amount was measured with a chlorophyll meter (Minolta SPAD-502, Osaka, Japan). Leaf nitrogen was determined by the Kjeldahl method with a Kjectec Auto 1030 Analyser (Tecator, Sweden). Fungicide residue analyses were evaluated by the AOAC 2007.01 method using liquid chromatography-mass spectrophotometer (LC-MS; mg/kg) and gas chromatography-mass spectrometry (GC-MS; mg/kg).

2.4. Statistical analysis

The assumptions of the data were tested with Kolmogorov-Smirnov tests. The homogeneity of the variances of the groups was determined using the Levene test statistic. The differences between the group means were revealed by using independent samples t-test or Mann Whitney U test for paired groups and two-way ANOVA and Welch's ANOVA, or Kruskal-Wallis H test statistics for more than two groups. Tukey post-hoc and Games-Howell test statistics were used to reveal possible differences. Existing differences are presented by the lettering method. The results were evaluated at the 5% significance level. All calculations were performed with SPSS v. 24 statistical software.

3. Results

The descriptive statistics results of all parameters were presented Table 2. According to the results of variance, it was observed that different doses of liquid vermicompost application were statistically significant on the leaf length averages at the 0.01 significance level.

The different doses of solid and liquid vermicompost were found statistically significant at 0.01 significance level on leaf width averages. When the sources of the differences were examined, it was observed that the averages of the leaf length and leaf width variables obtained from the control pots were statistically significant and lower compared to the liquid vermicompost added groups.

The number of marketable leaves was evaluated under the two-way Anova model in terms of vermicompost type and doses (Table 2). Vermicompost type, dose level, and vermicompost type*dose interaction were found to be statistically significant in the number of marketable leaves ($P<0.01$). Accordingly, it was observed that the solid vermicompost application averages (18.45±6.39) were more effective than the liquid averages (11±2.39), and the solid and liquid vermicompost usage averages were statistically significant compared to the control group averages (7.5±2.64 cm).

Chlorophyll amount was higher than control group (13.97±3.64) and statistically significant in 10% (17.83±3.39, $P<0.05$), 20% (22.68±5.38, $P<0.01$) and 30% (18.98±6.01, $P<0.05$) doses of solid vermicompost applications. However, 20% dose (22.68±5.38) of liquid worm compost application was higher and statistically significant than 10% (17.83±3.39) application.

The leaf nitrogen content analysis results have shown that while the interaction between vermicompost type and dose was not significant statistically ($P>0.05$), it was observed that both vermicompost type and dose alone had a statistically significant effect on nitrogen content ($P<0.01$). The nitrogen content of solid vermicompost application (7.01±2.21) was found to be statistically significant and higher than liquid vermicompost (4.03±1.33%) (Table 2). On the other hand, when the statistical differences in dose levels were examined regardless of the vermicompost type, it was observed that the average nitrogen content increased regularly as the dose increased. One source of this difference was the lower nitrogen mean of the control group (2.75±0.07) compared to the 20% and 30% dose mean (5.92±1.97 and 7.5±2.19). The other difference is since the average (7.5±2.19) at the 30% dose of any vermicompost type is higher than the 10% nitrogen average (4.2±1.61).

Two-way Anova results showing descriptive statistics and the effect of vermicompost type and dose on pesticide residue analysis results are presented in Table 2. The amount of fungicide was found no significant differences in terms of vermicompost type, dose and vermicompost type-dose interactions ($P>0.05$). It was no found statistical difference in terms of vermicompost type and doses in discarded leaves and pH ($P>0.05$).

