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Article

# Effect of Municipal Solid Waste Compost on Yield, Plant Growth and Nutrient Elements in Strawberry Cultivation

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**Abstract:** In terms of sustainable economic activities, environmental and production costs of plant nutrition material in agricultural production and wastes that harm the environment, humans and living beings are two important problems. This study, which combines these two problems into a common denominator, aimed to obtain plant nutrition input with low environmental and production costs by using the wastes generated during the domestic consumption process in strawberry cultivation. Municipal solid waste compost (MSWC) for plant nutrition input and an Albion strawberry variety as a trial plant were used as research materials. In the study, where the random block trial design method was used, the effects of MSWC on plant growth, fruit quality characteristics and plant nutrient parameters were investigated. According to the results of the study, it was concluded that the examined parameters (number of fruits per plant, fruit weight, fruit taste, macro and micronutrient content in plant leaves) were positively affected according to the rate of use of MSWC. In the parameters evaluated within the scope of the study, 4 tons of MSWC applications in fruit weight, stem number, root length, plant width, leaf area, K and Ca parameters; 1.2 tons of MSWC applications in the number of fruits per plant and TA parameters; all MSWC applications in fruit yield per plant, pH, plant height, N, Mn and Cu parameters; 2 tons of MSWC applications in the TSS parameter and 1, 2 and 4 tons of MSWC applications in P and number of leaves per plant parameters gave better results compared to the control. Research findings support the idea that the use of MSWC as a plant nutrition input will provide both the production of plant nutrition input with low environmental and production costs and the prevention of the harms of waste to the environment, humans and living creatures.

**Keywords:** sustainability; domestic waste; compost; strawberry; plant nutrition

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## 1. Introduction

Sustainability is a set of principles aiming at the protection, maintenance and development of human existence without harming the care of nature, humans or other living beings while designing the production and consumption processes carried out in nature to meet human needs [1]. The concept of sustainability has gained meaning as an inevitable necessity of the consumption of natural resources, especially in the industrial revolution and after, due to faulty production and consumption activities [2]. People forgot that the golden rule of economics, the concept of scarcity, is valid in nature, and they consumed nature without limit [3]. This consumption lasted until it finally threatened human existence, but now the sea is gone. Indeed, the unlimited consumption of nature by humans has depleted the Aral Sea [4,5]. Air, water resources, agricultural areas, and oceans such as the Aral Sea have been consumed by humans endlessly, creating an unhealthy environment that threatens the lives of humans and other living beings [6]. In order to redesign these faulty production and consumption processes, the concept of sustainability was adopted in the Brullant Report prepared by the UN World Commission on Environment and Development in 1987 [7]. Alternatively, ecological and soft tourism in tourism, ecological or organic agriculture in agriculture, and waste recycling management in the industry are reflections of sustainability principles in different areas.

The most important component of sustainable economic activities is the process of preserving, destroying and evaluating the waste arising from various production and consumption processes in a way that will not harm nature, people or other living things. As in other activities, in agricultural production processes, thanks to new technologies, a large part of organic waste is converted into very valuable raw materials and used in the re-production process [8]. Actually, cow, goat, sheep, chicken, etc., have been used for a long time as animal-derived waste that is useful as plant nutrients in agricultural production processes [9]. As with animal wastes, the use of organic-based waste (such as domestic waste) generated in various economic processes as plant nutrients by making compost is an important research area. According to the data of 2020, 104.8 million tons of waste are produced annually in Turkey, and 30.9 million tons of it are declared dangerous; 32.3 million tons of this amount are processed from domestic waste, and 127 thousand tons are processed in compost facilities [10].

Compost is a plant nutrient fertilizer known as black gold, rich in organic matter, obtained by decomposing organic wastes at various rates in oxygenated or oxygenic environments. Organic matter, which is a rich source of macro and micronutrients [11] in compost, affects the soil physically and chemically [12], improving soil texture in terms of water retention, aeration, preventing the formation of toxic substances, facilitating soil cultivation, developing soil microorganisms, facilitating the uptake of plant nutrients and preventing soil erosion [13]. In the preparation of compost, carbon (brown wastes, dry leaves, branches, straw, etc.) and nitrogen (green wastes, kitchen scraps, freshly cut grass, etc.) ratio (C/N), humidity ratio, ventilation oxygen ratio, particle size, pH and temperature levels are important [14]. The use of compost as a plant fertilizer material can be an alternative to inorganic fertilizers, which have higher environmental and production costs than organic fertilizers [15], and can also be used with chemical fertilizers to increase their effectiveness [16].

There are studies in the literature on the use of MSWC in agricultural production. In these studies, it is reported that the use of MSWC alone or in combination with different plant nutrients (chemical or organic fertilizers) improves physical and chemical soil properties [17–21], positively affects plant growth [17,22,23] and increases product yield [17,19,24,25]. Ranjbar et al. [24] reported in their study on rice that the use of chemical fertilizers with an MSWC of 45 tons ha$^{-1}$ in rice production increased the macronutrients in the soil and rice yield (51.33%). Yüksel and Kavdır [26] reported that MSWC applications improved the physical and chemical properties of the soil, excluding pH and salt content (200 tons ha$^{-1}$ application), in their study on the potential for improving soil structure of MSWC applications (0, 40, 80, 120, 160 and 200 tons ha$^{-1}$) at different doses in sunflower cultivation. Bhattacharyya et al. [27] examined the possibilities of applying different doses of MSWC (2.5, 10, 20 and 40 tons ha$^{-1}$) and cow manure (20 and 40 tons ha$^{-1}$) as soil structure regulators (such as microorganisms and enzymes) in rice cultivation, and reported that MSWC is an input that improves soil structure that can be used safely. Iovieno et al. [28] investigated the effect of MSWC applications at different doses (15, 30 and 45 tons ha$^{-1}$) on soil microbiological activity in tomato, dry bean and lettuce cultivation and reported that MSWC applications improve soil microbiological structure for Mediterranean region soils and are recommended to be used to maintain soil fertility.

Strawberry is one of the plant materials that responds quickly to new applications and is frequently used in new plant nutrition material trials [15]. Strawberry is suitable for all levels: individuals as a hobby and small or large businesses for commercial purposes. Strawberry, with its unique appearance, taste-aroma and red color, is an important food source for human health with its rich antioxidant properties and vitamin and nutritional element content [29,30]. It is in great demand as it is always consumed as a fresh or processed product by consumers at any time of the year [30].

In this study, the effects of MSWC on fruit yield, some fruit characteristics, plant growth and plant growth parameters in strawberry cultivation were investigated.

## 2. Material and Method

The study was carried out in the research area of Çukurova University Yumurtalık Vocational School in Yumurtalık District on the Mediterranean coast of Adana between 2020–2022. The research area is located within the boundaries of Yumurtalık District, which is 52.2 km from the center of Adana Province, on the coast of the Iskenderun Gulf in the Mediterranean, at 36.75° North Latitude and 35.71° East Meridian coordinates.

### *2.1. Study Area Soil Analysis*

The soil analysis of the study area is given in Table 1. From the soil analysis, it was determined that the soil texture of the research area is loamy (sand 37.4%, silt 35.7% and clay 26.9%) [31], the soil physical properties are very calcareous (21.35%) and the electrical conductivity value (19.50 EC dS $m^{-1}$) is slightly salty. Soil analyses of the study area were made by measuring saturation sludge, acid or alkaline value (pH) with a pH meter and electrical conductivity (EC, dS/m) Wheatstone bridge [32]; Organic Matter (OM, %) amount modified Walkley–Black method [33] (Black, 1957); Nitrogen (N, %) Kjeldahl method [34]; Phosphorus (P, ppm) Olsen method [35]; Potassium (K, ppm), Calcium (Ca, ppm) and Magnesium (Mg, ppm) 1 N Ammonium Acetate (pH: 7) method [36]; Iron (Fe, ppm), Manganese (Mn, ppm), Zinc (Zn, ppm) and Copper (Cu, ppm) DTPA method [37] (Table 1)

**Table 1.** Soil analysis results of the research area.

| Parameters | pH | EC dS/m | OM (%) | N (%) | P ppm * | K ppm | Ca ppm | Mg ppm | Fe ppm | Mn ppm | Zn ppm | Cu ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil | 7.62 | 19.50 | 1.12 | 0.12 | 13.60 | 115 | 680 | 36.50 | 1.31 | 12.30 | 1.39 | 13.40 |

* ppm = mg $kg^{-1}$. pH, Acid or Alkaline; EC, Electrical Conductivity; OM, Organic Matter; N, Nitrogen; P, Phosphorus; K, Potassium; Ca, Calcium; Mg, Magnesium; Fe, Iron; Mn, Manganese; Zn, Zinc; Cu, Copper.

### *2.2. Plant Material*

The study used Albion (a cross between Diamante and Cal 94.16-1), which is a day-neutral strawberry cultivar bred by the University of California in 1999 [38]. Frigo seedlings of the Albion Strawberry were purchased from a private company (Albion; Agriculture Enterprise Ltd. Sti.: Adana, Türkiye) operating in the agricultural sector. Albion strawberry variety was preferred for being a day-neutral variety, being early, having large, conical and round fruits, firm fruit flesh, dark red color and pleasant aroma properties due to the high amount of marketable product [38–40]. Its production is economical with its resistance to low temperatures, Verticillium, Phytophthora and Anthracose [30].

### *2.3. Plant Nutrition Material MSWC*

MSWC produced by Adana Seyhan Municipality (Kompost Gübre; Adana Seyhan Municipality: Adana, Turkey) was used as plant nutrition material. The analysis results of the compost are presented in Table 2. According to the C/N ratio in the composting process, market, park and garden wastes, organic kitchen wastes, green vegetables whose leaves are consumed, tomato peel, cucumber, pepper, cereal waste, eggplant, zucchini scraps, filter coffee, tea, nut shells, olive seeds, eggs bark and colored paper waste were used. Compost can be prepared by different methods, such as cold, hot and earthworm. For hot compost to be prepared in small quantities, layers are brown waste (to create a fungal population), green waste (to create a bacterial population) and soil (15, 15 and 3 cm high, respectively), in accordance with the C/N ratio, on an area of 1 $m^2$. Each layer (brown, green waste and soil) created is then wetted with chlorine-free water, and the process is repeated until it reaches a height of 1 m. The formed heap is mixed from inside to outside by controlling the temperature and humidity. The mixing frequency of the heap is determined by the C/N balance, humidity and ventilation factors. In this method, the compost preparation process takes an average of 60 days.

