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INFLUENCE OF DIFFERENT ORGANIC FERTILIZERS ON GROWTH, YIELD, QUALITY, AND ELEMENT CONTENT IN LETTUCE (*Lactuca Sativa* var. *Longifolia*)

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Abstract: This study was performed in order to determine the effects of pigeon manure, chicken manure, and vermicompost on lettuce's (*Lactuca sativa* var. *longifolia*) yield, vegetative growth, element content, and quality characteristics. The study was carried out in greenhouse. In the study, 0% (control), 0.50% pigeon manure, 0.50% chicken manure, and 0.50% vermicompost were applied via drip irrigation. The treatments began 20 days after the seedling planting, at 10-day intervals and four times. The experiment was set up with four replicates as per the randomized blocks experimental design. As per the research findings, the chicken manure significantly increased the lettuce's average head weight and total yield compared to the control and two other treatments. Even if the pigeon manure and vermicompost increased the yield parameters similar to chicken manure, they were statistically in the same group as the control. The pigeon manure again significantly increased the chlorophyll amount, root's fresh and dry weight, leaf's K and Zn content, leaf color's L value, and fruit juice's pH content compared to control. On the other hand, vermicompost generated the highest results for the leaf's Ca and Pb content. The Pb content in the lettuce leaves increased in all the organic fertilizer treatments compared to control, and the highest Pb content was obtained by the vermicompost, chicken manure, and pigeon manure, respectively. The treatments' effect on the leaf's Ni content was found to be insignificant. But the vermicompost increased the leaf's Ni content compared to the control. The treatments' effect on leaf color's a* and b* values, brix degree, head diameter, head height, leaf relative water content, and Na, Mg, Cu and Mn contents was again found to be insignificant. In conclusion, it is recommended to apply 0.50% chicken manure in greenhouse lettuce cultivation to obtain large heads and high yield. To achieve bright-colored plants, high chlorophyll content, high root fresh and dry weight, and high potassium and zinc content, 0.50% pigeon manure is suggested. However, 0.50% vermicompost is not recommended for greenhouse lettuce cultivation due to its potential to increase the Pb and Ni heavy metal content in the leaves.

Keywords: Organic fertilizer, Pigeon manure, Chlorophyll, Heavy metals, Calcium

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1. Introduction

Lettuce (*Lactuca sativa* var. *longifolia)* is a winter vegetable falling within the *Asteraceae* genus with economic significance. It is grown throughout the year, both in the field and greenhouse. It is generally consumed fresh. According to the production data from FAO, 27 million tons of lettuces were produced on an area of 1.2 million hectares in 2022. The Republic of Türkiye is in the position of being the 8th country with the highest lettuce production in the world.

In recent years, the usage of chemical fertilizers and pesticides in agriculture has increased. For this reason, the biological diversity and soil structure of agricultural areas are deteriorating (Chaudhary et al., 2022). Soil health and crop yield are closely related to the microorganisms living in the soil (Harman et al., 2021). In healthy soil, the activity of microorganisms is high, and thus, the soil's organic matter content also becomes high. Accordingly, the agricultural activities performed for the prevention and increase of organic matter in the soil become crucial.

In terms of sustainable agriculture, biofertilizers and organic fertilizers are used as alternatives to chemical fertilizers for the prevention of soil and environmental health. The use of biofertilizers and organic fertilizers improves the microbial content of the soil and increases the dissociation of organic matter, thus increasing accessibility of plants to dissolved nutrients (Wang et al., 2019; Chaudhary et al., 2021).

