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EFFECT OF SELENIUM SPRAYING ON GROWTH AND YIELD OF THREE BROCCOLI HYBRIDS (Brassica Oleracea Var.Italica) AND ITS CONTENT OF ACTIVE COMPOUNDS

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Abstract
The research was conducted throughout autumn 2023–2024 at Kalar Horticulture Station in Sulaymaniyah Governorate. The purpose of this study was to examine how different doses of selenium supplementation affected the growth and yield of broccoli (Brassica oleracea var. italica). The research examined selenium foliar application effects on the vegetative development and crop yield and chemical makeup of three broccoli hybrids as researchers sought to find the best selenium application amount for upgrading glucosinolate and antioxidant compounds. The research examined selenium biofortification methods for enhancing broccoli nutrition together with its yield potential through investigations of Se uptake variability in different broccoli varieties. The research discovered the best selenium intake level to improve crop productivity while improving nutritional quality thus supporting food security and human health. Two factors acted as major elements in this research investigation. The results demonstrated that foliar application of selenium, particularly at 10 mg L^{-1}, significantly improved vegetative growth, nutrient accumulation, and yield in broccoli hybrids. Among the hybrids, Wisdom exhibited superior growth traits, including the highest number of leaves and nutrient accumulation, while Hapa achieved the highest total yield at this selenium concentration. These findings highlight the potential of selenium supplementation in enhancing broccoli production. Further research is recommended to compare the performance of Wisdom with newly introduced hybrids to optimize broccoli cultivation practices.

Keywords: *Broccoli hybrids, selenium, foliar application, Bio fortification.*
** Part of the doctoral thesis of the first author.*

INTRODUCTION

Broccoli (Brassica oleracea. var. italica) is among the most significant crops for vegetables it is a member of the Brassicaceae family which is cruciferous, it is an annual herbaceous plant that resembles cauliflower in appearance but it is less widespread in Iraq[1].Broccoli is grown for its flowers, which, with their strong silky stems are the portion that is consumed during the vegetative flower bud stage it is regarded as one of this family's most nutritious crops and the most often used medicinal crop [2].The total world production of broccoli and cauliflower amounted to approximately 26 million tons annually, the world's largest producer of broccoli is China estimated at approximately 9,609,911 tons representing 38.21% of global production in Iraq the

cultivated area amounted to approximately 953 hectares with a total production of 8,993 tons representing 0.05% of global production [3]. This crop grown in winter contains abundant amounts of vitamins, minerals, carotenoids, ascorbic acid, thiamine, riboflavin, niacin, calcium, Iron, fiber and antioxidants [4]. A necessary trace element for humans, selenium (Se) has been regarded as a lifesaving substance and is crucial for preventing illness enhancing health and delaying the aging process because of its participation in numerous physiological functions[5] .There is evidence that dietary intakes of selenium greater than the requirement may help reduce the risk of cancer especially prostate cancer to men[6]. The nonmetallic element selenium (Se) is found in nature and can be roughly classified as either organic (selenoprotein, selenium peptide, selenium amino acid, selenium polysaccharide) or inorganic (selenite, selenium) [7].Regulates the activity of various enzymes in plant cells, its association with specific movement pathways of other elements especially sulfur renders it directly relevant to plant nutrition. [8]. The sixth group of the periodic table contains the element selenium. Plants take it in a variety of ways, including organic and mineral forms. Ionic compounds like selenite (SeO_3^{-2}) and selenate (SeO_4^{-2}) demonstrate enhanced absorption characteristics. These two forms of selenium diffuse more quickly in plants than any other form, and they accumulate in plants at higher concentrations than those in the medium or soil[9]. World soil elements typically contain between 0.01 mg to 2.0 mg Selenium per kilogram of soil while the average value amounts to 0.5 mg·kg-1. The amount of Se in deficient soil remains below 0.15 mg·kg-1. Research indicates that 1.5 billion people exist within the worldwide population of selenium deficiency[10]. Yield quality of broccoli depends on both genetic variations and soil nutritional conditions[11]. The influence of Selenium (Se) treatment on broccoli hybrids remains unknown regarding their growth improvement and yield benefits and bioactive compound production. The research evaluates how spraying with selenium affects chemical properties alongside growth and yield and active compounds within three broccoli hybrid varieties in order to identify optimal selenium usage methods. The scientific research investigates how selenium enrichments enhance broccoli nutrients and farming outputs. The study examines differences within plant species to acquire selenium and establishes guidelines for better crop production and nutritional returns. The investigation evaluates the effects of selenium application on broccoli hybrid growth alongside yield and chemical attributes with the purpose of determining optimal supplementation levels to enhance glucosinolates and antioxidants substances. These guidelines supply operational approaches for selenium biofortification along with methods to enhance both productivity and nutritional characteristics of crops and understanding of selenium's contribution to food security along with human health. This research targeted the identification of suitable hybrids showing good flower disc quality and optimal growth for fall broccoli planting purposes alongside indicators for plant development through selenium applications at different concentration levels in three broccoli hybrids of the Sulaymaniyah governorate south region.

