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BIOSTIMULANT ISABION AND ZINC EFFECT ON THE PRODUCTION AND QUALITY TRAITS OF CABBAGE (*BRASSICA OLERACEA* L.)

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SUMMARY

The following research assessed the effect of the biostimulant isabion and zinc on the productivity and quality parameters of two cabbage (*Brassica oleracea* L.) hybrids. The experiment, carried out in the autumn of 2023–2024, transpired at the University of Kerbala, District Al-Husseiniyah, Kerbala Governorate, Iraq. The experiment, laid out in a randomized complete block design, had a split-plot arrangement with three replications. The main plots comprised two cabbage hybrids: Zeina F1 (red cabbage) and Wight Moon (green cabbage). Meanwhile, the subplots included eight fertilizer combinations with different ratios. Results showed hybrid green cabbage was superior in head weight, marketable yield, total yield, and protein percentage in leaves, with average values of 1,087.34 g head^{-1}, 31.32 t ha^{-1}, 38.72 t ha^{-1}, and 12.44%, respectively. As for fertilizer treatments, evidently, the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) excelled in head weight, marketable yield, total yield, total dissolved solids, ascorbic acid, and protein content in leaves. Their average values are 1,252.43 g head^{-1}, 36.07 t ha^{-1}, 42.93 t ha^{-1}, 4.48%, 69.04 mg 100 mg^{-1}, and 17.26%, respectively. The interaction between both factors was also significant for all the cabbage traits under study.

Keywords: Cabbage (*B. oleracea* L.), biostimulant Isabion, zinc, growth and yield traits, ascorbic acid, protein content

Key findings: Results revealed hybrid green cabbage (*B. oleracea* L.) was leading in head weight, marketable yield, total yield, protein content, and ascorbic acid in the leaves. As for fertilizer treatments, the fertilizer combination of Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) also excelled in all the cabbage traits.

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INTRODUCTION

Cabbage (*Brassica oleracea* L.) has become a recognized culinary ingredient since ancient times. The foliage can be edible in its raw and cooked forms, exhibiting hues of green, whitish-green, and crimson. The plant's foliage gathered and encircled around a terminal bud to develop the head. Cabbage, considered among the top 20 vegetables, holds significant importance as a global food source (Gerszberg, 2018). Cabbage is a vegetable that has been cultivated for a long time. Based on the most recent data, the global cultivation of cabbage covers over 2.45 million hectares, with an average yield of 30,411 kg ha^{-1} (FAO, 2023).
Cabbage holds a significant position in nutritional values, rendering it a crucial food item. Cabbage leaves are abundant in iron, phosphorus, and calcium. The 100 g of cabbage contains 94% water, 20 g carbohydrates, a small protein content (1%–2.5%), sugar (6%), fixed oil, and minerals, such as iron (260 mg), phosphorus (41 mg), and calcium (42 mg). Additionally, cabbage leaves contain vitamins K, B1, B2, B3, B6, A, and C, as well as an anti-ulcer agent called vitamin U, and ascorbic acid (Meena *et al.,* 2010).

Recently, substantial research has demonstrated that specific organic products possess the capacity to induce biological processes. Currently, a collection of these efficacious products has attained the category of biostimulants. Biostimulants encompass a diverse array of chemicals and microorganisms, functioning to enhance the growth of crop plants. These biostimulants exert influence on several physiological processes, such as respiration, nucleic acid synthesis, photosynthesis, and the enhancement of element absorption and chlorophyll concentration in plants. Additionally, it plays a critical role in enhancing the plant's ability to withstand different stresses (Calvo *et al.,* 2014).

The micronutrient zinc emerged to be of utmost importance. Zinc ions' absorption of the plants is the form of Zn^{++}. Plant growth also bears adverse impacts from any deviation below the critical limit. Plants require zinc in minimal amounts, as the typical zinc concentration in plants falls within the range of 20–100 mg kg^{-1} (Chizzola, 2012). However, Al-Myali *et al.'s* (2020) findings indicated the zinc concentration in tissues of economically significant plants ranges from 25 to 150 mg kg^{-1}. Zinc deficiency symptoms manifest at concentrations below 20 mg kg^{-1}, while symptoms of toxicity appear at concentrations exceeding 400 mg kg^{-1}. Plants exhibit varying degrees of susceptibility to zinc shortage, namely, resistance, sensitivity, and moderate sensitivity. Typically, vegetable crops sustain moderate to high effects from zinc deficiency (Alloway, 2008).

