

EFFECT OF PLANT GROWTH REGULATORS ON PLANT GROWTH, YIELD AND ITS COMPONENTS IN BRINJAL: A REVIEW

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ABSTRACT

Plant growth regulators are organic compounds other than nutrients that affect the physiological processes of growth and development in plants when applied in low concentrations. Plant growth regulators like promoters, inhibitors or retardants play a key role in controlling internal mechanisms of plant by interacting with key metabolic processes such as, nucleic acid metabolism and protein synthesis. Use of the growth regulators (PGRs) might be a useful alternative to increase crop production. Recently, there has been global realization of the important role of PGR's in increasing crop yield. Therefore, the effect of plant growth regulators on plant growth, yield and yield components in brinjal is being reviewed herewith may helpful to the researchers in planning and execution of future research.

KEY WORDS: *Plant growth regulators, promoters, inhibitors, retardants*

INTRODUCTION

Plant growth regulators or phytohormones are organic substances produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts. Thimann (1948) proposed the term Phyto hormone as these hormones are synthesized in plants. Plant growth regulators include auxins, gibberellins, cytokinins, ethylene, growth retardants and growth inhibitors. Auxins are the hormones first discovered in plants and later gibberellins and cytokinins were also discovered.

Plant growth regulators are defined as organic compounds other than nutrients, that affects the physiological processes of growth and

development in plants when applied in low concentrations. They also defined as either natural or synthetic compounds that are applied directly to a target plant to alter its life processes or its structure to improve quality, increase yields, or facilitate harvesting.

The term plant growth regulators (PGRs) cover the broad category of organic substances (other than vitamins and nutrients) that in minute amounts, promote, inhibit, or otherwise modify physiological processes (Wareing and Phillips, 1978). The PGRs, where endogenous (Phytohormones) or Exogenous, elicit essentially the same plant responses. Presently, PGRs are used to control a host of physiological processes in crop production, including flowering and fruiting, partitioning of assimilate,

germination, growth suppression, and post harvest ripening.

Plant growth regulators like promoters, inhibitors or retardants play a key role in controlling internal mechanisms of plant by interacting with key metabolic processes such as, nucleic acid metabolism and protein synthesis. Use of the growth regulators (PGRs) might be a useful alternative to increase crop production. Recently, there has been global realization of the important role of PGR's in increasing crop yield. Gibberellic acid is an important growth regulator that may have many uses to modify the growth, yield and yield contributing characters of plant (Rafeekher *et al.* 2002). Plant growth regulators are used widely to improve plant performance. Gibberellic acid is one of those growth regulators that have positive effect on plant growth through the effect on cell division and elongation (Batlang *et al.*, 2006).

Effect of plant growth regulators on plant growth, yield and its components

The eggplant flowers can be stimulated for fruit development applying chemicals of growth regulators type. By introducing growth substances such as auxins onto the flowers, fruit setting can be induced before flower pollination. That fact drew to a supposition that pollination leading to fruit and seed formation is associated with production of endogenous growth regulators such as auxins. Further studies allowed for finding that the auxins or similar substances present or synthesized by a pollen or an ovary are the factors that stimulate pollen and ovary growth. After pollination, the level of auxins in ovary suddenly increases, which results in the beginning of a fruit growth. Also a variety of other growth agents were isolated from developing

fruits – gibberellins, for instance. Development of partenocarpic fruits can be also stimulated by gibberellins in plants insensitive towards auxins (Buczek, 1972).

Krishnamurthy and Subramanian (1954) examined brinjal flowers of a Long Black variety and have described the occurrence of four different types of flowers and their fruit-setting behaviour under normal conditions and when affected by 2,4-D as a plant growth-regulator, and have mentioned the scope of increasing fruit-set through the use of plant growth-regulators such as 2,4-D. He reported that 2,4-D was not able to set fruits in the true short-styled flowers, but pseudo-short-styled flowers could be induced to set fruits with 2,4-D with a minimum of 60 per cent fruit set obtained by the application of 0.01% 2,4-D compared with untreated control.

Mukherjee and Duta (1962) treated one month old potted seedlings of eggplant and tomato with GA at 2, 10, 100 and 1000 ppm for 3 consecutive days during two consecutive weeks. The style of the emasculated flower and plant height was increased by 32 and 62 per cent, respectively.