AIM OF THE STUDY

To determine the impact of applying a selenium spray on the growth traits and yield of three broccoli hybrids that exhibit good flower disc and the best possible growth in the south Sulaymaniyah governorate.

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2. Materials and Methods

The experiment was conducted in the fall of 2023–2024 in one of the private fields at the Kalar Horticulture Station, a research station affiliated with the General Directorate of Garmian Agriculture. It is situated south of Sulaymaniyah Governorate, at latitude (45.3275531) and longitude (34.6307795) from the west bank of the Sirwan River (Diyala).

2.1 Preparing the Land and Planting Seedlings

The seeds were planted in the wooden canopy on 8/1/2023 in plastic dishes (70 eyes), the area of the eye is 4 cm (volume 45 ml/eye) filled with peat moss - supplied by (MIKSKAAR) Made in Estonia, European Union. The seeds were planted a month ago. From planting seedlings on August 1, 2023, with one seed in each eye, inside a wooden canopy covered with a green shading net (Saran) to reduce the effect of sunlight[12]. The agricultural service operations of irrigation, fertilization, and pest control were carried out in a homogeneous manner for all seedlings, and before they were transferred to the field soil. They were hardened. The seedlings were acclimatized before planting to the natural field conditions by taking the seedlings out daily for nine days outside the wooden canopy in the morning and returning them in the evening. They also exposed them to thirst by spacing out the irrigation periods [13]. The seedlings were transferred to the soil of the plastic house after 30 days until they reached the appropriate age for planting is after the formation of 4-5 true leaves, i.e. on September 1, 2023, a harrow plow was used to prepare the ground by plowing it down to a depth of roughly 0.40 meters, followed by softening and leveling the soil and dividing it into three sectors, the planting was on lines with a length of 5.5 meters, the distance between one line and another was 0.75 meters, and the distance between one seedlings to another was 0.50 meters, the number of seedlings in the experimental unit was 12 seedlings, the area of one experimental unit was 6 square meters, leaving a distance of 0.50 meters between the experimental units and a distance of 1 m between the sectors to prevent confusion transactions random samples were collected at 0–30 cm depths from various locations within the field soil prior to planting and fertilization, the chemical and physical characteristics of the field's soil are displayed in Table1[14].

Table 1. Lists the experimental soil's physical and chemical properties.

properties			value
pH			7.8
EC ds m^{-1})at 25co			1.6
(g kg^{-1}) CaCO3			301
(g kg^{-1}) O.M			4.4
Zn total (mg kg^{-1})			56.17
% Field capacity			%27.036
% wilting point			%16.697
Soil Texture (g kg^{-1})	Sandy Clay Loam	Sand	457.0
		Silt	196.5

		Clay	346.5
CEC	Cmolckg^{-1}		27.26
Soluble Ions MmolcL^{-1}	se		0.37
	Ca^{+2}		16.25
	Mg^{+2}		1.4
	K^{+}		0.19
	Na^{+}		1.91
	Cl		0.72
	HCO_3		2.3
	SO_4^{-2}		2.43

Table 2. Average maximum, and minimum temperatures, average wind speed and precipitation rate the study from September - end of February 2023-2024

Date	climatic elements			
	Rainfall average (mm)	wind speed average (m.s)	Minimum temperature average\ (C)	Maximum temperature average (C)
September -/2023	9.6	0.0	29.2	39.4
October	5.2	18.4	12.1	31.2
November	4.8	110.7	6.8	22.7
December	5.3	98.4	4.9	19.5
January -/ 2024	9.8	56.3	3.7	10.9
February	12.7	40.9	6.21	12.3

2.2 Results of analysis of variance of split-plot design with completely randomized design (CRD)

In a completely randomized design (CRD), the analysis of variance (ANOVA) for a split-plot design assesses the importance of the main plot and subplot effects as well as their interactions, this design is particularly useful when studying factors that require different levels of experimental control, ensuring efficient use of resources. The results from ANOVA help determine whether variations in treatments significantly impact the response variable. Proper interpretation of these results guides decision-making in experimental research, improving the reliability of conclusions.

