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# Effect of IAA and $GA_3$ on the growth, curd formation and yield of cauliflower

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**ABSTRACT**

An experiment was carried out at the Horticultural Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 with two growth regulators, Gibberellic Acid ($GA_3$) and Indole Acetic Acid (IAA) applied at two different stages namely vegetative stage and curd formation stage to observe the growth, curd size and yield contributing characters of the modern HYV cauliflower cultivar, 'Shirajuki'. The experiment was laid out in a Randomized Complete Block Design (RCBD). The field experiment had three replications. There were three concentrations of IAA (0, 5, 10 ppm) and $GA_3$ (0, 80, 100 ppm). Application of IAA 10 ppm resulted the minimum (47.76) days from transplanting to curd initiation and the maximum (34.40 cm) plant height was at harvest while the minimum (28.86 cm) was recorded from control treatment. The maximum number of leaves per plant (25.04), length of the largest leaf (50.77 cm), breadth of the largest leaf (18.20 cm) at harvest, curd diameter at harvest (23.38 cm) were recorded from IAA 5 ppm ($I_1$) whereas, the minimum was recorded from control treatment. Application of $GA_3$ 100 ppm ($G_2$) resulted the highest pure curd height (14.59 cm), curd weight with leaves (1.90 kg) at harvest, marketable curd weight (1.33 kg $plant^{-1}$) and curd yield (53.33 t $ha^{-1}$) while the lowest was recorded from control treatment. The maximum benefit cost ratio (BCR) (2.93) was recorded from the treatment combination of $I_2G_2$ while the minimum (1.18) was recorded from control treatment. Therefore, IAA 10 ppm and $GA_3$ 100 ppm indicating the economic viability of using growth regulator in curd growth and yield of cauliflower.

## Introduction

Cauliflower (*Brassica oleracea* var. botrytis sub-var. cauliflora) is one of the most important cole crop belongs to the family Cruciferae. It is very popular winter vegetable and grown as annual plant without branching but it has biennial variety also in many countries of the world even in Bangladesh. The leading cauliflower producing countries of the world are china, Pakistan and India in respect of yield per hectare of land. It is a highly nutritious and delicious vegetable, rich in Vitamin A, C and minerals like calcium, iron and iodine (Haque, 1999). It supplies 50 mg Vitamin C, 40 IU Carotene, 30 Calorie, 8 gm Carbohydrate and 90% water per 100 gm edible part. In our country it is used only as fry and ingredient of curry. In western countries it is used as pickle also. The edible part of cauliflower is known as 'Curd'. According to botanical consideration, it is the pre-condition of inflorescence. It is a winter crop. The lifecycle of cauliflower can be divided into three phases, such as growth phase, curd phase, flower and seed phase. Application of $GA_3$ (50 mg/L + Urea 1%) have been reported to increase curd yield in cauliflower (Mishra & Singh, 1986). Many experiments have been carried out in developed nations to investigate the effect of bio-chemical substances on the yield and quality of Cauliflower. Reports so far been made indicate a promising results on yield and quality of Cauliflower and other crops due to the use of bio-chemical substances, such as Napthaline Acetic Acid (NAA), Gibberellic Acid ($GA_3$), Indole Acetic Acid (IAA) etc. (Voronova and Kozakov, 1983; Sentelhas et al., 1987; Tadzhiryan, 1990; Tomar et al., 1991). However, for attaining success an appropriate level and timing in terms of growth stage of the crop is important (Voronova & Kozakov, 1983; Tomar et al., 1991). Plant height, curd formation and curd size of cauliflower can be increased with foliar application of plant growth regulators. Several experiments were conducted to increase the yield of cauliflower. $GA_3$ and IAA has a positive effect on curd formation and size of cauliflower, (Sharma, SK; Mishra-RC, 1989). Exogenous application of $GA_3$ and Urea either alone or in combination increased curd size as well as yield. Greatest plant height at curd formation (58.2 cm), curd diameter at maturity (26.8 cm) and increase in yield over the control (164%) were obtained with the 2 applications of $GA_3$ (Reddy, 1989). Chauhan and Bordia (1971) carried out an investigation suing Drumhead variety of cabbage to assess the effects of Gibberellic acid (GA3) at 5, 10, 15, 25, 50, 100 ppm, Beta-naphthoxyacetic acid (NOA) at 5, 10, 25, 50, 100