Zinc is also necessary in a smaller amount; however, its influence is only within toxicity and weak growth, resulting in physiological disturbances in crop plants. Zinc deficiency leads to reduced yield, compromised quality, and weak roots. Yellowing of the leaves in the regions between the transport channels emerged as an indication of its lack (Mahmoud *et al.,* 2019). Zinc deficiency symptoms manifest initially on the newly sprouted leaves of plants due to their immobile nature. Consequently, it is not possible to transfer it from aged tissues to young tissues, and hence employing a foliar feeding technique to address the insufficiency (Livingstone, 2015). With this, the presented study sought to investigate the impact of the biostimulant Isabion and zinc and their interactions on the productivity and quality traits of two cabbage hybrids.

MATERIALS AND METHODS

Experimental site and procedure

The latest study transpired during the autumn of 2023–2024 at the University of Kerbala, Kerbala, Iraq, to study the effect of the biostimulant Isabion and zinc on the productivity and quality parameters of two cabbage (*B. oleracea* L.) hybrids. The experimental land's appropriate preparation comprised partitioning into three distinct sectors, with each sector containing a total of 16 experimental units. The experimental unit consisted of five planting lines, each measuring 5 m in length and 1.25 m in width. The spacing between lines was 1 m, while the spacing between plants was 35 cm. This resulted in an estimated distance of 1 m between sectors. Facilitating irrigation employed a drip irrigation system, with each plant receiving one dripper.

Treatments and experimental design

The experiment layout had a randomized complete block design (RCBD) with a split-plot arrangement and three replications. Main plots included two hybrids of cabbage: Zeina F1 (red cabbage) and Wight Moon (green cabbage). The subplots engaged the application of eight fertilizer combinations of the biostimulant Isabion and zinc, as follows: control, Isabion (3 L ha^{-1}) + zinc (0 g L^{-1}), Isabion (6 L ha^{-1}) + zinc (0 g L^{-1}), Isabion (9 L ha^{-1}) + zinc (0 g L^{-1}), Isabion (0 L ha^{-1}) + zinc (1 g L^{-1}), Isabion (3 L ha^{-1}) + zinc (1 g L^{-1}), Isabion (6 L ha^{-1}) + zinc (1 g L^{-1}), and Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}). The added biostimulant Isabion consists of nitrogen (10%), organic materials, amino acids (62.5%), and free amino acids (10.3%). Its application was at the following levels: 0, 3, 6, and 9 L ha^{-1}. In combination with two levels of zinc sulfate (0 and 1 g L^{-1}), their spraying on the leaves ensued after 30 days of planting, while the second application occurred two weeks later after the first spraying.

Experimental process

Cabbage seedlings, procured from a privately owned nursery, proceeded to subsequent sowing in the field until reaching maturity of 45 days. In each treatment, a quantity of 15 t ha^{-1} of decomposed sheep dung fertilizer succeeded application below the planting line (Hasan and Solaiman, 2012). Additionally, the use of granulated NPK chemical fertilizer (15:15:15) ensued. A total of 200 kg ha^{-1} application to seedlings occurred during the planting phase and the growth period. The cabbage plants' irrigation with chemical fertilizers (NPK) dissolved in water used a drip irrigation system every 15 days throughout the growing season. The harvesting process took place when plants reached the marketing stage. The experimental soil sustained three applications of the biostimulant Isabion, occurring two weeks after transplantation, with a two-week delay between each watering.

Data recorded

Head weight (g $plant^{-1}$) measurement was by weighing five heads and then averaged. The calculation of total marketable yield (t ha^{-1}) applied the following equation:

$$\text{Total marketable yield (kg ha}^{-1}\text{) = plant productivity (kg plant}^{-1}\text{)} \times \text{plant density per hectare}$$

The measurement of the percentage of total soluble solids (TSS) utilized a manual refractometer (Ibrahim, 2010). The percentage of carbohydrates in flower tablets also incurred calculation according to the method of Joslyn (1970). Calculating the protein percentage in the leaves was according to the following equation:

$$\text{Protein (\%) = Nitrogen (\%)} \times 6.25$$

Statistical analysis

After tabulating all the data related to the study, an analysis continued according to the RCBD with two factors. The least significant difference ($LSD_{0.05}$) test used helped compare and separate the means (Al-Rawi and Khalaf-Allah, 2000).

