Effect of Foliar Spraying with Liquid Sulfur (Zolfast) on Growth and Yield of White and Red Cabbage

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Abstract:

This study was conducted in one of the fields belonging to the research station of the Department of Horticulture and Landscape gardening at the College of Agriculture / University of Diyala for the agricultural season 2022/2023 as a factorial experiment with two factors, the first using five concentrations of liquid sulfur (zolfast), which are 0, 1, 1.5, 2, 2.5 ml L-1 (S1,S2,S3,S4,S5) and the second factor two types of cabbage (White cabbage Hybrid Durra F1(V1) and Red Cabbage Hybrid Secret F1(V2), according to the design of randomized complete block design and with three replications, as the number of experimental units reached 30 unit. The results were analyzed according to the SAS program and the averages were tested according to Duncan's polynomial test at a probability level of 0.05 .

The results showed that spraying of liquid sulfur concentration of 2.5 ml L-1 (S5) was significantly superior in characteristics (the number of total outer leaves, diameter of the head, percentage of nitrogen, sulfur concentration and concentration of total anthocyanins) compared to other treatments, while the treatment of spraying with liquid sulfur concentration of 1 ml L-1(S2) was significantly superior to other treatments in the two characteristics of head weight and total yield, compared to the control treatment that gave the lowest values in all traits.

The results also showed the superiority of white cabbage over red cabbage in most characteristics of vegetative growth and yield, which included plant height, total number of outer leaves, wet weight, diameter and weight of the head, total yield, percentage of potassium and sulfur concentration. The interaction between spraying with liquid sulfur concentration of 2 ml L-1 and the white cabbage S4V1 showed a significant superiority in plant height and percentage of phosphorus and potassium, while the S5V1 treatment gave the highest number of total outer leaves, while the S2V1 treatment had a significant superiority in both head weight and total yield .

Keywords: Red cabbage, White cabbage, Foliar spray, liquid sulfur

Introduction

Brassica oleracea var. capitata L. is one of the main winter vegetables in Iraq belonging to the cruciferae family [18]. The part that is eaten is the heads that contain a number of fresh wrapped leaves, which used in cooked, or pickles. The 100 gm of leaves contain 94% water, 14 calories, 1 g protein, 2 g carbohydrates, and also contain volatile sulfur materials [10]. It also contains two important elements (sulforaphane and indole), which

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have an effective role in preventing cancer, diabetes, and heart disease [27].There are three types of cabbage that produce heads: red, white, and wrinkled. The first and second types are the most common in the world [21]. Red cabbage is distinguished from other species by its red color and high nutritional and medicinal value because it contains anthocyanin, Its red color can be used in making distinctive salad dishes, and it is a vegetable that is used to dissolve body fat and reduce blood cholesterol [6]. The area cultivated with cabbage in 2020 in Iraq reached 5822 Dum-1, with a total production of 12481 tons, at an average of 2143.8 kg Dum-1 [9]. Foliar fertilization or foliar feeding is a good technique for rapid plant nutrition, as it facilitates the access of nutrients to their places of representation [19]. Researches and experiments have proven the possibility of supplying plants with various nutrients by spraying plants with solutions of these elements, Studies have also shown that the absorption of nutrients by the leaves is more rapid and efficient than the absorption through the roots, especially when the soil conditions are not suitable for the absorption of the elements such as high alkalinity and different stresses. Sulfur is one of the important elements that can be provided to the plant through foliar feeding, as it is entry in the composition of some amino acids such as cysteine, cystine, and methionine, and some vitamins such as thymine and biotin, It is also entry in the composition of enzymatic facilities and some vital proteins, such as ferredoxins, which are important in the process of photosynthesis, nitrogen fixation, and nitrate reduction [20]. There is a type of it, which is micronized sulfur, as it consists of 80% sulfur and has small particles that do not exceed 1 micron [12] and is in the form of granules that can be dispersed in water and is quickly soluble, while the other type of liquid agricultural sulfur is used, which is the Zolfast preparation. The sulfur content is 85%, which contributes to rapid plant nutrition .

