Int. J. Agricult. Stat. Sci. Vol. 18, No. 1, pp. 165-171, 2022
DocID: https://connectjournals.com/03899.2022.18.165
www.connectjournals.com/ijass
ISSN: 0973-1903, e-ISSN: 0976-3392
ORIGINAL ARTICLE

EFFECT OF CULTIVATION DATES AND DIFFERENT SOURCES OF SOIL FERTILIZATION ON VEGETATIVE CHARACTERISTICS, QUALITY AND YIELD OF BROCCOLI

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Abstract: This field experiment was conducted at Research Station B, Department of Horticulture and Landscape Engineering, College of Agricultural Engineering Sciences, University of Baghdad, Jadiriyah during the fall season of 2019-2020 to evaluate the effect of cultivation dates and soil fertilization source on the growth, yield and quality of broccoli. A split plot design within the RCBD design with three replicates was applied as the Max F_1 hybrid broccoli seedlings were transferred to the field at two dates 25, Sep. 2019 and 15, Oct. 2019, which were symbolized as A and B, respectively, and occupied at the main plot. After two weeks of cultivation, the soil fertilizers were applied three times during the season in 20 days between each application including Biohealth fertilizer at a rate of 1 and 2 kg per donum, symbolized as T_1, T_2 and NPK nano fertilizer at a rate of 250 and 500 ml donum, symbolized as T_3 and T_4, as well as the control treatment that was fertilized according to the fertilizer recommendation and symbolized as T_0. This factor was considered the most important (sub plot) and the number of plants per experimental unit reached 15 plants. The results revealed a significant effect under the combination of first cultivation date and the soil application of Biohealth fertilizer at a concentration of 1 kg dunum (AT1) on the leaves content of N and k, leaves number, leaves area, the diameter and weight of the main disc, the total yield, the total soluble solids percent (TSS) and the heads content of beta-carotene, which were recorded 3.96, 2.99%, 41.0 $Leaf^1$ plant, 227.44 dm^2 $Plant^{-1}$, 74.0 cm, 896.40 gm $Plant^{-1}$, 37.35 Tons Ha^{-1}, 11.00%, 6.95 mlg 100 gm wet $weight^{-1}$, respectively, which did not significantly differ from the combination of the first cultivation date and the application of nano-NPK fertilizer at a concentration of 500 ml dunum (AT4) on leaves area, the weight of the main head, and the total yield, which were recorded 212.39 dm^2 $plant^{-1}$ and 884.55 gm $plant^{-1}$ and 36.85 tons ha^{-1}, respectively compared to the second date of cultivation and the application of fertilizer recommendation (BT0), which gave 2.33, 1.68%, 34.0 leaves, 139.99 dm^2 $plant^{-1}$, 51.0 cm, 689.23 gm $plant^{-1}$ and 28.71 tons ha^{-1}, 8.17% and 4.57 mlg 100 gm wet $weight^{-1}$, respectively.

Keywords: Biohealth, Nano-fertilizer, Non-traditional crops, Fertilization.

Cite this article

Abeer Dawood Salman and Ahmed Hashim Abdul Razzaq (2022). Effect of Cultivation Dates and different Sources of Soil Fertilization on Vegetative Characteristics, Quality and Yield of Broccoli. *International Journal of Agricultural and Statistical Sciences*. DocID: https://connectjournals.com/03899.2022.18.165

1. Introduction

Both of cultivation dates and fertilization are important factors when it comes to the quantity and quality of the crop yield, this relies on their impact on the organs formation and growth, which vary in duration according to the environmental conditions. The cultivation date plays an important role in the growth and development of the plant and the optimal cultivation date considered as a main factor in increasing production, as crop varieties respond differently to cultivation dates and may cause a significant decrease in yield, the cultivation date is affected by temperature and light, which affects most of the physiological processes that take place in the plant [Riaz *el al*. (2010)]. The importance of studying cultivation dates has increased due to the variations and extremes in the weather conditions of recent years compared to the past decade and this variation is considered as one of

***Author for correspondence** **Received** August 11, 2021 **Revised** December 14, 2021 **Accepted** January 28, 2022*

the main factors affecting the plant growth and the physiological processes that take place in it, and then in the quantitative and qualitative yield characteristics. Yassin (2018) mentioned in a study of three dates of cultivation broccoli in Salah El-Din Governorate, that cultivation date at 28 September had a significant effect on most vegetative parameters and gave the highest yield per plant. Samra and Ali (2018) observed, in a study on the red cabbage plant, that the cultivation dates have a significant impact on the growth and production of the plant and its qualitative characteristics.

