

Response of Vegetative Growth and Yield of Two Hybrids of Broccoli (*Brassica oleracea* var. *italica*) to Liquid Organic Fertilizer and Hefe Algae

Ghurbat Hassan Mohammed^{1*} , Abdul Jebbar Ihsan Saeid¹ 

¹Department of Horticulture, College of Agricultural Engineering Sciences, University of Duhok, Kurdistan Region, Iraq.

*Corresponding author: Ghurbat.hassan@uod.ac

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Abstract

This research was conducted to evaluate the impact of liquid organic fertilizer and Hefe algae (seaweed) on various aspects of vegetative growth and yield in two hybrids of broccoli. The results revealed that the Agassi RZ hybrid outperformed the Wisdom hybrid in parameters such as leaf area (cm²), fresh leaf weight leaves (g), dry leaf weight (g), total yield (kg plant⁻¹), and total yield (t ha⁻¹). The foliar application of 3.0 and 6.0 ml L⁻¹ of organic fertilizer significantly enhanced all vegetative growth and yield parameters. Similarly, Hefe algae, particularly at a concentration of 8.0 ml L⁻¹, showed positive and significant effects on plant height (cm), number of leaves (leaves plant⁻¹), leaf area (cm²), fresh leaf weight (g), dry leaf weight (g), chlorophyll%, total yield (kg plant⁻¹), and total yield (t ha⁻¹). The combined influence of two factors, namely hybrids and organic fertilizer, hybrids and Hefe algae, and organic fertilizer and Hefe algae, had a significant impact on all vegetative growth and yield parameters. Notably, the interaction among Agassi RZ hybrid, 6.0 ml L⁻¹ organic fertilizer, and 8.0 ml L⁻¹ Hefe algae exhibited the most substantial effects, resulting in the highest plant height (cm), number of leaves (leaves plant⁻¹), fresh leaf weight (g), dry leaf weight (g), total yield (kg plant⁻¹), and total yield (t ha⁻¹).

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Introduction

Broccoli (*Brassica oleracea* var. *italica*) is an important vegetable crop known for its economic value. It is a member of the Brassicaceae family (Branham and Farnham, 2018), it is an exotic vegetable in Iraq, although its origins can be traced back to the Mediterranean region. Broccoli is highly nutritious, containing ample amounts of vitamins A, E, B1, B2, B5, and B6, as well as essential minerals including magnesium (Mg), calcium (Ca), iron (Fe), and zinc (Zn) (Weber, 2017). Additionally, it is recognized for its high content of carotenoids and antioxidants, further contributing to its nutritional value. Thus, it is serving as a good healthy food (Rodriguez-Casado, 2016). In Iraq, 989 hectares of broccoli and cauliflower were planted, yielding 7187 t of

production and 7.2669 t ha⁻¹ of productivity (FAO, 2019).

The improvement of vegetative growth is done in different ways, the most important of which is the organic fertilizers systems that make use of naturally occurring components is one approach to enhance the physical, chemical, and biological quality of the soil. One organic fertilizer alternative that can help cut down on the use of inorganic fertilizers is liquid organic fertilizer. Nutrients and biological microbes that are good for plant growth can be found in liquid organic fertilizer (Martínez-Alcántara *et al.*, 2016). The vegetative development, yield, and nutrient content of broccoli plants are all positively impacted by liquid organic fertilizers, as evidenced by Hashem and Abd-Elrahman, (2016).

The use of seaweed extracts (Hefe algae) is one of the basic substances that may be sprayed or added to the soil to give plants the essential elements they need because it contains the macro- and micronutrients that they require as well as some hormones and growth regulators including cytokinins, auxins, and gibberellins. (O'Dell, 2003). Stimulates and activates essential plant processes. It also contains a variety of macro and micronutrients. (Jan *et al.*, 2014). Mahmood *et al.* (2021) demonstrated in their experiment to show the effect of foliar application of marine algae extract on the vegetative and yield of cauliflower. The study used three different concentrations of the extract (0, 5, and 10 ml L⁻¹), and the results noticed that the 10 ml L⁻¹ significantly increased plant height, leaf number, and head weight when compared to the control. The present study aims to examine the effects of applying liquid organic fertilizer, seaweed extract (Hefe algae), and their combined influence on the vegetative growth and yield of two hybrids of broccoli plants.

Materials and Methods

This experiment was carried out during fall season 2022-2023, in the vegetable research crop, College of Agricultural Engineering Science, University of Duhok, to investigate the response of two hybrids of broccoli (Agassi RZ and Wisdom cv.) to three concentrations (0.0, 3.0 and 6.0 ml L⁻¹ of liquid organic fertilizer (Besto Humic) and three concentrations (0.0, 4.0 and 8.0 ml L⁻¹ of Hefe algae (seaweed extract) on vegetative growth and yield. After the land preparation, it was divided into rows and given a drip watering system before the planting of the seedlings. Two hybrids were sowing at August inside the lath house two seeds per pot.