[16] found that spraying with Zolfast at concentrations of 1 and 1.5 ml L-1 led to improved plant growth and increased the chlorophyll content of cauliflower leaves and the concentration of nitrogen, phosphorus, potassium and sulfur, while decreasing the content of sodium and proline. [3] and [2] also pointed out the positive effect of sulfur on the growth and yield of onion and tomato plants, respectively. [15] noted that spraying with Zolfast at a concentration of 1.5 or 3 ml L-1 significantly exceeded the leaves' content of total chlorophyll and the percentage of nitrogen on onion leaves compared to the control treatment, while the leaves of plants sprayed at a concentration of 3 ml L-1 significantly exceeded their content of carbohydrates and the percentage of phosphorus and sulfur. Compared to the control treatment. Based on the above, the research aims to determine the optimal concentration of Zolfast liquid sulfur and its effect on the growth and yield of white and red cabbage and determine the type that responds most to spray with this foliar fertilizer .

Materials and Methods

The research was carried out at the Vegetable Research Station in the Department of Horticulture and Landscape gardening of the College of Agriculture / University of Diyala for the agricultural season 2022-2023 .

The soil was prepared by conducting the operations of tillage, smoothing, leveling and divided into three terraces with a length of

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20m and a width of 75cm. Drip irrigation pipes were extended along the cultivation lines and the distance between plants was 40 cm. Samples of soil from different areas with a depth of 30 cm were taken and analyzed at the laboratory. Table 1 shows the physical and chemical properties of the experimental soil. The seeds of White Cabbage hybrid (Durra F1) Produced by the Dutch Company Paracid and the seeds of Red Cabbage hybrid (Secret F1) Produced by Taiwan and imported by the Delta Company were planted in the dishes of the seedlings with 209 eyes on 10/9/2022 in the special place to produce the seedlings of Cabbage, where all the conditions were provided to production the Cabbage seedlings, and the seedlings were transplanted to the field on 20/10/2022, As the seedlings were planted on the terraces. Recommended processing for planting including irrigation, weed control, insect and fungal infections control and crop harvesting were provided until the end of the season, and equally for all experimental units

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Table 1. Physical and chemical properties of the soil before planting

Trait	Value	Unit
Organic Matter	10.8	g kg^{-1}
$CaCO_3$	253.06	Mg kg^{-1}
EC(1:1)	1.41	Dsm^{-1}
P^H (1:1)	7.7	
Elements availability		
Nitrogen	18.09	Mg kg^{-1}
Phosphorus	9.96	Mg kg^{-1}
Potassium	223.71	Mg kg^{-1}
Soil Particle Size		
Clay	30	g kg^{-1}
Silt	340	g kg^{-1}
Sand	630	g kg^{-1}
Texture Class	Sandy loam	

Experimental Factors

The experiment included two factors: The first five Concentrations of liquid sulfur (Zolfast), which are 0, 1, 1.5, 2, 2.5 ml L-1 (S1, S2, S3, S4, S5) and the second factor two types of Cabbage (White cabbage Hybrid Durra F1 and Red Cabbage Hybrid Secret F1) (V1, V2). The treatments were (V1S1,V1S2,V1S3,V1S4,V1S5,V2S1,V2S2,V2S3,V2S4,V2S5(

The experiment was design as Randomized Complete Block Design (RCBD) with three replications, as a factorial experiment (5 × 2) into 10 treatments and 30 units (each experimental unit involved 10 plants), the measurements were made for five randomized plants from each unit the number of experimental units reached 30 unit. The statistical analysis of the studied traits was

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performed using the SAS program and Duncan Multiplicity test at a 0.05 probability level [7.[

Plants were treated for three times, the first after one month planting and the second after 15 days of the first treatment and the third after 15 days of the second treatment. The spraying was early in the morning, and a few drops of cleaning liquid were added when used to reduce the surface tension of the leaves and to achieve the most benefit from the liquid sulfur.

