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FOLIAR SPRAY OF GIBBERELLIC ACID INFLUENCES MORPHOLOGICAL ATTRIBUTES AND FOLIAGE YIELD OF CORIANDER (*Coriandrum sativum* L.)

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ABSTRACT

A field experiment was conducted at the research field of Sher-e- Bangla Agricultural University, Dhaka during the period from December 1, 2016 to January 11, 2017 to investigate the effect of gibberellic acid (GA_3) on vegetative growth, morphological attributes and foliage (leaf) yield of coriander (*Coriandrum sativum* L.). The experimental treatments consisted of eight different doses of GA_3 viz., 0 (distilled water spray), 5, 10, 15, 20, 25, 30 and 35 ppm. The variety Rosina (Pahuja Co., India) was used as planting material and different doses of GA_3 were applied on the plants at 25 and 30 days after sowing. The experiment was laid out in Randomized Complete Block Design with three replications. GA_3 had significant effect on vegetative growth, morphology, foliage yield and yield contributing characters of coriander. Plant height, number of leaves plant^{-1}, leaf length, plant spread and single plant weight were found maximum from the application of GA_3 at 20 ppm, which was closely followed by 25 ppm GA_3. Application of GA_3 at 20 ppm produced the highest weight of foliage m^{-2}. A strong positive correlation of foliage yield was observed with plant height, number of leaves plant^{-1}, leaf length, plant spread, single plant weight and weight of foliage m^{-2}. Application of GA_3 at 20 ppm gave maximum foliage yield (9.34 t ha^{-1}) which was followed by GA_3 at 15 ppm (8.46 t ha^{-1}) and 25 ppm (8.06 t ha^{-1}), and the minimum foliage yield was recorded from control (distilled water spray) (4.90 t ha^{-1}). Application of GA_3 at 20 ppm increased foliage yield over control by 47.54 %. A quadratic relationship between applied GA_3 concentration and foliage yield was found; the regression equation was $y = 4.87 + 0.375x - 0.009x^2$ from which it came up to be optimum dose of GA_3 as 20.83 ppm.

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INTRODUCTION

Coriander (*Coriandrum sativum* L) belonging to the family *Apiaceae* is an important spice crop cultivated during winter (*rabi*) season in Bangladesh. It is known as 'Dhania' in Bangla. The coriander plant yields both the fresh green herb and the spice seed. Its fresh twigs, leaves and seeds are used as spices and condiments which have the pleasant aroma. The entire plant of young coriander is used as appetizer in preparing fresh chutneys and sauces, leaves are used to flavour food, curries, soups, fish sauce, cream sauce for chicken, tomato soup, pickling sausages, bakery preparations, liqueurs, gins and meat (Janardhanan and Thoppil, 2004 ;Tiwary and Agarwal, 2004). Coriander leaves and seeds are valued as food mainly for its high Vit. A and Vit. C. Its leves contain 88% water, 32 kcal, 6.0 g carbohydrate, 2.7g protein, 0.5 g fat, 1.0 g fiber and 1.7 g ash , 150 mg Vit. C, 0.01 mg B1, 0.01 mg B2, 1.0 mg Niacin, 150 mg Ca, 55 mg P, 540 mg K, 6 mg Fe and 10, 000 I.U. Vit. A per 100 g fresh weight of leaves (Rubatzky et al., 1999).

Plant growth regulators are organic compounds, which in small amounts; somehow modify a given physiological process. It plays an essential role in many aspects of plant growth and development (Dharmender et al., 1996). These compounds have now been applied to a large variety of plant organs in several ways and it has been found to greatly enhance stem elongation as its most striking effect. Like other crops, application of growth regulators may have an important role in increasing the foliage productivity of coriander. Gibberellic acid is a plant growth hormone involved in various physiological activities such as growth, flowering and ion transport (Wareing and Phillips, 1981; Khan and Samiullah, 2003). This hormone stimulates leaf area expansion (Brock, 1993) and induces elongation and osmoregulation in internodes (Azuma et al., 1997) and ultimately increases dry matter. Application of GA_3 at proper growth stage also influenced growth of coriander (Verma and Sen, 2008). Information regarding coriander leaf (foliage) production by the foliar use of GA_3 is limited in Bangladesh. The present experiment was therefore, undertaken to investigate the effect of gibberellic acid (GA_3) on vegetative growth, morphological attributes and foliage (leaf) yield of coriander.

