

Effect of GA₃ on Morphological Characters of Different Varieties of Broccoli

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Abstract – An experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to evaluate the effect of GA₃ on morphological characters of broccoli. The experiment consisted of two factors: Factor A: Variety of broccoli (three levels) as-V₁: Green magic, V₂: Early green and V₃: Imperial; Factor B: Gibberellic acid-GA₃ (four levels) as G₀: 0 ppm GA₃, G₁: 50 ppm GA₃, G₂: 75 ppm GA₃ and G₃: 100 ppm GA₃. The two factorial experiment was laid out in Randomized Complete Block Design with three replications. Variety and GA₃ influenced significantly on most of the parameters. Among the varieties, green magic showed better morphological characters than others. On the contrary, at 75 ppm GA₃, all the varieties had maximum growth compare to other GA₃ concentrations. When green magic combined with 75 ppm GA₃, they gave the highest results regarding morphology considering other treatment combinations. So, from the findings of this experiment it can be concluded that Green magic and 75 ppm GA₃ was the best for growth and yield of broccoli.

Keywords – Broccoli, GA₃, Morphology, Variety.

I. INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica* L.) belongs to the family Brassicaceae is a biennial and herbaceous “Cole” crops. The edible portion of the broccoli plant consists of tender stem and unopened flower buds. The plants form a kind of head consisting of green buds and thick fleshy flower stalk. Unlike cauliflower, broccoli produces smaller flowering shoots (secondary curds) from the leaf axils after harvest of main apical curds which are also edible. Broccoli has high nutritive value especially vitamin A and vitamin C. Therefore, it can fulfill vitamin A and vitamin C requirement and contribute to solve malnutrition problem in Bangladesh. Sprouting broccoli has about 130 times more vitamin A contents than cauliflower and 22 times more than cabbage (Singh, 2007). Broccoli is a biennial, thermo sensitive herbaceous “Cole” crops in Bangladesh and the most widely grown vegetables in the temperate zones. Growth and curd development of broccoli are greatly influenced by growing environment. As a minor vegetable and newly introduced crop it has less attention by the researchers on various aspects especially plant growth regulators on different variety and a very few studies on the growth and yield of broccoli have been carried out in our climatic condition. Therefore, the research work so far done in Bangladesh is not adequate and conclusive.

Plant growth regulators (PGRs) play a vital role in modulating physiological and morphological traits in crop plants. Among these, gibberellic acid (GA₃) is one of the most widely studied and utilized PGRs due to its capacity to influence stem elongation, leaf expansion, germination and overall vegetative growth. However, the response to GA₃ can vary significantly depending on the genotype and environmental conditions.

Plant growth regulators are organic substances, other than nutrients, that affect physiological processes of plants when applied in small concentrations. Among plant growth regulators, GA₃ exhibited beneficial effect in

several cole crops by stimulating cell division or cell enlargement or both (Badawi, 2008). Application of GA₃ stimulates morphological characters like plant height, number of leaves, curd diameter as well as the weight of the primary curd of broccoli. The concentrations of these chemicals interacting with the environmental conditions play an important role in modifying the growth and yield components of broccoli. This study aims to evaluate the effect of GA₃ on the morphological characteristics of different broccoli varieties. By assessing parameters this research seeks to determine varietal differences in response to GA₃ application, which may aid in optimizing cultivation practices and selecting suitable varieties for enhanced performance under growth regulator treatments. So, to evaluate the response of GA₃ on growth of broccoli is taken and conducted.

II. MATERIAL AND METHOD

A. Description of Experimental Site

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experimental site was situated between 23°74'N latitude and 90°35'E longitude and at an elevation of 8.4 m from sea level.

B. Design and Layout of the Experiment

The experiment consisted of two factors:

Factor A: Variety of broccoli (three levels) as

- i V₁: Green magic.
- ii. V₂: Early green.
- iii. V₂: Imperial.

