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Role of zinc and potassium sulphate in the yield and productivity characteristics of two types of broccoli Brassica oleracea var.italica

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Abstract *The experiment was carried out in the Mosul Forest Area field of the College of Agriculture and Forestry, University of Mosul, during autumn 2024 and winter 2025, to study the response of the vegetative growth characteristics of two varieties of broccoli (Naxos, Blue Finn) to the effect of three concentrations of zinc sulfate (0, 500,750 mg.L^{-1}) and three levels of potassium sulfate (0,200,400 ton.h^{-1}).The experiment was carried out in the field using a factorial experiment within split plots in the design of complete random segments (RCBD) with three replicates, where the varieties were placed in the main plots and the compatibility between the fertilization treatments by zinc and potassium sulfate in the secondary plots (Sub plots) was repeated for each treatment three times. The study showed that plants of the Blue Finn variety achieved the highest weight of the main heads and the highest total yield of the main heads increased by 1.09% for the two traits when they were not sprayed with zinc sulphate and added 400 ton.h^{-1} potassium sulfate and the highest significant value for the weight of secondary heads was 121.60 g.Plant^{-1} at 750 mg.L^{-1}of zinc sulphate, not adding potassium sulphate. The same variety achieved the highest yield per plant for secondary heads when sprayed with 750 mg.L^{-1} of zinc sulfate and no potassium sulfate added amounted to 445.94 g.Plant^{-1}, while the highest number of secondary heads reached 5.7333 head.Plant-1 when sprayed with 500 mg.L^{-1} of zinc sulphate and add 400 ton.h^{-1} of potassium sulphate.*
Keywords: *zinc sulphate, potassium sulphate, verities, broccoli.*

INTRODUCTION

Broccoli (*Brassica oleracea* var.italica) Broccoli, which belongs to the Brassicacea family, to which a large number of winter vegetable crops belong (Hassn, 2003). The broccoli plant is considered to have a high economic value in all governorates of Iraq due to its high prices, due to its limited productivity locally, in addition to the economic value of this crop, as it is the richest crop of the Cruciferous family in terms of the nutrients included in its composition and the most widely used in terms of Indication in many countries of the world as it contains vitamins (A, B1, B2, B5, B6, B17,E) and fiber, and contains calcium, manganese, zinc, and Iron. It also contains carotene, which turns into vitamin A in the human body (Thapa et al., 2016) and prevents breast and colon cancer and also enhances liver function (Nilaratanakul et al., 2020.Zinc is one of the micronutrients that is necessary for plant growth, as it is needed in small quantities and for its important role in many physiological plant processes such as protein and sugar synthesis, growth regulation, and photosynthesis. If it is not available or lacking, it hinders the functioning of these pathways, which negatively affects plant productivity, low yield, and poor productivity.(Alloway,2008) Among its functions is that it helps in the process of photosynthesis, converting sugar into starch, resists vital stresses, reduces cell oxidation, and helps in the manufacture of the amino acid tryptophan, which contributes to the formation of indole acetic acid, which is important in cell elongation and is also involved in the processes of biological functions of cell membranes. Potassium is one of the main elements that plants need in relatively large quantities due to its important role in many vital physiological processes and stimulating many enzymatic reactions in the plant. It regulates the process of water absorption and opening and closing stomata, thus increasing the efficiency of water absorption and increasing the thickness of cell walls, which increases the tolerance of plants. Different environmental stresses and acts as a catalyst in the process of transferring nutrients from the roots to the upper parts of the plant or transporting them To grains or fruits (Ali et al., 2014),.Acknowledgments to the progress of plant breeding, it was possible to develop varieties that combine a set of good traits in one variety to suit their cultivation in a specific region.