-Study Indicators

Frist: Growth and production characteristics

Stem height (cm): the height was measured from the stem's contact area with the soil to the head's contact area by metric tape. Number of external leaves (leaf Plant-1) the number of external leaves (unwrapped) for each plant of the selected plants was calculated and then the average was calculated: Head diameter (cm): The head diameter of each experimental unit was measured by the Vernier: Head weight (g): The head weight of all experimental units was obtained by the digital scale: Total yield (for heads without external leaves) (ton.H-1): The total yield of cabbage heads that included the marketing heads from the yield of the experimental units for the heads.

Second: Biochemical characteristics of Cabbage heads :

A specific weight of leaves was taken from five plants randomly from each experimental unit, and then they were placed in a ventilated room for the purpose of drying. After that, they were placed in perforated paper envelopes in an electric oven at a temperature of 70°C until the weight was stable, then they were grind and placed in tightly closed plastic boxes. A process was conducted wet digestion according to the method used by [11] by taking 0.2 g of the plant sample, then digesting it using 4 ml of concentrated sulfuric acid, and after a full day had passed, 1 ml of per-chloric acid was added to it, then it was heated for 60 minutes until it boiled and white vapors appeared. Which indicates the end of digestion, after which a clear, colorless liquid appears. It was cooled, then transferred to a 50 ml flask and complete the volume with distilled water to the mark, after which the elements were estimated as follows :

Percentage of nitrogen in heads: Nitrogen was estimated using a Micro-Kjeldahl device according to the method [14]. Percentage of phosphorus in heads: The percentage of phosphorus in leaves digested with ammonium molybdate and ascorbic acid was estimated and measured with a spectrophotometer at a wavelength of 662 nm [22]. Percentage of potassium in heads: It was measured with a flame photo meter according to the method [14]. Sulfur concentration in heads (mg kg-1): Sulfur was estimated with a spectrophotometer at a wavelength of 420 nm, and then the sulfur concentration was extracted from the standard curve [17]. Concentration of total anthocyanins in heads (mg 100 g-1) : The percentage of anthocyanins was calculated by taking 5 ml of clear juice, placed in a 10 ml test tube, and adding 5 ml of ethanol to the extraction solution (96% and 1.5 m hydrochloric acid in a ratio of 15:85 for each of them, respectively). The mixture was mixed and then centrifuged for three minutes and at a speed of 3000 rpm -1, then the precipitate is removed, the filtrate is taken and complete the volume to 10 ml with acidified alcohol (extraction solution). The light absorption is read with a spectro photometer at a wavelength of 533 nm [23], and the

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anthocyanin content is calculated from the following equation :

Total anthocyanate content (mg 100 ml -1 juice) = [Spectrophotometer reading (533) × Volume of solution/volume of sample 98.2] ×dilution ×100 .

Results and Discussion

Frist: Growth and production characteristics

-1Stem height (cm(

The results in table 2 showed that spraying with liquid sulfur (Zolfast) at all concentrations was not significant and did not affect the height of the Cabbage plant, and if differences existed, they did not reach the level of significance. As for the types, the white cabbage excelled in this characteristic and reached 24.92 cm compared to the other type, the red cabbage, which recorded a plant height of 21.45 cm. As for the interaction treatments between liquid sulfur and cabbage types, the S4V1 interaction treatment was superior, and the effect was significant, reaching 26.53 cm. The lowest plant height was 19.63 cm in the S1V2 interaction treatment (control treatment with the red cabbage type .(

Table 2. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on plant height (cm(

Cabbage type	Liquid Sulfur concentrations (ml L^{-1})					Average of Cabbage type
	S_1	S_2	S_3	S_4	S_5	
White Cabbage V_1	24.06 ab	24.63 ab	24.50 ab	26.53 a	24.86 ab	24.92 A
Red Cabbage V_2	19.63 c	20.63 bc	21.96 bc	23.06 abc	21.96 bc	21.45 B
Average of Sulfur concentrations	21.85 A	22.63 A	23.23 A	24.80 A	23.41 A	

