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Improving growth, yield and quality of eggplant crop by application of bio-fertilization and mulch under cold soil conditions

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Abstract: Bio-fertilization considers a useful agricultural practice, which works to upsurge the soil nutrient and organic matter due to high plant productivity and stress-tolerant of environmental conditions. This study applied mulching and bio-fertilizer on vegetative growth, yield, quality, and tolerance to low soil temperatures stress of eggplant (*Solanum melongena* L.) during the two autumn seasons. The experiment was achieved inside the net house at the station of the Centre laboratory for agriculture climate, Dokki, Egypt during the two successive seasons 2020/2021 and 2021/2022. The five treatments were the application of two additional fertilizers types (compost & vermicompost), foliar spray of algae extract (green algae & seaweed (nanotechnology)) together, compared with the control (spray water) and two treatments of mulch. The design experimental was a split-plot design with three replicates. The outcomes showed that application mulching improved parameters compared to without mulch during the two seasons. In addition, applying biofertilizer (vermicompost + folia spray green algae (T3)) gave the best parameter compared with the control (T0) in the two study seasons. Finally, the interaction of the application mulching and bio-fertilizer (T3) led to a superior of all parameters. On the contrary, the least parameters were achieved by the interaction of the application bio-fertilizer (vermicompost + folia spray seaweed (NT) (T4)) without mulch in both seasons.

keywords: vermicompost, nanotechnology, green algae, compost, soil temperature.

1.Introduction

Eggplant (*Solanum melongena* L.) is one of the most important cultivated vegetable crops in various parts of the world. Which grown in the summer season of Egypt (1 & 2). Eggplant fruits are rich in a considerable amount of carbohydrates, proteins, vitamins and other vital mineral sources (3). Also, eggplant fruits contain a high quantity of polyphenol compounds and flavonoids, which endow with good antioxidant properties expressed leading to health-promoting and disease-preventing effects. (4). eggplant is a high biomass production and a long growing season, so it is a highly nutrient-exhausting crop (5). Eggplant is a temperature-sensitive species, and temperatures below 16^{o}C limit the growth of young plants (6).

Recently, surface mulch either by artificial plastic films or natural organic waste material is utilized to prevent plants from root-borne diseases, improve soil nutrient availability, moisture content, and bulk density, and decrease nutrient loss by leaching and controlling weeds (7 & 8). Also, using plastic culture in crops production can help to reduce the most extreme weather variations, for example, limited water resources, modification of soil temperature, decreased evaporation, precipitation, wind, weed competition, soil compaction, and erosion to overcome natural constraints to successful agriculture (7). Moreover, using mulches improves the growth conditions for eggplant (6). However, vermicompost at 4 ton/ha with water hyacinth mulching was appropriate for carrot cultivation (9).

