

Yield and quality responses of cos lettuce to organic fertilizers in greenhouse cultivation

Işın KOCABAŞ OĞUZ^{1*} 

¹Department of Medicinal and Aromatic Plants Vocational School, Akdeniz

*Corresponding author e-mail: isinkocabas@akdeniz.cdu.tr

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Abstract: The research occurred in a plastic greenhouse in the autumn season between 2022-2023 and 2023-2024. Lettuce was grown in the greenhouse with organic agriculture-origin fertilizers. The cos type lettuce cultivar 'Presidential' was used. The aim was to evaluate the effects of various fertilizer applications, including seaweed, vermicompost, humic-fulvic acid, and a control, on lettuce yield and quality. Fertilizers were applied to the soil in liquid form at the recommended rates for lettuce production. The study revealed significant variations in several parameters across applications. Total yield ranged from 21.42 to 43.75 t ha⁻¹, while market yield varied between 20.50 and 41.33 t ha⁻¹. Marketable plant weight ranged from 410.00 to 826.67 kg plant⁻¹, while the average plant weight was between 428.33 and 875.00 kg plant⁻¹. Additionally, the number of discarded leaves ranged from 5.00 to 24.33 units. The SPAD value showed a range of 27.18 to 38.30, while water-soluble dry matter (WSDM) and dry matter values varied between 0.80-4.90% and 3.63-10.15%, respectively, depending on the applications. The study found that the applications generally yielded better results than the control application. In addition, the highest yield and plant weight were observed in lettuce plants treated with seaweed fertilizer.

Keywords: Humic-fulvic acid, organic fertilizers, seaweed, vermicompost.

Sera yetiştiriciliğinde yedikule marul tipinin organik gübrelere verim ve kalite tepkileri

Öz: Deneme 2022-2023 ile 2023-2024 yılları arasında sonbahar döneminde plastik serada gerçekleştirilmiştir. Organik tarım menşeli gübrelere serada marul yetiştiriciliği yapılmıştır. Yedikule tipi "Presidential" marul çeşidi kullanılmıştır. Marul yetiştiriciliğinde, deniz yosunu, solucan gübresi, humik-fulvik asit ve kontrol olacak şekilde oluşturulan uygulamaların verim ve kalite üzerine etkilerini belirlemek amaçlanmıştır. Gübre uygulamaları sıvı formda kullanılarak, marul yetiştiriciliği için tavsiye edilen dozlarda topraktan uygulanmıştır. Çalışma sonucunda uygulamalara göre toplam verim, pazar verimi, ortalama bitki ağırlığı, pazarlanabilir bitki ağırlığı, ıskarta yaprak sayısı, SPAD klorofil değeri, suda çözünür kuru madde (SÇKM) ve kuru madde değerlerinin sırasıyla 21.42-43.75 t ha⁻¹, 20.50-41.33 t ha⁻¹, 428.33-875.00 kg bitki⁻¹, 410.00-826.67 kg bitki⁻¹, 5.00-24.33 adet, 27.18-38.30 SPAD, %0.80-4.90 ve %3.63-10.15 arasında değişim gösterdiği saptanmıştır. Çalışma sonucunda genel olarak uygulamaların kontrol uygulamasına göre daha iyi sonuçlar verdiği saptanmıştır. Ayrıca deniz yosunu gübre uygulamasının yapıldığı marul bitkilerinde en fazla verim ve bitki ağırlığı saptanmıştır.

Anahtar kelimeler: Humik-fulvik asit, organik gübreler, deniz yosunu, vermikompost.

