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Review Article

PLANT GROWTH REGULATORS IN VEGETABLE PRODUCTION : AN OVERVIEW

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Abstract

Indian agriculture becomes more mechanized and science increases the possibilities for using inputs to enhance production and food safety, the role of plant growth regulators becomes more vital; plant growth regulators provide an immediate impact on crop improvement programmes and are less time consuming, applications of plant growth regulators must lead to quantifiable advantages for the user plant growth regulators must be specific in their action and toxicologically and environmentally safe. Plant growth regulators in vegetables provides professionals and researchers with the information needed to effectively tap these versatile resources to enhance vegetables production. Most of the physiological activates and growth in plants are regulated by action and interaction of some chemical substance in them is called hormones and by some naturally occurring inhibitors.

Key words : Plant growth regulators, auxin, GA_3, cytokinins, ethylene, salicylic acid.

Introduction

Although, photosynthesis supplies the carbon and respiration supplies the energy for plant growth, a group of chemicals produced by plants known as plant growth regulators control the growth and development of trees. These chemicals act on plant processes at very low concentrations. Often they are produced at one location and transported to another, where they exert their influence; however, they may also act on the same tissue in which they are produced. Plant growth regulators are organic chemical substance, other than nutrients and vitamins which regulate the growth of plant when applied in small quantities. PGR are used in different forms like liquid, powder, paste etc. "Hormone" is Greek word derived from "*hormao*", which means to stimulate. Thimone (1948) suggested the use of term phytohormones as the organic substance, which are produced naturally in plants, synthesised in one part and usually translocated to other part where in every small quantity affect the growth and other physiological function of the plants. To distinguish them from the animal hormones they are termed as phytohormones. Auxin was the first hormone to be discovered in plants and at one time considered to be only naturally occurring plant growth hormone.

Growth, development and yield analysis in crop plants helps in understanding the contribution of various growth and yield components. Plant growth regulators considered as a new generation of agrichemicals when added in small amounts, modify the growth of plants usually by stimulating or modifying one part of the natural growth regulatory system, thereby the yield is enhanced. Higher production through breeding is a continuous endeavour of mankind. But, these methods are however, not only time consuming but also costly. The growth regulators have therefore, been known to be one of the quick means of increasing production. Similarly, nutrients are inorganic substances necessary for the normal growth and development of plants and have important role in various enzymatic processes, assimilation, oxidation and reduction reactions and help in increasing the biomass and pod yield. Hence, the present investigation was carried out to find out the suitable growth regulators and micronutrients to increase the yield and yield components in okra.

The relevant and important published work available on vegetable crops has been reviewed and presented

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here under the following heads:

1. Classes of plant growth regulators
2. PGRs and their associated functions
3. Commercial utility of PGRs in vegetable crops
4. PGRs effect on seed germination
5. PGRs effect on growth and development traits
6. PGRs effect on yield attributing traits
7. PGRs effect on sex ratio determination
8. PGRs effect on parthenocarpy induction
9. PGRs effect on plant regeneration.

1. Class of plant growth regulators

Auxins	: IAA, NAA, IBA, 2-4D, 4-CPA
Gibberellins	: GA_3
Cytokinins	: Kinetin, Zeatin
Ethylene	: Ethereal
Abscissic acid	: Dormins, Phaseic Acid
Phenolic substances	: Coumarin
Flowering hormones	: Florigin, Anthesin, Vernalin
Natural substances	: Vitamins, Phytochrome Tranmatic
Synthetic substances	: Synthetic Auxins, Synthetic Cytokinins
Growth inhibitors	: AMO-1618, Phosphon-D, Cycosel, B-999.

