



Effect of Bio-health and Hum-Zinc Fertilizers on Growth, Yield and Quality of Two Cabbage hybrids (*Brassica Oleracea* Var. Capitata) under Plastic house

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ABSTRACT

The experiment was conducted during the fall agricultural season of 2024–2025 under a plastic house (300 m²) without heating at the Department of Horticulture, College of Agricultural Engineering Sciences, University of Duhok, Kurdistan Region, the site is geographically positioned at a latitude of 36.51° N, longitude of 42.52° E, and an altitude of 473 meters above sea level. Iraq. A factorial experiment was carried out using a Randomized Complete Block Design (split plot design) with three replicates, comprising 54 treatments. The treatments were a combination of two cabbage hybrids ('Tropicana' and 'Globe Master'), three levels of Bio Health (0 g, 15 g, and 20 g per m²), and three levels of Hum-Zinc foliar spray (0 g, 1.5 g, and 3 g per liter). The objective was to evaluate the effects of Bio Health application and Hum-Zinc foliar spraying on the growth, productivity, and yield of cabbage.

The results showed that the 'Globe Master' hybrid was significantly superior to the 'Tropicana' hybrid in terms of the number of rolled leaves (29.43 leaves per plant), average head weight (1.61 kg), total yield (58.92 t. ha⁻¹), nitrogen percentage (2.65%), and potassium percentage (0.99%). In contrast, the 'Tropicana' hybrid showed superiority in stem length (9.60 cm) and phosphorus percentage (0.23 %). The application of Bio Health significantly affected all measured parameters, demonstrating its role in enhancing plant performance. Similarly, foliar application of Hum-Zinc significantly influenced all growth and yield traits, with the exception of stem length.

The best results for most vegetative growth characteristics, total yield, and yield components were obtained with the application of Bio Health at 20 g/m² and foliar spraying of Hum-Zinc at 3 g/L. These findings indicate that the integrated use of Bio Health and Hum-Zinc can effectively improve cabbage growth, yield, and nutrient content under protected cultivation conditions. This study highlights the potential of combining organic amendments with micronutrient foliar sprays to achieve sustainable and productive cabbage cultivation.

Keywords: cabbage, vegetables, hybrid, Biofertilizer, micronutrient, yield.

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INTRODUCTION

Cabbage (*Brassica oleracea* var capitata) belongs to the Brassicaceae family it has been cultivated more than 4,500 years. The plant was known to the ancient Egyptians, Greece and Romans. Soft, hard, conical, flat, and cylindrical shapes, as well as white, green and red colors are available [1].

Cabbage Leaves are low in calories (27%), fat (0.1%) and carbohydrates (4.6%). It is good sources of protein (1.3%) which contains all essential amino acids, particularly Sulphur containing amino acids, Cabbage is an excellent source of minerals such as calcium (39 mg), iron (0.8 mg), magnesium (10 mg), sodium (14.1 mg), potassium (114 mg) and phosphorus (44 mg). It has substantial amounts of β carotene provitamin A, ascorbic acid, riboflavin, niacin and thiamine, Ascorbic acid content varies from 30-65 mg per 100 g fresh weight. Flavor in cabbage leaves is due to the glycoside sinigrin. Cabbage contains goitrogens which cause enlargement of thyroid glands [2].

Flavor in cabbage leaves is due to the glycoside sin grin. Vegetables that are produced by using organic manures are also gaining importance because of less chemical residues and better taste [3].

Increased crop production is greatly influenced by the hybrids. With the introduction of new acceptable foreign hybrid

hybrids, there is a significant opportunity of increase cabbage production. Several hybrid cabbage types that have been introduced by various seed firms are readily accessible on the market. Therefore, it is essential to determine varietal performances before making recommendations to farmers [4].

Organic farming crops are becoming increasingly important in today's world to manage ecological health and provide linked health benefits for humans; demand for organic products is increasing globally [5].

Biofertilizers are substances that contain living microorganisms—such as bacteria, fungi, or protozoa—that enhance soil fertility by promoting key nutrient cycling processes. These beneficial microbes contribute to plant nutrition through mechanisms such as nitrogen fixation, phosphorus solubilization, and iron chelation, thereby converting insoluble forms of nutrients into forms that are readily absorbed by plant roots [6].