Table 2- The descriptive statistics and two-way ANOVA results

Vermicompost	*Dose*	*Leaf length (cm)*			*Leaf width (cm)*			*Marketable leaf number (pieces/plant)*			*Chlorophyll amount (SPAD)*			*Leaf N Content (%)*			*Fungicide Residue Analysis Results (mg/kg)*		
		n	*M ± Sd*	*CV*	*n*	*M ± Sd*	*CV*	*n*	*M ± Sd*	*CV*	*n*	*M ± Sd*	*CV*	*n*	*M ± Sd*	*CV*	*n*	*M ± Sd*	*CV*
Solid	0%	19	6.54±3.47Aa	1.89	19	3.74±2.08Aa	1.8	2	6.50±2.12Aa	3.06	19	13.19±4.93Aa	2.68	1	2.80±0.00Aa	-	2	0.35±0.26	1.36
	10%	77	14.99±4.09Ba	3.66	77	11.11±3.09Ba	3.59	3	23.67±2.52Ba	9.4	77	23.67±6.86Ba	3.45	2	5.55±0.64ABa	8.72	3	10.51±8.22	1.28
	20%	68	15.73±4.16Ba	3.78	68	11.22±2.85Ba	3.93	3	19.67±1.53Ba	12.87	68	24.45±6.99BCa	3.5	3	7.43±1.46BCa	5.08	3	15.25±10.28	1.48
	30%	67	15.11±4.07Ba	3.72	67	11.21±2.67Ba	4.2	3	20.00±2.00Ba	10	67	26.43±6.31Ca	4.19	3	8.97±0.32Ca	27.89	3	10.01±4.7	2.13
Liquid	0%	15	6.71±3.56Aa	1.89	15	4.85±2.47Aa	1.96	2	8.50±3.54Aa	2.4	15	13.97±3.64Aa	3.84	1	2.70±0.00Aa	-	1	0.35±0.00	-
	10%	20	11.19±3.01Bb	3.71	20	7.72±2.19Bb	3.52	2	9.50±0.71Ab	13.43	20	17.83±3.39Ab	5.26	2	2.85±0.21Ab	13.44	1	3.25±0.00	-
	20%	40	10.42±2.34Bb	4.45	40	8.46±1.70Bb	4.97	3	12.67±1.15Ab	10.97	40	22.68±5.38Ba	4.21	3	4.40±0.78Ab	5.63	2	6.52±2.32	2.81
	30%	25	11.10±3.34Bb	3.32	25	8.22±2.24Bb	3.67	2	12.50±0.71Ab	17.68	25	18.98±6.01ABb	3.16	2	5.30±1.70Ab	3.12	3	12.08±4.99	2.42
F stats. and p-values	V	F(1,323)=42.83, P<0.001			F(1,323)=33.68, P <0.001			F(1,12)=55.65, P<0.001			F(1,323)=19.38, P<0.001			F(1,9)=19.96, P<0.01			F(1,10)=1.01, P=0.340		
	D	F(3,323)=28.872, P<0.001			F(3,323)=41.577, P<0.001			F(3,12)=21.582, P<0.001			F(3,323)=23.376, P<0.001			F(3,9)=11.908, P<0.01			F(3,10)=1.88, P=0.198		
	V * D	F(3,323)=4.471, P<0.01			F(3,323)=6.196, P<0.001			F(3,12)=12.428, P<0.001			F(3,323)=5.123, P<0.01			F(3,9)=1.538, P=0.271			F(3,10)=0.74, P=0.558		

Different capital (/lower case) letters indicate significant difference at means for dose (/vermicompost) by multiple comparisons with Bonferroni adjustment

4. Discussion

Lettuce can grow in a short period of time in soils rich in organic matter. Therefore, fertilization is one of the most important factors affecting the yield and quality of lettuce. Excessive and unconscious use of nitrogenous chemical fertilizers increases the accumulation of nitrate, which is harmful to plant health. The use of materials of organic origin improves the physical, chemical, and biological properties of soils and ensures healthy and high-quality products. Therefore, it is reported that the use of organic soil conditioners in agriculture should be widespread (Wu et al. 2020; Ye et al. 2020). The earthworm vermicompost enriches the content of the soil, increases its fertility, and improves soils contaminated with chemicals (Chew et al. 2019). It has also been reported that vermicompost applied in soil contaminated with pesticides restricts the movement of pesticides (Romero et al. 2006; Fernandez-Bayo et al. 2009). The intensive and unconscious use of chemical inputs in crop production creates an increasing pollution burden on soil, groundwater, and the atmosphere. This situation has become a serious threat to the health, wildlife, and environment in the world. It is observed that soil pollution, especially in crop production, has also become a global problem and this situation poses great threats to sustainable agriculture and food security.