2. Plant growth regulators and their associated functions

Plant growth regulators	Associated functions
Auxins	: Apical dominance, root induction ,control fruits drops, regulation of flowering, parthenocarpy, phototropism, geotropism, herbicides, inhibit abscission, sex determination, xylem differentiation, nucleic acid activity.
Gibberellin	: Stimulate cell division and elongation, stimulate germination of seeds Stimulates bolting/flowering in response to long days, prevention of genetic dwarfism, increase flower and fruit size, dormancy, induces maleness in dioecious flowers, extending self life.
Cytokinin	: Promotes cell division, cell enlargement and cell differentiation, stimulate bud initiation and root growth, translocation of nutrients, prolong storage life of flowers and vegetables, prevent chlorophyll degradation, morphogenesis, lateral bud development, delay of senescence.
Ethylene	: Induce uniform ripening in vegetables, promotes abscission, senescence of leaf.
Absecisic acid	: Act as plant stress hormone, dormancy induction of buds and seeds, induces seeds to synthesize storage proteins, dormancy, seed development and germination, stomata closing.

3. Commercial Utility of PGRs in vegetable crops

Stimulation of fruit set : Poor fruit set is a major problem in solanum crops. In tomato apply 4-CPA, or 2,4-D@2-5ppm or PCPA 50-100ppm enhance the fruit set, and earliness.

Inhibition of sprouting : Application of MH @ 2500 ppm 15 days before harvesting prevents sprouting of onion in storage. Soaking potato tuber in IAA @ 250 to 1000 ppm solution or prolongs dormancy and thiourea @ 1% breaking the tuber dormancy.

Flowering : Application of GA at 50 mg/l to young leaves of non- flowering varieties of potato, when floral buds had just formed, resulted in flower induction in all varieties. MH delayed flowering in okra. GA has been reported to induce early flowering in lettuce.

Seed Germination : Pre-showing treatment of seed with growth regulators has been reported to enhance seed emergence. Okra IAA, NAA @ 20ppm enhances seed germination, In tomato, higher germination with GA_3 at 0.5 mg/l, and 2,4-D at 0.5 mg/l is reported. Soaking of seeds in ethephon at 480 mg/l for 24 h improved germination in muskmelon, bottle gourd, squash melon and watermelon at low temperature.

Seed Dormancy : Potato tubers fail to sprout before the termination of rest period; chemicals reported to break the rest period are GA, ethylene chlorhydrin and thiourea. For breaking of dormancy in potato comprise the vapour treatment with ethylene chlorhydrin (1 liter per 20 q) followed by dipping in thiourea (1%) for 1hr. finally in GA (1 mg/l) for 2 seconds. Lettuce is another vegetable in which treatment with GA has been reported to break seed dormancy induced by high temperatures**.**

Sex expression : Sex expression the treatment with growth regulators has been found to change sex expression in cucurbits, okra and pepper. GA_3 (10-25 ppm), IAA (100 ppm) and NAA (100 ppm) when sprayed at 2-4 leaf stage in cucurbits, then they have been found to increase the number of female flowers. Whereas, GA 3 (1500-2000 ppm), silver nitrate (300-400 ppm) and Silver thiosulphate (300-400 ppm) sprayed at 2-4 leaf stage induces male flower production in cucurbits

Parthenocarpy : Auxin produced seedless fruits in cucumbers and watermelon, PCPA 50-100 ppm induced parthenocarpy in tomato and brinjal, application of 2,4-D at 0.25% in lanolin paste to cut end of styles or foliar sprays to freshly opened flower cluster has been reported to induced parthenocarpy.

Gametocides : Plants growth regulators possess gametocidal actions to produce male sterility this can be used for F_1 hybrid seed production. MH at 100 to 500 mg/l in okra, okra, peppers and tomato, GA_3 in onion, 2,3- dichloro-isobutyrate (0.2 to 0.8%) in okra, muskmelon, okra, onion, root crops, spinach and tomato and TIBA in cucumber, okras, onion, and tomato. GA at 100 mg/l can also be used for inducing male sterility in pepper.

