Effects of Plant Growth Regulator on Yield and Economic Benefit of Sweet Pepper (*Capsicum annum* L.)

S. Akhter, T. Mostarin, K. Khatun, F. Akhter and A. Parvin

Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, 1207

*Corresponding author and Email: shilaakhter101@gmail.com

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Abstract

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Plant growth regulators were applied which had significant effect on yield of sweet pepper (*Capsicum annum* L.). The experiment consisted of four factors. Factor A: Plant growth regulators (four levels) as $G_0$: Control, $G_1$: Gibberellic Acid ($GA_3$) @ 30 ppm, $G_2$: 4-Chloro Phenoxy Acetic Acid ($4$-CPA) @ 45 ppm and $G_3$: 4-Chloro Phenoxy Acetic Acid ($4$-CPA) @ 45 ppm + Gibberellic Acid ($GA_3$) @ 30 ppm and Factor B: Number of spray (three levels) as $N_0$: Control (no spray), $N_1$: two spray, $N_2$: three spray. In case of plant growth regulators, the highest yield (27.77 t/ha) was found from $G_3$ treatment, whereas the lowest (18.87 t/ha) was from $G_0$ treatment. For number of spray the maximum yield (26.0 t/ha) was recorded from $N_2$ treatment, while the minimum yield (19.87 t/ha) was from $N_0$ treatment. The results indicated that the highest yield (31.8 t/ha) was observed from $G_3N_2$ treatment combination, while the lowest yield (17.5 t/ha) was from $G_0N_0$ treatment combination. Due to combined effect, the highest yield (31.8 t/ha) with net income (Tk/ha 1416558) and BCR (2.46) was observed from $G_3N_2$ treatment combination, while the lowest yield (17.5 t/ha) with net income (Tk/ha 433045) and BCR (1.49) from $G_0N_0$ treatment combination. Thus, three times spray with (4-Chloro Phenoxy Acetic Acid + Gibberellic Acid) may be recommended for achieving the higher growth, yield and economic benefit of sweet pepper.

Keywords: Sweet pepper, plant growth regulators, number of spray, yield.

1. Introduction

Sweet pepper (*Capsicum annum* L.) botanically referred to as the genus *Capsicum* is the member of *Solanaceae* family. Sweet pepper is relatively non-pungent or less pungent and it is the world second most important vegetables after tomato (AVRDC, 1989). Recent efforts are being made to grow sweet pepper in Bangladesh (Paul, 2009). But the production of sweet pepper is reduced due to flower and fruit drop which is caused by physiological and hormonal imbalance in the plants particularly under unfavourable environments (Erickson and Makhart, 2001). The varying responses of sweet pepper to plant growth regulators have been reported by Changli and Luisheng, (2009). Improvement in pepper growth and yield under $GA_3$ application was observed Vandana and verma, (2014). This might be ascribed to more effective utilization of food for reproductive growth (flowering and fruit set), higher photosynthetic efficiency and enhanced translocation and accumulation of sugars and other metabolites. Another growth regulators
namely, 4-chlorophenoxy acetic acid has been found to be effective in increasing fruit set and also used in reducing pre-harvest fruit drop and resulting in higher number of fruits and yield.

On the other hand, number of spray play an important role for producing maximum yield. However, information regarding the effectiveness of PGRs and different number of spray on growth and other physiological parameters of commercial pepper cultivars is very little. A detailed and systemic study is needed to find out the optimum concentration and the suitable combination of growth regulators and their number of spray for maximizing the yield of sweet pepper in Bangladesh.

2. Materials and Methods

2.1 Experimental site and experimental framework
The experiment was carried out at the horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2016 to March 2017. The location of the experimental site was at 23.41°N latitude and 90.22° longitude with an elevation of 8.24 m from sea level. Soil was having the texture of sandy loam with pH 5.6. Seeds of sweet pepper variety viz KS 2201 (Krishibid seed) was used as experimental material. The experiment was laid out in Randomized Complete Block Design with three replications. Factor- A had four levels of plant growth regulators viz. G0 - control, G1-GA3 at 30 ppm, G2-4-CPA at 45 ppm, G3-4-CPA @ 45 ppm + GA3 @ 30 ppm and Factor- B had three levels of number of spray viz. N0-control (no spray), N1-Two spray (vegetative+early flowering stage), N2-three spray (vegetative+early flowering+80% flowering stage).

2.2 Raising of seedling
Seeds were sown in the seedbed on 5 November 2016. The soil of the experimental plot was treated with savin 50WP at 5 kg per ha to protect the young plants from the attack of ants and cutworm. The size of the each plot was 1.5×1.2 m with 36 plots.