Materials and working methods:

The experiment was carried out in the field of the Mosul Forest Area, affiliated with the College of Agriculture and Forestry, University of Mosul, during the Autumn 2024 and winter 2025 seasons. Seeds of two types of broccoli were used in the experiment, the first Blue Finn produced by KNOWN-YOU from Taiwan, the second Naxos produced by SOKATA from Chile, and three concentrations of sulfate. Zinc (0, 500, 750 mg.L^{-1}) and three levels of potassium sulfate (0,200,400 ton.h^{-1}), DAP fertilizer (18% nitrogen and 46% phosphorus) was added at a rate of 400 kg.h^{-1}, while urea fertilizer (46% nitrogen) was added at a rate of 200 kg.h^{-1} is a complementary source of nitrogen and potassium sulfate (48%) Potassium) at the special addition rates for this agent used in the experiment. Potassium sulfate fertilizer was added at once after 14 days of seedling. According to the levels used in the experiment, fertilizers were added to the soil at the rate of one batch of DAP fertilizer 20 days after seedling and two batches of urea, the first 20 days after seedling and the second. At the beginning of the formation of heads (Muttalib et al., 1989).The experiment was carried out in the field using a factorial experiment within split plots, and each treatment was repeated three times. The seeds were planted in plastic dishes containing 50 eyes using house moss as a planting medium on 20/8, and the dishes were placed in a seedling preparation house covered with saran Green, and after the seedlings reached the stage of three-four true leaves, they were sown in the morning in the permanent field on 1/10 With complete care, while keeping the house moss around the roots during seedling and maintaining soil moisture, the plants were treated with zinc sulphate during three stages of plant growth: the first two weeks after seedling, the second and third stages with an interval of 15 days between one addition and another. As for potassium sulphate, it was added all at once after seedling.14 days as a result of the interaction between the levels of the factors studied, the number of treatments reached 18 (3×3×2). The statistical analysis of the results was adopted according to the design used using the SAS system (2017) and the averages were compared using the Duncan polynomial test at a probability level of ≤ 0.05(Al-Rawi and Khalafallah, 2000).

Characteristics studied:

1. Average weight of the main head (g.Plant^{-1})**2.** The total yield of main heads (ton.h^{-1}) **3.** Number of secondary heads(head.Plant^{-1}) **4.** Average secondary head weight (g.Head^{-1}) **5.** Single plant yield for secondary heads (g.Plant^{-1}).

RESULTS AND DISCUSSION

1.Average weight of the main head (g.Plant^{-1}) and the total yield of the main heads (ton.h^{-1}) We notice from the results of Tables (1) and (2) that the spray treatment was at both concentrations of 500 and 750 mg.L^{-1} of zinc sulphate produced positive increases, but did not reach significant limits, in terms of the average weight of the main head and the total yield of the main heads, with an increase of 4.278% and 2.268%, compared to the no-spray treatment and spraying with a concentration of 750 mg.L^{-1}, while the addition treatment gave the level of 200 ton.h^{-1} of potassium sulfate had the highest increase in the average weight of the main head and the quotient of the main heads by 7.513%, and it differed only significantly with the comparison treatment and the superiority of the Blue Finn variety in these two characteristics compared to the Naxos variety. Bi-interaction between zinc sulfate and potassium sulfate in all treatments. We notice a significant superiority of the non-spraying treatment with zinc sulfate with the addition of 400 ton. h^{-1} of potassium sulfate, where the weight of the main tablet reached 562.96 g.Plant^{-1}, and the total yield of the main heads amounted to 18.7653 ton.h^{-1} on all interference treatments except two 500 mg.L^{-1} spray treatments of zinc sulphate with both levels adding 200 ton.h^{-1} of potassium sulphate or no addition. It is clear from the coefficients of bi- interference between zinc sulphate and the varieties that the Blue Finn variety is significantly superior to the interference with the spraying and non-spraying coefficients in the average weight of the main head and the total yield of the main heads for the Naxos variety and for all coefficients, and they did not differ significantly between them. As for the treatment of the interaction between potassium sulphate and the varieties, we note from the same table that the Blue Finn variety achieved significant superiority in all levels of addition and non-addition compared to the Naxos variety in terms of the average weight of the main head and the total yield of the main heads, with an increase of 51.51% for the Blue Finn variety when adding 200 $ton.h^{-1}$ by analogy with the comparative treatment of the variety Naxos.It was clear from the same table in the triple interaction that the Blue Finn variety, with no spraying of zinc sulphate and the addition of potassium sulphate at the level of 400 $ton.h^{-1}$ gave the highest significant values in the average weight of the main head and the total yield of the main heads compared to most triangular interaction coefficients, amounting to 667.58 $g.Plant^{-1}$ and 22,253 $ton.h^{-1}$ and did not differ significantly with the non-spraying parameters of zinc sulphate with the addition of 200 $ton.h^{-1}$ potassium sulfate and also spray treatments of 500 $mg.L^{-1}$ of zinc sulphate, without additions, and 200 $ton.h^{-1}$ potassium sulphate, while the average weight of the main head and the lowest total yield of the main heads when comparing the Naxos variety reached 319.22 $g.Plant^{-1}$ and 10.641 $ton.h^{-1}$ respectively.