2.3 Study Treatment

The first factor hybrid varieties of broccoli included the following:

2.3.1 WISDOM F_1 hybrid: Produced by NONGWOO BIO, Chinese origin production 2022, with a 98% purity and 85% germination rate and it is coded V_1 in the study.

2.3.2 HANA F1 hybrid: Produced by Atlantis Seeds of Dutch origin, year of production 2023, with 99% purity and 90% germination rate and is symbolized in the study by the symbol V_2.

2.3.3 HAPA F_1 hybrid: Produced by the CLAUSE Company of Spanish origin, year of production 2023, with 99% purity and 88% germination rate and is symbolized in the study by the symbol V_3.

The second factor is adding selenium: This factor includes three levels of selenium, which are:

2.3.4 Spring the selenium element at a concentration of 0 mg L^{-1} (and symbolized in the study by the symbol Se0).

2.3.5 Spring the selenium element at a concentration of 5 mg L^{-1} (and symbolized in the study as Se1)

2.3.6 Spring the selenium element at a concentration of 10 mg L^{-1} (and symbolized by In the study (with the symbol Se2), the process of adding selenium was carried out once during the growing season for each planting date, that is, 15 days after planting for each date, and the addition process was carried out in the morning.

2.4 Studied Traits Include

2.4.1 Number of leaves (leaf. plant^{-1})

The number of all leaves of six selected plants was calculated for all experimental units were counted for taking average number of leaves per plant.

2.4.2 Measurement of the leaves relative chlorophyll content

Determination of the leaves' relative chlorophyll content (CCI) An electronic equipment (Chlorophyll content meter) made by Bio-Science in the USA was used to measure the amount of chlorophyll on six leaves of all the plants that were chosen. Five readings were taken from random locations on the leaf, and the average was then calculated[15].

2.4.3. Nitrogen Content in the Main Disc

Total nitrogen was determined by the Kjeldahl method in leaf samples and digested tablets using a steam distillation apparatus (Kjeldahl) based on the method of Brenner (1970). 10 ml of each sample was taken, and 10 ml of Nano 40 was added to it. The distillation process was carried out, and the liberated ammonia was collected in a glass beaker containing 2% boric acid and a mixture of methyl red and bromocresal green. The collected ammonia was filtered in the receiving beaker with 0.04% HCl[16].

2.4.4. The phosphorus% in the Main Disc

A spectrophotometer set at 332 nm was used to determine the percentage of phosphorus, which was estimated using the ammonium moly date and ascorbic acid method[17].

2.4.5. The potassium % in the Main Disc

The Flame Photometer was used to quantify the potassium element in the digested syphilitic disc samples [18].

2.4.6. Selenium in the Main Disc (µcg. g^{-1})

RP-HPLC was used to measure the amount of selenium in broccoli. Before being treated with hydrochloric acid to convert selenium (VI) to (IV), the samples were digested using either nitric acid and sulfuric acid hydrogen peroxide[19].

2.4.7. The percentage of Sulfate concentration in flower tablets

Sample of (floral tablet powder) was taken and mixed with 10 ml of an acidic solution comprised of nitric acid, per chloric acid, and sulfuric acid in a volume ratio of 5:2:1. The mixture was heated to a temperature of 75 °C. It was then concentrated to 0.5 ml and diluted by adding 25 ml of deionized water. This final solution was placed in a volumetric flask and measured at a wavelength of 245 nm using an HPLC[20].

2.4.8. The total yield of tubers (ton.ha^{-1})
This characteristic was calculated according to the following law:
Total product = (empirical unit quotient) / (empirical unit area) × 10,000
The experimental unit yield = the average yield of one plant x number of plants in the experimental unit.

