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Effect of Food Waste, Compost, Vermicompost, and Chemical Fertilizers on Red Radish (*Ravanello cherry belle*) Growth Measurement and Soil Quality

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Abstract: In this study, the effects of food waste (FW) compost, vermicompost, and chemical fertilizers on the growth of Organic Red radish and soil quality are investigated to promote sustainable agriculture. Utilizing a comparative approach, it assesses the impacts of these fertilizers on various plant growth metrics and soil characteristics, highlighting the potential of converting FW into nutrient-rich amendments as a sustainable alternative to chemical fertilizers. The results indicate a significant variation in fresh weight among different treatments. For example, the FV 25% treatment demonstrated a relatively high mean fresh weight of 7.9664, while CO 50% treatment yielded a much lower mean fresh weight of 0.2589. These numbers underscore the potential efficacy of specific FW treatments in enhancing plant growth, with VC 50% and FV 25% showing considerable promise in increasing crop yield. The study concludes that FW compost and vermicompost significantly enhance plant growth and soil quality, advocating for their use as sustainable and environmentally friendly alternatives to chemical fertilizers. The findings emphasize the importance of selecting appropriate fertilizer types and concentrations to optimize agricultural productivity and environmental sustainability, supporting the incorporation of FW into agricultural systems as a beneficial resource.

Keywords: food waste; vermicompost; chemical fertilizers; organic red radish (*Ravanello cherry belle*); soil quality; sustainable agriculture; compost; plant growth metrics; leave surface area

1. Introduction

The rapid and continuous growth of the urban population is causing a simultaneous increase in both food requirements and food waste (FW). This situation gives rise to various problems, including waste disposal, scarcity of agricultural resources, and reduced soil fertility. The deficiency of soil fertility necessitates a constant provision of fertilizers and nutrients [1], [2]. Uncontrolled anaerobic decomposition of solid waste at some dumping sites results in the release of methane and carbon dioxide, which contributes to global warming. It also produces unpleasant odours, attracts vermin, releases toxic gases, contaminates groundwater through leachate, and reduces landfill capacity[3]–[7].

Kumar et al. [8] found that 42% of waste originates from households, 39% from food industries, and 5% occurs during distribution. To attain development objectives for a sustainable environment, it is imperative to minimize these quantities. FW has a detrimental impact on both the environment and the agriculture industry [9]. The estimated annual cost of FW in the UAE is approximately 4 billion USD (14.69 billion dirhams) [10]. FW constitutes approximately 40% of the daily domestic waste in the UAE [7], [10].

The implementation of sustainable management practices for FW has become a significant obstacle [11], necessitating the development of novel approaches that not only alleviate environmental issues but also improve agricultural output. An effective and positive strategy involves repurposing diverse FW materials, such as vegetables, fruits, meat, bread, etc., as organic fertilizer. This approach is in line with the principles of circular economy and ecological sustainability, offering a comprehensive solution to tackle waste management and agricultural productivity simultaneously. A recent study reveals the various advantages of using FW as a valuable resource in the agricultural industry [12].

Organic manure is the term used for FW derived from plants and animals that has a positive impact on the physical, chemical, and biological characteristics of soil, as well as on the soil's fauna and nutrient content [3], [13], [14]. Organic residue comprises a variety of vital nutrients, including nitrogen, phosphorus, calcium, Sulphur, magnesium, potassium, iron, and zinc. These nutrients are crucial for achieving high crop yields and enhancing soil properties. Nevertheless, the incorrect application of chemical fertilizers can result in adverse environmental consequences, including soil deterioration, water contamination, and the release of greenhouse gases [15], [16]. There is a rising trend to reduce the frequency of applying inorganic fertilizers to soils by improving the efficiency of soil nutrient utilization and increasing the utilization of organic matter. Vermicompost is widely acknowledged as having significant potential as soil amendments among various sources of organic matter. Using fertilizers in a responsible manner is crucial for optimizing their advantages and minimizing their adverse effects on the environment. In addition, fertilizers are employed to enhance the productivity of crops and vegetables, as well as to augment the water-holding capacity of the soil [17], [18].

Using FW as fertilizers is a sustainable and environmentally conscious method to enhance agricultural productivity. Instead of allowing FW to contribute to environmental degradation and landfills, its conversion into nutrient-rich fertilizers provides a valuable resource for augmenting soil fertility. By transforming FW into fertilizers, we not only decrease the environmental impact of waste but also establish a closed-loop system that promotes the circular economy. This innovative approach not only deals with waste management issues but also agricultural productivity and fosters a more sustainable food production system. These practices align with the global goal of promoting responsible and eco-friendly farming methods [17], [19]–[21].

Research has demonstrated that the addition of vermicompost to soils can enhance the sprouting, development, and productivity of different vegetables, ornamental plants, and crops like cowpeas, cress, grapes, Chichorium, Chinese cabbage, bananas, strawberries, and tomatoes [22], [22]–[24].

Composting is a highly effective and cost-efficient method, but on the other hand, there are certain obstacles to overcome, such as the probability of odour emissions occurring during the biodegradation process and the extensive duration of the processing times. Various methods have been proposed to decrease the amount of time it takes to process household compost. One such method involves using a thermophilic composter in the shape of a drum, which can be adjusted to different temperatures. This allows for the activation of microbial metabolism and increases microbiological activity [7], [25]–[27].

Compost manufacturing devices are a crucial instrument in diminishing the quantity of waste that is disposed of in landfills. They have the ability to produce a soil amendment that is abundant in nutrients, which can be utilized to enrich garden beds, lawns, and houseplants. Additionally, these machines aid in curbing pollution caused by methane emissions and safeguarding essential topsoil. Composting technologies encompass a range of methods, including aerobic composting, vermicomposting, anaerobic digestion, and in-vessel composting [13], [28], [29].