**Table 2.** MSWC analysis results.

| Parameters | pH | Humidity (%) | EC dS/m | OM (%) | N (%) | $P_2O_5$ (%) | $K_2O$ (%) | CaO (%) | Mg ppm * | Na ppm | Fe ppm | Zn ppm | Cu ppm | Mn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Compost | 8.42 | 15 | 1.893 | 45 | 1.96 | 0.14 | 0.4 | 0.5 | 3542 | 502.42 | 6980 | 33.89 | 7.78 | 356.33 |

* ppm = mg $kg^{-1}$. pH, Acid or Alkaline; EC, Electrical Conductivity; OM, Organic Matter; N, Nitrogen; $P_2O_5$, Total Phosphate; $K_2O$, Total Potassium; CaO, Total Calcium Oxide; Mg, Magnesium; Na, Sodium; Fe, Iron; Mn, Manganese; Zn, Zinc; Cu, Copper.

### *2.4. Research Method*

In the study, which was created according to the randomized block experimental design, 6 different application plots and 20 plants (frigo saplings) in each plot were established with 4 replications. The seedlings were planted on August 15, 2020, during the summer planting period. According to Aynacı and Erdal [12], the MSWC application doses to be used in the study were determined as 0 (control), 0.25, 0.50, 1.00, 2.00 and 4.00 tons $da^{-1}$ (Decare: da = 1000 $m^2$) for each plot, respectively. Planting beds were prepared by mixing compost into the soil to be planted with the hoe machine in the determined amounts to provide a depth of 15 cm, base width of 100 cm, top width of 60 cm and base height of 15 cm. The planting beds were covered with a drip irrigation system and black mulch plastic. The planting beds were irrigated, and the plants were planted in the wet soil with the cross-planting method at 30 $\times$ 30 cm intervals. Within the scope of the fertilization program, a total of 24 kg of 33% N, 10 kg of MAP, 35 kg of $KNO_3$, 5 kg of $MgSO_4$ and 5 kg of $Ca(NO_3)_2$ (Ultra Azot, Monoamonyun Fosfat, Magnezyum Sülfat, Kalsiyum Nitrat; Toros Tarım Industry and Trade Inc.: İstanbul, Turkey) chemical fertilizers were given to all applications in a 6-month period from the drip irrigation system per decare (Toros Tarım) [41]. Within the scope of the study, in cultural processes, the first blooming flowers and shoots were taken, irrigation was done at least twice a week according to the irrigation need, hoeing were carried out regularly for weed control, and weed, disease and pest control was carried out once a week. Traditional control methods have been used against the red spider, aphid and snail pests [42] that are frequently seen in the region during the strawberry growing process since the cultivation area is an organic-certified area according to legal regulations.

### *2.5. Fruit Measurement and Analysis*

In this context, fruit weight, number of fruits per plant, yield per plant, degree of acidity or alkalinity of a solution (pH), the total amount of water-soluble dry matter (TSS) and titratable acid (TA) parameters were measured. For analysis, fruit and plant samples were transported to the laboratory environment by maintaining the cold chain and plant samples in paper storage packages.

Fruit weight was weighed by counting all the fruits obtained from each replication, and the average fruit weight was expressed in g. The number of fruits per plant was calculated by counting the fruits harvested from each plot and dividing by the number of plants in each plot. To calculate the yield per plant, all harvested fruits in each plot were weighed with a 0.01 g precision digital scale, and the yield values of each plot were determined. Afterwards, these values were divided by the number of plants in each plot and yield values per plant were obtained and expressed as g $plant^{-1}$.

For analysis, 20 randomly selected fruits from each plant during the harvesting period were kept in the cold chain and brought to the laboratory environment. At this stage, after the fruits were washed with distilled water for analysis, the fruits were squeezed with dense mesh gauze and a monthly 3-replication pomological analysis was carried out using the obtained fruit juice. pH was measured with a pH meter (Mettler, Toledo, OH, USA), TSS was measured by hand refractometer (0-53 Brixo Gauge ATAGO ATC-1, Tokyo, Japan), TA was calculated in g 100 $g^{-1}$ of citric acid in fruit juice by titration method; the pH, TSS (%) and TA (%) measurement values are presented. TA value was added to 1 mL of fruit juice taken from the fruit juice prepared for analysis, 49 mL of distilled water was added and mixed, the resulting mixture was titrated with 0.1 N NaOH until it turned pink, and the sodium hydroxide value used was determined. The acidity value was calculated in terms of citric acid with the following formula [43]:

$$\text{Acid value (\%)} = \text{Citric acid constant (0.0064)} \times \text{Spent NaOH} \times \text{NaOH factor} \times \text{Sample taken} \times 100$$

### 2.6. Plant Growth Values

Within the scope of plant development, the number of stems (piece $plant^{-1}$), number of leaves (pieces $plant^{-1}$), root length (cm), plant height (cm), plant width (cm) and leaf area ($mm^2$) parameters were measured.

The number of stems and stem numbers of the plants at the end of the harvest were determined, and the average number of stems per plant was determined as pieces. The number of leaves was determined as the average number of leaves per plant by counting the leaves of the plants at the end of the harvest. At the end of harvest, five plants at the same developmental level in each replication were removed without damaging their roots (approximately 95%), and root lengths were measured. The average plant height was determined by measuring the highest point of the plants from the soil surface at the end of the harvest [44]. The average plant width was determined by measuring the widest part of the vegetative part of the plants at the end of the harvest [45]. Leaf area was measured with the surface area meter (LI-COR brand, LI-3100A model) of the leaves taken from 5 plants removed from each plot at the end of the experiment, and the average of the measured leaf areas was determined.

### 2.7. Macro and Micronutrient Analysis in Leaves

During the flowering period, the leaf samples collected from the developed leaves in the inner parts of the plant were brought to the laboratory by maintaining the cold chain, and after being washed with pure water, they were dried at 65 ± 1 °C for at least 48 h and ground in a drying device (Niv oven). The ground samples were burned at 550 °C for 8 h and the ash formed was dissolved in 3.3% ($v/v$) HCl acid, and K, Ca and Mg readings were read in the atomic absorption spectrometer in emission mode, and Fe, Mn, Zn and Cu readings were read in absorbance mode. Phosphorus analyses were carried out by spectrophotometer according to the Barton method using the extract prepared above [46]. Nitrogen concentrations in strawberry leaves were determined by wet burning, according to the Khjeldal method [34].

### 2.8. Data Analysis Fruit Values

The data obtained within the scope of the study were analyzed with the Duncan Multiple Comparison Test in the SPSS 13 statistical package program, and the significant differences between the means obtained from the applications were evaluated at the $p < 0.05$ significance level.

## 3. Results and Discussion

In this study, the effects of MSWC applications on the yield, some physical and chemical fruit quality characteristics, plant growth and plant nutrients in leaves were examined, and the significant differences between applications were statistically evaluated at the $p < 0.05$ significance level.

### 3.1. Results

#### 3.1.1. Fruit Parameters

In Table 3, the study findings related to the effects of applications on fruit parameters fruit weight, number of fruit per plant, yield per plant, pH, TSS and TA were presented.

**Table 3.** Effect of applications on some physical and chemical properties of the fruit.

| Dose (tons $da^{-1}$) | Fruit Weight (g) | Number of Fruits (g $plant^{-1}$) | Yield per Plant (g $plant^{-1}$) | pH | TA (%) | TSS (%) |
|---|---|---|---|---|---|---|
| 0 | 13.47 [c] | 37.00 [b] | 296.86 [c] | 3.08 [b] | 0.91 [c] | 7.15 [d] |
| 0.25 | 13.75 [c] | 40.00 [ab] | 352.61 [b] | 3.68 [a] | 1.00 [c] | 7.51 [cd] |
| 0.50 | 14.85 [bc] | 41.38 [ab] | 364.78 [ab] | 3.75 [a] | 1.06 [abc] | 7.91 [bc] |
| 1.00 | 15.48 [bc] | 44.50 [a] | 381.63 [ab] | 3.79 [a] | 1.30 [a*] | 8.18 [ab] |
| 2.00 | 17.22 [ab] | 45.13 [a*] | 384.13 [ab] | 3.82 [a] | 1.29 [a] | 8.78 [a] |
| 4.00 | 17.98 [a*] | 43.13 [ab] | 401.62 [a*] | 3.87 [a*] | 1.19 [ab] | 8.36 [ab] |

The differences between the applications were evaluated statistically at the significance level of $p < 0.05$, and the differences between the table values are indicated by the letters [a], [b], [c] and [d]. The letter [a](*) represents the highest value among the values, while the other values represent the lower values in alphabetical order. There is no difference between the applications expressed with the same letter. pH, Acid or Alkaline; TA, Titratable Acidity; TSS, Total Soluble Solids.

When the effects of MSWC applications on yield and some physical and chemical fruit quality characteristics were examined, significant differences were found between the applications when compared to the control (Table 3). According to Table 3, as the amount of applied MSWC increased, the fruit weight value increased from the fruit quality characteristics and the highest fruit weight value was obtained from the 2 and 4 tons $da^{-1}$ application when compared to the control. Alam et al. [47] reported that fruit weight increased as the amount of vermicompost application increased in different doses of vermicompost (2.5, 5, and 10 tons $ha^{-1}$) and chemical fertilizer (NPKS, 50 and 100%) applications and the highest fruit weight was obtained from 10 tons $ha^{-1}$ of vermicompost and % chemical fertilizer application. According to Table 3, the highest number of fruits per plant compared to the control was obtained from MSWC applications of 1 and 2 tons $da^{-1}$. Larounga et al. [25], in their study of different doses of MSWC applications (10, 20, 30 and 40 tons $ha^{-1}$) in tomato cultivation, reported that the highest fruit number per plant in tomato was obtained from 30 tons $ha^{-1}$ MSWC application. According to Table 3, as the amount of MSWC applied increased, the fruit yield per plant increased and the highest fruit yield per plant was obtained from the 4.00-ton $da^{-1}$ application. Similarly, Alam et al. [47] reported that fruit yield increased as the amount of vermicompost applied in potato cultivation increased. Onwudiwe et al. [48] reported that fruit yield increased as the amount of MSWC application increased in different doses of MSWC and chemical fertilizer applications in maize, and the highest fruit weight was obtained from 2 tons $ha^{-1}$ MSWC and 300 NPK chemical fertilizer applications. Larounga et al. [25] reported that as the amount of MSWC applied to 30-ton $ha^{-1}$ increases, the fruit yield increases. There was a decrease in the amount in the application of 40 tons $ha^{-1}$, but this value was statistically in the same class as 30 tons $ha^{-1}$.