RESULTS AND DISCUSSION

Head weight

The cabbage hybrids showed notable differences for head weight in cabbage (Table 1). On marketable head weight, the green cabbage had a considerable advantage, with an average of 1,087.34 g $plant^{-1}$, representing a substantial increase (32.40%) compared with the red cabbage (821.28 g $plant^{-1}$). This disparity can be due to the differences in genetic makeup of the genotypes, with results as consistent with the findings reported by Al-Mousawi (2022).

The weight of the marketable head received significant influences from the combination of biostimulant Isabion and foliar spray with zinc (Table 1). The results indicated the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) outperformed the other treatments, with an average head weight of 1,252.43 g plant^{-1} versus the control treatment, which displayed the lowest head weight (631.99 g plant^{-1}). Optimal nutrient management will inevitably lead to an increase in the levels of some hormones, especially zinc, which, in turn, leads to an increase in the auxin content in plant leaves. This increased auxin content transferred to the head, where it plays a primary role in regulating cell division and elongation (Al-Tamimi, 2022).

The interactions between the fertilizer combinations and the hybrids revealed significant differences for head weight in cabbage hybrids. The interaction of the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) with the green cabbage showed a better head weight (1,402.74 g plant^{-1}) compared with the control treatment of fertilizers with the red cabbage exhibiting the lowest head weight (532.65 g plant^{-1}).

Marketable yield

The analysis revealed notable differences between the two cabbage hybrids for marketable yield (Table 2). Specifically, the green cabbage exhibited a greater advantage in this trait, averaging at 31.32 t ha^{-1}. This represents a substantial percent increase of 32.43% compared with the red cabbage, which yielded an average of 23.65 t ha^{-1}. The choice of cultivar is an essential element in enhancing productivity, in accordance with the appropriate environment. These results agreed with the observations reported by Al-Kaabi (2023), who stated the green cabbage had superior performance versus the red cabbage in most of the production traits.

The different combinations of fertilizers exhibited a favorable impact on the marketable yield in cabbage hybrids (Table 2). The results disclosed that the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) resulted in a productivity of 36.07 t ha^{-1} and excelled all other fertilizer treatments. In contrast, the control treatment exhibited the lowest productivity (18.20 t ha^{-1}). The increase in cabbage yield can refer to the heightened concentration of nutritional elements in the leaves, resulting in enhanced nutrient accumulation and subsequent transfer to storage sites. This, in turn, positively influenced vegetative traits, subsequently increasing yield characteristics. Badir (2021) reported the addition of tryptophan and methionine to red cabbage helped enhance productive indicators. Al-Tamimi's (2022) findings also indicated the application of the amino acid Terra-Sorb boosted productivity of cauliflower plants.

Table 1. Effect of adding the biostimulant Isabion and foliar application of zinc on the head weight of two cabbage hybrids.

Fertilizer combinations	Cabbage hybrids		Means (g head^{-1})
	Zeina F1 (Red cabbage)	Wight Moon (Green cabbage)	
Control	532.65	731.32	631.99
Isabion (3 L ha^{-1}) + Zinc (0 g L^{-1})	688.33	990.31	839.32
Isabion (6 L ha^{-1}) + Zinc (0 g L^{-1})	829.12	1101.92	965.52
Isabion (9 L ha^{-1}) + Zinc (0 g L^{-1})	942.00	1213.12	1077.56
Isabion (0 L ha^{-1}) + Zinc (1 g L^{-1})	677.21	917.00	797.11
Isabion (3 L ha^{-1}) + Zinc (1 g L^{-1})	840.09	1144.32	992.21
Isabion (6 L ha^{-1}) + Zinc (1 g L^{-1})	958.73	1198.02	1078.38
Isabion (9 L ha^{-1}) + Zinc (1 g L^{-1})	1102.11	1402.74	1252.43
Means (g head^{-1})	821.28	1087.34	
$LSD_{0.05}$ Treatments: 43.711, Hybrids: 43.635, Interaction: 61.816			

Table 2. Effect of adding the biostimulant Isabion and foliar application of zinc on the marketable yield of two cabbage hybrids.