The present research utilized the Organic Red radish variety known as (*Ravanello Cherry Belle*). This is a perennial root vegetable crop that is classified under the Brassicaceae family. The raw or sprouted seeds, leaves, and roots of the red radish can be consumed either on their own or as part of a salad. The radish root epidermis exhibits a range of hues, including white, red, pink, purple, and yellow. However, the flesh of the root is uniformly white and possesses a sharp, crunchy taste. The root skin exhibits a crimson hue as a result of the presence of anthocyanin pigment. The root contains an ample quantity of vitamins, glucosinolates, sulforaphane, polyphenolic compounds, Sulphur, calcium, potassium, and phosphorus. Vegetables from the Brassicaceae family are linked to notable

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health advantages because they contain biologically active and powerful antioxidant compounds [30].

The primary aim of this study is to emphasize the importance of using FW, such as vegetables, fruits, meat, rice, and bread, as well as compost, as organic fertilizer. The study also seeks to compare the impact of this organic fertilizer with vermicompost and chemical fertilizers on radish production and soil quality. This study offers a thorough comprehension of the advantages linked to integrating FW into agricultural systems, thereby facilitating informed and environmentally aware practices in contemporary farming. This study is the first to conduct a comparative analysis of the impacts of these three fertilizers on both radish production and soil quality in the UAE.

2. Materials and Methods

2.1. Experimental Site

The current study was carried out in the greenhouse at the United Arab Emirates University, College of Science, Biology Department during the winter seasons (January to April) of 2023.

2.2. Experimental Design

The experiment was set in a split-split plot design with three replicates. FW, compost, vermicompost, chemical fertilizer and control (only general media), were randomly distributed within the sub-plots. Each experimental sub-plot consisted of 8 rows, with three replicates. In each pot, there were two seeds.

2.3. Preparation of the Different Types of Fertilizers

Evaluation of the different fertilizers was carried out on organic red radish seeds (*Ravanello Cherry Belle*). Our aim was to test the efficacy of the FW fertilizer, FW compost fertilizer, vermicompost, and chemical fertilizers and control the growth rate and measurement of the radish and soil quality. In these experiments, the fertilizers and control used were prepared as follows:

2.3.1. Control (C):

Control exclusively utilized the General Media (GM), specifically the Seed Starter Potting Mix. The product specifications were utilized:

- Basic material: Decomposed Plant Material
- Density: >200 kg/m3
- Organic matter: 88%
- Moisture content: 47%
- Electrical Conductivity (EC): <1.5mmhos/cm
- Salt Content: <1.5 g/L
- pH: 5.5-6.5

The optimal electrical conductivity (EC) range for growing Radish is 1.0-1.5 ms/cm (1000 - 1500 µs/cm) [31].

2.3.2. Food Waste Fertilizer (FWF)

The food waste (FW) was obtained from the preparation area of the students' canteen located within the kitchen and from volunteering staff and students. It consisted of inedible raw food items such as vegetables, fruits, fish, chicken, and meat, along with remaining portions of rice, bread, pasta, used paper cups, and papers from the United Arab Emirates University (UAEU) canteen. The collection period spanned from January to February 2023. The FW includes vegetables, fruits, meat, chicken, fish, white cooked rice and pasta and bread leftovers and scraps were cleansed with water, diced into small pieces, and promptly deposited into the composting device within 48 hours of collection. Throughout this period, the FW was stored in a plastic bag within the laboratory cabinet,

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maintaining a temperature of 21°C. Subsequently, it was blended with the general media in varying proportions (10%, 25%, and 50% derived from the FW).

The FWF is processed using an Electric Compost Bin Kitchen Cavdle brand Waste Cycler, Which includes composting the FW at 120 C for 2-4 hours depending on waste volume under pressure. The characterization of the composer is as follows:

Table 1. The characterization of the composer.

Product Dimensions	25.3 x 25.3 x 31.5 cm; 7.12 Kilograms
Capacity	3 Liters
Shape	Cylindrical

Vegetables Waste Fertilizers (V%):

A mix of any vegetables leftovers and scraps was used as follows:

V%: Mixing the vegetable waste in different percentages with the general media (GM) from the first day as follows:

1. V 10% = 10% (10 parts of vegetable waste and 90 parts GM).
2. V 25% = 25% (25 parts of vegetable waste and 75 parts GM).
3. V 50% = 50% (50 parts of vegetable waste and 50 parts GM).

Fruits Waste Fertilizers (F%):

A mix of any fruit leftovers and scraps was used as follows:

F%: Mixing the fruit waste in different percentages with the general media (GM) from the first day as follows:

1. F 10% = 10% (10 parts of fruit waste and 90 parts GM).
2. F 25% = 25% (25 parts of fruit waste and 75 parts GM).
3. F 50% = 50% (50 parts of fruit waste and 50 parts GM).

Vegetables and Fruits Mixed Waste Fertilizers (FV%):

A mix of any fruit and vegetable leftovers and scraps with the same amount of vegetables and fruits after preparation, mixed together in different percentages (10%, 25% and 50% from the mixed) as follows:

FV%: Mixing the fruit and vegetable waste in different percentages with the general media (GM) from the first day as follows:

1. FV 10% = 10% (10 parts of fruit and vegetable waste and 90 parts GM).
2. FV 25% = 25% (25 parts of fruit and vegetable waste and 75 parts GM).
3. FV 50% = 50% (50 parts of fruit and vegetable waste and 50 parts GM).

Meat, Fish and Chicken Waste Fertilizer (M%):

The meat, fish and chicken waste fertilizer were collected from the canteen preparation area and the sources are as follows:

- Meat: sheep or Indian cow meat, skin and bones were used.
- Fish: Different fish types, bones, skins, and heads were used.
- Chicken: bones, skin and little flesh were used.

M%: Mixing the meat, fish and chicken waste in different percentages with the general media (GM) from the first day as follows:

1. M 10% = 10% (10 parts of meat, fish and chicken waste and 90 parts GM).
2. M 25% = 25% (25 parts of meat, fish and chicken waste and 75 parts GM).
3. M 50% = 50% (50 parts of meat, fish and chicken waste and 50 parts GM).

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Bread, Pasta and Rice Waste Fertilizer (B%):

Bread in different types and pasta and rice that were both cooked with boiling water little salt and water were used as follows:

B %: Mixing the bread, pasta and rice waste in different percentages with the general media (GM) from the first day as follows:

1. B 10% = 10% (10 parts of meat, fish and chicken waste and 90 parts GM).
2. B 25% = 25% (25 parts of meat, fish and chicken waste and 75 parts GM).
3. B 50% = 50% (50 parts of meat, fish and chicken waste and 50 parts GM).