The values of similar letters are not significantly different from each other according to the Duncan test below the 0.05*

-2 Number of external leaves (leaf/Plant-1 (

Table 3 shows that the spraying treatment with liquid sulfur (Zolfast) at a concentration of 2.5 ml L-1 was significantly superior in giving the highest number of external leaves of the plant, amounting to 13.70 leaf plant-1, compared to the control treatment, which recorded the lowest value, amounting to 11.51 leaf plant-1. As for the types of cabbage, the white cabbage excelled in the number of leaves reached 14.08 leaf plant-1, compared to the other type of red cabbage, which recorded the number of external leaves at 10.72 leaf plant-1 .

Regarding the interaction treatments between spraying with liquid sulfur and the types of cabbage, the interaction treatment S5V1 at a concentration of 2.5 ml L-1 with white cabbage excelled in recording the highest number of external leaves, which amounted to 15.43 leaf plant-1, while the control treatment with red cabbage achieved

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the lowest number of leaves. External reached 9.96 leaf plant-1 .

Table 3. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on the number of external leaves (leaf/plant-1(

Cabbage type	Liquid Sulfur concentrations (ml L^{-1})					Average of Cabbage type
	S_1	S_2	S_3	S_4	S_5	
White Cabbage V_1	13.06 abc	13.86 abc	13.73 abc	14.30 ab	15.43 a	14.08 A
Red Cabbage V_2	9.96 d	11.40 cd	10.20 d	10.10 d	11.96 bcd	10.72 B
Average of Sulfur concentrations	11.51 B	12.63 AB	11.96 AB	12.20 AB	13.70 A	

The values of similar letters are not significantly different from each other according to the Duncan test below the 0.05*

-3Head diameter (cm(

The results in table 4 indicate that spraying with liquid sulfur (Zolfast) at a concentration of 1 ml L-1 was significantly superior in giving the highest head diameter of 20.98 cm, which did not differ significantly from the treatment S5 concentration of 2.5 ml L-1 and reached 20.97 cm compared to the control treatment that was recorded the lowest value was 18.94 cm. As for the types, the white cabbage had a head diameter of 23.54cm compared to the other type, the red cabbage, which recorded a head diameter of 16.94 cm. The interaction treatments between spraying with liquid sulfur and the types of Cabbage, the interaction treatment S2V1 excelled with the white cabbage in recording the largest head diameter of the cabbage, which reached 24.71 cm, which did not differ significantly from the treatments S1V1, S3V1, S4V1, and S5V1, while the control treatment achieved with the red cabbage S1V2 the minimum head diameter was 15.53 cm .

Table 4. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on the head diameter (cm(

Cabbage type	Liquid Sulfur concentrations (ml L^{-1})					Average of Cabbage type
	S_1	S_2	S_3	S_4	S_5	
White Cabbage V_1	22.36 a	24.71 a	23.25 a	23.15 a	24.25 a	23.54 A
Red Cabbage V_2	15.53 b	17.26 b	16.76 b	17.48 b	17.70 b	16.94 B
Average of Sulfur concentrations	18.94 B	20.98 A	20.00 AB	20.31 AB	20.97 A	

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-4Head weight (g(

The results in Table 6 indicate that spraying with liquid sulfur (Zolfast) at a concentration of 1 ml L-1 was significantly superior in giving a higher head weight of 963.9 gm compared to the control treatment, which recorded the lowest value of 648.8 gm. As for the types, the white cabbage excelled in head weight and reached 1155.2 gm compared to the other type of red cabbage, which recorded a head weight of 462.2 gm The interaction treatments between spraying with liquid sulfur and types of cabbage, the interaction treatment S2V1 at a concentration of 1 ml L-1 with white cabbage, was superior overlapping and the effect was significant reached to 1433.3 gm, while the control treatment with red cabbage S1V2 achieved the lowest head weight, reached to 338.9 gm .