The application of bio-fertilizer, organic manuring, and bio-control agriculture appeared as a system promising complex for supplying nutrients in agriculture. So, fertilizers of microbiological are major environment-friendly pliable agricultural practices (10& 11). Moreover, using vermicompost as a fertilizer and optimizing fertilizer management improved tomato growth, fruit quality, and yield, reduced using chemical fertilizer, and kept quality soil under sustainable production systems (12). Whereas, vermicompost production is produced from feeding some special earthworm species on vegetable and animal waste. The use of vermicompost provides many benefits directly and indirectly to plant growth and product quality. Therefore, applying vermicompost develops organic matter, the physical, chemical, and biological properties of the soil, which is critical for their long-term fertility (13). Also, the gross yield of carrot plants was significantly influenced by doses of vermicompost at 4 ton/ha (9). Therefore, the application of vermicompost from 30 to 50% of the soil volume gave a good effect on plant growth (14). Whereas, the treatment vermicompost at the rate of 100% gave the highest growth characteristics and yield characteristics on bean plants (15). In addition, the highest value of most growth characteristics and yield of lettuce plants were recorded by application of vermicompost at 2 ton fed^{-1} and foliar spraying of spirulina platensis extract $2gL^{-1}$(16). Hence, the application of organic fertilizers such as vermicompost and growth stimulants upgraded coriander plants even more than NPK fertilization (17). Furthermore, Ebrahimi, *et al.* (2021) explained that using vermicompost at 1.5 Kg/m^2 and biochar increased eggplant vegetative growth and yield (18). On the other hand, microbiological fertilizers are beneficial microscopic organisms, which are significantly environmentally friendly, renewable, and less-cost sources for agricultural practices. Biofertilizers such as green algae consider a promising alternative to agrochemicals which works on recovering the content nutrients in the soil. So, it upsurges the soil nutrient content, bio-active substances, and organic matter to improve soil structure to enhance plant growth on avoid soil pollution. Thereby, algae are a positive impact on human health (19&20). For example, Chlorella vulgaris Beijerinck (green algae) is the largest photosynthetic biofuel, in addition to being the biggest oxygen-producing species in the world. Also, microalgae are necessary to the ecosystem's ecological functions and environmental sustainability which, improves nutrient uptake, growth, and abiotic tolerance to stressors (21). Moreover, spraying algae extract at 10 or 15 % enhanced the vegetative growth characteristics and yield and its components compared to the other algae extract concentrations on pea plants (22). In addition, the length and fresh mass of maize root, stem length of wheat and stem mass of lettuce were improved by application of *Chlorella Vulgaris* (19). Nevertheless, Chlorella vulgaris extract in 1 and 2 g/L was more total flavonoids than control on cardoon plants (23). Whereas, the use of the 10% algal suspension worked as an alternative foliar fertilizer to enhance the growth of Swiss chard and succeed in more sustainable and eco-friendly food production (24). However, the foliar application of *Chlorella Vulgaris* (5% v/v) was beneficial for the biochemical processes, nutrition contents, total phenolic contents, total flavonoids and antioxidative enzyme activities of broccoli plants (21). Also, algae (*Chlorella sp*) stimulated important agronomic-valuable functions in tomato plants (25).

Nevertheless, seaweed extracts consider environmentally safe for the health of animals and humans (26). Marine algal seaweed species are considered bioresources. Moreover, seaweed and seaweed-derived products contain the presence of a number of plant growth-stimulating compounds (26). In addition, vegetative growth and yield of cucumber plants were improved by a suitable application of seaweed extract of green alga (*E. intestinelis*), red alga (*G.pectinutum*) or commercial seaweed extracts with compost (27). Also, foliar spraying of seaweed extract provided some phytonutrients for the nutrition of the cucumber plants and enhanced the quality of fruits by obtaining larger antioxidant capacity (28). The spraying of seaweed extract at a concentration of 1 $ml.l^{-1}$ has a good influence on plant growth and yield parameters of eggplant (29). Whereas, Mekawy and Galal, (2021) recommended that the foliar application of seaweed extract improved yield and berry quality (30).

Furthermore, using nanofertilizers (NF) is more environmentally friendly than synthetic fertilizers and potentially increases the productivity of agricultural systems in modern agriculture. Also, it increases the nutrient use efficiency (NUE) of field and greenhouse crops and the tolerance of plants to environmental stresses (20&31). Though NF applications may have many benefits for sustainable agriculture, there are some concerns about the release of nanoparticles (NPs) from NFs into the environment, which could have a negative impact on both human and animal health (31). Otherwise, spraying nano-seaweed extract resulted in growth rootstock saplings improvement of volkamer lemon in most traits under study (32). Moreover, using a solution of *Chlorella vulgaris* soluble polysaccharides (Silver nanoparticles) increased the growth of *Phaseolus vulgaris*, which may be attributed to the increase in antioxidant activities (33).

In order to conserve the best growth, yield, and quality of eggplant plants to circumvent unsuitable soil conditions during the winter season. Therefore, this study aims to improve eggplant crop by using mulch or without and five types of soil fertilizer compost (spray green algae or seaweed (NT)) or vermicompost (green algae or seaweed (NT)) and control (spray water) during the two autumn growth seasons.

2. Materials and methods

The experiment was investigated during the two consecutive seasons 2020/2021 and 2021/2022 inside an insect-proof white net house at Centre laboratory for agriculture climate, Dokki, Egypt. This study was on the effect of mulch or without and the use of two additional fertilizers types (compost or vermicompost) with foliar spray of algae extract (green algae or seaweed (NT)) together compared with control (spray water) on vegetative growth, yield and quality of eggplant crop for improving under cold soil conditions of the two autumn seasons.

