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Enhancement of yield and quality of cabbage through application of some biostimulants

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Abstract: Plant biostimulants are utilized in order to improve cabbage production and enhance qualitative characteristics while avoiding negative and harmful effects on human health because they are completely biodegradable, nontoxic, and do not pose a threat to humans. This study was executed during two winter seasons (2021/2022 and 2022/2023) to study the influence of plant biostimulants e.g. glycine, proline, seaweed extract, ascorbic acid and citric acid on growth, productivity, and head quality of cabbage cv. Brunswick. The results revealed that seaweed extract, glycine and ascorbic acid promoted vegetative growth traits i.e. number and weight of non-wrapped leaves and head weight in both seasons of the study. Moreover, seaweed extract surpassed glycine and ascorbic acid treatments for enhancement of vegetative traits. Treated plants with seaweed extracts showed the highest mean values for yield traits such as plant weight, marketable and total yield. Additionally, glycine and ascorbic acid treatments showed relatively positive effects for yield traits in both seasons, while proline and citric acid insignificant effects. Regarding head traits, glycine treated plants exhibited the largest mean values for equatorial and polar diameters followed by the seaweed extract and ascorbic acid. Likewise, glycine resulted in the largest mean values of head volume followed by seaweed extracts and ascorbic treatments. Dry matter content increased with the application of seaweed extract and glycine, whereas glycine, seaweed extract and ascorbic showed positive effects for TSS in both seasons. Generally, the results reflected relatively high improvement in vegetative, yield and head traits by the exogenous application of plant biostimulants, namely seaweed extracts, glycine and ascorbic; with superiority of seaweed extracts for enhancing cabbage productivity and quality.

Key words: Cabbage, Brunswick, biostimulants, productivity and quality.

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1. Introduction

Cabbage (*Brassica olearacea* var capitata), which belongs to the crucifer family, is an important and most diffused vegetables which can be used raw, in salads, pickles, boiled or cooked. It contains vitamins A, B1, B2, C, dietary fiber and some nourishing minerals. Additionally, it contains important compounds with high antioxidant capacity such as polyphenolic compounds, carotenoids and ascorbic acid (**Podsędek, 2007**)

Current agricultural production mainly depends on chemical fertilizers to achieve high yield; therefore, the conventional practices of fertilization involve the use of nitrogen-based fertilizers to promote vegetative growth. Major problem of cabbage production is the excessive application of synthetic fertilizers to improve productivity, but adversely impact cabbage quality, human health, degradation of soil quality and increase nutrients leaching. Leafy vegetables, moreover, may accumulate high concentrations of nitrate over excess application of nitrogen fertilizers (**Bao-Ming *et al.*, 2004 and Caruso *et al.*, 2011**). Furthermore, the indiscriminate use of agro-chemicals is a serious threat to the natural environment. Thus, the application of biostimulants is increasingly regarded as an environment-friendly agricultural approach namely with edible vegetables; so that the utilization of biostimulants is a viable sustainable practice in order to improve crop production and enhancing qualitative characteristics of cabbage while avoiding negative and harmful effects on human health as they are completely biodegradable, non-toxic, and do not pose a threat to human.

Biostimulants have been reported to considerably increase plant productivity by improving plant growth (**Bashir *et al.*, 2021 and Zarzecka *et al.*, 2020**), nutrients uptake (**Calvo *et al.*, 2014; Brown 2020**); promote crop productivity (**Soltaniband *et al.*, 2022**), promote plant metabolic processes (**Bonini *et al.*, 2020; Rouphael *et al.*, 2022**), induce physiological activities (**Yakhin *et al.*, 2017**), stress tolerance (**Bulgari *et al.*, 2019; Lee *et al.*, 2019** and **Nephali *et al.*, 2020**).

Seaweeds have functional properties that can alter physiological processes. At the same time, they are utilized as a natural source of plant growth promoters. In addition, they are a rich source of minerals, trace elements, amino acids, auxines and cytokinens. The biostimulatory effects of seaweeds extracts in improving various plant growth parameters, quality attributes and crop yield have been reported (**Ali *et al.*, 2023, Rahman *et al.*, 2021 and Shabani *et al.*, 2013)**. Field trials have demonstrated that the application of biostimulant based on seaweed extract, applied at relatively low rates as foliar sprays or soil fertigation, promoted cabbage development expressed as plant fresh weight, total and marketable yields beside ascorbic acid and total sugars content (**Satekge *et al.*, 2016; Nofal *et al.*, 2017and Abou El Magd. 2019**).

