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Maize Grain Extract as a Plant-Derived Biostimulant for Improving Growth and Yield of Chinese Cabbage

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Abstract

Maize grain extract (MGE) is a low-cost plant-derived input with potential to improve crop performance. This study evaluated the effects of foliar-applied MGE on the growth and yield of Chinese cabbage (*Brassica rapa* var. *chinensis*) under field conditions in Peshawar, Pakistan. Plants were treated with MGE at 0, 50, 100, and 150 g L⁻¹ in a randomized complete block design with three replications. MGE significantly ($P < 0.01$) improved all measured growth and yield traits, with responses increasing with application concentration. The 150 g L⁻¹ treatment produced the highest plant weight (739.72 g) and marketable yield (56.68 t ha⁻¹), compared with 373.97 g and 28.66 t ha⁻¹ in the control, representing a 97.6% increase in yield. It also resulted in the greatest plant height, leaf development, chlorophyll content, and root length. Overall, foliar MGE showed potential as a low-cost input for enhancing Chinese cabbage productivity. Further multi-season trials with nutrient-matched controls are required to confirm its biostimulant effects.

Keywords: Maize grain extract; Biostimulant; Chinese cabbage; Foliar application; Growth; Yield

1. INTRODUCTION

Chinese cabbage (*Brassica rapa* L. var. *chinensis*), commonly known as pak choi or bok choi, is an economically important leafy vegetable belonging to the family Brassicaceae [1, 2]. Believed to have been domesticated in China several thousand years ago, the crop has diversified into several subspecies and cultivar groups, of which *Utilis*, *Pekinensis*, *Rapifera*, and *Chinensis* are the principal ones [3]. Today, Chinese cabbage is cultivated extensively across East, Northeast, and Southeast Asia, occupying 30-40% of the total

vegetable cultivation area in China [4, 5]. Its short growth cycle, wide adaptability to diverse climatic conditions, and high market demand make it an attractive crop for smallholder farmers, including those in Pakistan, where off-season and leafy vegetable production is increasingly important for farm income. In addition to its agronomic value, Chinese cabbage is highly nutritious. It is a rich source of minerals, vitamin C, glucosinolates, polyphenols, amino acids, and carotenoids such as lutein and zeaxanthin, which contribute to human health by reducing oxidative damage and

lowering the risk of certain cancers [6, 7]. However, despite rising consumer demand, its productivity is often constrained by suboptimal growing conditions and intensive reliance on synthetic fertilizers and agrochemicals, which raise production costs and pose environmental risks [8]. Consequently, improving the growth and productivity of Chinese cabbage through sustainable, low-cost, and environmentally friendly inputs is of considerable practical interest to growers. In this context, plant biostimulants have emerged as a promising alternative. Biostimulants are substances or microorganisms that, when applied in small quantities, stimulate natural processes in plants to enhance nutrient use efficiency, abiotic stress tolerance, and crop quality, independent of their nutrient content [8]. Among these, organic biostimulants derived from plant materials are gaining particular attention as environmentally friendly complements or alternatives to synthetic agrochemicals. Maize grain extract (MGE), obtained from *Zea mays* L., is one such biostimulant. It is naturally rich in phytohormones (cytokinins, gibberellic acid, and indole-3-acetic acid), osmoprotectants (proline and soluble sugars), vitamins (ascorbic acid and glutathione), and essential minerals [9, 10].