MATERIALS AND METHODS

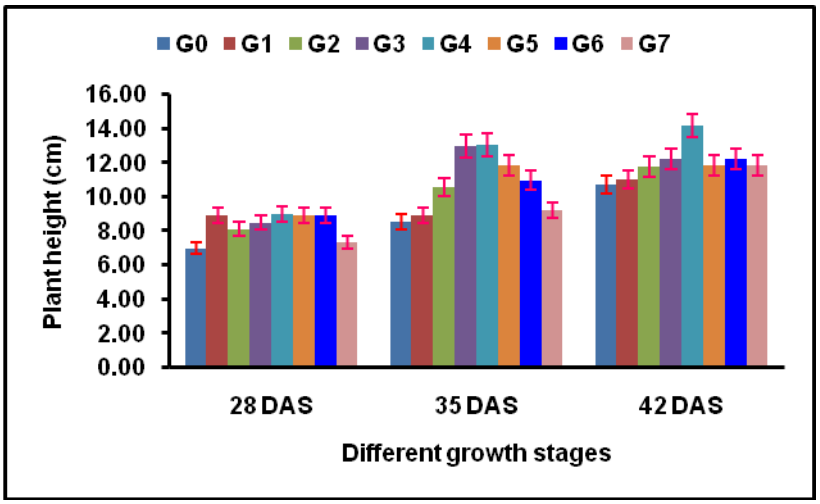
The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from November 2016 to February 2017 to examine the effect of foliar spray of gibberellic acid (GA_3) on the growth, morphological attributes and foliage yield of coriander. The farm is located at $90^0 22'$ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28. The soil was sandy loam in texture having pH 5.47 - 5.63. Coriander variety Rosinan (Pahuza seed Co., India) was used as a test crop. The seed was collected from Siddiq Bazzar, Gulistan, Dhaka. Manures and fertilizers were applied at the rate of cowdung 5 t ha^{-1}, N-P-K: 60-11-25 kg ha^{-1} (Moniruzzman, 2011). The source of N, P and K was Urea, Tripple Super Phosphate (TSP) and Muriate of potash (MoP). The entire amount of cowdung, phosphorus and potassium with the half of nitrogen was applied during final land preparation. The rest of the nitrogen was top dressed at 30 days after sowing of seeds. The experiment consisted of 8 different doses of gibberellic acid (GA_3) (G_0 = 0 ppm, G_1 = 5 ppm, G_2 = 10 ppm, G_3= 15 ppm, G_4= 20 ppm, G_5= 25 ppm, G_6= 30 ppm and G_7= 35 ppm). The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The unit plot size was 3 m x 1 m (3.00 m^2). The seeds (fruits) were rubbed for separating the two mericarps and were soaked in water for 24 hours to facilitate germination. Seeds were also treated with Bavistin @ 2 g per kg of seeds before sowing and were sown in rows 20 cm apart continuously by hand @ 40 kg ha^{-1}. To allow uniform sowing in rows seeds were mixed with some loose soil (about four to five times of weight of seeds). The seeds were covered with good pulverized soil just after sowing and gently pressed by hands. The sowing was done on December 1, 2016 with slight watering just to supply sufficient moisture needed for quick germination. Gibberellic acid solutions were applied in two installments. First spray was done at 2 to 4 true leaf (fully expanded) stage of seedlings with the help of a hand sprayer (2 litre volume) on 5th January, 2017. Two liters spray volume of each GA_3 concentration was sprayed to the plants. Second spray was done after 7 d of 1st spray.