Fertilizer combinations	Cabbage hybrids		Means (t ha^{-1})
	Zeina F1 (Red cabbage)	Wight Moon (Green cabbage)	
Control	15.34	21.06	18.2
Isabion (3 L ha^{-1}) + Zinc (0 g L^{-1})	19.82	28.52	24.17
Isabion (6 L ha^{-1}) + Zinc (0 g L^{-1})	23.88	31.74	27.81
Isabion (9 L ha^{-1}) + Zinc (0 g L^{-1})	27.13	34.94	31.04
Isabion (0 L ha^{-1}) + Zinc (1 g L^{-1})	19.50	26.41	22.96
Isabion (3 L ha^{-1}) + Zinc (1 g L^{-1})	24.19	32.96	28.58
Isabion (6 L ha^{-1}) + Zinc (1 g L^{-1})	27.61	34.5	31.06
Isabion (9 L ha^{-1}) + Zinc (1 g L^{-1})	31.74	40.40	36.07
Means (t ha^{-1})	23.65	31.32	
$LSD_{0.05}$ Treatments: 1.2587, Hybrids: 1.2879, Interaction: 1.7801			

The results additionally indicated notable disparities in the interactions between the fertilizer combinations and the cabbage hybrids for marketable yield. The highest marketable yield (40.40 t ha^{-1}) appeared with the interaction of fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) and green cabbage. Meanwhile, the control treatment of the fertilizers with the red cabbage hybrid exhibited the lowest productivity (15.34 t ha^{-1}).

Total yield

For total cabbage yield, remarkable variations were evident in the two cabbage hybrids (Table 3). The green cabbage demonstrated the topmost total yield (38.72 t ha^{-1}), while the red cabbage hybrid showed an average of 31.53 t ha^{-1}). The difference in cabbage hybrids can affect the total yield as a result of the diversity in genetic makeup and morphological characteristics of each hybrid. Some cabbage hybrids were characteristically rapid in growth rates and high in productivity, leading to an increased total yield. Some adapt better to different climatic conditions, such as heat, cold, and drought, which helps in increasing the total yield. Moreover, some hybrids produce larger and denser heads, which increases the weight and total size of the yield of broccoli (*B. oleracea*) (Hatif and Ghazal, 2024).

Outcomes indicated larger differences among fertilizer combinations for the total yield (Table 3). The fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) produced the maximum total yield (42.93 t ha^{-1}), surpassing all treatments. The control treatment gave an average of 24.71 t ha^{-1}). The application of amino acids and zinc can contribute to increasing the yield of cabbage plants for several reasons, including the role of amino acids in improving plants' absorption of other nutrients. This enhances the development of roots and leaves and, thus, increases the accumulation of dry matter. Amino acids also play a primary role in enhancing plants' immunity against diseases and pests, reducing losses resulting from spoilage (Al-Nuaimi, 2011). Additionally, the role of zinc contributes to the synthesis of many enzymes participating in growth and metabolism, as reflected in increasing the total yield in cabbage plants (Taheri *et al.,* 2020).

The interactions between fertilizer combinations and cabbage hybrids also demonstrated significant differences for total yield. The fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) with the green cabbage yielded the greatest total production (44.29 t ha^{-1}), while the control treatment using the red cabbage hybrid had the lowest productivity, with an average of 21.36 t ha^{-1}.

Table 3. Effect of adding the biostimulant Isabion and foliar application of zinc on the total yield of two cabbage hybrids.

Fertilizer combinations	Cabbage hybrids		Means (t ha^{-1})
	Zeina F1 (Red cabbage)	Wight Moon (Green cabbage)	
Control	21.36	28.05	24.71
Isabion (3 L ha^{-1}) + Zinc (0 g L^{-1})	26.74	36.65	31.7
Isabion (6 L ha^{-1}) + Zinc (0 g L^{-1})	32.14	40.00	36.07
Isabion (9 L ha^{-1}) + Zinc (0 g L^{-1})	35.65	43.92	39.79
Isabion (0 L ha^{-1}) + Zinc (1 g L^{-1})	26.87	33.75	30.31
Isabion (3 L ha^{-1}) + Zinc (1 g L^{-1})	31.86	40.73	36.3
Isabion (6 L ha^{-1}) + Zinc (1 g L^{-1})	36.05	42.38	39.22
Isabion (9 L ha^{-1}) + Zinc (1 g L^{-1})	41.56	44.29	42.93
Means (t ha^{-1})	31.53	38.72	
$LSD_{0.05}$ Treatments: 0.4698, Hybrids: 0.1467, Interaction: 0.6644			

Table 4. Effect of adding the biostimulant Isabion and foliar application of zinc on the total soluble solids (%) in the leaves of two cabbage hybrids**.**

