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ON

Yield and Quality Improvement of Vegetable Crops Using Plant Growth Regulators

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BY

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ABSTRACT

Plant growth regulators have contributed a great deal of progress and an outstanding achievement to the agricultural science. During the recent years, a no. of plant growth regulators is used on vegetables to enhance production. It was found that 80 ppm GA_3 and 100 ppm NAA gave maximum pod weight (130.8 g & 128.6 g) and yield (48.36 t/ha & 47.42 t/ha) respectively in tomato. Besides, 2,4-D (10 ppm) and BARI Hybrid Tomato-8 with combined application of 60 ppm (4-CPA+GA_3) gave maximum fruit weight and yield(t/ha) over control. In okra, GA_3 (100 ppm), NAA (20 ppm) and Chitosan (125 ppm) provided better yield and maximum pod size & average wt. of pods/plant compared to control condition. In the cole crops-cabbage & broccoli are resulted maximum yield (104.66 t/ha & 24.5 t/ha respectively) from the application of 50 ppm GA_3. Maximum dry wt. of curd /100 fresh wt. (171.95 g) in cabbage & maximum curd size in broccoli was also obtained from 50 ppm GA_3 application. Combined application of 60 ppm & 40 ppm (GA_3+kinetin) gave the better yield and maximum vit-A & vit-C content respectively in broccoli. Besides, a number of growth regulators like GA_3 (150 ppm), NAA (140 ppm), IBA (15 ppm) & IAA (10 ppm) were also found to provide maximum yield and better curd quality in cauliflower. This review deals with the use of growth regulators on vegetable crops.

CONTENTS

LIST OF THE TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The term vegetable in its broadest sense refers to any kind of plant life or plant product and in the narrower sense it refers to the fresh, edible portion of herbaceous plant consumed in either raw or cooked form. Vegetables are very important to the human diet. They are the main sources of nutrients such as vitamins, minerals, folic acid and dietary fiber and low in fat and sodium (en.wikipedia.org/wiki/Vegetable). The American Cancer Society states that eating vegetables reduces cancer rates and the American Heart Association states that eating vegetables reduces the incidence of heart disease (Arteca, 2015).

Nutrition experts recommended 3 to 5 servings per day for a healthy diet which provides an individual about 20% lower risk of coronary heart disease and stroke (He, *et al*., 2007). In addition, research has shown that eating vegetables reduces stress, insomnia and aging-related eye diseases i.e. cataracts and macular degeneration (Christen, *et al*., 2005). People are now becoming more interested in their health and to increase their quality of life, which has led to a rise in vegetables consumption in recent years (Arteca, 2015).

According to Yearbook of Agricultural Statistics 2014-2015, in Bangladesh, vegetables occupies an area of 989000 acres of land with production of 3729000 M tons and per acre yield of 3770 kg (BBS, 2015) and besides, global production volume of vegetables are 1106.13 million metric tons (Statistic Brain Research Institute, 2017). In Bangladesh, vegetable production is not uniform round the year: plenty in winter but less in summer season. Around, 30% of total vegetables are produced during summer and 70% in winter (Hossain, 1992). The present consumption of vegetables in Bangladesh is 112 g/day/capita (23 g leafy vegetables, 89 g non leafy vegetables), which is far below the minimum average requirement of 400 g/day/capita (FAO/WHO, 2003). Therefore, there is a big gap between the requirement and the supply of vegetables in Bangladesh.

As vegetables occupy a vital place in our balanced diet, it is equally important that the area and production of vegetables crops should be increased more. Use of high-yielding varieties and improved technologies can increase the production to meet our growing demand for vegetables (Chand *et al*., 2014). Besides this, application of plant growth regulators has become essential for increasing the productivity of vegetable crops. These chemicals are highly regulated because they are used on plants or their products which will be consumed (Arteca, 2015).

Plant growth regulators have been used as important component in agricultural production even prior to the identification of plant hormone. Plant growth regulators are now used on over one million hectares worldwide on a diversity of crops each year (Lee, 2003). However, most of these applications are confined to high-value horticultural crops.

Growth regulators are organic chemical substance, other than nutrients and vitamins which regulate the growth of plant when applied in small quantities (Arteca, 2015). In case of vegetables, growth regulators are used mainly to improve seed germination power, increase yield, plants become resistant to diseases and unfavorable growth conditions (Halter *et al*., 2005; Jankauskienė and Survilienė, 2009; Mukhtar, 2008).

Many plant growth regulators are now used for increasing crops yields. For example, Activol and ProGibb are gibberellins used in vegetable crops to increase size and fruit quality. In brinjal, soaking of seedlings roots in NAA at 0.2 mg/l has been reported to produce higher fruit yield (Chand *et al*., 2014). Foliar sprays of 2,4-D @ 6 ppm and 4 ppm gave the highest yield of tomato and brinjal respectively (Patel *et al*., 2012). Besides, in tomato, 75 ppm 4-CPA resulted not only the highest increase in fruit set (32.19%) but also increased the yield (64.99%) (Baliyan *et al*., 2013).

In Greece and other European countries, the PGRs are commonly used on food crops (melon, pepper, celery etc) in order to improve and accelerate plant productivity. The role of plant growth regulators becomes more vital in our country as well as other countries. Plant growth regulators provide an immediate impact on crop improvement programs. Considering the above, here are the following objectives in this review paper related to the topic:

1. To know about the suitable plant growth regulators used in vegetable crops.
2. To review the effect of plant growth regulators on yield and quality of different vegetable crops.

CHAPTER II

MATERIALS AND METHODS

The topic of this seminar paper was selected with the consultation of Major Professor. This paper is exclusively a review paper. So, all of the information has been collected from the secondary sources such as various relevant books, journals, proceedings, reports, publications etc. for preparing this manuscript. Topic related findings have been reviewed with the help of the library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University. Some information has also been collected by searching internet web sites. Valuable suggestion and information were collected from course instructors, major professor and other resource personnel. After collecting information, these were compiled and used for preparing this seminar manuscript.

CHAPTER III

REVIEW OF LITERATURE

Plant Growth Regulators

Plant growth regulators are organic substances other than nutrients, which in small amount promotes/inhibit or otherwise modify any physiological response in plants (Prajapati *et al*., 2015).

Classification of plant growth regulators (Prajapati *et al*., 2015)

1. Auxins: (IAA, NAA, IBA, 2,4-D, 4-CPA)
2. Gibberellins: (GA_3)
3. Cytokinins: (Kinetin, Zeatin)
4. Ethylene: (Etheral)
5. Abscissic acid: (Dormins, Phaseic Acid)
6. Flowering hormones: (Florigen, Vernalin)
7. Natural substances: (Vitamins, Phytochrome Tranmatic)
8. Synthetic substances: (Synthetic Auxins, Synthetic Cytokinins)

Different Plant growth regulators and their associated functions (Prajapati *et al*., 2015)

- Auxins: Apical dominance, root induction, control fruits drops, regulation of flowering.
- Gibberellin: Seed germination, stimulates flowering, increase flower and fruit size.
- Cytokinin: Bud initiation and root growth, storage life prolongation of vegetables.
- Ethylene: Uniform ripening in vegetables, promotes abscission, senescence of leaf.
- Abscisic acid: Stress hormone, dormancy, seed development and germination.