The fertilization of vegetable crops is one of the most focusing points in plant production producers, which plays an important role in influencing the quantity and quality of the product. However, the application of large quantities of fertilizers may cause a pollution, Fernãndez *et al.* (2018) observed that the use of chemical fertilizers with concentrations of 60 kg N, 40 kg P and 55 kg K per ha was significantly superior of all studied fertilization levels in the total yield of broccoli.

In order to enhance the efficiency in the use of fertilizers and reduce the quantities used, nano-fertilizers are considered among the alternatives for their advantages such as high absorption and increasing the absorption surface, which leads to a higher photosynthesis process and thus increases the production of active substances in the plant. Abdul Rahman *et al.* (2018) indicated that spraying cauliflower with nano-fertilizer at a concentration of 50 ppm gave a significant increment on the characteristics of the tablets and the total yield of the plant. In general high amounts of chemical fertilization can lead to negative effects on the crop, humans and the environment, so the tendency was to take advantage of biological fertilizers, the most important of which are bacterial and fungal fertilizers, which help reduce fertilization rates and then reduce fertilizer cost and the pollution rate while increasing production in quantity and quality. Allawi and Drifel (2016) found that the triple interaction between Biohealth, Selabor and Siapton recorded the highest results in most of the characteristics of cucumber plant compared to the rest of treatments.

Broccoli (*Brassica oleracea* var. Italica) is a winter crop that belongs to Brassicaceae family. It is characterized by good nutritional value as it is rich in vitamins and carotenoids, and antioxidants, it is also considered as a rich source of glucoraphanin, which is the initiation component of the sulforaphane [Bessler and Djaldetti (2018)], which has been shown to reduce cancer, it is also considered as one of the non-traditional crops in Iraq. All given above, the study was aimed to evaluate the response of the growth, yield and quality of broccoli to the cultivation dates and different sources of fertilization.

2. Materials and Methods

This study was carried out at Research Station B, Department of Horticulture and Landscape design, College of Agricultural Engineering Sciences, University of Baghdad, Jadiriyah during the fall season of 2019-2020. The land was prepared and divided into three terraces, each terrace is considered as a replicate, the distance between each terrace was 0.60 m. Then each terrace was divided into two parts representing the main plots, which included five experimental units which is considered as the sub-plots, 1.6 m in length and 1.2 m in width, including three cultivation lines with a distance of 0.60 m between each line and 0.40 m between each plant and a distance of 0.40 m between the experimental units. The Max F_1 hybrid broccoli, produced by Horti Seeds Company, were transplanted to the field on 25, September 2019 and 15, October 2019, symbolized as A and B, respectively. Two weeks after cultivation, the soil fertilizers were applied three times during the season, with an interval of 20 days between each portion, which included Biohealth fertilizer at a rate of 1 and 2 kg per 2500 m^2, symbolized as T_1 and T_2, and NPK nano fertilizer at a rate of 250 and 500 ml per 2500 m^2, symbolized as T_3 and T_4, as well as the control treatment that was fertilized according to the fertilizer recommendation (145kg N, 80kg P_2O_5 and 120kg K_2O) and symbolized as T_0. Table 1 revealed the contents of the soil fertilizers that were applied in the experiment. The experiment was carried out according to the split plot design within the RCBD design including three replications. The cultivation date was considered as main plot and the soil fertilization were considered as the sub plot including 15 plants per each experimental unit.

The leaves content of Nitrogen (%) was determined by using the Kjeldahl [Jackson (1958)] and the leaves content of phosphorous by ammonium molybdate and ascorbic acid using a spectrophotometer at a wavelength of 620 nm [Al-Sahhaf (1989)]. The leaves content of potassium was estimated by Atomic Absorption [Al-Sahhaf (1989)] device. The leaves content of chlorophyll was estimated by a SPAD meter and the leaves number was calculated during the harvest, while

Table 1: The soil fertilizer content.