According to Table 3, a higher pH value was obtained in all MSWC applications, compared to the control of chemical quality characteristics of pH in fruit. Zaccardelli et al. [49] reported that the pH value in the fruit was higher in all MSWC applications (15, 30 and 45 tons $ha^{-1}$) compared to the control in different doses of MSWC applications applied in tomato cultivation. According to Table 3, the second chemical property TA was higher in all MSWC treatments, except 0.25 and 0.5 tons $ha^{-1}$, compared to the control. Finally, according to Table 3, a higher TSS value was obtained in all MSWC applications, except 0.25 tons $da^{-1}$, when compared to the control of chemical quality characteristics of TSS in fruit. Ameen and Dohuki [50] reported that TSS increased as the amount of MSWC application increased in different doses of MSWC (40 and 80 tons $ha^{-1}$) and chemical fertilizer applications in sweet pepper, and compared to the control, the TSS value in the fruit was higher than 80 tons $ha^{-1}$ of MSWC application.

### 3.1.2. Plant Growth Parameters

In Table 4, the study findings related to the effects of applications on plant growth parameters, number of fruit per plant, yield per plant, pH, TSS and TA, number of stems, number of leaves, root length, plant height, plant width and leaf area were presented.

**Table 4.** Effect of applications on plant growth.

| Dose (tons $da^{-1}$) | Number of Plant Stems (pcs) | Number of Leaves (pcs) | Root Length (pcs) | Plant Height (cm) | Plant Width (cm) | Leaf Area ($cm^2$) |
|---|---|---|---|---|---|---|
| 0 | 3.75 $^{c}$ | 20.72 $^{c}$ | 15.13 $^{b}$ | 13.90 $^{c}$ | 25.96 $^{c}$ | 47.86 $^{c}$ |
| 0.25 | 4.63 $^{bc}$ | 21.16 $^{bc}$ | 16.13 $^{ab}$ | 16.75 $^{b}$ | 27.17 $^{bc}$ | 54.11 $^{bc}$ |
| 0.50 | 4.88 $^{bc}$ | 25.50 $^{ab}$ | 16.75 $^{ab}$ | 16.88 $^{b}$ | 31.30 $^{ab}$ | 59.17 $^{ab}$ |
| 1.00 | 5.00 $^{ab}$ | 26.52 $^{a}$ | 16.88 $^{ab}$ | 18.63 $^{ab}$ | 31.57 $^{ab}$ | 61.52 $^{ab}$ |
| 2.00 | 5.75 $^{ab}$ | 26.78 $^{a}$ | 17.25 $^{ab}$ | 18.83 $^{ab}$ | 31.77 $^{ab}$ | 62.77 $^{ab}$ |
| 4.00 | 6.13 $^{a*}$ | 26.88 $^{a*}$ | 18.88 $^{a*}$ | 20.08 $^{a*}$ | 33.17 $^{a*}$ | 65.81 $^{a*}$ |

The differences between the applications were evaluated statistically at the significance level of $p < 0.05$, and the differences between the table values are indicated by the letters $^{a}$, $^{b}$ and $^{c}$. The letter $^{a}$(*) represents the highest value among the values, while the other values represent the lower values in alphabetical order. There is no difference between the applications expressed with the same letter.

When the effects of MSWC applications on plant growth were examined, significant differences were found between the applications when compared to the control (Table 4). It was observed that at different doses, one of the plant growth parameters and plant stem number were affected by the amount of MSWC applied on the strawberry plant, and the number of plant stems increased as the amount applied increased (Table 4). Compared to the control, the highest number of trunks was taken from the applications of 1, 2 and 4 tons $da^{-1}$. Srivastav et al. [51] reported the highest number of stems (5.16) from the $T_8$ application (Vermicompost + Azotobacter + Phosphorus Solubilizing Bacteria)) and the third highest value (4.24) from the $T_3$ application (Vermicompost) in worm fertilizer application in different organic fertilizer applications in strawberry. It was seen that the number of leaves was affected by the amount of MSWC applied from the plant growth parameters and the number of leaves increased as the amount applied increased, and when compared with the control, the number of leaves was higher in all MSWC applications except 0.25 tons $da^{-1}$. The same findings, Singh and Kaur [52] reported that in different doses of vermicompost and biofertilizers applications, the number of leaves increased as the amount of vermicompost applied increased, and the highest leaf number was obtained from $T_1$ application (vermicompost 2.8 tons $ha^{-1}$ and biofertilizers). According to Table 4, root length, one of the plant growth parameters, was obtained from the 4 tons $da^{-1}$ application in MSWC applications, when compared to the control. The same findings, Benedict et al. [53] reported that the root length increased as the amount of MSWC applied increased in different doses of MSWC (20 and 40 tons $ha^{-1}$) and chemical fertilizer applications, and the highest root length was obtained from the application of 40 tons $ha^{-1}$ of MSWC.

It was observed that plant growth parameters, plant height, plant width and leaf area were affected by the amount of MSWC applied and the plant height increased as the amount applied increased, and the highest plant height, plant width and leaf area compared to the control were obtained from 4 tons $da^{-1}$ of applications. Singh and Kaur [52] reported the same findings for plant height and leaf area parameters. They reported that in different doses of vermicompost and biofertilizers applications on strawberries, plant height and leaf area values increased as the amount of vermicompost applied increased, and the highest plant height and leaf area values were obtained from $T_1$ application (vermicompost 2.8 tons $ha^{-1}$ and biofertilizers). According to Table 4, the highest plant width was obtained from the 4.00 tons $da^{-1}$ application compared to the control (Table 4). Chowhan et al. [54], in their study examining the field performance of different strawberry cultivars, reported that the Festival strawberry cultivar had the highest plant width in plant nutrient component applications consisting of cow manure (37 tons $ha^{-1}$), diammonium phosphate (DAP, 640 kg $ha^{-1}$) and potassium chloride (MoP, 333 kg $ha^{-1}$).

### 3.1.3. Macro and Micronutrient Elements in Leaves Parameters

In Table 5, the study findings related to the effects of applications on the macro (N, P, K, Ca) and micro (Fe, Zn, Mn, Cu) plant nutrient parameters in the leaves were presented.

**Table 5.** Effect of applications on micro and macronutrients in leaves.

| Dose (tons $da^{-1}$) | N | P (%) | K | Ca | Fe | Zn (mg $kg^{-1}$) ** | Mn | Cu |
|---|---|---|---|---|---|---|---|---|
| 0 | 2.00 $^{c}$ | 1.42 $^{b}$ | 0.28 $^{d}$ | 1.40 $^{c}$ | 126.25 $^{c}$ | 34.95 $^{b}$ | 244.25 $^{d}$ | 9.63 $^{c}$ |
| 0.25 | 2.56 $^{b}$ | 1.92 $^{ab}$ | 0.29 $^{cd}$ | 1.62 $^{bc}$ | 128.75 $^{c}$ | 36.25 $^{ab}$ | 311.25 $^{c}$ | 12.75 $^{b}$ |
| 0.50 | 2.78 $^{ab}$ | 1.99 $^{ab}$ | 0.32 $^{bc}$ | 1.81 $^{bc}$ | 157.25 $^{b}$ | 39.41 $^{ab}$ | 314.00 $^{c}$ | 13.25 $^{b}$ |
| 1.00 | 2.84 $^{ab}$ | 2.07 $^{a}$ | 0.32 $^{bc}$ | 1.94 $^{ab}$ | 166.50 $^{ab}$ | 40.06 $^{ab}$ | 358.23 $^{b}$ | 13.38 $^{b}$ |
| 2.00 | 2.90 $^{ab}$ | 2.09 $^{a}$ | 0.36 $^{ab}$ | 2.04 $^{ab}$ | 181.25 $^{a}$ | 40.89 $^{a}$ | 365.15 $^{b}$ | 16.13 $^{ab}$ |
| 4.00 | 2.93 $^{a*}$ | 2.11 $^{a*}$ | 0.37 $^{a*}$ | 2.42 $^{a*}$ | 182.75 $^{a*}$ | 41.66 $^{a*}$ | 402.75 $^{a*}$ | 17.38 $^{a*}$ |

The differences between the applications were evaluated statistically at the significance level of $p < 0.05$, and the differences between the table values are indicated by the letters $^{a}$, $^{b}$, $^{c}$ and $^{d}$. The letter $^{a}$(*) represents the highest value among the values, while the other values represent the lower values in alphabetical order. There is no difference between the applications expressed with the same letter. ** ppm = mg $kg^{-1}$. N, Nitrogen; P, Phosphorus; K, Potassium; Ca, Calcium; Fe, Iron; Zn, Zinc; Mn, Manganese; Cu, Copper.

When the effects of MSWC applications on micro and macronutrients in leaves were examined, significant differences were found between the applications when compared to the control (Table 4). According to Table 5, as the MSWC application rate increases, the N value of macro elements increases, and the N value is higher in all MSWC applications compared to the control. Tzortzakis et al. [17] examined the effect of MSWC and wastewater irrigation applications on pepper cultivation in greenhouses and reported that the N value in the leaf was affected by the amount of MSWC application (Soil: MSWC ratio; 0, 5%, 10%, 20% and 40%) when compared to the control (except 95:5 application), and the N value increased as the application rate increased. Tzortzakis et al. [55] examined the effect of MSWC, wastewater irrigation and fertilization applications in tomato cultivation, and reported that the N value in the leaf was affected by the amount of MSWC application (Soil: MSWC ratio; 0, 5%, 10%, 20% and 40%) compared to the control, and the N value increased as the application rate increased in the irrigated and fertilized plot. According to Table 5, the macronutrient $p$-value was obtained from MSWC 1, 2 and 4 tons $da^{-1}$ applications compared to the control. Ranjbar et al. [24] investigated the effects of using different doses of MSWC (15, 30 and 45 tons $ha^{-1}$) and chemical fertilizers (25%, 50% and 75%) together on yield and macronutrients in the soil in rice cultivation. According to this study, only as the MSWC application rate increased, the N, P and K values of the macronutrients in the soil also increased and the same effect was reported in the use of chemical fertilizers. A similar study, which reported that the N, P and K values in the soil increased as the MSWC application rate increased, was also reported in a study conducted by Yuksel [56], in which MSWC at different doses (0, 40, 80, 120 ve 160 tons $ha^{-1}$) examined the effects on the chemical properties of vertisol and non-calcareous brown soils. According to Table 5, the highest macronutrient K value was obtained from the MSWC 4-ton $da^{-1}$ application when compared to the control. The K value is affected by the MSWC application dose and the K value increases as the application dose increases. According to Table 5, it is seen that the K value in the leaf is high in all MSWC applications (except 0.25 tons $da^{-1}$) compared to the control. Similar K values of Tzortzakis et al. [55] reported that they were obtained from MSWC application in the plot where irrigation and fertilization were applied in tomato cultivation. According to Table 5, the macronutrient Ca value was higher in all MSWC applications compared to the control, and the highest Ca value was obtained from the 4 tons application. Cercioglu [19] investigated the effects of different MSWC doses (animal manure 40 tons $ha^{-1}$: tomato residues, 40 and 80 tons $ha^{-1}$) and chemical fertilizer (N, P and K) applications on soil macronutrients and green pepper crop yield. Cercioglu [19] also reported that MSWC applications increased the macronutrients in the soil for sandy loam soils and the crop yield in pepper.