Effect of different growth regulators on vegetable crops

For vegetable production, plant growth regulator is a modern concept as a management practices. Numerous studies have been performed evaluating the influence of growth regulators on vegetable crops. At present time, different plant growth regulators like GA_3, NAA, 2, 4-D, IAA, IBA, 4-CPA etc. at various concentration is used in vegetables like tomato, cabbage, cauliflower, okra and broccoli for improving yield and quality.

1.0 Effect of growth regulators at different concentration on yield and quality improvement of tomato

Tomato (*Solanum lycopersicum*) is one of the important vegetable crop belongs to solanaceae family. It is an important protective food because of its special nutritive value and widespread production. Tomato is the world's third largest vegetable crop. At present time, different plant growth regulators like GA_3, NAA, 2, 4-D is used in tomato for increasing yield and quality.

1.1 Effect of GA_3 and NAA application on yield and quality of tomato

Prasad *et al.* (2013) conducted an experiment on tomato with GA_3 levels (20, 40, 60, 80 ppm) and NAA levels (25, 50, 75, 100 ppm). They observed that application of GA_3 and NAA significantly increased the % fruit set, number of fruits per plant, and fruit yield as compared to the control. The maximum fruit yield (48.36 t/ha) was obtained with application GA_3 @80 ppm closely followed by NAA@ 100 ppm (47.42 t/ha). (Table 1).

Table 1: Effect of GA_3 and NAA on yield and yield contributing characters of tomato

Treatments	% fruit set	No. of fruits/plant	Fruit yield (t/ha)
Control	30.6	13.2	38.07
GA_3 (20 ppm)	35.4	18.7	39.62
GA_3 (40 ppm)	40.2	22.7	41.86
GA_3 (60 ppm)	47.3	26.2	44.65
GA_3 (80 ppm)	51.6	30.2	48.36
NAA (25 ppm)	32.1	18.5	39.05
NAA (50 ppm)	37.7	21.7	40.27
NAA (75 ppm)	44.5	23.4	43.36
NAA (100 ppm)	49.1	24.7	47.42

Source: Modified from Prasad *et al.* (2013)

From the table no. 2, it was observed that with the increasing concentration of GA_3 and NAA, fruit length, fruit width, fruit weight and rind thickness was increased compared with control. But maximum fruit length (6.46 cm), fruit width (6.86 cm) and fruit weight (130.8 g) was found from GA_3 80 ppm concentration. Rind thickness (0.56 cm) was also the highest at GA_3 80 ppm concentration followed by NAA 100 ppm. (Table 2).

Table 2: Effect of GA_3 and NAA on fruit size and quality of tomato

Treatments	Fruit length(cm)	Fruit width(cm)	Fruit weight(g)	Rind thickness(cm)
Control	4.3	4.4	80.5	0.40
GA_3(20 ppm)	4.8	4.92	85.1	0.45
GA_3 (40 ppm)	5.06	5.21	120.2	0.48
GA_3(60 ppm)	5.92	6.20	125.7	0.52
GA_3(80 ppm)	6.46	6.86	130.8	0.56
NAA(25 ppm)	4.6	4.72	84.1	0.44
NAA(50 ppm)	4.82	4.90	118.2	0.45
NAA(75 ppm)	5.78	6.11	121.8	0.50
NAA(100 ppm)	6.08	6.38	128.6	0.55

Source: Prasad *et al.*, (2013)

1.2 Effect of GA_3 application on quality characters of tomato

Kumar *et al.* (2014) conducted an experiment on growth, yield and quality of tomato using different GA_3 levels. They observed the maximum fresh fruit weight (kg/plant) from T_5 (3.12 kg) followed by T_4 (2.96 kg). Besides, maximum ascorbic acid (mg/100gm) and maximum TSS (^{o}Brix) were found from T_5 (1.88 mg/100 gm and 4.95 ^{o}Brix) followed by T_4 (1.74 mg/100 gm and 4.70 ^{o}Brix) respectively. (Table 3).

Table 3: Effect of GA_3 levels on quality characters of tomato

Treatment (ppm)	Fresh fruit weight (kg)	Ascorbic acid (mg/100 gm)	Total soluble solid (^{o}Brix)
T_0 (0 ppm)	1.10	1.10	3.80
T_1 (10 ppm)	2.08	1.38	4.25
T_2 (20 ppm)	2.22	1.52	4.37
T_3 (30 ppm)	2.47	1.66	4.52
T_4 (40 ppm)	2.96	1.74	4.70
T_5 (50 ppm)	3.12	1.88	4.95

Source: Kumar *et al.*, (2014)

1.3 Effect of GA_3 and 4-CPA application on yield contributing characters of tomato

The information regarding on the use of plant growth regulators in summer tomato production is not adequate. Rahman *et al.* (2015) conducted an experiment on different levels of GA_3 and 4-chlorophenoxy acetic acid (4-CPA) by using two varieties of summer tomato named BARI Hybrid Tomato-4 and BARI Hybrid Tomato-8. From the interaction effect of variety and plant growth regulators, they found the highest yield (27.28 t/ha) from V_2T_3 whereas V_1T_0 gave the lowest (13.05 t/ha). In that case, variety was the BARI Hybrid Tomato-8 which gave highest yield in combined application of GA_3 and 4-CPA at 60 ppm concentration. Besides, highest fruits no./plant (21.91) and individual fruit wt. (61.16 g) were also found from V_2T_3 treatment. (Table 4).

Table 4: Interaction effect of plant growth regulators on yield of summer tomato

Treatment combination	No. of fruits/plant	Individual fruit weight (gm)	Yield (t/ha)
V_1T_0	12.07	53.01	13.05
V_1T_1	18.08	55.87	20.56
V_1T_2	21.50	57.22	25.05
V_1T_3	21.66	59.56	26.25
V_2T_0	12.11	55.31	13.64
V_2T_1	20.60	57.79	24.23
V_2T_2	21.54	59.51	25.86
V_2T_3	21.91	61.16	27.28

Source: Rahman *et al.*, (2015)

Here, V_1 & V_2 indicate BARI Hybrid Tomato-4 & BARI Hybrid Tomato-8 and T_0, T_1, T_2 & T_3 indicate control, 4-CPA (20 ppm), GA_3 (40 ppm) and 4-CPA + GA_3 (60 ppm), respectively.