For control plants, distilled water was sprayed. The field was kept weed free by hand weeding. Weeding was done after 35 days after sowing (DAS). For good germination water was given to the plots every two days by water can with fine mashed nozzle till germination. Then two irrigations were given at 25 and 35 days after sowing. There was no disease incidence and insect infestation to the crops. Unit plot was divided into three portions, each measuring 1.0 square meter. Ten plants from each portion of the plot were selected as random and were tagged for the data collection. Ten plants from two portions of the unit plot were harvested separately at 28 DAS and 35 DAS by cutting just beneath the soil and data on plant height, number of leaves plant^{-1}, length of the largest leaf (cm), plant spread (cm), individual plant weight (g) and dry weight of individual plant (g) were recorded. Final harvesting of all plants from the unit plot was done on 11 January 2017 by cutting just beneath the soil when few plants were seen to bolt at 42 DAS, and from the selected ten plants of the third portion of unit plot data on plant height, number of leaves plant^{-1}, length of the largest leaf (cm), plant spread (cm), individual plant weight (g) and dry weight of individual plant (g) were taken; data on other parameters (number of plants per square meter, weight of foliage per square meter (kg) and foliage yield per plot (kg) were also recorded. Foliage yield per plot (kg) was converted to per hectare yield (t ha^{-1}). Data were statistically analyzed by using MSTAT C statistical package programme. Significance of differences between pairs of treatment means was evaluated by Duncan's Multiple Range Test at 5% level of probability by DMRT.

RESULTS AND DISCUSSION

Plant height

The plant height recorded at 28, 35 and 42 days after sowing (DAS) varied significantly due to application of GA_3 (Fig.1). At 28 DAS, the maximum plant height (8.95 cm) was observed in G_4 (20 ppm GA_3) treatment, which was statistically similar with G_1, G_2, G_5, G_6 and the minimum plant height (6.98 cm) was observed in G_0 (control) treatment. At 35 DAS, the tallest plant (13.03 cm) was found in G_4 treatment, which was statistically similar with G_3 and G_5 treatment and the shortest plant (8.54 cm) was obtained from G_0 treatment. At 42 DAS, the maximum plant height (14.17 cm) was recorded from G_4 treatment which was statistically different from other and the shortest plant (10.73 cm) was found from G_0(control). Roy et al. (2011) noticed the maximum plant height with GA_3 at 50 ppm in cabbage. Similar results were also found by Chaurasiy et al. (2014) who noticed that GA_3 60 ppm significantly increased the plant height (33.26 cm) than control in cabbage. Patel (2006) obtained maximum plant height of radish by spraying of GA_3 at 20 ppm. Haq et al. (2013) and Pariari et al. (2012) reported that GA_3 100 ppm and 25 ppm application to black cumin crop gave the highest plant height, respectively.

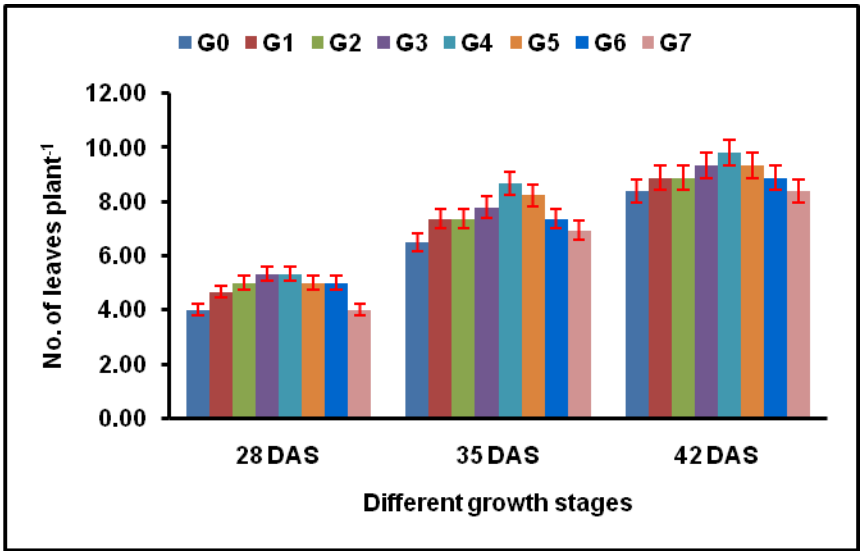


G_0 = 0 ppm GA_3, G_1 = 5 ppm GA_3, G_2 = 10 ppm GA_3, G_3 = 15 ppm GA_3, G_4 = 20 ppm GA_3, G_5 = 25 ppm GA_3, G_6 = 30 ppm GA_3 and G_7 = 35 ppm GA_3 ; DAS = Days after sowing

Figure 1. Effect of gibberellic acid (GA_3) on plant height of coriander at different growth stages. Error bars indicate standard error (SE) of three replicates.