According to Table 5, the highest values of micronutrient Fe were obtained in the applications of 1, 2 and 4 tons da$^{-1}$ in MSWC applications at different doses compared to the control. Aynacı and Erdal investigated MSWC applications at different doses in pepper and corn cultivation. According to the studies of Aynacı and Erdal [12], when compared to the control, the highest Fe value was obtained from 4 tons da$^{-1}$ of MSWC application in pepper and 2 and 4 tons da$^{-1}$ of application in maize. The highest values in the micronutrient Zn were obtained from 1 and 2 tons da$^{-1}$ applications. Aynacı and Erdal [12] reported that the Zn value was obtained from 0.50 tons da$^{-1}$ of MSWC application in pepper and 2 tons da$^{-1}$ of MSWC application in maize. The highest values of micronutrients Mn and Cu were obtained in the 4-ton da$^{-1}$ application in MSWC applications at different doses compared to the control. According to the study data, different doses of MSWC applications are effective on micronutrients, and as the MSWC application dose increases, the values of micronutrients also increase. Similar results were reported in the study by Rajaie and Tavakoly and Cataldo et al. [57], who investigated the effects of the combined use of MSWC (MSWC/dry soil; 1%, 2%, and 4%) and chemical fertilizers (N application soil as urea; 0, 50, 100, and 200 mg kg$^{-1}$) on plant growth and soil properties in tomato cultivation in greenhouses. According to this study, they reported that as the N application rate increased by 4% MSWC application, the micronutrients Fe, Mn and Cu values in plant roots increased. This increase in Zn value was obtained in 2% of MSWC applications; Zn value increased in 1% and 2% of MSWC applications but decreased in 4% of MSWC applications [57]. Cataldo et al. [21] examined alternatives to MSWC applications at different doses (2.5, 15 and 40 tons ha$^{-1}$) to provide sustainable crop yield and vegetative growth in vines. According to the 2019 data of Cataldo et al. [21], micronutrients Fe, Zn and Cu are affected at MSWC application doses, and they reported that as the MSWC application dose increased, the Fe and Cu values also increased, and the highest values were obtained from 40 tons ha$^{-1}$ of MSWC application compared to the control. In the Mn value, when compared to the control, the highest value was obtained from 15 tons ha$^{-1}$ of MSWC application, according to the 2019 data of Cataldo et al. [21].

### 3.2. Discussion

In this study, the effects of MSWC on fruit, plant and nutrient uptake in strawberry cultivation were investigated in order to find solutions to two important problems: environmental pollution caused by domestic wastes and plant nutrition materials with high production and environmental costs in agricultural production.

#### 3.2.1. Fruit Parameters

In the study, fruit-related findings, such as fruit weight, number of fruit per plant, yield per plant, pH, TA and TSS parameters presented in Table 3, were examined, and statistically significant differences were found between the treatments when compared with the control ($p < 0.05$).

Regarding the fruit weight in strawberry cultivation, Shaw and Larson [38], who found the Albion variety, reported that the fruit weight was 33.00 g in the patent registration document. Şener and Türemiş [58] reported 18.03 g of Albion fruit weight in their study, where they used organic fertilizers in strawberry cultivation. Kılıc et al. [59] reported an Albion fruit weight of 18.81 g in vermicompost in organic fertilizer applications in strawberry cultivation. Sayğı [15] reported the fruit weight of Albion as 18.50 g in vermicompost application and 15.50 g in chemical fertilizer application in his study comparing the performance of different organic fertilizers and chemical fertilizers in strawberry cultivation. Except for Shaw and Larson, the fruit weight values obtained from the studies using organic fertilizers above are compatible with our study findings. Gecer et al. [60] reported that the highest fruit weight (14.93 g) was obtained from the Albion strawberry variety in their open and greenhouse cultivation studies carried out to determine the appropriate planting method of different strawberry varieties. Among the applications that did not use organic fertilizers, the fruit weight of Sayğı only in the application of chemical fertilizers and the fruit weight reported by Gecer et al. are lower than our study findings. It was concluded that MSWC applications, which provide sufficient Ca, which is effective in high yield and quality fruit formation, increase fruit weight and affect fruit weight positively [61].

Regarding the number of fruits in strawberry plants, Çolak et al. [62] examined the effect of honey bees on pollination and pollination in strawberry cultivation and reported the number of fruits per plant in Albion 36.00 pieces. Gecer et al. [60] reported the number of fruits per plant in Albionda at 41.67 pieces. Geçer et al. [63] have examined the effect of cultivar compatibility and fruit yield in the cultivation of different strawberry varieties in Merzifon ecological conditions and reported the number of fruit per plant in Albion at 22.91 pieces. Pakyürek et al. [64] examined the effect of seaweed (Alga 600) on plant growth and fruit quality in strawberry cultivation in Iraqi ecological conditions and reported the number of fruits per plant in Albion as 17.70 pieces. Karaca and Pirlak [65] investigated the effects of different strawberry varieties on fruit yield and quality using frigo seedlings in Ereğli conditions and reported the number of fruit per plant in Albion as 9.28 pieces. While our study findings are higher than the fruit number per plant values obtained from the studies using organic fertilizers above, they are compatible with the value in the study of Gecer et al. It was concluded that MSWC applications provide a sufficient amount of K, which provides photosynthesis, water and nutrient intake in flower formation, thus increasing the number of fruits, increasing the number of fruits and positively affecting the number of fruits [66,67].

Regarding fruit yield per plant, Şener and Türemiş [58] reported the fruit yield per plant as 645.80 g in Albion. Çolak et al. [62] examined the effect of bees on pollination and pollination in strawberries and reported the fruit yield per plant as 540.00 g in Albion. The study of Gecer et al. [60] reported the fruit yield per plant was reported as 486.16 g in Albion. While the yield values per plant obtained from the above organic fertilizer studies are higher than our study findings, the following values are lower. Çolak et al. [62] reported the fruit yield per plant as 326.00 g in the absence of bees. Geçer et al. [63] reported the fruit yield per plant as 283.70 g in Albion. Pakyürek et al. [64] reported fruit yield per plant as 295.03 g in Albion. Kılıc et al. [59] reported fruit yield per plant as 190.61 g fruit$^{-1}$ in the Albion strawberry variety. It was concluded that MSWC (as the application dose increases) applications, which provide sufficient amounts of K, which is effective in fruit number, and Ca, which is effective in high yield and quality fruit formation, increase fruit weight and fruit yield per plant and positively affect fruit yield [61,67–69].

Regarding pH, the pH and titratable acidity of the strawberry fruit nutrient content, taste, texture and appearance are important indicators in meeting marketable fruit standards and determining the level of adequate maturity [16]. Ornelas-Paz [70], in his study examining the ripening stages of the organically grown Albion strawberry variety, reported that the highest TSS value was 3.80% from the RS6. Şener and Türemiş [58] reported that the highest pH value was 3.83% from Camaroza and 3.65% from Alnion. Karaca and Pırlak [65] reported that the highest pH value was obtained from 3.83% Albion. Sayğı [15] in his study examining the effect of organic fertilizers on the Albion strawberry variety, reported that the highest pH value of 3.95% was obtained from vermicompost. Gecer et al. [60] reported that the highest pH value of 3.79% was obtained from Albion grown in open fields and 4.13 in low tunnels. When we compare the pH findings in reference studies with our study results, our pH findings have approximate values. It has been observed that the performance of MSWC applications meets the standards in terms of pH, and as the amount of MSWC applied increases [71], it affects the pH level positively [69,72,73].

Regarding TA, Gecer et al. [60], in their study examining the greenhouse and open field performance of different strawberry varieties, reported that the highest TA value of 0.92% was obtained from Albion grown in open fields and 1.05 in low tunnels. Saygı [15] reported that the highest TA value of 1.12% was obtained from farm manure. Ornelas-Paz [70] reported that the highest TA value was 1.20% from RS1. Şener and Türemiş [58] reported that the highest TA value of 1.40% was obtained from Albion. Our TA findings are approximate to the TA values obtained from the above studies. Karaca and Pırlak [65] reported that the highest TA value was obtained from 1.69% Albion. Khalid et al. [74] reported in their study examining the effects of organic fertilizer applications in the Chandler strawberry variety that the highest TA was obtained from T3 (planting media + 200 g $kg^{-1}$ leaf manure) application with 1.80%. Contrary to our study findings, Khalid et al. and Karaca and Pırlak reported high TA values. The only valid reason for this situation is not using solid organic fertilizers in the application of the TA value obtained in the study conducted by Khalid et al. and Karaca and Pırlak. Indeed, Khalid et al. [74] reported the lowest TA value in vermicompost application in the same study.

TSS is effective in determining fruit taste, with its feature indicating the level of fruit sweetness [75,76]. Khalid et al. [74] reported that the TSS was obtained from T4 (planting media + 200 g $kg^{-1}$ vermicompost) application with 8.33%. Gecer et al. [60] reported that the highest TSS value of 8.83% was obtained from Albion grown in an open field. Sayğı [15] reported that the highest TSS value of 8.88 was obtained from chicken manure. Ornelas-Paz [70] reported that the highest TSS value was 9.00% from RS6. Şener and Türemiş [58] reported that the highest TSS value of 9.05% was obtained from Albion. The TSS values obtained from the above studies are compatible with the TSS values obtained from our study. Gecer et al. [60] reported that the highest TSS value of 9.97% was obtained from Albion grown in low tunnels. Karaca and Pırlak [65] reported that the highest TSS value was obtained from 15.10% Albion. Contrary to our findings, Geçer et al. and Karaca and Pırlak reported higher TSS values. This situation can be explained by the differences in growing conditions, cultural processes, plant feeding materials and timing, and ecological conditions, but the only visible difference between the studies is that solid organic fertilizer was used in our study, but it was not used in the studies conducted by Geçer et al. and Karaca and Pırlak.