2:Number of secondary head(head.$Plant^{-1}$) We note from Table (3) the superiority of the spray treatment with the concentration of 500 $mg.L^{-1}$ significantly, giving the highest rate of number of secondary heads, which reached 4.2017 $head.Plant^{-1}$, as measured by the non-spraying and spraying treatments, with a concentration of 750 $mg.L^{-1}$, where it amounted to 3.2017 and 3.3778 $head.Plant^{-1}$, respectively. As for the addition of potassium sulfate, we notice from the same table that it caused significant increases in the number of secondary heads compared to the non-addition treatment, as the addition treatment achieved the level of 200 $ton.h^{-1}$ The highest rate of secondary heads reached 3.7256 $head.Plant^{-1}$ The varieties Naxos and Blue Finn did not differ significantly in this trait, with the number of secondary heads reaching 3.7567 and 3.4307 $head.Plant^{-1}$ respectively. Bi- interference coefficients between zinc sulphate and potassium sulphate indicate that the spray treatment with zinc sulphate is at a concentration of 500 $mg.L^{-1}$, with all levels of addition of potassium sulfate, achieved significant superiority compared to all bi-interference coefficients, and the highest number of secondary heads reached 4.4500 $head.Plant^{-1}$ at 500 $mg.L^{-1}$ spray of zinc sulphate and add 400 $ton.h^{-1}$ of potassium sulphate. In the coefficients of bi-interaction between zinc sulphate and the varieties, we notice that the Naxos variety is superior to the Blue Finn variety by giving the highest significant values with the average number of secondary heads at the spraying treatment with a concentration of 500 $mg.L^{-1}$ and over all coefficients of bi-interference amounted to 4.8700 $head.Plant^{-1}$ In the coefficients of bi- interference between potassium sulfate and the varieties, we note that adding potassium sulfate to plants of the Naxos variety achieved significant increases compared to all the coefficients of bi- interference, as the highest rate of the number of secondary heads reached 4.0922 $head.Plant^{-1}$ at level 200 $ton.h^{-1}$. In the same table, we notice the results of the triple interaction between the factors of the factors studied, from which it appears that the spray treatment is 500 $mg.L^{-1}$ of zinc sulphate with the addition of 400 $ton.h^{-1}$ potassium sulfate on plants of the Naxos variety achieved significant superiority over all triple interference coefficients by giving the highest significant values in the average number of secondary heads, which amounted to 5.7333 $head.Plant^{-1}$, and the lowest value for the average number of secondary heads was when the comparison was treated for plants of the Naxos variety, which amounted to 2.5 $head.Plant^{-1}$.

