The Effect of Organic Fertilizer Algae Fertilizer (Spirulina powder) and Fish Fertilizer (Fish Compost) Used as an Alternative to Chemical Fertilizer on the Growth and Mineral Content of Yedikule (*Lactuca sativa L.* var. *Longifolia*) Lettuce Plant

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Abstract: Our country's soils are quite poor in organic matter, excessive chemicals are used to enrich the soil; product balance is disrupted, soil productivity decreases. In the study, the amount of chemical fertilizer was reduced and the effects of alternative fertilizers (NPK-50, NPK-100, Fish, Algae Fertilizer) on the growth and mineral contents (N, P, K, Ca, Mg, Fe, Cu, Mn, Zn, B, Mo) were investigated. In Yedikule, compared to the control, N, P, K contents were (106.29; 5.36; 38.14) ppm in algae fertilizer and (101.36; 5.99; 31.43) ppm in fish fertilizer. Nitrogen, potassium were found to be high in algae fertilizer and phosphorus were found to be high in fish fertilizer and this was attributed to the fact that algae fertilizer is rich in nitrogen and fish fertilizer is rich in phosphorus. In Yedikule, compared to the control; (Ca, Mg, Fe, Cu, Mn, Zn, B, Mo) in algae fertilizer (11.79; 8.99; 217.5; 16.87; 16.87; 34.73; 0.41) ppm, in fish fertilizer (10.58; 8.80; 201.84; 16.41; 16.41; 30.69; 0.36) ppm. In Yedikule, the highest root-leaf dry matter was determined in algae fertilizer (29.60%, 8.72%) and fish fertilizer (28.35%, 7.85%) compared to control. The highest values (root collar, root length, plant length) in Yedikule were (1.01, 14.01, 25.21) cm in algae fertilizer and (0.95, 10.51, 24.3) cm in fish fertilizer. While growth parameters differed in Yedikule compared to control; statistically significant differences were found in plant length only in fish and algae fertilizer (P<0.05). It was determined that algae-fish fertilizer positively affected plant development.

Keywords: Chemical fertilizer, Fish compost, Spirulina powder, Soilless agriculture, Yedikule plants

INTRODUCTION

The food demand that emerged with the increase in the world population brought about wrong agricultural practices in the 20th century, and the intensive use of hormones, synthetic fertilizers and pesticides to achieve high yields in conventional agriculture began to threaten soil, water and human health even more [1]. Therefore, it is also very important to reduce the use of chemical fertilizers, which are dangerous for human and environmental health, and to move more sustainable agricultural systems with environmentally friendly agricultural practices [2]. Excessive use of chemical fertilizers makes the product more prone to diseases and causes a decrease in soil fertility. It is reported that the use of high amounts of nitrogenous fertilizers causes nitrogen storage in the plant, and the consumption of plants that accumulate high amounts of nitrogen in the form of fertilizer and nitrate causes toxic effects in humans. In order to prevent pollution caused by chemical fertilizers, scientists developed "Natural Fertilizers" and researchers began to turn to soil management

technologies that are more sensitive to the environment and human health without reducing the quality of production [3]. Organic farming and ecological farming practices developed for these purposes are rapidly spreading today. Environmentally friendly farming approaches include the use of natural or biological substances that can reduce or replace the chemical inputs used [4].

Algae used as biofertilizers in agriculture ensure the release of phos phate and trace elements from insoluble minerals in the soil and the transfer and storage of atmospheric nitrogen to the soil. In addition, microalgae directly affect plant development with theirbenefits such as controlling pathogenic microorganisms, adjusting plant hormone levels and holding soil particles together. Cyanobacteria, known as blue-green algae, are photosynthetic organisms with a cylindrical shape [5]. *Spirulina* is a source of many minerals such as iron, selenium, magnesium and calcium, as well as high-quality protein content (500-700 g kg^{-1} crude protein). The most common use of *Spirulina* is as a food supplement in human nutrition due to its rich nutritional content [6]. *Spirulina* is the first microalgae produced worldwide and is one of the most widely used organic agricultural fertilizer sources due to its high content of protein, polyunsaturated fatty acids [7], carotenoid pigments [8], vitamins and phenolic compounds [9], lipids and polysaccharides [10]. *Spirulina* fertilizer helps stimulate plant growth and development, increases soil fertility, increases resistance to diseases and pests, and is more environmentally friendly than chemical fertilizers. Algae are currently attracting attention as a raw material for marketed biofertilizers [11]. It is known that fertilizers consisting of unevaluated fish waste obtained through hunting or farming increase crop productivity in agriculture. By-products obtained from the fish processing industry contain valuable nutrients and their use as fertilizer is an acceptable alternative [12]. Studies show that the use of organic fertilizers is an important method that provides economic gain by both ensuring the continuity of agricultural production and reducing costs. Lettuce (*Lactuca sativa* L.) is a member of the Asteraceae family and is one of the most important leafy vegetables in terms of nutritional value and is intensively produced [13]. Lettuce plant is one of the most valuable vegetables used in human nutrition worldwide with its rich nutritional properties such as crispness, pleasant aroma, high levels of phytonutrients such as phenolic compounds, vitamins (C, K and folate) and fibers [14]. It has been determined that lettuce grown with organic fertilizers has similar mineral content to lettuce grown conventionally, and lettuce grown with organic fertilizers is richer in some minerals [15].