Factor B: Gibberellic acid-GA₃ (four levels) as

- i. G₀: 0 ppm GA₃ (control).
- ii. G₁: 50 ppm GA₃ (50 mg/l).
- iii. G₂: 75 ppm GA₃ (75 mg/l).
- iv. G₃: 100 ppm GA₃ (100 mg/l).

There were 12 (3×4) treatments combination such as V₁G₀, V₁G₁, V₁G₂, V₁G₃, V₂G₀, V₂G₁, V₂G₂, V₂G₃, V₃G₀, V₃G₁, V₃G₂ and V₃G₃.

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 250.98 m² with length 26.7 m and width 9.4 m. The total area was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were allotted at random. There were 36 unit plots and the size of each plot was 1.8 m × 1.6 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively.

C. Collection, Preparation and Application of Growth Regulator

Plant growth regulator Gibberellic Acid (GA₃) was collected from Hatkhola Road, Dhaka. A 1000 ppm stock solution of GA₃ was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled

water in one litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 50 ml of this stock solution was diluted in 1 litre of distilled water to get 50 ppm GA₃ solution. In a similar way, 75 and 100 ppm stock solutions were diluted to 1 litre of distilled water to get 75 and 100 ppm solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. GA₃ as per treatment were applied at four times 15, 30 and 45, 60 days after transplanting by a mini hand sprayer.

D. Data Collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth as affected by different treatments of this experiment. Data on root length, number of leaves and length of largest leaf were collected at 20, 30, 40 and 50 days after transplanting (DAT) and at harvest. All other yield contributing characters were recorded during harvest and after harvest.

E. Statistical Analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different variety and level of GA₃ on growth and yield contributing characters of broccoli. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

III. RESULTS

A. Number of Leaves Per Plant

Statistically significant differences was recorded due to different varieties of broccoli in terms of number of leaves per plant at 20, 30, 40, 50 DAT and at harvest. At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves per plant (6.55, 8.49, 16.6, 21.4 and 22.9, respectively) was obtained from V₁ which was statistically similar (6.27, 8.27, 15.6, 20.7 and 22.0, respectively) to V₃, whereas the minimum number (5.38, 7.67, 14.0, 17.5 and 19.8, respectively) was found from V₂ at 20, 30, 40, 50 DAT and at harvest, respectively (Table 1). Management practices influence the number of leaves per plant but varieties itself also manipulated it. Ngullie and Biswas (2014) reported that the performances of different hybrids of this crop proved that there was ample scope to grow broccoli due to the prevailing suitable agro-climatic conditions of the region.

Different levels of GA₃ varied significantly in terms of number of leaves per plant of broccoli at 20, 30, 40, 50 DAT and at harvest. At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves per plant (6.91, 8.96, 16.7, 21.4 and 23.2, respectively) was recorded from G₂ which was statistically similar (6.73, 8.66, 16.2, 20.4 and 23.0, respectively) to G₃ and followed (5.60, 8.25, 15.4, 19.9 and 21.6, respectively) by G₁, while and the minimum number (5.02, 6.71, 13.3, 17.7 and 18.4, respectively) was recorded from G₀ at 20, 30, 40, 50 DAT and at harvest, respectively (Table 1). Lendve *et al.* (2010) found that application of GA₃ @ 50 ppm was found significantly superior in terms of number of the leaves.

Different varieties and levels of GA₃ showed statistically significant variation in terms of number of leaves per plant of broccoli at 20, 30, 40, 50 DAT and at harvest due to combined effect. At 20, 30, 40, 50 DAT and at

harvest, the maximum number of leaves per plant (7.47, 9.33, 18.1, 22.8 and 24.0, respectively) was found from V₁G₂, whereas the minimum number (4.53, 8.13, 14.7, 18.1 and 20.0, respectively) from V₂G₀ (Table 2).

Table 1. Effect of different varieties and levels of GA₃ on number of leaves per plant of broccoli at different days after transplanting (DAT).