### 3.2.2. Plant Growth Parameters

In the study, fruit-related findings, plant stem number, plant leaf number, root length, plant height, plant width and leaf area parameters presented in Table 4 were examined, and statistically significant differences were found between the treatments when compared with the control ($p < 0.05$). Bartczak et al. [77] investigated the effects of dry and fresh weight, stem number, root number and length on yield in different strawberry cultivars and reported that there was a positive relationship between fresh and dry weight of strawberry plants, number of stem and root length and yield amount.

Regarding the number of stems, Çay and Kaynaş [78] reported that the highest plant stem number was 4.75 from Albion and 5 from Sweet Ann. Çiylez and Eşitken [79] observed the effects of three different mycorrhiza and plant growth-promoting rhizobacteria on plant growth in the Albion strawberry cultivar and reported that the number of leaves per plant was 9.16 from the G. fasciculatum + A18 application. Srivastav et al. [51] reported in their study examining the effects of organic fertilizer applications on plant growth in Chandler strawberry varieties that the highest plant stem number was obtained from T8 (Vermicompost + Azotobacter + Phosphorus Solubilizing Bacteria) application as 5.16 pieces. Pakyürek et al. [64] reported that the highest plant stem number was obtained from T3 (4 g·$L^{-1}$) application as 3.64 pieces. Our study findings in the number of stems were lower than the value reported by Çiylez and Eşitken but higher than the values reported in other studies. Accordingly, it is seen that MSWC applications have a positive effect on the number of bodies. The fact that Srivastav obtained a value close to our finding from the application of vermicompost also supports this situation.

Regarding the number of leaves per plant, Srivastav et al. [51] reported that the highest number of leaves was obtained from the T8 application at 17.81 pieces. Çay and Kaynaş [78] observed the effect of leonardite application on plant growth and yield in two different strawberry cultivars, and reported that the highest number of leaves per plant was 19.93

from Albion and 25.48 from Sweet Ann. Although our study findings are relatively high, they are in approximation with the findings of Srivastav et al., Çay and Kaynaş. Pakyürek et al. [64] reported that the highest number of leaves was obtained from T4 (8 $g \cdot L^{-1}$) application as 11.33 pieces. Tiwari et al. [80] reported that the highest number of leaves per plant was obtained from T8 (Triacontanol @ 150 ppm) application as 8.55 pieces in their study, in which they examined the effects on the determination of suitable plant growth regulators in strawberries. Our study findings have higher values than those of Pakyürek et al. and Tiwari. Accordingly, macronutrients N, P and especially K have an effect on increasing the number of leaves [81], and MSWC applications increased the uptake of N, P and K, causing an increase in the number of leaves.

Regarding plant root length, Sharma et al. [82] observed the effect of different growth media on root development in the Sweet Charlie strawberry variety and reported that the average maximum root length was 14.13 cm from the T5 application. Çay and Kaynaş [76] observed the effect of leonardite application on plant growth and yield in two different strawberry cultivars and reported that the highest root length was 16.70 cm from Albion and 17.90 cm from Sweet Ann. Our study findings have higher values than the findings of Sharma et al. and Çay and Kaynaş. Mattner et al. [83] observed the effect of seaweed extract on root development in two different strawberry cultivars and reported that the mean maximum root length was 24 cm from Albion and 21.50 cm from Fortuna. Çiylez and Eşitken [79] reported that the highest root length in the Albion strawberry cultivar was 27.16 cm, obtained from G. fasciculatum application. Our study findings have lower values than those of Mattner et al. and Çiylez and Eşitken. K is effective in root development [84], and MSWC applications increased K uptake, which had a positive effect on root growth. According to our study findings, root length has an average value, and MSWC applications provide sufficient root length.

Regarding plant height, Singh and Kaur [52] observed the effect of organic fertilizer applications on plant growth and yield in the Sweet Charlie strawberry variety and reported that the highest plant height was 15.05 cm from the T1 (Vermicompost 2.8 t/ha + Biofertilizers) application. Tiwari et al. [80] reported that the highest plant height was obtained from the T8 application as 16.91 cm. Srivastav et al. [51] reported that the highest plant height was obtained from T8 application as 19.80 cm. Sharpe et al. [85] reported the highest plant height of 22 cm in the Festival strawberry variety, 20 cm in Sensation Florida 127 strawberry variety and 18 cm in the Florida Radiance strawberry variety in their study examining the effects of spray penetration on different strawberry cultivars. Sim et al. [44] reported the highest plant height of 35.40 cm in the Seolhyang strawberry variety in their study to predict plant growth and yield in strawberries. Our study findings are higher than Tiwari et al. and Singh and Kaur's findings, lower than Sim et al.'s findings, and the same as Srivastav et al. and Sharpe et al.'s findings. According to our study findings, plant height has an average value, and MSWC applications provide sufficient plant height.

Regarding plant width, Khalid et al. [74] reported that the highest plant width was obtained from T1 (soil + silt + farmyard manure) application with 20.37 cm. Srivastav et al. [51] reported that the highest plant width was obtained from T8 application at 24.81 cm. Chowhan et al. [54] reported that the highest plant width was obtained from Camaroza at 29.94 cm in their study examining the plant growth performances of different strawberry cultivars. Sharpe et al. [85] reported the highest plant widths of 30 cm in the Florida Radiance strawberry variety, 35 cm in Sensation™ 'Florida 127' (University of Florida: Gainesville, FL, USA) and 36 cm in the Festival strawberry variety. Khalid and Srivastav reported lower plant widths than our study findings, while Chowhan and Sharpe reported plant widths close to our study findings. According to these findings, MSWC applications provide sufficient plant-width development.

Regarding the leaf area, Khalid et al. [74] reported that the highest leaf area was obtained from the T4 application with 43.07 $cm^2$. Çiylez and Eşitken [79] observed the effects of three different mycorrhiza and plant growth-promoting rhizobacteria on plant growth in the Albion strawberry cultivar and reported that the most leaf area was 45.12 cm from G. moseae application. Srivastav et al. [51] reported that the highest plant leaf area was obtained from T8 application as 97.72 $cm^2$. Pakyürek et al. [64] reported that the highest leaf area was obtained from T4 (8 $g \cdot L^{-1}$) application as 127.88 $cm^2$. When our study findings were compared with other studies, it was observed that an average value was obtained in the leaf area. Accordingly, our findings are lower than the findings of Srivastav et al. and Pakyürek et al., while the findings of other studies are higher.

In general, it has been observed that MSWC applications have a positive effect on plant growth parameters by encouraging the intake of macro and micronutrients with the content of organic matter and other properties, and this effect continues to increase as the MSWC application dose increases. In similar studies in which different doses of a single type of organic fertilizer were applied, it was observed that plant growth was positively affected as the application dose increased [12,64,86,87].

#### 3.2.3. Macro and Micro Nutrient Elements in Leaves Parameters

If the optimum amount of nutrient elements to be applied is not determined at the desired level of product quantity and quality, over or under supply of plant nutrients may lead to important problems such as product loss, decrease in product quality [88], waste and loss of resources (labor, time and money). Leaf analyses are made to determine the most appropriate dose for the nutrients to be used in plant nutrition in the agricultural production process [88]. Analysis of macro and micronutrients within the scope of the study is as follows:

In the study, macro and micronutrient in leaves related findings were examined, and N, P, K, Ca, Fe, Zn, Mn and Cu parameters are presented in Table 6. Statistically significant differences were found between the treatments when compared with the control ($p < 0.05$).

**Table 6.** Upper and lower values of macronutrients (except for control).

| Macro Nutrients Studies | * | (%) N | P | K | Ca |
|---|---|---|---|---|---|
| Our Finding | | 2.56–2.93 | 0.29–0.37 | 1.92–2.11 | 1.62–2.42 |
| NCDA&CS. | [89] | 3.00–4.00 | 0.20–0.40 | 1.10–2.50 | 0.50–1.50 |
| Pritts (Eastern USA) | [90] | 2.00–2.80 | 0.25–0.40 | 1.50–2.50 | 0.70–1.70 |
| Pritts (Western USA) | [90] | 2.50–3.00 | 0.15–0.30 | 1.00–2.00 | 1.00–2.00 |
| Strik | [91] | 2.50–3.00 | 0.15–0.30 | 1.00–2.00 | 1.00–2.00 |
| Kılıc et al. | [59] | 1.72–2.01 | 0.50–0.73 | 0.65–1.36 | 0.96–1.20 |
| Develi et al. | [92] | 2.63–2.82 | 0.32–0.41 | 2.05–2.12 | 1.65–1.87 |

* References. N, Nitrogen; P, Phosphorus; K, Potassium; Ca, Calcium.

In Table 6, the lower and upper values of our study findings and macronutrients obtained from other studies are presented.

Regarding macronutrients (N, P, K and Ca), NCDA&CS [89] reported the amounts of N, P, K and Ca macronutrients that should be at sufficient levels in the leaves, as in Table 6. Pritts [90] determined the amount of standard macronutrients (Eastern and Western America) that should be in the leaves of a healthy strawberry plant, as shown in Table 6. Likewise, Strik [91] determined the number of standard macronutrients required in the leaves of the strawberry plant for the State of Oregon, as shown in Table 6. Our study findings meet the standards of applications excluding Ca when compared with the standard values specified by Pritts, Strik and NCDA&CS. In a similar study, Develi et al. [92] investigated the effects of organic fertilizer (vermicompost) applications at different rates on the yield and quality of the San Andreas strawberry cultivar and reported the lower and upper levels of N, P, K and Ca macronutrients in the leaves of San Andreas strawberry cultivar as in Table 6. The macronutrient elements of Develi et al. [92], who conducted a similar study to our study, support our study findings, and they also reported that the Ca level is higher than the specified standards (Table 6). The reason for this is the use of chemical fertilizers in addition to organic fertilizers in plant nutrition in both studies, and organic fertilizers increase the effectiveness of these chemical fertilizers. Findings supporting this result were conducted in another similar study by Kılıc et al. In this study, Kılıc et al. [59] reported the lower and upper levels of macronutrients in the leaves, as shown in Table 6. Kılıc et al. obtained lower values in our study. On the other hand, although Ca is higher than in reference studies, Jones [93], who is an important reference on strawberries in the literature, reported that the Ca value in the leaves should be in the range of 1.00–2.50%. Accordingly, our Ca study findings are the limit values.