EXPERIMENT DESIGN: The experiment contained on the two factors mulch and fertilizers. The split-plot design was used in the analysis of the experimental design within three replications. The main plots were using mulch or without. The sub-plots were randomly arranged with the five different fertilizers types of vermicompost or plant compost form according to the recommendation with folia spray algae extract (green algae or seaweed (NT)) compared with spray water.

PLANT MATERIAL: Seedlings of eggplant petra (F1 hybrid) were transplanted on the 20^{th} August during the two seasons 2020/2021 and 2021/2022 inside the net-house. The net-house area was length 40m * width 9m. It was divided into five terraces**.** The treatments distributed two terraces mulch and two without and control (mulch and without). The first, the addition of vermicompost or compost from recommended doses to prepare agricultural land for eggplant crops inside the two terraces. The second, the two terraces were covered with plastic mulch. Then, the foliar spray was applied with green algae extract or seaweed three times per two weeks after three months from transplanting during the two months December and January. Meanwhile, the spray solution was diluted with green algae at $15ml.l^{-1}$ and seaweed extract (nanotechnology (NT)) at 3 ml, which were EC 1.5, $1ms.cm^{-1}$ and pH 7.6, 6, respectively. In addition, the recommended doses of chemical fertilizers of NPK were applied in this experiment according to the bulletin for growers.

The experimental treatments were 10 treatments as follows:

- ❖ Mulch + T1 (compost and foliar spray green algae extract).
- ❖ Mulch + T2 (compost and foliar spray seaweed extract (NT)).
- ❖ Mulch + T3 (vermicompost and foliar spray green algae extract).
- ❖ Mulch + T4(vermicompost and foliar spray seaweed extract (NT)).
- ❖ Mulch + control spray water.
- ❖ Without mulch + T1 (compost and foliar spray green algae extract).
- ❖ Without mulch + T2 (compost and foliar spray seaweed extract (NT)).
- ❖ Without mulch + T3 (vermicompost and foliar spray green algae extract).
- ❖ Without mulch + T4 (vermicompost and foliar spray seaweed extract (NT)).
- ❖ Without mulch + T0 (control spray

water).

Preparation of Algae Extract: Green algae (*Chlorella* sp.) belonged to cyanobacteria (*Anabaena oryzae*) and Spirulina platensis NIES-39 (A00800). green algae (Chlorella sp.) belonged to cyanobacteria (Anabaena oryzae) and Spirulina platensis NIES-39 (A00800). It was attained from the Department of Microbiology, the Agriculture Department, Soil, water and environment, Agricultural Research Center**,** Egypt. The plants were sprayed with algae extract after diluted green with tap water. The solution concentration of green algae was EC 14.7 mmhos^{-1} and pH 8. The foliar spray algae extract was applied to plants after diluting green with tap water.

Seaweed nanotechnology (NT) is named Active iron. (Active iron) is commercial product bio nanotech from company El-sharok for chemicals, which contained on iron 6%, seaweed extract 2%, vitamins1% and amino acids 10%. It was applied spray 1.5L/600L water for protected crops.

Vermicompost was from Centre laboratory for agriculture climate, Dokki, Egypt. Also, plant compost was commercial product from El Neil co.

DATE RECORDED: The three plant samples were chosen to measure (plant height (cm), stem diameter (cm), number of leaves and branches, fresh weight and day weight of shoots (g) and total leaf area (cm^2)) at the end of two seasons. (34) Leaf area /plant (m^2): It was determined by the fresh weight of 10 leaves (fourth leaf) per plant method using the following formula:

Leaf area /plant(m^2) = (fresh wt. of inedible and edible leaves/ fresh weight of the 10 disks) x No. of disks x disk area.

Also, stem diameter was measured by Vernier Caliper. data (the number of fruits, average fruit weight (g), yield (kg/m^2) and total yield (360m^2)) were measured started November to the end of the two seasons. However, the average number of collects was in the range 12 of times throughout the two seasons. in addition, data (the percentage of N, P and K for the fourth leaf (%)) and (total phenol, flavonoid and percentage of dry weight of fruits (g) for fruits) estimated after finishing all treatments. The average soil temperature (C°) monthly was obtained from the Centre laboratory for agriculture climate, Dokki, Egypt as Table (4).