Compost Fertilizer (CO%):

A mixture of green materials, which was mainly from a mixture of FW and brown materials such as leaves, stems, waste desk papers and cup papers with a carbon: nitrogen ratio of 30:1.

CO %: Mixing of green materials, which was mainly from a mixture of FW and brown materials waste in different percentages with the general media (GM) from the first day as follows:

1. CO 10% = 10% (10 parts of green and brown materials and 90 parts GM).
2. CO 25% = 25% (25 parts of green and brown materials and 75 parts GM).
3. CO 50% = 50% (50 parts of green and brown materials and 50 parts GM).

2.3.3. Vermicompost Fertilizer (VC%)

Vermicomposting is a natural process whereby earthworms convert waste material with rigid structures into compost. Vermicompost is the product of the decomposition process using various species of worms. In this study, *red wigglers* were used. The mixed FW was used to feed earthworms. Then, the vermicompost products were mixed with the GM in different percentages:

VC %: Mixing of vermicompost product in different percentages with the general media (GM) from the first day as follows:

1. VC 10% = 10% (10 parts of vermicompost product and 90 parts GM).
2. VC 25% = 25% (25 parts of vermicompost product and 75 parts GM).
3. VC 50% = 50% (50 parts of vermicompost product and 50 parts GM).

2.3.4. Chemical Fertilizer (CF)

The 1 gram (g) of chemical fertilizer was mixed with 1000 millilitres (ml) of water to create a 1.2 Electronic conductivity (EC) solution. It was applied in the second and third weeks after planting the seeds. The product details were as follows:

- Composition: 20% N, 20% P_2O_5, 20% K_2O + micro elements
- Formulation: Powder
- Application type: Fertigation (Fertigation is the method of administering fertilizer solutions alongside irrigation water, usually via a micro-sprinkler or drip system) [32].

2.4. Greenhouse Experiments

In these experiments, the treatments included the control and all the treatment fertilizers explained previously were used. Control and inoculated soil were maintained in the greenhouse (15 h day/9h night; temperature of 28 ± 2 °C; relative humidity of 42 ± 5%).

Table 2. Experiment layout.

Treatments Percentage		**V**	**F**	**FV**	**M**	**B**	**CO**	**VC**	**CF**	**C**
R_1	**10%**	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)

25%	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)
50%	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)	8 (2)

All sub-plots were received with vermicomposting and FW compost from day one, while chemical fertilizer was added after two weeks. Then the Organic Red Radish (*Ravanello Cherry Belle*) was grown during January 2023. All plots received the same water amount (150 ml.) on alternate days.

2.5. Plant Growth Measurements:

The plant parameters measurements include:

2.5.1. Radish Height

1. Height of the whole fresh radish (including shoot, leaves and roots) by using tap measure by unit (cm).
2. Height of the shoot of the fresh radish by using tap measure by unit (cm).
3. Height of the root of the fresh radish by using a tap measure by unit (cm).
4. Diameter: Diameter of the whole fresh radish by using a tap measure in the units (cm).

2.5.2. Radish Weight

1. Weight of the whole radish fresh and dry by using (Analytical Balance Mod. M214Ai).

2.5.3. Leaf Surface Area (LSA) Was Done by

1. Digital applications software (Leaf Byte) [33].
2. The grid count method [34], [35].
3. The width and length of the leaf [36].

2.6. Soil Quality

To determine the soil quality, these tests were done through:

- pH meter and EC: These were done using the HEM Conductivity Meter, Technical Jica by The Government of Japan Cooperation on UAEU laboratory. The pH and EC were done for all soil used.
- Viable cell count for all soil was done according to [37].
- Laboratory analysis of micronutrients and minerals of soil.

2.7. Statistical Analyses

The statistical package for social science (SPSS 27) was used for data analysis. Initial data analysis involved computing basic descriptive statistics (mean, median, standard deviation, minimum, maximum, and variance) for each treatment group. This provided a preliminary understanding of the data distribution and the central tendency. The Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to assess the normality of the data distribution across different groups. These tests were crucial to determine the appropriateness of subsequent parametric tests. To compare the effects of different fertilizers on each growth parameter, ANOVA was conducted. This test helped identify significant differences between the mean values of different groups.

This study explored the impact of various types of food waste, vermicompost, and chemical fertilizers on the growth and soil quality of organic red radish plants (*Ravanello Cherry Belle*). The independent variables were categorized into nine factors: Bread (B), Vegetables (V), Fruits (F), Fruits and Vegetables (FV), Meat (M), Compost (CO), Vermicompost (VC), Chemical Fertilizers (CF), and a Control variable (C). Each factor had specific conditions, such as percentages for vermicompost and

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soil mixtures and quantities for chemical fertilizer applications. The dependent variables measured were plant length (including root and shoot length and diameter), plant weight (fresh weight, shoot fresh weight, root fresh weight, all dry weight, shoot dry weight, root dry weight), and plant leaves (number, width, height, surface area, mean). Soil fertility was assessed using pH, EC, and mineral levels, with an ideal carbon-to-nitrogen ratio of 30:1.

2.8. Data Collection

Data were collected on plant growth dimensions such as plant length, fresh weight, dry weight, leaf measurements, and leaf surface area. Fertilizer treatments included different proportions of food waste (bread, fruits, vegetables, meat), vermicompost, chemical fertilizers, and a control group using standard potting mix.

3. Results

3.1. Reliability and Normality Tests

The reliability of the measures used in the study was assessed using Cronbach's alpha. The dimensions tested included length, weight, and leaves. The Cronbach's alpha values ranged from .714 to .852, indicating good reliability for the measures employed in the study. This suggests that the instruments used to measure plant growth dimensions were consistently reliable.

Table 3. Reliability test.