Biohealth	*Tricoderma harzianum*	*Bacillus subtilis*	Humic acid	Seaweed extract	Organic materials	Boron	K_2O
Concentration	10%	10%	75%	5%	65%	15mg.Kg^{-1}	11%
Nano-fertilizer	**Total Nitrogen**		**P_2O_5**		**K_2O**		
Concentration	10%		12%		12%		

the leaves area were calculated by using Digimizer software. The heads diameter (cm) was measured from the widest area of the head with a measurement tape, and the weight of the main head (g $plant^{-1}$) was calculated with a scale, the number of lateral heads (plant $head^{-1}$) were calculated and the total yield (ton ha^{-1}) also. The number of total soluble solids was estimated by Hand Refracto meter and the concentration of beta-carotene pigment was estimated by a spectrophotometer at wavelengths of 663, 505 and 453 nm according to Nagata and Yamashita (1992), Noaema *et al*. (2020a, 2020b) and finally the concentration of ascorbic acid (V.C) was estimated according to Abbas and Muhsen **(1992)** method.

3. Results and Discussion

The results in Table 2 revealed that the first cultivation date (A) gave the most significant values in the leaves content of nitrogen, phosphorous, potassium, and chlorophyll, leaves number and leaves area, which recorded 3.53%, 0.42%, 2.64%, 102.38 Spad and 37.0 leaf $plant^{-1}$, 192.62 dm^2 $plant^{-1}$, respectively, compared to the second cultivation date (B), which recorded 2.74%, 0.30%, 1.99%, 81.74, 34.8 leaf $plant^{-1}$ and 158.71 dm^2 $plant^{-1}$, respectively.

The soil fertilization treatments also recorded a significant effect on the studied parameters; the application of Bio-health fertilizer at a concentration of 1 kg per 2500 m^2 (T_1) gave a significant increment in the leaves content of nitrogen, phosphorous, potassium, and chlorophyll, leaves number and leaves area, which reached to 3.57%, 0.43% and 2. 71%, 98.05 Spad, 38.0, leaf $plant^{-1}$ and 195.75 dm^2 $plant^{-1}$, respectively, which did not significantly differ from the nano-fertilization treatment at the concentration of 500 ml per 2500 m^2 (T_4) in concentration of phosphorous in leaves and the nano-fertilization treatments 500 and 250 ml per 2500 m^2 (T_4) and (T_3) in each of the leaves content of chlorophyll and the leaves area compared to the control treatment (T_0), which gave 2.62%, 0.29%, 1.99%, 84.80 Spad, 34.2 leaf $plant^{-1}$ and 141.11 dm^2 $plant^{-1}$, respectively.

The interaction between cultivation dates and soil fertilization had a significant effect on most of the studied parameters as revealed in Table 2, as the interaction treatment between the first cultivation date and the soil application of Biohealth fertilizer at a concentration of 1 kg per 2500 m^2 (AT1) gave the most significant values in nitrogen percentage in leaves, and potassium, the leaves number and the leaves area, reached to 3.96%, 2.99%, 41.0 leaf $plant^{-1}$ and 227.44 dm^2 $plant^{-1}$ respectively, which did not significantly differ from the treatment of first cultivation date and the fertilization of nano-fertilizer at a concentration of 500 ml per 2500 m^2 (AT4) in leaves area, which gave 212.39 dm^2 $plant^{-1}$, compared with the lowest values in the treatment of the second cultivation date and the application of fertilizer recommendation (BT0), which gave 2.33%, 1.68%, 34.0 leaf $plant^{-1}$ and 139.99 dm^2 $plant^{-1}$, respectively, while the interaction between the study treatments did not give a significant effect on the leaves content of phosphorous and chlorophyll.

The significant values revealed by the broccoli plants grown in the first date in terms of nutrients content and vegetative growth may be due to the appropriate climatic conditions, including temperatures, which affect the activity of the vital and enzymatic processes that are responsible for the cells division and elongation, as part of the vital reactions, especially the photosynthesis that is regulated by enzymes depends directly on the temperature [Yaseen (2018)].

Also, broccoli is a heat-sensitive crop that needs a short day for optimal growth and is greatly affected by the surroundings environment, which varies according to cultivation dates, or the reason may be due to the availability of appropriate environmental conditions in the first date to increase the growth of the root system and its ability to absorb water and nutrients, including N, P, K and their role in the formation of chlorophyll pigment (Table 2). Also, Nitrogen is an essential component of protein and chloroplasts [Chaudhary *et*

Table 2: The effect of cultivation dates and sources of soil fertilization on the chemical characteristics and vegetative growth of broccoli during the fall season of 2019-2020.