In recent years, organic and conventional agricultural practices have gained importance, while conventional agricultural studies focused on the "Green Revolution" are still intensively carried out.

This study was conducted to reduce the conventional cultivation widely used in our country, increase production in traditional and organic agricultural systems, protect the environment by reducing the use of chemical fertilizers; to investigate the possibilities of using alternative biofertilizers (algae and fish fertilizers) in agriculture, to evaluate and reveal the effects of alternative fertilizer types on the development, yield and product quality of Yedikule lettuce plants. Therefore, in study, the effects of reducing chemical fertilizers by half in the cultivation of Yedikule lettuce plants and using supported by organic fertilizers such as algae (Spirulina powder) and fish fertilizers (fish waste) on the growth parameters and mineral content of Yedikule lettuce plants were investigated.

MATERIALS AND METHODS

A slightly dark green, rounded Yedikule lettuce (*Lactuca sativa L. var. longifolia*) plant grown in a greenhouse environment was used in the experiment and was supplied by Artı Fide company (Antalya, Turkey).

Fertilizers Used in the Experiment

Algae fertilizer (commercially sold Nutriga® Organic Spirulina Powder) and fish fertilizer (fish waste: fish head, skin, internal organs, and fish bones) were composted as biofertilizers in the experiment. Gübretaş® 15-15-15 NPK was used as a chemical fertilizer. Soil Used in the Experiment Cocopeat, which is obtained from MagicPlant® company, was used in the experiment, which is formed by breaking coconut shell fibers into small pieces, has high water holding capacity and low nutrient content, and is used in soilless agriculture.

Other Materials Used in the Experiment

The Yedikule plant production used in the experiment was carried out in a greenhouse environment. Plastic pots with a volume of 4 L were used in the experiment. To provide controlled irrigation in the pots, a drip irrigation system was applied to the plastic pots.

Preparation of Fertilizers Used in the Experiment

In the trial, chemical fertilizer was supplied by Gübretaş® company, and Spirulina powder was supplied by Nutriga® company. A composting technique was applied for fish fertilizer. For this purpose, fish waste (head, internal organs, skin, bones, etc.) taken from the fish market was roughly chopped with a knife to accelerate the composting process. Fish waste and molasses were added to the 20 L demijohn based on the ratio of 1 kg (molasses) - 3 kg (fish waste) - 10 kg (water) [16,17]. To accelerate the dissolution process, some sawdust was added and the mixture was topped up with water. To remove the gas released during fermentation, the lid of the demijohn was pierced a pipe was placed and the lid was tightly closed. The pipe coming out of the lid was immersed in a water-filled PET bottle, creating an oxygen-free environment in the demijohn and ensuring that regular gas release was observed. The mixture was mixed regularly every day without opening the lid and the mixing process was continued until the gas release stopped [16,17]. After two months, the fish oil formed on the surface of the mixture was removed.

Experiment Design

The study was prepared in plastic pots (black inside plastic pots) with 9 root plants in each group. It was arranged as 45 pots with 5 groups of 3 replications (3 roots x 3 replications) together with the control group. The pots were filled with equal amounts of soil by being weighed and arranged so that each pot had 4 L of soil. After the fertilizers were weighed and transferred to the pots, the soil in each pot was mixed homogeneously. Randomly selected plants were planted in pots and placed in the greenhouse. The seedlings were harvested 1.5 months after planting and measurements and analyses were carried out. The amount of fertilizer used in the experiment was calculated in kg da^{-1} N and in the groups to

which fish and algae fertilizer were added, the total nitrogen amount was added to the soil at a rate not exceeding 15 kg N da^{-1} (Table 1).

Table 1: The Experiment groups and fertilizer amounts

Trial Groups	Plants	Fertilizer amounts
Control (0 kg NPK+ 0 fish and algae fertilizer)	Yedikule	0
NPK-50 (½ dose NPK)	Yedikule	7,5 kg N da-1 Commercial Fertilizer
NPK-100 (full dose NPK)	Yedikule	15 kg N da-1 Commercial Fertilizer
Fish Fertilizer (½ dose NPK+ ½ dose fish compost)	Yedikule	7,5 kg N da-1 Commercial Fertilizer+7,5 kg N da-1 Fish Fertilizer (Compost)
Algae Fertilizer (½ dose NPK+ ½ dose Spirulina powder)	Yedikule	7,5 kg N da-1 Ticari Gübre + 7,5 kg N da-1 Algae Fertilizer (Spirulina powder)

[a] Commercial fertilizer: NPK (15% Nitrogen-15% Phosphorus-15% Potassium) fertilizer used as base fertilizer was supplied by Gübretaş company)

Fertilizer Analyses

Fertilizer analyses were carried out at METALAB Analysis Laboratory (Mersin, Turkey).