Vermicompost and chicken manure are organic fertilizers widely used in agriculture as alternatives to chemical fertilizers. Similarly, pigeon manure has recently emerged as another organic fertilizer alternative in agriculture. Numerous studies have investigated the effects of chicken manure and vermicompost on plant growth, yield, and quality. Likewise, in recent years, there has been growing research on the effects of pigeon manure on various plant species. But it was observed that the studies conducted regarding pigeon manure were less compared to the ones performed regarding chicken manure and vermicompost. In addition, the studies conducted regarding the effects of pigeon manure, chicken manure, and vermicompost on vegetables and their usage doses are very limited. In the previous studies, the reaction of lettuce against different organic fertilizers was investigated (Abd-Elmoniem et al., 2000; Hernández et al., 2010; Islam et al., 2012; Özkan and Müftüoğlu, 2016; Durak et al., 2017; Ullah et al., 2017; Pizarro et al., 2019; Üçok et al., 2019; Tarakçıoğlu and Özenç, 2022; Karademir and Kibar, 2022; Korkmaz and Akıncı, 2022; Altuntaş et al., 2022). But most of the studies conducted are relevant to vermicompost. No study was conducted in which the effects of pigeon manure, chicken manure, and vermicompost on lettuce were examined together. In this context, the determination of the effects of pigeon manure, chicken manure, and vermicompost on lettuce's plant development, yield, and quality characteristics will contribute to future studies.

The aim of this study was to search for the effects of pigeon manure, chicken manure, and vermicompost on lettuce's vegetative growth, yield, element content, and quality characteristics. The study has the characteristic of being the initial study in which the effects of pigeon manure, chicken manure, and vermicompost on lettuce, grown under the ecological conditions of the GAP region, were investigated together.

2. Materials and Methods

2.1. Plant Materials and Study Site

The study was carried out at the research and application greenhouse (37°20'22.2"N, 41°53'55.7"E) of Şırnak University's Faculty of Agriculture (İdil, Şırnak, Republic of Türkiye). In the experiment, the Cospirina F1 lettuce cultivar from Syngenta Company was used as plant material. The Cospirina cultivar is suitable for production in the greenhouse and field. It has a heavy head structure with its strong leaves. Moreover, its tolerance for leaf tip blight is high (Anonymous, 2023a). In the study, pigeon manure (PM), chicken manure (CM) (Anonymous, 2023b), and vermicompost (VM) (Anonymous, 2023c) were used (Table 1).

Table 1. Some chemical properties of biofertilizers

Pigeon manure		Chicken manure		Vermicompost	
Content	Amount	Content	W/W%	Content	W/W%
Fe	0.12 ppm	Organic matter	10%	Organic matter	25%
Cu	0.025 ppm	Total (Humic+Fulvic) Acid	6.3%	Total (Humic+Fulvic) Acid	8%
Pb	0.44 ppm	Total Nitrogen	1.5%	Total Nitrogen	2%
SO_4^{2-}	19 ppm	Organic Nitrogen	1%	Organic Carbon	10%
Zn	2.81 ppm	pH	5-7	pH	5.5-7.5
K	221.5 ppm	Max. EC	4 dS/m	Max. EC	12 dS/m
NO_3^-	0.9 ppm	-	-	Water-Soluble Potassium Oxide	3.5%
NH_4	1.206 ppm	-	-	-	-
pH	7.19	-	-	-	-
EC	3.84 dS/m	-	-	-	-

2.2. Experimental Design

The seedlings were transplanted into the greenhouse on November 14, 2023. The treatments began 20 days after the seedling planting. In the study, 0% (control), 0.50% pigeon manure, 0.50% chicken manure, and 0.50% vermicompost were applied via drip irrigation. Fertilizer doses were determined based on previous studies to ensure they would not harm the plants. The treatments were performed at 10-day intervals and four times. The study was formed of 16 parcels, with 4 treatments and 4 replicates as per the randomized blocks experimental design. A total of 160 seedlings were used, with 10 seedlings per replicate.

Seedling plantings were performed at 30 cm by 40 cm intervals. Plant nutrition, plant disease management, and pesticide management actualized at the experiment area were performed in the direction of the suggestions of Vural et al. (2000). The harvest was conducted on January 27, 2024.

2.3. Yield and Quality Measurement

2.3.1. Total yield (kg/da)

The total yield was calculated as a result of the weighing of all the heads collected from the parcels.

2.3.2. Average head weight (g)

It was calculated as a result of the weighing of the head weights of 5 plants that were determined prior to each replicate and that reached harvest maturity.

2.3.3. Head diameter (cm)

In each replicate, the head diameter of 5 plants was measured by a digital caliper.

2.3.4. Head height (cm)

In each replicate, the head height of 5 lettuces was measured with the aid of a digital caliper.