In Table 7, the lower and upper values of our study findings and micronutrients obtained from other studies are presented.

**Table 7.** Upper and lower values of micronutrients (except for control).

| Micro Nutrients Studies | * | mg kg$^{-1}$ | | | |
|---|---|---|---|---|---|
| | | Fe | Zn | Mn | Cu |
| Our Finding | | 128.75–182.75 | 36.25–41.66 | 311.25–402.75 | 12.75–17.38 |
| NCDA and CS | [89] | 50.00–300.00 | 15.00–60.00 | 30.00–300.00 | 3.00–15.00 |
| Pritts (Eastern USA) | [90] | 60.00–250.00 | 20.00–50.00 | 50.00–200.00 | 6.00–20.00 |
| Pritts (Western USA) | [90] | 60.00–200.00 | 20.00–50.00 | 50.00–650.00 | 6.00–20.00 |
| Strik | [91] | 60.00–200.00 | 20.00–50.00 | 50.00–650.00 | 6.00–20.00 |
| Kılıç et al. | [59] | 70.00–127.67 | 13.00–16.00 | 37.00–63.00 | 2.67–3.67 |
| Develi et al. | [92] | 174.03–191.08 | 18.48–24.89 | 74.02–79.70 | |
| Çeliktopuz and Özekici | [88] | 53.00–101.00 | 12.10–19.90 | 185.00–338.00 | 3.39–7.00 |

* References. Fe, Iron; Zn, Zinc; Mn, Manganese; Cu, Copper.

Regarding micronutrients (Fe, Zn, Mn and Cu), NCDA and CS [89], Pritts [90] and Strik [91] reported the lower and upper levels of standard Fe, Zn, Mn and Cu micronutrients that should be in the leaves of a healthy strawberry plant, as shown in Table 7. Our study findings are compatible with the lower and upper levels of micronutrients specified by Pritts, Strik and NCDA and CS, except for Mn and Cu, according to NCDA and CS (Table 7). Mn and Cu are higher than the upper level set by NCDA and CS. This situation can be explained by the fact that the P level is between normal values, which causes deficiencies of Ca, B, Cu and Mn nutrients at high levels. Çeliktopuz and Özekici [82] examined the effects of different irrigation and bio-activator applications on the micronutrient elements in the fruit and leaves of the Rubigem strawberry cultivar and reported the micronutrient amounts, lower and upper levels, as shown in Table 7. Kılıc et al. [59] reported the lower and upper levels of micronutrients in the leaves, as shown in Table 7. A study similar to ours was conducted by Develi et al. [92], who reported the lower and upper levels of micronutrients in the leaves, as shown in Table 7. While the findings obtained from these studies are consistent with the lower and upper levels in the reference studies indicated in the table, these findings, except for the Fe value, are lower than our study findings. We think that the difference is due to the positive interaction between the chemical fertilizers used in the composting program and the MSWC. Another important issue is that, according to the results of the leaf analysis conducted within the scope of the study, it has been observed that the Fe content in the leaves is at a high level as a result of MSWC applications and that MSWC applications can be a solution to the iron deficiency problem, which is very common in strawberry-growing plants [94].

When the study findings are evaluated in terms of macro and micronutrients in general, the amount of macro and micronutrients in the leaves increases as the amount given per decare increases with the use of a single type of organic fertilizer at different doses [54,59].

## 4. Conclusions

In the near future, the production of safe and sufficient food and the waste arising from various economic activities are the two major problems of humanity that need to be solved. In order to produce solutions to these two important problems, it is imperative to establish sustainable economic processes in accordance with the 5R rule of return, rethink, reduce, reuse and recycle. The aim of this study is to examine the effects of MSWC, which is produced by evaluating organic wastes from domestic wastes as plant nutrition material, on plant growth, product yield and quality in strawberry cultivation. The difference between the applications was found to be significant, and the product quality parameters examined within the scope of the study were better than 4 tons da$^{-1}$ of MSWC application in fruit weight and yield per plant, 1 and 2 tons da$^{-1}$ of MSWC application in fruit per plant and TA, 2 tons da$^{-1}$ of MSWC application in TSS and all MSWC applications in pH compared to the control. In terms of plant growth parameters, 4 tons da$^{-1}$ of MSWC applications in stem number, root length, plant width and leaf area, and 1 and 2 tons da$^{-1}$ of MSWC applications in leaf number and plant height; all MSWC applications gave better results compared to the control. In macro-micro elements parameters, 4 tons da$^{-1}$ of MSWC applications in K and Ca, 2 and 4 tons da$^{-1}$ of MSWC applications in Fe, and all MSWC applications in N, Mn and Cu gave better results compared to the control. When our study findings were evaluated in general, it has been concluded that MSWC can be used as an effective solution both in the evaluation of domestic waste and in the production of a suitable plant nutrition material in agricultural production and that the increasing application of MSWC has a positive effect on the parameters examined in the study and can be used as a suitable plant nutrient.

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## References

1. Sayğı, H. Relationship Between Sports and Organic Agriculture. *Environ. Toxicol. Ecol.* **2022**, *2*, 133–143.
2. Tıraş, H.H. Sürdürülebilir Kalkınma ve Çevre: Teorik Bir İnceleme. *KSÜ İktisadi Ve İdari Bilim. Fakült. Derg.* **2012**, *2*, 57–73.
3. Çelik, İ. Kıtlık ve Rekabet: Rekabetin Negatif Sonuçları. *Atatürk Üniv. İktisadi Ve İdari Bilim. Derg.* **2011**, *25*, 1–12.
4. Krivonogov, S.K.; Burr, G.S.; Kuzmin, Y.V.; Gusskov, S.A.; Kurmanbaev, R.K.; Kenshinbay, T.I.; Voyakin, D.A. The fluctuating Aral Sea: A multidisciplinary-based history of the last two thousand years. *Gondwana Res.* **2014**, *26*, 284–300. [CrossRef]
5. Xu, H. The Study on Eco-environmental Issue of Aral Sea from the Perspective of Sustainable Development of Silk Road Economic Belt. *IOP Conf. Ser. Earth Environ. Sci.* **2016**, *57*, 012060. [CrossRef]
6. WWF. *Living Planet Report 2020—Bending the Curve of Biodiversity Loss*; Almond, R.E.A., Grooten, M., Petersen, T., Eds.; WWF: Gland, Switzerland, 2020. Available online: https://membership.zsl.org/sites/default/files/LPR%202020%20Full%20report.pdf (accessed on 9 March 2023).
7. Brundtland, G. *Report of the World Commission on Environment and Development: Our Common Future*; Document A/42/427; United Nations General Assembly: New York, NY, USA, 1987.
8. Ayilara, M.; Olanrewaju, O.; Babalola, O.; Odeyemi, O. Waste Management through Composting: Challenges and Potentials. *Sustainability* **2020**, *12*, 4456. [CrossRef]
9. Loss, A.; Couto, R.D.R.; Brunetto, G.; Veiga, M.D.; Toselli, M.; Baldi, E. Anımal Manure As Fertılızer: Changes in Soıl Attrıbutes, Productıvıty and Food Composıtıon. *Int. J. Res. Granthaalayah* **2019**, *7*, 307–331. [CrossRef]
10. TUİK. Atık İstatistikleri, 2020. 2020. Available online: https://data.tuik.gov.tr/Bulten/Index?p=Atik-Istatistikleri-2020-37198#:~:text=Olu%C5%9Fan%20at%C4%B1k%20miktar%C4%B1%20104%2C8,8%20milyon%20ton%20at%C4%B1k%20olu%C5%9Ftu (accessed on 9 March 2023).
11. Dhaliwal, S.S.; Naresh, R.K.; Mandal, A.; Singh, R.J.; Dhaliwal, M.K. Dynamics and transformations of micronutrients in agricultural soils as influenced by organic matter build-up: A review. *Environ. Sustain. Indicators.* **2019**, *1–2*, 100007. [CrossRef]
12. Aynacı, D.; Erdal, İ. Evsel Atıklardan Elde Edilen Kompostun Mısır ve Biberin Gelişimi ve Besin Elementi İçeriğine Etkisi. *Süleyman Demirel Üniv. Fen Bilim. Enst. Derg.* **2016**, *20*, 123–128. [CrossRef]
13. Ayangbenro, A.S.; Chukwuneme, C.F.; Ayilara, M.S.; Kutu, F.R.; Khantsi, M.; Adeleke, B.S.; Glick, B.R.; Babalola, O.O. Harnessing the Rhizosphere Soil Microbiome of Organically Amended Soil for Plant Productivity. *Agronomy* **2022**, *12*, 3179. [CrossRef]
14. Şahin, E.; Dardeniz, A.; Kavdır, Y.; Müftüoğlu, N.M.; Türkmen, C. Bağ Budama Artığı Kompostu Oluşturma Süreci ile Kompostun Bazı Fiziksel ve Kimyasal Özelliklerinin Belirlenmesi. *Çomü Ziraat Fakültesi Derg.* **2018**, *6*, 19–25.
15. Sayğı, H. Effects of Organic Fertilizer Application on Strawberry (*Fragaria vesca* L.) Cultivation. *Agronomy* **2022**, *12*, 1233. [CrossRef]