ppm and 2, 4- Dichlorophenoxy acetic acid (2, 4-D) at 0.25, 0.5, 1.0, 2.0, 2.5, ppm as pre-sowing seed treatment on the growth and yield of cabbage and mentioned that none of the treatments affected the height of the plants and the time taken for head formation. Maximum weight of head (1.72 kg) was obtained with 50 ppm $GA_3$ as against 0.81 kg under control. Abdalla et al, (1980) conducted an experiment with the cauliflower varieties and the plants were treated with different concentration of IBA (5-40 ppm), $GA_3$ (10-80 ppm) or NAA (120-160 ppm) 4 weeks after twice more at fortnightly intervals. NAA at 160 ppm gave the highest yield with regard to curd diameter, weight and colour. Similar results were obtained from plants treated with $GA_3$ at 80 ppm and NNA at 40 ppm. Vegetable consumption in Bangladesh is very low, only 32 g per person per day against the minimum recommended quantity of 200g per day (FAO, 2007). The total vegetable production in Bangladesh is far below the requirement. In addition, it is generally accepted that a biochemical processes are affected by a single chemical or a mixture of chemicals is not only different for between species but also for cultivars within the species and due to climatic regions (Hardy, 1979). However, recently done preliminary trials indicate possibility of yields increase of Cauliflower in Bangladesh with the use of the biochemical (Islam el al., 1993; Biswas & Mondal, 1994). Plant height, curd formation and curd size of Cauliflower can be increased with foliar application of plant growth hormone. In 2015-2016, the annual production of cauliflower cultivation in Bangladesh amounts to about 296,000 m tons (BBS, 2017). In 2003-2004, cauliflower covered an area of 30900 hectares with a total production of 101485 metric tonnes (BBS, 2004). The average yield per hectare of cauliflower is far below than its actual yield potentially. With the background stated above, the present study was undertaken to investigate the effect of the level of two bio-chemical substances namely $GA_3$ and IAA on yield components like curd formation and size of curd as well as yield of cauliflower applying at different growth stages. The present study was aimed to know the effect of different plant growth regulators on growth, curd formation and yield of cauliflower. From this study, we will also able to select the appropriate doses of IAA and $GA_3$ for the growth and yield of cauliflower.

## Materials and methods

The experiment was conducted at the Horticulture Farm and Laboratories of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The experimental site was previously used as vegetable garden and recently developed for research work. The location of the site in 23° 74' N latitude and 90° 35' E longitude with an elevation of 8.2 meter from sea level. The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The total rainfall of the experimental site was 218 mm during the period of the experiment. The average Rabi season maximum and minimum temperature were 29.45 °C, respectively during the experimental period in characterized by plenty of sunshine. The maximum and minimum temperature, humidity, rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (climate division) and have been presented. The soil of the experimental area belongs to the Modhupur Tract. The analytical data of the soil sample collected from the experimental area were determined in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka. The experimental site was a medium hightof the soil. The morphological characters of soil of the experimental plots are given below - Soil series - Tejgaon AEZ No. 28. General soil- Non-calcarious dark grey. Seed of cauliflower cultivar, Shirajuki variety was used in the experiment.

The experiment was designed to study the effects of different concentration of IAA and $GA_3$ on growth and curd yield of cauliflower. The experiment consisted of two factors, Factor A: Indole acetic acid (IAA) (Three concentration) i. $I_0$-IAA (0 ppm) ii. $I_1$-IAA (5 ppm) iii. $I_2$ - IAA (10 ppm) and Factor B: Gibbrellic acid (three concentration) i. Control ($G_0$) - $GA_3$ —► 0 ppm ii. ($G_1$)-$GA_3$—►80 ppm iii. ($G_2$) - $GA_3$—► 100 ppm. There were altogether 9 treatments combinations such as $I_oG_o$, $I_oG_1$, $I_oG_2$, $I_1G_o$, $I_1G_1$, $I_1G_2$, $I_2G_o$, $I_2G_1$, and $I_2G_2$. The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 12 m × 19.5 m was divided into three equal blocks. Each block was divided into 09 plots where 9 treatments were allotted at random. Thus there were 27 unit plots altogether in the experiment. The size of each plot was 3 m × 1.5 m. The distance between two blocks and two plots were kept 1 m and 0.5 m, respectively. Thirty day old seedlings were transplanted in the main field on 10 November 2006 following (50 × 50) cm spacing. Fertilizers were applied at the rate of 15 ton cowdung, 240 kg urea, 150 kg TSP, 220 kg MP, 5kg boron and 2 kg molybdenum per hectare. Cowdung, TSP, boron, molybdenum and 50% MP were applied during final land preparation. Urea and the rest MP were applied as top dressing in three instalments at 15, 30 and 45 days after transplanting.

Seeds were sown in a wooden tray filled with vermiculite. After sowing seeds were covered with thin layer of vermiculite. The entire seed tray was then covered with a sheet of newspaper to preserve moisture until germination. Complete germination of seeds took place within 5 days of sowing. Nine days old seedlings were transplanted individually in polythene bags filled with equal proportion of sand, soil and cowdung. Seedlings were left under shade for 2 to 3 days and then brought to the sunlight. After three days these seedlings were gradually exposed to sunlight. Healthy and uniform sized 30 days aged seedlings were transplanted in the experimental plots. Before transplanting of seedlings polybags were removed to facilitate growth of root from basal media so that they can easily established in the field. At the time of

removing poly bags, care was taken to protect the earth ball bagged soil. There was no need of irrigation immediately after transplanting because of moderate rainfall. So sufficient soil moisture was present there for the seedling establishment. After seedling establishment, the soil around the base of each seedling was pulverized and new ones from the same stock was used to replace the damaged seedlings. Gibberellic acid in different concentrations viz. 80 and 100 ppm IAA in different concentrations viz. 5, 10 ppm were prepared following the procedure mentioned below and spraying was done during noon by using a hand sprayer.