3. RESULTS AND DISCUSSION:
3.1 Number of leaves (leaf. plant^{-1})
The results of Table (3) showed significant differences between hybrids in the number of leaves trait, as the Wisdom hybrid plants achieved the highest value in the number of leaves, reaching 51.36 leaves. Plant^{-1}, which significantly outperformed the Hana hybrid plants, which gave a number of leaves of 46.66 leaves. Plant^{-1}, and the Hapa hybrid plants, which recorded the lowest value in the number of leaves, reaching 24.84 leaves. Plant^{-1}. Regarding the effect of selenium spray treatments, the results of the same table showed that selenium spray treatments had a significant effect on the number of leaves, as all types used significantly outperformed the comparison treatment of 34.96 leaves. Plant. While the spray treatments did not differ among themselves in the number of leaves at a concentration of (10 mg. L^{-1}) and a concentration of (5 mg. L^{-1}), the values were recorded at 46.76 and 41.14 leaves. Plant, respectively. The interaction between hybrids and spray treatments had a significant effect on the number of leaves for plants, the Wisdom hybrid plants fertilized with a concentration of (10 mg.L^{-1}) had the highest number of leaves, reaching 60.10 leaves. Plant^{-1}, while the Hapa hybrid plants not fertilized with any type of organic fertilizer gave the lowest number of leaves, reaching 20.40(leaves. Plant^{-1}).

Table 3. Effect of spraying with selenium in three broccoli hybrids and their interactions on the number of leaves in the three hybrids of broccoli (Leaf $^{-1}$)

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	45.43 b c	48.56 b c	60.1 a	51.36 A
HANA (V2)	39.06 c d	52.14 a b	48.78 b c	46.66 B
HAPA (V3)	20.4 f	22.73 e f	31.4 d e	24.84 C
Average selenium	34.96 B	41.14 A	46.76 A	

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3.2 Measurement of relative chlorophyll content in leaves (SPAD)

Table 4. findings show that the hybrids under study did not significantly differ in terms of the amount of chlorophyll in their leaves, the plants were fertilized with a concentration of 10 mg. L^{-1} had the highest relative chlorophyll content in their leaves, reaching 81.88 SPAD, according to the statistical analysis of the same table, further demonstrating the superiority of the selenium concentration treatments used over the comparison treatment in the same trait, however, the concentration treatment of 5 mg. L^{-1} did not differ in its chlorophyll content and yielded 79.56 SPAD, while the comparison treatment recorded the lowest result, reaching 76.29 SPAD. The chlorophyll value in the leaves was significantly impacted by the two-way interaction treatments between hybrids and selenium spray treatments, the Wisdom hybrid plants were fertilized with a concentration of 10 mg. L^{-1} had the highest chlorophyll value, measuring 83.43 SPAD, whereas the Hana hybrid plants that were not treated with any concentration of selenium had a value of 72.83 SPAD. For a number of reasons pertaining to selenium's impact on plant growth, increasing the amount of selenium added resulted in a rise in the proportion of chlorophyll in broccoli leaves. Enzymatic response stimulation, selenium plays an important role in enhancing the activity of some enzymes involved in photosynthesis and chlorophyll synthesis, these enzymes help increase the plant's ability to use light energy and convert it into chemical energy, which stimulates the production of chlorophyll.

Table 4. Effect of spraying with selenium and their interaction on the relative content of chlorophyll in leaves of broccoli hybrids (Spad)

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	78.27 ab	79.47 ab	83.43 a	80.39 A
HANA (V2)	72.83 c	79.53 ab	81.1 ab	77.82 A
HAPA (V3)	77.77 a b	79.67 ab	81.1 ab	79.51 A
Average selenium	76.29 B	79.56 A	81.88 A	

3.3 Total nitrogen% in the Main Disc

Table 5. showed indicated that there were no appreciable variations in the study hybrids' averages for the nitrogen percentage trait in the Main Disc , when compared to the comparative treatment, the use of selenium was successful in raising the nitrogen percentage, especially spraying at a concentration of (10 mg.L^{-1}) which gave the highest value and reached 6.40%, which did not differ significantly from spraying at a concentration of (5 mg.L^{-1}) which recorded 5.78%, while the comparison treatment without spraying gave the lowest nitrogen content in flower discs and reached 4.66, the results also showed that there were differences between the values of

the interactions for the nitrogen content of the discs, as the interaction treatment between the hybrid Wisdom and selenium spray concentration (10 mg.L^{-1}) gave the highest values and reached 6.95%, while the interaction treatment between the hybrid Hana and without spraying treatment recorded the lowest and reached 3.64%.

Table 5.the effect of spraying with selenium in three broccoli hybrids and their interactions on the Total nitrogen% in the Main Disc.