Table 5. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on the head weight (g

Cabbage type	Liquid Sulfur concentrations (ml L^{-1})					Average of Cabbage type
	S_1	S_2	S_3	S_4	S_5	
White Cabbage V_1	958.7 b	1433.3 a	1125 ab	1055 ab	1204 ab	1155.2 A
Red Cabbage V_2	338.9 c	494.4 c	416.6 c	511.1 c	550 c	462.2 B
Average of Sulfur concentrations	648.8 B	963.9 A	771.0 AB	783.0 AB	877.0 AB	

The values of similar letters are not significantly different from each other according to the Duncan test below the 0.05*

Total yield (ton.H-1)-5

In table 6 the results showed that spraying with liquid sulfur (Zolfast) at a concentration of 1 ml L-1 was significantly superior in giving the highest total yield of 32.129 ton H-1 compared to the control treatment, which recorded the lowest value of 21.626 ton H-1. As for the types, white cabbage was superior in total yield, which reached to 38.506 ton H-1, compared to the other type, red cabbage, which recorded a total yield of 15.406 ton H-1. As for the interaction treatments between spraying with liquid sulfur and types of cabbage, the S2V1 interaction treatment was significantly superior in giving the highest

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total yield, which reached to 47.777 ton H-1. While the S1V2 and S3V2 treatments achieved the lowest total yields, reaching 11.295 and 13.888 ton H-1 respectively .

Table 6. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on the Total yield (ton.H-1(

Cabbage type	Liquid Sulfur concentrations (ml L^{-1})					Average of Cabbage type
	S_1	S_2	S_3	S_4	S_5	
White Cabbage V_1	31.956 bc	47.777 a	37.500 ab	35.166 bcd	40.132 ab	38.506 A
Red Cabbage V_2	11.295 e	16.480 ed	13.888 e	17.035 ed	18.332 cde	15.406 B
Average of Sulfur concentrations	21.626 B	32.129 A	25.694 AB	26.100 AB	29.232 AB	

The values of similar letters are not significantly different from each other according to the Duncan test below the 0.05*

The results in Tables 3, 4, 5 and 6 (number of total leaves, diameter and weight of the head, and total yield) indicate that there are significant differences between the spraying treatments with liquid sulfur and the concentrations exceeding 1 and 2.5 ml L-1, and the reason may be due to the important role of sulfur in synthesis. Some important organic compounds and vital proteins, such as Ferrodoxins, which are necessary in the process of photosynthesis. It also has an important role in the formation of chlorophyll, although it does not participate in its synthesis [13]. This role played by sulfur in the formation of chlorophyll positively affected the photosynthesis process, which led to an increase in the number of leaves, This result is consistent with [5], who found that spraying with sulfur led to an increase in the number of leaves of tomato plants, and their leaf area and chlorophyll content. This increase in the number of leaves (Table 3) reflected positively on the nutritional content of the plant and consequently the accumulation of manufactured nutrients in the formed heads, which led to an increase in the diameter and weight of the heads, which was reflected in an increase in the overall yield of the plant. Or the reason may be that spraying sulfur may lead to an increase in the efficiency of sulfur use by the plant (absorption efficiency and use efficiency) and thus affects the crop. This is consistent with what was found by [1], who found that spraying with sulfur at a concentration of 2.5 ml L-1 showed significant differences in the number of fruits, yield, and increased quality of eggplant fruits .

As for the types of cabbage (white and red), Tables 2, 3, 4, 5, and 6 showed that the white type of cabbage was superior to the red type in all the characteristics studied (plant height, number of total leaves, head diameter and weight, and total yield), The reason for the difference between types in vegetative and productive characteristics is mainly due to the difference in genetic composition, which affects the ability and efficiency of species in the nature of growth and the efficiency of converting the products of photosynthesis in favor of the formation of heads and increasing their size and weight. From another side, Vegetative characteristics are determined by genetic factors and the response of the species to the influence of environmental factors, which affects its vegetative growth and then its production of heads and thus the total yield. These results are consistent with [8] as they found significant differences in most of the vegetative andproductive traits of three varieties of cabbage .