1.4 Effect of 2,4-D application on yield contributing characters of tomato

Another experiment was conducted by Luitel *et al.* (2015) and they worked on 2, 4-D and observed the improvement of yield of tomato under protected condition. They observed that spraying of 5 ppm 2,4-D on flowers gave the highest (55.0%) fruit set followed by 10 ppm. But the maximum total fruits/plant (14.8) produced at 10 ppm 2,4- D spray. Besides, they found the highest fruit yield/plant (587.9 g) at 10 ppm spray followed by 5 ppm spray. (Fig. 1)

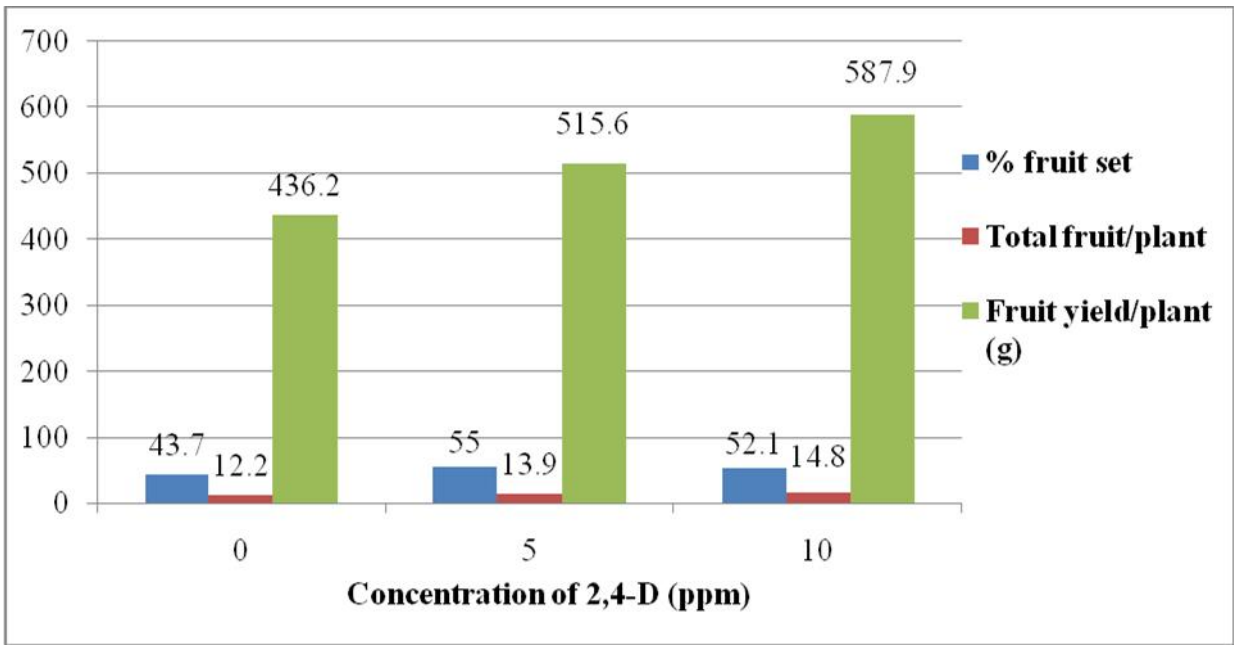

Fig. 1: Effect of 2,4-D on yield contributing characters of tomato.

Source: Luitel *et al.*, (2015)

2.0 Effect of growth regulators at different concentration on yield and quality improvement of okra

Okra (*Abelmoschus esculentus* (L.) is an annual vegetable crops grown in the tropical and sub tropical parts of the world. Various practices may help to achieve this target like use of growth regulators named GA_3, NAA, Miraculan etc. seems to be most effective. GA_3 has been reported beneficial in okra because it is involved in the regulation of growth and development of the crop (Sachs, 1965). NAA is also being used in many vegetable crops at various stages of development for increasing growth and yield by way of cell elongation, enlargement and differentiation. Artificial foliar spray of growth regulators has been found effective in increasing vegetative growth, early fruiting, total yield and quality of fruits in many vegetables (Ramu and Muthuswamy, 1964). Very limited amount of works have been conducted on the effect of NAA on growth, yield and quality of okra but appreciable amount of works have been done.

2.1 Effect of GA_3 and Miraculan on yield and pod quality (size) of okra

Chowdhury *et al.* (2014) worked on the effect of GA_3 and miraculan on yield and pod quality of okra and used BARI Dherosh-1 as a test crop. They observed the maximum number of pods per plant (33.77) from G_1 (100 ppm GA_3) whereas the minimum (24.30) was observed from G_0 (Control). The highest yield (16.67 t/ha) was observed from G_1 (100 ppm GA_3) whereas the lowest yield (14.08 t/ha) was attained from G_0 (control). (Fig. 2).

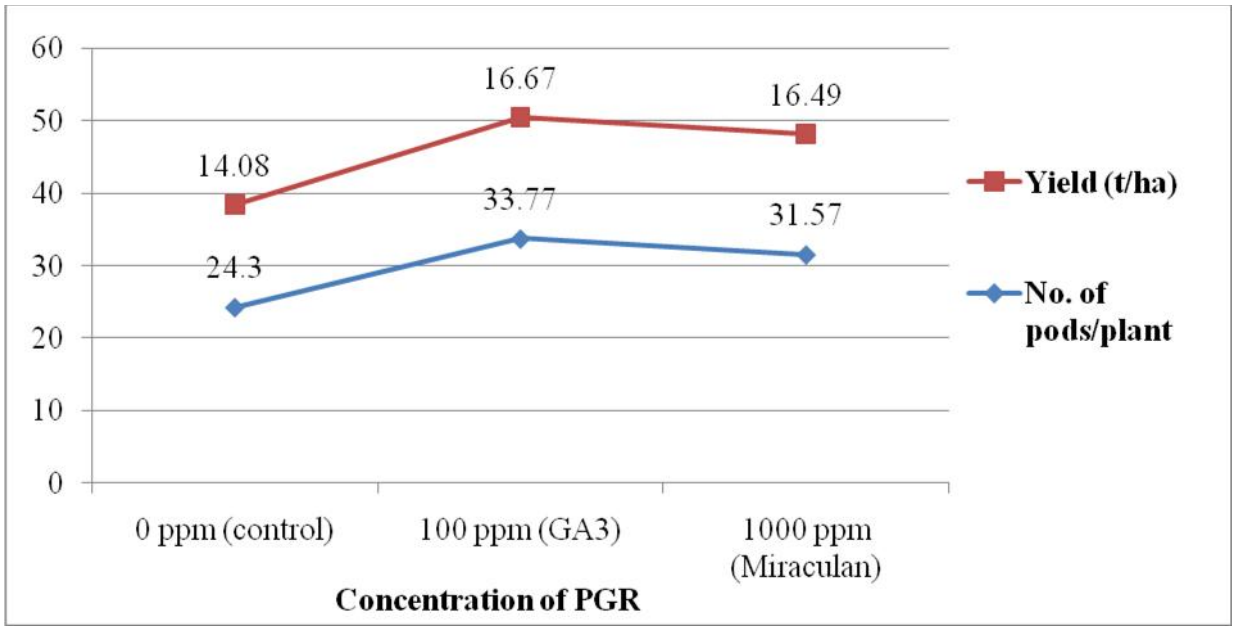

Fig 2: Effect of GA_3 and Miraculan on yield of Okra (BARI Dherosh-1).

Source: Chowdhury *et al.*, (2014)

In case of GA_3 application, Vijayaraghavan (1999) reported that he was found the highest number of fruits per plant with the highest fruit yield 15.7 t/ha at 50 ppm GA_3 application as compared with the control yield which was 8.07 t/ha. Surendra *et al*. (2006) also reported that GA_3 @25 and 50 ppm gave the highest fruit yields (15.81 t/ha and 18.69 t/ha, respectively) over control.