Muthukkishnan and Srinivasan (1963) found that treatment of brinjal with 2,4-D at 2 and 10 ppm and NAA at 50 and 100 ppm increased fruit set and yield without plant damage.

Sadawarte and Gupta (1968) reported that 24h soaking of brinjal seeds in GA at 40 ppm, IAA at 50 ppm or NAA at 25 ppm improved seed germination.

Avieli (1970) conducted trials to test various auxin-type growth regulators with a view to improving the set of eggplants during March-April. At Yotvata, where vegetative growth is slow in winter, the tops were

not damaged by any of the sprays, although growth was slightly retarded. At Ein Gedi the sprays resulted in marked growth inhibition, and 2,4-D caused plant decline. The percentage set was increased by 2,4-D (2 ppm), 4-CPA (20 ppm) and Duraset (0.5%). Fruit development at Ein Gedi was accelerated by 4-CPA and Duraset, but not at Yotvata. None of the treatments affected fruit colour. Spraying with 2,4-D at all concentrations resulted in a considerable proportion of deformed fruit.

Even (1970) tested the effects of spraying of 2, 4-D at 2.5 ppm and 4-CPA at 21 ppm on Black Queen aubergines in two places. Both compounds produced earlier and more uniform ripening compared with control plants. Spraying the flowers advanced fruit set, while spraying the tops shortened the harvest period. The best time to spray the flowers was at the onset of anthesis and again 5-7 days later. Top sprays were most effective when applied at the stage of 8-12 open flowers, with a second application 15-25 days later. 4-CPA had a slightly depressing effect on plant growth. Spraying with 2, 4-D did not seem to have any undesirable effect even at fairly high temperatures.

Gupta (1971) reported that when eggplants seeds were treated for 24 hours before sowing with GA, IAA or NAA each at 10, 20 and 40 ppm, the germination was enhanced. However, the lowest rate was found most effective.

Das and Prusty (1972) carried out a pot culture experiment with GA, CCC, MH having 0, 10, 50 and 100 ppm concentrations with Brinjal (*Solanum melongena*) variety kuliposh. GA treated plants enhanced the germination of the seeds and stimulated growth significantly than CCC, MH and control, while CCC and

MH treated plants significantly increased the stem thickness. GA and CCC increased the leaf number while MH decreased it. CCC and MH increased leaf thickness and leaf area significantly. GA extended the internodal length whereas CCC and MH reduced it forming a compact plant. It is also observed that MH and CCC could influence to increase the number of branches per plant while CCC and GA significantly increased the fresh and dry weight of the shoots and roots. However, the effect of these chemicals on the leniar growth of the roots was not significant.

Kaso and Kiyato (1974) exposed eggplant, tomato and cucumber seedlings under glass house to 2,4-D and GA₃ in heat vapourized form. The vapour was applied for 30 min. and the house remained closed for a further period of 30 min. Very low concentration (150 ppm) produced advances in growth and maturity similar to those obtained with normal high rate sprays of such compounds.

Increased yield and quality due to the application of 2, 4-D at 10 ppm was reported by Pampapathy and Rao (1975) in brinjal.

Olympies (1976) examined the influence of various combinations of gibberelic acid (GA₃), auxin (2-naphthoxyacetic acid-NOA) and cytokines (benzyloaminopurine – BA) on eggplants growth and yielding during cold season in Cyprus. He recorded the best fruit setting when NOA, NOA + BA, and NOA + BA + GA₃ combinations were applied. The best results were achieved after application of auxins and cytokines altogether. Applying the auxins had positive effects only when cytokines concentration was optimum. Treating the flowers only with cytokines caused the decrease of early and commercial fruit yields indicating that the presence

of auxins is also necessary for an efficient action of other growth regulators. Applying only gibberelic acid did not bring positive results.

Nothmann and Koller (1975) reported that gibberellins (GA_3) induced the development of completely seedless fruits during all the seasons. They also noted that the auxin like substances, 2,4-D, NAA and NOA induced the development of degenerated seeds, both in the period of normal seed development (summer) and in the period of climate induced seedlessness (winter).