Algae Fertilizer Analysis

The Kjeldahl method was used for nitrogen determination of the algae powder (Spirulina powder) used in the experiment [18]. The Spirulina powder to be used in the analyses was placed in paper bags and dried in an oven for 48 hours at 65ºC. The dried samples were ground in a grinding device and 0.3 g of the homogenized sample was weighed and transferred to Kjeldahl combustion tubes. The total nitrogen amount was found with the formula used in the determination [19].

$$\text{Total nitrogen (N)\%} = (T - B) \times N \times 1.4 / S \qquad (1)$$

T:Acid used in titration (mL), B: Acid used in blank titration (mL), N: Normality of acid, S: Amount of sample taken (g)

For phosphorus and potassium determination, readings were performed on the ICP-OES device using the wet combustion method. The wavelength with the highest emission intensity was selected as 213.617 nm for P (Phosphorus) analysis and 766.490 nm for K (Potassium). Spirulina powder to be used in the analysis was placed in paper bags and dried in an oven at 65 for 48 hours. The dried samples were ground in a grinding device. Then, the wet combustion method was applied to the samples with sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) [20]. The ground Spirulina powder sample was weighed at 0.5 g with a precision balance and added to the 100 mL combustion tube. After dissolving the powdered algae fertilizer (Spirulina Powder) in pure water at 7.5 N kg da^{-1}, the measurement was carried out with a pH meter. According to the analysis results, pH was determined as 7.3, Nitrogen (N) 10.56%, Phosphorus (0.76%), and Potassium (K) 1.93%.

Fish Fertilizer Analysis

The Kjeldahl method was used for nitrogen determination of fish fertilizer used in the experiment [18]. For phosphorus and potassium determination, the wet combustion method was used and readings were taken on the ICP-OES device. After diluting fish fertilizer with pure water to provide 7.5 N kg da^{-1}, the measurement was made with a pH meter. According to my analysis results, pH was determined as 6.9, Nitrogen (N) 8.35%, Phosphorus (4.45%), and Potassium (K) 1.38%.

Soil Analyses Physical and chemical analyses of the soil (pH, electrical conductivity (EC), salinity, lime determination, and organic matter content) were carried out in the METALAB analysis laboratory.

Electrical Conductivity (EC) and Salinity Determination

The soil used in the experiment was diluted at a ratio of 1:2.5 and then shaken in a horizontal shaker for 15 minutes. The measurement was then made with a conductivity meter (Hanna®) (Table 2). The EC value was multiplied by 0.064 to determine the salinity in ppm. The Salinity Level of the Soil (%) was reported as 0.00-0.15 unsalted, 0.15-0.35 slightly salty, 0.35-0.65 moderately salty, >0.65 extremely salty [21].

Lime Determination

The soil used in the experiment was mixed homogeneously and ground. The CO_2 gas released by reacting with dilute hydrochloric acid was measured in a Scheibler calcimeter. Since the lime in the soil is in the form of $CaCO_3$, the calculations were made according to the following formulas [22]. Classification of Soil According to Lime Content (%); the amount of lime ($CaCO_3$) was reported as 0-2 non-calcareous, 2-4 low-calcareous, 4-8 medium-calcareous, 8-15 calcareous, 15-50 very calcareous, >50 very calcareous [21].

$$\% \text{ Lime } (CaCO_3) = (V0 \times 0.4464) / A \qquad (2)$$

$$V0 = [Vt \times (b\text{-}e) \times 273] / [760 \times (273) \qquad (3)$$

Vo: Gas volume converted to normal conditions (cm^3); A: Sample amount (g); 0.4464: Coefficient 1 mole of CO_2 released from 1 mole of $CaCO_3$ under normal conditions. Vt: Carbon dioxide gas volume read in the calcimeter (cm^3), b: Barometer pressure corrected for temperature (mm/Hg), e: Vapor pressure of water at the measured temperature, t: Ambient temperature (0°C), 760: Barometer pressure value at sea level, 273: Value for converting 0°C to K (Kelvin)

pH Determination

The soil used in the experiment was diluted at a ratio of 1:2.5 and then shaken in a horizontal shaker for 30 minutes. Then, the measurement was made with a pH meter [23]. Classification of Soil According to pH Value; >9.0 is very strong alkaline, 8.5 – 9.0 is strong alkaline, 8.5 – 9.0 is moderately alkaline, 7.4 – 7.8 is slightly alkaline, 6.6 – 7.3 is neutral, 6.1 – 6.5 is slightly acidic, 5.6-6.0 is moderately acidic, 5.1-5.5 is strong acidic, 4.6-5.0 is very strong acidic, <4.5 is extremely acidic [21].