1. Introduction

Lettuce (*Lactuca sativa*) is an annual plant belonging to the Asteraceae family, cultivated for its leaves, which are consumed as a vegetable. The leaves grow in rosettes, creating either loose or compact heads. The root system, characterized by a strong taproot and fibrous roots, enables the absorption of water and nutrients. Lettuce, a plant that thrives in cool climates, grows best at temperatures between 15°C

and 18°C and prefers well-drained soils that are high in organic matter with a pH range of 6.0 to 7.0. It has a cultivation period of 2-3 months. Lettuce has significant nutritional value due to its low protein and fat content, high levels of vitamins A and C, and rich antioxidant content (Eşiyok, 2012). The growing demand requires the development of alternative farming methods to achieve high yield and quality in lettuce production. Türkiye holds an important

position in global rankings, with total lettuce production of approximately 602,848 tons, including 263,829 tons of curly lettuce, 225,542 tons of cos lettuce, and 113,477 tons of iceberg lettuce, according to 2024 data (Anonymous, 2025). Türkiye's lettuce production is concentrated especially in the Aegean, Marmara, and Mediterranean regions.

The application of chemical fertilizers to enhance productivity is a common practice in lettuce production. Leafy vegetables with short development cycles require growing media that are rich in organic matter and that deliver nutrients rapidly. Therefore, the use of high rates of chemical fertilizers is often preferred in lettuce production (Zandonadi et al., 2014). The excessive use of chemical fertilizers is frequently criticized for inducing soil degradation, environmental pollution, and adverse effects on food safety. Organic fertilizers provide a significant alternative for eco-friendly and sustainable agriculture. Several studies have demonstrated the beneficial effects of organic fertilizers, including vermicompost, humic-fulvic acid, and seaweed, on lettuce (*Lactuca sativa* L.) yield and quality parameters. Seaweed extracts enhance plant growth due to their natural growth regulators and nutrients, support root development, increase resistance to stress conditions, improve product quality, and boost yield (Yusuf et al., 2019; Mohammed et al., 2022). Humic-fulvic acid improves soil structure and increases plant roots' access to nutrients and thus positively affects crop yield (Lüdtke et al., 2021). Vermicompost, a type of fertilizer produced by the biological transformation of organic materials, is notable for its nitrogen, phosphorus, and potassium content, which are easily absorbed by plants (Unito, 2023). The use of these fertilizers, whether used alone or in combination, is an effective option for sustainable agriculture, providing an alternative to the negative environmental impacts of chemical fertilizers.

This study assessed the impact of seaweed, vermicompost, and humic-fulvic acid applications on the production and quality of the cos type lettuce cultivated in greenhouse conditions during the fall seasons of 2022–2023 and 2023–2024. The study also aimed to compare these practices with those of the control group and to identify the most effective methods for sustainable agriculture.

2. Materials and Methods

The Korkuteli district of Antalya Province, Türkiye (longitude 30° 12' E, latitude 37° 04' N), served as the study site. The district's average altitude is approximately 1,000 meters, resulting in a transitional climate between the Mediterranean and continental climates (Fig. 1). The study was conducted over two trials during the autumn-winter periods of 2022 and 2023, within a 200 m² plastic-covered greenhouse at the Akdeniz University Korkuteli Vocational School Medicinal and Aromatic Plants Program (Fig. 1).



Figure 1. The experimental area is in the Korkuteli district of Antalya, Türkiye, and the cos type lettuce cv. 'Presidential' plants reached harvest maturity in the greenhouse.

The soil in the greenhouse where the experiment will be set up was subjected to several physical and chemical analyses. The soil samples were analyzed for texture using the Bouyoucos hydrometer method (Bouyoucos, 1962); pH values were measured in a 1:2.5 soil/water mixture according to Thomas (1996); electrical conductivity (EC) was determined in a 1:2.5 soil/water mixture following Rhoades (1982); CaCO₃ content was evaluated using the Scheibler calcimeter (Schlichting et al., 1995); organic matter content was analyzed according to Nelson and Sommers (1996); available phosphorus (P) was determined via the Olsen method (Nelson & Sommers, 1996); exchangeable potassium (K), calcium (Ca), and magnesium (Mg) were quantified