Bisaria and Bhatnagar (1978) studied the effect of plant growth regulators on brinjal (*Solarium melongena* L.) cv. 'Pusa kranti'. The crop was sprayed with IAA and GA_3 at 0, 10, 25, 50, 100 and 200 ppm. IAA stimulated the vegetative growth up to a concentration of 100 ppm and suppressed at 200 ppm. GA_3 promoted the vegetative growth at all the concentrations used. IAA increased formation of flowers, fruits and yield upto 100 ppm and reduced them at 200 ppm. GA_3 enhanced the formation of flowers, fruits, and yield progressively with increasing concentration.

Experiments made by Nothmann *et al.* (1983) revealed that treating the eggplant flowers with 2,4-D at concentration of 2.5 mg/l four times every 3 weeks considerably improved the fruit setting. Variety, flower structure, and localization within an inflorescence were important for fruit setting and seed formation processes. Percentage of high-pistil flowers in total fruit setting was 90%. Although hormonization increased the fruit setting from low-pistil flowers four times as compared to the control, maximum fruit setting (8%) was still very poor. Fruits formed from so-called additional flowers were of worse quality than those from main flowers.

Auxins stimulated growth of both, but fruits grown from additional flowers were usually smaller than those formed from the main ones. In general, set fruits had no seeds or contained undeveloped seeds.

Van Ravestijn (1983) applied a spray mixture consisting of 20 mg/l 4-CPA and 500 mg/l iprodion [3-(3,5-dichlorophenyl)-N-isopropyl-2,4-dioximidazolidine-1-carboxamide] or 500 mg/l vinchlozolin [3-(3,5-dichlorophenyl)-5-methyl-vinyl-1,3-oxazolidine)-2,4-dione] weekly to flowers of eggplant and found earlier and higher yield through an increase number of fruits and higher mean fruit weight. He also reported that different varieties react positively to the plant growth regulators, but not to the same degree. Gibberelins are not preservable in solution, moreover they increase plant elongation and reduced the rate of fruit ripening.

Hooda *et al.* (1985) reported higher fruit yield with cytozyme seed treatment at 10 % and foliar spray at 1.25 per cent.

Shukla and Prabhakar (1986) applied mixtalol, a mixture of long chain aliphatic alcohols (C24 — C34), as foliar spray on brinjal (Cv. Arka Navneet). Application of the chemical at the rate of 4 ppm, 6 to 8 weeks after transplanting in fields, increased the brinjal yield by 35 to 52 per cent over control.

Glaps and Gorecki (1989) reported the increase of early and commercial yields at 'Rodo' eggplant by applying Betokson R (NOA), Betokson Super (NOA), Nasuleaf (2,4-D), Racine (NAA) for developed flowers as well as Nevirrol 60 WP for whole plants. Analysis of the yield structure revealed that achieved yield increase mainly depended on fruit weight increase, and not their number. Applied growth regulators did not

cause the increase of the deformed or infected fruits percentage in the yield.

Reddy and Joshi (1990) studied the effects of carbaryl (0.2%), dimethoate (0.05%), monocrotophos (0.04%), phosalone (0.05%) and endosulfan (0.07%) alone and in combination with planofix X [NAA] (100 ppm) on the growth and yield of brinjal [aubergine]. The results showed that carbaryl or endosulfan combined with the plant growth regulator gave the best yields. The endosulfan combination was the most economical.

Ramanandam *et al.* (1991) recorded the highest number of long styled flowers by the application of plant growth regulator 1-triacontanol (5 ppm).

Sharma *et al.* (1992) studied the effect of GA₃, IAA and NAA in different concentrations as seed treatment or whole plant spray in Brinjal cv. Pusa Purple Long. Plants sprayed with 300 ppm GA₃ were earliest to flower and recorded highest number of fruits and yield per plant. Whole plant sprays with NAA 50 ppm and IAA at 100 and 150 ppm and seed treatment with GA₃ and IAA at 10 ppm were the next best treatment, which recorded significant increase in fruit yield. Non-significant differences were observed amongst the seed treatment with GA₃, IAA and NAA for most of the characters. However, GA₃ (10 ppm) recorded the highest yield per plant. Therefore, for getting highest returns, brinjal seed should be treated with 10 ppm GA₃ or IAA or whole plants spray of GA₃ (300 ppm) or NAA (50 ppm), or IAA (100 and 150 ppm).