The beneficial effects of MGE have been documented in several crops. Presoaking bean seeds in MGE improved growth, fresh and dry biomass, and membrane stability under salinity stress [9], while foliar and seed treatments with maize grain-derived biostimulants enhanced salinity and drought tolerance in wheat [10] and mitigated cadmium toxicity by improving antioxidant and polyamine metabolism [11]. Similarly, Mady et al. i.e., Rady et al. [12] reported that MGE alleviated salt-induced growth inhibition and improved physiological performance in common bean. Comparable growth-promoting responses to other plant-derived extracts have been reported in vegetable crops; for example, moringa leaf extract increased yield and postharvest quality of lettuce [13], and seaweed extract enhanced the growth and productivity of Chinese cabbage [14]. In other Brassica species, foliar biostimulants improved physiological performance and yield under drought and heat stress in Indian mustard [15] and kimchi cabbage [16], and enhanced growth and yield of turnip (*Brassica rapa* L.) relative to chemical fertilization [17]. Despite this growing body of evidence in cereals, legumes, and several Brassica crops, information on the response of leafy vegetables, particularly Chinese cabbage (var. *chinensis*) to foliar-applied MGE remains limited. Foliar spraying offers a rapid and efficient route of delivery, allowing bioactive compounds to be absorbed directly through the leaf surface and translocated to growing tissues, which may be especially advantageous for fast-growing leafy vegetables with high canopy demand.

Therefore, the objective of this study was to evaluate the effect of foliar application of maize grain extract at different concentrations (0, 50, 100, and 150 g L⁻¹) on the growth and yield of Chinese cabbage (*Brassica rapa* var. *chinensis*) under field conditions in Peshawar.

2. MATERIALS AND METHODS

2.1 Experimental Site and Design

Table 1. Effect of maize grain extract levels on plant height, leaf length, leaf width, and midrib length of Chinese cabbage. Means followed by different letters within a column differ significantly ($P < 0.01$).

MGE (g L ⁻¹)	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Midrib length (cm)
0	27.333 D	22.800 D	12.310 C	11.267 B

The experiment was conducted during 2024-2025 at the Agriculture Research Institute, Tarnab Farm, Peshawar, Khyber Pakhtunkhwa, Pakistan. A single-factor Randomized Complete Block Design (RCBD) with three replications was used, comprising four levels of maize grain extract (0, 50, 100, and 150 g L⁻¹), giving a total of twelve experimental units.

2.2 Nursery Raising and Transplanting

Chinese cabbage seeds were sown in pods containing nutrient-rich soil on 7 September 2024. Standard land preparation practices clearing of previous crop residues and weeds, deep ploughing, incorporation of organic matter, and bed levelling were carried out prior to transplanting. Seedlings were transplanted into the field on 30 October 2024 at a spacing of 48 cm between plants and 45 cm between rows. Recommended agronomic practices, including irrigation and weeding, were kept uniform across all treatments.

2.3 Preparation of Maize Grain Extract

Maize grain extract was prepared from a local maize genotype following the methods of Alzahrani and Rady (2019) and Alharby et al. (2020). Maize grains were ground with an appropriate volume of distilled water, and the resulting mixture was filtered through filter paper. Stock solutions were then diluted to obtain foliar spray concentrations of 50, 100, and 150 g L⁻¹, alongside a distilled-water control (0 g L⁻¹).

2.4 Data Recorded

Data were recorded for plant height, leaf length, leaf width, midrib length, midrib width, number of leaves plant⁻¹, chlorophyll content (SPAD units), root length, plant weight, and yield (t ha⁻¹), following standard measurement procedures using a measuring tape, a SPAD chlorophyll meter, and an electronic balance, on randomly selected sample plants per treatment/replication. Yield (t ha⁻¹) was calculated as:

$$Yield (t ha^{-1}) = [Yield per plot (kg) \times 10,000 m^2] / [Plot area (m^2) \times 1000].$$

2.5 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using Statistix 8.1, and treatment means were separated using the Least Significant Difference (LSD) test at $P < 0.01$.

3. RESULTS AND DISCUSSION

3.1 Plant Height, Leaf Length, Leaf Width, and Midrib Length

Foliar application of maize grain extract (MGE) significantly ($P < 0.01$) affected plant height, leaf length, leaf width, and midrib length of Chinese cabbage (Table 1). The maximum plant height (33.41 cm), leaf length (28.37 cm), leaf width (16.46 cm), and midrib length (17.15 cm) were recorded at 150 g L⁻¹ MGE, while the minimum values for all four traits were observed in the untreated control. Values increased progressively with increasing MGE concentration.