using the 1 N ammonium acetate (pH = 7) method (Nelson & Sommers, 1996); and available iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) were analyzed using the DTPA method (Lindsay & Norwell, 1978). The general properties of the experimental soil are as follows: The soil structure is 62.7% clay loam. The pH value is 7.2, indicating neutrality. The electrical conductivity (EC) is 1.10 dS/m, showing that the soil is salt-free, and the CaCO₃ content is 29.9%, indicating a highly calcareous soil. The organic matter content is 3.1%, which is sufficient. The available phosphorus is 32 ppm (very high), exchangeable potassium is 638 ppm (very high), exchangeable calcium is 2864 ppm (high), and exchangeable magnesium is 842 ppm (very high). The available iron is 6.7 ppm (medium), available manganese is 12.3 ppm (high), available zinc is 3 ppm (medium), and available copper is 5.9 ppm (high).

A cos type lettuce cultivar (cv.) "Presidential" from Syngenta was used as plant material in the experiment. This cultivar is characterized by medium earliness, a growth period of 90–100 days, an oily, crisp texture, a substantial belly, and a closed-head structure (Fig. 1). A commercial enterprise provided seedlings that were ready for planting.

Upon evaluating the soil analysis data, it was determined that the soil contained adequate nutrients; therefore, neither organic nor mineral fertilizers were applied prior to planting the seedlings in greenhouse soil. The experiment was conducted in a controlled greenhouse, with four replications of sixteen plants per replication, using a randomized plot design. A rooting agent was applied to lettuce seedlings obtained from a private seedling company. The seedlings were then planted in two rows using the triangular planting method, with a spacing of 40 cm between rows. The first trial was conducted on October 4, 2022, and the second trial on November 7, 2023. The first application of fertilizer, apart from the control, was made 20 days after planting, and the second 40 days later. In the study, the recommended rates of commercially available fertilizers were applied to plants in liquid form from the soil. Ekosol Farm is an organic liquid worm fertilizer used for greenhouse lettuce growth, including 7% organic matter, 1% total nitrogen, and 0.2% organic nitrogen, with a suggested application rate of 1000 cc/da. Agra Gron is a humic-fulvic acid

fertilizer with 9% organic matter, 12% total humic-fulvic acid, 1.4% water-soluble potassium oxide (K₂O), and 2% salt with a recommended application rate of 1500 cc/da. Terra Strong is a liquid seaweed fertilizer with 10% organic matter, 3% water-soluble potassium oxide (K₂O), and 1% alginic acid, with a suggested application rate of 500 cc per decane. The fertilizer applications selected for the research subjects were vermicompost (0.2 cc per plant), humic-fulvic acid (0.3 cc per plant), seaweed (0.15 cc per plant), and a control group. Lettuces grown in the unheated greenhouse were harvested when they began forming heads, which occurred 70 days after planting in the first year's experiment and 100 days after planting in the second year's experiment. Weather data for both cultivation periods (first experiment: October-December 2022; second experiment: November 2023-February 2024) were obtained from the General Directorate of Meteorology. This data includes monthly average, maximum, and minimum temperature values, as well as relative humidity. The average climate data for the cultivation periods of both experiments are presented in Figure 2.

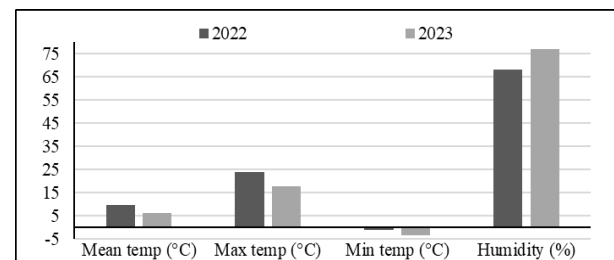


Figure 2. Average climate data for periods of experiments conducted in Korkuteli

The meteorological data from the research trials conducted in Korkuteli are as follows: The average temperature for the first period was 9.53 °C, whereas for the second period it was 6.38 °C; the average maximum temperature in the first period was 23.97 °C, compared to 17.65°C in the second period; the average minimum temperature for the first period was -1.03°C, while the second period recorded an average of -3.43 °C; the average relative humidity in the first period was 68.03%, increasing to 77.03% in the second period. Lower temperatures and higher relative humidity during the second phase delayed lettuce head formation and extended the harvest period relative to the first period (Figure 2).