16. Kakar, K.; Xuan, T.D.; Noori, Z.; Aryan, S.; Gulab, G. Effects of organic and inorganic fertilizer application on growth, yield, and grain quality of rice. *Agriculture* **2020**, *10*, 544. [CrossRef]
17. Tzortzakis, N.; Gouma, S.; Dagianta, E.; Saridakis, C.; Papamichalaki, M.; Goumas, D.; Manios, T. Use of fertigation and municipal solid waste compost for greenhouse pepper cultivation. *Sci. World J.* **2012**, *2012*, 973193. [CrossRef]
18. Singh, Y.P.; Arora, S.; Mishra, V.K.; Dixit, H.; Kumar, R.G. Conjoint Use of Chemical Amendments and Municipal Solid Waste Compost for Amelioration of Degraded Sodic Soil. *J. Indian Soc. Soil Sci.* **2018**, *66*, 392–398. [CrossRef]
19. Cercioglu, M. Compost Effects on Soil Nutritional Quality and Pepper (*Capsicum annuum* L.) Yield. *J. Agric. Sci.* **2019**, *25*, 155–162. [CrossRef]
20. Arrobas, M.; Carvalho, J.T.N.; Soraia Raimundo, S.; Poggere, G.; Rodrigues, M.Â. The safe use of compost derived from municipal solid waste depends on its composition and conditions of application. *Soil Use Manag.* **2021**, *38*, 917–928. [CrossRef]
21. Cataldo, E.; Fucile, M.; Mattii, G. Composting from organic municipal solid waste: A sustainable tool for the environment and to improve grape quality. *J. Agric. Sci.* **2022**, *160*, 502–515. [CrossRef]
22. Ferreira, A.K.D.C.; Dias, N.D.S.; Sousa, F.S.D., Jr.; Ferreira, D.A.D.C.; Fernandes, C.D.S.; Leite, T.D.S. Composting of household organic waste and its effects on growth and mineral composition of cherry tomato. *Rev. Ambiente Água* **2018**, *13*, e2141. [CrossRef]
23. Wandansari, N.R.; Suntari, S.; Suntari, R.; Kurniawan, S. Organic Waste Management As Compost To Improving Germination And Sweet Corn Production. *Nat. Volatiles Essent. Oils* **2021**, *8*, 1854–1877.
24. Ranjbar, M.; Sadeghnejadtalouki, G.; Ghajar Sepanlou, M.; Sadegh Zadeh, F.; Bahmanyar, M. Effects of long-term municipal waste compost application on the concentrations of macro elements and yield of rice. *Int. J. Hum. Cap. Urban Manag.* **2016**, *1*, 243–252. [CrossRef]
25. Larounga, T.; Kossi, S.; Gbénonchi, M.; Priscilla, T.B. Effects of compost from urban solid household waste on the respiration of soil microbial flora and the yield of tomato (*Lycopersicon esculentum*) at the agronomic experimental station of Lome in Togo. *GSC Adv. Res. Rev.* **2022**, *12*, 42–50. [CrossRef]
26. Yüksel, O.; Kavdır, Y. Improvement of Soil Quality Parameters by Municipal Solid Waste Compost Application in Clay-Loam Soil. *Türk Tarım Gıda Bilim Ve Teknol. Derg.* **2020**, *8*, 603–609. [CrossRef]
27. Bhattacharyya, P.; Chakrabarti, K.; Chakraborty, A. Effect of MSW compost on microbiological and biochemical soil quality indicators. *Compost. Sci. Util.* **2003**, *11*, 220–227. [CrossRef]
28. Iovieno, P.; Morra, L.; Leone, A.; Pagano, L.; Alfani, A. Effect of organic and mineral fertilizers on soil respiration and enzyme activities of two Mediterranean horticultural soils. *Biol. Fertil. Soils* **2009**, *45*, 555–561. [CrossRef]
29. Taghavi, T.; Siddiqui, R.; Rutto, L.K. *The Effect of Preharvest Factors on Fruit and Nutritional Quality in Strawberry*; IntechOpen: London, UK, 2019. [CrossRef]
30. Quarshi, H.Q.; Ahmed, W.; Azmant, R.; Chendouh-Brahmi, N.; Quyyum, A.; Abbas, A. *Post-Harvest Problems of Strawberry and Their Solutions*; IntechOpen: London, UK, 2023. [CrossRef]
31. Bouyoucos, G.H. A Recalibration of the Hydrometer for Making Mechanical Analysis of Soils. *Agron. J.* **1951**, *43*, 434–438. [CrossRef]
32. Schlichting, E.; Blume, H.P. *Bodenkundliches Praktikum*; Verlag Paul Paney: Hamburg, Germany; Berlin, Germany, 1966; pp. 121–125.
33. Black, C.A. *Soil-Plant Relationships*; John Wiley and Sons: New York, NY, USA, 1957.
34. Bremmer, J.M. Determination of Nitrogen in Soil by the Kjeldahl Method. *J. Agric. Science.* **1960**, *55*, 11–33. [CrossRef]
35. Olsen, S.R.; Sommers, E.L. Phosphorus Soluble in Sodium Bicarbonate. In *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties*; Page, A.L., Miller, R.H., Keeney, D.R., Eds.; Soil Science Society of America, Inc.: Madison, WI, USA, 1982; pp. 404–430.
36. Kacar, B. *Chemical Analysis of Plant and Soil, III. Soil Analysis*; A.U. Faculty of Agriculture Education, Research and Development Foundation Publications: Ankara, Turkey, 1995; Volume 3, p. 704.
37. Lindsay, W.L.; Norvell, W.A. Development of a Dtpa Soil Test for Zinc, Iron, Manganese, and Copper. *Soil Sci. Soc. Am. J.* **1978**, *42*, 421–428. [CrossRef]
38. Shaw, D.V.; Larson, K.D. Strawberry Plant Named 'Albion'. U.S. Patent No. US PP16228 P3, 31 January 2006. Available online: https://patents.google.com/patent/USPP16228P3/en (accessed on 9 March 2023).
39. Paparozzi, E.T.; Meyer, G.E.; Schlegel, V.; Blankenship, E.E.; Adams, S.A.; Conley, M.E.; Loseke, B.A.; Read, P.E. Strawberry cultivars vary in productivity, sugars and phytonutrient content when grown in a greenhouse during the winter. *Sci. Hortic.* **2018**, *227*, 1–9. [CrossRef]
40. Gabriel, A.; de Resende, T.V.J.; Zeist, A.R.; Resende, L.V.; Nathalia, C.V.; Resende, N.C.V.; Zeist, R.A. Phenotypic stability of strawberry cultivars based on physicochemical traits of fruits. *Hortic. Bras.* **2019**, *37*, 75–81. [CrossRef]
41. Toros Tarım. *Fertilization in Strawberry Growing*; Taros Tarim: Istanbul, Turkey, 2018. Available online: https://www.toros.com.tr/documents/file/FlipBook/Cilek%20Yatistiriciliginde%20Gubreleme-2018-03-22-12-10-20/Cilek%20Yatistiriciliginde%20Gubreleme/index.html#4 (accessed on 9 March 2023).
42. Yetgin, M.A. *Organik Tarımda Bitki Koruma Yöntemleri*; Samsun İl Tarım Müdürlüğü Çiftçi Eğitimi Ve Yayım Şubesi Yayını: Samsun, Turkey, 2010; pp. 1–24. Available online: https://samsun.tarimorman.gov.tr/Belgeler/Yayinlar/Kitaplarimiz/organik_tarimda_bitki_koruma_yontemleri.pdf (accessed on 19 May 2023).

43. Adak, N.; Pekmezci, M. Topraksız Çilek Yetiştiriciliğinde Fide Tipi ve Yetiştirme Ortamının Meyve Kalitesi Üzerine Etkileri. *Ege Üniv. Ziraat Fakült. Derg.* **2012**, *49*, 135–142.
44. Sim, H.S.; Kim, D.S.; Ahn, M.G.; Ahn, S.R.; Kim, S.K. Prediction of Strawberry Growth and Fruit Yield based on Environmental and Growth Data in a Greenhouse for Soil Cultivation with Applied Autonomous Facilities. *Hortic. Sci. Technol.* **2020**, *38*, 840–849. [CrossRef]
45. Orde, K.M.; Sideman, R.G. Low Tunnel and Cultivar Effects on Day-neutral Strawberry Yield and Characteristics in New Hampshire. *HortTechnol. Hortte* **2019**, *29*, 795–810. [CrossRef]
46. Barton, C.J. Photometric Analysis of Phosphate Rock. *Anal. Chem.* **1948**, *20*, 1068–1073. [CrossRef]
47. Alam, M.N.; Jahan, M.S.; Ali, M.K.; Ashraf, M.K. Effect of Vermicompost and Chemical Fertilizers on Growth, Yield and Yield Compenents of Potato in Barind Soils of Bangladesh. *J. Appl. Sci. Res.* **2007**, *3*, 1879–1888.
48. Onwudiwe, N.; Benedict, O.U.; Ogbonna, P.E.; Ejiofor, E.E. Municipal solid waste and NPK fertilizer effects on soil physical properties and maize performance in Nsukka, Southeast Nigeria. *Afr. J. Biotechnol.* **2014**, *13*, 68–75. [CrossRef]
49. Zaccardelli, M.; Pane, C.; Di Mola, I.; Ronga, D.; Mori, M. Municipal organic waste compost replaces mineral fertilization in the horticultural cropping systems, reducing the pollution risk. *Ital. J. Agron.* **2021**, *16*, 1756. [CrossRef]
50. Ameen, H.A.; Dohuki, M.S.S.M. Effect of Leached and Co-Composted Organic Fraction of Municipal Solid Waste with Bulking Agents on Soil Properties and Sweet Pepper Plant Development Under Calcareous Soil. *Commun. Soil Sci. Plant Anal.* **2023**, *54*, 1627–1643. [CrossRef]
51. Srivastav, B.K.; Singh, R.; Pandey, K. Singh. Effect of organic manures and bio-fertilizers on vegetative growth and yield of strawberry cv. chandler. *J. Pharmacogn. Phytochem.* **2018**, *7*, 2841–2844.
52. Singh, S.; Kaur, A. Impact of organic fertilizers on performance of strawberry cv. Sweet Charlie under sub-tropical conditions of Punjab. *J. Pharmacogn. Phytochem.* **2019**, *8*, 111–115.
53. Benedict, O.; Unagwu, B.O.; Obiora, C.I.; Ajoagu, G.M. Changes in soil nutrient status of a coarse-textured Ultisol and tomato growth performance following composted sawdust-household waste application. *Int. J. Recycl. Org. Waste Agric.* **2023**, *12*. [CrossRef]
54. Chowhan, S.; Hossaın, M.M.; Hoque, M.A.; Rasul, G.; Roni, M.S. Yield performance of strawberry genotypes. *Bangladesh J. Agril. Res.* **2016**, *41*, 481–489. [CrossRef]
55. Tzortzakis, N.; Saridakis, C.; Chrysargyris, A. Treated Wastewater and Fertigation Applied for Greenhouse Tomato Cultivation Grown in Municipal Solid Waste Compost and Soil Mixtures. *Sustainability* **2020**, *12*, 4287. [CrossRef]
56. Yuksel, O. Effect of Municipal Waste Compost on Some Chemical Characteristics of Clay Soils. *J. Agron.* **2004**, *3*, 43–45. [CrossRef]
57. Rajaie, M.; Tavakoly, A.R. Effects of municipal waste compost and nitrogen fertilizer on growth and mineral composition of tomato. *Int. J. Recycl. Org. Waste Agric.* **2016**, *5*, 339–347. [CrossRef]
58. Şener, S.; Türemiş, N.F. Influence of Mulch Types on Yield and Quality of Organically Grown Strawberry Cultivars. *Ziraat Fakültesi Dergisi.* **2017**, *12*, 66–72.
59. Kılıc, N.; Turemis, N.F.; Dasgan, H.Y. The Effect Of Fertılızers On Crop Yıeld, Fruıt Qualıty And Plant Nutrıtıon Of Organıcally Grown Strawberry (*Fragaria* × *ananassa* Duch.). *ALOKI* **2021**, *19*, 2201–2211. [CrossRef]
60. Gecer, M.K.; Orman, E.; Gundogdu, M.; Ercisli, S.; Karunakaran, R. Identification of Metabolites Changes and Quality in Strawberry Fruit: Effect of Cultivation in High Tunnel and Open Field. *Plants* **2022**, *11*, 1368. [CrossRef]
61. Mohamed, M.H.M.; Petropoulos, S.A.; Ali, M.M.E. The Application of Nitrogen Fertilization and Foliar Spraying with Calcium and Boron Affects Growth Aspects, Chemical Composition, Productivity and Fruit Quality of Strawberry Plants. *Horticulturae* **2021**, *7*, 257. [CrossRef]
62. Çolak, A.M.; Şahinler, N.; İslamoğlu, M. The Effect of Honeybee Pollination on Productivity and Quality of Strawberry. *Alinteri J. Agric. Sci.* **2017**, *32*, 87–90. [CrossRef]
63. Geçer, M.K.; Gündoğdu, M.; Başar, G. Bazı Çilek Çeşitlerinin Merzifon (Amasya) Ekolojisindeki Verim Durumlarının Tespiti. *J. Inst. Sci. Technol.* **2018**, *8*, 11–15. [CrossRef]
64. Pakyürek, M.; Al-Shatri, A.H.N.; Yaviç, A. Effect of Seaweed Application on The Vegetative Growth of Strawberry Cv. Albion Grown Under Iraq Ecological Conditions. *Appl. Ecol. Environ. Res.* **2020**, *18*, 1211–1225. [CrossRef]
65. Karaca, N.F.; Pırlak, L. Studies on Determination of Strawberry Cultivars Suitable for Ereğli-Konya Ecological Conditions. *SJAFS* **2022**, *36*, 48–57. [CrossRef]
66. Nakro, A.; Bamouh, A.; El Khatib, O.; Ghaouti, L. Effect of Potassium Source and Dose on Yield and Quality of Strawberry Fruit. *Am. J. Plant Sci.* **2022**, *13*, 1196–1208. [CrossRef]
67. Schwarz, K.; Vilela-Resende, J.T.; Pierozan-Junior, C.; Paula, J.T.; Baier, J.E.; de Souza-Silva, M.L.; Brendler-Oliveira, F. Yield and nutrition of greenhouse-grown strawberries (*Fragaria* × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier. cv. Camarosa) as affected by potassium fertilization. *Acta Agron.* **2018**, *67*, 114–119. [CrossRef]
68. Kaya, C.; Higgs, D.; Saltali, K.; Gezerel, O. Response of Strawberry Grown at High Salinity and Alkalinity to Supplementary Potassium. *J. Plant Nutr.* **2002**, *25*, 1415–1427. [CrossRef]
69. Zelelew, D.; Lal, S.; Kidane, T.; Ghebreslassie, B. Effect of Potassium Levels on Growth and Productivity of Potato Varieties. *Am. J. Plant Sci.* **2016**, *7*, 1629–1638. [CrossRef]