Micronutrients, though required in much smaller quantities compared to macronutrients, are essential for proper plant growth and development. Deficiencies in micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), boron (B), and molybdenum (Mo) can significantly impair physiological and biochemical functions in plants. Recent research has emphasized the effectiveness of foliar fertilization as a rapid and efficient method of delivering micronutrients directly to the plant tissues, bypassing potential soil-related nutrient limitations [7].

Therefore, the study aimed to produce cabbage crops early under protected cultivation, and evaluation of the performance of two varieties of cabbage to choose the best one and to assess the effect of Bio Health and Hum-zinc on growth, yield and quality of Cabbage and Creating the self-efficiency of this newly introduced crop in Kurdistan region without importing it from outside.

Material and methods

The experiment was conducted at the Horticulture Department, College of Agriculture Engineering Science University of Duhok, during the autumn season (2024). The treatments were laid out in factorial experiment within using the Randomized Complete Block Design (RCBD), with the cabbage hybrids in the main plot and Bio health fertilizer treatments in the subplots and Hum-zinc in the sub subplots.

They were included (18) treatments ($2 \times 3 \times 3$) with three replications equal (54 experimental units), which means the experiment consisted of three factors A- consisted of two hybrids of cabbage which are A1- Tropicana= (purity 98% and germination 90%) and A2- Globe master (purity 99% and germination 90%). B- Three levels of Bio health (0, 15, 20 g .M²) .C- Three levels of Hum-zinc (0, 1.5 3, g. L⁻¹) All treatments were randomly distributed to the trial units. The number of plants in the experimental unit was 10 plants.

First, Cabbage seeds were sown in plastic trays on 1st Sep. 2024, the planting medium was peat moss only, then after one month after appear 3-5 true leaves they moved to their permanent place (experimental site) in the plastic house on 1st Oct. 2024 with a spacing of 40 cm between them, and 60 cm between rows. Both fertilizers were applied three times. The fertilizer of Bio health was applied to the soil and the fertilizer of Hum-zinc was sprayed as a foliar application by a backpack sprayer. The first fertilization after 15th of planting the seedling in the plastic house and repeated three times and repeated three times interval 15 days between them. Cabbage was harvested 120 days after planting the seeds. Five cabbage plants were selected randomly from each experimental unit for recording data on the following parameters which have been taken in the physiology lab (The number of rolled leaves plant⁻¹, stem length cm, average head weight kg, total yield t. ha⁻¹, N, P, and K percentage). The recorded data on various parameters were statistically analyzed by using SAS statistical analyses software (SAS, 2007) [8], using a factorial analysis of variance (ANOVA, PROC MIXED), and the difference between treatment means were determined by Duncan's Multiple Range Test (DMRT) at 5% level of probability [9].

Results:

1-Number of rolled leaves

Table (1) shows the effect of hybrids that the Globe master cv. Had significant differences compared to the Tropicana cv. The highest number of leaves (29.43) Leaves per plant was observed in the Globe master cv. while (21.22) leaves per plant are noticed in the Tropicana cv. Whereas adding Bio health had significant effect on this parameter. The third concentration of hum-zinc (3 g.L⁻¹) had a significant influence which recorded the highest value (26.76) leaves per plant compared to the other treatment concentrations. In an interaction between hybrids and bio health, it was found that the second concentration of bio health (15 g. M²) significantly affected the Globe master cv., the maximum number of leaves was (30.17) leaves per plant compared to the lowest value, which was (20.50) leaves in Tropicana cv. Meanwhile, the third concentration of hum-zinc (3 g.L⁻¹) significantly affected the Globe master hybrid which recorded (30.11) leaves in the interaction between hybrids and Hum-zinc treatments. The interaction of hum-zinc (3 g.L⁻¹) with the third concentration of bio health (20 g.M²) was significant in the number of leaves which recorded the highest value (26.67 leaves) as compared to others and the lowest value was (23.67) leaves per plant at control treatment (0 g.L⁻¹) of both fertilizers. Finally, the table shows the interaction among all factors the superiority

of the Globe master cv. and the third level (3 g.L⁻¹) hum zinc, and (15 g.M²) of Bio health (31.11) leaves on all other concentrations, while the interaction among Tropicana cv., (0 g. L⁻¹) of hum- zinc, and (0 g. M²) of Bio health gave the lowest value in this trait which was (19.83) leaves per plant.