2.3 Transplanting of seedling
About 25 days old seedlings were transplanted into the prepared plot on 1 December 2016 with plant to plant spacing 50×30 cm. Fertilizers were applied at 250, 330, 250, 110 and 10 ton per ha for urea, TSP, MP, gypsum, and cow dung, respectively according to BARI (2011). Harvesting of fruits was done by hand picking.

3. Results and Discussion

3.1 Days from transplanting to 1st flowering
No significant variation was observed in terms of initiation of flowering due to imposition of treatments.

3.2 Number of flowers per plant
The maximum number of flowers per plant (32.58) was recorded by the application of G3 treatment, whereas the minimum number (30.06) was obtained from G0 treatment (Table 1). Similarly, maximum number of flowers per plant (31.68) was recorded from N2 treatment while the minimum number (30.64) was found from N0 treatment (Table 2). The highest number of flowers per plant (33.33) was recorded from G3N2 treatment combination, while the lowest number (29.66) was found from G0N0 treatment combination (Table 3). So, more flowers are produced where hormones are applied in combination than control. It was noticed that application of 4-CPA + GA3 enhanced flower production, reduced flower abscission that contributed the maximum number of flower per plant compared to plants treated with others hormone and control. This result is in agreement with the findings of Choudhury et al. (2013) who found that, the highest number of flowers per plant (39.69) were obtained in combined application of 20 ppm 4-CPA and 20 ppm GA3 in summer tomato plant.

3.3 Number of fruits per plant
Number of fruits per plant of sweet pepper showed significant differences due to the effect
of different plant growth regulators. The maximum number of fruits per plant (12.81) was found from G3 treatment and the minimum number (9.89) was recorded from G0 treatment (Table 1).

**Table 1. Main effect of plant growth regulators on flower and fruit setting in sweet pepper**

| Treatments | Days from transplanting to 1st flowering | Number of flowers per plant | Number of fruits per plant | Number of marketable fruits per plant | Fruit Setting (%) | Days from transplanting to 1st harvest |
|------------|----------------------------------------|-----------------------------|---------------------------|--------------------------------------|------------------|---------------------------------------|
| G0         | 49.16                                  | 30.06 d                     | 9.89 d                    | 5.37 d                               | 31.45 d          | 121.52 a                             |
| G1         | 50.25                                  | 30.65 c                     | 10.46 c                   | 5.93 c                               | 34.09 c          | 117.80 b                             |
| G2         | 51.38                                  | 31.51 b                     | 11.56 b                   | 6.52 b                               | 36.65 b          | 113.44 c                             |
| G3         | 51.98                                  | 32.58 a                     | 12.81 a                   | 7.24 a                               | 39.09 a          | 107.99 d                             |
| CV%        | 11.43                                  | 7.45                        | 8.62                      | 5.81                                 | 4.88             | 5.39                                  |

In a column means having similar letter(s) are significantly different per 0.05 level of probability.

**Table 2. Main effect of number of spray on flower and fruit setting in sweet pepper**

| Treatments | Days from transplanting to 1st flowering | Number of flowers per plant | Number of fruits per plant | Number of marketable fruits per plant | Fruit Setting (%) | Days from transplanting to 1st harvest |
|------------|----------------------------------------|-----------------------------|---------------------------|--------------------------------------|------------------|---------------------------------------|
| N0         | 49.96                                  | 30.64 c                     | 9.90 c                    | 5.58 c                               | 32.27 c          | 118.39 a                             |
| N1         | 50.71                                  | 31.29 b                     | 11.33 b                   | 6.27 b                               | 35.99 b          | 114.76 b                             |
| N2         | 51.41                                  | 31.68 a                     | 12.03 a                   | 6.94 a                               | 37.86 a          | 112.42 c                             |
| CV%        | 11.43                                  | 7.45                        | 8.62                      | 5.81                                 | 4.88             | 5.39                                  |

In a column means having similar letter(s) are significantly different per 0.05 level of probability.