Plant growth dimensions	Number of items	Cronbach alpha
Length	4	0.852
Weight	3 (fresh)	0.714
	3 (dry weight)	0.739
Leaves	3 (leaves measures)	0.749
	2 (leave surface area)	0.783

Normality tests were conducted to assess the distribution of data across key plant growth dimensions: plant length, fresh weight, dry weight, leaf measurement, and leaf surface area. Utilizing both the Kolmogorov-Smirnov and Shapiro-Wilk tests, the study aimed to determine the appropriateness of parametric statistical methods for analysis by verifying the normal distribution of data. The results revealed varying degrees of normality across the different fertilizer treatments. Specifically, for plant length, certain groups such as FV 25% showed borderline significance in the Shapiro-Wilk test, hinting at potential deviations from normality. In the case of fresh weight, significant deviations were observed in groups like FV 25%, as indicated by the Shapiro-Wilk test. Similarly, the dry weight data for groups like CO 10% also demonstrated significant deviations from normality. Leaf measurements and leaf surface area results varied, with some groups, such as CO 50%, suggesting possible deviations from normality. These findings are crucial as they underscore the importance of carefully choosing statistical methods for analysis, especially considering the non-normal distributions observed in several treatment groups. The presence of these deviations necessitates a cautious approach to data interpretation and may warrant the application of non-parametric methods in subsequent analyses, ensuring the robustness and validity of the study's conclusions.

3.2. Plant Length

In this comprehensive study that assessing the impact of various fertilizers, including different types of food waste, vermicompost, and chemical fertilizers, on the growth of organic red radish plants (*Ravanello Cherry Belle*), the plant length was measured as a key indicator of plant growth.

Detailed in Table 4, the descriptive statistics for plant length across different fertilizer treatments included the number of observations (N), minimum and maximum values, median, mean, standard

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deviation, standard error of the mean, and variance. Notably, the treatments varied widely in their impact on plant length, with certain treatments like VC 50% and CF showing higher mean lengths, indicating their potential effectiveness; both FV 10% and B 10% give similar results. Conversely, treatments such as B 25% and F 50% demonstrated lower mean lengths.

Table 4. Plant length (composite score).

Fertilizers	N	Min	Max	Median	Mean	Std. Deviation	Std. Error of Mean	Variance
F 25%	19	6.75	17.00	11.5000	12.5803	3.61076	.82837	13.038
B 25%	4	10.78	15.78	14.5875	13.9313	2.30799	1.15400	5.327
B 10%	12	12.88	21.25	18.4375	18.2958	2.49891	.72137	6.245
CF	34	15.75	27.75	20.5000	20.8279	2.62530	.45023	6.892
CO 10%	17	9.25	20.50	12.6250	13.7647	3.15711	.76571	9.967
CO 25%	23	6.25	18.50	11.1250	11.5489	2.91614	.60806	8.504
CO 50%	9	3.23	4.15	3.5250	3.6111	.33333	.11111	.111
C	31	11.88	31.67	20.4250	20.2242	5.33410	.95803	28.453
F 10%	7	4.23	14.01	6.8000	8.5268	3.79439	1.43415	14.397
F 25%	11	8.82	17.38	12.0000	12.5114	2.45752	.74097	6.039
F 50%	6	3.53	7.63	4.8875	5.5292	1.70766	.69715	2.916
FV 10%	18	12.75	26.70	19.8000	19.7042	4.74573	1.11858	22.522
M 10%	6	6.50	11.30	9.7875	9.0625	1.87941	.76727	3.532
M 25%	3	4.03	7.25	4.1250	5.1333	1.83377	1.05873	3.363
V 10%	11	9.32	25.90	16.5750	17.0341	5.32089	1.60431	28.312
V 25%	11	2.27	30.03	11.3750	13.3795	9.78603	2.95060	95.766
VC 10%	9	16.00	21.38	19.2500	18.6806	2.07488	.69163	4.305
VC 25%	10	13.63	22.33	18.1375	18.3425	2.45532	.77644	6.029
VC 50%	9	19.50	27.25	23.2500	23.3917	2.96287	.98762	8.779
Total	250	2.27	31.67	16.2875	15.7323	6.34980	.40160	40.320

An ANOVA, as shown in Table 5, was conducted to compare the effects of different fertilizers on plant length, yielding a significant F-statistic ($F(18, 231) = 21.838$, $p < .001$). This result suggests that the type of fertilizer had a substantial impact on plant growth. The between-groups sum of squares (6323.518) compared to the within-groups sum of squares (3716.150) further highlights the variation in plant length attributed to the different treatments.

Table 5. ANOVA Table Plant length.

			Sum of Squares	df	Mean Square	F	Sig.
Plant length (composite score) * Fertilizers	**Between Groups**	**(C(Combind)**	6323.518	18	351.307	21.838	.000
	Within Groups		3716.150	231	16.087		
	Total		10039.668	249			

The measures of association, as presented in Table 6, revealed an Eta of .794 and an Eta Squared of .630. These values indicate a strong correlation between the type of fertilizer and plant length, with the Eta Squared value suggesting that approximately 63% of the variance in plant length can be explained by the type of fertilizer used. This high level of association underscores the significant influence of fertilizer choice on the growth of organic red radish plants, providing valuable insights for optimizing agricultural practices and selecting appropriate fertilization strategies.

Table 6. Measures of Association.

	Eta	Eta Squared
Plant length (composite score) * Fertilizers	.794	.630

3.3. Plant Weight

3.3.1. Fresh Weight

Table 7 presents a comprehensive analysis of fresh weight across different fertilizer treatments. This analysis includes the number of observations (N), minimum and maximum values, median, mean, standard deviation, standard error of the mean, and variance.

Table 7. Fresh weight.