Amino acids act as biostimulants that positively impact on plant growth and productivity. Thus, amino acids are considered as essential components of proteins, and play a substantial role in plant metabolism and development. Furthermore, they are important for the synthesis of phytohormones, coenzymes and secondary metabolites and participate in many essential plant growth pathways. Exogenous application of amino acids shows rapid stimulatory effects due to the readily absorbance when applied externally.

The stimulatory effects are the improvement of the growth characters and biochemical constitutes of cabbage plants. The amino acid application significantly increased the growth characters of cabbages such as plant height, shoot fresh and dry weight, leaves number, head weight, and chlorophyll index (**Haghighi *et al.*, 2022**). In the same manner, **Shekari and Javanmardi (2017)** showed that exogenous application of cysteine, methionine and mixtures of amino acid stimulated the broccoli vegetative development encompassing weight of shoot and plant height. Moreover, recent investigation indicated that replacing nitrate nutrition with exogenous amino acids resulted in a reduction of nitrate accumulation in the leaves of leafy vegetables (**Jalali *et al.*, 2020**).

Ascorbic acid showed stimulatory effects to enhance plant development and productivity of different vegetables (**Parađiković *et al.*, 2011 and Naz *et al.*, 2022**). It is integral to physiological processes such as photoprotection, photosynthesis, biosynthesis of enzymes, as well as its function as coenzymes (**Smirnoff, 2002; Hadavi and Ghazijahani, 2022**). In addition, it acts as an enzyme factor, antioxidant, and as a growth regulatory factor. Additionally, it helps plants withstand environmental stresses through the production of gibberellins, anthocyanins and hydroxyproline (**Nicholas and Wheeler, 2000**). Likewise, citric acid promoted plant growth and increased the productivity of various vegetables (**Amer and El Assiouty, 2004 and Soltaniband *et al.*, 2022**).

Therefore, this investigation was undertaken to evaluate the influence of various natural biostimulants e.g. glycine, proline, seaweed extract, ascorbic acid and citric acid on growth, field performance and yield of cabbage plants.

2. Materials and Methods

During the winter seasons of 2021/2022 (first season) and 2022/2023 (second season), two field trials were carried out at the experimental farm. Horticulture Research Institute, to explore the effects of some plant biostimulants on growth, productivity and head attributes of cabbage cv. Brunswick.

Cabbage plants 45 days old were transplanted in the field on ridges (70 cm width) at distance of 50 cm apart on 20th of October during both seasons. The experiments were laid out in a randomized complete blocks design with three replications. Each experimental unit comprised of four rows of five meters long.

Plant biostimulants were applied thrice as a foliar spray during the growth seasons after 20, 40 and 60 days of transplanting in the field as follows (Distilled water (control), Glycine 300 ppm, ascorbic acid 200 ppm, citric acid 250 ppm, seaweed extract at 2 g L^{-1} (*Ascophyllum nodosum*), and Proline 200 ppm). The plants were sprayed in the morning using a pressure sprayer.

Agricultural practices were implemented in accordance with the guidelines provided by the Ministry of Agriculture for the cultivation of cabbage.

When plants reached maturity, ten randomly selected plants were harvested from each plot during the harvesting period to conduct measurements of vegetative growth, yield parameters record and head attributes. The following observations were recorded in both seasons: number and weight of non-wrapped leaves (kg), average plant weight (kg), head weight (kg), marketable yield (ton/fed), total yield (ton/fed), equatorial and polar diameters (cm), head volume (cm^3), dry matter content (%) and total soluble solids (TSS).

The data were subjected to statistical analysis of variance (ANOVA) using a randomized complete block design with Statistix 9.0 (Statistix Analytical Software, 1985 to 2009). The means of the treatments were compared employing the least significant difference (LSD) test, with a significance level set at $P \leq 0.05$ % according to the procedures mentioned by Snedecor and Cochran (1989).