The study involved various measurements to analyze the performance of harvested lettuce plants. Plant

weights and total yield ($t\ ha^{-1}$) were calculated by weighing the harvested plants on a scale with a precision of 0.01 g, while marketable weights and yields were determined after removing non-marketable leaves. Yield calculations assumed of planting 5000 seedlings per hectare. The number of discarded leaves indicated the count of leaves without market value. Additionally, chlorophyll (SPAD) values were measured by randomly selecting five plants from each replication and using a Minolta SPAD-502 chlorophyll meter on ten leaves from each plant. Water-soluble dry matter (WSDM) was assessed using a digital refractometer on extracts from crushed and filtered second- and third-leaf material of five randomly selected plants, and results were reported as percentage ($^{\circ}$ Brix). Finally, after removing non-marketable leaves, the fresh weight of the harvested lettuce was recorded; the dry weight was determined after drying at $65\ ^{\circ}C$; and the dry matter ratio was calculated as the percentage of dry weight to fresh weight.

The licensed SPSS (2017) statistics package (SPSS Statistics Base v. 23) was used to analyze the research data based on experimental design. Using a randomized plot design, the study was conducted four times. The P (probability) value was used to interpret the results ($p < .01$).

3. Results and Discussion

The use of fertilizer had a significant effect on the total yield ($p < .05$) and marketable yield ($p < .01$) of lettuce plants. However, the year and year \times fertilizer interaction effects were not significant. In general, fertilizer applications were more effective for yield than the control group. Among fertilizer treatments, seaweed application yielded the highest total yield ($38.37\ t\ ha^{-1}$) and marketable yield ($36.10\ t\ ha^{-1}$) in lettuce (Fig. 3).

The results of this research, which examined the effects of organic fertilizers on plants and their potential for use, showed that organic fertilizer applications increased both total and marketable yields compared with control applications. Üçok et al. (2019) reported in their study that the highest increases in total and marketable lettuce yields were obtained with a combination of chemical and organic fertilizers. Tüzel et al. (2011) reported that the total yield of the cos type lettuce was between $26.55\ t\ ha^{-1}$ and $34.35\ t\ ha^{-1}$ in a study using Biofarm, leonardite,

and humic-fulvic acid fertilizers. Şaltan and Ünlü (2023) reported that the lettuce yield of the organic fertilizers they applied at different doses in the Orta variety varied between $2.92\ t\ ha^{-1}$ and $13.94\ t\ ha^{-1}$, and that fertilizer applications increased the yield. Altuntaş et al. (2022) reported lettuce yield between $22.99\ t\ ha^{-1}$ and $23.64\ t\ ha^{-1}$ in their study using chicken manure in cos lettuce cultivation. Although the effects of organic fertilizers are similar to those reported in the literature, our study yielded higher yields. This situation is due to multiple factors, including variety, climate, harvest timing, and application differences. The use of organic fertilizers enables plants to obtain macronutrients and micronutrients, including zinc, manganese, boron, copper, and iron, thereby increasing plant growth, crop yield, and fruit quality (Dhaliwal et al., 2019). In addition, it strengthens soil aggregate structure, increases water retention capacity, supports microbial activity, and reduces ammonium loss through evaporation, thereby increasing crop nitrogen use efficiency (Zhang, 2018). The lettuce yield produced with biofertilizer, seaweed, and inorganic fertilizers, as well as the combination of these fertilizers, was found to have significantly increased, going from $44.7\ t\ ha^{-1}$ to $47.5\ t\ ha^{-1}$ in the fertilization that included the seaweed combination, as reported by Mohammed et al. (2022).