IAA solution: IAA 1 ppm IAA solution was prepared by dissolving 1 mg IAA powder with 10 ml Ethyl Alcohol and the volume was made 1000 ml by adding distilled water in a volumetric flask. So, 5 ppm and 10 ppm IAA solution were prepared in the similar way.

$GA_3$ solution: To prepare 80 ppm and 100 ppm $GA_3$ solution $GA_3$ granules are measured by an electrical balance and dissolved into 1000 ml distilled water.

The observations (data) for various growth and yield contributing characters were statistically analysed to find out the significance of variation from the resulting treatments following the MSTATC tool. The mean for all the calculated and the analysis of variance for each of the characters under study was done by F (variance ratio) test for Randomized Complete Block Design (RCBD). The treatment means were compared by Least Significant Difference (lsd) at 5% level of significance (Gomez and Gomez, 1984).

## Results and discussion

The effect of plant growth regulators (PGR) on curd yield and yield contributing characters of cauliflower was significant (Table 1 & 2). Most of the plant characters such as plant height at 50 DAT (Days from transplanting to curd initiation, days from planting to 50% curd initiation, plant height at harvest days from curd initiation to harvest, no. of leaves per plant at harvest, length and breadth of the biggest leaf at harvest, curd diameter at harvest, pure curd height, curd weight with leaf, marketable curd weight, curd weight and curd yield per plot and yield (t $ha^{-1}$) were significantly influenced by different levels of PGR ($GA_3$ and IAA). The plant height varied significantly due to foliar application of different levels of IAA and $GA_3$ (Table 1). During the period of plant growth the maximum plant height (34.40 cm) was observed in $I_2$ treatment where 10 ppm of IAA and the minimum was (28.86 cm) found in $I_0$ treatment where no IAA was sprayed at 50 days after transplanting. In general plant height increased gradually at the early stages and decreased at the later stages of the plant growth. The plant height was also varied significantly due to different levels of $GA_3$ application. During the period of plant growth the highest plant height was observed in $G_2$ treatment where 100 ppm of $GA_3$ was sprayed. At 50 days, the maximum (34.36 cm) plant height was observed in respective to $G_2$ treatment when the plants received 100 ppm $GA_3$ and the minimum (29.45 cm) was found in the control treatment The results support to those of Sharma and Mishra (1989). The interaction effect was taken between IAA and $GA_3$ application. The plant height was not significantly influenced by the interaction effect of IAA and $GA_3$ application. But the highest plant height (37.22 cm) was recorded from the treatment combination of $I_2G_2$ (Table 2).

Days from transplanting to curd initiation: Significant difference was noted on days required from transplanting to curd initiation at different concentrations of IAA. The maximum days (50.22) were required in IAA (10 ppm) which was followed by $I_0$ treatment and the minimum days were required (49.89) in $I_1$ (Table 1). This result was similar to those of Denisova and Lupinovich (1962) that $GA_3$ application brought about rapid vegetable growth, which subsequently helped in the early formation of large and compact heads. The probable cause of this may be increased nutrient transport from root to the aerial parts and increased rate of photosynthesis and accelerated transport of photosynthates by GA3. Significant variation was found in case of days from transplanting to curd initiation due to application of different levels of $GA_3$ (Table 1). The maximum days (49.44) were required in $G_1$ (80 ppm $GA_3$) which was followed by $G_2$ (100 ppm $GA_3$) treatment and the minimum days were required (48.00) in $G_0$ (0 ppm $GA_3$) treatment. The interaction effect was observed in combination of IAA and $GA_3$ application. There was no significant effect on days required for transplanting to curd initiation. However, the highest value (51.00) was recorded in $I_0G_1$ and $I_0G_2$ treatment combination (Table 2). A significant variation was found from IAA application in days from transplanting to curd initiation. The maximum number of days (50.89) were obtained from $I_0$ treatment (IAA 0 ppm) and the minimum number of days (47.67) was obtained from $I_1$, treatment (IAA 5 ppm) (Table 1). There was no significant variation was found in $GA_3$ application. However, the maximum days (50.22) were found in $G_2$ treatment ($GA_3$ 100 ppm) and the minimum days (49.11) obtained from $G_1$ treatment ($GA_3$ 80 ppm) (Table 1). The combined effect of IAA and $GA_3$ was also not significant on days from transplanting to 50% curd initiation. The maximum number of days (51.67) required for 50% curd initiation from $I_2G_2$ treatment and the minimum number of days (47.00) from $I_1G_1$ treatment. A significant variation was observed in plant height at harvest due to the application of IAA. The maximum plant height (44.73 cm) at harvest was recorded from the $I_1$ (5 ppm) treatment while the minimum plant height at harvest (39.30 cm) was found in $I_0$ (0 ppm) which was statistically similar with $I_2$ (10 ppm) treatment (Table 1).