Table (1): The effect of Hybrids by bio health and hum-zinc, and their interactions on the Number of rolled leaves per plant of cabbage.

hybrids	Bio health (g.M ²)	Hum-zinc (g.L ⁻¹)			hybrids *Bio-health	Mean effect of hybrids
		0	1.5	3		
Tropicana	0	19.83 e	20.17 e	21.50 de	20.50 c	
	15	22.00 de	20.33 e	21.33 de	21.22 c	21.22 b
	20	20.67 e	21.50 de	23.67 d	21.94 c	
Globe master	0	27.50 c	28.33 bc	29.33 abc	28.39 b	
	15	29.67 abc	29.50 abc	31.33 a	30.17 a	29.43 a
	20	30.50 ab	29.00 abc	29.67 abc	29.72 ab	
Mean effect of Hum-zinc		25.03 b	24.81 b	26.14 a		
hybrids *	Tropicana	20.83 bc	20.67 c	22.17 b	Mean effect of Biohealth	
Hum-zinc	Globe master	29.22 a	28.94 a	30.11 a		
Bio health *	0	23.67 c	24.25 bc	25.42 abc	0	24.44 b
	15	25.83 ab	24.92 abc	26.33 a	15	25.69 a
	20	25.58 abc	25.25 abc	26.67 a	20	25.83 a

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

2-Stem length (cm)

Table (2) illustrated below, the two hybrids show no significant differences between them regarding the stem length cm. The third concentration of bio health (20 g.M²) had a significant influence which recorded the highest value (9.44) stem length compared to the other treatment concentrations. as well as no significant differences were observed with spraying the plant with Hum zinc fertilizer. In the case of the dual interaction between the hybrids and bio health fertilizer, the highest result was recorded from a combination of Tropicana cv. and bio health at (20 g. M²) as it reached (9.71 cm). The results of the binary interaction between hybrids and (1.5 g. L⁻¹) Hum zinc fertilizer indicates the significant superiority of Tropicana cv. With hum- zinc by giving the highest stem length, which was (9.88 cm), where it differed significantly from the globe master cv. of the same control concentration (8.39 cm). Meanwhile, the second concentration of hum zinc (1.5 g. L⁻¹) and second concentration of bio health (15 g. M²) significantly affected the Tropicana hybrid which recorded (9.77) stem length in the interaction between bio health and hum zinc treatments. Finally, the table shows the interaction among all factors the superiority of the Tropicana cv. and the third level (5 g. L⁻¹) of hum zinc, (10.85) stem length on all other concentrations, while the interaction among Globe master cv, (15 g. M²) bio health, and gave the lowest value in this trait which was (7.88) stem length cm.

Table (2): The effect of Hybrids by bio health and hum-zinc, and their interactions on the stem length (cm) of cabbage.

Hybrids	Bio health (g.M ²)	Hum-zinc (g.L ⁻¹)			Hybrid *Bio- health	Mean effect of Hybrid
		0	1.5	3		
Tropicana	0	9.50 bc	10.22 ab	8.94 cde	9.56 a	9.60 a

	15	10.22 ab	8.56 cde	9.83 abc	9.53 a	
	20	9.11 b-e	10.85 a	9.17 bcd	9.71 a	
	0	8.85 cde	8.58 cde	8.84 cde	8.76 bc	
Globe master	15	8.65 cde	7.88 e	8.07 de	8.20 c	8.71 b
	20	9.20 bcd	8.70 cde	9.58 bc	9.16 ab	
Mean effect of Hum-zinc		9.25 a	9.13 a	9.07 a		
Hybrid	Tropicana	9.61 a	9.88 a	9.32 ab	Mean effect of Bio health	
* Hum-zinc	Globe master	8.90 bc	8.39 c	8.83 bc		
	0	9.17 a	9.40 a	8.89 ab	0	9.16 ab
Bio health*	15	9.44 a	8.22 b	8.95 ab	15	8.87 b
Hum-zinc	20	9.15 a	9.77 a	9.38 a	20	9.44 a