MGE (g L ⁻¹)	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Midrib length (cm)
50	29.667 C	24.647 C	13.303 BC	12.127 B
100	31.310 B	26.253 B	13.957 B	13.700 B
150	33.410 A	28.367 A	16.460 A	17.153 A
LSD (P<0.01)	2.0412	1.7146	2.1832	3.8127

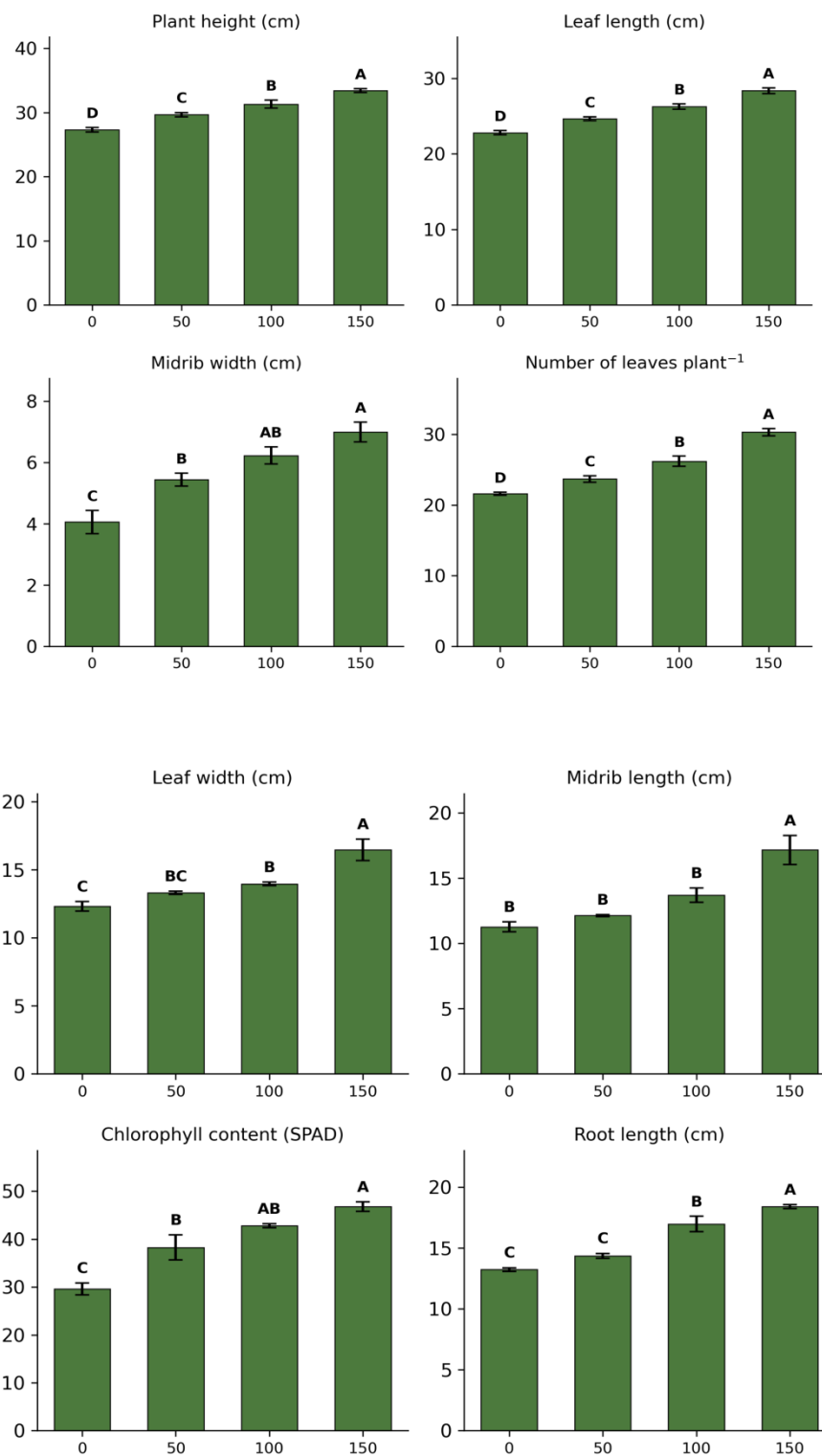


Figure 1. Growth parameters of Chinese cabbage as affected by foliar application of maize grain extract at 0, 50, 100 and 150 g L⁻¹. Bars are means $\pm$ SE (n = 3); different letters above bars indicate significant differences (LSD, P < 0.01).

The improvement in these vegetative traits can be attributed to the rich phytohormonal and nutritional composition of MGE, including cytokinins, indole-3-acetic acid (IAA), gibberellic acid (GA), soluble sugars, ascorbic acid, and minerals. These findings are consistent with [9], who reported improved growth and stress tolerance in bean seedlings raised from MGE-soaked seeds. Similarly, Sarkar et al. [18] reported that IAA application increased plant height and yield attributes in soybean, while Verma and Sen [19] found that foliar application of GA3 and NAA enhanced

coriander growth. The increase in leaf width and midrib length is likely linked to the cytokinin content of MGE, which promotes cell division and expansion in developing leaf tissue [20, 21].

3.2 Midrib Width, Number of Leaves, Chlorophyll Content, and Root Length

Midrib width, number of leaves plant⁻¹, chlorophyll content, and root length were also significantly (P<0.01) improved by MGE application (Table 2). Plants treated with 150 g L⁻¹ recorded the highest midrib width (6.997 cm), number of leaves (30.3), chlorophyll content (46.79 SPAD), and root length (18.40 cm), which were statistically at par with the 100 g L⁻¹ treatment for midrib width and chlorophyll content.