Treatment	N%	P%	K%	Chlorophyll Spad	No. of Leaves Leaf. plant^{-1}	Leaf area dsm^2.plant^{-1}
A	3.53	0.42	2.64	102.38	37.0	192.62
B	2.74	0.30	1.99	81.74	34.8	158.71
L.S.D. 0.05	**0.06**	**0.03**	**0.07**	**2.27**	**0.6**	**8.98**
T_0	2.62	0.29	1.99	84.80	34.2	141.11
T_1	3.57	0.43	2.71	98.05	38.0	195.75
T_2	2.93	0.33	2.18	90.20	36.2	164.22
T_3	3.18	0.37	2.26	93.00	35.5	187.73
T_4	3.39	0.39	2.47	95.25	35.5	189.53
L.S.D. 0.05	**0.09**	**0.06**	**0.05**	**6.11**	**0.7**	**11.74**
AT0	2.91	0.31	2.30	93.20	34.5	142.24
AT1	3.96	0.51	2.99	107.80	41.0	227.44
AT2	3.40	0.38	2.55	101.20	36.5	178.72
AT3	3.68	0.44	2.64	104.70	37.0	202.32
AT4	3.73	0.46	2.76	105.00	36.0	212.39
BT0	2.33	0.27	1.68	76.40	34.0	139.99
BT1	3.18	0.35	2.43	88.30	35.0	164.07
BT2	2.47	0.28	1.81	79.20	36.0	149.72
BT3	2.68	0.30	1.88	81.30	34.0	173.14
BT4	3.05	0.32	2.19	85.50	35.0	166.66
L.S.D. 0.05	**0.11**	**N.S**	**0.08**	**N.S**	**0.9**	**15.37**

al. (2021)]. It also participates with phosphorous in the formation of the membranes of plastids, while potassium is involved as a catalyst in the formation of the pigments [Stigter and Plaxton (2015)], which is reflected on the plant nutrition and the acceleration of its growth and the increase of the photosynthesis products, which increased the leaves number and area (Table 2).

The increment in the plant's nutrient content and the vegetative growth improvement in broccoli under the application of Biohealth fertilizer may be due to its content of bio-fertilizers, the fungus *Tricoderma harzianum* has a high ability to settle in the root area and improve the absorption of organic compounds that stimulates plant growth and maintain the soil pH, which leads to an increase in the availability, absorption and transportation of some important micro nutrients [Hermosa *et al.* (2012)], which is involved in the plant metabolism processes and contributes to the regulation and increase of plant growth, which is reflected in the formation of a dense root system represented by an increase in the surface area for the absorption of water and nutrients, including N, P and K (Table 2), which has a major role in increasing the leaves content of chlorophyll as nitrogen works to form chlorophyll [Chaudhary *et al*. (2021)]. While phosphorous increases ATP compounds [Stigter and Plaxton (2015)], while potassium stimulates the activity of the enzymatic system and prevents the decomposition of chlorophyll [Oosterhuis *et al* (2014)], which leads to activating and increasing the photosynthesis process and its products from processed carbohydrates that lead to an increase in the growth rate represented by an increase in leaves number and area of the plant (Table 2), while the *Bacillus subtilis* works on the dissolution of phosphorous as a result of its secretion of organic acids that maintain the soil pH and thus increase the nutrients availability [Sharma *et al*. (2012)], especially the Iraqi soils are characterized by a high content of calcium carbonate and high soil pH, which exposes nutrients to sedimentation or loss, the most important of which are nitrogen and phosphorous.

The significant values of interaction treatments may be due to the integration of these two treatments in creating a suitable balance to increase the plants efficiency, which led to an increase in their growth and development and its reflection on the parameters of

vegetative growth and the plant's nutrient content.

The results in Table 3 revealed that the first cultivation date (A) gave a significant superior in the diameter and weight of the main head, the number of lateral heads, the total yield and the concentration of beta-carotene in the head, which recorded 64.4 cm and 826.74 g plant^{-1}, 7.2 head plant^{-1} and 34.44 ton ha^{-1} and 6.01 mg 100 g^{-1} fresh weight, respectively in comparison with the second cultivation date (B), which recorded 60.8 cm, 725.19 g plant^{-1}, 5.3 head plant^{-1}, 30.21 ton ha^{-1}, 5.47 mg 100 g^{-1} fresh weight, respectively, while the broccoli plants in the second cultivation date recorded the highest values of VC concentration in the head reached 95.80 mg 100 g^{-1} fresh weight compared to the first cultivation date, which recorded 79.80 mg 100 g^{-1} fresh weight, while the two cultivation dates had no significant effect on the percentage of total soluble solids in the head.