Treatments	Number of leaves per plant at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
Variety					
V ₁	6.55 a	8.49 a	16.6 a	21.4 a	22.9 a
V ₂	5.38 b	7.67 b	14.0 c	17.5 b	19.8 b
V ₃	6.27 a	8.27 a	15.6 b	20.7 a	22.0 a
LSD _(0.05)	0.312	0.318	0.956	1.24	1.44
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of GA₃					
G ₀	5.02 c	6.71 c	13.3 c	17.7 b	18.4 b
G ₁	5.60 b	8.25 b	15.4 b	19.9 a	21.6 a
G ₂	6.91 a	8.96 a	16.7 a	21.4 a	23.2 a
G ₃	6.73 a	8.66 a	16.2ab	20.4 a	23.0 a
LSD _(0.05)	0.361	0.367	1.10	1.43	1.66
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	6.07	4.60	7.33	7.36	7.88

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Table 2. Combined effect of different varieties and levels of GA₃ on number of leaves per plant of broccoli at different days after transplanting (DAT).

Treatments	Number of leaves per plant at				
	20 DAT	30DAT	40 DAT	50 DAT	Harvest
V ₁ G ₀	5.40 cd	7.20 ef	14.8 cde	20.6 abc	20.3 bc
V ₁ G ₁	6.13 b	8.21 bcd	16.0 abcd	21.0 ab	22.8 ab
V ₁ G ₂	7.47 a	9.33 a	18.1 a	22.8 a	24.0 a
V ₁ G ₃	7.20 a	9.23 a	17.6 ab	21.1 ab	24.4 a
V ₂ G ₀	5.00 de	6.27 g	11.5 f	15.0 e	16.2 d
V ₂ G ₁	4.53 e	8.13 cd	14.7 cde	18.1 cd	20.0 bc
V ₂ G ₂	6.07 b	8.67 abc	15.5 bcde	19.3 bcd	22.4 ab
V ₂ G ₃	5.93 bc	7.60 de	14.4 de	17.5 d	20.4 bc
V ₃ G ₀	4.67 e	6.67 fg	13.7 e	17.6 d	18.6 cd
V ₃ G ₁	6.13 b	8.40 bc	15.4 cde	20.6 abc	22.1 ab

Treatments	Number of leaves per plant at				
	20 DAT	30DAT	40 DAT	50 DAT	Harvest
V ₃ G ₂	7.20 a	8.87 ab	16.6 abc	22.0 ab	23.1 ab
V ₃ G ₃	7.07 a	9.13 a	16.7 abc	22.6 a	24.3 a
LSD _(0.05)	0.625	0.636	1.91	2.48	2.88
Level of significance	0.01	0.01	0.05	0.05	0.05
CV(%)	6.07	4.60	7.33	7.36	7.88

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

B. Length of leaf

The findings of this experiment showed that all the varieties of broccoli had significant effect on leaf length. At 20, 30, 40, 50 DAT and at harvest, the highest length of leaf (16.5, 24.6, 33.0, 39.0 and 40.9 cm, respectively) was recorded from V₁ which was statistically similar (15.9, 23.4, 31.9, 37.5 and 39.3 cm, respectively) to V₃, again the lowest length (15.0, 22.2, 29.9, 36.0 and 37.4 cm, respectively) was attained from V₂ at 20, 30, 40, 50 DAT and at harvest, respectively (Figure 1).

Length of leaf of broccoli varied significantly due to different levels of GA₃ at 20, 30, 40, 50 DAT and at harvest. At 20, 30, 40, 50 DAT and at harvest, the longest leaf (16.6, 24.5, 32.9, 40.0 and 41.5 cm, respectively) was recorded from G₂ which was statistically similar (16.3, 24.2, 32.4, 39.4 and 40.4 cm, respectively) to G₃ and followed (15.9, 23.6, 31.8, 37.5 and 39.6 cm, respectively) by G₁ and the shortest leaf (14.4, 21.3, 29.3, 33.0 and 35.2 cm, respectively) was found from G₀ at 20, 30, 40, 50 DAT and at harvest, respectively (Figure 2).