70. de Jesús Ornelas-Paz, J.; Yahia, E.M.; Ramírez-Bustamante, N.; Pérez-Martínez, J.D.; del Pilar Escalante-Minakata, M.; Ibarra-Junquera, V.; Acosta-Muñiz, C.; Guerrero-Prieto, V.; Ochoa-Reyes, E. Physical attributes and chemical composition of organic strawberry fruit (*Fragaria* × *ananassa Duch*, Cv. Albion) at six stages of ripening. *Food Chem.* **2013**, *138*, 372–381. [CrossRef]
71. Tognetti, C.; Mazzarino, M.J.; Laos, F. Improving the quality of municipal organic waste compost. *Bioresour. Technol.* **2007**, *98*, 1067–1076. [CrossRef]
72. Machado, R.M.A.; Alves-Pereira, I.; Robalo, M.; Ferreira, R. Effects of Municipal Solid Waste Compost Supplemented with Inorganic Nitrogen on Physicochemical Soil Characteristics, Plant Growth, Nitrate Content, and Antioxidant Activity in Spinach. *Horticulturae* **2021**, *7*, 53. [CrossRef]
73. Civeira, G. Influence of Municipal Solid Waste Compost on Soil Properties and Plant Reestablishment in Peri-Urban Environments. *Chil. J. Agric. Res.* **2010**, *70*, 446–453. [CrossRef]
74. Khalid, S.; Qureshi, K.M.; Hafiz, I.A.; Khan, K.S.; Qureshi, U.S. Effect of organic amendments on vegetative growth, fruit and yield quality of strawberry. *Pak. J. Agric. Res.* **2013**, *26*, 104–112.
75. Perkins-Veazie, P. Growth and ripening of strawberry fruit. *Hort. Rev.* **1995**, *17*, 267–297. [CrossRef]
76. Hadiwijaya, Y.; Putri, I.E.; Mubarok, S.; Hamdani, J.S. Rapid and non-destructive prediction of total soluble solids of guava fruits at various storage periods using handheld nearinfrared instrument. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *458*, 012022. [CrossRef]
77. Bartczak, M.; Lisiecka, J.; Knaflewski, M. Correlation between selected parameters of planting material and strawberry yield. *Folia Hortic.* **2010**, *22*, 9–12. [CrossRef]
78. Çay, S.; Kaynaş, K. Leonardit Uygulamasının Albion ve Sweet Ann Çilek Çeşitlerinde Bitki Gelişimi ve Verime Etkileri. *Çomü Ziraat Fakült Derg.* **2016**, *4*, 13–19.
79. Çiylez, S.; Eşitken, A. Mikoriza ve BBAR Uygulamalarının Çilekte Büyüme Üzerine Etkileri. *Selcuk. J. Agric. Food Sci.* **2018**, *32*, 361–365. [CrossRef]
80. Tiwari, A.K.; Saravanan, S.S.; Lall, D. Influence of different plant growth regulators on vegetative growth and physico-chemical properties of strawberry (*Fragaria* × *ananassa Duch.*) cv. Chandler. *Plant Arch.* **2017**, *17*, 367–370.
81. Medeiros, R.F.; Pereira, W.E.; Rodrigues, R.D.M.; Nascimento, R.D.; Suassuna, J.F.; Dantas, T.A. Growth and yield of strawberry plants fertilized with nitrogen and phosphorus. *Rev. Bras. Eng. Agríc. Ambient.* **2015**, *19*, 865–870. [CrossRef]
82. Sharma, V.K.; Godara, A.K.; Kumatkar, R.B. Effect Of Soilless Growing Structures on Vegetative Growth and Roots of Strawberry cv. Sweet Charlie. *Ecoscan* **2015**, *9*, 89–91.
83. Mattner, S.W.; Milinkovic, M.; Arioli, T. Increased growth response of strawberry roots to a commercial extract from *Durvillaea potatorum* and *Ascophyllum nodosum*. *J. Appl. Phycol.* **2018**, *30*, 2943–2951. [CrossRef] [PubMed]
84. Ahmad, H.; Sajjid, M.; Hayat, S.; Rizwan Ullah, R.; Ali, M.; Jamal, A.; Rahman, A.; Aman, Z.; Ali, J. Growth, Yield and Fruit Quality of Strawberry (*Frageria ananasa* Dutch) under Different Phosphorus Levels. *Res. Agric.* **2017**, *2*, 19–28. [CrossRef]
85. Sharpe, S.; Boyd, N.; Dittmar, P.; MacDonald, G.; Darnell, R.; Ferrell, J. Spray Penetration into a Strawberry Canopy as Affected by Canopy Structure, Nozzle Type, and Application Volume. *Weed Technol.* **2018**, *32*, 80–84. [CrossRef]
86. Kurt, D.; Ayan, A. Effect of the Different Organic Fertilizer Sources and Doses on Yield in Organic Tobacco (*Nicotiana tabacum* L.) Production. *Gaziosmanpaşa Üniv. Ziraat Fakült. Derg.* **2014**, *31*, 7–13.
87. Sönmez, İ.; Maltaş, A.Ş.; Sarikaya, H.Ş.; Doğan, A.; Kaplan, M. Tavuk gübresi uygulamalarinin domates (*Solanum lycopersicum* L.) gelişimi ve verim üzerine etkilerinin belirlenmesi. *Mediterr. Agric. Sci.* **2019**, *32*, 101–107. [CrossRef]
88. Çeliktopuz, E.; Özekici, B. Çilek Meyve ve Yaprak Mikro Besin Elementlerinin Farklı Sulama Seviyeleri ile Biyo-aktivatör Uygulamasına Tepkileri. *Yuz. Yıl Univ. J. Agric. Sci.* **2020**, *30*, 18–29. [CrossRef]
89. NCDA&CS. 2017. Available online: https://www.ncagr.gov/agronomi/documents/StrawberryInterpretationArticle2017.pdf (accessed on 9 April 2021).
90. Pritts, M.P. Nutrient Management Practices in Perennial Strawberry are Informed by Understanding the Relationships among Carbohydrate Status, Nitrogen Availability, and Soil Composition. *HortTechnology* **2015**, *25*, 447–451. [CrossRef]
91. Strik, B.C. *Nutrient Management of Berry Crops in Oregon*; May 2013 Version; Oregon State University: Corvallis, OR, USA, 2013. Available online: https://agsci.oregonstate.edu/sites/agscid7/files/horticulture/berry/nutrient_management_berry_crops_osu.pdf (accessed on 9 April 2021).
92. Develi, E.A.; Yavuz, A.; Erdoğan, Ü. The Effects of Vermicompost Applications on the Yield and Quality of San Andreas (*Fragaria* × *ananassa* Duch.) Strawberry Variety. *Turk. J. Agric. Food Sci. Technol.* **2021**, *9*, 2641–2648. [CrossRef]
93. Jones, J.R.; Wolf, B.; Mills, H.A. *Plant Analysis Handbook*; Micro Macro Publishing, Inc.: Athens, GA, USA, 1991; ISBN 9781878148001.
94. Torun, A.A.; Erdem, N.; Serçe, S.; Kaçar, Y.A.; Torun, M.B. Screening of Wild Strawberry Germplasm for Irondeficiency Tolerance Under Hydroponic Conditions. *J. Agric. Sci.* **2022**, *28*, 189–199. [CrossRef]