2.3.5. Chlorophyll analysis

In lettuce plants, the chlorophyll rate was determined by a Minolta brand chlorophyll meter (Konica Minolta SPAD-502 Plus) from about the 5th leaf from the plant's top.

2.3.6. Determination of the fresh and dry weight ratio in the roots and leaves

In the harvest period, roots and leaves were sampled from each treatment, and fresh and dry weights were measured (Şahin et al., 2022).

2.3.7. Leaf color

In randomly selected 5 plants from each replicate, the color of the leaves was measured by a Minolta CR-300 colorimeter as L, a*, and b*. In this system, the colors are determined as a point in a three-dimensional spherical space. L indicates the color's lightness or darkness; positive a indicates the red color, and negative a indicates the green color; positive b indicates the yellow color, and negative b indicates the blue color (McGuire, 1992).

2.3.8. Determination of the leaves' relative water content

By the end of the harvest, the fresh weights of the leaf samples were measured. Then, the leaf samples were kept in pure water for 4 hours, and by the end of the referred period, their turgor weights were determined. After drying the leaf samples, whose weights were determined, by keeping them in an 80ºC drying oven for 48 hours, their dry weights were determined in g. The leaves' relative water contents (%) were calculated by the following formula (equation 1) using the obtained dry and fresh weights (Sanchez et al., 2004).

$$TuW: (FW-DW)/(TuW-DW)x100 \qquad (1)$$

which is;

FW: fresh weight, DW: dry weight, TuW: turgor weight.

2.3.9. Mineral element analyses

Mineral element analyses were performed on the ICP-MS device. About 500 mg was weighted from the serum samples and transferred to the teflon cups of the microwave oven. Concentrated 10 ml of Merck nitric acid at 65% was added to each sample. For the blank, 10 ml of nitric acid at 65% was added to an empty teflon cup. Teflon cups were placed in the microwave disintegrator oven. The maximum temperature was increased to 210°C within 25 minutes, and they were kept at that temperature for 15 minutes. They were kept in a closed system for 40 minutes in total, and the dissolution operation was actualized. Following the decrease of the microwave oven's temperature to ambient conditions, the solution in the teflon cups was well washed along with the teflon cups with pure water and taken into 50 ml volumetric flasks. Following a suitable dilution of the solutions, their readings under the determined conditions were made on the ICP-MS device.

The ICP-MS calibration solutions were diluted with 1% Suprapur nitric acid – ultrapure water as per the commercially available multiple element standards, and the calibration graph was formed by preparing the concentrations specified in Table 2. In the study conducted, for the element analyses of the samples, a quartz nebulizer, a cyclonic spray chamber, and an ICP-MS NexION® 2000 C (PerkinElmer®Inc., USA) device with an integrated autosampler were used. Using the 18.2 MΩ ultrapure water obtained from the Sartorius™ Wall Mounted Arium Pro Ultrapure Water System device, and the irrigation solution containing 1% Suprapur nitric acid – ultrapure water was prepared in the concentrations specified in Table 2. For the control of element analyses, the ^{89}Y internal standard of 25 ppb concentration was used (Table 2).

By means of the peristaltic pump, the samples were sent to the cyclonic spray chamber by the argon gas flow. In order to prevent the attempts, high rates of helium gas as well as argon gas were used. In the analyses, ICP-MS software version 2.2 was used for checking the device and for the adjustment, data collection, and data analysis. All the operating conditions of the ICP-MS device are shown in Table 3.

2.4. Statistical Analysis

The data obtained by the end of the experiment was subjected to variance analysis by the JMP 8 (SAS Institute Inc., Cary, NC, USA) software pack, and the differences among the averages were calculated as per the Tukey's test.

3. Results

Organic fertilizer treatments increased the average head weight and total yield (Table 4). The pigeon manure, chicken manure, and vermicompost treatments increased the average head weight at a rate of 27.63%, 65.25%, and 19.23%, respectively. The highest average head weight (238.51 g) was obtained by the chicken manure treatment. Similarly, all the treatments increased the total yield compared to the control. The chicken manure constituted the highest total yield (2.868 kg/da). As shown in Table 4, following the chicken manure, the pigeon manure and vermicompost treatments constituted the highest total yield, respectively (Table 4). In terms of head diameter and head height, we couldn't determine a significant effect of the treatments ($P<0.05$; Table 5). In addition to this, organic fertilizer treatments increased both the head diameter and head height compared to the control (Table 5).