Chemical constituents: Nitrogen, potassium and phosphorous contents were determined (35)**.**

Total Phenolic content (mg /g FW): The colorimetric method of Folin-Denis (36)

Total Flavonoid content (mg /g FW): determination have been determined (37).

Statistical analysis:

The study experimental was statistically analyzed split-plot design with three replicates. All data (different studied treatments) were obtained during each season. it was statistically analyzed by the table ANOVA to the variance method (38). The means of the treatments were compared using Duncan's multiple-range testing at a 5% level of probability.

3. Results and Discussion

Effect of mulching treatments: In **Table (1)** showed that the best values measured of vegetative growth (stem diameter, number of leaves, plant height, number of branches, total leaf area, fresh and dry shoots) were recorded by applying mulch during both of seasons. On the contrary, without mulch led to the least values measured in both seasons.

Data presented in Table (2) explained clearly that all values measured (number of fruit, average fruit weight, total yield/plant, and total yield/360m^2) were improved by applying mulch in the two seasons. Meanwhile, without mulch decreased all values measured fruits during both seasons.

Concerning the response positive of chemical measurements of leaves and quality measurements of fruits, the highest values measured of N, P and K percentage, dry weight/100g fresh weight, total phenol and flavonoid content were explained by applying mulch as in **Table (3)** during the two seasons. In respect, without mulch gave a response negative on chemical measurements of leaves and quality measurements of fruits in the two study seasons.

The plastic mulch treatment enhanced all the measurement parameters of eggplant plants. Data in Table (4) illustrated that applying mulch was higher average soil temperatures than without mulch during the two seasons. This result was in agreement with (8) on eggplant, (6) on eggplant, (9) on carrot, (39) on wheat, (40) on tomato on cereals and (41). Whereas, (40) proved that plastic mulch produced beneficial environmental conditions by eliminating weed competition, and reducing competition with the plant for water and soil resources. In addition, plastic mulching increased crop yields, soil enzymes, microbial activities and soil temperature (39). Also, Plastic film mulching influenced the flowering of plants and productivity because it alters the soil microclimate (41). Nevertheless, soil temperature variations seasonally and daily alter radiant energy and energy changes taking place through the soil surface. It leads the soil physiochemical and biological processes and also affects the inter-spheric processes of gas exchange between the atmosphere and the soil (42). The effect of low soil temperature reduced the absorption of soil water by the plant roots and the rate of nutrient uptake, the solubility reactions of different nutrients and the amount released of nutrient elements in the soil solution. Also, the rate of decomposition of organic matter in soil is slow at low temperatures. Whereas, the activity of micro-organisms having thermophobic and thermophilic nature is influenced by the difference in soil temperature. Various microbiological processes like mineralization of nitrogen, nitrogen fixation, pesticide degradation, etc. are influenced by the temperature. The activity of micro-organisms is least when the soil temperature is below 5°C and above 54°C. The optimum temperature for the activity of most of the micro-organisms is in the range of 25-35°C (42&43).

Effect of bio-fertilization treatments: Concerning, applying vermicompost + folia spray green algae (T3) increased all values measured of vegetative growth (stem diameter, number of leaves, plant height, number of branches, total leaf area, fresh and dry shoots) in the two study seasons. On the contrary, the lowest values (total leaf area, number of leaves and branches,) were registered by applying vermicompost + folia spray seaweed (NT) (T4) and control (spray water) (T0) during the two seasons. In comparison, the lowest values of fresh and dry shoots were achieved by spraying water (control) and applying vermicompost + folia spray seaweed (NT) (T4) deceased stem diameter and plant height during the two studied seasons as in **Table (1)**.

Regarding, applying (T3) raised the values (average fruit weight, total yield/plant, and total yield/360m^2), adding the best values of the number of fruits were realized by applying compost + folia spray seaweed extract (T2) during the two seasons in Table (2). On the contrary, control (spray water) (T0) decreased the values measured for fruits, except the lowest values of average fruit weight were concluded by applying (T4) in both seasons.