Amount of Organic Matter

The amount of organic matter in the soil was determined by the Walkey-Black method (Nelson and Sommer, 1982) [23]. The analysis results of the soil used in the experiment are given (Table 2). Classification of soil according to the amount of organic matter (%); rates between 0-1 are reported as very little, 1-2 as little, 2-3 as medium, 3-6 as much, and >6 as very much [21].

$$\% \text{ Organic Matter} = [(A - (B \times Nk) \times 0.581] \qquad (4)$$

A: Amount of K2Cr2O7 spent in analysis (mL), B: Amount of $FeSO_4$ spent in titration (mL), T: Amount of sample used (g), Nk: Absolute normality of iron sulphate solution

$$Nk = 10 / V$$

10: Amount taken from potassium dichromate (mL), V: Amount of iron sulphate spent in titration for normality (mL).

<u>Table 2</u>: **Analysis Results of Soil Used in the Experiment**

Analysis	Analysis Result	Classification
pH	7,3	Neutral
Lime ($CaCO_3$)	% 1,29	Non-calcareous
Organic Matter	% 1,73	Few
Electrical Conductivity (EC)	0,05 ms/cm	low
Salinity	% 0,0032	Non-salt

[b]Toprak analizleri: (pH değeri: 6.6-7.3 nötr, 0-2 aralığı kireçsiz, organik madde miktarı: 1-2 az, Elektriksel iletkenlik (EC): 0-2 aralığında (EC) değeri: 0.05 ms cm^{-1}, tuzluluk oranı: 0,00-0,15 arası tuzsuz)

Plant Analyses

Chemical analyses of plants (determination of N, P, K, Ca, Mg, Fe, Cu, Mn, Zn, B and Mo) were carried out in METALAB Analysis Laboratory (Mersin, Turkey).

Plant Height, Leaf Dry Matter Amount, Root Length, Root Collar Width, Root Dry Matter Amount Measurements

The distance between the root collar and the top point of the harvested plants was measured with a ruler and the plant height was determined in cm. The leaves were washed and weighed after harvest and the fresh weight was calculated as (g). The leaves whose fresh weights were determined were then dried at 65 °C for 48 hours and weighed and the dry weight was calculated as (g). Then, the dry matter ratio was calculated in % by comparing the leaf fresh and dry weights. The root collar diameter was measured with a caliper and the root collar width was determined in cm. The root length was determined in cm by measuring with a ruler from the root collar. The roots were washed and weighed after harvest and the fresh weight was calculated as (g). The roots whose fresh weights were determined were then dried at 65 °C for 48 hours and weighed and the dry weight was calculated as (g). Then, the dry matter ratio was calculated in % by comparing the root fresh and dry weights [24].

Nitrogen Determination

After the experiment, the harvested lettuce leaves were washed and cleaned, then placed in paper bags and dried in an oven for 48 hours at 65°C. The dried samples were ground in a grinding device. Then, the Kjeldahl method was used for nitrogen determination [18].

Determination of P, K, Ca, Mg, Fe, Cu, Mn, Zn, B and Mo

For the determination of elements (P, K, Ca, Mg, Fe, Cu, Mn, Zn, B, and Mo), readings were performed on the ICP-OES device using the wet combustion method. In the readings performed after the analysis, the wavelengths of mineral substance recommended for the device; Phosphorus (P) is given as 213.617 nm, Potassium (K) is given as 766.490 nm, Calcium (Ca) is given as 317.933 nm, (Mg) is given as 280.271 nm, Iron (Fe) is given as 238.234 nm, Copper (Cu) at 324.752 nm, Zinc (Zn) is given as 213.856 nm, Boron (B) is given as 249.667 nm, Molybdenum (Mo) is given as 202.031 nm.

Statistical Analysis

The trial was set up with three replications. The data obtained as a result of the trial were subjected to Two-Way Anova analysis in the SPSS 16 package program, and the differences in the means were determined with the Duncan multiple comparison test [25].

RESULTS AND DISCUSSIONS

Mineral Substance Content (Nitrogen, Phosphorus, Potassium) of Yedikule Lettuce Plant

The effects of different fertilizer applications on the nitrogen and potassium contents of Yedikule plants are given in (Table 3).