Table 2. Calibration standards

Analytes	Std1 (ppb)	Std2 (ppb)	Std3 (ppb)	Std4 (ppb)	Std5 (ppb)	Std6 (ppb)	Internal standard
Cu, Mn, Ni, Pb, Zn	0.5	1	5	25	50	100	^{89}Y

Table 3. Operating conditions of the ICP-MS analysis

Parameter	Description / Value
Nebulizer	MEINHARD® plus Glass Type C
Spray Chamber	Glass cyclonic (baffled), 4°C
One-Piece Torch	w/2.5mm Quartz Injector
Injector	2.0 mm i.d.
Nebulizer Flow	Optimized for < 2% oxides
RF Power	1600 W
Cones	Ni
Replicates	3.0
Dwell time	50 ms
Aerosol Dilution	Set to 2.5x
Sample Delivery Rate	350 µL/min
Rinse time	45 seconds
Nebulizer gas flow rate	0.93 L/min
Deflector voltage	−12 V
Analog stage voltage	−1750 V
Pulse stage voltage	1100 V
Discriminator threshold	26
Sample Tubing (Orange-Yellow)	Flared PVC Pump Tubes 0.51mm/0.89mm
Internal Standard Tubing (Orange-Red)	Flared PVC Pump Tubes 0.19mm/0.91mm
Peristaltic pump rate	35 rpm
Alternating current (AC) rod offset	−4.0

Table 4. The effect of the treatments on the yield values

Treatment	Average Head Weight (g)	Total yield (kg/da)
Control	231.46±7.29 b	1.735,98±54.65 b
PM	295.43±14.97 b	2.215,73±112.25 b
CM	382.51±18.91 a	2.868,86±141.84 a
VM	275.98±10.74 b	2.069,90±80.55 b
P	0.0004*	0.0004*

*The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

Table 5. The effect of the treatments on the head diameter and head height

Treatment	Head Diameter (cm)	Head Height (cm)
Control	12.91±0.60	29.41±0.96
PM	18.25±1.31	31.33±0.62
CM	17.41±0.70	31.91±1.03
VM	15.75±1.63	32.27±0.40
P	0.0639^{ns}	0.1659^{ns}

ns= not significant, *The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

Based on the results, while the effect of organic fertilizer treatments on the plant color's a* and b* values was found to be insignificant, their effect on the L value was found to be significant (Table 6). While the highest L value was obtained by the pigeon manure treatment, the lowest L value was determined by the control treatment. The L color value increased in all the organic fertilizer treatments compared to the control (Table 6). In the CIE color system, L represents the lightness, +a represents the red, -a represents the green, +b represents the yellow, and -b represents the blue. While the differences among the leaf color's a* values were found to be statistically insignificant, organic fertilizer treatments ensured the formation of darker green leaves. When the pigeon manure was compared to the control and other treatments, it ensured the formation of darker green leaves (Table 6).

The effect of the treatments on the water-soluble dry matter amount was found to be insignificant (P<0.05; Figure 1). Organic fertilizer treatments didn't positively affect the water-soluble dry matter amount (Figure 1).

The effect of organic fertilizer treatments on the pH content of fruit juice was found to be statistically significant at the level of P ≤ 0.05 (Figure 2). While the highest fruit juice pH content was obtained by the pigeon manure treatment, the lowest fruit juice pH content was determined by the control treatment. The chicken manure, vermicompost, and control treatments statistically fell within the same group (Figure 2).

Significant differences were determined in the effect of organic fertilizer treatments on the chlorophyll content (P<0.05; Figure 3). The pigeon manure increased the chicken manure content at a rate of 13.15% compared to the control. Similarly, while chicken manure increased the leaf chlorophyll content at a rate of 4.14%, vermicompost increased it at a rate of 3.67% (Figure 3).