3. Results and Discussion

3.1. Vegetative growth traits

The effect of plant biostimulants on number and weight of non-wrapped leaves, and head weight of cabbage in 2021/22 and 2022/23 seasons are presented in Table 1. These data revealed that the number of non-wrapped leaves increased by the application of seaweed extract in both seasons (14.27 and 12.60, respectively), whereas glycine, proline and ascorbic acid positively influenced the number of outer leaves. Likewise, the seaweed extract treatment gave the highest mean value of weight of non-wrapped leaves (1.41 and 1.23 kg), which indicate that it was the best stimulant for cabbage plants during the early vegetative growth. Furthermore, the treatment of seaweed extract showed largest means of head weight (3,73 and 3.58 kg) in the first and second seasons, respectively followed by the influence of glycine and ascorbic acid.

Table (1). Effect of different plant biostimulants on vegetative growth of cabbage during 2021/22 and 2022/23 seasons

Treatment	No. of non-wrapped leaves		Wt. of non-wrapped leaves		Head weight (kg)	
	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
Control	11.83	10.70	1.05	0.95	2.75	3.03
Glycine	12.90	12.03	1.20	1.11	3.50	3.34
Proline	12.17	11.93	0.98	1.07	3.07	3.10
Seaweed	14.27	12.60	1.41	1.23	3.73	3.58
Citric	12.11	11.42	1.06	1.05	2.80	3.20
Ascorbic	13.77	11.70	1.21	1.14	3.38	3.13
LSD	0.97	1.04	0.25	1.30	0.12	0.28

The enhancement of vegetative growth parameters through the application of seaweed extract may be attributed to its rich content of a various of plant growth-promoting substances including auxins, cytokinins, gibberellins, as well as amino acids, essential nutrients, and trace elements which promote plant growth and development (**Lötze and Hoffman, 2016**). These findings of stimulatory effect of seaweed extract on cabbage growth are in harmony with (**Nofal *et al.*, 2017** and **Abou El Magd, 2019**). Additionally, the positive effect of glycine and ascorbic acid was reported by **Abd Alla *et al.*, 2015; Shooshtari *et al.*, 2020** and **Rosa *et al.*, 2022**)

3.2. Yield traits

Data in Table 2 reveal the impact of plant biostimulants on yield traits, e.g. plant weight, marketable yield and total yield in 2021/22 and 2022/23 seasons. Significant differences were detected on all yield traits by the application of various plant biostimulants in both growing season. A significant stimulation of yield and yield components of cabbage was observed by numerous treatments. In this respect, the largest means of plant weight were attained with the seaweed treatment giving average plant weight of 4.76 and 4.62 kg in the first and second seasons, respectively. Additionally, exogenous stimulation of glycine or ascorbic acid showed that they induce less effects for yield traits. Marketable and total yields were significantly enhanced by the application of seaweed extracts, glycine and ascorbic acid, with the most potent biostimulants were expressed by the saweed extract. The seaweed extract apparently increased marketable yield to 41.84 and 37.85 ton/fed. in the first and second seasons, respectively. Otherwise, using proline or citric acid showed insignificant effects for yield traits when compared to control in both seasons.

Table (2). Effect of different plant biostimulants on yield traits of cabbage during 2021/22 and 2022/23 seasons

Treatment	Plant weight		Marketable yield		Total yield	
	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
Control	4.15	3.90	33.76	32.90	44.62	40.01
Glycine	4.41	4.43	37.50	35.56	47.84	46.54
Proline	4.20	4.02	33.93	32.15	43.03	41.83
Seaweed	4.76	4.62	41.84	37.85	49.30	46.43
Citric	4.25	4.00	33.67	32.76	44.57	40.39
Ascorbic	4.40	4.36	38.81	33.96	46.23	42.59
LSD	0.19	0.31	1.64	1.94	2.45	2.11

Foliar application of biostimulant based on seaweed extract, applied as foliar sprays or soil fertigation, significantly increased the yield parameters of cabbage viz. head fresh weight, total yield, marketable yield. (**Satekge *et al.*, 2016; Nofal *et al.*, 2017** and **Abou El Magd, 2019**).

The stimulating influence of seaweed extracts on increment of yield traits of cabbage might be due to seaweed alga contain many natural plant promoting substances like gibberellins, auxins, cytokinins and, macro-and micronutrients (Fe, Mn, Zn, and Cu), proteins, carbohydrates, amino acids. The increases in yield observed in plants treated with seaweed are believed to be associated with numerous growth-promoting elements found within the seaweed extracts. Furthermore, applying seaweed extracts to plants grow in poor soils demonstrated improved root system, so that plants with more robust root and longer roots are more efficient for uptake of nutrients from the soil (**Craigie, 2011**).