3: Average secondary head weight (g.$head^{-1}$) Referring to the results shown in Table (4), spraying with zinc sulphate at a rate of 750 $mg.L^{-1}$ exceeded the significant values in average secondary head weight, reaching 95.825 $g.head^{-1}$: As for the effect of adding potassium sulfate, we note that there are no significant differences for all levels used in the experiment, and the superiority of the Blue Finn variety is 107.206 $g.head^{-1}$.It was also shown from the interference coefficients between zinc sulphate and potassium sulphate that the spray treatment was at a concentration of 750 $mg.L^{-1}$ zinc sulphate alone, without the addition of potassium sulphate, was significantly superior, giving the highest average secondary head weight, which amounted to 101,798 $g.head^{-1}$ compared to the comparison treatment and when spraying 500 $mg.L^{-1}$ zinc sulphate and 400 $ton.h^{-1}$ potassium sulphate. The coefficients of bi- interaction between the spraying treatment between zinc sulphate and the varieties indicated that the variety Blue Finn when sprayed had a concentration of 750 $mg.L^{-1}$ excelled by giving the highest values for the average secondary head weight of 116.168 $g.head^{-1}$ in comparison to the Naxos variety and on all interference coefficients except the comparison treatment for the Blue Finn variety. The interference coefficients indicated that adding potassium sulfate to plants of the Blue Finn variety achieved significant superiority and did not differ from the non-addition and addition treatments at the level of 400 ton.h^{-1}.The highest weight of the secondary head is achieved when adding 200 ton.h^{-1} amounted to 109.531 g.$head^{-1}$. All spray treatments with zinc sulfate and potassium sulfate were significantly superior to plants of the Blue Finn variety in the triple interference treatment, reaching the highest value of 121.60 g.$head^{-1}$ when sprayed with 750 mg.L^{-1} of zinc sulphate without the addition of potassium sulphate, and the value of the secondary head weight rate decreased when treated with spraying at a concentration of 500 mg.L^{-1} of zinc sulphate and an addition of 400 ton.h^{-1} of potassium sulfate amounted to 49.90 g.$head^{-1}$.

4: The plant yield for secondary heads (g.$Plant^{-1}$) It appears to us from Table (5) that spraying zinc sulphate at a concentration of 500 achieved a significant superiority in the yield of one plant for secondary heads. Table (5) with an increase rate of 17.666% compared to the no-spray treatment. As for potassium sulphate, no significant differences were achieved at all levels, and the highest yield was achieved. One plant for secondary heads increased by 3.611% when 200 ton.h^{-1}, compared to the non-addition treatment, and the Blue Finn variety outperformed the Naxos variety in the yield of secondary heads per plant, amounting to 367.59 g.$Plant^{-1}$.The coefficients of bi- interference between zinc sulphate and potassium sulphate were superior in producing the highest significant increase in the characteristic of the yield of secondary heads per plant and in all interactions compared to the comparison treatment. and the highest yield per plant for secondary heads was achieved when the plants were sprayed with 500 mg.L^{-1} of zinc sulphate, without the addition of potassium sulphate, with an increase of 84.583% compared to the comparison treatment, Table (5). In the bi- interaction between zinc sulphate and the varieties, the Blue Finn variety achieved the highest significant value of 392.14 g.$Plant^{-1}$ when sprayed at a concentration of 750 mg.1 liter of zinc sulphate on all interference coefficients for the variety Naxos, in which the yield of secondary heads per plant decreased to 219.04 g.$Plant^{-1}$, when the comparison was treated in Table (5) respectively, and the interaction between adding potassium sulfate with the varieties shows that it followed the same results, as the Blue Finn variety achieved significant superiority in this characteristic and for all treatments and for all treatments of the Naxos variety, which gave the plant the lowest yield of secondary heads. It reached 251.14 g.$Plant^{-1}$ table (5) respectively. It is clear in the triple interaction between the studied factors that spraying zinc sulphate and adding potassium sulphate on plants of the Blue Finn variety was significantly superior in all treatments, and the highest yield per plant for secondary heads was 445.94 g.$Plant^{-1}$ at 750 mg.L^{-1} spray of zinc sulphate without adding potassium sulphate, compared to the comparative treatment of plants of the Naxos variety, which produced the lowest values of 138.75 g.$Plant^{-1}$.

CONCLUSIONS

1.Superiority of zinc sulphate spray treatments in all spray treatments in weight of secondary heads, single plant quotient of secondary heads and 500 mg.L^{-1} then exceeds the number of secondary heads.
2.In addition to potassium sulfate, there was a significant superiority in most of the characteristics of the yield (the weight of the main head, the total yield of the main heads, and the number of secondary heads).
3.The Blue Finn variety was significantly superior in most of the characteristics studied, except for the characteristic of the number of secondary heads, the results of which did not reach significant limits.
4.Bi-interactions between both fertilizing factors or triple interactions between fertilizing factors and varieties gave the best results compared to the effect of single factors or with comparison factors.