When the seedlings reached the appropriate stage for transplanting, they were transferred to the field and planted in September 2022 with a 40 cm plant-to-plant spacing and 70 cm row spacing. Each experimental unit received the other management practices similarly used by local farmers. In a factorial experiment, the treatments were set up using a Randomized

Complete Block Design (RCBD). Consequently, this trial involved 18 treatments (2*3*3=18) with three replications, each plot 9 meters long and 70 cm wide, containing twenty-two plants. The results were statistically analyzed utilizing the Duncan test at the 0.05% level to confirm the variations found in the treatment means that were found. (SAS, 2007)

Experiment measurements

1-Vegetative traits

- a- **Plant height (cm):** using metric tape, the height of the plant was measured from the point where the stem and soil surface met to the end of the stem height of five plants, with the average height being determined. (Al Kareem and Al Ajil, 2012).
- b- **Leaves number (Number plant⁻¹):** five plants from each experimental unit were counted to determine the number of leaves per plant, and an average was taken. (Al Kareem and Al Ajil, 2012).
- c- **Leaf area (cm²):** a leaf area meter (model:20A4 copy meter) was used to calculate the leaf area (Abdel, 1994)
- d- **Fresh leaf weight (g):** an electrical balance was used to determine fresh weight (five leaves) (AL-Sahaf, 1989).
- e- **Dry leaf weight (g):** the five leaves dried at 70 °C for 48-72 hours (Wilson *et al.*, 1999).
- f- **Chlorophyll% (SPAD):** The chlorophyll content of leaves was measured using the Konica Minolta, INC. Chlorophyll Meter, SPAD-502. As mentioned by Biscontin, and Pestana (2001).

2-Yield traits

- a- **Curd circumference (cm):** The curd circumference was measured by metric tape. (Al-Habar and Al-Rashidi, 2014).
- b- **Total yield (kg plant⁻¹):** The number of plants in the experimental unit and the overall yield of the unit were calculated in order to measure the plant yield (Ibrahim, 2007).
- c- **Total yield (t ha⁻¹):** By calculating the plant yield for each experimental unit and converting it to yield per hectare, the rate of the overall yield was calculated (Ibrahim, 2007).

Results and Discussions

Results in Table 1 showed that there were no significant differences between the two hybrids on plant height. Foliar spraying with organic fertilizer significantly enhanced plant height, the highest value 71.29 cm was noticed at a concentration of 6.0 ml L⁻¹ organic fertilizer compared with the control. For the effect of Hefe algae, using Hefe algae at both concentrations significantly increased plant height, maximum value 69.26 cm was noticed at 8.0 ml L⁻¹ Hefe algae.

The combination of different hybrids and organic fertilizers was shown to be significant. The most favorable interaction occurred between the Wisdom hybrid and 6.0 ml L⁻¹ of organic fertilizer, resulting in a plant height of

71.89 cm. Regarding the interaction between hybrids and Hefe algae, the highest plant height of 69.80 cm was observed when the Wisdom hybrid was combined with a concentration of 8.0 ml L⁻¹ of Hefe algae. Additionally, the combination of 3.0 ml L⁻¹ organic fertilizer with 4.0 ml L⁻¹ Hefe algae significantly enhanced plant height, reaching 72.80 cm. Furthermore, the combination of hybrids, liquid organic fertilizer, and Hefe algae had a notable impact, with the highest plant height of 73.57 cm observed in the combination involving the Wisdom hybrid, 3.0 ml L⁻¹ organic fertilizer, and 4.0 ml L⁻¹ Hefe algae. On the other hand, the lowest plant height of 55.33 cm was observed in the combination involving the Agassi RZ hybrid, 0.0 ml L⁻¹ organic fertilizer, and 0.0 ml L⁻¹ Hefe algae.

Table 1. Effect of Liquid organic fertilizer and Hefe algae on plant height (cm) of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrids* Organic Fertilizer | Effect of hybrids |
|-------------------------------|---|----------------------------------|----------|-----------|------------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 55.60 f | 61.37 e | 65.27 c-e | 60.74 b | 67.77 a |
| | 3.0 | 67.13 bc | 73.57 a | 71.30 ab | 70.67 a | |
| | 6.0 | 71.50 ab | 71.33 ab | 72.83 a | 71.89 a | |
| Agassi RZ | 0.0 | 55.33 f | 61.03 e | 62.33 de | 59.57 b | 66.87 a |
| | 3.0 | 66.73 b-d | 72.03 a | 72.30 a | 70.36 a | |
| | 6.0 | 69.83 a-c | 70.73 ab | 71.53 ab | 70.70 a | |
| Hybrid*Hefe Algae | Wisdom | 64.74 b | 68.76 a | 69.80 a | Effect of organic fertilizer | |
| | Agassi RZ | 63.97 b | 67.93 a | 68.72 a | | |
| Organic Fertilizer*Hefe Algae | 0.0 | 55.47 d | 61.20 c | 63.80 c | | |
| | 3.0 | 66.93 b | 72.80 a | 71.80 a | 60.16 b | |
| | 6.0 | 70.67 a | 71.03 a | 72.18 a | 70.51 a | |
| Effect of Hefe algae | | 64.36 b | 68.34 a | 69.26 a | 71.29 a | |