Plant height at harvest was not significantly differed by $GA_3$ application. However, the maximum height (41.49 cm) and the minimum plant height (41.26 cm) was found from the $G_2$ and $G_0$ treatment respectively (Table 1). This result support to that of exogenous application of $GA_3$ and Urea either alone or in combination enhanced curd size as well as yield. Greatest plant height at curd formation (58.2 cm), curd diameter at maturity (26.8 cm) and increase in yield over the control (164%) were obtained with the 2 applications of $GA_3$ (Reddy, 1989). Interaction effect between IAA and $GA_3$ on plant height was also not significant. The highest value of plant height was (35.43 cm) recorded from $I_1G_1$ treatment and the lowest value (29.00 cm) was obtained from $I_1G_0$ treatment (Table 2). A significant effect was recorded on days from curd initiation to harvest due to the application of IAA. The maximum (12.44) days from curd initiation to harvest was found from $I_0$ (0ppm) treatment and the minimum (10.67) days from curd initiation to harvest was found from $I_1$ (5 ppm) treatment (Table 1). The effect of $GA_3$ application on days from curd initiation to harvest was not significant. However, the highest (11.67) value of days required for curd initiation to harvest from $G_0$ (0 ppm) treatment and $G_1$ (80 ppm) and the lowest value (11.56) was recorded from $G_2$ (100 ppm) treatment (Table 1). The result was similar to those of Dharmender et al., (1996) studied that $GA_3$ alone or in combination with NAA (both at 25, 50 or 75 ppm) on the growth of cabbage (cv. Pride of India) was investigated in the field at Horticulture Farm S. K. A. College of Agriculture. Jobner, Rajasthan, India during rabi (winter) 1993-94. The best growth (plant height, plant spread, number of leaves, leaf area and days to maturity) was observed following treatment with $GA_3$ at 50 ppm followed by NAA at 50 ppm. $GA_3$ at 75 ppm reduced the mean number of days required to start head formation. The highest chlorophyll content in outer leaves was observed following treatment with NAA at 50 ppm.

The interaction effect between IAA and $GA_3$ also not significant. The combination of IAA and $GA_3$ does not make any change to the days from curd initiation to harvest. The maximum days (12.67) was recorded from the treatment combination of IAA with (0 ppm) and $GA_3$ with (100 ppm) ($I_oG_2$). However the lowest (10.33) was observed from the $I_1G_1$ treatment has been shown in table 2.

**Table 1.** Main effect of foliar application of IAA and $GA_3$ on curd yield and yield attributes of cauliflower

| Growth regulators | Plant height at 50 DAT (cm) | Days from transplanting to 50% curd initiation | Plant height at harvest (cm) | Days from curd initiation to harvest |
|---|---|---|---|---|
| IAA | | | | |
| $I_0$ | 28.86 | 50.89 | 39.30 | 12.44 |
| $I_1$ | 33.05 | 47.67 | 44.73 | 10.67 |
| $I_2$ | 34.40 | 50.11 | 40.00 | 11.78 |
| Significance Level | ** | ** | ** | ** |
| | | | | |
| $GA_3$ | | | | |
| $G_0$ | 29.45 | 49.33 | 41.26 | 11.67 |
| $G_1$ | 32.51 | 49.11 | 41.28 | 11.67 |
| $G_2$ | 34.36 | 50.22 | 41.49 | 11.56 |
| Significance Level | ** | NS | NS | NS |

Figure in a column accompanied by similar letter (s) do not differ significantly as per lsd.
**Significant at 0.01 level of probability
*Significant at 0.05 level of probability

**Table 2.** Interaction effect between foliar application of IAA and $GA_3$ on curd yield and yield attributes of cauliflower

| Growth regulators | Plant height at 50 DAT (cm) | Days from transplanting to curd initiation | Days from transplanting to 50% curd initiation | Plant height at harvest (cm) | Days from curd initiation to harvest |
|---|---|---|---|---|---|
| $G_0I_0$ | 25.15 | 47.67 | 50.67 | 36.88 | 12.33 |
| $G_1I_0$ | 29.70 | 51.00 | 51.00 | 40.20 | 12.33 |
| $G_2I_0$ | 31.73 | 51.00 | 51.00 | 40.82 | 12.67 |
| $G_0I_1$ | 29.00 | 45.67 | 48.00 | 47.05 | 11.00 |
| $G_1I_1$ | 35.43 | 47.33 | 47.00 | 43.03 | 10.33 |
| $G_2I_1$ | 34.12 | 46.00 | 48.00 | 44.10 | 10.67 |
| $G_0I_2$ | 33.60 | 50.67 | 49.33 | 39.83 | 11.67 |
| $G_1I_2$ | 32.38 | 50.00 | 49.33 | 40.60 | 12.33 |
| $G_2I_2$ | 37.22 | 50.00 | 51.67 | 39.57 | 11.33 |
| Significance | NS | NS | NS | NS | NS |
| CV % | 9.23 | 8.33 | 8.84 | 8.23 | 7.42 |