Fertilizers	N	Min	Max	Median	Mean	Std. Deviation	Std. Error of Mean	Variance
F 25%	19	.07	25.98	4.7317	7.9664	8.47417	1.94411	71.812
B 25%	4	1.00	2.98	1.4097	1.6976	.92946	.46473	.864
B 10%	12	12.18	37.87	17.0545	21.5702	9.48464	2.73798	89.958
CF	34	12.20	28.75	20.8052	21.0510	4.07587	.69901	16.613
CO 10%	17	.84	23.80	8.3800	8.2313	6.78161	1.64478	45.990
CO 25%	23	3.26	6.73	5.7667	5.5227	1.05428	.21983	1.112
CO 50%	9	.06	.59	.2277	.2589	.18065	.06022	.033
C	31	1.34	46.84	16.7270	19.2573	12.82222	2.30294	164.409
F 10%	7	.00	1.15	.1310	.3170	.42488	.16059	.181
F 25%	11	2.32	2.34	2.3243	2.3274	.00807	.00243	.000
F 50%	6	.08	.32	.2048	.1926	.10182	.04157	.010
FV 10%	18	.04	46.07	19.3498	22.6135	14.62584	3.44734	213.915
M 10%	6	.67	1.53	.6725	.8816	.35625	.14544	.127
M 25%	3	.13	.37	.2970	.2641	.12164	.07023	.015
V 10%	11	.86	60.01	39.2837	30.6541	21.75798	6.56028	473.410
V 25%	11	8.61	8.61	8.6077	8.6078	.00050	.00015	.000
VC 10%	8	4.64	46.16	23.2893	24.8346	13.42968	4.74811	180.356
VC 25%	10	13.03	36.33	18.7923	21.4280	7.84334	2.48028	61.518
VC 50%	9	30.04	35.55	33.2930	33.0861	1.78229	.59410	3.177
Total	249	.00	60.01	12.2000	14.3924	13.04131	.82646	170.076

The data illustrates considerable variability in fresh weight among the different treatments. For instance, treatments like FV 25% showed a relatively high mean fresh weight (7.9664), whereas treatments such as CO 50% showed much lower mean fresh weights (0.2589).

An ANOVA, as delineated in Table 8, was performed to compare the effects of different fertilizers on fresh weight, yielding a significant F-statistic ($F(18, 230) = 15.982$, $p < .001$). This indicates a substantial impact of the type of fertilizer on plant fresh weight, as evidenced by the large between-groups sum of squares (23438.980) compared to the within-groups sum of squares (18739.819).

Table 9. Measures of Association.

	Eta	Eta Squared
Fresh weight * Fertilizers	.745	.556

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Furthermore, measures of association, presented in Table 9, revealed an Eta of .745 and an Eta Squared of .556. These values demonstrate a strong correlation between the type of fertilizer and the fresh weight of the plants, with the Eta Squared value suggesting that approximately 55.6% of the variance in fresh weight can be explained by the type of fertilizer used. This high level of association underscores the significant influence of fertilizer choice on the fresh weight of organic red radish plants, providing valuable insights for optimizing agricultural practices and selecting appropriate fertilization strategies for maximizing plant growth.

3.3.2. Dry Weight

Table 10 presents extensive descriptive statistics for dry weight across different fertilizer treatments. These statistics encompass the number of observations (N), minimum and maximum values, median, mean, standard deviation, standard error of the mean, and variance.

Table 10. Dry weight.

Fertilizers	N	Min	Max	Median	Mean	Std. Deviation	Std. Error of Mean	Variance
F 25%	19	.89	2.63	1.3700	1.5053	.62525	.14344	.391
B 25%	4	.08	.42	.2438	.2453	.15274	.07637	.023
B 10%	12	.02	4.01	1.3400	1.6484	1.58813	.45845	2.522
CF	34	.69	4.55	2.1087	2.5530	1.17579	.20165	1.382
CO 10%	17	.59	6.76	.9623	2.7175	2.72073	.65987	7.402
CO 25%	23	.59	.89	.6813	.7185	.09699	.02022	.009
CO 50%	9	.00	.03	.0097	.0126	.00968	.00323	.000
C	31	.19	5.45	2.0277	2.2306	1.50239	.26984	2.257
F 10%	7	.06	.11	.0863	.0813	.01955	.00739	.000
F 25%	11	.17	.38	.2793	.2636	.05607	.01691	.003
F 50%	6	.01	.03	.0290	.0249	.01083	.00442	.000
FV 10%	18	.87	2.83	1.3635	1.4128	.46341	.10923	.215
M 10%	6	.06	.10	.0657	.0732	.01735	.00708	.000
M 25%	3	.01	.02	.0153	.0158	.00801	.00462	.000
V 10%	11	1.13	3.90	2.4107	2.4293	.94974	.28636	.902
V 25%	11	1.24	1.54	1.5413	1.4188	.14401	.04342	.021
VC 10%	9	4.41	7.24	5.8410	5.7705	.92148	.30716	.849
VC 25%	10	2.68	7.07	5.3637	5.1997	1.20887	.38228	1.461
VC 50%	9	.71	6.11	4.1090	3.7398	2.10125	.70042	4.415
Total	250	.00	7.24	1.3078	1.9104	1.82742	.11558	3.339

The results demonstrate significant variations in dry weight among the treatments. For example, treatments like VC 10% and VC 25% showed higher mean dry weights (5.7705 and 5.1997, respectively), indicating their effectiveness in influencing plant dry weight. Regarding the treatment fertilizers V 10% gave the highest mean. In contrast, treatments such as CO 50% exhibited much lower mean dry weights (0.0126).

An ANOVA, as shown in Table 11, was conducted to compare the effects of different fertilizers on dry weight, yielding a significant F-statistic ($F(18, 231) = 19.020$, $p < .001$). This indicates that the type of fertilizer significantly influences the dry weight of the plants, as highlighted by the large between-groups sum of squares (496.514) compared to the within-groups sum of squares (335.015).

Furthermore, measures of association in Table 12, revealed an Eta of .773 and an Eta Squared of .597. These values indicate a strong correlation between the type of fertilizer and the dry weight of the plants, with the Eta Squared value suggesting that approximately 59.7% of the variance in dry weight is explained by the type of fertilizer used. This significant level of association emphasizes the impact of fertilizer choice on the dry weight of organic red radish plants, providing valuable insights

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for optimizing agricultural practices. The study thus highlights the importance of selecting appropriate fertilization strategies to maximize plant growth and development.

Table 12. Measures of Association.

	Eta	Eta Squared
Dry weight * Fertilizers	.773	.597

3.4. Leaves

3.4.1. Leave Measures

Table 13 provides an extensive analysis of leaf measurements across different fertilizer treatments. This analysis includes the number of observations (N), minimum and maximum values, median, mean, standard deviation, standard error of the mean, and variance. The results show considerable variation in leaf measurements among the different treatments. For instance, treatments such as FV 10% and B 10% showed relatively higher mean leaf measurements (9.1741and 9.0722, respectively), suggesting their effectiveness in promoting leaf growth. On the other hand, treatments like M 25% exhibited much lower mean leaf measurements (2.3778).