Plant growth regulators have been reported to improve germination, growth, fruit set, fresh vegetable and seed yields and yield quality (Saimbhi, 1993). Application of plant growth regulators as seed treatment and

seedling root dip at transplanting have been found effective in enhancing germination and seedling growth, and in reducing transplanting shock.

Handique and Sharma (1995) applied NAA at 10 ppm concentration and observed the increase of high-pistil flowers number only at some varieties, whereas higher rates (25 ppm) significantly decreasing the number of low-pistil flowers at all tested varieties. Treating the eggplants with kinetin considerably decreased the number of low-pistil flowers; however, higher concentration (40 ppm) was more efficient for all varieties than 20 ppm rate. There is a hypothesis that hormones such as kinetins are more focused on female preferences, while gibberelic acid favors male expression. Hormones modify flowers heterostyly by influencing on anatomical structure and nutrients transport through pistils ducts. Observations of low-pistil anatomy revealed smaller cells as compared to high-pistils, and hormones application affected the enlargement of those cells. At *Solanum sisymbriifolium*, applying the kinetin favoured the development of high-pistil flowers, while reduced low-pistil ones; gibberelic acid (GA₃) invoked opposite reaction.

Leonardi and Romano (1997) when using auxins for growing eggplants, achieved fruits that were characterized by larger weight than those harvested from plants treated with no growth regulator.

Patel *et al.* (1997) conducted an experiment to study the effect of 2,4-D (2, 4, 6 and 8 ppm) and NAA (25, 50, 75 and 100 ppm) on growth and yield of brinjal. They reported that the Surati Ravaiya with application of 2,4-D at 4 ppm produced higher yield (54.11 t/ha) than with control treatment (33.07 t/ha).

According to Lawande and Chavan (1998), applying the growth regulators (2,4-D and NAA) affected the improvement of fruit setting by 50%. Similar effects were achieved due to seed soaking in growth regulators solutions for 24 before seeding.

Pablo (2000) determined the effect of several plant growth regulators on the yield of 'Jira' eggplant. Treatments consisted of aqueous solutions of folcysteine (25, 50, 75 ppm), giberellic acid 3 (10, 20, 30 ppm), kinetine (25, 50, 75 ppm), naphthalenacetic acid (NAA) (25, 50, 75 ppm), 2,3,4-dichloro-phenoxy-triethyl-amine hydrochloride (DCPTA) (25, 50, 75 ppm), triacontanol (5, 10, 15 ppm), ethanol (5, 10, 15%), and chlormequat (50, 100, 150 ppm) sprayed at early flowering, directed to the crop upper leaves and flowers. 'Jira' eggplant fruit set and yield was significantly improved by folcysteine, giberellic acid 3, and NAA, but not by kinetine, DCPTA, ethanol, triacontanol, or chlormequat. Eggplant yield increased as folcysteine rate increased from 0 to 50 ppm, but no further yield increase was obtained when increasing the rate from 50 to 75 ppm. Similarly, eggplant yield significantly increased as gibberellic acid increased from 0 to 20 ppm, but not when rates increased from 20 to 30 ppm. With NAA, eggplant fruit set and yield significantly increased above that of control plants when 25 ppm was applied, with no significant yield increase at higher rates. Results indicated that the yield of 'Jira' eggplants could be enhanced by the treatments with either folcysteine, NAA, or gibberellic acid.

In experiments of Passam *et al.* (2001), application of auxins (IAA) significantly reduced the pistil length in eggplant flowers. Hormonization

had negative effects of eggplants flowering intensification.

Experiments made by Kowalska [2003a, 2003b, 2006] confirmed positive influence of flower hormonization process on the eggplant's yielding. Significantly higher early and commercial yields of fruits were produced by plants stimulated with growth regulators as compared to those with self pollination.

Khedr *et al.* (2004) reported that all the vegetative growth characteristics, earliness of flowering, fruit set percentage, total yield and fruit quality were improved by sprayed of eggplant with 50 mg B/L, 100 mg Zn/L and 2000 mg Ca/L alone or in combinations, the spraying was repeated 3-times with intervals of 20 days started at one month after transplanting.