Application of IAA with different concentration significantly increases the number of leaves per plant (Table 3). The maximum (25.04) number of leaves per plant was produced by $I_1$ treatment (IAA 5 ppm) and the minimum (20.82) number was obtained from control ($I_0$) treatment. There was no significant variation was found in case of production of leaves per plant due to the effect of $GA_3$ with different concentrations. $GA_3$ at 80 ppm ($G_1$) treatment produced the maximum (23.44) number of leaves which was identical with that of $GA_3$ 100 ppm (23.19). The control treatment gave the minimum number of leaves (22.53) per plant. This result support to that of Patil et al., (1987) conducted an experiment in a field trial with the cultivar pride of India applied $GA_3$ and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Both the $GA_3$ and NAA increased the plant height significantly. The maximum plant height and head diameter and head weight were noticed with $GA_3$ at 50 ppm followed by NAA at 50 ppm. Significant increase in number of outer and inner leaves were noticed with both $GA_3$ and NAA. Head formation and head maturity was 13 and 12 days earlier with 50 ppm $GA_3$. Maximum number of leaves and maximum yield (23.83 t $ha^{-1}$) were obtained with 50 ppm $GA_3$. The number of leaves per plant was also not significantly influenced by the interaction effect of IAA and $GA_3$ with different levels (Table 4). The maximum (25.20) number of leaves was recorded from the treatment combination of $I_1G_1$ (IAA 5 ppm + $GA_3$ 80 ppm) and the minimum (19.72) number of leaves was found from $I_0G_0$ (control) treatment.

The length of the biggest leaf was varied significantly due to the application of different levels of IAA. IAA at 5 ppm ($I_1$) gave the highest (50.77 cm) leaf length and the control treatment ($I_0$) gave the lowest length (44.47 cm) (Table 3). A significant variation was observed in case of $GA_3$ application with different concentration. The highest (53.00 cm) length of leaf was found from $G_2$ ($GA_3$ 100 ppm) treatment while the lowest control ($G_0$) treatment gave the lowest (45.44 cm) length (Table 3). There was no significant variation observed by the interaction effect of IAA and $GA_3$. However, the maximum (57.71 cm) length of leaf was found from $I_2G_2$ (IAA 10 ppm + $GA_3$ 100 ppm) treatment combination and the minimum (42.03 cm) length was found from the $I_0G_1$ (IAA 0 ppm + $GA_3$ 80 ppm) treatment combination (Table 4). Application of IAA at different concentration significantly increases the breadth of leaf. The maximum (18.20 cm) breadth of leaf was found from (IAA 5 ppm) treatment and the minimum (13.42 cm) breadth of leaf was observed in control $I_0$ treatment (Table 3). This is similar to those (Sharma & Mishra, 1989) of plant height, curd formation and curd size of cauliflower can increase with foliar application of plant growth regulators. Several experiments were conducted to increase the yield of cauliflower. $GA_3$ and IAA have a positive effect on curd formation and size of cauliflower.

Application of $GA_3$ at different levels had no significant effect on the breadth of the biggest leaf. However, the maximum (16.56 cm) breadth was found in $G_1$ (80 ppm) treatment and the minimum (16.03 cm) breadth was recorded from ($G_0$) control treatment (Table 3). The result was similar to those of Pandey and Sinha (1987) reported that photosynthetic area of the plant increased when treated with gibberellic acid naphthalene acetic acid.