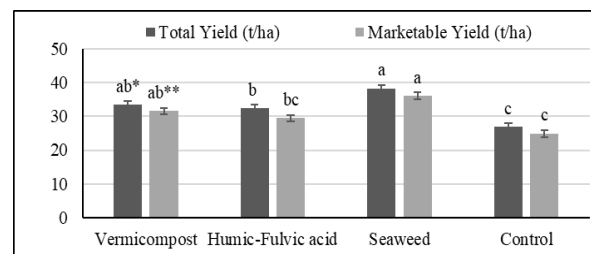


Figure 3. Impact of treatments on the total yield and marketable yield of lettuce plants. Each bar represents the mean of a specific treatment. The statistical variation between bars of the same colour indicates significant differences, with two asterisks (**) representing $p < 0.01$ for significant differences and one asterisk (*) representing $p < 0.05$ for significant differences.

When examining the effects of fertilizer applications on both average plant weight and marketable plant weight in lettuce, the applications were found to have statistically significant effects on both. When the average fertilizer application rates across both years were examined, seaweed applications had the greatest effect, with average plant weights of $767.34\ g/plant$ and marketable plant weights of $722.00\ g/plant$ (Table 1). Korkmaz and Akıncı (2023)

reported that, in studies in which they grew Paris Island lettuce, a cos-type variety, with different vermicompost types, plant head weight ranged from 308.53 g/plant to 464.78 g/plant, and marketable head weight ranged from 294.00 g/plant to 467.07 g/plant. They found that the lettuce head weights increased compared to control treatments. Sağlam et al. (2015) stated that increasing the doses of liquid vermicompost led to increased plant head and marketable head weight in curly leaf lettuce, and that the macro- and micronutrients, enzymes, and other compounds contained in the vermicompost played a role in this increase. Tüzel et al. (2011) reported, in a study using Biofarm, leonardite, and humic acid fertilizers, that the marketable yield of the cos type lettuce variety ranged from 290.7 to 387.8 g per plant. Bozokalfa and Acun (2020) examined the effects of foliar applications of *Spirulina plantensis*

(blue-green algae) doses on the cos-type lettuce cv. "Presidential" and reported that the plant weight varied between 830.1 g and 1133.5 g. Reports indicate that treatments with vermicompost (Korkmaz & Akıncı, 2020), seaweed (Mohammed et al., 2022), and humic acid (Tüzel et al., 2011) enhance yield in several lettuce cultivars. The number of discarded leaves in lettuce is important for yield and quality. The effect of years on the number of discarded leaves in lettuce was found to be statistically significant ($p < 0.01$). The number of discarded leaves lacking market value (17.98 leaves per plant) was highest in the 2023 lettuce harvest (Table 1). It is thought that the reason why the data for 2023 is high in terms of the number of leaves thrown is due to late planting, delayed head formation of lettuce due to cold climate and longer cultivation period.

Table 1. Impact of treatments on quality metrics of lettuce plants.