Plant growth regulators (PGRs) can be used to induce fruit setting and development of eggplant during unfavorable winter conditions, such as low light intensity and low temperature. Lee *et al.* (2004) tested three PGR (cloxyfonac, 4-CPA, and CPPU), at three levels of concentration and two spray intervals (once every day and every five days) on eggplant planted in a plastic house. Fruit set and development were similar in cloxyfonac and 4-CPA. However, cloxyfonac at 490 mg/L produced higher marketable yield than the other treatments. Spray interval did not affect marketable yield. Therefore, cloxyfonac applied at 490 mg/L every five days was recommended, because it is labour-saving.

Meena *et al.* (2005) calculated the economics of plant growth regulators in brinjal under semi-arid condition of Rajasthan. It was found that the yield of brinjal can be increased significantly by two

successive sprays of GA₃ and NAA at 35 and 45 days after transplanting. The maximum net profit of Rs. 107498.07/ha was obtained with the spray of 100 6 ppm GA₃ followed by 50 ppm NAA (Rs. 102383.27/ha) as compared to control (Rs. 78493.07/ha). The maximum cost: benefit ratio (1: 5.60) was found with the spray of 50 ppm NAA. However, the higher concentrations of GA₃ and NAA were found uneconomic.

Sharma (2006) conducted field study to assess the effect of plant growth regulators (PGRs) on morphological characters and yield of brinjal cvs. Pusa Purple Long (PPL) and Pusa Purple Cluster (PPC). The results revealed that the treatments had no significant influence on fruit number per plant and fruit yield. The interaction effect showed that the PPL did not produced statistically different fruit number per plant with respect to growth regulators, while it had significantly higher fruit yield (17.76 t/ha) at 40 ppm NAA than that at 10 ppm GA₃ and 30 ppm BAP. The PPC produced significantly higher fruit number per plant and higher fruit yield at 30 ppm BAP than all other treatments except 5 ppm triacontanol.

Patil *et al.* (2008) studied the effect of growth regulators and fruit load on seed yield and quality in brinjal hybrid seed production. The results revealed that GA₃ 50 ppm recorded significantly more seed yield (33.96 g) per plant, germination (75.52%), root length (7.81 cm), shoot length (6.86 cm), seedling vigour index (1297) and seedling dry weight (14.12 mg) compared to NAA 40 ppm and control (30.97 g, 71.89%, 7.38 cm, 6.28 cm, 859 and 12.39 mg, respectively) irrespective of growth. Four fruit retention per plant recorded significantly highest germination, root length, shoot length, seedling vigour

index and seedling dry weight (83.28%, 8.43 cm, 7.48 cm, 1136 and 16.85 mg, respectively) compared to retention of all fruits per plant.

Boyaci *et al.* (2011) set an experiment on eggplants to determine the relationship between flower development and gibberellic acid (GA₃) levels in parthenocarpic and non-parthenocarpic eggplant (*Solanum melongena* L.) genotypes. The results showed that there was no relationship between flower development and GA₃ levels in parthenocarpic and non-parthenocarpic eggplant genotypes.

Sarker *et al.* (2011) investigated the yield potential of some eggplant varieties using plant growth regulator. Seven varieties of eggplant viz., BARIBegun1, BARIBegun2, BARIBegun4, BARIBegun5, Bismillah, BARIBegun6 and Islampur were used for test crop and Naphthalic acetic acid (NAA) 100 ppm was used as plant growth regulator. Eggplant variety, BARIBegun5 showed the highest plant height (31.0 cm) at vegetative stages among the tested varieties. The mean leaf number (32.0) was also higher in BARIBegun 5 in comparison to others.