Chowdhury *et al*. (2015) recorded significant variation in pod length and pod diameter as an effect of growth regulators. They found the longest pods (17.66 cm) in G_1 (100 ppm GA_3) treated crops and the shortest pods (15.33 cm) from G_0 (control). Besides, the highest pod diameter (1.77 cm) was recorded from G_1 whereas the lowest diameter (1.33 cm) was recorded from G_0. (Table 5).

Table 5: Effect of GA_3 and Miraculan (0.05% Triacontanol) on pod quality (size) of okra

Treatment	Pod length (cm)	Pod diameter (cm)
G_0 (control)	15.33 b	1.33 b
G_1 (GA_3 100 ppm)	17.66 a	1.77 a
G_2 (Miraculan 1000 ppm)	17.61 a	1.70 a

Source: Chowdhury *et al.*, (2014)

2.2 Effect of GA_3 and NAA on yield and pod quality (size) of okra

Recently, an experiment was conducted by Meena *et al.* (2017) on growth, yield and quality of okra by foliar application of NAA and GA_3. Seven treatments were used with different concentration and all the treatments showed better results than control. The maximum numbers of pods/plant (28.23) and average weight of pods/plant (251.03 g) were recorded under T_6 (NAA 20 ppm) over control and other treatments. The maximum pod diameter (2.63cm) and pod length (13.93 cm) was also recorded from T_6 (NAA 20 ppm). Besides, T_6 (NAA 20 ppm) obtained higher yield (16.73 t/ha) than other treatment application including control which is followed by 16.30 t/ha and 16.19 t/ha obtained from T_7 and T_5 respectively. (Table 6).

Table 6: Effect of NAA and GA_3 on yield and pod quality of okra

Treatments	No. of pods/plant	Pod length (cm)	Pod diameter (cm)	Avg. wt. of pods/plant (g)	Yield (t/ha)
T_0 (Control)	22.00	12.00	1.73	210.53	14.03
T_1 (Only water)	25.53	13.87	1.97	215.91	14.39
T_2 (GA_3 10 ppm)	22.90	13.87	1.97	223.18	14.84
T_3 (GA_3 20 ppm)	24.57	13.87	1.97	225.40	15.02
T_4 (GA_3 30 ppm)	25.37	13.83	2.37	234.14	15.60
T_5 NAA 10 ppm)	25.77	13.73	2.13	242.11	16.19
T_6 (NAA 20 ppm)	28.23	13.93	2.63	251.03	16.73
T_7 (NAA 30 ppm)	27.07	13.67	2.24	244.71	16.30

Source: Modified from Meena *et al.*, (2017)

2.3 Effect of chitosan application on yield of okra

Mondal *et al.* (2012) also conducted an experiment to investigate the effect of foliar application of chitosan on growth and fruit yield of okra cv. BARIdherosh-1. They used five levels of chitosan concentrations *viz*., 0, 50, 75, 100 and 125 ppm. They found the results that yield were increased with increasing concentration of chitosan. The higher fruit yield/ha were recorded 15.31 t/ha in 125 ppm chitosan treatments followed by 15.21 t/ha in 100 ppm. Besides the lowest yield (11.97 t/ha) were obtained from control (0 ppm). (Fig. 3).

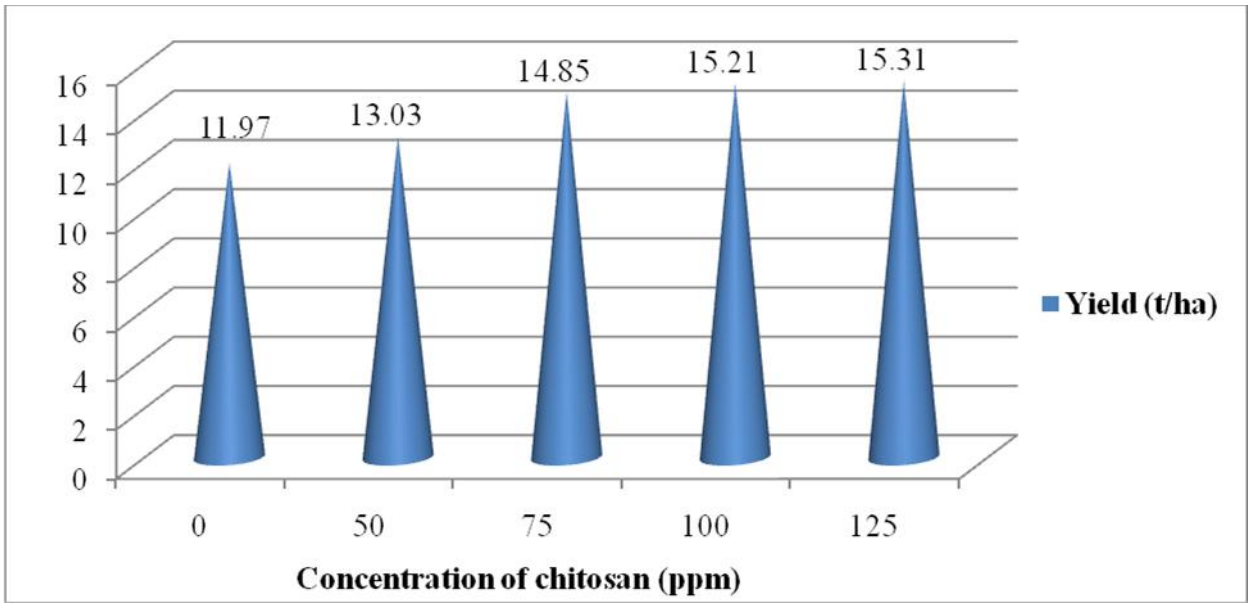

Fig. 3: Effect of different levels of Chitosan on yield of okra.

Source: Mondal *et al.*, (2012)

3.0 Effect of growth regulators at different concentration on yield and quality improvement of cabbage

Cabbage (*Brassica oleracea* var. *capitata* L.), a member of the family Cruciferae, is one of the five leading vegetables in Bangladesh. The production of cabbage can be increased by using GA_3. Cabbage was found to show a quick growth when treated with plant growth regulators (Islam *et al*., 1993). Application of GA_3 stimulates yield contributing characters, yield and quality of cabbage. Ram *et al.* (1973), Patil *et al*. (1987) and Kumar *et al.* (1996) tried various growth regulators to obtain better yield of good quality heads in cabbage and obtained encouraging results.

3.1 Effect of GA_3 application on yield components and yield of cabbage

Roy and Nasiruddin (2011) worked on different concentration of GA_3 on okra and found better result over control. The maximum economic yield/plant (2.80 kg) was recorded from 50 ppm GA_3 which was followed by 75 ppm GA_3 (2.60 kg). While the lowest economic yield/plant (1.91 kg) was recorded from 0 ppm (control). The highest yields (104.66 t/ha) was also found with 50 ppm GA_3 (G_2), followed by 75 ppm GA_3 (98.55 t/ha). Similarly, the lowest yield (66.56 t/ha) was recorded from the control treatment (G_0). (Fig. 4).