In addition, in Table (3) N, P and K percentage, dry weight/100g fresh weight, total phenol and flavonoid content, applying (T3) improved all values measured of the chemical content of leaves and quality fruits in the two seasons. On the contrary, the lowest values were obtained by applying (T0) during both studied seasons. Whereas, values measured of K percentage were the same response between T4 and T0 in the second season.

Overall, this study showed that applying vermicompost as preparing land for cultivation before transplanting and foliar spray green algae improved all measured characteristics. In spite of applying compost were higher average soil temperatures than applying vermicompost. Therefore, the application of compost or vermicompost in preparing the land for cultivation raised average soil temperatures whether with mulch or without as Table (4). Whereas, the soil temperature estimation is the best effective knowledge of the humus layer and most microbial activities prominent at the upper layers of the soil profile where plant roots grow (44). Also, distinct differences between specific vermicomposts and composts appeared in terms of their nutrient contents, the nature of their microbial communities, and their effects on plant growth (45). In addition, using vermicompost as a fertilizer more effectively promoted plant growth, including stem diameter and plant height, fruit quality, and yield of tomato plants (12). Moreover, vermicompost contained rich in nutrients, hormones, vitamins, enzymes, and humic substances. It improved the rate of organic matter and soil structure of agricultural soils (13). So, applying vermicompost is more influential than compost on plants.

On the other hand, green algae are rich in nutrients, especially nitrogen, and oxygen is available. Both of them are important reasons for the growth, yield, and quality of eggplant crops under low temperatures. This result gave the same positive effect on the vegetative growth characteristics and yield and its components of pea plants as (22), the growth and yield of wheat plants as (46**),** the production of willow plants as (47), the total flavonoids of cardoon plants as (23), plant height, fresh and dry matter of leaves, number of leaves, leaf area and yield of lettuce plants as (16), the fruit weight of tomato plants as (25) and the total flavonoid and phenolic contents, and nutrition uptake of broccoli plants as (21).

However, freshwater green microalgae extracts contain high macro and micronutrient concentrations in addition to the natural enzymes and hormones, which appeared as promising natural fertilizers (46). Also, algae (*Chlorella sp*) treatment significantly positively affected to increase the bioactive compounds (auxins, cytokinins, betaines, gibberellins or other low-weight components) available to plants (25& 48). Overall, algae bioproducts contain different metabolites, minerals and phytohormones that stimulate plant growth and yield, improve soil biological properties and increase productivity under conditions of abiotic and biotic stress (48). In algae, the amount of natural substances is relatively smaller as compared to synthetic mineral fertilizers. So, their foliar application seems to be the most appropriate way to increase the efficiency of biofertilization. During foliar fertilization, more than 90% of the compounds are used by a plant, while when they are supplied to the soil, only 10% of the compounds are absorbed by crops (47). Thus, the use of vermicompost for algal growth in plants is a lot better and safer option than the other alternatives (49).

This study is clear the application of green algae can be used as an effective foliar spray with the addition of vermicompost. Whereas, the application of seaweed algae (NT) can be a low influential foliar spray if it is combined with vermicompost.

Effect of interactions between the application mulching and biofertilizer:

Comparisons of the interaction between the application of mulch and (T3) improved all values measured of vegetative growth all values measured (number of fruit, average fruit weight, total yield/plant, and total yield/360m^2) in Table (1). Also, plant height and number of branches values have the same positive affected by the application (T1) without mulch in the second season and the two seasons respectively. In addition, application (T4) with mulch gave the best values of number of branches in the first season. Contrarily, the least all values measured of vegetative growth were obtained by the interaction between applications (T4) without mulch in the two seasons.

In the same table, there was a positive significant effect of the interaction between application the mulch and (T3) among values measured of fruits (number of fruit, average fruit weight, total yield/plant, and total yield/360m^2) in Table (2). While, the negative significant effect on the values measured of fruits was realized by the interaction between application (T4) without mulch in two successive seasons.

On the other hand, in Table (3), the interaction between application of mulch and (T3) encouraged all values measured of chemical of leaves content (N, P and K percentage) and quality of fruits content (dry weight/100g fresh weight, total phenol and flavonoid content). Also, dry weight per 100 (g) fresh fruit values were the best by applying (T1) without mulch in the second season. On the contrary, the interaction between application T4 without mulch reduced all values measured of chemical of leaves content and quality of fruits content in two consecutive seasons.