The growth, development parameters and fungicide resistance of lettuce plants treated with different doses of solid and liquid vermicompost were compared in this study. It is seen that studies on vermicompost have started to increase especially in recent years, and there are many studies, especially on solid vermicompost applications (Srivastava et al. 2020; Yuvaraj et al. 2021, Ducasse et al. 2022). However, there is no detailed study comparing the effects of solid and liquid vermicompost on plant growth and development and tolerance to pesticide applications on the same plant.

The leaf length, leaf width, chlorophyll amount (SPAD), number of marketable leaves, leaf nitrogen values were found statistically significant in terms of vermicompost type and dose ($P<0.01$ and $P<0.05$). It was found no statistically significant number of discarded leaves and, leaf pH values.

The leaf width and length values of the lettuce plant, which is one of the important indicators of vegetative development of the plant and a vegetable whose leaves are eaten, were found to be higher and statistically significant in both vermicompost types compared to the control. Different forms of vermicompost applications are observed to affect plant growth parameters at different levels (Öztürkci & Akköprü 2021). We observed that solid vermicompost application results were better than liquid vermicompost application in this study. Some researchers have reported that solid vermicompost had a significant and positive effect on plant growth. Karademir & Kibar (2022) detected that vermicompost had positive effects on plant growth, quality properties and element contents in curly lettuce. We determined that leaf growth parameters showed a positive effect, especially at low doses of solid vermicompost. Our results are consistent with the findings of some previous studies (Yourtchi et al. 2013; Öztürkci & Akköprü 2021).

Solid vermicompost has plant growth-promoting properties such as high organic matter, macro- and micronutrient content and enhanced beneficial microbial activity and diversity in the soil (Şimşek-Erşahin 2011). However, the slow release of solid vermicompost can be an important advantage. In addition, it was stated that the solomic fluid in the digestive system of earthworms contains many enzymes, namely proteases, lysozymes, fibrinolytic enzymes, polysaccharides, antimicrobial proteins, and nutrients (Wang et al. 2010; Kocakurt 2022). At the same time, unlike chemical fertilizers, vermicompost stays in the soil for a long time due to the solomic fluid it contains (Samal et al. 2019). It has also been stated that cow manure is the best material for vermicompost production (Xie 2016). An increase in plant biomass was reported in a meta-analysis study evaluating the effects of earthworms on plant growth. It has been reported that Asteraceae family is one of the most sensitive families to vermicompost application (Blouin et al. 2019).

It was found that solid vermicompost applications had significant differences in the leaf size of *Plectranthus amboinicus* (Lour.) Spreng (Cuban oregano) (Yüksek et al. 2020). Many studies have reported that vermicomposting positively affected leaf size in onion (Srivastava et al. 2012), eggplant (Kumari et al. 2017) and garlic (Kenea & Gedamu 2018) compared to the control. Arancon et al. (2003) found that vermicompost increased the leaf area of pepper and tomato. Ducasse et al. (2022) was determined that solid vermicompost application higher than liquid vermicompost application on the yield of tomato. The low effectiveness of liquid vermicompost may be that the frequency of application is insufficient for the plant. Contrary to our results, a study using sunflower plant (*Helianthus annuus* L.), in which solid and liquid vermicompost applications were performed at similar rates to our study, showed better results with liquid vermicompost application. This difference may be due to the difference in plant species and genetic characteristics of the species (Gül et al. 2021).

The number of marketable leaves showed statistical significance according to vermicompost type and dose. The higher marketable leaves were determined from the solid vermicompost applications than the control and liquid application. Similar results were found in the study carried out by Maloisane & Kayombo (2022) on the lettuce. Karademir & Kibar (2022) reported that vermicompost applications increased the number of marketable leaves in lettuce compared to the control. It has been stated that the cow manure vermicompost application significantly increased the marketable yield of Chinese cabbage (Wang et al. 2010). The increases in yield may be due to the production of plant growth regulators by microorganisms.