Combined effect of different varieties and levels of GA₃ showed statistically significant variation in terms of leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest. At different DAT and at harvest, the highest length of leaf (17.6, 26.0, 34.9, 42.6 and 43.9 cm, respectively) was found from V₁G₂ and the lowest length (13.5, 19.6, 28.1, 31.7 and 33.4 cm, respectively) from V₂G₀ (Table 3).

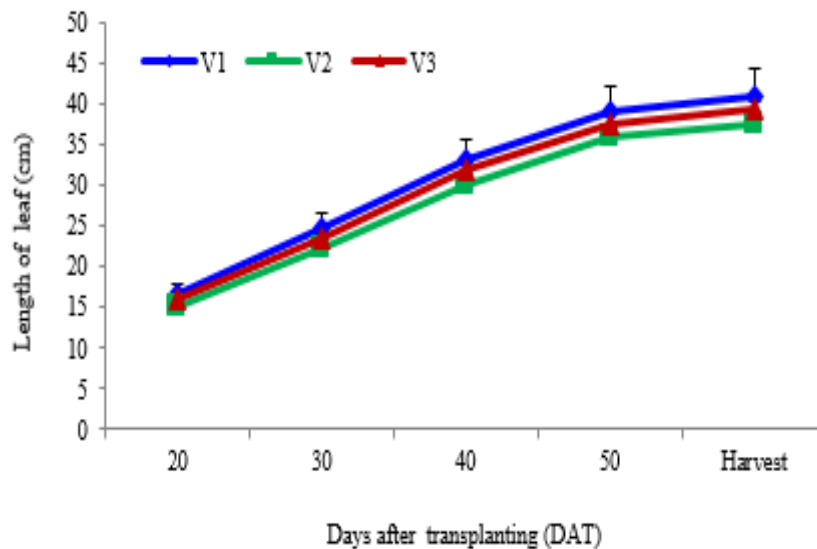


Fig. 1. Effect of different varieties on length of leaf of broccoli. (Vertical bars represent LSD value at 5% level of probability).

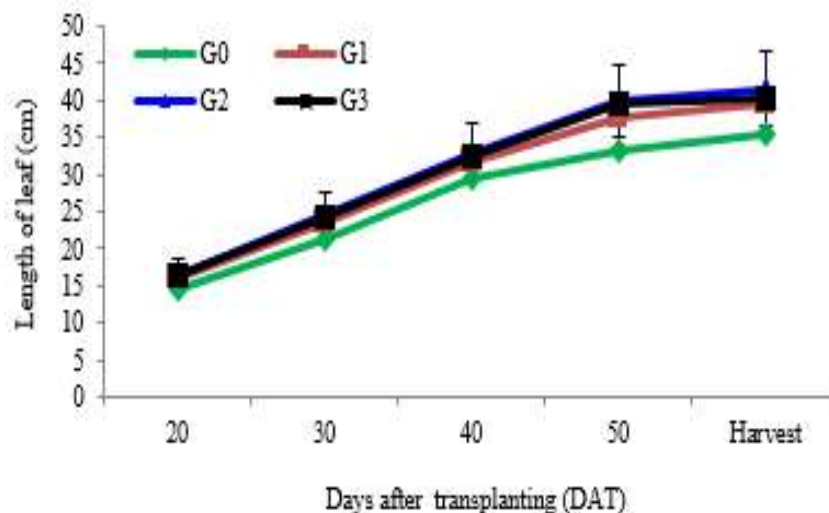


Fig. 2. Effect of different levels of GA₃ on length of leaf of broccoli. (Vertical bars represent LSD value at 5% level of probability).