The interaction effect between IAA and $GA_3$ had no significant effect on breadth of leaf. The maximum (18.80) breadth of leaf was observed in $I_1G_1$, (IAA 5 ppm + $GA_3$ 80 ppm) and the minimum (12.75 cm) breadth was recorded from $I_0G_0$ (control) treatment (Table 4). A significant variation was found due to the application of IAA at different concentration on the curd diameter at harvest. The maximum (23.38 cm) curd diameter was recorded from $I_1$ (IAA at 5 ppm) treatment and the minimum (19.82 cm) curd diameter was found from the control ($I_0$) treatment. This result support to that of exogenous application of $GA_3$ and Urea either alone or in combination enhanced curd size as well as yield. Greatest plant height at curd formation (58.2 cm), curd diameter at maturity (26.8 cm) and increase in yield over the control (164%) were obtained with the 2 applications of $GA_3$ (Reddy, 1989). A significant variation was found due to the application of $GA_3$ on curd diameter. The maximum (22.55 cm) curd diameter was found from $G_2$ ($GA_3$ 80 ppm) treatment and minimum (20.88 cm) curd diameter was found from the control ($G_0$) treatment. The interaction effect between IAA and $GA_3$ at different levels was also significantly effect on curd diameter. However, the maximum (24.13) diameter had recorded from the $I_1G_1$ (IAA 5 ppm + $GA_3$ 80 ppm) treatment combination and the minimum (18.52 cm) curd diameter was observed in control treatment. There was no significant variation was observed on pure curd height due to the application of IAA with different concentrations. The maximum pure curd height was (15.22 cm) recorded from $I_1$ (IAA 5 ppm) treatment, while the minimum pure curd height was (11.09 cm) which was recorded from $I_2$ (IAA 10 ppm) treatment (Table 3). A significant variation was found on pure curd height in case of $GA_3$ application at different levels. The highest value (14.59 cm) was recorded from $G_1$, ($GA_3$ 80 ppm) which was closely followed by $G_2$ and the lowest value (12.04 cm) was found from ($G_0$) control treatment (Table 3). The interaction effect between IAA and $GA_3$ was also significantly effect on pure curd height. The highest value (15.50 cm) was found in $I_0G_1$ (IAA 0 ppm + $GA_3$ 80 ppm) treatment combination and lowest value (10.58 cm) was observed in $I_0G_0$ (IAA 0 ppm) control treatment combination (Table 4). Curd weight with leaf at harvest was also found to differ significantly by the application of IAA at different concentrations. The maximum curd weight (1.87 kg) with leaf was recorded from the $I_1$ (IAA 5 ppm) treatment, which was statistically similar with $I_2$ and the minimum (1.62 kg) was from the control ($I_0$) treatment at final harvest of the crop (Table 5).

**Table 3.** Main effect of foliar application of IAA and $GA_3$ on curd yield and yield attributes of cauliflower

| Growth regulators | Number of leaves per plant at harvest | Length of the biggest leaf at harvest (cm) | Breadth of the biggest leaf at harvest (cm) | Curd diameter at harvest (cm) | Pure curd height (cm) |
|---|---|---|---|---|---|
| IAA | | | | | |
| $I_0$ | 20.82 | 44.47 | 13.42 | 19.82 | 13.73 |
| $I_1$ | 25.04 | 50.77 | 18.20 | 23.38 | 15.22 |
| $I_2$ | 23.31 | 50.48 | 17.07 | 21.76 | 11.09 |
| Significance | ** | ** | ** | ** | ** |
| $GA_3$ | | | | | |
| $G_0$ | 22.53 | 45.44 | 16.03 | 20.88 | 10.49 |
| $G_1$ | 23.44 | 47.28 | 16.56 | 21.53 | 13.12 |
| $G_2$ | 23.19 | 53.00 | 16.10 | 22.55 | 14.80 |
| Significance | NS | ** | NS | ** | ** |

Figure in a column accompanied by similar letter (s) do not differ significantly as per lsd.
**Significant at 0.01 level of probability
*Significant at 0.05 level of probability

**Table 4.** Interaction effect between foliar application of IAA and $GA_3$ on curd yield and yield attributes of cauliflower

| Growth regulators | Number of leaves per plant at harvest | Length of the biggest leaf at harvest (cm) | Breadth of the biggest leaf at harvest (cm) | Curd diameter at harvest (cm) | Pure curd height (cm) |
|---|---|---|---|---|---|
| $G_0I_0$ | 19.72 | 43.74 | 12.75 | 18.52 | 10.58 |
| $G_1I_0$ | 21.60 | 42.03 | 13.65 | 21.10 | 15.50 |
| $G_2I_0$ | 21.13 | 47.64 | 13.86 | 19.83 | 14.05 |
| $G_0I_1$ | 24.75 | 47.78 | 18.20 | 22.43 | 13.80 |
| $G_1I_1$ | 25.20 | 50.89 | 18.80 | 24.13 | 13.35 |
| $G_2I_1$ | 25.18 | 53.65 | 17.60 | 23.57 | 13.68 |
| $G_0I_2$ | 23.13 | 44.79 | 17.15 | 21.68 | 11.73 |
| $G_1I_2$ | 23.53 | 48.93 | 17.23 | 22.42 | 14.92 |
| $G_2I_2$ | 23.27 | 57.71 | 16.83 | 21.18 | 13.23 |
| Significance | NS | NS | NS | ** | ** |
| CV % | 8.76 | 7.23 | 8.28 | 10.24 | 9.52 |

Figure in a column accompanied by similar letter (s) do not differ significantly as per lsd.
**Significant at 0.01 level of probability
*Significant at 0.05 level of probability