Number of leaves per plant

GA_3 significantly increased the number of leaves per plant at 28, 35 and 42 DAS (Fig.2). At 28 DAS, the maximum number of leaves plant^{-1} (5.33) was produced by G_4 closely followed by G_3 treatments and the minimum (4.00) was produced by the control (G_0). At 35 DAS, the maximum number of leaves plant^{-1} (8.67) was recorded from G_4, which was closely followed by all other treatments except G_0 and G_7, while the minimum number of leaf (6.50) was recorded from G_0. At 42 DAS, the maximum number of leaves per plant (9.80) was observed from G_4 closely followed by most of the treatments except G_0 and G_7 and the minimum number of leaves plant^{-1} (8.40) was found from G_0. This indicated that number of leaves plant^{-1} increased with increasing GA_3 levels at certain level. Yadav et al. (2000) observed the highest number of open leaves (23.60) in cabbage with 2 sprays of gibberellic acid at 100 ppm. In cabbage similar results were also found by Chaurasiy et al. (2014) who noticed that GA_3 60 ppm significantly increased the number of leaves (21.48) than control.



G_0 = 0 ppm GA_3, G_1 = 5 ppm GA_3, G_2 = 10 ppm GA_3, G_3 = 15 ppm GA_3, G_4 = 20 ppm GA_3, G_5 = 25 ppm GA_3, G_6 = 30 ppm GA_3 and G_7 = 35 ppm GA_3 ; DAS = Days after sowing

Figure 2. Effect of gibberellic acid (GA_3) on number of leaves plant^{-1} of coriander at different growth stages. Error bars indicate standard error (SE) of three replicates.

Length of the largest leaf

The length of the biggest leaf varied significantly due to the application of different GA_3 levels at 28, 35 and 42 DAS (Table 1). Spraying of GA_3 at 20 ppm (G_4) gave the maximum leaf length (7.39 cm) which was identical with 25 ppm (G_5) (6.48 cm) and the control treatment (G_0) gave the lowest length of leaf (3.86 cm). At 35 DAS, the maximum leaf length (9.24 cm) was produced by G_4 treatment closely followed by all of the treatments except control and the minimum (1.82 cm) was produced by the control (G_0) treatment. At 42 DAS, the maximum leaf length (12.43 cm) was recorded from G_4, which was statistically different from all other treatment, while the minimum number of leaves plant^{-1} (7.00) was observed from G_0. Patel (2006) obtained maximum plant height of radish by spraying of GA_3 at 20 ppm.

Table 1. Effect of gibberellic acid on different growth parameters of coriander at different growth stages

Parameter	Growth stage	Treatment (GA_3 concentrations)								CV (%)
		G_0 (0ppm)	G_1 (5ppm)	G_2 (10ppm)	G_3 (15ppm)	G_4 (20ppm)	G_5 (25ppm)	G_6 (30ppm)	G_7 (35ppm)	
Length of the largest leaf (cm)	28 DAS	3.86e	4.74cde	5.02cd	5.38bc	7.39a	6.48ab	4.68cd	4.10de	7.22
	35 DAS	4.83b	5.85ab	6.27ab	6.72ab	9.24a	8.10 ab	5.85ab	5.13ab	13.06
	42 DAS	7.00c	7.39bc	8.16bc	10.74b	12.43a	10.89b	9.35ab	7.54bc	8.86
Plant spread (cm)	28 DAS	3.63c	3.98bc	4.44ab	4.78ab	4.90a	4.48ab	4.29abc	3.98bc	9.03
	35 DAS	4.84c	5.31abc	5.93ab	6.38a	6.54a	5.97ab	5.72abc	5.31bc	13.86
	42 DAS	8.44c	9.32c	9.70c	12.86ab	13.68a	11.12abc	10.54bc	8.80c	10.47
Individual plant weight (g)	28 DAS	0.22c	0.22c	0.32bc	0.40ab	0.48a	0.38ab	0.31bc	0.31bc	8.43
	35 DAS	0.45b	0.50ab	0.67ab	0.72a	0.73a	0.51ab	0.55ab	0.71ab	9.94
	42 DAS	1.38d	1.84c	2.05bc	2.43b	2.75a	2.41b	1.88c	1.86c	7.45
Dry weight of individual plant (g)	28 DAS	0.019e	0.020e	0.029cd	0.036b	0.043a	0.036c	0.028d	0.028d	5.43
	35 DAS	0.043f	0.048ef	0.064c	0.068ab	0.069a	0.067ab	0.052d	0.067b	6.57
	42 DAS	0.128d	0.171c	0.191c	0.226b	0.256a	0.225b	0.0175c	0.173c	6.45