Table 2. Effect of maize grain extract levels on midrib width, number of leaves, chlorophyll content, and root length of Chinese cabbage. Means followed by different letters within a column differ significantly (P<0.01).

MGE (g L ⁻¹)	Midrib width (cm)	No. of leaves plant ⁻¹	Chlorophyll content (SPAD)	Root length (cm)
0	4.060 C	21.600 D	29.600 C	13.233 C
50	5.443 B	23.663 C	38.267 B	14.350 C
100	6.233 AB	26.167 B	42.793 AB	16.967 B
150	6.997 A	30.300 A	46.787 A	18.400 A
LSD (P<0.01)	1.7467	2.0308	7.5468	1.7773

The increase in leaf number can be attributed to the cytokinin, gibberellic acid, and IAA content of MGE, which promote lateral bud development and cell division [22, 23]. The rise in chlorophyll content with increasing MGE concentration is likely due to the ascorbic acid, salicylic acid, and plant growth regulator content of the extract, consistent with reports that gibberellic acid and IAA enhance chlorophyll and photosynthetic pigment synthesis [24, 25]. The improvement in root length agrees with Sushil Kumar [26] and Karan and Özdemir [27], who reported that cytokinin- and gibberellin-based treatments enhanced root number, length, and weight.

3.3 Plant Weight and Yield

Plant weight and yield were significantly (P<0.01) influenced by MGE application (Table 3). The highest plant weight (739.72 g) and yield (56.68 t ha⁻¹) were recorded at 150 g L⁻¹, compared with the lowest plant weight (373.97 g) and yield (28.66 t ha⁻¹) in the control.

Table 3. Effect of maize grain extract levels on plant weight and yield of Chinese cabbage. Means followed by different letters within a column differ significantly (P<0.01).