Table 13. Leave measurement.

Fertilizers	N	Minimum	Maximum	Median	Mean	Std. Deviation	Std. Error of Mean	Variance
F 25%	19	1.57	10.17	6.5000	5.7228	2.30107	.52790	5.295
B 25%	4	5.43	7.80	6.1000	6.3583	1.01119	.50559	1.022
B 10%	12	1.50	14.67	10.2333	9.0722	4.87137	1.40624	23.730
CF	34	5.00	8.67	6.4167	6.6471	.99558	.17074	.991
CO 10%	17	3.67	7.43	5.3333	5.2431	1.20322	.29182	1.448
CO 25%	23	3.50	7.50	4.6667	5.1087	1.21814	.25400	1.484
CO 50%	9	1.80	3.50	2.5000	2.4889	.55951	.18650	.313
C	31	4.23	9.70	7.1667	7.2957	1.60796	.28880	2.586
F 10%	7	1.75	7.67	3.5667	3.9214	2.28385	.86322	5.216
F 25%	11	4.50	9.27	6.6000	6.9545	1.48491	.44772	2.205
F 50%	6	1.87	3.83	2.9333	2.8000	.84169	.34362	.708
FV 10%	18	3.40	13.30	9.9167	9.1741	2.73330	.64424	7.471
M 10%	6	2.73	7.53	4.3167	4.7000	1.86905	.76303	3.493
M 25%	3	1.63	3.00	2.5000	2.3778	.69148	.39923	.478
V 10%	11	4.73	13.00	10.0000	8.8970	2.56209	.77250	6.564
V 25%	11	3.97	12.33	6.6667	7.2909	2.90781	.87674	8.455
VC 10%	9	4.67	9.33	7.3333	7.1481	1.66759	.55586	2.781
VC 25%	10	5.60	12.42	7.8000	8.0785	1.88790	.59701	3.564
VC 50%	9	7.50	9.67	8.6667	8.6037	.80337	.26779	.645
Total	250	1.50	14.67	6.4167	6.5843	2.63923	.16692	6.966

An ANOVA, as detailed in Table 14, was conducted to compare the effects of different fertilizers on leaf measurement, yielding a significant F-statistic ($F(18, 231) = 10.846$, $p < .001$). This significant finding suggests that the type of fertilizer had a substantial impact on leaf measurement, as indicated by the large between-groups sum of squares (794.413) compared to the within-groups sum of squares (939.999).

Table 14. ANOVA Table Leave measurement.

			Sum of Squares	df	Mean Square	F	Sig.
Leave measurement * Fertilizers	Between Groups	(Combined)	794.413	18	44.134	10.846	.000
	Within Groups		939.999	231	4.069		
	Total		1734.412	249			

Moreover, measures of association, presented in Table 15, revealed an Eta of .677 and an Eta Squared of .458. These values indicate a strong correlation between the type of fertilizer and leaf measurement, with the Eta Squared value suggesting that approximately 45.8% of the variance in leaf measurement can be explained by the type of fertilizer used. This significant level of association

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emphasizes the impact of fertilizer choice on leaf measurement in organic red radish plants, providing valuable insights for optimizing agricultural practices. The study highlights the importance of selecting appropriate fertilization strategies to enhance leaf development, crucial for plant health and productivity.

Table 15. Measures of Association.

	Eta	Eta Squared
Leave measurement * Fertilizers	.677	.458

3.4.2. Leave Surface Area

Table 16 details the descriptive statistics for leaf surface area across different fertilizer treatments. These statistics include the number of observations (N), minimum and maximum values, median, mean, standard deviation, standard error of the mean, and variance.

Table 16. Leave surface area.

Fertilizers	N	Min	Max	Median	Mean	Std. Deviation	Std. Error of Mean	Variance
F 25%	19	22.94	44.69	35.4383	32.7980	9.07007	2.08082	82.266
B 25%	4	17.94	30.94	19.7970	22.1200	5.98650	2.99325	35.838
B 10%	12	31.71	80.82	53.7473	54.0017	15.86490	4.57980	251.695
CF	34	30.02	50.58	39.9583	40.0787	5.10234	.87504	26.034
CO 10%	17	20.68	38.23	25.3100	26.6425	5.26512	1.27698	27.721
CO 25%	23	14.82	25.50	18.3457	19.9590	3.89568	.81231	15.176
CO 50%	9	3.46	6.29	5.0427	5.0871	1.01999	.34000	1.040
C	31	52.17	52.17	52.1667	52.1667	.00000	.00000	.000
F 10%	7	11.27	41.51	20.6910	19.8918	10.51318	3.97361	110.527
F 25%	11	32.76	32.77	32.7633	32.7646	.00210	.00063	.000
F 50%	6	5.04	5.35	5.0418	5.1462	.16163	.06599	.026
FV 10%	18	41.60	90.85	79.8915	72.3313	15.87648	3.74212	252.063
M 10%	6	7.34	16.51	8.1502	9.8595	3.50601	1.43132	12.292
M 25%	3	1.96	4.52	2.6770	3.0508	1.31813	.76102	1.737
V 10%	11	71.25	86.58	83.0000	80.4697	6.53753	1.97114	42.739
V 25%	11	16.46	16.46	16.4612	16.4612	.00001	.00000	.000
VC 10%	9	12.87	70.07	48.8532	42.6529	16.69107	5.56369	278.592
VC 25%	10	22.97	53.49	34.5193	36.7966	10.20452	3.22695	104.132
VC 50%	9	35.22	71.81	58.8883	58.3295	11.53497	3.84499	133.056
Total	250	1.96	90.85	36.9315	38.1645	21.36271	1.35110	456.365

The data shows significant variability in leaf surface area among the treatments. For example, treatments like V 10% and FV 10% exhibited high mean leaf surface areas (80.4697 and 72.3313, respectively), suggesting their effectiveness in enhancing leaf growth. Conversely, treatments such as M 25%presented much lower mean leaf surface areas (3.0508).