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

3-Average head weight (Kg)

Results in Table (3) indicated that there were significant differences between the two hybrids on Average head weight (Kg) when the best value was recorded in the Globe master cv. (1.61 kg) compared to the Tropicana cv. (1.02 kg). As well as, the third concentration (20 g. M²) documented the highest result (1.45 kg), in comparison to other treatments. While, spraying with Hum-zinc showed significant effect on Head circumference. The collaboration of hybrid and Bio health showed a difference between them, where the superior interaction was recorded in the Globe master cv. and at the concentration (20 g. M²) of Bio health which were (1.77 kg) respectively. Moreover, the lowest value was recorded in the Tropicana cv. (0.94 kg) at control of Bio health. Also, the interaction between hybrid and Hum-zinc recorded significant influences on head circumference. The concentration (3 g. L⁻¹) of Hum-zinc in the Globe master cv. had the highest value (1.68 kg), compared to Tropicana cv. Concerning interaction between Bio health and Hun-zinc resulted in a significant effect between them, where the maximum value was measured in the interaction between (0 g. L⁻¹) of Hum-zinc plus (20 g. M²) of Bio health which was at (1.49 kg) and the lowest value at control of both fertilizer (1.11 kg). Regarding the triple interaction, the results revealed that there were significant differences among all factors in Average head weight. Indicating that the combination among the Globe master cv., (3g. L⁻¹) of Hum-zinc, and (20 g. M²) of Bio health improved average head weight to the highest value of (1.94 kg), and the lowest value was recorded among the Tropicana cv. Control of both fertilizers which was (0.86 kg) as compared to other interactions.

Table (3): The effect of Hybrids by bio health and hum-zinc, and their interactions on Average head weight (kg) of cabbage.

Hybrids	Bio health (g.M ²)	Hum-zinc (g.L ⁻¹)			Hybrid *Bio-health	Mean effect of Hybrid
		0	1.5	3		
	0	0.86 f	0.95 ef	1.00 ef	0.94 d	
Tropicana	15	1.01 ef	0.95 ef	1.04 e	1.00 d	1.02 b
	20	1.36 d	1.00 ef	1.03 e	1.13 c	
	0	1.36 d	1.60 c	1.56 c	1.51 b	
Globe master	15	1.49 cd	1.59 c	1.54 c	1.54 b	1.61 a
	20	1.61 c	1.77 b	1.94 a	1.77 a	
Mean effect of Hum-zinc		1.28 a	1.31 ab	1.35 a	Mean effect of Bio	

Hybrid	Tropicana	1.08 c	0.96 d	1.02 cd	health	
* Hum-zinc	Globe master	1.49 b	1.65 a	1.68 a		
	0	1.11 d	1.27 c	1.28 bc	0	1.22 b
Bio health *	15	1.25 c	1.27 c	1.29 bc	15	1.27 b
Hum-zinc	20	1.49 a	1.38 b	1.48 a	20	1.45 a

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

4- Total yield (t. ha⁻¹)

Data presented in Table (4) indicated that there were significant differences between the two hybrids on total yield (t. ha⁻¹) when the best value was recorded in the Globe master cv. (58.92 t. ha⁻¹) compared to the Tropicana cv. (37.43 t. ha⁻¹). However, Bio health showed significant effect on total yield the highest value (53.20 t. ha⁻¹). while spraying with Hum-zinc significantly influenced plant total yield, the third concentration (3 g. L⁻¹) documented the highest result (49.52 t. ha⁻¹), in comparison to other treatments. The interaction of hybrid and Bio health showed a difference between them, where the superior interaction was recorded in the Globe master cv. and at the concentration (20, 15, and 0) g. M of Bio health which were (65.04, 56.38, 55.33 t. ha⁻¹) respectively. Moreover, the lowest value was recorded in the Tropicana cv. (34.30 t. ha⁻¹) at (0 g.M²) of Bio health. Also, the interaction between hybrid and Hum-zinc recorded significant influences on plant yield. The concentration (3 g. L⁻¹) of Hum-zinc in the Globe master cv. had the highest value (61.62 t. ha⁻¹), compared to Tropicana cv. Concerning interaction between Bio health and Hum-zinc resulted in a significant effect between them, where the maximum value was measured in the interaction between (20 g.M²) of Bio health plus (0 g. L⁻¹) of Hum-zinc which was at (54.54 t. ha⁻¹) and the lowest value at (0 g.L⁻¹) of both fertilizers (40.75 t. ha⁻¹). Regarding the triple interaction, the results revealed that there were significant differences among all factors in total yield. Indicating that the combination among the Globe master cv., (20 g. M²) of Bio health, and (3 g. L⁻¹) of Hum-zinc improved total yield to the highest value of (71.13 t. ha⁻¹), and the lowest value was recorded among the tropicana cv. at (0 g. M²) of each fertilizer which was (31.50 t. ha⁻¹) as compared to other interactions.