The leaf relative water content was not significantly affected by the organic fertilizer treatments (Figure 4). In terms of root fresh weight and root dry weight values, the effect of organic fertilizer treatments was found to be significant (P<0.05; Table 7). The highest root fresh weight and root dry weight were determined by the pigeon manure treatment. As shown in Table 7, the pigeon manure increased the root fresh and dry weights by about two times. The chicken manure and vermicompost increased the root fresh and dry weights compared to the control even if not as much as the pigeon manure (Table 7).

In terms of leaf fresh weight and leaf dry weight values, we couldn't find a significant effect of organic fertilizer treatments (P<0.05; Table 8). While the effect of the treatments on the leaf's sodium (Na) and magnesium (Mg) content was not found to be significant, their effect on the leaf's calcium (Ca) and potassium (K) content was found to be significant (P<0.05; Table 9). The vermicompost treatment increased the leaf's Ca content. But the pigeon manure and chicken manure treatments decreased the leaf's Ca content. On the other hand, the leaf's K content showed an increase with the organic fertilizer treatments. The pigeon manure treatment constituted the leaf's highest K content. The chicken manure treatment and vermicompost treatments followed the pigeon manure treatment, respectively (Table 9).

Table 6. The effect of the treatments on the plant color

Treatment	L	a*	b*
Control	37.03±1.15 b	-30.61±3.51	42.60±2.11
PM	45.75±1.53 a	-39.58±2.12	46.35±0.84
CM	39.72±1.24 b	-33.23±1.85	43.00±0.63
VM	41.99±1.09 ab	-37.17±2.46	43.71±1.65
P	0.0061*	0.1442^{ns}	0.4053^{ns}

ns= not significant, *The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

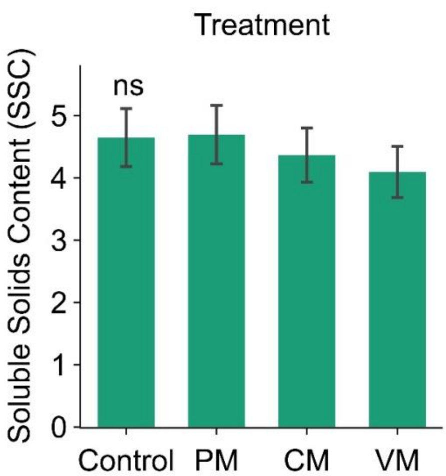

Figure 1. The analysis of soluble solids content in tomato fruit. Vertical bars are used to display all data, which are the means of 4 replicates (+SE). Different letters above the error bars indicate significant differences among treatments at the 5% level.

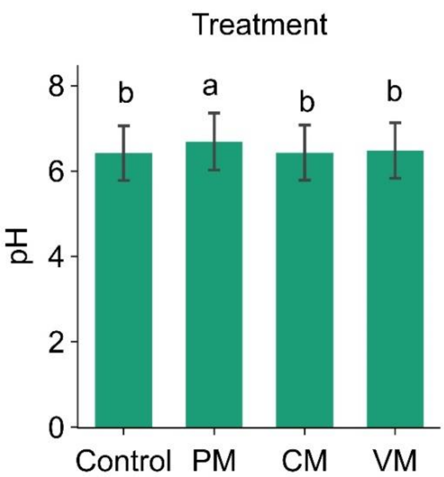

Figure 2. The effect of organic manure on pH content in tomato fruit. Vertical bars are used to display all data, which are the means of 4 replicates (+SE). Different letters above the error bars indicate significant differences among treatments at the 5% level.

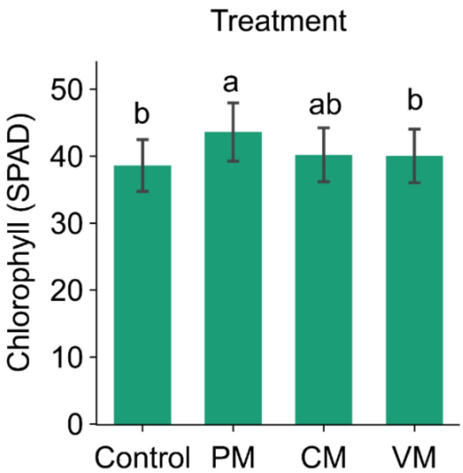

Figure 3. The effect of organic manure on chlorophyll content. Vertical bars are used to display all data, which are the means of 4 replicates (+SE). Different letters above the error bars indicate significant differences among treatments at the 5% level.