Figures showing different letter (s) are significantly different at 5% probability level by DMRT; DAS = Days after sowing

Plant spread

Different levels of GA_3 showed significant variation for plant spread at 28, 35 and 42 DAS (Table 1). At 28 DAS, the highest plant spread (4.90 cm) was recorded from G_4, which was statistically similar with all of the treatments except G_0, G_1 and G_7, whereas the lowest plant spread (3.63 cm) was obtained from G_0. At 35 DAS, the highest plant spread (6.54) was observed from G_4 which was statistically similar with all of the treatments except G_0 and G_7 whereas the lowest was obtained from G_0 (4.84 cm), which was statistically similar with G_1, G_2 and G_7 treatment. At 42 DAS, the highest plant was obtained from G_4 (13.58 cm) closely followed by G_3 and G_7, while the lowest was obtained from G_0 (8.44 cm), which was statistically similar with G_0, G_1,G_2, G_5, G6 and G_7 (Table 1).

Individual plant weight

Different concentrations of gibberellic acid showed significant variation for individual plant weight at each of 28, 35 and 42 DAS (Table 1). At 28 DAS, the highest individual plant weight was recorded from G_4 (0.48 g) closely followed by G_3 and G_5, whereas the lowest was obtained from G_0 (0.22 g). At 42 DAS, the highest individual plant weight was observed from G_4 (2.75 g), which was by G_3 and G_5, whereas the lowest was obtained from G_0 (1.38 g) (Table 1). Patel (2006) obtained maximum plant weight of radish by spraying of GA_3 at 20 ppm. Roy et al. (2011) also got maximum plant weight in cabbage from application of GA_3 at 50 ppm.

Dry weight of individual plant

Application of GA_3 had significant influence on dry weight of individual plant at different after sowing (Table 1). At 28 DAS, the highest dry weight of individual plant was recorded from G_4 (0.043 g), where as the lowest was obtained from G_0 (0.019 g). At 35 DAS, the highest dry weight of individual plant was observed from G_4 (0.069 g) closely followed by G_3 and G_5, whereas the lowest was obtained from G_0 (0.042 g). At 42 DAS, the maximum dry weight of individual plant was obtained from G_4 (.0.256) followed by G_3 and G_5, while the lowest was obtained from G_0 (0.128 g) (Table 1).

Number of plants per square meter

Number of plants m^{-2} were found insignificant for GA_3 spray (Table 2). However the highest number of plants m^{-2} was obtained from 10 ppm GA_3 and the lowest from 25 ppm GA_3.

Weight of foliage per square meter

Weight of foliage m^{-2} was significantly influenced due to foliar application of GA_3 (Table 5). Application of GA_3 at 20 ppm produced maximum weight of foliage m^{-2} (1.05 kg) followed by GA_3 15 ppm (0.91 kg) and GA_3 25 ppm (0.89 kg). The lowest yield was obtained from the control (0.53 kg). Application of GA_3 @ 5 ppm, 10 ppm, 30 ppm and 40 ppm gave the identical results in respect of weight of foliage m^{-2}.

Foliage yield (t ha^{-1})

Foliage yield of coriander varied significantly due to different GA_3 concentration (Table 2). All concentrations of GA_3 gave higher yield over control. The maximum yield (9.34 t ha^{-1}) was recorded from 20 ppm GA_3 (G_4) treatment followed by G_3 (8.46 t ha^{-1}) and G5 (8.05 t ha^{-1}) treatments. The treatments G_1, G_2, G_6 and G_7 gave the identical results with regard to foliage yield ha^{-1}. Again no significant difference was observed between G_3 and G_7 treatments. The minimum yield (4.90 t ha^{-1}) was obtained from the control treatment. Application of GA3 at 15, 20 and 25 ppm increased foliage yield 42.08, 47.54 and 39.13% over control (Table 2). The increase in coriander foliage yield due to application of GA_3 may be ascribed to improvement in growth and enhancement in the photosynthetic and other metabolic activities which led to increase in various plant metabolisms responsible for cell division and cell elongation. The present results corroborate the result of Patel (2006) who got the highest leaf weight in radish by spraing GA_3 at 20 ppm. Yadav et al. (2000) observed the highest yield of cabbage with 2 sprays of gibberellic acid at 100 ppm.