Table 3: Effect of different fertilizer applications on N, P, K content of Yedikule lettuce plant

Trial Groups	Nitrogen Content of Yedikule Lettuce Plant (ppm) ($\overline{X} \pm S_{\overline{X}}$)	Phosphorus Content of Yedikule Lettuce Plant (ppm) ($\overline{X} \pm S_{\overline{X}}$)	Potassium Content of Yedikule Lettuce Plant (ppm) ($\overline{X} \pm S_{\overline{X}}$)
Control (0 kg N da^{-1} NPK+ 0 fish and algae fertilizer)	76,65 ± 4,34[ax]	3,40 ± 0,48[ax]	20,92 ± 1,47[ax]
NPK-50 (½ dose NPK)	90,64 ± 6,83[bx]	4,69 ± 0,78[bx]	21,99 ± 2,08[ax]
NPK-100 (full dose NPK)	93,00 ± 5,64[cx]	5,85 ± 0,71[cx]	26,71 ± 3,44[bx]
Fish Fertilizer (½ dose NPK+ ½ dose fish compost)	101,36 ± 13,76[dx]	5,99 ± 0,63[cx]	31,43 ± 3,06[cx]
Algae Fertilizer (½ dose NPK+ ½ dose Spirulina powder)	106,29 ± 9,49[dx]	5,36 ± 0,51[cx]	38,14 ± 4,34[dx]

[*]Duncan; The letters a, b, c, d are used to indicate the distinction between different trial applications. There is a statistical difference between the data shown with different letters at the $P<0.05$ level. $\overline{X} \pm S_{\overline{X}}$: Arithmetic mean ± Standard error.

In all applications of Yedikule plants supported with different fertilizer types (NPK-50, NPK-100, fish fertilizer, and algae fertilizer), a significant difference was observed compared to the control application in terms of nitrogen and potassium contents (P<0.05). Among the trial applications, the highest nitrogen-potassium content was determined in algae fertilizer (106.29± 9.49; 38.14± 4.34)ppm and the second highest in fish fertilizer (101.36± 13.76; 31.43± 3.06) ppm applications. It was determined the increase in phosphorus level was at close values compared to the control group (P<0.05). Among the trial applications, the highest phosphorus content was found in the fish fertilizer and the second NPK-100 application (5.99 ± 0.63; 5.85 ± 0.71) ppm (Table 3). Kul [24], as a result of the study in which he investigated the effects of fish fertilizer, mineral fertilizer, and their combinations on plant development, nutrient element content in lettuce, recorded the highest potassium (K) content in 20 kg da^{-1} fish fertilizer. The highest phosphorus (P) content was recorded in Mineral Fertilizer + Fish Fertilizer,20 kg da^{-1} Fish Fertilizer.

Demirci [26] as a result of his study, found that %N values of various basic and top fertilizers were between 2.41 and 3.78 in lettuce grown in the Autumn-Winter and Winter-early Spring periods. When the Nitrogen, Phosphorus (N, P), and Potassium (K) contents of Yedikule plants used in the experiment were examined; the highest Nitrogen (N) and Potassium (K) values were determined in the Algae fertilizer, while the highest Phosphorus (P) content was determined in the Fish fertilizer. Since the algae fertilizer is rich in Nitrogen (N) and the fish fertilizer is rich in Phosphorus (P); it is thought that it positively affects the content of the Yedikule plants. In our study, the values found are consistent with those of other studies.

Other Mineral Substance Contents of Yedikule Lettuce Plant

The effects of different fertilizer applications on the calcium, magnesium, and iron contents of Yedikule plants are given in (Table 4). A significant difference was determined in terms of calcium (Ca) content of Yedikule plants supported with different fertilizer types (NPK-50, NPK-100, fish fertilizer, and algae fertilizer) compared to the control application. The highest calcium, magnesium, and iron contents were determined in seaweed fertilizer as (11.79± 1.16; 8.99± 1.48; 217.5± 13.24) ppm (P<0.05). The lowest calcium, magnesium, and iron contents in Yedikule plants were determined as NPK-50 (10.29± 1.23; 6.64± 0.65; 165.81± 15.95) ppm (P<0.05). The effects of different fertilizer applications on the copper content of Yedikule lettuce plants are given in (Table 4). Among the experimental treatments, the highest Copper, Manganese and Zinc contents were found in algal fertilizer application in Yedikule lettuce (16.87± 1.29; 16.87± 1.29; 16.87± 1.29) ppm, the lowest Copper, Manganese and Zinc contents were found in NPK-50 application (15.41± 1.24; 15.41± 1.24; 15.41± 1.24) ppm. Although the treatment groups in the Yedikule plant were different from the control, no significant difference was found between them (P<0.05). The effects of different fertilizer applications on the boron and molybdenum contents of Yedikule lettuce plants are given in (Table 4). It was determined that the boron contents of Yedikule plants did not differ from each other (P<0.05). The highest boron and molybdenum content in Yedikule lettuce plants was found in Algae fertilizer (34.73± 2.00; 0.41± 0.04) ppm, while the lowest boron and molybdenum content was found in NPK-50 application (24.67± 2.19; 0.25± 0.05) ppm (P<0.05).