RECOMMENDATIONS:

.We recommend using an interaction between foliar spraying of zinc sulphate and adding potassium sulphate and treating independently and sequentially for each one.
2.We also recommend planting the Blue Finn variety because the variety has the ability to adapt to the climate of the city of Mosul.

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Table (1): The effect of zinc sulfate, potassium, and other types and the interference between them in the weight of the main head ($g.Plant^{-1}$)

Zinc sulphate concentrations ($mg. L^{-1}$)	potassium sulphate concentrations ($ton.h^{-1}$)	Verities		Zinc sulphate × potassium sulphate	Average Effect of Zinc sulphate
		Naxos	Blue Finn		
0	0	319.22 h	473.17 d-f	396.19 d	483.88 a
	200	383.67 g h	601.33 a-c	492.50 b c	
	400	458.33 d-g	667.58 a	562.96 a	
500	0	434.33 e-g	624.87 a b	529.60 a b	504.53 a
	200	465.00 d-g	595.10 a-c	530.05 a b	
	400	391.55 f-h	516.33 c-e	453.94 c	
750	0	412.00 f g	575.50 b c	493.75 b c	493.34 a
	200	437.67 e- g	569.58 b c	503.63 b c	
	400	436.83 e-g	528.43 c d	482.63 b c	
zinc sulphate X varieties	0	387.07 b	580.69 a	Average effect of Potassium sulphate	
	500	430.30 b	578.77 a		
	750	428.83 b	557.84 a		

Potassium sulphate X varieties	0	388.52 b	557.84 a	473.18 b
	200	428.78 b	588.67 a	508.73 a
	400	428.91 b	570.78 a	499.85 a b
Average effect of varieties		415.40 b	572.43 a	

*Averages that share the same letter for each factor and for each overlap do not differ significantly from each other according to the Duncan polynomial test at the probability level ≤ (0.05)

Table (2): The effect of zinc and potassium sulphate and the varieties and the interaction between them on the total yield of the main heads (ton.h $^{-1}$)

Zinc sulphate concentrations (mg. L $^{-1}$)	potassium sulphate concentrations (ton.h $^{-1}$)	Verities		Zinc sulphate × potassium sulphate	Average Effect of Zinc sulphate
		Naxos	Blue Finn		
0	0	10.641 h	15.772 d-f	13.2064 d	16.1295 a
	200	12.789 g h	20.044 a-c	16.4167 b c	
	400	15.278 d-g	22.253 a	18.7653 a	
500	0	14.478 e-g	20.829 a b	17.6533 a b	16.8177 a
	200	15.500 d-g	19.837 a-c	17.6683 a b	
	400	13.052 f-h	17.211 c-e	15.1314 c	
750	0	13.733 f g	19.183 b c	16.4583 b c	16.4445 a
	200	14.589 e-g	18.986 b c	16.7875 b c	
	400	14.561 e-g	17.614 c d	16.0878 b c	
zinc sulphate X varieties	0	12.902 b	19.356 a	Average effect of Potassium sulphate	
	500	14.343 b	19.292 a		
	750	14.294 b	18.595 a		
Potassium sulphate X varieties	0	12.9506 b	18.5948 a	15.7727 b	
	200	14.2926 b	19.6224 a	16.9575 a	
	400	14.2969 b	19.0261 a	16.6615 a b	

Average effect of varieties	13.8467 b	19.0811 a

*Averages that share the same letter for each factor and for each overlap do not differ significantly from each other according to the Duncan polynomial test at the probability level ≤ (0.05)

Table (3): The effect of zinc and potassium sulphate and their types and the interaction between them in the number of secondary heads (head .Plant^{-1})