*The same latter are not significantly different according to Duncan's multiple range test at the probability of 5% level.

Table 2 demonstrates that the Wisdom hybrid outperformed the Agassi RZ hybrid in terms of the number of leaves plant⁻¹, yielding 23.11 leaves. The application of organic fertilizer had a noteworthy impact on the number of leaves plant⁻¹, with the highest number 24.11 leaves observed when using 6.0 ml L⁻¹ of organic fertilizer. The application of Hefe algae via foliar spraying also greatly enhanced the number of leaves per plant; the highest number of leaves 23.39 was noted at 8.0 ml L⁻¹ of Hefe algae. The interaction between hybrids and organic fertilizer also had a

significant effect. The combination of the Agassi RZ hybrid and 6.0 ml L⁻¹ of organic fertilizer resulted in the highest number of leaves 24.78 leaves. Furthermore, the highest number of leaves plant⁻¹ 23.67 leaves was observed in the interaction between the Wisdom hybrid and 4.0 ml L⁻¹ of Hefe algae. Similarly, the combination of the Agassi RZ hybrid and 8.0 ml L⁻¹ of Hefe algae had similar results. Notably, the interaction between 3.0 ml L⁻¹ of organic fertilizer and 8.0 ml L⁻¹ of Hefe algae resulted in a significantly high number of leaves 24.67 leaves. Considering the combination of

hybrid, liquid organic fertilizer, and Hefe algae, the highest number of leaves 25.67 leaves was achieved with the Agassi RZ hybrid, 6.0 ml L⁻¹

of organic fertilizer, and 8.0 ml L⁻¹ of Hefe algae.

Table 2. Effect of Liquid organic fertilizer and Hefe algae on the number of leaves plant⁻¹ of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrid*Organic Fertilizer | Effect of hybrids |
|-------------------------------|---|----------------------------------|-----------|-----------|------------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 21.33 ef | 22.33 c-e | 22.67 b-e | 22.11 c | 23.11 a |
| | 3.0 | 23.67 a-d | 24.67 ab | 23.00 b-e | 23.78 ab | |
| | 6.0 | 22.67 b-e | 24.00 a-c | 23.67 a-d | 23.44 b | |
| Agassi RZ | 0.0 | 15.00 h | 17.67 g | 20.00 f | 17.56 d | 21.96 b |
| | 3.0 | 21.67 d-f | 23.67 a-d | 25.33 a | 23.56 b | |
| | 6.0 | 24.00 a-c | 24.67 ab | 25.67 a | 24.78 a | |
| Hybrid*Hefe Algae | Wisdom | 22.56 bc | 23.67 a | 23.11 ab | Effect of organic fertilizer | |
| | Agassi RZ | 20.22 d | 22.00 c | 23.67 a | | |
| Organic Fertilizer*Hefe Algae | 0.0 | 18.17 e | 20.00 d | 21.33 c | 19.83 b | |
| | 3.0 | 22.67 b | 24.17 a | 24.17 a | 23.67 a | |
| | 6.0 | 23.33 ab | 24.33 a | 24.67 a | 24.11 a | |
| Effect of Hefe algae | | 21.39 b | 22.83 a | | | |

Noticed that in Table 3 Agassi RZ hybrid was superior to the Wisdom hybrid, which had the highest value 699.94 cm² compared with 622.97 cm² respectively. Spraying organic fertilizer significantly enhanced leaf area, the highest value 733.17 cm² was at 6.0 ml.l⁻¹ organic fertilizer compared with other concentrations. Also spraying Hefe algae enhanced leaf area significantly, highest value 700.43 cm² when using 8.0 ml L⁻¹ Hefe algae.