Aydöner Çoban et al. [27] determined higher nutrients in leaf analysis in applications where *C. vulgaris* was used after different doses of *Chlorella vulgaris* application together with mineral fertilizer in soilless tomato cultivation compared to controls. El-Baky et al. [28] sprayed *Chlorella ellipoda* and *Spirulina maxima* on wheat plants irrigated with sea water in a study they conducted. As a result of the experiment, they reported a positive increase in total chlorophyll and antioxidant contents as well as macro and micro elements. Radziemska et al. [29] reported that there was an increase in macro and micro mineral concentrations in lettuce grown in soil added with fish waste and pine bark compost compared to the control group. Emphasizing the importance of soil composition and chemical parameters for the growth of a product, Bhuimbar and Dandge [30] reported that fish waste hydrolysate added to the soil improved soil quality and, accordingly, significantly affected the nutritional contents of black-eyed peas and pepper. Zou et al. [31] stated that there was a significant increase in microelements in their study on the effect of green tea and fish waste on lettuce plant growth. They reported that the highest increase rate was in Na, and the increase rate in microelements was Na>Cu>Co>Mg>Zn>Fe, respectively.

In our study, it was determined that the mineral content of the plants increased, and when the growth parameters were examined in terms of nutritional values, it was concluded that alternative algae fertilizer and fish fertilizer positively affected plant development. According to the study data, the highest mineral substance content was obtained in the combination of 7,5 N kg da^{-1}dose NPK (chemical fertilizer) + algae fertilizer, and the second fish fertilizer + NPK (chemical fertilizer). The highest mineral substance content was determined as Iron> boron> copper=manganese=zinc>calcium>magnesium>molybdenum ppm, respectively (Table 4).

Tablo 4: Effect of different fertilizer applications on Ca, Mg, Fe, Cu, Mn, Zn, B, Mo contents of Yedikule lettuce

Trial Groups	Ca Content (ppm)	Mg Content (ppm)	Fe Content (ppm)	Cu Content (ppm)	Mn Content (ppm)	Zn Content (ppm)	B Content (ppm)	Mo Content (ppm)
Control (0 kg N da-1 NPK+ 0 fish and algae fertilizer)	7,79 ±0,69ax	5,56 ± 1,44ax	137,18 ±15,96ax	13,68 ±1,65ax	13,68 ± 1,65ax	13,68 ± 1,65ax	20,46 ± 2,44ax	0,17 ±0,04ax
NPK-50 (½ dose NPK)	10,29 ±1,23bx	6,64 ± 0,65bx	165,81 ± 15,95bx	15,41 ± 1,24bx	15,41 ± 1,24bx	15,41 ± 1,24bx	24,67 ± 2,19bx	0,25 ± 0,05bx
NPK-100 (full dose NPK	10,93 ±0,92bx	7,50 ± 1,13bx	175,86 ± 15,34bx	16,03 ± 2,34bx	16,03 ± 2,34bx	16,03 ± 2,34bx	26,46 ± 2,22bx	0,31 ± 0,06cx
Fish Fertilizer (½ dose NPK+ ½ dose fish compost)	10,58 ±1,21bcx	8,80 ± 0,91cx	201,84 ± 22,34cx	16,41 ± 1,77bx	16,41 ± 1,77bx	16,41 ± 1,77bx	30,69 ± 2,72cx	0,36 ± 0,04dx
Algae Fertilizer (½dose NPK+½dose Spirulina powder)	11,79 ± 1,16cx	8,99 ± 1,48cx	217,5 ± 13,24dx	16,87 ± 1,29bx	16,87 ± 1,29bx	16,87 ± 1,29bx	34,73 ± 2,00dx	0,41 ± 0,04ex

*Duncan; The letters a, b, c, d are used to indicate the distinction between different trial applications. There is a statistical difference between the data shown with different letters at the P<0.05 level.$\bar{X}±S_{\bar{X}}$: Aritmetik ortalama ± Standart error.

Effect of Different Fertilizer Applications on Growth Parameters of Yedikule Lettuce Plant

The dry matter ratio in the root and leaf of the Yedikule plant was found to be (29.60±2,6 %, 8.72± 0,8 %) for algae fertilizer, and root collar, root length, and plant length were found to be (1.01±0,08,14.01±0,7, 25.21± 1,39) cm for algae fertilizer, respectively. In fish fertilizer, root, and leaf dry matter ratio was determined as (28.35±2,2 and 7.85± 0,6) cm, and root collar, root length, and plant length were determined as (0.95±0,07, 10.51± 0,9, and 24.3± 2,22) cm. When the physical parameters of the plants were examined in our experimental study, it was determined algae and fish fertilizers positively affected plant development, and these findings are consistent with other studies. The effect of different fertilizer applications on the root and leaf dry matter ratio of the Yedikule plant is given in (Table 5). When the root dry matter ratio of the Yedikule lettuce plant was examined, there was no statistically significant difference in the NPK-50 application compared to the control group, while there were statistically significant differences in other applications ($P<0.05$).