C. Dry Matter Content of Leaves

Different varieties of broccoli had a significant influence, in terms of dry matter content of leaves. The highest dry matter content of leaves (9.08%) was achieved from V₁ which was followed (8.71%) by V₃, while the lowest dry matter content of leaves (8.14%) was found from V₂ (Table 4).

Dry matter content of leaves of broccoli varied significantly due to different levels of GA₃. The highest dry matter content of leaves (9.14%) was found from G₂ which was statistically similar (9.00%) to G₃ and closely followed (8.77%) by G₁, whereas the lowest dry matter content of leaves (7.66%) was recorded from G₀ (Table 8). This result is closely align with Lendve *et al.* (2010). They found that application of GA₃ 50 ppm was found significantly superior in terms of number of dry weight of the leaves.

Combined effect of different varieties and levels of GA₃ showed statistically significant variation in terms of dry matter content of leaves. The highest dry matter content of leaves (9.61%) was recorded from V₁G₃ and the lowest dry matter content of leaves (7.15%) from V₂G₀ (Table 5).

D. Length of Stem

Different varieties of broccoli showed statistically significant differences in terms of length of stem. The highest length of stem (23.3 cm) was noted from V₁ which was followed (21.6 cm) by V₃, while the lowest length (18.5 cm) was found from V₂ (Figure 3).

Length of stem of broccoli varied significantly due to different levels of GA₃. The highest length of stem (22.6 cm) was recorded from G₂ which was statistically similar (22.0 cm) to G₃ and followed (20.9 cm) by G₁, and the lowest length (18.9 cm) was found from G₀ (Figure 4). This finding is in agreement with Singh (2011). He stated that GA₃ increase the length of stem upto a certain limit of GA₃ concentration.

Table 3. Combined effect of different varieties and levels of GA₃ on length of leaf of broccoli at different days after transplanting (DAT).

Treatments	Length of Leaf at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
V ₁ G ₀	14.8 d	22.5 bc	29.8 e	34.0 f	36.3 f

Treatments	Length of Leaf at				
	20 DAT	30 DAT	40 DAT	50 DAT	Harvest
V ₁ G ₁	16.3 b	24.1 abc	32.5 bc	38.2 cde	40.3 cd
V ₁ G ₂	17.6 a	26.0 a	34.9 a	42.6 a	43.9 a
V ₁ G ₃	17.5 a	25.8 a	34.6 a	41.0 ab	42.9 ab
V ₂ G ₀	13.5 e	19.6 d	28.1 f	31.7 g	33.4 g
V ₂ G ₁	15.4 cd	23.0 bc	30.8 de	36.1 e	38.7 de
V ₂ G ₂	15.8 bc	24.0 abc	31.2 cde	38.8 cd	40.2 cd
V ₂ G ₃	15.0 d	22.2 bc	29.6 ef	37.2 de	37.3 ef
V ₃ G ₀	15.0 d	21.7 cd	29.9 e	33.5 fg	36.0 f
V ₃ G ₁	15.9 bc	23.8 abc	32.0 bcd	38.1 cde	39.9 cd
V ₃ G ₂	16.3 b	23.4 abc	32.5 bc	38.7 cd	40.3 cd
V ₃ G ₃	16.5 b	24.5 ab	33.1 b	40.0 bc	41.0 bc
LSD _(0.05)	0.629	2.34	1.50	2.00	2.00
Level of significance	0.05	0.05	0.05	0.05	0.05
CV(%)	4.35	5.90	4.80	5.15	4.01

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

E. Length of Root

Statistically significant differences were observed in case of length of root. The longest root (22.8 cm) was obtained from V₁ which was followed (21.3 cm) by V₃, while the shortest root (18.8 cm) was recorded from V₂ (Table 4).

Regarding GA₃, the longest root (22.4 cm) was recorded from G₂ which was statistically similar (22.1 cm) to G₃ and followed (20.9 cm) by G₁, whereas the shortest root (18.4 cm) was found from G₀ (Table 4).