The combined effect of two factors demonstrated a significant impact. The interaction between the Agassi RZ hybrid and 3.0 ml L⁻¹ of organic fertilizer resulted in the

highest value of leaf area 771.75 cm². Similarly, the interaction between the Agassi RZ hybrid and 8.0 ml L⁻¹ of Hefe algae had the highest value 765.54 cm². The highest leaf area 762.88 cm² was observed in the interaction involving 60 ml L⁻¹ of organic fertilizer and 4.0 ml L⁻¹ of Hefe algae. Furthermore, the interaction among the Agassi RZ hybrid, 3.0 ml L⁻¹ of organic fertilizer, and 8.0 ml L⁻¹ of Hefe algae produced the largest leaf area 834.00 cm². On the other hand, the lowest value 471.25 cm² was observed in the combination involving the Wisdom hybrid, 0.0 ml L⁻¹ of organic fertilizer, and 0.0 ml L⁻¹ of Hefe algae.

Table 3. Effect of Liquid organic fertilizer and Hefe algae on leaf area (cm²) of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrids*Organic Fertilizer | Effect of hybrids |
|-----------|---|----------------------------------|------------|------------|----------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 471.25 j | 529.56 h-j | 603.44 fg | 534.75 d | 622.97 b |
| | 3.0 | 611.50 fg | 660.00 c-f | 630.75 d-h | 634.08 c | |
| | 6.0 | 692.00 b-f | 736.50 a-d | 671.75 c-f | 700.08 b | |
| Agassi RZ | 0.0 | 497.00 ij | 538.83 g-j | 649.63 c-g | 561.82 d | 699.94 a |
| | 3.0 | 756.75 a-c | 724.50 a-e | 834.00 a | 771.75 a | |
| | 6.0 | 696.50 b-f | 789.25 ab | 813.00 a | 766.25 a | |

| | | | | | |
|--------------------------------------|------------------|-----------|-----------|-----------|-------------------------------------|
| Hybrid*Hefe Algae | Wisdom | 591.58 c | 642.02 bc | 635.31 bc | Effect of organic fertilizer |
| | Agassi RZ | 650.08 bc | 684.19 b | 765.54 a | |
| Organic Fertilizer*Hefe algae | 0.0 | 484.13 c | 534.20 c | 626.53 b | 548.28 b |
| | 3.0 | 684.13 ab | 692.25 ab | 732.38 a | 702.92 a |
| | 6.0 | 694.25 ab | 762.88 a | 742.38 a | 733.17 a |
| Effect of Hefe algae | | 620.83 b | 663.11 a | | |

According to Table 4, the Agassi RZ hybrid exhibited the highest fresh leaf weight of 51.81 g, whereas the Wisdom cv. had a slightly lower weight of 49.64 g. Among the different treatments, foliar application of 6.0 ml L⁻¹ organic fertilizer resulted in the maximum and statistically significant fresh leaf weight of 56.13 g. Similarly, a higher level of Hefe algae application also led to a notable fresh leaf weight of 54.02 g. The combination of the Agassi RZ hybrid and 6.0 ml L⁻¹ of organic fertilizer showed the highest fresh leaf weight at 57.19 g. When considering the interaction

between cultivars and Hefe algae, the maximum value of 55.81 g was observed between the Agassi RZ hybrid and 8.0 ml L⁻¹ of Hefe algae. Furthermore, the interaction between 60.0 ml L⁻¹ of organic fertilizer and 8.0 ml L⁻¹ of Hefe algae resulted in the highest fresh leaf weight of 58.17 g. Moreover, the triple interaction between the Agassi RZ hybrid, 6.0 ml L⁻¹ of organic fertilizer, and 8.0 ml L⁻¹ of Hefe algae had a significant effect, with the maximum fresh leaf weight reported at 60.33 g.

Table 4. Effect of Liquid organic fertilizer and Hefe algae on fresh leaf weight (g) of two broccoli hybrid

| Hybrids | Liquid organic fertilizer (ml L⁻¹) | Hefe algae (ml L⁻¹) | | | Hybrids*Organic Fertilizer | Effect of hybrids |
|--------------------------------------|--|---------------------------------------|-----------|-----------|-------------------------------------|--------------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 40.00 f | 41.89 f | 48.00 e | 43.30 c | 49.64 b |
| | 3.0 | 48.22 de | 50.78 c-e | 52.67 b-e | 50.56 b | |
| | 6.0 | 53.67 b-d | 55.56 a-c | 56.00 a-c | 55.07 a | |
| Agassi RZ | 0.0 | 33.56 g | 47.22 e | 50.67 c-e | 43.81 c | 51.81 a |
| | 3.0 | 51.56 b-e | 55.33 a-c | 56.44 ab | 54.44 a | |
| | 6.0 | 54.22 bc | 57.00 ab | 60.33 a | 57.19 a | |
| Hybrid*Hefe Algae | Wisdom | 47.30 cd | 49.41 c | 52.22 b | Effect of organic fertilizer | |
| | Agassi RZ | 46.44 d | 53.19 ab | 55.81 a | | |
| Organic Fertilizer*Hefe Algae | 0.0 | 36.78 f | 44.56 e | 49.33 d | 43.56 c | |
| | 3.0 | 49.89 cd | 53.06 bc | 54.56 ab | 52.50 b | |
| | 6.0 | 53.94 b | 56.28 ab | 58.17 a | 56.13 a | |
| Effect of Hefe algae | | 46.87 c | 51.30 b | | | |