When the root-leaf dry matter ratio of the Yedikule plant was examined, the highest root and leaf dry matter ratio was found in the algae fertilizer and the second in the fish fertilizer compared to the control group. The highest root collar and root length were found in the 7.5 N kg da^{-1} dose NPK (chemical fertilizer) + algae fertilizer combination and the highest plant length was found in the 7.5 N kg da^{-1} dose NPK (chemical fertilizer) + fish fertilizer combination (Table 5).

Table 5: Effect of different fertilizer applications on growth parameters of Yedikule lettuce plant

Trial Groups	Dry matter content (%)		Root Collar (cm)	Root Length (cm)	Plant Length (cm)
	Root(%)	Leaf(%)			
Control (0 kg N da-1 NPK+ 0 fish and algae fertilizer)	19,71±1,3a	6,35±0,53a	0,95±0,07a	10,51 ± 0,9a	24,3 ± 2,22a
NPK-50 (½ dose NPK)	20,39±1,7a	6,44±0,66ab	1,01±0,08a	14,01±0,75b	25,21 ± 1,39a
NPK-100 (full dose NPK)	23,71±1,8b	6,98 ± 0,47b	1,41±0,15b	17,01±1,73c	26 ± 2,14a
Fish Fertilizer (½ dose NPK+ ½ dose fish compost)	28,35±2,2c	7,85 ± 0,6c	0,95±0,07a	10,51 ± 0,9a	24,3 ± 2,22a
Algae Fertilizer (½dose NPK+½dose Spirulina powder)	29,60±2,6c	8,72 ± 0,8d	1,01±0,08a	14,01±0,7b	25,21 ± 1,39a

*Duncan; The letters a, b, c, d are used to indicate the distinction between different trial applications. There is a statistical difference between the data shown with different letters at the $P<0.05$ level. $\bar{X}±S_{\bar{X}}$: Aritmetik ortalama ± Standart error.

Xu and Mou [32] grew lettuce plants with protein hydrolysates obtained from fish and reported that the number of leaves, stem diameter, shoot and root dry weight of the plant increased significantly. Abbasi [33, 34] applied fish waste-based liquid fertilizer to tomatoes, cucumbers, radishes, peppers and eggplants in studies conducted in different years. It was reported that after the application, resistance and yield of tomatoes and peppers against diseases increased and the growth of radish seedlings increased. Hepsibha and Geetha [35] reported that the application of liquid fish fertilizer as a soil conditioner caused an increase in plant growth and root elongation in mung beans (*Vigna radiata*). Karim

et al. [36] reported that when compared to commercial fertilizer (15-15-15 NPK), 5%; 7.5%; It was reported that fish silage at 10% concentrations caused an increase in plant growth, yield, pigment content and postharvest quality parameters of Chinese cabbage (*Brassica rapa L. chinensis*) called pakchoi.

Faheed et al. [37] germinated lettuce seeds in culture medium containing microalgae and reported that the best application for seed germination and seedling development was 2 and 3 g dry algae kg^{-1} addition to the soil. El-Baky et al. [28] sprayed *Chlorella ellipoda* and *Spirulina maxima* on wheat plants irrigated with sea water in a study they conducted. As a result of the experiment, it was reported that algae applications caused an increase in plant fresh weight and grain weight. Zodape et al. [38] reported that there was a significant increase in fruit yield compared to the control group in the foliar spray application of liquid seaweed to okra plants. Shaaban [39] investigated the effect of *Chlorella vulgaris* on the development of corn plants. In the experiment, it was reported that the best increase in rooting, root and shoot dry weight and length of corn plants to which different doses of algae were added in addition to NPK fertilizer were in the groups applied with 150 and 200 kg fed $^{-1}$ algae. Kul [24] reported that organic substances applied to the soil improve the physical, chemical and biological properties of the soil, increase the humic substance content, water retention rate, microbial activities, and plant-beneficial nutrient elements, thus stimulating the division of root cells and allowing the plant to benefit more from nutrient elements. Zou et al. [31], in their study on the effect of green tea and fish waste on lettuce plant growth, recorded an average increase of 2.47 cm in leaf lengths in the group using fish waste. It was stated that root development in plants facilitates nutrient uptake in the soil and therefore directly affects plant productivity.

In our study, the effects of different fertilizer combinations (NPK-50: (½ dose NPK), NPK-100: full dose NPK, Fish fertilizer: (½ dose NPK+½ dose Fish compost) and Algae fertilizer: ½ dose NPK+½ dose Spirulina powder) on growth parameters (plant height, leaf fresh/dry weight, root diameter, root length, root fresh/dry weight) and mineral substance content (N, P, K, Ca, Mg, Fe, Cu, Mn, Zn, B and Mo) of Yedikule lettuce plants grown in greenhouse environment were investigated and it was determined that the most effective fertilizer was algae fertilizer (Spirulina powder) and the second most effective fertilizer was fish fertilizer (fish compost). In addition, when the growth parameters of the plants were examined, it was determined that algae and fish fertilizer affected plant development positively and these findings are consistent with other studies. Similar to other studies, it was determined that lettuce grown with organic fertilizers had similar mineral content to lettuce grown with conventional methods and that lettuce grown with organic fertilizers was richer in some minerals.