**Table 3. Combined effect of plant growth regulators and number of spray on yield contributing characters and yield of sweet pepper**

| Treatments | Days from transplanting to 1st flowering | Number of flowers per plant | Number of fruits per plant | Number of marketable fruits per plant | Fruit Setting (%) | Days from transplanting to 1st harvest |
|------------|----------------------------------------|-----------------------------|---------------------------|--------------------------------------|------------------|---------------------------------------|
| G0N0       | 48.86                                  | 29.66 g                     | 8.92 k                    | 5.04 j                               | 30.08 j          | 122.28 a                             |
| G0N1       | 49.15                                  | 29.98 fg                    | 9.12 j                    | 5.32 i                               | 31.72 k          | 121.54 b                             |
| G0N2       | 49.46                                  | 30.54 def                   | 10.12 i                   | 5.75 h                               | 33.14 h          | 120.74 c                             |
| G1N0       | 49.33                                  | 30.15 efg                   | 9.61 j                    | 5.37 i                               | 31.87 j          | 119.42 d                             |
| G1N1       | 50.18                                  | 30.81 de                    | 10.54 g                   | 5.87 g                               | 34.22 f          | 117.74 e                             |
| G1N2       | 51.25                                  | 30.99 cd                    | 11.21 e                   | 6.55 d                               | 36.17 e          | 116.23 g                             |
| G2N0       | 50.72                                  | 31.00 cd                    | 10.23 h                   | 5.79 gh                              | 33.00 i          | 117.58 f                             |
| G2N1       | 51.36                                  | 31.68 b                     | 11.79 d                   | 6.38 e                               | 37.22 d          | 113.51 i                             |
| G2N2       | 52.07                                  | 31.85 b                     | 12.65 c                   | 7.39 c                               | 39.73 c          | 109.23 j                             |
| G3N0       | 50.95                                  | 31.73 b                     | 12.65 c                   | 6.12 f                               | 34.10 g          | 114.27 h                             |
| G3N1       | 52.15                                  | 32.69 a                     | 13.47 b                   | 7.51 b                               | 40.79 b          | 106.23 k                             |
| G3N2       | 52.84                                  | 33.33 a                     | 14.13 a                   | 8.10 a                               | 42.39 a          | 103.47 l                             |
| CV%        | 11.43                                  | 7.45                        | 8.62                      | 5.81                                 | 4.88             | 5.39                                  |

In a column means having similar letter(s) do not differ significantly at 0.05 level of probability.
Similarly the maximum number of fruits per plant (12.03) was obtained from N₂ treatment, while the minimum number (9.90) was obtained from N₀ treatment (Table 2). Combine effect shows that the maximum number of fruits per plant (14.13) was recorded from G₃N₂ treatment, while the minimum number (8.92) was found from G₀N₀ treatment (Table 3). Maximum number of fruit was recorded in plant growth regulators (4-CPA + GA₃) treated plants compared to control. This might be occurred due to application of auxin at the time of flowering which resulted lower flower drop and maximum number of fruits per plant.

3.4 Number of marketable fruits per plant
Application of plant growth regulators significantly enhanced fruit quality of sweet pepper. The maximum number of marketable fruits per plant (7.24) was found from plants under G₃ treatment, while the minimum number (5.37) was obtained from G₀ treatment (Table 1). The maximum number of marketable fruits per plant (6.94) was found from N₂ treatment, while the minimum number (5.58) from N₀ treatment (Table 2). From the results of the present study indicated that different number of spray can affect the fruit quality. The maximum number of marketable fruits per plant (8.10) was recorded from G₃N₂ treatment combination, while the minimum number (5.04) was for G₀N₀ treatment (Table 3). Application of plant growth regulators significantly enhanced fruit.

3.5 Fruit setting percentage
The maximum fruit setting (39.09%) was obtained from G₃ treatment, while the minimum fruit setting (31.45%) was found from G₀ treatment (Table 1). The maximum fruit setting (37.86%) was found from N₂ treatment, while the minimum (32.27%) was recorded from N₀ treatment (Table 2). The highest fruit setting (42.39%) was observed from G₃N₂ treatment combination, while the lowest (30.08%) was found from G₀N₀ treatment combination (Table 3). This result is in agreement with the findings of Sasaki et al. (2005) where he obtained that the tomato plants treated with a mixture of 4-CPA and GA₃ showed increased fruit set and proportion of normal fruits compared to plants of the same crop treated with 4-CPA alone.

3.6 Days from transplanting to 1st harvest
The minimum days from transplanting to 1st harvest (107.99) was found from G₃ treatment, while the maximum days (121.52) was recorded from G₀ treatment (Table 1). However, minimum days from transplanting to 1st harvest (112.42) was attained from N₂ treatment, while the maximum days (118.39) was found from N₀ treatment (Table 2). The minimum days from transplanting to 1st harvest (103.47) was recorded from G₃N₂ treatment combination, while the maximum days (122.28) was found from G₀N₀ treatment combination (Table 3). Hasanuzzaman et al. (2007) reported that, plant hormones promoted the harvesting of sweet pepper a few days earlier than control.