Table 2. Effect of gibberellic acid on number of plants m^{-2}, weight of foliage m^{-2} and foliage yield of coriander

Treatment	Number of plants m^{-2}	Weight of foliage m^{-2} (kg)*	Foliage yield (t ha^{-1})*	% yield increase over control
G_0 (0 ppm)	408.3	0.53 d	4.90 d	-
G_1 (5 ppm)	408.7	0.71 c	6.53 c	24.96
G_2 (10 ppm)	411.0	0.80 bc	7.31 c	32.97
G_3 (15 ppm)	410.0	0.91 b	8.46 b	42.08
G_4 (20ppm)	409.7	1.05 a	9.34 a	47.54
G_5 (25 ppm)	408.7	0.89 b	8.05 b	39.13
G_6 (30 ppm)	410.0	0.74 c	6.77 c	27.62
G_7 (35 ppm)	409.7	0.73 c	6.76 c	27.51
SE (±)	0.32	0.15	0.19	-
CV (%)	5.43	7.94	5.87	-

Means with same letter (s) in a column are not significantly different at 5% level of probability by DMRT
* harvest at 42 days after sowing

Table 3. Correlation coefficients among different parameters of coriander at harvest as influenced by GA_3 application

Parameters	LP	LL	PS	SPW	WF	FY
PH	0.437	0.848**	0.832**	0.775**	0.797**	0.791**
LP		0.622	0.645	0.764**	0.728**	0.741**
LL			0.958**	0.928**	0.914**	0.721**
PS				0.916**	0.907**	0.906**
SPW					0.997**	0.998**
WF						0.999**

'**'and '*" indicate significant at 1% and 5% level of probability
PH = Plant height (cm) at 42 DAS, LP = number of leaves plant^{-1} 42 days after sowing,
LL = leaf length (cm) at 42 DAS, PS = Plant spread at 42 DAS, SPW = Single plant weight (g) at 42 DAS,
WF = Weight of foliage m^{-2} and FY = Foliage yield (t ha^{-1})

Correlation between growth parameters and foliage yield

Correlation coefficient values and level of significance among foliage yield and other seven parameters influenced by GA_3 application are presented in Table 3. There was a strong positive correlation of foliage yield with plant spread (cm) (0.906**), single (individual) plant weight (g) (0.998**) and weight of foliage m^{-2} (kg) but medium positive correlation with plant height (cm) (0.791**), number of leaves plant^{-1} (0791**), no. of leaves plant^{-1} (0.741) and leaf length (cm).

There also exists a positive correlation of weight of foliage m^{-2} (kg) with leaf length, plant spread, single plant weight (g) and plant height (cm), but moderate correlation with no. of leaves plant^{-1}.The strong positive correlation was also found between weight of foliage m^{-2} (kg) and plant spread (cm) (0.906**) and moderate correlation between weight of foliage m^{-2} and leaf length (cm). Plant spread had strong correlation with plant height (0.775**) but weak correlation with number of leaves plant^{-1}. The weak correlation was observed between leaf length and no. of leaves plant^{-1} (0.622), and plant spread and between plant height and leaves plant^{-1} (0.437). The correlation between no. of leaves plant^{-1} and plant spread (0.645). It revealed that most of the parameters showed strong positive association with each parameter.

Dry foliage yield

GA_3 spray had significant effect on dry foliage yield ha^{-1} (Fig. 3). Application of GA_3 gave higher yield compared to control. Spray of GA_3 at 20 ppm produced the highest dry foliage yield followed by GA_3 15 and GA_3 25 ppm.

Response equation

There depicted a quadratic relationship beteen GA_3 concentrations and foliage yield of corider (Fig. 4). Foliage yield increased upto 20 ppm GA_3 beyond which foliage yield declined. The regression equation was $y = 4.828 + 0.379x - 0.009x^2$, $R^2 = 0.939$. The coefficient of determination R^2 indicated that 93.9% foliage yield increase was due to GA_3 application and the rest (6.10%) was due to other factors. From the regression equation it came up to be optimum dose of GA_3 as 20.83 ppm.