The results presented in Table 5 indicate that the Agassi RZ hybrid exhibited the highest dry leaf weight of 9.02 g, whereas the Wisdom hybrid had the lowest value of 7.75 g. Among the different treatments, the use of 6.0 ml L⁻¹ of organic fertilizer resulted in a significantly higher dry leaf weight of 9.33 g compared to other levels. Similarly, the application of a high level of hefe algae increased dry leaf weight significantly by 8.96 g. The interaction between hybrid and organic fertilizer had a significant effect, the highest value 10.30 g was noticed

between Agassi RZ hybrid and 6.0 mL L⁻¹ organic fertilizer. Interaction between Agassi RZ hybrid and 8.0 ml L⁻¹ hefe algae significantly enhanced dry leaf weight 9.67 g. The highest value 9.84 g was noticed between 6.0 ml L⁻¹ organic fertilizer and 8.0 mL L⁻¹ hefe algae.

Moreover, the three factors (hybrids, organic fertilizers and Hefe algae) interacted to produce a substantial effect, the maximum dry leaf weight of 11.32 g was found among Agassi

RZ hybrid, 6.0 ml L⁻¹ organic fertilizer and 8.0 ml L⁻¹ hefe algae. Conversely, the minimum value of 6.43 g was observed among Wisdom

hybrid, 0.0 ml L⁻¹ organic fertilizer and 0.0 ml L⁻¹ hefe algae.

Table 5. Effect of Liquid organic fertilizer and Hefe algae on dry leaf weight (g) of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrids*Organic Fertilizer | Effect of hybrids |
|-------------------------------|---|----------------------------------|----------|----------|------------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 6.43 e | 6.62 de | 8.03 c-e | 7.03 d | 7.75 b |
| | 3.0 | 7.50 c-e | 7.76 c-e | 8.38 b-d | 7.88 cd | |
| | 6.0 | 8.15 c-e | 8.57 bc | 8.35 cd | 8.36 bc | |
| Agassi RZ | 0.0 | 6.44 e | 7.68 c-e | 8.43 b-d | 7.52 cd | 9.02 a |
| | 3.0 | 9.22 bc | 9.23 bc | 9.27 bc | 9.24 b | |
| | 6.0 | 9.31 bc | 10.27 ab | 11.32 a | 10.30 a | |
| Hybrid*Hefe Algae | Wisdom | 7.36 c | 7.65 c | 8.25 c | Effect of organic fertilizer | |
| | Agassi RZ | 8.32 bc | 9.06 ab | 9.67 a | | |
| Organic Fertilizer*Hefe Algae | 0.0 | 6.43 d | 7.15 cd | 8.23 bc | 7.27 c | |
| | 3.0 | 8.36 bc | 8.49 b | 8.82 ab | 8.56 b | |
| | 6.0 | 8.73 ab | 9.42 ab | 9.84 a | 9.33 a | |
| Effect of Hefe algae | | 7.84 b | 8.36 ab | | | |

Table 6 revealed that there were no significant effects between the two hybrids in terms of chlorophyll percentage. However, foliar spraying with organic fertilizer had a significant effect on chlorophyll percentage, with the highest value of 62.41% observed at 6.0 ml L⁻¹ of organic fertilizer. Similarly, the application of Hefe algae at 8.0 ml L⁻¹ resulted in the highest chlorophyll percentage of 61.64%. Additionally, the combination of the two factors was a significant effect, the maximum value of 63.50% was observed between Wisdom hybrid and 6.0 ml L⁻¹ organic

fertilizer. When considering the interaction between Agassi RZ hybrid and 8.0 ml L⁻¹ Hefe algae gave the highest chlorophyll% 61.72%. For the interaction between organic fertilizer and Hefe algae, the highest percentage was noticed between 6.0 ml L⁻¹ organic fertilizer and 8.0 ml L⁻¹ Hefe algae. Furthermore, the interaction among Wisdom hybrid, 6.0 ml L⁻¹ organic fertilizer and 8.0 ml L⁻¹ Hefe algae gave the largest chlorophyll percentage 65.17%. While the lowest value 53.07% was among 6.0 ml L⁻¹ organic fertilizer and 8.0 ml L⁻¹ Hefe algae.