Fertilizer combinations	Cabbage hybrids		Means (%)
	Zeina F1 (Red cabbage)	Wight Moon (Green cabbage)	
Control	3.46	3.43	3.45
Isabion (3 L ha^{-1}) + Zinc (0 g L^{-1})	3.69	3.73	3.71
Isabion (6 L ha^{-1}) + Zinc (0 g L^{-1})	3.94	3.93	3.94
Isabion (9 L ha^{-1}) + Zinc (0 g L^{-1})	4.24	4.19	4.22
Isabion (0 L ha^{-1}) + Zinc (1 g L^{-1})	3.73	3.69	3.71
Isabion (3 L ha^{-1}) + Zinc (1 g L^{-1})	3.97	3.87	3.92
Isabion (6 L ha^{-1}) + Zinc (1 g L^{-1})	4.29	4.24	4.27
Isabion (9 L ha^{-1}) + Zinc (1 g L^{-1})	4.46	4.49	4.48
Means (%)	3.97	3.95	
$LSD_{0.05}$ Treatments: 0.0438, Hybrids: N.S, Interaction: 0.0619			

Total soluble solids

According to the analysis of variance for total soluble solids' percentage, nonsignificant differences resulted in the leaves of two cabbage hybrids (Table 4). However, the combination of fertilizers revealed noteworthy variations for total soluble solids' percentage. The treatments Isabion (9 L ha^{-1}) and zinc (1 g L^{-1}) exhibited the supreme concentration of total dissolved solids (4.48%), while in contrast, the control treatment had the least average concentration of TSS (3.45%). The observed elevation in the proportion of TSS can potentially be because of the influence of the biostimulant on the leaf area expansion. This phenomenon optimizes the use of transmitted light rays, thereby exerting a substantial impact on the photosynthesis process. Consequently, it led to an augmentation in carbon metabolism and the synthesis of intricate compounds, including carbohydrates and organic acids like ascorbic acid. These compounds subsequently transferred to the fruits, resulting in an enhanced percentage of TSS and the percentage of soluble solids (Calvo *et al.,* 2014).

The results further showed significant interaction effects between the fertilizer treatments and the cabbage hybrids for the total soluble solids. The peak interaction effects appeared in the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) with the green cabbage, with an average of 4.49%, while the least overlap was in the control treatment for the same hybrid (3.43%).

Ascorbic acid content

From the data, it was evident that the cabbage hybrids demonstrated considerable differences in vitamin C content in the leaves (Table 5). Specifically, the red cabbage hybrid displayed the ultimate vitamin C content (61.18 mg 100 g^{-1}). This value represents a significant change as compared with the green cabbage, which exhibited the lowest vitamin C content (59.18 mg 100 g^{-1}). It is clear that hybrids exert a substantial impact on the enhancement of qualitative indices. The rationale behind this phenomenon is ascribable to the genetic composition of the hybrid and its adaptability to existing environmental conditions. Alternatively, it refers to the physiological disparities between the cabbage hybrids in the composition of raw materials generated during their respective processes. The vitality of the plant was visible in its morphological structure, which, in turn, enhanced its ability to produce and respond to environmental factors. Consequently, it directly and indirectly affected and caused an increase in the qualitative indicators, including amino acids (Burhan and AL-Taey, 2018).

Applying biostimulant Isabion and zinc spraying resulted in notable variations for the ascorbic acid content (Table 5). The fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) gave the highest average of ascorbic acid (69.04 mg 100 g^{-1}) and occurred significantly superior to all other treatments. However, the control treatment had the lowest average, measuring 51.18 mg 100 g^{-1}. The application of biostimulant and zinc spray led to improving the qualitative indicators of the cabbage plant. This phenomenon could be due to the significant effect of the biostimulant in facilitating the plant's acquisition of organic matter and nutrients, thus enhancing the efficiency of carbon metabolism and the accumulation of amino acids in cabbage plants. Nutrient efficiency can also enhance the accrual of nitrogen concentration in plant leaves, which is one of the basic elements in building amino acids and enriching the plants' quality parameters (Alisawi, 2019).

The combined application of fertilizers and the cabbage hybrids resulted in a notable and significant effect on the vitamin C levels in leaves. Specifically, the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) with the red cabbage provided a significantly higher vitamin C content (70.77 mg 100 g^{-1}) than all other treatments. Conversely, the control treatment involving the green cabbage exhibited the lowest vitamin C content (50.63 mg 100 g^{-1}).