Second: Biochemical characteristics of Cabbage heads

Percentage of N, P and K in heads

The statistical analysis of obtained data for the effects of sulfur treatments on N, P, K concentrations in white and red cabbage heads is shown in table 7, the spraying treatment with liquid sulfur at a concentration of 2.5 ml L-1 (S5) was superior to recording the highest percentage of nitrogen in the leaves of the cabbage head, reaching 3.970%, while the control treatment gave the lowest percentage of nitrogen, amounting to 2.370%. The S3 and S4 treatments did not differ significantly in this characteristic, Also the spraying treatment with liquid sulfur concentration of 2 ml L-1 (S4) excelled by gave the highest percentage concentration of both phosphorus and potassium elements, reaching 0.441% and 4.410% respectively, superior to other spray treatments, including the control treatment, which achieved the lowest percentage, which was 0.333% and 3.480% respectively. In the same table, the red cabbage type was superior in recording the highest percentage of nitrogen in the heads, reaching 3.507%, while the percentage was 2.790% in the white cabbage type. The two types did not differ significantly in the phosphorus concentration for each of them, while the white cabbage achieved the highest percentage of potassium concentration in the heads. It reached 4.207% compared to the percentage of potassium in red cabbage, which amounted to 3.808%. As for the interaction between types and spraying with liquid sulfur, the interaction treatment S5V2 excelled by recording the highest concentration of nitrogen, reaching 4.890%, while the interaction treatment S1V1 gave the lowest concentration of nitrogen, amounting to 2.350%. As for the concentration of phosphorus and potassium in the leaves of cabbage heads, the interaction treatment S4V1 excelled. It gave the highest percentage was 0.445% and 4.680% respectively, while the S1V1 interaction treatment recorded the lowest percentage of phosphorus and potassium, amounting to 0.311% and 3.380% respectively

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Table7. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on the on the biochemical characteristics of Cabbage heads

Cabbage type	Liquid Sulfur concentrations (ml L^{-1})					Average of Cabbage type
	S_1	S_2	S_3	S_4	S_5	
	Nitrogen (%)					
White Cabbage V_1	2.350 d	2.730 cd	2.830 c	2.990 c	3.050 c	2.790 B
Red Cabbage V_2	2.390 d	2.850 c	3.900 b	3.507 b	4.890 a	3.507 A
Average of Sulfur concentrations	2.370 D	2.790 C	3.365 B	3.248 B	3.970 A	
Cabbage type	**Liquid Sulfur concentrations (ml L^{-1})**					**Average of Cabbage type**
	S_1	S_2	S_3	S_4	S_5	
	Phosphorus (%)					
White Cabbage V_1	0.311 g	0.346 f	0.375 e	0.445 a	0.373 ef	0.370 A
Red Cabbage V_2	0.356 ef	0.380 de	0.410 bc	0.437 ab	0.405 cd	0.397 A
Average of Sulfur concentrations	0.333 D	0.363 C	0.392 B	0.441 A	0.389 B	
Cabbage type	**Liquid Sulfur concentrations (ml L^{-1})**					**Average of Cabbage type**
	S_1	S_2	S_3	S_4	S_5	
	Potassium (%)					
White Cabbage V_1	3.380 f	3.990 cd	4.580 a	4.680 a	4.407 ab	4.207 A
Red Cabbage V_2	3.580 ef	3.850 cde	3.783 de	4.140 bc	3.688 def	3.808 B
Average of Sulfur concentrations	3.480 D	3.920 BC	4.181 AB	4.410 A	4.047 **B**	

The values of similar letters are not significantly different from each other according to the Duncan test below the 0.05*

Sulfur concentration (mg kg-1) and Concentration of total anthocyanins (mg 100 g-1 (

The results of Table 8 indicate that the treatment of spraying with liquid sulfur, concentration of 2.5 ml L-1 (S5), was superior by giving the highest concentration of sulfur and anthocyanin pigment in cabbage heads. It recorded 851.5 mg kg-1 and 186.49 mg 100 g-1, while treatments S2 and S3 did not differ from they were both significantly different in the concentration of sulfur, Also the treatment S3 and S4 did not differ significantly from each other in the concentration of the anthocyanin pigment, while the control treatment gave the lowest concentration of