Table 6. Effect of Liquid organic fertilizer and Hefe algae on chlorophyll% of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrids*Organic Fertilizer | Effect of hybrids |
|-------------------------------|---|----------------------------------|-----------|-----------|------------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 53.97 de | 55.97 c-e | 56.57 b-e | 55.50 c | 59.73 a |
| | 3.0 | 59.23 a-e | 58.37 a-e | 62.93 ab | 60.18 ab | |
| | 6.0 | 63.20 ab | 62.13 a-c | 65.17 a | 63.50 a | |
| Agassi RZ | 0.0 | 53.07 e | 58.97 a-e | 59.27 a-e | 57.10 bc | 59.79 a |
| | 3.0 | 60.13 a-d | 60.43 a-d | 62.27 a-c | 60.94 a | |
| | 6.0 | 59.27 a-e | 61.03 a-c | 63.63 a | 61.31 a | |
| Hybrid*Hefe Algae | Wisdom | 58.80 ab | 58.82 ab | 61.56 a | Effect of organic fertilizer | |
| | Agassi RZ | 57.49 b | 60.14 ab | 61.72 a | | |
| Organic Fertilizer*Hefe Algae | 0.0 | 53.52 d | 57.47 cd | 57.92 c | 56.30 b | |
| | 3.0 | 59.68 bc | 59.40 bc | 62.60 ab | 60.56 a | |
| | 6.0 | 61.23 a-c | 61.58 a-c | 64.40 a | 62.41 a | |
| Effect of Hefe algae | | 58.14 b | 59.48 ab | | | |

The results presented in Table 7 indicated that the Agassi RZ hybrid gave the highest cured circumference 72.53 cm compared with the Wisdom hybrid 63.18 cm. Among the different treatments, spraying 6.0 mL L⁻¹ organic fertilizer gave the highest significant value 72.53 cm compared with the control. Using 4.0 mL L⁻¹ Hefe algae significantly enhanced the cured circumference 70.34 cm. The interaction between the two factors demonstrated a significant effect. The combination of the Agassi RZ hybrid and 6.0 mL L⁻¹ of organic fertilizer resulted in a maximum cured circumference of 75.98 cm. Likewise, the interaction between the Agassi RZ hybrid and

4.0 mL L⁻¹ of Hefe algae had the largest value of 76.79 cm. When considering the interaction between organic fertilizer and Hefe algae, the highest circumference of 76.18 cm was observed in the combination involving 6.0 mL L⁻¹ of organic fertilizer and 4.0 mL L⁻¹ of Hefe algae. Furthermore, the triple interaction among the Agassi RZ hybrid, 6.0 mL L⁻¹ of organic fertilizer, and 4.0 mL L⁻¹ of Hefe algae resulted in the largest cured circumference of 80.47 cm. Conversely, the lowest value of 51.60 cm was observed in the combination involving the Wisdom hybrid, 0.0 mL L⁻¹ of organic fertilizer, and 0.0 mL L⁻¹ of Hefe algae.

Table 7. Effect of Liquid organic fertilizer and Hefe algae on curd circumference (cm) of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (mL L ⁻¹) | | | hybrids*organic fertilizer | Effect of hybrids |
|-------------------------------|---|----------------------------------|-----------|-----------|------------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 51.60 h | 54.47 gh | 60.13 e-h | 55.40 c | 63.18 b |
| | 3.0 | 62.40 d-g | 65.30 c-f | 67.47 c-e | 65.06 b | |
| | 6.0 | 65.30 c-f | 71.90 a-c | 70.03 b-d | 69.08 b | |
| Agassi RZ | 0.0 | 57.10 f-h | 71.20 b-d | 72.27 a-c | 66.86 b | 72.53 a |
| | 3.0 | 74.23 a-c | 78.70 ab | 71.37 a-d | 74.77 a | |
| | 6.0 | 74.03 a-c | 80.47 a | 73.43 a-c | 75.98 a | |
| hybrid* Hefe algae | Wisdom | 59.77 d | 63.89 cd | 65.88 c | Effect of organic fertilizer | |
| | Agassi RZ | 68.46 bc | 76.79 a | 72.36 ab | | |
| organic fertilizer*Hefe algae | 0.0 | 54.35 d | 62.83 c | 66.20 bc | 61.13 b | |
| | 3.0 | 68.32 bc | 72.00 ab | 69.42 b | 69.91 a | |
| | 6.0 | 69.67 b | 76.18 a | 71.73 ab | 72.53 a | |
| Effect of Hefe algae | | 64.11 b | 70.34 a | | | |

The results presented in Table 8 indicated that the Agassi RZ hybrid significantly increased the total yield 1.98 kg plant⁻¹ compared to the Wisdom hybrid 1.74 kg plant⁻¹. Foliar application of 6.0 mL L⁻¹ organic fertilizer produced the highest value 2.14 kg plant⁻¹ both levels of Hefe algae significantly enhanced total yield, and spraying 8.0 mL L⁻¹ Hefe algae had a maximum value 1.99 kg plant⁻¹.