Table (4): The effect of Hybrids by bio health and hum-zinc, and their interactions on total yield (t. ha⁻¹) of cabbage.

Hybrids	Bio health (g.M ²)	Hum-zinc (g.L ⁻¹)			Hybrid * Bio health	Mean effect of Hybrid
		0	1.5	3		
Tropicana	0	31.50 f	34.75 ef	36.67 ef	34.30 d	
	15	37.18 ef	34.77 ef	37.96 e	36.64 d	37.43 b
	20	49.88 d	36.58 ef	37.60 e	41.36 c	
Globe master	0	50.00 d	58.65 c	57.34 c	55.33 b	
	15	54.63 cd	58.13 c	56.39 c	56.38 b	58.92 a
	20	59.20 c	64.78 b	71.13 a	65.04 a	
Mean effect of Hum-zinc		47.07 b	47.94 ab	49.52 a		
Hybrid	Tropicana	39.52 c	35.37 d	37.41 cd	Mean effect of Bio health	
* Hum-zinc	Globe master	54.61 b	60.52 a	61.62 a		
Bio health *	0	40.75 d	46.70 c	47.00 bc	0	44.82 b
	15	45.91 c	46.45 c	47.18 bc	15	46.51 b
	20	54.54 a	50.68 b	54.37 a	20	53.20 a

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

5 - Nitrogen percentage (%)

As shown in Table (5) indicated that there were significant differences between the two hybrids on nitrogen percentage when the best value was recorded in the Globe master cv. (2.65 %) compared to the Tropicana cv. (2.62%). However, Bio health showed significant effect on nitrogen percentage the highest value was (2.72 %). while spraying with Hum-zinc significantly influenced plant nitrogen percentage, the third concentration (3 g.L⁻¹) documented the highest result (2.74%), in comparison to other treatments. The interaction of hybrid and Bio health showed a difference between them, where the superior interaction was recorded in the Tropicana cv. at the concentration (15 g.M²) of Bio health which was (2.83%) respectively. Also, the interaction between hybrid and Hum-zinc recorded significant influences on nitrogen percentage. The concentration (1.5 g. L⁻¹) of Hum-zinc in the Globe master cv. had the highest value (2.76 %), compared to Tropicana cv. Concerning interaction between Bio health and Hum-zinc resulted in a significant effect between them, where the maximum value was measured in the interaction between (15 g.M²) of Bio health plus (1.5 g. L⁻¹) of Hum-zinc which was at (2.98%) and the lowest was (2.47%). Regarding the triple interaction, the results revealed that there were significant differences among all factors in nitrogen percentage. Indicating that the combination among the globe master cv., (20 g.M²) of Bio health, and (3 g. L⁻¹) of Hum-zinc improved Nitrogen percentage to the highest value of (3.05 %), and the lowest value was recorded among the tropicana cv. at (0 g. M²) of each fertilizer which was (2.41%) as compared to other interactions.

Table (5): The effect of Hybrids by bio health and hum-zinc, and their interactions on Nitrogen percentage of cabbage.