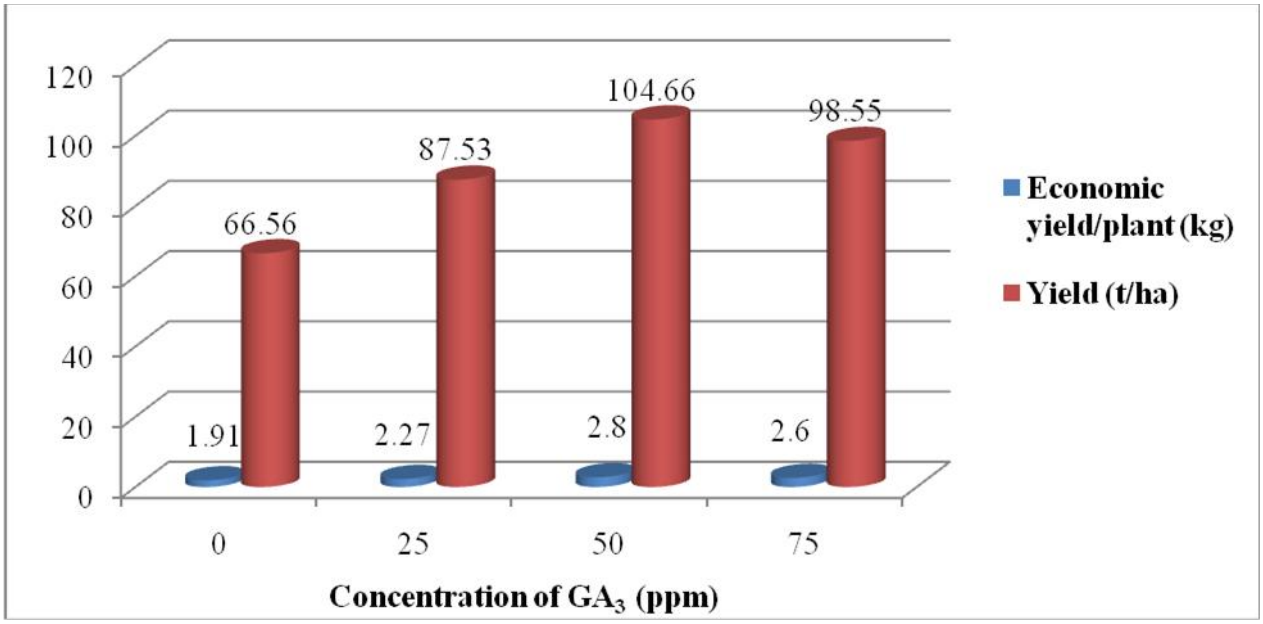

Fig. 4: Effect of GA_3 levels on yield of cabbage.

Source: Roy and Nasiruddin, (2011)

3.2 Effect of GA_3 application on head quality of cabbage

Application of GA_3 significantly influenced the dry weight of head of cabbage. The maximum dry weight of cabbage head (171.95 g) was found in 50 ppm GA_3 and the lowest dry weight of head (115.97 g) was found in the control treatment (G_0). (Table 7).

Table 7: Effect of GA_3 levels on the head quality of cabbage

Conc. of GA_3 level (ppm)	Size of the head		Gross weight of head (kg)	Dry weight of head (g)
	Thickness of head (cm)	Diameter of head (cm)		
0	12.65	17.89	2.69	115.97
25	14.13	20.84	2.80	148.27
50	14.92	23.81	3.55	171.95
75	14.70	22.81	3.43	150.10

Source: Roy and Nasiruddin, (2011)

The findings indicated that the yield and head quality of cabbage was greatly improved by 50 ppm GA_3 concentration over control.

4.0 Effect of growth regulators at different concentration on yield and quality improvement of cauliflower

Cauliflower (*Brassica oleracea* var. *botrytis* sub-var. *cauliflora*) is one of the most important cole crop belongs to the family cruciferae. Many experiments have been carried out in developed nations to investigate the effect of plant growth regulators on the yield and quality of Cauliflower. Promising results was found on yield and quality of Cauliflower and other crops due to the use of PGR, such as NAA, GA_3, IAA etc. (Sentelhas *et al*., 1987, Tomar *et al*., 1991). GA_3 and IAA have a positive effect on curd formation and size of cauliflower, (Sharma and Mishra, 1989).

4.1 Effect of foliar application of IAA and GA_3 on curd yield and quality of cauliflower

A research was conducted by Akhter (2007) where GA_3 in different concentrations viz. 80 and 100 ppm and IAA in different concentrations viz. 5, 10 ppm were used as compared to control. From this experiment, highest curd diameter (23.38 cm) and curd length (15.22 cm) was found in application of I_1 (5 ppm IAA) followed by G_2 (100 ppm GA_3). But maximum curd wt. (1.33 kg/plant) and maximum curd yield (53.33 t/ha) was found from 100 ppm GA_3 application followed by 1.08 kg/plant curd weight and 43.37 t/ha yield from I_2 (10 ppm) and in both cases lowest result was found from control application. (Table 8).

Table 8: Effect of IAA and GA_3 on curd yield and quality of cauliflower

Treatments (ppm)	Curd diameter (cm)	Curd length (cm)	Curd weight (kg/plant)	Curd yield (t/ha)
I_0 (control)	19.82	13.73	0.83	33.24
I_1 (5 ppm)	23.38	15.22	1.00	39.11
I_2 (10 ppm)	21.76	11.09	1.08	43.37
G_0 (control)	20.88	10.49	0.65	26.04
G_1 (80 ppm)	21.53	13.12	0.93	37.15
G_2 (100 ppm)	22.55	14.80	1.33	53.33

Source: Modified from Akhter, (2007)

4.2 Effect of GA_3, NAA and IBA on curd quality and yield of cauliflower

Jadon *et al.* (2009) conducted experiment on cauliflower by the effect of GA_3, NAA and IBA as Foliar Spray. They found the maximum curd diameter (15.80 cm) and curd length (22.87 cm) from GA_3 150 ppm as compared with others including control. Maximum dry weight of curd/ per 100 gm fresh weight was also recorded from foliar sprays of 150 ppm GA_3. (Table 9).

Table 9: Effect of GA_3, NAA and IBA as foliar spray on the curd quality of cauliflower

Treatments	Curd diameter (cm)	Curd length (cm)	Dry weight of curd/100 fresh weight
G_0 (control)	11.63	16.96	8.03
G_1 (GA_3 50 ppm)	13.80	20.37	8.20
G_2 (GA_3 100 ppm)	15.30	21.68	9.50
G_3 (GA_3 150 ppm)	15.80	22.87	10.50
G_4 (NAA 100 ppm)	13.10	19.88	8.13
G_5 (NAA 120 ppm)	14.50	20.35	9.43
G_6 (NAA 140 ppm)	15.10	21.58	10.40
G_7 (IBA 5 ppm)	12.86	18.88	8.10
G_8 (IBA 10 ppm)	13.80	19.40	9.27
G_9 (IBA 15 ppm)	14.53	20.68	10.23

Source: Jadon *et al.*, (2009)

Jadon *et al*. (2009) found that all the plant growth regulator treatments increased the yield of cauliflower over control. The following figure showed that with increase in concentration of all growth regulators there was increase in yield. In case of GA_3, foliar application of GA_3 at 150 ppm resulted in maximum yield (16 t/ha). Then, in case of NAA application, highest yield (15.5 t/ha) was obtained from 140 ppm NAA and finally in case of IBA, 15 ppm showed the highest yield (11.2 t/ha). With comparing the highest yield of these three, the successive increase in this character was with increase in 150 ppm concentration of GA_3. (Fig. 5).