3.7 Length and diameter of fruits
The maximum length (7.59 cm) and diameter of fruit (5.33 cm) were found from G₃ treatment, where the minimum length (6.14 cm) and the minimum diameter (4.25 cm) were found from G₀ treatment (Table 4). Plant growth regulators have possibility to increase fruit length and diameter. This result is in agreement with the findings of Hasanuzzaman et al. (2007). The maximum length (7.39 cm) and diameter of fruit (5.09 cm) were recorded from N₂ treatment, while the minimum length (6.29 cm) and minimum diameter (4.42 cm) were found from N₀ treatment (Table 5). From the results of the present study indicated that different number of spray can affect the fruit quality. The maximum length of fruit (8.11 cm) and diameter of fruit (5.71 cm) were found from G₃N₂ treatment combination, while the minimum length (5.75 cm) and diameter (4.1 cm) were found from G₀N₀ treatment combination (Table 6).
Table 4. Main effect of plant growth regulators on yield contributing characters and yield of sweet pepper

| Treatment | Length of fruit (cm) | Diameter of fruit (cm) | Pericarp thickness (mm) | Individual fruit weight (g) | Yield per plant (g) | Yield per hectare (ton) |
|-----------|----------------------|------------------------|-------------------------|-----------------------------|--------------------|-------------------------|
| G₀        | 6.14 d               | 4.25 d                 | 5.42 d                  | 52.70 d                     | 283.56 a           | 18.80 d                 |
| G₁        | 6.71 c               | 4.55 c                 | 5.67 c                  | 53.73 c                     | 318.94 c           | 21.24 c                 |
| G₂        | 7.13 b               | 4.88 b                 | 5.97 b                  | 55.38 b                     | 361.80 b           | 24.11 b                 |
| G₃        | 7.59 a               | 5.33 a                 | 6.33 a                  | 57.38 a                     | 416.90 a           | 27.70 a                 |
| CV%       | 6.31                 | 8.87                   | 9.35                    | 10.93                       | 9.34               | 9.63                    |

In a column means having similar letter(s) are significantly different per 0.05 level of probability.

Table 5. Main effect of number of spray on yield contributing characters and yield of sweet pepper

| Treatment | Length of fruit (cm) | Diameter of fruit (cm) | Pericarp thickness (mm) | Individual fruit weight (g) | Yield per plant (g) | Yield per hectare (ton) |
|-----------|----------------------|------------------------|-------------------------|-----------------------------|--------------------|-------------------------|
| N₀        | 6.29 c               | 4.42 c                 | 5.42 c                  | 53.40 c                     | 298.34 c           | 19.87 c                 |
| N₁        | 6.99 b               | 4.74 b                 | 5.89 b                  | 55.08 b                     | 347.02 b           | 23.11 b                 |
| N₂        | 7.39 a               | 5.09 a                 | 6.16 a                  | 55.95 a                     | 390.54 a           | 26.00 a                 |
| CV%       | 6.31                 | 8.87                   | 9.35                    | 10.93                       | 9.34               | 9.63                    |

In a column means having similar letter(s) are significantly different per 0.05 level of probability.

Table 6. Interaction of plant growth regulators and number of spray on yield contributing characters and yield of sweet pepper