Protein content

For protein content, the cabbage hybrids revealed significant variations (Table 6). The protein concentration of the green cabbage hybrid unveiled the topmost value (12.44%), but the red cabbage hybrid demonstrated the lowest protein percentage (11.86%). The

Table 5. Effect of adding the biostimulant Isabion and foliar application of zinc on the ascorbic acid in the leaves of two cabbage hybrids.

Fertilizer combinations	Cabbage hybrids		Means (mg 100 mg^{-1})
	Zeina F1 (Red cabbage)	Wight Moon (Green cabbage)	
Control	51.73	50.63	51.18
Isabion (3 L ha^{-1}) + Zinc (0 g L^{-1})	58.27	55.57	56.92
Isabion (6 L ha^{-1}) + Zinc (0 g L^{-1})	61.80	60.27	61.04
Isabion (9 L ha^{-1}) + Zinc (0 g L^{-1})	67.33	65.73	66.53
Isabion (0 L ha^{-1}) + Zinc (1 g L^{-1})	55.30	52.47	53.89
Isabion (3 L ha^{-1}) + Zinc (1 g L^{-1})	58.73	57.47	58.10
Isabion (6 L ha^{-1}) + Zinc (1 g L^{-1})	65.5	63.97	64.74
Isabion (9 L ha^{-1}) + Zinc (1 g L^{-1})	70.77	67.30	69.04
Means (mg 100 mg^{-1})	61.18	59.18	

$LSD_{0.05}$ Treatments: 0.5758, Hybrids: 0.5435, Interaction: 0.8143

Table 6. Effect of adding the biostimulant Isabion and foliar application of zinc on the protein (%) in the leaves of two cabbage hybrids.

Fertilizer combinations	Cabbage hybrids		Means (**%**)
	Zeina F1 (Red cabbage)	Wight Moon (Green cabbage)	
Control	7.28	7.38	7.33
Isabion (3 L ha^{-1}) + Zinc (0 g L^{-1})	9.39	9.67	9.53
Isabion (6 L ha^{-1}) + Zinc (0 g L^{-1})	12.08	12.84	12.46
Isabion (9 L ha^{-1}) + Zinc (0 g L^{-1})	13.96	14.61	14.29
Isabion (0 L ha^{-1}) + Zinc (1 g L^{-1})	8.70	9.08	8.89
Isabion (3 L ha^{-1}) + Zinc (1 g L^{-1})	11.85	12.95	12.4
Isabion (6 L ha^{-1}) + Zinc (1 g L^{-1})	14.54	15.59	15.07
Isabion (9 L ha^{-1}) + Zinc (1 g L^{-1})	17.08	17.43	17.26
Means (**%**)	11.86	12.44	
L.S.D $_{0.05}$ Treatments: 0.2251, Hybrids: 0.7033, Interaction: 0.3183			

superiority of green cabbage comes from its efficiency in absorbing added nutrients, which consequently reflects positively on the protein percentage in the broccoli *(B. oleracea* var. *Italica* L.) plants (Bagale *et al.,* 2024).

The data presented remarkable variations among the fertilizer combinations for protein content in cabbage leaves (Table 6). Specifically, the fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) exhibited significantly higher protein content (17.26%) than the other treatments. Conversely, the control treatment indicated the lowest protein content (7.33%). Zinc enhances the metabolism of carbohydrates, proteins, and some growth enzymes by boosting the activity of most enzymes, including starch synthetase, leading to an increase in carbohydrate’s production. Additionally, it participates in the activation of several enzymes, including dehydrogenases, proteinases, anhydrases, and peptidases. These enzymes are crucial in the process of protein synthesis, which is essential for the growth of plants (Souri and Hatamian, 2019). Abed-Mater *et al.’s* (2019) findings revealed an increase emerged in the levels of carbohydrates, proteins, ascorbic acid, and the total dissolved solids in broccoli following the foliar zinc treatment (Al-Bayati *et al.,* 2021).

The interactions of fertilizer combinations and cabbage hybrids revealed significant differences in protein content in leaves. The fertilizer combination Isabion (9 L ha^{-1}) + zinc (1 g L^{-1}) with the green cabbage resulted in the maximum protein content (17.43%). In contrast, the control treatment with red cabbage exhibited the minimum protein (7.28%).

CONCLUSIONS

The results revealed the application of the biostimulant Isabion with zinc through foliar spraying performed better and achieved the highest values across most productivity and quality parameters. This could be due to the positive role of the inputs, providing an ideal environment, which led to raising the plant’s efficiency in exploiting available resources.

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