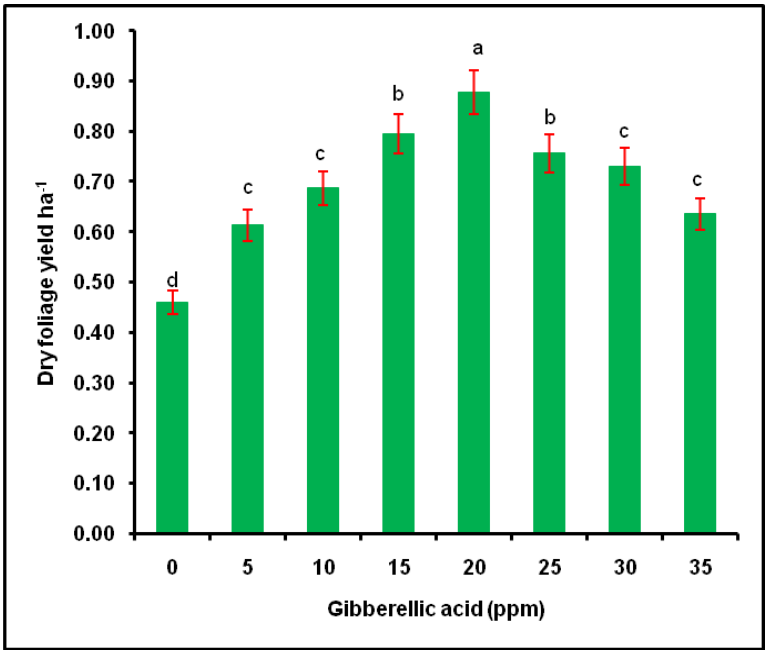


Figure 3. Dry foliage yield (t ha^{-1}) as influenced by different gibberellic acid concentrations. Error bars indicate standard error (SE) of three replicates. Bars showing different letter (s) are significantly different at 5% level by DMRT

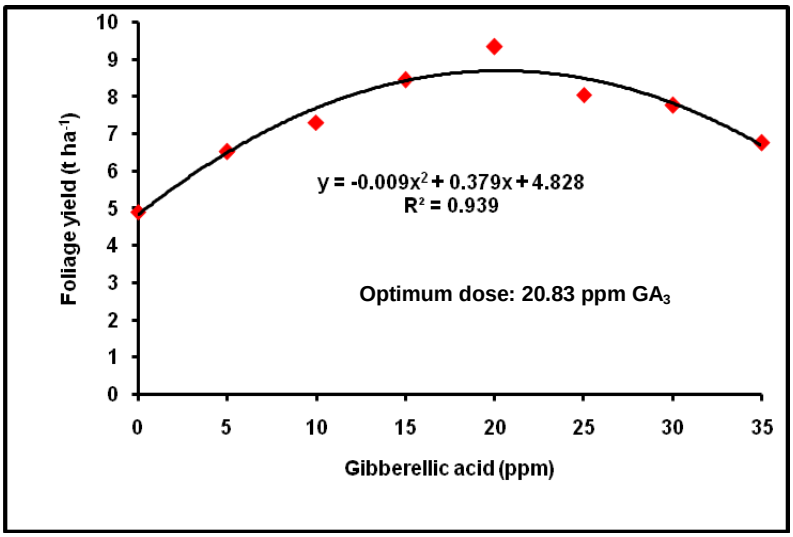


Figure 4. Response of foliage yield of coriander to different concentrations of gibberellic acid

CONCLUSION

The research was conducted to observe the influence of gibberellic acid on coriander leaf (foliage) production. Spraying of GA_3 @ 20 ppm twice at 25 and 30 days after sowing, produced maximum plant height, number of leaves plant^{-1}, leaf length, plant spread, single plant weight and weight of foliage m^{-2} and as a result, the highest foliage yield was obtained from the application of GA_3 at 20 ppm. Thus, foliar application of GA_3 @ 20 ppm twice at 25 and 30 days after sowing can be recommended for obtaining maximum yield of fresh leaf (foliage) of coriander.

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