Hybrids	Bio health (g.M ²)	Hum-zinc (g.L ⁻¹)			Hybrid Bio	* Mean effect of Hybrid
		0	1.5	3		
Tropicana	0	2.41 i	2.35 j	2.45 h	2.40 e	
	15	2.65 f	3.02 b	2.82 d	2.83 a	2.62 b
	20	2.43 hi	2.53 g	2.92 c	2.63 c	
Globe master	0	2.52 g	2.65 f	2.74 e	2.64 c	
	15	2.54 g	2.81 d	2.45 h	2.60 d	2.65 a
	20	2.25 k	2.83 d	3.05 a	2.71 b	
Mean effect of Hum-zinc		2.47 c	2.70 b	2.74 a		
Hybrid* Hum-zinc	Tropicana	2.50 e	2.63 d	2.73 c	Mean effect of Bio health	
	Globe master	2.44 f	2.76 a	2.75 b		
Bio health * Hum zinc	0	2.47 g	2.50 f	2.60 e	0	2.52 c
	15	2.60 e	2.92 b	2.64 d	15	2.72 a
	20	2.34 h	2.68 c	2.98 a	20	2.67 b

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

6- Phosphorus percentage (%)

Data presented in Table (6) indicated that there were significant differences between the two hybrids on phosphor percentage when the best value was recorded in the Tropicana cv. (0.23 %) compared to the globe master cv. (0.22%). However, Bio health showed significant effect on phosphor percentage the highest value was (0.25 %). while spraying with Hum-zinc significantly influenced plant phosphor percentage, the third concentration (3 g.L⁻¹) documented the highest result (0.25%), in comparison to other treatments. The interaction of hybrid and Bio health showed a difference between them, where the superior interaction was recorded in the globe master cv. at the concentration (15 g.M²) of Bio health which was (0.26%) respectively. Also, the interaction between hybrid and Hum-zinc recorded significant

influences on phosphor percentage. The concentration (3 g. L⁻¹) of Hum-zinc in the Globe master and Tropicana cv. had the highest value (0.25 %). Concerning interaction between Bio health and Hum-zinc resulted in a significant effect between them, where the maximum value was measured in the interaction between (0 g.M²) of Bio health plus (3 g.L⁻¹) of Hum-zinc which was at (0.27%) and the lowest was (0.15%). Regarding the triple interaction, the results revealed that there were significant differences among all factors in phosphor percentage. Indicating that the combination among the globe master cv., (20 g.M²) and (15 g.M²) of Bio health, and (0 g. L⁻¹) of Hum-zinc improved phosphor percentage to the highest value of (0.28 %), and the lowest value was recorded which was (0.11%) as compared to other interactions.

Table (6): The effect of Hybrids by bio health and hum-zinc, and their interactions on phosphor percentage of cabbage.

Hybrids	Bio health (g.M ²)	Hum-zinc (g.L ⁻¹)			Hybrid * Bio	Mean effect of Hybrid
		0	1.5	3		
Tropicana	0	0.24 d	0.25 d	0.28 ab	0.26 a	0.23 a
	15	0.21 e	0.25 cd	0.26 bc	0.24 b	
	20	0.21 e	0.20 f	0.21 ef	0.21 c	
Globe master	0	0.15 h	0.17 g	0.26 c	0.19 d	0.22 b
	15	0.28 ab	0.24 d	0.25 cd	0.26 a	
	20	0.28 a	0.11 i	0.25 cd	0.21 c	
Mean effect of Hum-zinc		0.23 b	0.20 c	0.25 a		
Hybrid* Hum-zinc	Tropicana	0.22 c	0.23 b	0.25 a	Mean effect of Bio health	
	Globe master	0.24 b	0.17 d	0.25 a		
Bio health * Hum-zinc	0	0.19 f	0.21 e	0.27 a	0	0.22 b
	15	0.25 bc	0.24 c	0.26 b	15	0.25 a
	20	0.24 bc	0.15 g	0.23 d	20	0.21 c

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

7- Potassium percentage (%)

Data presented in Table (7) indicated that there were significant differences between the two hybrids on potassium percentage when the best value was recorded in the globe master cv. (0.99 %) compared to the Tropicana cv. (0.90 %). However, Bio health showed significant effect on potassium percentage the highest value was (0.97 %). while spraying with Hum-zinc significantly influenced plant potassium percentage, the third concentration (3 g.L⁻¹) and control documented the highest result (0.25%). The interaction of hybrid and Bio health showed a difference between them, where the superior interaction was recorded in the globe master cv. at the concentration (15 g.M²) of Bio health which was (1.02%). Also, the interaction between hybrid and Hum-zinc recorded significant influences on potassium percentage. The concentration (0 g.L⁻¹) of Hum-zinc in the Globe master cv. had the highest value (1.00 %). Concerning interaction between Bio health and Hum-zinc resulted in a significant effect between them, where the maximum value was measured in the interaction between (20 g.M²) of Bio health plus (0 g. L⁻¹) of Hum-zinc which was at (1.00%) and the lowest was (0.88%). Regarding the triple interaction, the results revealed that there were significant differences among all factors in potassium percentage. Indicating that the combination among the globe master cv., (15 g.M²) of Bio health, and (0 g. L⁻¹) of Hum-zinc improved potassium percentage to the highest value of (1.07 %), and the lowest value was recorded which was (0.83%) as compared to other interactions.