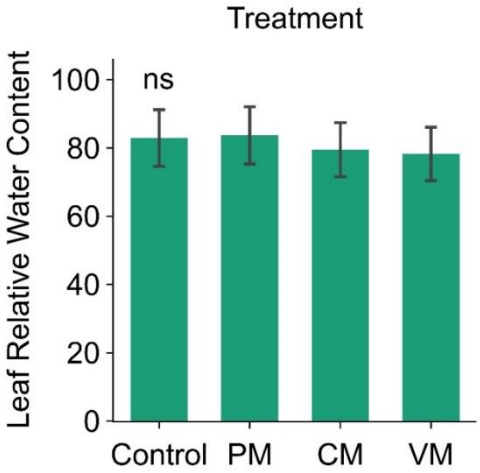

Figure 4. The effect of organic manure on leaf relative water content. Vertical bars are used to display all data, which are the means of 4 replicates (+SE). Different letters above the error bars indicate significant differences among treatments at the 5% level.

Table 7. The effect of the treatments on the root fresh and root dry weights

Treatment	Root Fresh Weight (g)	Root Dry Weight (g)
Control	15.74±0.89 b	3.08±0.33 b
PM	28.90±2.06 a	6.00±0.47 a
CM	22.58±2.02 ab	4.03±0.50 ab
VM	16.13±1.56 b	3.17±0.37 b
P	0.0011*	0.0041*

*The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

Table 8. The effect of the treatments on the leaf fresh and leaf dry weights

Treatment	Leaf Fresh Weight (g)	Leaf Dry Weight (g)
Control	5.07±0.45	0.58±0.03
PM	8.78±0.87	0.69±0.05
CM	5.98±0.90	0.61±0.07
VM	5.98±1.06	0.61±0.09
P	0.1030^{ns}	0.6447^{ns}

ns= not significant.

Table 9. The effect of the treatments on the leaf's Ca, Na, K, and Mg content

Treatment	Ca (ppm)	Na (ppm)	K (ppm)	Mg (ppm)
Control	7.459,00±490.75 ab	1.002,93±203.34	6.605,66±224.67 b	925.06±37.63
PM	5.833,33±313.27 ab	796.60±76.77	11.744,33±562.92 a	886.56±12.43
CM	5.643,33±484.61 b	725.66±49.39	7.747.00±119.72 ab	859.90±39.35
VM	7.657,00±261.86 a	671.53±38.89	7.276.00±53.98 ab	947.16±5.08
P	0.0213*	0.2204^{ns}	0.0390*	0.3120^{ns}

ns= not significant, *The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

While the effect of the organic fertilizer treatments on the leaf's copper (Cu) and manganese (Mn) content was found to be insignificant, their effect on the leaf's zinc (Zn) and iron (Fe) content was found to be significant (P<0.05; Table 10). It was observed that the pigeon manure increased the leaf's Zn content. But the chicken manure and vermicompost decreased the leaf's Zn content compared to the control. Similarly, the leaf's Fe content decreased with the organic fertilizer treatments. The pigeon manure decreased the leaf's Fe content at a rate of 48.78% compared to the control (Table 10).

The effect of organic fertilizers on the leaf's nickel (Ni) content was found to be insignificant (P<0.05; Table 11). But their effect on the leaf's lead (Pb) content was found to be statistically significant at a level of P≤0.05. The Pb content of the lettuce leaves increased with the organic fertilizer treatments. The highest Pb content was obtained by the vermicompost treatment. The chicken manure and pigeon manure ranked second and third, respectively. In addition, the pigeon manure, chicken manure, and control statistically fell within the same group (Table 11).