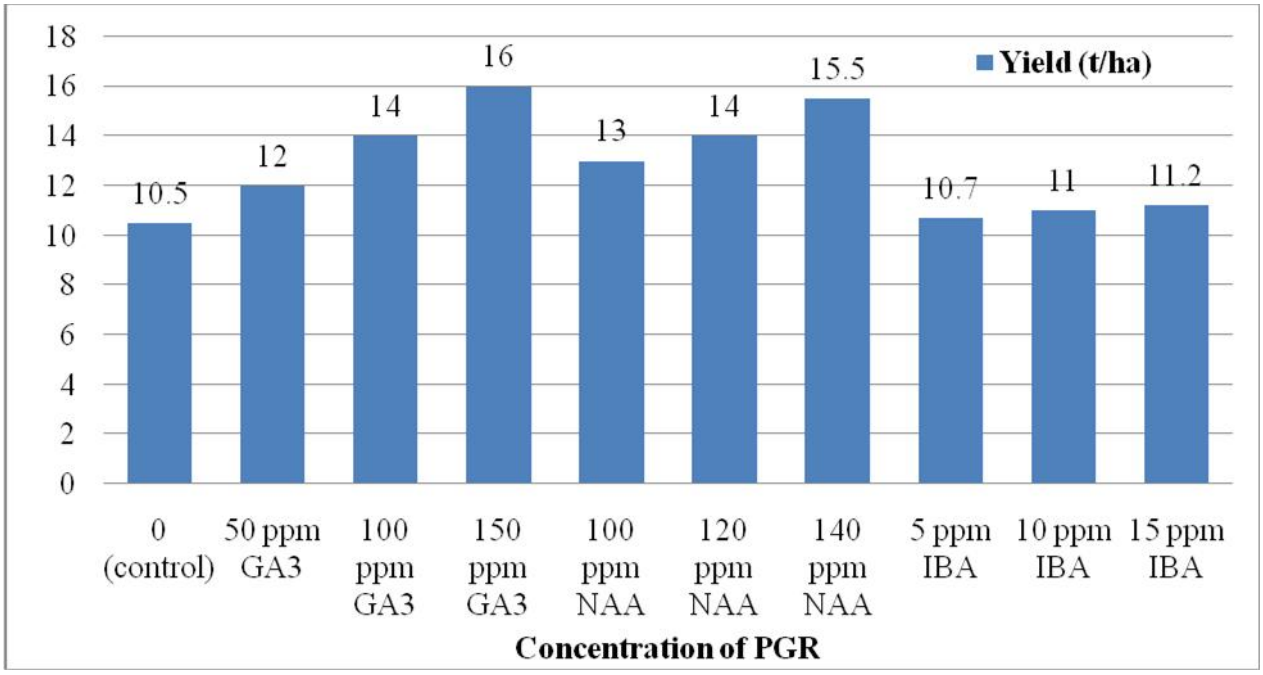

Fig. 5: Effect of GA_3, NAA and IBA as foliar spray on the yield of cauliflower.

Source: Modified from Jadon *et al.*, (2009)

5.0 Effect of growth regulators at different concentration on yield and quality improvement of broccoli

Broccoli (Brassica oleracea var. italica) is an important winter season vegetable crop, which resembles cauliflower. In recent years a great deal of research work has been reported on the uses of plant growth regulators in vegetable crops. Among, plant growth regulators, GA_3 and kinetin exhibited beneficial effect in several cole crops (Chhonkar and Singh, 1963). GA_3 has close relation with growth and yield of broccoli and determination of exact concentrations of GA_3 is important for growth and yield broccoli.

5.1 Effect of GA_3 application on yield and curd quality of broccoli

Reza *et al.* (2015) conducted an experiment on effect of GA_3 on growth and yield of broccoli. They use four levels of GA_3 viz. G_0 (Control), G_1 (25 ppm), G_2 (50 ppm) and G_3 (75 ppm). They found the longest curd from G_2 (21.3 cm) and the maximum curd diameter from G_2 (19.3 cm) followed by G_1 (18.5 cm). Variation was observed among the GA_3 levels for yield of broccoli. The maximum yield was found from G_2 (24.5 t/ha) followed by G_3 (22.9 t/ha), whereas minimum from G_0 (18.2 t/ha). (Fig. 6).

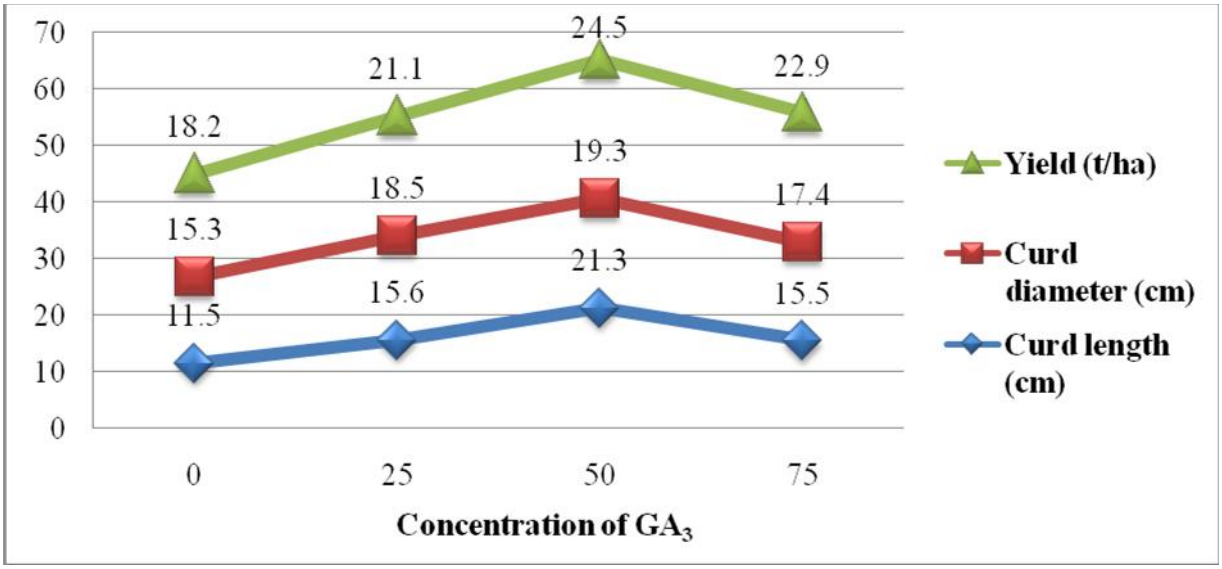

Fig. 6: Effect of GA_3 on yield and curd quality of broccoli.

Source: Reza *et al.*, (2015)

5.2 Effect of GA_3 and kinetin combined application on yield and curd quality of broccoli

Another experiment was conducted by Singh *et al.* (2011) who worked on the effect of GA_3 and kinetin on broccoli. They use control treatment and different concentration of GA_3 & kinetin separately and combined application of both viz. T_1 (10 ppm GA_3 + 10 ppm kinetin), T_2 (20 ppm GA_3 + 20 ppm kinetin), T_3 (30 ppm GA_3 + 30 ppm kinetin), T_4 (40 ppm GA_3 + 40 ppm kinetin) and T_5 (50 ppm GA_3 + 50 ppm kinetin).