This study revealed that the application of plastic mulch and foliar spray of green algae with the addition of vermicompost was the best affected on eggplant plants. On the contrary, the application of without mulch and foliar spray of seaweed algae (NT) with the addition of vermicompost gave negative affected on eggplant plants during low soil temperatures in the two seasons. However, the presented study indicated close relations between the studied physiological activities of black plastic mulching with vermicompost as a fertilizer and foliar spray green algae under low soil temperatures conditions which caused tolerance of unsuitable conditions and enhanced production and quality.

4. Conclusion:

These above results confirm that the practice use of black plastic mulch gave the best of all the measured traits on eggplant plants under low soil temperatures. In addition, bio-fertilization is a sustainable agricultural practice that includes using bio-fertilizer to upsurge the nutrient content of the soil and organic matter, resulting in higher productivity. Micro and Macro algae are correct environmentally friendly bio-based fertilizers for pollution-free agricultural applications. In the meantime, the application of bio-fertilizer (vermicompost as fertilizer with foliar spray green algae) was useful growth, yield, and quiaty of eggplant plants during the two autumn growth seasons. The use of mulching and biofertilizers gave the most beneficial for tolerant eggplant plants for low soil temperatures during the winter season. As, they improved the growth, yield, and quality of plants under trial conditions.

Table (1) Effect of application mulching with bio-fertilization on growth of eggplant plants in two mid-winter seasons of 2020/2021 and 2021/2022.

	First season						Second season					
Treat-ments	**Stem diameter (cm)**											
	T0	**T1**	**T2**	**T3**	**T4**	**Mean**	**T0**	**T1**	**T2**	**T3**	**T4**	**Mean**
Mulch	1.41c	1.07h	1.26f	1.70a	1.52b	1.39A	1.43c	1.08h	1.28f	1.66a	1.51b	1.39A
Without	1.30e	1.35d	1.40c	1.19g	0.88i	1.22B	1.33e	1.36d	1.42c	1.21g	0.85i	1.23B
Mean	1.36B	1.21D	1.33C	1.445A	1.20E		1.38B	1.22D	1.35C	1.44A	1.18E	
Number of leaves												
Mulch	187.75f	122.00i	183.5g	270.50a	230.20c	198.79A	188.5f	120.78i	180.94g	268.26a	235.29c	198.75A
Without	159.75h	267.50b	216.60e	225.50d	118.25j	197.52B	161.5h	266.33b	210.70e	226.28d	116.71j	196.30B
Mean	173.75D	194.75C	200.05B	248.00A	174.23D		175.00D	193.56C	195.82B	247.27A	176.00D	
Plant height (cm)												
Mulch	115.18d	99.63f	120.50c	128.9a	118.90c	116.62A	117.00d	98.20g	123.00b	130.50a	117.79d	117.30A
Without	110.00e	126.60b	109.40e	125.80b	89.63g	112.29B	111.00e	128.50a	108.13f	120.50c	88.47h	111.32B
Mean	112.59C	113.12C	114.95B	127.35A	104.26D		114.00C	113.35C	115.57B	125.50A	103.13D	
Number of branches												
Mulch	16.00ef	14.25g	17.75cd	21.80a	20.80ab	18.12A	16.25c	14.19d	18.77b	22.38a	19.52b	18.22A
Without	15.00fg	21.25a	17.00de	19.25bc	10.75h	16.65B	14.30d	22.02a	17.17c	19.31b	11.10e	16.78B
Mean	15.50C	17.75B	17.38B	20.53A	15.78C		15.28C	18.11B	17.97B	20.85A	15.31C	
Fresh Shoots (g)												
Mulch	660.42e	302.43i	553.54g	1004.58a	880.91c	599.33A	658.77e	297.10i	538.20g	1006.50a	892.30c	678.57A
Without	420.50h	942.18b	565.63f	748.51d	283.00j	552.83B	421.75h	951.58b	565.41f	761.21d	289.75j	597.94B
Mean	540.46E	622.31B	559.59D	876.55A	581.96C		540.26E	624.34B	551.80D	883.86A	591.03C	
Dry Shoots (g)												
Mulch	83.71f	65.23g	117.09d	161.34a	158.22b	117.12A	84.65f	66.77h	120.00d	162.91a	157.81b	118.43A
Without	83.05f	160.75a	109.18e	121.73c	57.62h	106.47B	76.45g	162.50a	108.50e	125.97c	59.74i	106.63B
Mean	83.38E	112.99C	113.14B	141.54A	107.92D		80.55D	114.64B	114.25B	144.44A	108.78C	
Total leaf area / plant ($cm)^2$												
Mulch	16115.8e	8886.3h	13870.2g	26522.0a	20347.5d	17148.4A	15994.2e	8808.5h	14122.3g	25583.5a	20390.5d	16979.8A
Without	11369.4i	24798.9b	18274.7f	20281.0c	8005.5j	16545.9B	11332.5i	24690.1b	16979.6f	20512.6c	8025.5i	16308.1B
Mean	13742.6D	16842.6 B	16072.4C	23401.5A	14176.5D		13663.3D	16749.3B	15551.0C	23048.0A	14208.0D	