Comparison of Costs of Fertilizers Used in the Experiment

To evaluate the fertilizers used in the experiment economically, the fertilizers needed for 1 decare of lettuce cultivation and their costs were calculated and given in (Table 6).

For fish fertilizer, cost calculations were made based on molasses and water used in preparing the fertilizer, and for algae fertilizer, algae fertilizer cost calculations were made based on chemical fertilizer sold in the market and used in the experiment.

Tablo 6: Cost of different fertilizer applications in 1 decare lettuce cultivation

Trial Groups	Fertilizer Amount (kg da^{-1})	Price (₺)	Price(€)*
NPK commercial fertilizer	100 kg	2.800,00	80,08
%50 NPK + Fish Fertilizer	50 kg + 420 L Sıvı Balık Gübresi	2.150,00	61,49
%50 NPK + Algae Fertilizer	50 kg + 7,5 kg Ticari Toz *Spirulina*	8.900,0	254,53

* Exchange rate: 1 € = 34,97 ₺ (17March 2024)

CONCLUSIONS

Our study aims to investigate the potential of using fish waste and algae fertilizer in agriculture and to popularize the use of organic fertilizer by reducing the use of chemical fertilizers. When evaluated in terms of morphological and chemical aspects, it was determined that the growth parameters of the Yedikule Lettuce plant grown with algae-fish fertilizer and semi-reduced chemical fertilizer were positively affected. Since fish fertilizer is obtained at a very low cost and due to the high nutrient content of algae fertilizer, using it in low amounts reduces the costs significantly. According to the study data; N, P, and K contents of Yedikule Lettuce Plant according to control application were determined as (106.29 ± 9.49; 5.36 ± 0.51; 38.14 ± 4.34) ppm, respectively, and in fish fertilizer as (101.36 ± 13.76; 5.99 ± 0.63; 31.43 ± 3.06) ppm, respectively. While nitrogen and potassium contents were the highest in algae fertilizer, it was found that the phosphorus content of fish fertilizer was higher. The reason for this is associated with the fact that algae fertilizer is rich in nitrogen and fish fertilizer is rich in phosphorus. It was concluded that it positively affected the nutrient content of the Yedikule plant. Again, according to the control application of the Yedikule lettuce plant; The values of (Ca, Mg, Fe, Cu, Mn, Zn, B and Mo) in algae fertilizer were (11.79 ± 1.16; 8.99 ± 1.48; 217.5 ± 13.24; 16.87 ± 1.29; 16.87 ± 1.29; 16.87 ± 1.29; 34.73 ± 2.00; 0.41 ± 0.04) ppm, and the values in fish fertilizer were (10.58 ± 1.21; 8.80 ± 0.91; 201.84 ± 22.34; 16.41 ± 1.77; 16.41 ± 1.77) ppm; In Yedikule Marul plants, the highest matter ratio in roots and leaves compared to control application was in algae fertilizer (29.60 ± 2.6%, 8.72 ± 0.8% and fish fertilizer (28.35 ± 2.2%, 7.85 ± 0.6%). The highest dry matter ratio (root collar, root length, and plant height) in the Yedikule plant was determined as algae fertilizer (1.01 ± 0.08 cm, 14.01 ± 0.7 cm, 25.21 ± 1.39 cm) and fish fertilizer (0.95 ± 0.07 cm, 10.51 ± 0.9 cm, 24.3 ± 2.22 cm), respectively.

In the Yedikule plant, except for NPK-50 application, differences were observed compared to the control group in terms of root-leaf dry matter, root collar diameter, and root length, while statistically significant difference was determined in plant height only in fish and algae fertilizers (P<0.05). According to the study results, when plant growth parameters were examined, it was determined that algae and fish fertilizer affected plant development positively. When the root-leaf dry matter ratio of the Yedikule lettuce plant was examined, it was seen that the root and leaf dry matter ratio was in algae fertilizer compared to the control group, and the second was in fish fertilizer. The highest root collar and root length were found in the 7.5 N kg da^{-1} dose NPK (chemical fertilizer) + algae fertilizer combination, and the highest plant length was found in the 7.5 N kg da^{-1} dose NPK (chemical fertilizer) + fish fertilizer combination. In the study, it was determined that the most effective fertilizer in terms of growth parameters of the Yedikule plant was algae fertilizer, and the second most effective fertilizer was fish fertilizer. It was determined that reducing the use of chemical fertilizers by half and increasing the use of natural fertilizer

sources would be effective in spreading organic and conventional product cultivation, reducing fertilizer costs in production, and developing sustainable agriculture. In addition, it was determined that products of equivalent or higher quality have been proven in terms of nutritional value compared to the products obtained in conventional cultivation.

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