**Table 5.** Main effect of foliar application of IAA and $GA_3$ on curd yield and yield attributes of cauliflower

| Growth regulators | Marketable curd weight (Kg) | Curd weight with leaf at harvest (Kg) | Curd weight (Kg $plant^{-1}$) | Curd yield (Kg $plot^{-1}$) |
|---|---|---|---|---|
| IAA | | | | |
| $I_0$ | 1.19 | 1.62 | 0.83 | 14.96 |
| $I_1$ | 1.59 | 1.87 | 1.00 | 17.96 |
| $I_2$ | 1.58 | 1.86 | 1.08 | 19.52 |
| Significance | ** | ** | ** | ** |
| $GA_3$ | | | | |
| $G_0$ | 1.20 | 1.64 | 0.65 | 11.72 |
| $G_1$ | 1.47 | 1.81 | 0.93 | 16.72 |
| $G_2$ | 1.70 | 1.90 | 1.33 | 24.00 |
| Significance | ** | ** | ** | ** |

Figure in a column accompanied by similar letter (s) do not differ significantly as per lsd.
**Significant at 0.01 level of probability
*Significant at 0.05 level of probability

A significant variation was observed on curd weight with leaf due to the application of different concentration of $GA_3$. $GA_3$ at 100 ppm ($G_2$) gave the maximum (1.90 kg) curd weight which was followed by $GA_3$ at 80 ppm ($G_1$). On the other hand control treatment ($G_o$) showed the minimum (1.64 kg) curd weight with leaf at harvest (Table 5). The interaction effect between IAA and $GA_3$ did not show significant variation on curd weight with leaf. However, the highest value (2.04 kg) was recorded from $I_1G_2$ (IAA 5 ppm + $GA_3$ 100 ppm) treatment combination. The lowest value (1.55 kg) was found from the control treatment $I_0G_0$ (Table 6). Marketable curd weight of cauliflower varied significantly due to the different levels of IAA. The maximum marketable curd weight (1.59 kg) was obtained from $I_1$ (IAA 5 ppm) treatment which was followed by $I_0$ and the minimum (1.19 kg) was found from control treatment (Table 5). The marketable curd weight of cauliflower was found to be statistically significant due to the application of $GA_3$ at different concentration. The highest curd weight (1.70 kg) was found from $G_2$ ($GA_3$ 100 ppm) and the lowest (1.20 kg) was recorded from control ($G_0$) treatment.

This result was similar to that of Yabuta et al., (1981) reported that application of $GA_3$ had significantly increased marketable weight, petiole length, number of leaves and height many leafy vegetables the leaf area. The interaction effect of IAA and $GA_3$ on marketable curd weight was significant. The combined effect of IAA and $GA_3$ on marketable curd weight showed the maximum (1.90 kg) from $I_2G_2$ (IAA 10 ppm + $GA_3$ 100 ppm) and the minimum (1.13 kg) was obtained from the control ($I_0G_0$) treatment. The curd weight varied significantly due to the application of different concentration of IAA. The maximum (1.08 kg) curd weight was recorded from the $I_2$ (IAA 10 ppm) which was statistically similar with $I_2$ and the minimum (1.19 kg) from the control treatment (Table 5). The curd weight differs significantly in case of $GA_3$ application at different levels. The highest (1.33 kg) curd weight per plant was obtained from $G_2$ ($GA_3$ 100 ppm) and the lowest (1.20 kg) was recorded from ($G_0$) control treatment (Table 5). A significant interaction effect was found between IAA and $GA_3$ on the curd weight. However, the maximum (1.52 kg) curd weight from $I_2G_2$ (IAA 10 ppm + $GA_3$ 100 ppm) treatment combination and the minimum (0.55 kg) from $I_0G_0$ (IAA 0 ppm + $GA_3$ 0 ppm) treatment combination. A significant variation was found due to the application of IAA at different levels on the curd yield. The maximum (19.52 kg) curd yield per plot was recorded from $I_2$ (IAA 10 ppm) treatment which was statistically similar with $I_1$ (IAA 5 ppm) and the minimum (14.96 kg) was found from the control ($I_0$) treatment (Table 3). The curd yield as also varied significantly by the application of $GA_3$ at different levels. The maximum (24.00 kg) curd yield per plot was obtained from $G_2$ ($GA_3$ 100 ppm) and the minimum (11.72 kg) was recorded from the control ($G_o$) treatment (Table 5). A significant interaction effect was found between IAA and $GA_3$ on curd yield per plot. The highest value (27.30 kg) was found from the $I_2G_2$ (IAA 10 ppm + $GA_3$ 100 ppm) treatment combination and the lowest (9.90 kg) from the control ($I_0G_0$) treatment (Table 6).

A significant variation was found due to the application of IAA at different levels. The maximum (43.38 kg) curd yield was recorded from $I_2$ (IAA 10 ppm) and the minimum (33.24 kg) from the control ($I_0$) treatment. The effect of $GA_3$ at different levels on the curd yield (t $ha^{-1}$) was also significant. The maximum (53.30 kg) as recorded from $G_2$ ($GA_3$ 100 ppm) treatment and the minimum (26.04) from the control ($G_0$) treatment. This result support to those of Muthoo et al. (1987) found that the foliar application of different concentration of $GA_3$ NAA and molybdenum increased the average fresh and dry weight of leaves. Curd and yield of cauliflower amongst the individual treatments, Gibberellic acid proved to be the best for the vegetative growth and molybdenum proved to be the best for growth of curd and yield of cauliflower (q $ha^{-1}$) followed by naphthalene acetic acid. The interaction between IAA and $GA_3$ at different levels were also show the significant effect. However, the highest value was (60.67 t $ha^{-1}$) from $I_2G_2$ (IAA 10 ppm + $GA_3$ 100 ppm) treatment combination and the lowest (22.00 t $ha^{-1}$) from the control ($I_1G_o$) treatment combination.