Zinc sulphate concentrations (mg. L^{-1})	potassium sulphate concentrations (ton.h^{-1})	Verities		Zinc sulphate × potassium sulphate	Average Effect of Zinc sulphate
		Naxos	Blue Finn		
0	0	2.5000 f	3.0667 c-f	2.7833 d	3.2017 b
	200	3.5667 c-e	3.3433 c-f	3.4550 b c	
	400	2.9667 e f	3.7667 c-e	3.3667 b-d	
500	0	4.0000 c	3.9667 c d	3.9833 a b	4.2017 a
	200	4.8767 b	3.4667 c-e	4.1717 a	
	400	5.7333 a	3.1667 c-f	4.4500 a	
750	0	3.0000 d-f	3.6333 c-e	3.3167 c d	3.3778 b
	200	3.8333 c-e	3.2667 c-f	3.5500 b c	
	400	3.3333 c-f	3.2000 c-f	3.2667 c d	
zinc sulphate X varieties	0	3.0111 b	3.3922 b	Average effect of Potassium sulphate	
	500	4.8700 a	3.5333 b		
	750	3.3889 b	3.3667 b		
Potassium sulphate X varieties	0	3.1667 c	3.5556 b c	3.3611 b	
	200	4.0922 a	3.3589 c	3.7256 a	
	400	4.0111 a b	3.3778 c	3.6944 a b	
Average effect of varieties		3.7567 a	3.4307 a		

*Averages that share the same letter for each factor and for each overlap do not differ significantly from each other according to the Duncan polynomial test at the probability level ≤ (0.05)

Table (4): The effect of zinc sulfate, potassium, and other types, and the interaction between them in the average secondary head weight (g.h^{-1})

Zinc sulphate concentrations (mg. L^{-1})	potassium sulphate concentrations (ton.h^{-1})	Verities		Zinc sulphate × potassium sulphate	Average Effect of Zinc sulphate
		Naxos	Blue Finn		
0	0	55.50 h i	89.45 b-f	72.473 c	87.588 a b
	200	86.94 b-g	109.57 a-d	98.257 a	
	400	70.40 e-i	113.67 a b	92.035 a-c	
500	0	91.83 b-e	98.33 a-e	95.080 a b	84.185 b
	200	59.72 g h	104.77 a-d	82.242 a-c	
	400	49.90 i	100.57 a-d	75.233 b c	
750	0	82.00 d-h	121.60 a	101.798 a	95.825 a
	200	61.28 f-h	114.26 a b	87.768 a-c	
	400	83.17 c-h	112.65 a-c	97.908 a	
zinc sulphate X varieties	0	70.948 c	104.229 a b	Average effect of Potassium sulphate	
	500	67.150 c	101.220 b		
	750	75.482 c	116.168 a		
Potassium sulphate X varieties	0	76.444 b	103.123 a	89.784 a	
	200	69.313 b	109.531 a	89.422 a	
	400	67.822 b	108.962 a	88.392 a	
Average effect of varieties		71.193 b	107.206 a		

*Averages that share the same letter for each factor and for each overlap do not differ significantly from each other according to the Duncan polynomial test at the probability level ≤ (0.05)

Table (5): The effect of zinc sulfate, potassium, and varieties and the interaction between them on the yield of secondary heads per plant (g. Plant^{-1})

Zinc sulphate concentrations (mg. L^{-1})	potassium sulphate concentrations (ton.h^{-1})	Verities		Zinc sulphate × potassium sulphate	Average Effect of Zinc sulphate
		Naxos	Blue Finn		
0	0	138.75 f	272.60 c-e	205.68 b	285.91 b

	200	305.11 b-e	364.02 a-d	334.56 a	
	400	213.25 e f	421.74 a b	317.50 a	
500	0	368.67 a-d	390.63 a-c	379.65 a	336.42 a
	200	289.91 b-e	364.34 a-d	327.13 a	
	400	286.41 b-e	318.54 a-e	320.59 a	
750	0	246.00 d-f	445.94 a	345.97 a	323.26 a b
	200	235.34 d-f	371.10 a-d	303.22 a	
	400	281.78 c-e	359.39 a-d	320.59 a	
zinc sulphate X varieties	0	219.04 d	352.79 a b	Average effect of Potassium sulphate	
	500	315.00 b c	357.84 a b		
	750	254.37 c d	392.14 a		
Potassium sulphate X varieties	0	251.14 b	369.72 a	310.43 a	
	200	276.79 b	366.49 a	321.64 a	
	400	260.48 b	366.55 a	313.52 a	
Average effect of varieties		262.80 b	367.59 a		

*Averages that share the same letter for each factor and for each overlap do not differ significantly from each other according to the Duncan polynomial test at the probability level ≤ (0.05)