MGE (g L ⁻¹)	Plant weight (g)	Yield (t ha ⁻¹)
LSD (P<0.01)	123.31	9.4488

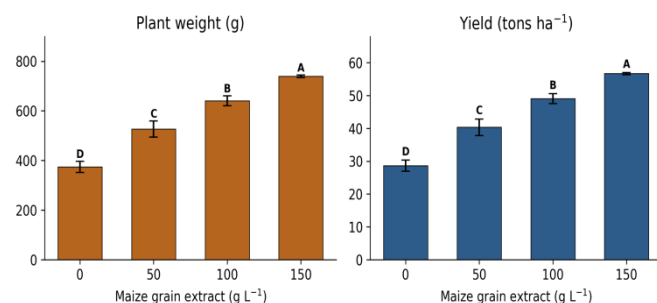


Figure 2. Plant weight and marketable yield of Chinese cabbage as affected by foliar application of maize grain extract. Bars are means $\pm$ SE (n = 3); different letters above bars indicate significant differences (LSD, P < 0.01).

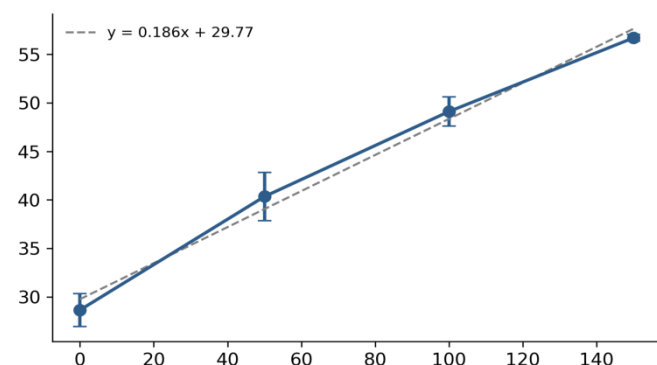


Figure 3. Dose response relationship between maize grain extract concentration and Chinese cabbage marketable yield. Points are treatment means $\pm$ SE ($n = 3$); dashed line is the fitted linear regression.

The increase in plant weight and yield with increasing MGE concentration mirrors the cumulative improvement observed in vegetative and physiological parameters, and is consistent with Semida and Rady (2014), who reported enhanced fresh and dry weight, membrane stability, and drought tolerance in MGE-treated bean seedlings. The results also align with Kumari et al. [28] and Mahender Singh et al. [29], who reported that foliar application of plant growth regulators, particularly gibberellic acid, significantly enhanced growth, yield, and economic returns in okra and maize, respectively. Overall, these findings confirm that MGE acts as an effective, low-cost organic biostimulant capable of improving both the vegetative growth and marketable yield of Chinese cabbage.

4. CONCLUSION

This study demonstrated that a single foliar application of maize grain extract (MGE) significantly enhanced the growth, physiological performance, and marketable yield of Chinese cabbage (*Brassica rapa* var. *chinensis*) under field conditions in the Peshawar valley. All measured parameters, plant height, leaf length and width, midrib length and width, leaf number, chlorophyll content, root length, plant weight, and yield responded positively and progressively to increasing MGE concentration. The 150 g L⁻¹ treatment produced the most favorable results, increasing marketable yield by 97.6% over the untreated control (56.68 vs. 28.66 t ha⁻¹), and is therefore recommended as an effective, low-cost, and environmentally friendly input for Chinese cabbage production in the region. The observed improvement in vegetative growth and yield is consistent with the phytohormone-rich and nutritionally complete composition of MGE, particularly its cytokinins, gibberellins, and indole-3-acetic acid, which likely promoted cell division and expansion, chlorophyll synthesis, and root development. However, because this was a single-site, single-season trial without a nutrient-matched control, it cannot be conclusively determined whether the response reflects a genuine biostimulant effect, a supplementary nutrient effect, or both. Future research should therefore include nutrient-matched and phytohormone-characterized controls, multi-season and multi-location field validation, and physiological and biochemical characterization of the response, before MGE is generalized as a standing grower recommendation. In addition, evaluating higher MGE concentrations and extending this work to other leafy vegetable and Brassica crops would further establish the agronomic and commercial value of this plant-derived biostimulant.

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DECLARATIONS

CONFLICT OF INTEREST: The authors declare no competing interests.

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