| Treatment | Length of fruit (cm) | Diameter of fruit (cm) | Pericarp thickness (mm) | Individual fruit weight (g) | Yield per plant (g) | Yield per hectare (ton) | Net return (Tk/ha) | BCR   |
|-----------|----------------------|------------------------|-------------------------|-----------------------------|--------------------|-------------------------|-------------------|-------|
| G₀N₀      | 5.75 h               | 4.10 g                 | 5.19 h                  | 52.02 k                     | 262.71 l           | 17.50 k                 | 433045           | 1.49  |
| G₀N₁      | 6.12 g               | 4.19 f                 | 5.40 g                  | 52.66 j                     | 280.69 k           | 18.67 j                 | 433045           | 1.49  |
| G₀N₂      | 6.54 f               | 4.49 e                 | 5.67 f                  | 53.44 h                     | 307.30 i           | 20.43 h                 | 433045           | 1.49  |
| G₁N₀      | 6.15 g               | 4.24 f                 | 5.35 g                  | 52.84 i                     | 283.73 j           | 18.90 i                 | 405858           | 1.53  |
| G₁N₁      | 6.75 e               | 4.50 e                 | 5.67 f                  | 53.56 g                     | 314.38 g           | 20.93 f                 | 622789           | 1.66  |
| G₁N₂      | 7.23 d               | 4.91 d                 | 5.99 de                 | 54.79 f                     | 358.70 d           | 24.93 d                 | 828423           | 1.87  |
| G₂N₀      | 6.45 f               | 4.51 e                 | 5.56 f                  | 53.65 g                     | 310.63 h           | 20.72 g                 | 637450           | 1.69  |
| G₂N₁      | 7.25 d               | 4.88 d                 | 6.09 d                  | 55.95 d                     | 356.89 e           | 23.79 d                 | 856518           | 1.93  |
| G₂N₂      | 7.69 c               | 5.23 c                 | 6.26 c                  | 56.54 c                     | 417.89 c           | 27.82 c                 | 1158085          | 2.25  |
| G₃N₀      | 6.82 e               | 4.86 d                 | 5.88 e                  | 54.94 e                     | 336.30 f           | 22.38 e                 | 225238           | 2.24  |
| G₃N₁      | 7.83 b               | 5.41 b                 | 6.41 b                  | 58.15 b                     | 436.13 b           | 29.05 b                 | 1218423          | 2.27  |
| G₃N₂      | 8.11 a               | 5.71 a                 | 6.70 a                  | 59.05 a                     | 478.27 a           | 31.87 a                 | 1416558          | 2.46  |
| CV%       | 6.31                 | 8.87                   | 9.35                    | 10.93                       | 9.34               | 9.63                    | 433045           | 1.49  |

In a column means having similar letter(s) do not differ significantly at 0.05 level of probability.
3.8 Pericarp thickness
The higher pericarp thickness (6.33 mm) was recorded from G₃ treatment, while the lower thickness (5.42 mm) was observed from G₀ treatment (Table 4). The maximum pericarp thickness (6.16 mm) was recorded from N₂ treatment, while the minimum thickness (5.50 mm) was observed from N₀ treatment (Table 5). The maximum pericarp thickness (6.70 mm) was found from G₃N₂ treatment combination, while the minimum thickness (5.19 mm) was recorded from G₀N₀ treatment combination (Table 6).

3.9 Individual fruit weight
The maximum weight of individual fruit (57.38 g) was recorded from G₃ treatment, while the minimum weight (52.70 g) was observed from G₀ treatment (Table 4). The maximum weight of individual fruit (55.95 g) was found from N₂ treatment, while the minimum weight (53.40 g) was recorded from N₀ treatment (Table 5). The maximum weight of individual fruit (59.05 g) was attained from G₃N₂ treatment combination, while the minimum weight (52.02 g) was found from G₀N₀ treatment combination (Table 6).

3.10 Fruit yield
The maximum yield per plant (416.90 g) and yield per hectare (27.70 ton) were recorded from G₃ treatment, while the minimum, yield per plant (283.56 g) and fruit yield per hectare (18.80 ton) were found from G₀ treatment (Table 4). Kannan et al. (2009) reported that application of GA₃ had significant effect on growth and yield attributes on pepperica hot pepper. The maximum yield per plant (390.54 g) and hectare (26.00 ton) were observed from N₂ treatment, while the minimum yield per plant (298.34 g) and yield per hectare (19.87 ton) were recorded from N₀ treatment (Table 5). The highest yield per plant (478.27 g) and yield per hectare (31.87 ton) was attained from G₃N₂ treatment combination, while the lowest yield per plant (262.71 g) and yield per hectare (17.50 ton) were found from G₀N₀ treatment combination (Table 6). From the results of the study indicated that plant growth regulators can affect the fruit quality. Hasanuzzaman et al. (2007) reported that, due to hormonal treatments significant variation exists in respect of fruit yield. The results revealed that the maximum growth, yield and yield attributes were found with PGRs than control.

3.11 Net return
In case of net return, different treatment combination showed various levels of net return under the present trial. The highest net return (Tk. 1416558) was obtained from the treatment combination G₃N₂ and the lowest (Tk. 433045) was found from G₀N₀ treatment combination (Table 6).

3.12 Benefit Cost Ratio
The highest benefit cost ratio (2.46) was found from the treatment combination of G₃N₂ and the lowest (1.49) was found from the G₀N₀ treatment combination. From the economic point of view, it was apparent that the treatment combination of G₃N₂ was more profitable than others.

4. Conclusions
Considering the results of this experiment, it may be concluded that the plant growth regulators (4-CPA @ 45 ppm + GA₃ @ 30 ppm) and three sprays would give better performance than others. However, the experiment should be carried out with more variables in different AEZs to reconfirm the recommendation.

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