Table (7): The effect of Hybrids by bio health and hum-zinc, and their interactions on Potassium percentage of cabbage.

Hybrids	Bio health	Hum-zinc (g.L ⁻¹)	Hybrid *	Mean effect
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	(g.M ²)	0	1.5	3	Bio	of Hybrid
Tropicana	0	0.83 g	0.84 g	0.88 f	0.85 e	
	15	0.88 f	0.84 g	0.96 cd	0.89 d	0.90 b
	20	0.98 c	0.95 d	0.96 cd	0.96 c	
Globe master	0	0.93 e	0.98 c	0.98 c	0.96 c	
	15	1.07 a	1.02 b	0.97 c	1.02 a	0.99 a
	20	1.02 b	0.97 c	0.96 cd	0.98 b	
Mean effect of Hum-zinc		0.95 a	0.93 b	0.95 a		
Hybrid * Humic	Tropicana	0.90 e	0.88 f	0.93 d	Mean effect of Bio health	
	Globe master	1.00 a	0.99 b	0.97 c		
	0	0.88 f	0.91 e	0.93 d	0	0.91 c
Bio health *	15	0.98 b	0.93 d	0.97 bc	15	0.96 b
	20	1.00 a	0.96 bc	0.96 c	20	0.97 a

Means of each factor and their interactions followed by different letters are significantly different from each other according to DMRT at 5% level.

Discussion

Cabbage has many hybrids around the world, in this experiment Globe master hybrid was superior to the Tropicana hybrid significantly in most all studied parameters. This trend agreed with [10], Globe Master hybrid excelled in total head weight, marketable weight, total yield, marketable yield, the chlorophyll content of the wrapped leaves.

This could be due to that the hybrids have different potential for growth and productivity and the sensitivity of genes, morphological properties, and physiological factors during the crop's growth phase are responsible for this diversification, which primarily depends on physiological processes regulated by the interaction of genetic and environmental variance [11]. Also plays a great role for higher yield of the crop. [12]. showed that Tatsoi hybrid had significantly more leaves than Misome, when study the effect of hybrids on cabbages growth. [13] carry out a study of two cabbage hybrids (Glob Master and Ruby Perfection), Result showed that Glob Master plants recorded higher head weight, and yield than those of Ruby Perfection. [14] who illustrated in a study of two cabbage hybrid that the fireball F1 superior to Zeina hybrid in (number of leaves, wight of head kg, total yield and marketable yield ton ha¹). Application of bio health at 20 g·m⁻² resulted in significantly higher values across several growth and yield parameters compared to other treatment levels. Specifically, it led to marked increases in stem length (Table 2), average head weight (Table 3), and total yield (Table 4), along with improved phosphorus and potassium content in plant tissues (Table 6 and Table 7, respectively). This enhanced performance can be attributed to the synergistic effect of the biofertilizer components—*Trichoderma* spp., *Bacillus* spp., humic acid, and seaweed extract. These bio-components contribute to improved soil fertility and nutrient availability by promoting nutrient solubilization, organic matter decomposition, and root development Bashan [15]. The increase in organic matter also boosts microbial activity and nutrient cycling, further supporting plant growth.