		Average Plant Weight (kg plant ⁻¹)	Marketable Plant Weight (kg plant ⁻¹)	Discarded Leaves (number plant ⁻¹)	WSDM (% Brix)	Dry Matter Amount (%)	Chlorophyll Value (SPAD)
Year	2022	0.66	0.62	6.25 B	3.58 A	4.17 B	33.35
	2023	0.65	0.60	17.98 A	2.81 B	7.97 A	33.66
Fertilizer	Vermicompost	0.67 ab	0.63 ab	12.13	3.78 a	6.31 a	33.82 a
	Humic-fulvic Acid	0.65 b	0.59 bc	13.38	3.76 a	6.64 a	34.97 a
	Seaweed	0.77 a	0.72 a	10.58	3.11 b	6.02 a	33.61 a
	Control	0.54 c	0.50 c	12.38	2.13 c	5.30 b	31.61 b
2022	Vermicompost	0.65	0.61	6.33	3.83	4.26	33.55
	Humic-fulvic Acid	0.69	0.62	6.25	4.13	4.53	35.00
	Seaweed	0.75	0.71	6.33	3.73	4.18	34.11
	Control	0.54	0.52	6.08	2.65	3.70	30.73
2023	Vermicompost	0.70	0.65	17.92	3.73	8.36	34.09
	Humic-fulvic Acid	0.61	0.56	20.50	3.40	8.75	34.95
	Seaweed	0.78	0.73	14.83	2.50	7.85	33.11
	Control	0.53	0.60	18.67	1.60	6.91	32.49
F value	Year	0.01	0.13	227.22**	16.57**	312.50**	0.21
	Fertilizer	6.94*	7.67**	2.20	16.65**	7.05**	4.37*
	Year × Fertilizer	0.72	0.72	2.41	1.69	0.40	0.75

Significant differences in $p < 0.01$ levels were indicated with two asterisks (**) and $p < 0.05$ with one asterisk (*). Different letters indicate different groups in the same column.

Water-soluble dry matter is a crucial parameter in production and quality assurance. According to Table 1, the amount of water-soluble dry matter in lettuce was statistically significant, with effects attributable to applications and years. The highest amounts of water-soluble dry matter were obtained from

vermicompost (3.78%) and humic-fulvic acid (3.76%) applications. These applications were followed by the seaweed application, which had 3.11% water-soluble dry matter. The water-soluble dry matter content in lettuce leaves ranged between 1.60% and 4.13% (Table 1). The amount of water-

soluble dry matter in the lettuce harvested in 2022 was higher than that found in the lettuce harvested in 2023. Due to the harsher climate in the second year, the head formation of the lettuces was delayed, and as the harvesting period was extended, the sugar content of the plants decreased, leading to a reduction in the amount of water-soluble dry matter. The water-soluble dry matter values in lettuce ranged from 4.58% to 6.34%, as reported by Şaltan and Ünlü (2023) in a similar study, with the highest value (6.34%) achieved with three applications of humic acid. Katgıcı et al. (2019) reported that the water-soluble dry matter content in curly lettuce ranged from 2.40% to 4.80%, and that microbial fertilizer applications at varying concentrations had a statistically significant effect on this variable.

The impact of applications on dry matter content in lettuce, a vegetable variety with high water content, is statistically significant for both the application and the year. The average dry matter content was 4.17% for the 2022 harvest and 7.97% for the 2023 harvest; the increase was statistically significant (Table 1). It is believed that the increase in the dry matter content of the plants in the second year may be due to the harsh climate and the extended harvesting period. Fertilizer applications increased the dry matter percentage of lettuce relative to control applications, and this increase was statistically significant.

In the study by Bozokalfa and Acun (2020), the dry matter content of the cv. "Presidential" was reported to range from 3.9% to 5.1%. The dry matter ratio in the cos lettuce variety ranged from 4.22% to 5.35% across applications with varying irrigation levels and liquid fertilizers (Yavuz, 2023).

The dry matter content of lettuce varies with factors such as variety, climate, growing period, cultivation method, and plant density. Plant chlorophyll concentration is an important characteristic commonly measured to assess overall plant health, including nutritional stress, photosynthetic capacity, and developmental status. Chlorophyll is the primary pigment system used in photosynthesis in green plants and is closely linked to their physiological condition (Sack & Scoffoni, 2013). Monitoring chlorophyll content can reflect plant health. According to Netto et al. (2005), a chlorophyll meter, also known as a SPAD meter, is a straightforward, portable diagnostic instrument that gauges the relative chlorophyll concentration or the greenness