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sulfur in cabbage heads, recording 577.65 mg kg-1, and the S2 treatment gave the lowest concentration of anthocyanin pigment, amounting to 181.51 mg 100 g-1. As for the types, white cabbage excelled by recording the highest concentration of sulfur in the heads, amounting to 770.12 mg kg-1, while red cabbage had a lower concentration of sulfur, amounting to 682.66 mg kg-1, and a higher concentration of anthocyanin pigment, amounting to 344.33 mg 100 gm-1, superior to white cabbage. This gave 23.014 mg 100g-1. The interaction treatments between types and spraying with liquid sulfur, the interaction treatment S5V1 excelled by recording the highest concentration of sulfur in the heads, which was 930.1 mg kg-1, while the interaction treatment S1V2 gave the lowest concentration of sulfur, amounting to 535.1 mg kg-1. As for the anthocyanin pigment the treatment S5V2 recorded the highest concentration of anthocyanin pigment, amounting to 347.33 mg 100 g -1, while interaction treatment S1V1 recorded the lowest concentration of anthocyanin pigment, amounting to 20.524 mg 100 g -1, which did not differ significantly from treatment S2V1 .

Table 8. Effect of spraying with liquid sulfur and the type of cabbage and their interaction on the concentration of sulfur and total anthocyanins in Cabbage heads

Cabbage type	**Liquid Sulfur concentrations (ml L^{-1})**					**Average of Cabbage type**
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	
	Sulfur concentration (mg kg^{-1})					
White Cabbage V_1	620.2 f	716.6 d	706.6 de	877.1 b	930.1 a	770.12 A
Red Cabbage V_2	535.1 g	637.5 f	695.2 e	772.6 c	772.9 c	682.66 B
Average of Sulfur concentrations	577.65 D	677.05 C	700.9 C	824.85 B	851.5 A	
Cabbage type	**Liquid Sulfur concentrations (ml L^{-1})**					**Average of Cabbage type**
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	
	Concentration of total anthocyanins(mg 100 g^{-1})					
White Cabbage V_1	20.524 e	20.692 e	24.769 c	23.424 d	25.663 c	23.014 B
Red Cabbage V_2	342.66 b	342.33 b	343.33 b	346.00 a	347.33 a	344.33 A
Average of Sulfur concentrations	181.59 C	181.51 C	184.04 B	184.71 B	186.49 A	

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The values of similar letters are not significantly different from each other according to the Duncan test below the 0.05*

In general, the results in tables 7 and 8 suggested that sulfur application increased uptake of nutrients N, P, K, and S. These results are similar to those obtained by [25] on cabbage, [24] on rapeseed. And [16]when found that spraying with Zolfast at concentrations of 1 and 1.5 ml L-1 led to improved plant growth and increased the concentration of nitrogen, phosphorus, potassium and sulfur in cauliflower leaves . The positive effects of sulfur on nutrient it may be due to fact that the sulfur spray had a role in providing the sulfur needed by the plant in the process of making chlorophyll, which plays a major role in increasing the efficiency of photosynthesis and the transfer of part of the processed food to the roots, which leads to an increase in the growth and spread of roots and thus a high percentage of absorbed nutrients from the soil solution [26].As for the types, differences have appeared in the percentage of nutrients in the heads. The reason may be due to the difference in the genotypes of the species, as the genotype of the species affects the plant's ability to absorb nutrients and accumulate them in the plant. This is consistent with the findings of [4], as he found a difference in the percentage of nitrogen, phosphorus, and potassium in the curds between the hybrids studied.

Conclusions: We conclude from this research that the both Concentrations of liquid sulfur was better by giving higher values and improving the vegetative and productive characteristics of cabbage. The research also proved that white cabbage is better than red cabbage in achieving the best response to spraying with liquid sulfur by achieving the best vegetative and productive results .

Competing Interests: The author declare that they have no competing interests .

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