An ANOVA, as shown in Table 17, was conducted to compare the effects of different fertilizers on leaf surface area, resulting in a significant F-statistic ($F(18, 231) = 80.214$, $p < .001$). This indicates that the type of fertilizer significantly influences the leaf surface area of the plants, as demonstrated by the large between-groups sum of squares (97962.101) compared to the within-groups sum of squares (15672.868).

Table 17. ANOVA Table Leave surface area.

	Sum of Squares	df	Mean Square	F	Sig.

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Leave surface area * Fertilizers	Between Groups	(Combined)	97962.101	18	5442.339	80.214.000
	Within Groups		15672.868	231	67.848	
	Total		113634.969	249		

Furthermore, measures of association, outlined in Table 18, revealed an Eta of .928 and an Eta Squared of .862. These values indicate a very strong correlation between the type of fertilizer and the leaf surface area of the plants, with the Eta Squared value suggesting that approximately 86.2% of the variance in leaf surface area can be explained by the type of fertilizer used. This substantial level of association emphasizes the critical impact of fertilizer choice on the leaf surface area of organic red radish plants, providing vital insights for agricultural practices. The study highlights the importance of selecting appropriate fertilization strategies to optimize leaf growth, a key factor for the overall health and productivity of the plants.

Table 18. Measures of Association.

	Eta	Eta Squared
Leave surface area * Fertilizers	.928	.862

3.5. Characterization of Soil Properties

Table 19 shows the effect of different fertilizers on soil properties. pH is an important factor affecting microbial growth and reproduction. The addition of fertilizers to the soil modified pH availability and EC for plants. The pH ranges from (5.75 – 8.52) with the use of F 10% and M 50%, respectively.

Table 19. Characterization of soil properties.

Treatments	**PH**	**EC**	**PPM**
V 10%	6.84	3.81	2438.4
V 25%	7.07	5.36	3430.4
V 50%	7.27	6.07	3884.8
F 10%	5.75	2.94	1881.6
F 25%	6.66	3.73	2387.2
F 50%	6.97	4.47	2860.8
FV 10%	6.77	7.17	4588.8
FV 25%	7.52	5.11	3270.4
FV 50%	8.04	3.28	2099.2
M 10%	6.09	5.53	3539.2
M 25%	7.65	5.39	3449.6
M 50%	8.52	6.25	4000.0
B 10%	6.5	6.25	4000.0
B 25%	6.85	5.24	3353.6
B 50%	7.31	3.67	2348.8
CO 10%	6.65	2.71	1734.4
CO 25%	6.52	4.57	2924.8
CO 50%	6.44	8.74	5593.6
VC 10%	6.47	2.04	1305.6
VC 25%	6.73	1.2	768.0
VC 50%	6.83	2.79	1785.6
CF	6.7	1.12	716.8
C	6.4	0.538	344.32

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4. Discussion

The study reveals valuable insights regarding the potential utilization of different forms of FW as fertilizers in organic farming. The findings add to an expanding body of research that supports sustainable agricultural practices and provide practical solutions for waste management and environmental conservation.

Noticeable disparities in plant, shoot, and root length were observed among the various treatments in this study. The VC 50% exhibited the greatest values for both plant and root length, while treatment B10% resulted in the highest shoot length. The lowest results showed when exposed to a concentration of 50% CO (Table S1). The utilization of VC 50% surpassed the other fertilizer treatments in terms of quantity. This treatment exhibited the highest values for root diameter and fresh weight, and the difference was statistically significant. The addition of B 25% and M 25% resulted in the lowest root diameter (1.1) and fresh weight (0.2). The data demonstrates significant variation in the fresh weight among the various treatments. For example, the application of FV 25% treatments resulted in a relatively high average fresh weight of 7.9664, while treatments with CO 50% showed significantly lower average fresh weights of 0.2589. In dry weight results, The results indicate notable disparities among the treatments, particularly in terms of shoot and root fresh weight. The treatment of VC at a concentration of 50% resulted in the highest fresh weight of shoots and roots, surpassing the treatments of F 50% and M 25%, which had the lowest fresh weight values, as shown in Table S2. However, there was a disparity observed in the shoot and root dry weight between the different fertilizer treatments. The shoot dry weight was highest (9.2138g) in the treatment with VC 10%, while the treatment with M 25% had the lowest shoot dry weight (0.0213g). Conversely, the root dry weight was highest (0.9362g) in the treatment with a concentration of CO 10%, while the treatment with a concentration of CO 50% had the lowest root dry weight (0.0004g) (Table S5).

It has been observed that the use of various fertilizers resulted in a substantial increase in the number of leaves (7.1) with VC 50%, whereas the lowest number of leaves (3.2) was recorded with CO 50%. The results of this study indicated that the inclusion of FV 10% resulted in the greatest increase in both leaves height and LSA, with values of 13.7 and 86.0, respectively. In comparison, M 25% yielded values of 1.8 and 2.9 for leaves height and LSA, respectively. Treatment V yielded a maximum leaf width of 10%, while treatment F resulted in the lowest leaf width of 50% (Table S3).

Table 19 displays the impact of various fertilizers on soil characteristics. The pH level is a crucial determinant of microbial growth and reproduction. The application of fertilizers to the soil altered the pH levels and electrical conductivity (EC) that affect plant growth. The pH values range from 5.75 to 8.52 when F 10% and M 50% are utilised, respectively.

The research investigation revealed significant variations in plant growth parameters among various fertilizer treatments. Significantly, treatments such as VC and specific FW compositions exhibited substantial beneficial impacts on plant growth measurements. The findings emphasised the pivotal significance of the type of fertilizer in determining plant growth parameters. The ANOVA results yielded evidence of substantial disparities among the groups, suggesting that the type of fertilizer has a statistically significant influence on plant growth. The results have practical ramifications for the implementation of sustainable agricultural methods, specifically in the context of organic farming.