Singh *et al.* (2011) found that GA_3 and kinetin combination increased the central and secondary heads and yield as compared to control. Combination treatment GA_3 30 mg/L + kinetin 30 mg/L

produced the maximum yield of 18.97 t/ha, while the lowest yield of 14.52 t/ha was found in absolute control. (Fig. 7).

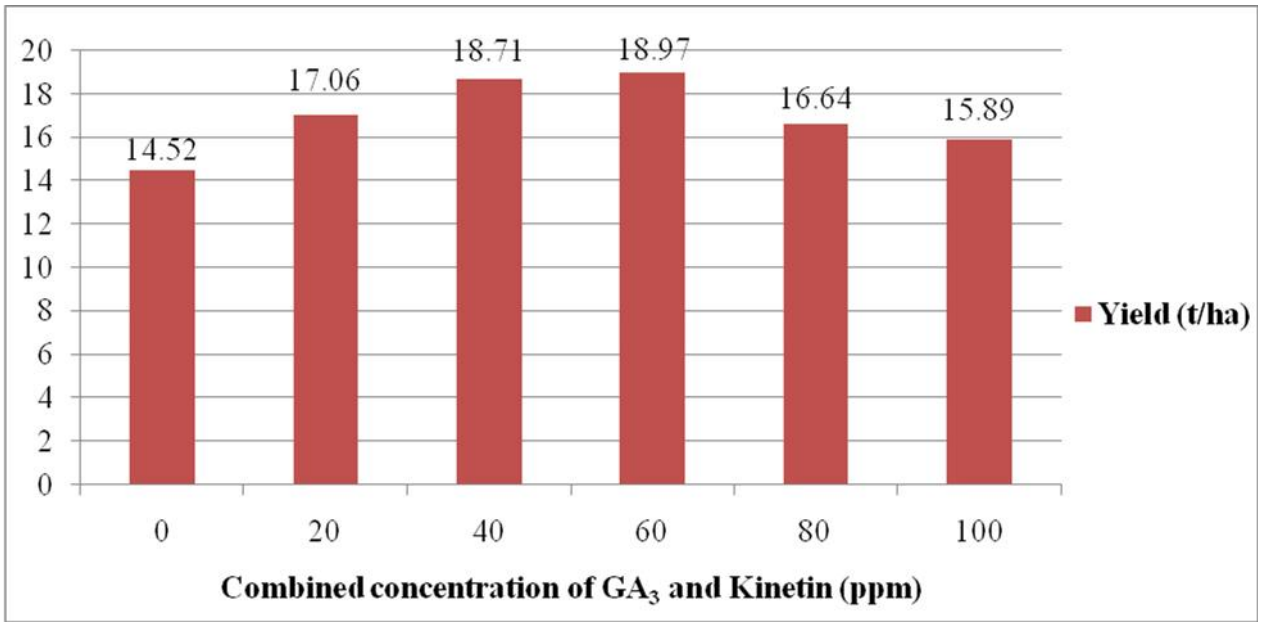

Fig. 7: Combined effect of GA_3 and kinetin on yield of broccoli.

Source: Modified from Singh *et al.*, (2011)

In this investigation, the combination of GA_3 and kinetin gives the best result in terms of quality. Both vit. A and vit. C content increased and highest vit. A content (5278.69 I.U/100 g) and highest vit. C content (117.59) was obtained from T_2 treatment. (Table 10).

Table 10: Combined effect of GA_3 and kinetin on quality characters of broccoli

Treatment (ppm)	Vit. A content (I.U/100 g)	Vit. C content (mg/100 g)
T_0 (control)	2289.08	60.94
T_1 (10 ppm GA_3 + 10 ppm kinetin)	4914.64	114.33
T_2 (20 ppm GA_3 + 20 ppm kinetin)	5278.69	117.59
T_3 (30 ppm GA_3 + 30 ppm kinetin)	3695.63	103.63
T_4 (40 ppm GA_3 + 40 ppm kinetin)	4346.51	112.01
T_5 (50 ppm GA_3 + 50 ppm kinetin)	5110.45	103.87

Source: Singh *et al.*, (2011)

CHAPTER IV

CONCLUSION

Plant growth regulators has an immense potential in vegetable production to increase all attributable characters to better meet the requirements of food supply in general. It can be concluded from this review that use of plant growth regulators in vegetables has been found beneficial for improving yield and quality. In every case of those experiments, growth regulators are found to show satisfactory results than control condition. Among different concentrations of growth regulators, it is found that-

- GA_3 (80 ppm), NAA (100 ppm), 2,4-D (10 ppm) and combined application of 60 ppm (4-CPA+GA_3) provided better result in tomato over control.
- In okra, GA_3 (100 ppm), NAA (20 ppm) and Chitosan (125 ppm) resulted better yield and maximum pod size over control.
- 50 ppm GA_3 was found to result maximum dry wt. of curd/100 fresh wt. and yield in cabbage.
- Better result was also obtained from 50 ppm GA_3 and combined application of 60 ppm & 40 ppm (GA_3+kinetin) in broccoli over control condition.
- Besides, in cauliflower, it was found that GA_3 (150 ppm), NAA (140 ppm), IBA (15 ppm) & IAA (10 ppm) resulted maximum yield and better curd quality over control.

Use of growth regulators is not only interesting but also profitable to the growers, distributors and manufacturer. So, more research is needed to develop simple, economical and technical viable production system of plant growth regulators and they must be environmentally safe.

REFERENCES

Akhter, M. N. 2007. Effect of IAA and GA_3 on the growth, curd formation and yield of cauliflower. MS Thesis, Department of Horticulture and Postharvest Technology, Sher-e-bangla agricultural university.

Arteca, R. N. 2015. Olericulture. *Introduction to Horticultural Science, 2nd edition.* Nelson Education. pp. 189, 494-496.

Baliyan, S. P., K. M. Rao, P. S. Baliyan and M. Mahabile. 2013. The effects of 4-chlorophenoxy acetic acid plant growth regulator on the fruit set, yield and economic benefit of growing tomatoes in high temperatures. *International Journal of Research in Agricultural Science,* 3:29-36.

BBS (Bangladesh Bureau of Statistics). 2015. Yearbook of Agriculturral Statistics. Ministry of Planning Government of the People's Republic of Bangladesh. P. 286.

Chand, P., B. Nair and K. P. Singh. 2014. Use of plant growth regulators in vegetable crops. *Fundamentals of Vegetable Crop Production.* pp. 50-56.

Chhonkar, V. S. and R. Singh. 1963. Effect of gibberellic acid on growth, yield and quality of cabbage (*Brassica oleracea* var. *capitata* L.). *Indian Journal of Horticulture*, 21:57-63.

Chowdhury, M. S., Z. Hasan, K. Kabir, M. Shah Jahan and M. H. Kabir. 2014. Response of okra (*Abelmoschus esculentus* L.) to growth regulators and organic manures. *The Agriculturists,* 12(2):56-63.