T0=(Control) water foliar spray, T1= compost with spray algae green, T2= compost with spray seaweed extract (NT), T3= vermicompost with spray algae green, T4= vermicompost with spray seaweed extract (NT). Different letters indicate significant difference at 5%

Table (2) Effect of application mulching with bio-fertilization on yield of eggplant plants in two mid-winter seasons of 2020/2021 and 2021/2022.

	First season						Second season					
Treat-ments	Average fruit weight											
	T0	T1	T2	T3	T4	Mean	T0	T1	T2	T3	T4	Mean
Mulch	242.85d	248.25c	252.21b	278.99a	229.46e	250.35 A	245.60e	251.70 d	255.60 c	280.70a	228.90 g	252.50 A
Without	222.87f	253.50b	216.66g	228.57e	199.50h	224.22 B	225.20 h	261.10 b	218.30i	236.50f	210.50j	230.32 B
Mean	232.86 D	250.88 B	234.44 C	253.78 A	214.48 E		235.40 D	256.40 B	236.95 C	258.60 A	219.70 E	
Number of fruit/m^2												
Mulch	18.36h	19.25g	43.25c	55.52a	27.62f	32.80A	16.99i	18.49f	43.21c	55.04a	29.08d	32.56A
Without	16.89j	27.99e	53.09b	30.47d	17.50i	29.19B	17.30h	28.27e	51.70b	29.23d	18.10g	28.92B
Mean	17.62E	23.62C	48.17A	42.99B	22.56D		17.15E	23.38D	47.46A	42.14B	23.59C	
Total yield (kg) per m^2												
Mulch	4.46h	4.78g	10.91c	15.49a	6.34f	8.39A	4.17h	4.65g	11.05c	15.45a	6.66f	8.40A
Without	3.76i	7.10d	11.50b	6.96e	3.49j	6.56B	3.90i	7.38d	11.29b	6.91e	3.81j	6.66B
Mean	4.11E	5.94C	11.21B	11.23A	4.91D		4.03E	6.02C	11.17B	11.18A	5.23D	
Total yield per greenhouse (ton)/360m^2												
Mulch	1.60h	1.72g	3.93c	5.58a	2.28f	3.02A	1.50h	1.68g	3.98c	5.56a	2.40f	3.02A
Without	1.36i	2.55d	4.14b	2.51e	1.26j	2.36B	1.40i	2.66d	4.06b	2.49e	1.37j	2.40B
Mean	1.48E	2.14C	4.03B	4.04A	1.77D		1.45E	2.17C	4.02B	4.03A	1.88D	

T0=(Control) water foliar spray, T1= compost with spray algae green, T2= compost with spray seaweed extract (NT), T3= vermicompost with spray algae green, T4= vermicompost with spray seaweed extract (NT). Different letters indicate significant difference at 5%

Table (3) Effect of application mulching with bio-fertilization on chemical and quality characteristics of eggplant plants in two mid-winter seasons of 2020/2021 and 2021/2022.