The findings align with numerous studies conducted on FW, compost, and VC. Transforming FW into valuable soil amendments, such as compost, VC, anaerobic digestate, biofertilizer, biochar, and engineered biochar, is considered an optimal strategy for recovering and reusing the nutrient-rich organic waste. These amendments have the potential to enhance soil fertility and crop yield by serving as direct sources of essential nutrients (such as carbon (C), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), iron (Fe), and zinc (Zn) and/or by improving nutrient availability through alterations in soil porosity, water retention, surface interactions, soil pH, and cation exchange capacity [38], [39]. FW is typically abundant in nitrogen and can be utilized in soils that lack nutrients. O'Connor et al. 2022 [40]–[42]discovered that dehydrated vegetables exhibited elevated levels of total N and plant-available N. Consequently, it can serve as a fertilizer to enhance crop growth, among other applications [14]. Another study aims to investigate the effectiveness of recycling kitchen waste as an organic N-fertilizer for sustainable agriculture in both cool and warm seasons. The findings indicate that kitchen waste outperformed mineral fertilizer as a fertilizer, but this effect was only observed during the cool season. Furthermore, it resulted in a 20–40% increase in plant yields for nitrogen. Introducing kitchen waste into the soil yielded superior soil characteristics compared to mineral fertilizer [19]. A separate study investigated the efficacy of an Organic liquid fertilizer derived from recycled FW when applied to lettuce, cucumber, and cherry tomatoes in hydroponic systems, and compared its performance to that of a commercially available liquid fertilizer. The N and P concentrations in the structural components of lettuce and the fruit and plant structural components of cucumber seem to be comparable between recycled food fertilizer and commercial liquid fertilizer. These findings indicate that recycled food fertilizer could be a viable substitute for commercial liquid fertilizer in hydroponic systems used for growing lettuce and cucumber [21]. another researchers in addition to using FW as a fertilizer they use recycling techniques to produce both chicken feed and liquid fertilizer (CFLF), . The liquid extract obtained from the CFLF process exhibited elevated nutrient concentrations comparable to those found in the feed solution utilised in hydroponic systems. Consequently, the liquid extract derived from CFLF possesses the potential to serve as a substitute for the commercially available liquid fertilizer commonly employed in hydroponic systems [43]. VC and compost are recognised for their capacity to improve plant growth and combat both abiotic and biotic stress. Additionally, they enhance the levels of N, P, and K in both the soil and experimental plants [13]. The morphophysiological traits of tomato include leaf length, plant height, leaf breadth, leaf count, flowering time, number of primary branches per plant, stem diameter, fruit diameter, fruit count per plant, and petiole length [44] were improved with the VC compared to CF. An Innovative Approach for Utilising dairy waste as a Nutritional Source for Wheat Plants The application of dairy waste as an organic fertilizer resulted in a significant enhancement of soil quality. The organic fertilizer that was extracted demonstrated a significant advantage over mineral fertilisation by effectively meeting the nutrient needs of wheat [45].

In line with our finding out, a study also observed that different compost and vermicompost treatments have an impact on soil characterization. They discovered that a fertilizer derived from FW had the following properties: electrical conductivity (EC) of 6.36 mS/cm, and a pH of 6.5, and the FW also have an positive impact on the growth and plant nutrient levels. For example, they affect the plant height, number of leaves, length and width of leaves, as well as the uptake and bioactivity of pineapple [13], [46]. Another study found that, They also affect the length of the shoot, length of internode, number of leaves, and number of branches in Capsicum annum [47]. Additionally, composting is an effective strategy for converting agricultural and urban waste into forms that can benefit crops. A study investigated the impact of using recycled waste compost on soil food webs, nutrient cycling, and tree growth in a young almond orchard. The researchers discovered that both compost dairy manure compost and FW compost resulted in an increase in soil organic matter pools, as well as soil nitrate and ammonium levels. Both composts had a noticeable impact on bacterial communities following application, particularly on groups capable of breaking down carbon, and resulted in an increase in populations of nematodes that feed on bacteria, although at different time intervals. Distinct associations were found between nematode and bacterial groups in compost treatments, which were absent in the control group. The application of FW compost resulted in an increase in trunk diameters compared to the control group. Additionally, the compost had a higher relative abundance of nematodes that feed on the tips of herbivorous roots. The findings indicate that the use of FW composts enhances the process of biologically mediated nitrogen cycling and has the potential to promote tree growth, particularly in the initial year following application [48].

The study conducted by [49] examined the morphology, specifically root length and microbial traits, during the initial growth stage of mint and rosemary plants.

The research aims to cultivate lettuce using VC and thermophilic compost. According to Schröder et al. (2021), the lettuce crop produced the highest amount of P, K, Ca, and Mg when grown in VC made from coir-based VC [50].

The presence of small sample sizes in our treatment groups may compromise the generalizability of the findings. Although attempts were made to regulate extraneous variables, fluctuations in environmental conditions may have influenced the outcomes.

5. Conclusions

The study presents comprehensive insights into the potential use of food waste (FW) as fertilizers in organic farming, contributing to sustainable agricultural practices and waste management. Different forms of FW and their treatment variations (like VC, CO, B, M, F, and FV) were examined for their impact on plant growth parameters including plant, shoot, and root lengths, diameters, fresh and dry weights, leaf count, height, and Leaf Surface Area (LSA). The most effective was VC at 50% concentration, showing significant improvement in plant growth metrics like root diameter and fresh weight, whereas CO at 50% concentration generally led to the poorest outcomes.

The study highlighted how specific FW treatments affect soil properties such as pH and electrical conductivity, crucial for plant growth and microbial activity. FW, when transformed into compost, VC, or other biofertilizers, can significantly enhance soil fertility and plant growth by providing essential nutrients and improving soil characteristics. These findings are supported by various other researches emphasizing the beneficial use of FW in increasing crop yield and enhancing soil quality.

However, the research also underscores the variability and specificity of the results to different treatment types and concentrations, emphasizing the importance of tailored fertilizer application based on specific plant and soil needs. The study concludes that utilizing FW as fertilizer in organic farming not only contributes to sustainable agriculture and waste reduction but also significantly impacts plant growth and soil health, with implications for large-scale agricultural practices and policies.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1: Effect of different fertilizers on plant growth (plant, shoot and root length), Table S2: Effect of different fertilizers on root diameter and fresh weight, Table S3: Effect of different fertilizers on Leaves, Table S4: Effect of different fertilizers on shoot and root weight, Table S5: Effect of different fertilizers on shoot and root dry weight, Appendix1.

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