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	6.17 abc	5.97 abcd	6.95 a	5.36 A
HANA (V2)	3.64 d	5.99 abcd	6.58 ab	5.40 A
HAPA (V3)	4.18 cd	5.38 bcd	5.68 bcd	5.08 A
Average selenium	4.66 B	5.78 A	6.40 A	

3.4 Total phosphorus % in the Main Disc

The results of Table (6) we note that there are no significant differences between the studied hybrids in the content of Main Disc of phosphorus. The results of the same table also indicate that all selenium concentrations used are superior to the comparison treatment and no significant differences appeared between them, as the fertilization treatments with fertilizer concentration (10 mg.L^{-1}) and concentration (5 mg.L^{-1}) achieved the following values 0.35, 0.37% correspondingly in the phosphorous content of Main Disc , while the comparison treatment (without adding any fertilizer) recorded the lowest values 0.30%.We note that the interaction between the hybrid Wisdom and selenium at a concentration of (10 mg.L^{-1}) received the highest number percentage, which is 0.39%, while the interaction treatment between the hybrid Hapa and without adding any fertilizer recorded the lowest values, which is 0.27%.

Table 6. The effect of spraying with selenium in three broccoli hybrids and their interactions on the phosphorus % content of Main Disc

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	0.29 cd	0.4 a	0.39 a	0.36 A
HANA (V2)	0.33 abc	0.36 ab	0.32 bcd	0.34 A
HAPA (V3)	0.27 d	0.34 abc	0.35 ab	0.32 A

Average selenium	0.30 B	0.37 A	0.35 A	

3.5 Total potassium% in the Main Disc

The results shown in Table (7) the hybrid Wisdom was significantly superior to the other two hybrids in the characteristic of the content of the flower discs of the element potassium, as it gave the highest value, which reached 2.63%, while the value in the hybrid Hana reached 2.48%, while the hybrid Hapa recorded the lowest content of potassium in the flower discs, which reached 2.43%. the same table's results also showed the plants sprayed with a concentration of (10 $mg.L^{-1}$) recorded the highest values of potassium in the flower discs, where the value reached 2.58%, surpassing the comparison treatment, which recorded the lowest values, reaching 2.38%. As for the values of the interaction between the hybrids and the spray concentrations used, the results indicate that the interaction between the hybrid and the concentration of (10 $mg.L^{-1}$) gave the highest value, reaching 2.74%, and the unfertilized Hapa hybrid broccoli plants gave the lowest percentage of potassium, reaching 2.31%

Table 7. The effect of spraying with selenium in three broccoli hybrids and their interactions on the potassium % content of Main Disc

Hybrid	Levels of selenium. ($mg.L^{-1}$)			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	2.42 c	2.73 ab	2.74 ab	2.63 A
HANA (V2)	2.42 c	2.42 c	2.59 bc	2.48 B
HAPA (V3)	2.31 d	2.57 bc	2.42 c	2.43 C
Average selenium	2.38 B	2.42 A	2.58 A	

3.6 Selenium in the Main Disc (µcg. g^{-1})

Table 8. Revealed that the amount of selenium in the flower discs of broccoli plants ($mcg.gm^{-1}$) varied significantly amongst hybrids, the Se concentration increased with increasing Se fertilization for all varieties, as the hybrid (Wisdom) outperformed and gave the highest rate of selenium, reaching (0.69 $mcg.gm^{-1}$) compared to the hybrid (Hapa), which recorded the lowest rate of selenium, reaching (0.38 $mcg.gm^{-1}$), the results of the same table showed significant superiority when spraying with selenium in the rate of selenium, as the concentration (10 mg. L^{-1}) outperformed in achieving the highest rate of selenium in the flower discs of broccoli plants, reaching (0.65 $mcg.gm^{-1}$) compared to the plants that were not sprayed, which recorded the lowest rate of selenium, reaching (0.42 $mcg.gm^{-1}$), regarding the interaction between the two experimental factors, the hybrid (Wisdom) as indicated by the results in the table was significantly impacted by selenium spraying at a concentration of 10 mg L^{-1}.which achieved the highest rate of selenium,

which reached (0.86 mcg g^{-1}), compared to plants that were not sprayed with selenium in the hybrid (Hapa), which gave the lowest rate of selenium, which reached (0.24 mcg.gm^{-1}).