of leaves. The effects of applications on the chlorophyll SPAD values of lettuce leaves were found to be statistically significant ($p < .05$). Compared to the control applications, other organic fertilizer applications increased the chlorophyll SPAD values; although this increase had a statistically similar effect among the applications, the highest value was obtained from the humic-fulvic acid application (34.97 SPAD units), while the lowest value was obtained from the control application (31.61 SPAD units) (Table 1). In a similar study, Şaltan and Ünlü (2023) reported that chlorophyll SPAD values in lettuce leaves ranged from 25.67 to 29.17, with the highest values observed in leaves treated with worm and seaweed fertilizers. The SPAD values of lettuce leaves grown with various amounts and types of vermicompost were found to be between 31.36 and 19.88 (Korkmaz & Akıncı, 2023). Yusuf et al. (2019) reported that the SPAD chlorophyll values of lettuce leaves treated with two different seaweed fertilizers at different doses ranged between 30.60 and 38.55. Mohammed et al. (2022) noted that the chlorophyll content decreased in lettuce that was fertilized with increasing doses of seaweed. Studies have shown that chlorophyll content in plants varies with various factors, and the results obtained are similar to those of our study.

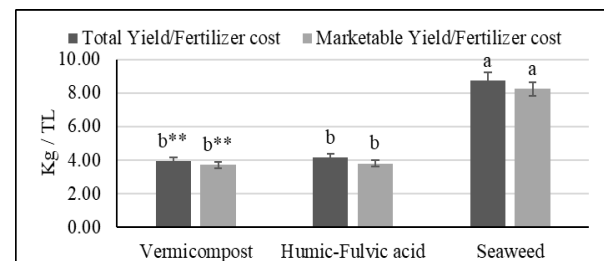


Figure 4. Yield analysis per unit price of fertilizer. Each bar represents the mean of a specific treatment. The statistical variation between bars of the same colour indicates significant differences, with two asterisks (**) representing $p < .01$ for significant differences and one asterisk (*) representing $p < .05$ for significant differences.

Fertilizer is one of the most important inputs for economic profitability in agricultural production. Therefore, it is crucial for producers to use the correct type and amount of fertilizer. In our research, we aimed to investigate the effect of fertilizer prices on product yield by dividing post-harvest yield by fertilizer prices. This approach allows us to quickly assess the yield per unit price of fertilizer. We compared organic fertilizers with one another, excluding control applications. As shown in Figure 4,

the highest total yield/fertilizer price for lettuce treated with seaweed was 8.76 kg/TL, whereas the highest market yield/fertilizer price was 8.24 kg/TL. Moreover, the highest lettuce yield at the lowest cost among organic fertilizers, such as vermicompost, humic-fulvic acid, and seaweed, was achieved with seaweed applications. This calculation is based on direct comparisons between fertilizer prices and yields. However, it is recommended that a more comprehensive cost analysis be conducted to enhance the clarity of the results.

5. Conclusion

This research demonstrates that, when organic fertilizers are evaluated alongside control applications in lettuce cultivation, they yield positive results. Organic fertilizers improve growth, development, total yield, market yield, and quality parameters in lettuce. Among organic fertilizers, such as vermicompost, humic-fulvic acid, and seaweed, the highest-quality lettuce samples with the lowest cost are obtained with seaweed applications. However, long-term studies are needed for the available data on plant development and soil change. The health and environmental issues associated with the use of chemical fertilizers in lettuce farming underscore the importance of organic fertilizers and necessitate reducing their use. In sustainable agriculture, organic fertilizers play an important role in improving soil fertility, plant development, and environmental factors. In this regard, the evaluation of our study's results will make a significant contribution to increasing efficiency in agricultural production and will also serve as an important reference for other academic studies in this field.

Authorship contribution statement

I.K.O.: Planning, conducting the experiment, taking observations and measurements, writing, reviewing, and editing.

Conflict of interest

The authors declare no conflicts of interest.

Ethical Statement

There is no need to obtain ethics committee approval for this study.

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