Table 10. The effect of the treatments on the leaf's micro-element content

Treatment	Cu (ppb)	Mn (ppb)	Zn (ppb)	Fe (ppb)
Control	399.17±21.14	3.212,47±147.15	2.358,80±209.65 ab	439.53±23.17 a
PM	396.47±25.59	3.508,19±119.60	3.001,31±219.22 a	295.41±4.28 c
CM	324.83±2.89	2.907,59±54.74	1.828,58±217.83 bc	331.07±35.22 bc
VM	326.21±42.91	2.616,53±335.00	1.126,67±101.42 c	418.56±14.17 ab
P	0.1918^{ns}	0.1161^{ns}	0.0050*	0.0036*

ns= not significant, *The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

Table 11. The effect of the treatments on the leaf's heavy metal content

Treatment	Ni (ppb)	Pb (ppb)
Control	67.79±4.38	7.15±0.72 b
PM	61.22±5.51	10.83±1.49 b
CM	57.84±12.10	11.41±0.62 b
VM	72.15±1.19	19.66±1.71 a
P	0.3803^{ns}	0.0023*

ns= not significant, *The averages indicated with the same letters on the same column are statistically different from each other as per the Tukey's test (P<0.05).

4. Discussion

The study revealed that the pigeon manure, chicken manure, and vermicompost treatments ensured improvements in the lettuce's yield, vegetative growth, some element contents, and quality characteristics.

4.1. Effect of Pigeon Manure, Chicken Manure, and Vermicompost on the Yield and Quality of Lettuce

Biofertilizers and organic fertilizers increase the crop yield, soil productivity, and nutrient cycle (Singh et al., 2020; Haroun et al., 2023; Wei et al., 2024). The lettuce yield and quality results obtained from the study revealed that the pigeon manure, chicken manure, and vermicompost treatments have significant potential for increasing the yield and some quality parameters (average head weight, yield per decare, fruit juice pH, leaf color's L value, root fresh and dry weights). But they didn't significantly increase the water-soluble dry matter and leaf color's a* and b* values. The increase in average head weight and total yield may be attributed to the role of the organic fertilizers used in root development, the functioning of photosynthesis, and the increased effectiveness of many physiological processes in the plant (Chaudhary et al., 2022). Hence, in our study, root fresh and dry weights (Table 7) and leaf's chlorophyll content (Figure 3) increased with all three organic fertilizer treatments. Özkan and Müftüoğlu (2016) reported that vermicompost in different doses increased the lettuce's yield. Hernández et al. (2010) suggested the treatment of 60 t ha^{-1} chicken manure in order to obtain a higher yield in lettuce cultivation. Similarly, Pizarro et al. (2019) specified that the yield increased in lettuce cultivation with the treatment of 4 kg m^{-2} chicken manure. In another study, Islam et al. (2012) specified that, instead of commercial fertilizer, the use of cow manure in lettuce cultivation constituted maximum leaf number, root length, and yield. In the literature, it was determined by the studies conducted that the organic fertilizer treatments had different results on the quality, similar to their effect on the yield of lettuce. Karademir and Kibar (2022) specified that, with the vermicompost treatment of different doses applied to lettuce, the leaf color's L and a* values were not affected, but the leaf color's b* value decreased. In another study conducted regarding vermicompost (Korkmaz and Akıncı, 2022), it was determined that the lettuce's L value decreased but its a* and b* values increased. In another study, the vermicompost increased the lettuce's L color value compared to chemical fertilizer and chicken manure (Üçok et al., 2019). These results show parallelism with the findings obtained by us.

4.2. Effect of Pigeon Manure, Chicken Manure, and Vermicompost on the Vegetative Growth of Lettuce

The results revealed that pigeon manure, chicken manure, and vermicompost didn't positively affect some of the growth and development parameters in lettuce (head diameter, head height, leaf relative water content, leaf fresh weight, and leaf dry weight). But the effect of all three manures on the leaf chlorophyll content, root fresh weight, and root dry weight was positive. The reason behind that may be due to the vegetation period of the lettuce plant. Hence, when compared with other plant species, the lettuce plant has a shorter vegetation period. Moreover, organic fertilizers are taken in by the plant more slowly compared to chemical fertilizers. This status arises from the slowness of the dissolution of organic fertilizers in the soil. For this reason, the plants' exploitation of organic fertilizers takes a long time. Üçok et al. (2019), in a study in which they studied the effects of organic fertilizers (vermicompost, chicken manure) and chemical fertilizers on the lettuce plant, reported that the chemical fertilizers constituted better results by themselves in terms of yield and some growth parameters compared to organic fertilizers. Similarly, Abd-Elmoniem et al. (2000) specified that, in lettuce plants grown for two seasons in aquaculture, inorganic fertilization generally ensured the highest growth compared to organic fertilization (pigeon manure and chicken manure). These results tally with the information reported in the literature.