Table 8. The limits of the effect of selenium (mg. L^{-1}) in three broccoli hybrids and their interactions in in the syphilis discs selenium (mcg.gm^{-1})

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	0.56 b c	0.66 b	0.86 a	0.69 A
HANA (V2)	0.46 b c	0.51 b c	0.58 b c	0.52 B
HAPA (V3)	0.24 d	0.38 cd	0.51 b c	0.38 C
Average selenium	0.42 C	0.52 B	0.65 A	

3.7 Percentage of sulfur in flower discs

From Table 9. The sulfur level of flower discs did not significantly differ among the study hybrids, according to the data, the results of the same table also showed that spraying with selenium used had a significant effect in increasing the sulfur content of broccoli flower discs compared to the comparison treatment, as spraying with a concentration of (10 and 5 mg.L^{-1}) recorded the following values of selenium 6.0 and 6.2% respectively, while the percentage in the comparison treatment reached 4.9%. In terms of hybrid interaction with selenium, the results of Table 22 indicated that the interaction between the hybrid Wisdom and fertilizer concentration (10 mg.L^{-1}) gave the highest percentage of sulfur in the interactions, as it recorded 6.6%, while this percentage decreased to 4.7% when planting broccoli hybrid Hana plants without spraying with selenium.

Table 9: Effect of selenium spraying on three broccoli hybrids and their interactions on the sulfur content of flower discs.

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	4.9 bc	6 abc	6.6 a	5.8 A
HANA (V2)	4.7 c	6.2 ab	6.2 ab	5.7 B
HAPA (V3)	5 bc	5.8 abc	5.7 abc	5.5 C
	4.9	6	6.2	

Average selenium concentration	B	A	A	

3.8 Total yield of main discs (ton. ha^{-1})

Table 10. Showed significant distinctions between the study hybrids in the total yield of main discs, where Hapa variety outperformed the other two hybrids recording a value of 18.33 (ton. ha^{-1}), while the hybrid Hana recorded a total yield of 16.51 (ton. ha^{-1}). As for the hybrid Wisdom, it recorded 15.14 (ton. ha^{-1}), regarding the impact of selenium spraying on the overall yield of major discs, it had a significant effect compared to the comparison treatment, where the fertilizer concentration (10 mg. l^{-1}) recorded the highest 17.54 (ton. ha^{-1}). While the comparison treatment (without spraying with selenium) gave the lowest values 15.65 (ton. ha^{-1}). The results of the same table also showed significant differences in the interaction. The interaction between the fertilizer concentration (10 mg.L^{-1}) and the Hapa hybrid gave the highest total yield of 19.43 (ton. ha^{-1}). Ha, while the Wisdom hybrid broccoli plants not fertilized with any fertilizer recorded the lowest yield of 14.45 (ton. ha^{-1}).

Table 10, Effect of selenium spraying on three broccoli hybrids and their interactions on the total yield of main flower discs (ton. h^{-1})

Hybrid	Levels of selenium. (mg.L^{-1})			Average Hybrid
	Control (F0)	(5 mg L^{-1}) (F5)	(10 mg L^{-1}) (F10)	
WISDOM (V1)	14.45 d	15.32 cd	15.65 bcd	15.14 C
HANA (V2)	15.46 cd	16.52 abcd	17.54 abcd	16.51 B
HAPA (V3)	17.05 abcd	18.51 abc	19.43 a	18.33 A
Average selenium concentration	15.65 B	16.78 A	17.54 A	

*The mean values with similar letters for each factor or their interactions individually are not significantly different according to the Duncan multiple range test at the 0.05 probability level.

*Capital letters indicate comparison of main effects and small letters indicate comparison of interaction means.

Table 11. ANOVA results

	S.O.V.	d.f.	S.S	M.S.	F	Critical F
whole plot	Factor A	2	138.961	69.480	0.029	3.47
	Error a	21	50000.214	2380.963		
split plot	Factor B	2	98.238	49.119	8.609	3.23
	Factor A * Factor B	4	15.786	3.946	0.692	2.61
	Error b	42	239.635	5.706		
	Total	71	50492.833			
Factor A: is Broccoli hybrids with three levels (WISDOM (V1), HANA (V2), and HAPA (V3)), Factor B; is Levels of selenium. (mg.L^{-1}) with three levels (Control (F0), 5 mg L^{-1} (F5), and 10 mg L^{-1} (F10)).						