In parallel, foliar spraying of Hum-Zinc at 3 g·L⁻¹ significantly influenced number of rolled leaves per plant (Table 1), nitrogen percentage (Table 5), and again phosphorus percentage (Table 6). The positive impact of micronutrient foliar application can be scientifically explained by their role as cofactors in numerous metabolic pathways. For instance, zinc is involved in enzyme activation and auxin synthesis, while iron and manganese play critical roles in chlorophyll production and photosynthesis. Foliar-applied nutrients also bypass soil constraints and are readily absorbed through leaf cuticles and stomata, leading to faster physiological responses [16]. The overall enhancement in cabbage growth and yield attributes through both biofertilization and foliar fertilization is consistent with previous findings in cabbage and related crops [17] [6]. Notably, all micronutrients—except boron—positively influenced growth and yield traits, indicating that balanced nutrient management, both through soil and foliar pathways, is crucial for optimal cabbage production [18] [19].

Conclusion:

According to the previous results, Hybrids, Hum-zinc and Bio health have a positive effect on plant growth and yield. The Globe master F1 hybrid has superiority over the Tropicana F1 hybrid in almost all parameters. The spraying of Hum-zinc and Bio health affected in most parameters. Globe master hybrid and Bio health at (20 g.M²), Hum-zinc at (1.5g. L⁻¹) it was the best effect on cabbage.

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تأثير اسمدة بايو هيلث و هيوم-زينك على النمو والعائد وجودة هجيني كرنب تحت البيت البلاستيكي

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الخلاصة

أجري هذا التجريب خلال موسم الزراعة الخريفي لعام 2024-2025 في بيت بلاستيكي بمساحة 300 متر مربع بدون تدفئة، في قسم البستنة بكلية علوم الهندسة الزراعية، جامعة دهوك، إقليم كردستان، حيث يقع الموقع جغرافياً عند خط عرض 36.51° شمالاً، وخط طول 42.52° شرقاً، وارتفاع 473 متراً فوق سطح البحر، العراق. تم تنفيذ تجربة عاملية باستخدام التصميم العشوائي الكامل للكتل (تصميم مقسم) مع ثلاث مكررات، وشملت 54 معالجة. تراوحت المعالجات بين مزيج من هجيني ملفوف الكرنب 'Tropicana' و 'Globe Master'، وثلاثة مستويات من مادة "بايو هيلث" (0 جم، 15 جم، و 20 جم لكل متر مربع)، وثلاثة مستويات من الرش الورقي بمحلول "هيوم-زينك" (0 جم، 1.5 جم، و 3 جم لكل لتر). هدفت الدراسة إلى تقييم تأثيرات تطبيق مادة بايو هيلث والرش الورقي بمحلول هيوم-زينك على النمو والإنتاجية وعائد محصول الكرنب.

أظهرت النتائج تفوق الهجين 'Globe Master' بشكل ملحوظ مقارنة بالهجين 'Tropicana' من حيث عدد الأوراق الملفوفة (29.43 ورقة لكل نبات)، ومتوسط وزن الرأس (1.61 كجم)، والإجمالي الكلي للعائد (58.92 طن/هكتار)، ونسبة النيتروجين (2.65%)، ونسبة البوتاسيوم (0.99%). بينما تفوق الهجين 'Tropicana' في طول الساق (9.60 سم) ونسبة الفوسفور (0.23%). كما أثر تطبيق مادة بايو هيلث بشكل كبير على جميع المتغيرات المقاسة، مما يبرز دورها في تعزيز أداء النبات. وبالمثل، أثر الرش الورقي بمحلول هام-زينك بشكل ملحوظ على جميع صفات النمو والعائد ما عدا طول الساق.

كانت أفضل النتائج لمعظم خصائص النمو الخضري، والعائد الكلي، ومكونات العائد مع تطبيق مادة بايو هيلث بمعدل 20 جم/م² والرش الورقي بمحلول هام-زينك بتركيز 3 جم/لتر. تشير هذه النتائج إلى أن الاستخدام المتكامل لمادة بايو هيلث والرش الورقي بمحلول هام-زينك يمكن أن يحسن بشكل فعال نمو الكرنب وعائده ومحتوى العناصر الغذائية فيه تحت ظروف الزراعة المحمية. تسلط هذه الدراسة الضوء على إمكانيات الجمع بين المحسنات العضوية والرش الورقي بالمغذيات الدقيقة لتحقيق زراعة كرنب مستدامة ومنتجة.

الكلمات المفتاحية: الكرنب، الخضروات، الهجين، الأسمدة الحيوية، المغذيات الدقيقة، العائد.