Patel *et al.* (2012) studied the effect of plant growth regulators on growth, yield and quality of brinjal (*Solanum melongena* L.) cv. Surati Ravaiya with nine treatments viz., 2, 4-D @ 2, 4, 6 and 8 ppm as well as NAA @ 25, 50, 75 and 100 ppm along with control (water spray). Among the treatments the foliar sprays of 2, 4-D @ 4 ppm gave the highest yield of brinjal (64.35 t/ha), while plant height of brinjal (74.47 cm) was found to be maximum with 50 ppm NAA. For quality parameters, TSS (5.06 OB) and acidity (0.29 %) were found maximum with foliar spray of 100 ppm NAA in brinjal. In brinjal, ascorbic acid was

found maximum maximum (16.46 mg/100g) with 100 ppm NAA.

Telang *et al.* (2013) conducted an experiment to study the various yield parameters in brinjal cv. 'Manjari Gota'. The crop was sprayed with four types of growth hormones and two types of fertilizers along with the control (water spray). Results obtained during this investigation clearly indicated that in Manjari gota variety of brinjal during both the seasons yield per plant as well as per hectare was recorded more under urea and SSP spray followed by GA, NAA spray. However, yield per plant and per hectare was significantly higher under control, CCC and ethrel spray treatments. Regarding quality data recorded during both the seasons, indicated that highest ascorbic acid content was recorded under GA and urea spray while lowest ascorbic acid content was recorded under ethrel spray followed by CCC spray.

Moniruzzaman *et al.* (2014) studied the effect of seven growth regulators treatments viz., control, 30 ppm GA₃, 40 ppm GA₃, 50 ppm GA₃, 20 ppm NAA, 40 ppm NAA, and 60 ppm NAA and two varieties viz., BARI Begun-5 and BARI Begun -10 on brinjal (*Solanum melongena* L.). The GA₃ (Gibberellic acid) and NAA (Naphthalene acetic acid) had no significant effect on plant height and stem diameter at the end of the crop period and days to 100% flowering. NAA 40 ppm produced highest percentage of long and medium styled-flower, leaf photosynthesis and Fv/Fm (efficiency of photosystem II), number of fruits /plant and fruit yield (45.50 t/ha). The variety BARI Begun-5 was earlier to 100% flowering which took 44 days after transplanting which out yielded BARI Begun-10. NAA 40 ppm coupled with BARI Begun-5 gave the maximum Fv/Fm, long-styled flower

percent, number of fruits/plant, and the highest fruit yield (49.73 t/ha).

Netam and Sharma (2014) studied the efficacy of different plant growth regulators and their combinations of NAA, GA₃ and 2,4-D spray on fruit yield and quality in brinjal cv. Brinjal 3112 . The plants were sprayed three times at 30, 60 and 90 days after transplanting. The highest number of branches, number of fruits, fresh fruit weight, total soluble solid and nitrate reductase activity was recorded by the treatment combination of GA₃ @ 10 ppm and NAA @ 20 ppm. The combined application of GA₃, NAA and 2,4-D significantly increased vegetative growth, yield and quality of brinjal compared with control. Based on the results, it can be concluded that combined application of GA₃, NAA and 2,4-D @ 10 ppm, 20 ppm and 1 ppm of 2,4-D had significantly on plant growth, flowering, quality and yield potential.

Dhakar and Singh (2015) studied the effect of plant growth regulator (GA₃) (G₀: 0 ppm, G₁: 100 ppm, G₂: 150 ppm and G₃: 200 ppm) for the growth and yield of brinjal (*Solanum melongena* L.). The seedlings were soaked in prepared solution of each concentration of GA₃ as per requirement of treatment combinations. Seedlings for control plots were, however, dipped in distilled water. After 24 hours, seedlings were taken out and dried in shade for two hours, and the hormonized seedlings were then transplanted in the experimental field. Results showed that G₂ (150 ppm GA₃) recorded maximum plant height, number of leaves per plant, leaf length, number of branches per plant and stem diameter followed by G₃ (200 ppm GA₃) and G₁ (100 ppm GA₃), whereas, the minimum was recorded with G₀ (0 ppm GA₃). G₂ (150 ppm GA₃) also recorded

maximum number of flowers and fruits per plant; length, diameter and weight of fruit; fruit yield per plant, per plot and per hectare followed by G₃ (200 ppm GA₃) and G₁ (100 ppm GA₃).

CONCLUSION

Plant growth regulators like GA₃, NAA, 2,4-D were found effective in increasing the plant growth as well as yield in brinjal at very low concentrations.

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