The combination of hybrid and organic fertilizer had a significant impact, the best value 2.22 kg plant⁻¹ was found between Agassi RZ hybrid and 6.0 mL L⁻¹ organic fertilizer. The interaction between the Agassi RZ hybrid and 8.0 mL L⁻¹ Hefe algae significantly enhanced the total yield 2.13 kg plant⁻¹. The interaction between organic fertilizer and Hefe algae had a significant impact, the highest total yield 2.31 kg plant⁻¹ was found between 6.0 mL L⁻¹ organic fertilizer and 8.0 mL L⁻¹ Hefe algae.

The best interaction 2.35 kg plant⁻¹ was reported among Agassi RZ hybrid, 6.0 mL L⁻¹ organic fertilizer and 8.0 mL L⁻¹ Hefe algae, while the lowest interaction 1.07 kg plant⁻¹ was reported among Wisdom hybrid, 0.0 mL L⁻¹ organic fertilizer and 0.0 mL L⁻¹ Hefe algae.

Table 8. Effect of Liquid organic fertilizer and Hefe algae on total yield (kg plant⁻¹) of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrids*Organic Fertilizer | Effect of hybrids |
|-------------------------------|---|----------------------------------|----------|----------|------------------------------|-------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 1.07 g | 1.30 fg | 1.66 eg | 1.34 c | 1.74 b |
| | 3.0 | 1.84 b-e | 1.94 a-e | 1.62 ef | 1.80 b | |
| | 6.0 | 1.74 de | 2.19 a-c | 2.28 ab | 2.07 a | |
| Agassi RZ | 0.0 | 1.18 g | 1.92 a-e | 1.77 c-e | 1.62 b | 1.98 a |
| | 3.0 | 2.01 a-e | 2.00 a-e | 2.27 ab | 2.10 a | |
| | 6.0 | 2.08 a-e | 2.22 a-c | 2.35 a | 2.22 a | |
| Hybrid*Hefe Algae | Wisdom | 1.55 d | 1.81 bc | 1.85 bc | Effect of organic fertilizer | |
| | Agassi RZ | 1.76 cd | 2.05 ab | 2.13 a | | |
| Organic Fertilizer*Hefe Algae | 0.0 | 1.13 e | 1.61 d | 1.71 cd | 1.48 c | |
| | 3.0 | 1.92 bc | 1.97 bc | 1.95 bc | 1.95 b | |
| | 6.0 | 1.91 bc | 2.20 ab | 2.31 a | 2.14 a | |
| Effect of Hefe algae | | 1.65 b | 1.93 a | | | |

Table 9 found that the Agassi RZ hybrid produced the highest total yield 62.15 t ha⁻¹ compared to the Wisdom hybrid which gave 54.59 t ha⁻¹. Foliar spraying of organic fertilizer at level 6.0 mL L⁻¹ had the maximum significant value 67.32 t ha⁻¹ compared to other treatments. Using 8.0 mL L⁻¹ Hefe algae had the maximum significant value 62.60 t ha⁻¹.

The combination of two factors had a significant effect, the interaction between Agassi RZ hybrid and 6.0 mL L⁻¹ organic fertilizer produced the maximum total yield 69.63 t ha⁻¹. The highest value 66.91 t ha⁻¹ was observed between (Agassi RZ hybrid and 8.0 mL L⁻¹ Hefe algae). For the effect between

organic fertilizer and Hefe algae, the best interaction 72.71 t ha⁻¹ was found between (6.0 mL L⁻¹ organic fertilizer and 8.0 mL L⁻¹ Hefe algae). The best interaction among three factors was observed among (Agassi RZ hybrid, 6.0 mL L⁻¹ organic fertilizer and 8.0 mL L⁻¹ Hefe algae) which gave 73.72 t ha⁻¹. The lowest value 33.61 t ha⁻¹ was observed among (Wisdom hybrid, 0.0 mL L⁻¹ organic fertilizer and 0.0 mL L⁻¹ Hefe algae).