The soil application treatments significantly were affected the studied parameters as revealed in Table 3, the application of Biohealth fertilizer at a concentration of 1 kg per 2500 m^2 (T_1) gave a significant increment in the diameter and weight of the main head, the number of lateral heads, the total yield, the total soluble solids, the concentration of beta-carotene, and vitamin C in head, which gave 71.5 cm, 817.01 g plant^{-1}, 7.5 plant head^{-1}, 34.04 ton ha^{-1}, 10.67%, 6.78, 106.50 mg 100 g^{-1} fresh weight, respectively which did not differ significantly from the nano-fertilization treatment with a concentration of 500 ml per 2500 m^2 (T_4) in the weight of the main head and the total yield, which recorded 811.69 g plant^{-1} and 33.81 ton ha^{-1}, respectively, compared to the control treatment (T_0), which gave 53.5 cm and 721.36 g Plant^{-1}, 5.2 head plant^{-1}, 30.05 ton ha^{-1}, 8.25%, 4.88 and 64.50 mg 100 g^{-1} fresh weight, respectively.

The interaction treatments between the cultivation dates and the soil fertilization had a significant effect on most of the studied parameters as revealed in Table 3, the interaction treatment between the first date of cultivation and the soil application of Biohealth fertilizer at a concentration of 1 kg per 2500 m^2(AT1) recorded a significant values in the diameter and weight of the main head of the plant, the total yield and the total soluble solids, and the concentrations of beta-carotene in the head reached 74.0 cm, 896.40 g plant^{-1}, 37.35 ton ha^{-1}, 11.00% and 6.95 mg 100 g^{-1} fresh weight, respectively, which did not significantly differ from the first cultivation date and the application of nano-fertilizer at a concentration of 500 ml per 2500 m^2 (AT4) in the weight of the main head of the plant and the total yield, which gave 884.55 gm plant^{-1} and 36.85 ton ha^{-1}, respectively compared with the lowest values under the second cultivation date and the application of fertilizer recommendation (BT0), which gave 51.0 cm and 689.23 g plant^{-1} and 28.71 ton ha^{-1} and 8.17% and 4.57 mg 100 g^{-1} fresh weight respectively, while the interaction between the study factors did not record a significant effect on the number of lateral heads and the concentration of vitamin C in the main head of broccoli.

The cultivation date affects both the temperature and the day length, which in turn affects the yield characteristics of the plant. Therefore, the reason for the yield increment and the quality under the first cultivation date may be attributed to the appropriate environmental conditions, including temperature, that is highly required for the plant growth, which were reflected on the vegetative growth characteristics (leaves number, leaves area and leaves content of chlorophyll) (Table 2), which increases the photosynthesis efficiency, which increases the production of primary and secondary compounds, which improves the yield indicators (the diameter and weight of the main head and the number of side discs) (Table 3), which is positively reflected on the total yield.

The plant's yield depends mainly on the leaves growth and the yield in most agricultural crops is closely related to the photosynthesis efficiency per leaves area and the surface capacity of leaves that receive and interact with light and heat. It produces Acetyl COA, which represents the main substance in the manufacture of beta-carotene, while the reason for the increase in the concentration of vitamin C in the discs when cultivation broccoli in the second date may be attributed to the small number of leaves and the small leaves area (Table 2), which led to expose the discs to more light than resulted in a higher concentration of the vitamin and this result is consistent with what was indicated by Gest *et al.* (2013) that the concentration of this vitamin increases in the organs exposed to light and decreases in the parts with lower light exposure.

Improving the quantity and quality of the product depends on improving the properties of the soil that contributes to increase production, so the reason for the increase in the yield of broccoli and the improvement of its quality characteristics under the application of Biohealth fertilizer may be attributed to its content of

Table 3: The effect of cultivation dates and sources of soil fertilization on yield characteristics, and its components and product quality for broccoli during the fall season of 2019-2020.