The examination of selenium levels (Factor A) and broccoli hybrids (Factor B) on the response variable occurred through analysis of variance (ANOVA) using a split-plot experimental design showed in table (11). The split-plot design required this arrangement because it applied selenium levels as whole-plot factors while broccoli hybrids received their assignments within individual selenium levels as split-plot factors. The analysis of variance results identify how broccoli hybrids (Factor A) and selenium levels (Factor B) affect the response variable as well as their combined effects on it. As the initial step Factor A broccoli hybrids (Wisdom, Hana, and Hapa) shows 138.961 S.S. and 69.480 M.S. Analysts found that the F-Value (0.029) remained much below the critical F-Value (3.47). This indicates that broccoli hybrids show no statistically significant variations in their properties. The tested traits show similar results regardless of which hybrid is chosen when the experiments are conducted under the current conditions. Error a establishes broad unexplained variations in the experimental outcomes as its sum of squares reaches 50000.214 with a mean square of 2380.963 while its degrees of freedom equals 21. The values for Factor B (selenium levels at Control (F0), 5 mg/L (F5) and 10 mg/L (F10)) demonstrate significance through S.S. of 98.238, M.S. of 49.119, and F-value of 8.609 exceeding critical F-value (3.23). The introduction of selenium proved to be a significant factor that improved plant characteristics by influencing the response variable effectively. The experiment results show that the Error b term containing a smaller Sum of Squares value (S.S. = 239.635) with Median Squares value (M.S. = 5.706) and degrees of freedom (d.f. = 42) indicate that selenium factor produces more precise measurable outcomes than the broccoli hybrid factor.The interactions of broccoli hybrid types with selenium application levels (A×B) does not produce a significant interaction effect due to an F-value score (0.692) lower than (2.61). The collected S.S. amount to 15.786 and M.S. equals 3.946. All tested broccoli hybrids demonstrate parallel responses toward the selenium factor according to this outcome. Research indicates that selenium treatment functions as an independent influencing factor which shows no dependency on hybrid type. The total sum of squares amounts to 50492.833 but most of the data variability remains unexplained by Error a thus indicating the necessity for further research on plant performance-related factors. The research indicates that selenium treatment enhances plant features strongly yet hybrid types of broccoli show no major effect on

measured traits. Future research needs to determine the optimal selenium application levels to achieve peak results and analyze genetic and environmental elements which affect broccoli production.

4. CONCLUSION

The experiment demonstrated that applying 10 mg.L^{-1} selenium to the vegetative group as a spray yielded optimal results for enhancing (number of leaves and average weight of lateral flower discs) thus we suggest this selenium concentration for broccoli cultivation in Kalar area of Sulaymaniyah Governorate. Most vegetative growth characteristics and quantitative yield values demonstrated significant increases when selenium was used at various concentrations. Application of selenium showed substantial changes in diverse physiological and agronomic characteristics of broccoli hybrids according to this study's results. Among the tested broccoli hybrids Wisdom showed the maximum number of leaves and Hapa exhibited the minimum leaf production. The application of selenium as a foliar spray at 10 mg L^{-1} resulted in the most significant improvements of leaf number and chlorophyll levels and macro-nutrient uptake when compared to the remaining concentrations. The relationships between selenium applications and hybrid varieties demonstrate how selenium improves plant performance most effectively in plants of the Wisdom variety. Broccoli flower discs treated with selenium showed higher accumulation of nitrogen, phosphorus, potassium, sulfur and selenium among all nutrients. The nutrient content of hybrid Wisdom achieved greater results than other hybrid plant varieties thus demonstrating its capability to optimize selenium-supplemented nutrition uptake. The Hapa hybrid displayed the maximum total yield following selenium spraying while receiving 10 mg L^{-1} selenium treatment. The research establishes that supplementing broccoli crops with selenium produces advantageous outcomes for plant growth together with nutrient content and production output, the application of highly concentrated dose of selenium 10 mg L^{-1} has proved to be an effective method for increasing broccoli hybrid performance based on physiological and agronomic properties. Future research could explore the long-term effects of selenium supplementation and its potential implications for commercial broccoli production. we recommended using selenium at these concentrations in Kalar area in order to improve the quantitative and qualitative yield, the hybrid (Wisdom) was significantly superior in most of the vegetative characteristics and yield studied above compared to the hybrids (Haba) and (Hana), Which indicates the importance of adopting this hybrid for broccoli cultivation, with the suggestion that more research be done in the future to compare this hybrid to other new hybrids that are coming to the nation for the first time.

5. References

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