F. Fresh Weight of Roots Per Plant

Three varieties of broccoli had positive effect on fresh weight of roots per plant. The highest fresh weight of roots per plant (35.6 g) was recorded from V₁ which was similar (34.6 g) by V₃, while the lowest weight (33.3 g) was found from V₂ (Table 4).

Fresh weight of roots per plant of broccoli varied significantly due to different levels of GA₃. The highest fresh weight of roots per plant (35.7 g) was found from G₂ which was statistically similar (35.2 g and 34.4 g) to G₃ and G₁ and the lowest weight (32.6 g) was recorded from G₀ (Table 4).

Combined interaction of varieties and GA₃ showed statistically significant variation in terms of fresh weight of roots per plant. The highest fresh weight of roots per plant (37.1 g) was recorded from V₁G₂ and the lowest weight (31.3 g) from V₂G₀ (Table 5).

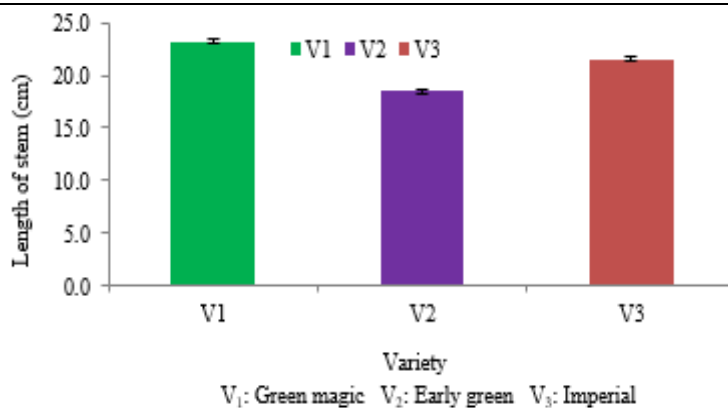


Fig. 3. Effect of different varieties on length of stem at harvest of broccoli. (Vertical bars represent LSD value at 5% level of probability).

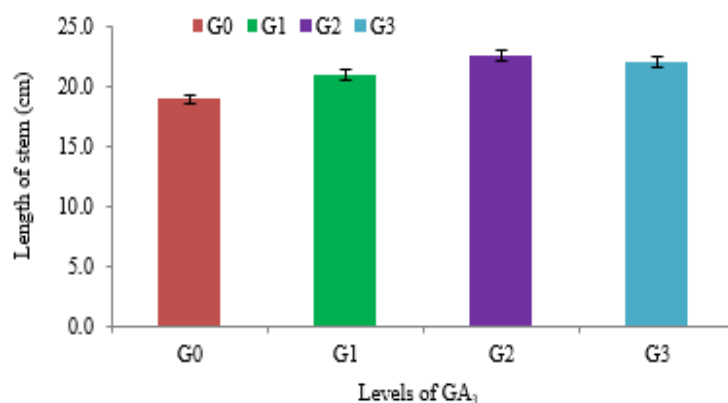


Fig. 4. Effect of different levels of GA₃ on length of stem at harvest of broccoli. (Vertical bars represent LSD value at 5% level of probability).

Table 4. Effect of different varieties and levels of GA₃ on growth and yield contributing characters of Broccoli.

Treatments	Length of root (cm)	Fresh weight of roots per plant (g)	Dry matter content of leaves (%)
Variety			
V ₁	22.8 a	35.6 a	9.08 a
V ₂	18.8 c	33.3 b	8.14 c
V ₃	21.3 b	34.6 a	8.71 b
LSD _(0.05)	0.941	1.06	0.216
Level of significance	0.01	0.01	0.01
Levels of GA ₃			
G ₀	18.4 c	32.6 b	7.66 c
G ₁	20.9 b	34.4 a	8.77 b
G ₂	22.4 a	35.7 a	9.14 a
G ₃	22.1 a	35.2 a	9.00 ab
LSD _(0.05)	1.087	1.23	0.249
Level of significance	0.01	0.01	0.01