**Table 6.** Interaction effect between foliar application of IAA and $GA_3$ on curd yield and yield attributes of cauliflower

| Growth regulators | Marketable curd weight (Kg) | Curd weight (Kg $plant^{-1}$) | Curd yield (Kg $plot^{-1}$) | Curd yield (t $ha^{-1}$) |
|---|---|---|---|---|
| $G_0I_0$ | 1.17 | 0.55 | 9.90 | 22.00 |
| $G_1I_0$ | 1.13 | 0.78 | 13.98 | 31.07 |
| $G_2I_0$ | 1.27 | 1.17 | 21.00 | 46.67 |
| $G_0I_1$ | 1.16 | 0.67 | 12.00 | 26.67 |
| $G_1I_1$ | 1.70 | 1.01 | 18.18 | 40.40 |
| $G_2I_1$ | 1.92 | 1.32 | 23.70 | 52.67 |
| $G_0I_2$ | 1.27 | 0.74 | 13.26 | 29.47 |
| $G_1I_2$ | 1.57 | 1.00 | 18.00 | 40.00 |
| $G_2I_2$ | 1.90 | 1.52 | 27.30 | 60.67 |
| Significance | ** | ** | ** | ** |
| CV % | 15.73 | 17.26 | 14.62 | 14.09 |

## Economics analysis

The variation in cost of production was noticed due to different levels of Indole Acetic Acid and Gibbrellic Acid (Table 7). The production cost of the highest (82698 Tk. $ha^{-1}$) when 10 ppm IAA and 100 ppm $GA_3$ ($I_2G_2$) was applied. The lowest cost of production (74858 Tk. $ha^{-1}$) was found in control ($I_0G_0$) treatment. The highest gross return (Tk. 242680 $ha^{-1}$) was obtained from $I_2G_2$ treatment while the lowest (88000 Tk. $ha^{-1}$) was found against $I_0G_0$ treatment. It was evident that the maximum net return (Tk. 159982 $ha^{-1}$) was obtained from $I_2G_2$ treatment and the plants which were in control treatment gave the minimum net return (13142 Tk. $ha^{-1}$). The maximum (2.93) benefit cost ratio (BCR) was recorded in $I_2G_2$ treatment while the minimum (Tk. 1.18) was found against $I_0G_0$ treatment. The cost of materials is such as seed of cauliflower @ 500 Tk. $kg^{-1}$, Cowdung @ 600 Tk. $ton^{-1}$, Urea @ 8 Tk. $kg^{-1}$, TSP @ 16 Tk. $kg^{-1}$, MP @ 16 Tk. $kg^{-1,}$ IAA @ 1800 Tk. Per 10 g, $GA_3$ @ 750 Tk. $g^{-1}$ and labour cost @ 70 Tk. $day^{-1}$.

**Table 7.** Cost and return of cauliflower due to the application of IAA and $GA_3$

| Growth regulators | Curd yield (t $ha^{-1}$) | Gross return (Tk $ha^{-1}$) | Total cost of production (Tk $ha^{-1}$) | Net return (Tk $ha^{-1}$) | Benefit cost ratio (BCR) |
|---|---|---|---|---|---|
| $G_0I_0$ | 22.00 | 88000 | 74858 | 13142 | 1.18 |
| $G_1I_0$ | 31.00 | 124280 | 80990 | 43290 | 1.53 |
| $G_2I_0$ | 46.67 | 186680 | 82522 | 104158 | 2.26 |
| $G_0I_1$ | 26.67 | 126680 | 74947 | 31733 | 1.42 |
| $G_1I_1$ | 40.40 | 161600 | 81078 | 80522 | 1.99 |
| $G_2I_1$ | 52.67 | 210680 | 82610 | 128070 | 2.55 |
| $G_0I_2$ | 29.47 | 117880 | 75036 | 42844 | 1.57 |
| $G_1I_2$ | 40.00 | 160000 | 75212 | 84788 | 2.12 |
| $G_2I_2$ | 60.67 | 242680 | 82698 | 159982 | 2.93 |

## Conclusions

From the above discussion it may be concluded that, growth hormone IAA and $GA_3$ has conspicuous effects on growth (plant height, leaf size curd formation and curd size which led to an increased yield of cauliflower, relative to treatments without growth hormones application. However, the growth hormone, IAA at 10 ppm and $GA_3$ at 100 ppm, showed the best performance in curd growth and yield of cauliflower. Such study can be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other different combination may be included in further study.

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