In the present study, the leaf SPAD chlorophyll amount was found to be higher and statistically significant in both vermicompost types compared to the control groups. Solid vermicompost chlorophyll values were higher than liquid fertilizer values as in other parameters. Theunissen et al. (2010) reported that vermicompost application has a positive effect on SPAD chlorophyll amount. Narkhede et al. (2011) in pepper, Srivastava et al. (2012) in onion, and Altunlu (2021) in lettuce and Karademir & Kibar (2022) in lettuce reported that the amount of SPAD chlorophyll in vermicomposted plants was higher than in the control group. However, Luján-Hidalgo et al. (2016) reported that the amount of chlorophyll in Mexican Pepper leaf (*Piper auritum* Kunth) was not affected by vermicompost applications, contrary to our results. Leaf nitrogen (N) values were found to be statistically significant according to vermicompost type and doses. Solid vermicompost applications have higher values in terms of leaf nitrogen (N) values than liquid vermicompost applications. Leaf nitrogen values found higher than the control was between 5.55-8.97. Similar results were found in previous studies (Aslam & Ahmad 2020; Gül et al. 2021). A parallelism was observed between nitrogen and SPAD chlorophyll content values determined depending on different vermicompost and dose applications in the present study. Since nitrogen is one of the important elements in photosynthesis, leaf chlorophyll content is considered an indicator of nitrogen uptake by plants.

Fungicide residue analysis results were not statistically significant. However, residues above the MRL (Maximum Residue Limit) were determined in the control group (0.3510 mg/kg), solid vermicompost (10.0143 mg/kg -15.249 mg/kg) and liquid vermicompost applicated samples (3.25 mg/kg -12.0783 mg/kg). This limit is 0.03 for Captan fungicide for lettuce according to the Maximum Acceptable Residue Limits for Turkish Food Codex and the European Union Food Codex (Yaşa 2011). Fungicide residue amounts were higher in solid vermicompost applications compared to liquid vermicompost applications in the present study. The highest value was determined at 20% (15.2490 mg/kg) dose and the lowest value was determined at 30% (10.0143 mg/kg) dose in the solid vermicompost applications, while a dose-dependent increase in fungicide residue amount was determined in the liquid vermicompost application. A review of pesticide residues in food samples published in 2010 and later in Turkey showed that the Maximum Residue Levels (MRL) were exceeded in 20 of 120 studies on lettuce (Tözün & Akar 2022). Since the fungicide was applied in the greenhouse, airborne contamination may be the reason why fungicide residues were found in the control samples, although no direct application was performed (Table 7). In addition, pesticides can be carried by air currents passing through the applied surface by passing into the vapor phase. Pesticides can be transported to different areas where they are not sprayed by the wind. The reason for the pesticide residues to be found in the samples applied vermicompost may be that there is a period of approximately one week between the application and the harvest time.

Leaf samples were collected according to the recommended harvest time and analyzed for fungicide residue in the present study. It has been stated that the time between fungicide application and harvest should be considered to avoid residues (Stensvand 2000). It has been reported that washing and cold storage significantly affect pesticide dissipation (Cengiz et al. 2007). However, in fresh vegetables such as lettuce the washing process will have a limited impact on the pesticide residue content (Eştürk et al. 2014). Although pesticide resistance of vermicompost applications was tried to be determined in this study, it is known that vermicompost application increases plant resistance against various pests and diseases. It has been reported that vermicompost application reduces pest attacks and prevents them from harmful pests (Olle 2019).

5. Conclusions

We examined the effects of different types and doses of vermicompost applications on the product and quality characteristics of lettuce plants and fungicide application in the present study. We found that solid vermicompost is better than both the control and commercial liquid vermicompost in all parameters examined in terms of yield and quality. The highest leaf length and width values were determined at 20% dose of solid vermicompost, while chlorophyll amount and leaf nitrogen values were determined at 30% dose. The number of marketable leaves was the same in all doses of solid vermicompost application. However, fungicide residues above the limits were found in all the solid and liquid vermicompost doses studied. The residue amounts were less in liquid vermicompost. It can be concluded from the present study that a much longer period of seven days will be needed between application and harvest. Alternative techniques can also be developed to reduce the amount of pesticide residues after harvest. Therefore, different studies can be carried out in liquid vermicompost applications to reduce the amount of fungicide residue amount. In addition, it would be useful to investigate the resistance of vermicompost-applied plants against different harmful pests.

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