	First season						Second season					
Treat-ments	Nitrogen percentage (%)											
	T0	T1	T2	T3	T4	Mean	T0	T1	T2	T3	T4	Mean
Mulch	3.12g	3.33e	3.39c	3.43a	3.35d	3.32A	3.14h	3.34f	3.43c	3.51a	3.37e	3.36A
Without	3.08h	3.41b	3.29f	3.38c	2.89i	3.21B	3.10i	3.45b	3.32g	3.41d	2.90j	3.24B
Mean	3.10E	3.37B	3.34C	3.41A	3.12D		3.12E	3.40B	3.38C	3.46A	3.14D	
Phosphorus percentage (%)												
Mulch	0.540h	0.655g	0.710e	1.020a	0.820d	0.749A	0.545h	0.650g	0.750e	1.040a	0.830d	0.763A
Without	0.520i	0.940b	0.680f	0.850c	0.410j	0.680B	0.522i	0.870b	0.670f	0.840c	0.420j	0.664B
Mean	0.530E	0.798B	0.695C	0.935A	0.615D		0.534E	0.760B	0.710C	0.940A	0.625D	
Potassium percentage (%)												
Mulch	2.24h	2.33g	2.67d	3.00a	2.80c	2.61A	2.26h	2.30g	2.56d	2.98a	2.79c	2.58A
Without	2.21i	2.89b	2.43f	2.50e	2.17j	2.44B	2.22i	2.85b	2.40f	2.52e	2.19j	2.44B
Mean	2.23E	2.61B	2.55C	2.75A	2.49D		2.24D	2.58B	2.48C	2.75A	2.49D	
Total phenol content (mg/g)												
Mulch	553.00h	620.20f	633.20e	761.80a	645.00d	642.64 A	550.50 h	619.00f	629.00 e	763.00 a	643.00 d	640.90 A
Without	542.00i	716.30 b	563.50 g	670.50c	540.4j	606.54 B	545.70i	717.00 b	562.70 g	671.70 c	536.00j	606.62 B
Mean	547.50E	668.25 B	598.35 C	716.15A	592.70 D		548.10 E	668.00 B	595.85 C	717.35 A	589.50 D	
Total flavonoid content (mg/g)												
Mulch	54.36h	63.18f	67.66e	105.30a	71.46d	72.39A	57.34h	65.27f	70.86e	102.31 a	74.36d	74.03A
Without	52.27i	84.83b	57.34g	73.87c	50.36j	63.73B	53.46i	85.65b	62.68g	77.80c	50.25j	65.97B
Mean	53.32E	74.01B	62.50C	89.59A	60.91D		55.40E	75.46B	66.77C	90.06A	62.31D	
dry weight / 100(g) fresh fruit												
Mulch	6.36f	6.43d	6.44d	7.30a	6.55c	6.62A	6.40f	6.46e	6.50d	6.80a	6.59b	6.55A
Without	6.30g	6.61b	6.39e	6.56c	6.25h	6.42B	6.32g	6.78a	6.44e	6.53c	6.28h	6.47B
Mean	6.33E	6.52B	6.42C	6.93A	6.40D		6.36E	6.62B	6.47C	6.67A	6.44D	

T0=(Control) water foliar spray, T1= compost with spray algae green, T2= compost with spray seaweed extract (NT), T3= vermicompost with spray algae green, T4= vermicompost with spray seaweed extract (NT). Different letters indicate significant difference at 5%

Table (4) average soil temperatures of months during the first season (2020/2021) and the second season (2021/2022).

Months	First season (2020/2021)					
	Mulch			Without mulch		
	Compost	Vermicompost	Control	Compost	Vermicompost	Clay
September	32.61	32.52	32.40	31.20	31.03	31.00
October	28.63	28.55	28.31	27.39	27.25	27.09
November	22.72	22.52	21.52	21.87	21.86	21.09
December	17.65	17.63	16.90	17.51	17.32	16.77
January	16.56	16.54	15.86	16.43	16.25	15.74
February	17.00	16.84	16.63	16.34	16.34	16.14
	Second season (2021/2022)					
September	30.58	30.50	30.45	29.26	29.15	29.13
October	26.90	26.82	26.65	25.74	25.60	25.50
November	22.86	22.65	22.47	21.97	21.98	21.60
December	16.54	16.45	16.18	16.00	15.91	15.65
January	14.03	13.95	12.99	13.87	13.51	12.83
February	15.76	15.62	15.50	15.15	15.16	14.90

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