Treatments	Length of root (cm)	Fresh weight of roots per plant (g)	Dry matter content of leaves (%)
CV (%)	5.31	6.64	4.94

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

IV. DISCUSSION

A. Varietal Response

Among the three tested varieties, 'Green Magic' consistently exhibited superior vegetative performance across most measured parameters. This can be attributed to its greater inherent vigor and possibly a higher sensitivity to GA₃. These findings corroborate with prior studies indicating significant genotypic variation in response to plant growth regulators (Kumar et al., 2022; Sharma et al., 2019). Genotypic influence on PGR response has also been linked to differences in hormone perception and signal transduction pathways (Zhang et al., 2021).

B. Effect of GA₃ Concentration

The application of GA₃ significantly improved all morphological traits compared to the control (0 ppm), with the optimal effect observed at 75 ppm. Higher concentrations (100 ppm) also enhanced growth but did not provide substantial gains beyond 75 ppm and, in some cases, showed diminishing returns, possibly due to hormonal imbalance or resource competition. These results align with those reported by Singh et al. (2023), who found that moderate GA₃ levels (60-80 ppm) enhanced vegetative and yield traits in cole crops more effectively than higher dosages.

GA₃ is known to promote cell elongation and division, especially in elongating tissues like stems and leaf petioles (Gou et al., 2019). The increase in leaf number and length observed in this study can be attributed to GA₃-induced stimulation of meristematic activity, as described by Farooq et al. (2020), who demonstrated enhanced chlorophyll content and leaf expansion in Brassica crops treated with GA₃.

C. Interactive Effects of Variety × GA₃

The interaction between variety and GA₃ concentration was found to be statistically significant across all observed parameters. Notably, the V1G2 treatment (Green Magic + 75 ppm GA₃) outperformed all other combinations in terms of leaf count, leaf length, stem length, root development and fresh root biomass. This synergistic interaction emphasizes the need for variety-specific PGR optimization, as also highlighted by Zhao et al. (2018) in their work with Chinese cabbage.

Moreover, dry matter content in leaves was also maximized in the V1G3 combination, suggesting that GA₃ may enhance assimilate partitioning to vegetative organs. This is consistent with the findings of Raza et al. (2021), who observed increased dry matter accumulation in GA₃-treated leafy vegetables, attributed to enhanced photosynthetic efficiency and nutrient uptake.

D. Agronomic and Commercial Implications

The study's findings have practical significance for broccoli growers in Bangladesh and similar agro-ecological regions. By selecting the appropriate GA₃ concentration and responsive variety (such as Green

Magic), farmers can improve early vigor, biomass accumulation and possibly curd initiation and size factors critical for marketable yield.

Furthermore, the results emphasize the importance of controlled and optimized use of growth regulators. Excessive or misapplied GA₃ can potentially lead to excessive vegetative growth at the expense of reproductive development (Kumar & Singh, 2020). Hence, integrated management involving varietal selection optimized GA₃ dosing and appropriate cultural practices should be promoted.

V. CONCLUSION

Based on the results of this study, the variety Green Magic demonstrated superior morphological performance when treated with 75 ppm GA₃, indicating its potential as the most responsive genotype under the given conditions. Among all GA₃ concentrations and varieties tested, Green Magic at 75 ppm GA₃ consistently showed enhanced growth traits, suggesting this combination as the most effective for promoting vegetative development in broccoli. The identified concentration (75 ppm GA₃) may serve as an optimal benchmark for further evaluation under field conditions to validate its effectiveness on a larger scale. Additionally, the morphological parameters studied could serve as useful indicators for determining ideal GA₃ concentrations and suitable genotypes in future experiments. These findings provide a foundation for more extensive research aimed at maximizing broccoli yield through the strategic use of plant growth regulators and variety selection.

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