Treatment	Curd perimeter (cm)	Weight of main head g.plant^{-1}	No. of secondary head head.Plant^{-1}	Total yield t.ha^{-1}	T.S.S %	β-Carotene mg.100g fresh wt.$^{-1}$	V.C mg.100g fresh wt.$^{-1}$
A	64.4	826.74	7.2	34.44	9.72	6.01	79.80
B	60.8	725.19	5.3	30.21	9.40	5.47	95.80
L.S.D. 0.05	**0.6**	**6.11**	**0.2**	**0.25**	**N.S**	**0.05**	**1.49**
T_0	53.5	721.36	5.2	30.05	8.25	4.88	64.50
T_1	71.5	817.01	7.5	34.04	10.67	6.78	106.50
T_2	59.5	739.00	5.5	30.79	9.17	5.27	77.50
T_3	61.5	790.75	6.2	32.95	9.63	5.66	92.50
T_4	67.0	811.69	6.7	33.81	10.09	6.12	98.00
L.S.D. 0.05	**1.1**	**9.40**	**0.5**	**0.39**	**0.22**	**0.07**	**5.33**
AT0	56.0	753.50	6.5	31.39	8.33	5.18	58.00
AT1	74.0	896.40	8.5	37.35	11.00	6.95	97.00
AT2	60.0	769.25	6.5	32.05	9.00	5.63	68.00
AT3	64.0	830.00	7.0	34.58	9.75	5.92	87.00
AT4	68.0	884.55	7.5	36.85	10.50	6.37	89.00
BT0	51.0	689.23	4.0	28.71	8.17	4.57	71.00
BT1	69.0	737.63	6.5	30.73	10.33	6.60	116.00
BT2	59.0	708.76	4.5	29.53	9.33	4.91	87.00
BT3	59.0	751.50	5.5	31.31	9.50	5.40	98.00
BT4	66.0	738.83	6.0	30.78	9.67	5.87	107.00
L.S.D. 0.05	**1.5**	**12.17**	**N.S**	**0.51**	**0.29**	**0.10**	**N.S**

biological fertilizers that increase the availability of nutrients as well as its content of humic acid, which has a role in improving plant growth and increasing the efficiency of roots to absorb water and dissolved nutrients and stimulate the activity of microorganisms in the soil [Khalil and Al-Hubaity (2013)], which is reflected on the plant's growth and its content of N, P and K (Table 2). Thus, the amount required of nutritional balance is achieved, which prevents a physiological or biological defect in the life cycle of the plant, and increases the efficiency of agricultural production and creates a balance between the size of the vegetative growth and its results of dry matter.

Nitrogen increases the activity of gibberellins within the plant tissues, which leads to an increase in cell division and enlargement, as well as its role in the production of auxin, which encourages the processes of cell division and elongation [Al-Asadi and Al-Khaikani (2019)], as well as the role of phosphorus in the formation of floral buds**,** which increases the lateral discs. As for potassium, which is one of the major important nutrients in plant nutrition, it contributes to increasing production in terms of quantity and quality due to its positive role in increasing the transport of nutrients and products of carbon metabolism from the places of production (the source) to the places of storage and distribution within the plant tissues [Oosterhuis *et al*. (2014)].

As a result, the total yield of the plant is increased and its quality is improved by increasing the products of photosynthesis and the production of complex compounds, including carbohydrates, amino acids and organic acids and their transfer to the storing areas, thus increasing the TSS, and sugars work to increase the concentration of vitamin C on the basis that D-glucose is the initiating compound for the formation of this vitamin [Paciolla *et al* (2019)], while the decomposition of those sugars provides the basis for the synthesis of beta-carotene.

The positive effect of the interaction between the two study factors may be due to the availability of appropriate conditions for the plant to benefit from fertilizers and nutrients, which was reflected on the photosynthesis process and the resulting manufactured materials that improve the characteristics of vegetative growth and yield.

The result from this study that the best cultivation date of broccoli in Baghdad is 1 October as it improves the vegetative growth and the total yield of the plant in term of quantity and quality, as well as the high values of the application of Biohealth fertilizer, which reduces pollution of the environment, soil and water. We can conclude that the dates of cultivation of many vegetable crops were changed as a result of the climatic extremes and environmental changes prevailing recently. Also, a need existed to apply alternative and safe methods of fertilization for increasing the quantitative and qualitative production of various types of vegetables as a type of sustainable agriculture under different environmental changes.

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