Christen, W. G., S. Liu, D. A. Schaumberg and J. E. Buring. 2005. Fruit and vegetable intake and the risk of cataract in women. *The American Journal of Clinical Nutrition, 81*(6):1417-1422.

FAO/WHO. 2003. Food and Agriculture Organization of the United Nations. Diet, nutrition and the prevention of chronic diseases. Report of a Joint FAO/WHO Expert Consultation. WHO Technical Report Series 916. Geneva, World Health Organization.

Halter, L., R. Habegger and W. H. Schnitzler. 2005. Gibberellic acid on artichokes (*Cynara scolymus* L.) cultivated in Germany to promote earliness and to increase productivity. *Acta Horticulturae.*, 681:75–82.

He, F. J., C. A. Nowson, M. Lucas and G. A. MacGregor. 2007. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *Journal of Human Hypertension, 21*(9):717-728.

Hossain, S. M. 1992. Status, constrains and strategies of vegetable research. In: Katherine and Eli. L (eds.). Vegetable production and marketing. *Proceedings of a National Review and Planning Workshop Held at BARI, Gazipur, Bangladesh*, 31:26-29.

Islam, M. A., A. Siddiqua and M. A. Kashem. 1993. Effect of growth regulators on the growth, yield and ascorbic acid content of cabbage. *Bangladesh Journal of Agricultural Science,* 20(1):21-27.

Jadon, R. S., R. Lekhi, S. Sharma and R. Sharma. 2009. Effect of Gibberelic acid, IBA and NAA as foliar spray on the growth, yield and quality of cauliflower (*Brassica oleracea* var. *botrytis* L.). *Agriculture: Towards a New Paradigm of Sustainability*. P. 230.

Jankauskiene, J. and E. Surviliene. 2009. Influence of growth on seed germination energy and biometrical parameters of vegetables. *Scientific Works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture,* 29 (3):69–77.

Kumar, A., T. K. Biswas, N. Singh and Dr. E.P. Lal. 2014. Effect of Gibberellic acid on growth, quality and yield of tomato (*Lycopersicon esculentum* Mill.) *Journal of Agriculture and Veterinary Science*, 7:28-30

Kumar, D., K. D. Gujar and R. Paliwal. 1996. Yield and yield attributes of cabbage as influenced by GA and NAA. *Crop Research Hisar*, 12:120-122.

Lee, I. J. 2003. Practical application of plant growth regulator on horticultural crops. *Journal of Horticultural Science,* 10:211-217.

Luitel, B. P., T. J. Lee, W. H. Kang. 2015. Fruit Set and Yield Enhancement in Tomato (Lycopersicon esculentum Mill.) Using Gibberellic Acid and 2,4-Dichlorophenoxy Acetic Acid Spray. *Protected Horticulture and Plant Factory.* 24(1):27-33.

Meena, R. K., R. S. Dhaka, N. K. Meena and S. Meena. 2017. Effect of foliar application of NAA and GA_3 on growth and yield of okra (*Abelmoschus esculentus* L.) Moench cv. Arka Anamika. *International Journal of Pure Applied Bioscience,* 5 (2):1057-1062.

Mondal, M. M. A., M. A. Malek, A. B. Puteh, M. R. Ismail, M. Ashrafuzzaman and L. Naher. 2012. Effect of foliar application of chitosan on growth and yield in okra. *Australian Journal of Crop Science,* 6(5):918-921.

Mukhtar, F. B. 2008. Effect of some plant growth regulators on the growth and nutritional value of *Hibiscus sabdariffa* L. (Red Sorrel). *International Journal of Pure and Applied Sciences,* 2(3):70-75.

Patel, J. S., H. H. Sitapara and K. A. Patel. 2012. Influence of plant growth regulators on growth, yield and quality of tomato and brinjal. *International Journal of Forestry & Crop Improvement,* 3(2):116-118.

Patil, A.A., S. M. Manipur and U. G. Nalwadi. 1987. Effects of GA_3 and NAA on growth and yield of cabbage. *South Indian Horticulture,* 35:393-394.

Prajapati, S., T. Jamkar, O. P. Singh, N. Raypuriya, R. Mandloi and P. K. Jain. 2015. Plant growth regulators in vegetable production: an overview. *Plant Archives, 15*(2):619-626.

Prasad, R. N., S. K. Singh, R. B. Yadava and S.N.S. Chaurasia. 2013. Effect of GA_3 and NAA on growth and yield of tomato. *Vegetable Science,* 40(2):195-197

Rahman, M., M. A. Nahar, M.S. Sahariar and M.R. Karim. 2015. Plant growth regulators promote growth and yield of summer tomato (*Lycopersicon esculentum* Mill.). *Progressive Agriculture,* 26(1):32-37

Ram, K., A. N. Varma and P. K. Sharma. 1973. Effects of NAA on growth, protein and ascorbic acid content of cabbage. *Plant Science,* 5:150-153.

Ramu, N. and S. Muthuswamy. 1964. Preliminary studies on foliar application of nitrogen in Bhindi and Brinjal. *The Madras Agricultural Journal,* 51:80-81.

Reza, M., M. Islam, A. Hoque, R. K. Sikder, H. Mehraj and A. F. M. J. Uddin. 2015. Influence of different GA_3 concentrtions on growth and yield of broccoli. *American-Eurasian Journal of Scientific Research,* 10 (5):332-335.

Roy, R. and K. M. Nasiruddin. 2011. Effect of different level of GA_3 on growth and yield of Cabbage. *Journal of Environmental Science & Natural Resources*, 4(2):79-82.

Sachs, R. M. 1965. Stem elongation. *Annual Review of Plant Physiology,* 16(1):73-96.

Sentelhas, P. C., J. R. G. Caetano and N. T. Teixeira. 1987. The effect of IAA and foliar nitrogen on wheat. *Ecossistema,* 12:123-128.

Sharma, S. K. and R. C. Mishra 1989. Effect of growth-regulators on flower morphometries with reference to insect pollinators. *Indian Journal of Agricultural Science,* 59(8):546-547.

Singh, M., D. K. Rana, J. M. S. Rawat and S. S. Rawat. 2011. Effect of GA_3 and kinetin on growth, yield and quality of sprouting broccoli (*Brassica oleracea* var. *italica*). *Journal of Horticulture and Forestry,* 3(9):282-285.

Surendra, P., C. M. Nawalagatti, M. B. Chetti, M. B. and S. M. Hiremath, 2006. Effect of plant yield and yield components in okra. *Karnataka Journal of Agricultural Sciences,* 19(2):264-267.

Tomar, V. P. S., G. D. Singh and G. L. Keshwa. 1991. Effect of plant growth chemicals on morpho-physiological characters of late sown wheat. *Indian Journal of Agronomy*, 36(1):7-11.

Vijayaraghavan, H. 1999. Effect of seed treatment with plant growth regulators on bhendi (*Abelmoschus esculentus* L.,) grown under sodic soil conditions. *Madras Agricultural Journal*, 86(4/6):247-249.

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1. https://www.statisticbrain.com/vegetable-consumption-and-production-statistics/ (Statistics Brain Research Institute, 2017)
2. en.wikipedia.org/wiki/Vegetable (Vegetable)