The leaf's chlorophyll content showed an increase with the organic fertilizer treatments. Ullah et al. (2017), in a study in which they examined the effects of farm manure and chicken manure on local iceberg cultivar lettuce and Chinese cultivar lettuce, specified that the chicken manure treatment ensured more leaf and total chlorophyll content in Chinese cultivar lettuce. Similarly, Çukurcalıoğlu et al. (2023) specified that the chicken manure increased the leaf's chlorophyll content in bean plants. The researchers attributed this status to the richness of chicken manure in terms of nutrients, such as nitrogen and phosphorus, in the first place. Again, similarly, Hosseinzadeh et al. (2016) specified that the vermicompost treatment positively affected the chlorophyll content in chickpea cultivation. In other studies conducted by other researchers, it was determined that the organic fertilizers positively affected the leaf's chlorophyll content (Keçe et al., 2024; Ye et al., 2022; Toor et al., 2024; Khalid et al., 2017).

With the organic fertilizer treatments, root fresh and dry weights increased. Similar to the results of this study, Tarakçıoğlu and Özenç (2022) specified that the lettuce's root fresh and dry weights increased with the vermicompost treatments. In another study carried out by Kashem et al. (2015), it was reported that the vermicompost treatments increased the root dry weight of tomatoes. Similarly, Özkan et al. (2016) reported that the root fresh weight of spinach increased with increasing vermicompost treatments. These findings tally with the results obtained by the study.

4.3. Effect of Pigeon Manure, Chicken Manure, and Vermicompost on the Mineral Content of Lettuce

When organic fertilizers are added to the soil, they mineralize the compounds in the soil and make it more favorable for agriculture (Wei et al., 2024). In addition to this, increasing the organic matter in the soil (Altuntaş et al., 2022) ensures the secretion of plant hormones that are useful for the plants and the biodegradation of organic matter (Khan et al., 2023). Our results indicated that the organic fertilizer treatments caused significant increases in lettuce's macro, micro, and heavy metal contents. Ca and Pb content reached the highest level in vermicompost, and K and Zn content reached the highest level in pigeon manure. The chicken manure increased the leaf's K and Pb content compared to the control. This status indicates that all three organic fertilizers have the macro- and micro-nutrient contents required for vegetative growth and development. Hence, Karademir and Kibar (2022) specified that the vermicompost treatments significantly increased the nitrogen, phosphorus, potassium, calcium, magnesium, sodium, copper, iron, and zinc content in curly lettuce. Similarly, Hernández et al. (2010) specified that the highest Mg, Fe, Ca, Cu, and Mn content in lettuce was obtained by vermicompost. In another study, through vermicompost treatments on lettuce, the P, Mg, Mn, Fe, Cu, and Zn content increased (Durak et al., 2017). Similar results were also obtained in other studies (Üçok et al., 2019). These results show parallelism with the findings obtained by us.

5. Conclusion

In this study, the usage potential of pigeon manure, chicken manure, and vermicompost in lettuce cultivation was examined. To summarize, chicken manure significantly increased the average head weight and total yield. The highest yield was obtained with chicken manure. However, pigeon manure resulted in the best values for leaf color L, fruit juice pH, chlorophyll content, root fresh and dry weight, and leaf K and Zn content. On the other hand, vermicompost resulted in the highest values for leaf Ca and Pb content. Vermicompost increased the heavy metal (Ni and Pb) content in the leaves. In conclusion, for high yield in greenhouse lettuce cultivation, 0.50% chicken manure is recommended. However, for improving fruit quality, 0.50% pigeon manure is recommended. Vermicompost generally had a positive effect on lettuce yield and quality. However, due to its potential to increase the heavy metal (Ni and Pb) content in the leaves, the application rate of vermicompost in greenhouse lettuce production should be carefully considered.

Author Contributions

The percentage of the author contributions is presented below. The author reviewed and approved the final version of the manuscript.

	Y.N.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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