Ascorbic acid (Vitamin C) treatment showed stimulatory effect due to the role of ascorbic in different physiological process such as photosynthesis, synthesis of enzymes, antioxidant, synthesis of

gibberellins, ethylene, and proline (Smirnoff and Wheeler 2000). Furthermore, ascorbic acid showed stimulatory effects to improve plant growth and yield of different vegetables (**Parađiković *et al.*, 2011; Rahman *et al.*, 2021** and **Naz *et al.*, 2022**). In the same manner, it has been demonstrated that glycine applied exogenously promotes growth of various crops (**Souri*et al.*, 2018** and **Noroozlo *et al.*, 2019**)

3.3. Head traits

The head traits including equatorial and polar diameters and head volume are presented in Table 3. The results showed significant differences among treatments for studied characters of head attributes. Plants treated with seaweed extracts exhibited growth improvement when compared to control plants. Plants treated with glycine exhibited equatorial diameter of 23.63 and 22.13 cm in the first and second seasons, respectively, while they exhibited polar diameters 0f 14.67 and 13.70 cm in the first and second seasons, respectively. In General, the treated plants with glycine showed significantly larger equatorial and polar diameters measurements when compared with other treatments; indicating that the glycine may change the head shape of the treated plants with larger measurements. In the same manner, the treatments of seaweed extracts and ascorbic acid significantly showed the same effect with lesser effect. Meanwhile, the effects of proline and citric acid are fluctuating in the two seasons for the polar and equatorial diameters. With respect to head volume, the glycine treatment showed the largest head volume in both seasons of the study, followed by the treatments of seaweed extracts and ascorbic acid.

Table (3). Effect of different plant biostimulants on head characteristics of cabbage during 2021/22 and 2022/23 seasons

Treatment	Equatorial diameter		Polar diameter		Head volume	
	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
Control	20.07	20.77	12.60	12.53	2653.01	2830.18
Glycine	23.63	22.13	14.67	13.70	4289.91	3517.05
Proline	21.47	20.87	12.20	12.17	2944.59	2772.13
Seaweed	22.03	22.47	13.90	13.07	3532.86	3454.92
Citric	20.97	20.27	11.50	11.97	2649.70	2572.98
Ascorbic	21.83	21.17	13.07	12.73	3266.19	2988.65
LSD	1.45	1.04	0.69	0.34	423.21	251.42

The enhancement of glycine maybe attributed to the rapid stimulatory effects because it is easily absorbed so that could promote the growth and increase head indicators such as head diameters and head volume. Otherwise, the stimulation of seaweed extract and ascorbic acid could be due to their functional characteristics for plant establishment and on further growth and development. Similar results were reported by **Nofal *et al.*, 2017 and Abou El Magd, 2019**).

3.4. Quality traits

Table 4 show the influence of plant biostimulants on percentage of dry matter (DM) content and total soluble solids (TSS) of plant foliage. There is significant variation among treatments for both quality traits. Apparently, spraying plants with seaweed extracts resulted in an increment in dry matter content 11.13 and 10.83% in the first and second seasons, respectively. At the same time, the treatment with glycine or ascorbic acid showed a significant positive effect in both growing seasons. Similar results are in agreements with those reported by **Souri *et al.* (2018)** and **Norzoolo *et al.* (2019)**. In regard to TSS, the data showed favorable positive effects for the glycine, seaweed extract and ascorbic acid. It is difficult, however, to determine precisely which was the optimal influencer on TSS.

Table (4). Effect of different plant biostimulants on quality characteristics of cabbage during 2021/22 and 2022/23 seasons

Treatment	Dry matter (%)		TSS.	
	2021/22	2022/23	2021/22	2022/23
Control	8.63	8.43	6.33	6.63
Glycine	10.03	10.37	7.07	7.30
Proline	9.30	9.47	6.43	6.57
Seaweed	11.13	10.83	7.43	7.53
Citric	8.83	8.47	6.80	6.67
Ascorbic	9.30	9.17	7.80	6.80
LSD	0.41	0.54	0.48	0.36

Dry matter content increments in plants treated with biostimulants are thought to be linked with the improvement of vegetative growth in conjunction with yield parameters and head traits as a result of stimulation effects of various biostimulants. These findings are in agreement with those obtained by **Satekge *et al.*, 2016; Abou El Magd, 2019 and Naz *et al*., 2022**).

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