Table 9. Effect of Liquid organic fertilizer and Hefe algae on total yield (t ha⁻¹) of two broccoli hybrids

| Hybrids | Liquid organic fertilizer (ml L ⁻¹) | Hefe algae (ml L ⁻¹) | | | Hybrids*Organic fertilizer | Effect of hybrid |
|-------------------------------|---|----------------------------------|-----------|-----------|------------------------------|------------------|
| | | 0.0 | 4.0 | 8.0 | | |
| Wisdom | 0.0 | 33.61 g | 40.90 fg | 52.09 ef | 42.20 c | 54.59 b |
| | 3.0 | 57.70 b-e | 60.93 a-e | 51.05 ef | 56.56 b | |
| | 6.0 | 54.61 de | 68.70 a-c | 71.71 ab | 65.01 a | |
| Agassi RZ | 0.0 | 37.12 g | 60.24 a-e | 55.55 c-e | 50.97 b | 62.15 a |
| | 3.0 | 63.24 a-e | 62.81 a-e | 71.47 ab | 65.84 a | |
| | 6.0 | 65.36 a-e | 69.82 a-c | 73.72 a | 69.63 a | |
| Hybrid*Hefe Algae | Wisdom | 48.64 d | 56.84 bc | 58.28 bc | Effect of organic fertilizer | |
| | Agassi RZ | 55.24 cd | 64.29 ab | 66.91 a | | |
| Organic Fertilizer*Hefe algae | 0.0 | 35.36 e | 50.57 d | 53.82 cd | 46.59 c | |
| | 3.0 | 60.47 bc | 61.87 bc | 61.26 bc | 61.20 b | |
| | 6.0 | 59.99 bc | 69.26 ab | 72.71 a | 67.32 a | |
| Effect of Hefe algae | | 51.94 b | 60.57 a | | | |

Found that there were notable variations between the two hybrids in terms of their vegetative growth characteristics. (Number of leaves, leaf area, fresh weight and dry weight) and the best performance belonged to the Agassi RZ hybrid. Compared to the other hybrids, the Agassi RZ hybrid could be more suited to the environmental conditions of the research location. The effect of hybrids might be because of environmental factors as well as variations in hybrid genotype and phenotype. This aligns with the conclusions of Alam and Hossain (2008) who revealed there was a significant environmental influence on the aspects of vegetative development, as evidenced by the differences in phenotyping and genotype variance.

The improvement in vegetative growth characteristics is the outcome of liquid organic fertilizer, It could be related to how liquid organic fertilizer increases plants' physiological activity, which is reflected in increased growth and nutrient content in the plants, boosting endogenous auxin and cytokinin, which are humat substances that nourish plants.

(Anonymous, 2005). Al-barmaei (2007) obtained that the application of liquid organic fertilizer (humic acid) to broccoli plants at a concentration of 20 ml L⁻¹, caused significantly enhanced vegetative growth represented by plant height, leaf area and dry weight. Or because they contain organic acids such as fulvic and humic acids, amino acids, and other easily obtainable, low-cost components that don't damage the environment or agricultural crops, liquid organic fertilizers are among the most significant and environmentally friendly alternatives to the nutrients for plants require. They also help to improve the biological, chemical, and physical properties of the soil, which positively influence the development and yield of different plants (Alwan and Al-Hamdani, 2012).

Plant height, leaf area, leaf area, fresh weight, dry weight, and percentage of chlorophyll all increased. By the use of seaweed (Hefe Algae), the enhanced root system observed in these seaweed extracts could potentially be attributed to endogenous auxins and other compounds present in the extracts.

Additionally, the extracts enhance roots' ability to absorb nutrients, leading to improved water and nutrient efficiency in the root systems. Furthermore, the extracts promote cell division and extension, as well as their role in maintaining the balance of biological processes within plant tissues, ultimately producing increased plant height and vigor (Khan *et al.*, 2009). Similar results were observed by Manea *et al.* (2018) in broccoli plants. Alternatively, seaweed may have essential nutrients that promote plant growth and development. It does this by activating physiological processes including photosynthesis, which has a good impact on vegetative growth characteristics. (Abd El-Motty *et al.*, 2010).

The hybrids effect on broccoli yield might be a product of environment and genotype. The growing habits of different broccoli genotypes vary which in turn affects crop output. The significant increase in the weight of main yield, secondary yield and total yield of the broccoli plant (7, 8 and 9 Tables) when spraying seaweed and liquid organic fertilizers the reason for this could be that the extract has a high concentration of macro and micronutrients, which play a crucial role in the plant's viral construction, carbon metabolism, and the leaves' synthesis of sugars. Following their transfer and storage, these nutrients increase the curds' weight and, eventually, the plant's overall output (Nardi *et al.*, 2002). The outcomes concurred with the discovery of Abdulrhman (2014) that when seaweed is used, the radish plant exhibits improved yielding characteristics.

Conclusions

Based on the findings, it can be concluded that the use of liquid organic fertilizer, Hefe algae, and their combination resulted in the improvement of all characteristics in two broccoli hybrids. Specifically, the Agassi RZ hybrid demonstrated enhancements in certain vegetative growth and yield traits. Moreover, the using of liquid organic fertilizer and Hefe algae positively influenced vegetative growth and yield parameters.

Conflicts of interest

Regarding the publication of this manuscript, the authors declare that there are no conflicts of interest.

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