Hybrid seed production : Ethephon has been used for producing female lines in some cucurbits. Successful F_1 hybrid in butter-nut squash has been made by using female line produced with ten weekly sprays of ethephon. Plant growth regulators have also been used for maintenance of gynoecious lines. In cucumber, GA_3 sprays have been made to induce staminate flowers in gynoecious lines. Silver nitrate at 500 mg/l has been reported to be as effective as GA_3 in inducing male flowers on gynoecious lines of cucumber. However, in muskmelon foliar sprays of Silver thiosulphate at 400 mg/l was found best for induction of male flower on gynoecious lines.

Fruit ripening : Ethephon, an ethylene releasing compound, has been reported to induce ripening in tomato and pepper. Application of ethephon at 1000 mg/l at turning stage of earliest fruits induced early ripening of fruits thus increasing the early fruit yield by 30-35%. Post-harvest dip treatment with ethephon at 500-2000 mg/l has also been reported to induce ripening in mature green tomatoes.

Fruit yield enhancer : Soaking of seed in NOA at 25-50 mg/l, GA at 5-20 mg/l and CIPA at 10-20 mg/l, 2,4-D, 0.5 mg/l or thiourea at 10^{-1} M have been reported to improve fruit yield in tomato. In brinjal soaking of seedlings roots in NAA at 0.2 mg/l and ascorbic acid at 250 mg/l has been reported to produce higher fruit yield.

4. PGRs effect on seed germination

Asparagus seeds were soaked in different growth regulators like IAA, IBA, naphthalene acetic acid and various concentrations of GA_3 to evaluate their effect on germination. It was found that GA_3 had a significant effect on germination rate as compared to control, IAA, IBA and NAA during light and dark period. The result indicates that GA_3 at 50 ppm gave best response but as the concentration increased above 60 ppm the germination decreased rapidly and vigour index also decreased during light and dark period (Dhoran *et al*., 2012). In the study of Influence of growth regulators of ridge gourd among the treatments of growth regulators, application of NAA at 50 ppm recorded significantly higher germination percentage (96.04 and 89.34) during summer and *kharif* season, respectively (Hilli *et al*., 2008).

5. PGRs effect on growth and development

Plant growth regulator affects the physiology of plant growth and influence the natural rhythm of a plant. (IAA) and (GA) can manipulate a variety of growth and developmental phenomena in various crops. IAA has been found to increase the plant height; number of leaves per plant, GA stimulated stem elongation increase dry matter accumulation (Hore *et al*., 1988). The application of ethrel in Watermelon (*Citrullus janatus*) at 500 ppm concentration brought significant improvement in vegetative characters of plants i.e. main vine length and number of secondary branches plant^{-1} (Dixit *et al*., 2001).

Southern California growers raise artichokes from seed as annuals for a winter harvest to take advantage of the favourable winter market prices, result have revealed that multiple applications of GA_3 produce an earlier and more uniform first harvest in annual artichokes (Wayne *et al*., 1994). Spraying of GA_3 40 mg/l at flowering stage recorded the maximum number of leaves, leaf area, leaf area index and dry weight of plant at harvest stage (Satodiya *et al*., 2012). GA_3 increased shoot extension, leaf area, number of leaves, stolen and tubers but decreased dry matter of stem, leaf and tuber, IAA (Kumar *et al*., 1981).

Four sweet potato (*Ipomoea batatas* L.) cultivars responded differently to growth regulator application for number of flowers produced, percentage capsule set. GA_3, 2,4-D and BA application resulted in the highest number of flowers by 'Jewel', 'Shore Gold' and 'Vardaman' plants, respectively. Application of GA_3 to 'Jewel', 2, 4-D or ethephon to 'Shore Gold' and BA to 'Vardaman' produced the highest number of seeds.

Source: R. N. Chowdhury (2007). *Bangladesh J. Pl. Breed. Genet.*, **20(2)** : 17-22.

Fig. 1 : Fruit development with 2, 4-D treatment which started turning (A) Green (B) Yellow10 days after spraying, (C) 2, 4-D treated fruits in Kakrol (no seeds).

Grafting to rootstock of *Z. carnea* Jacq. spp. *Fistulosa* (Mart. ex Choisy) D. Austin increased flower numbers, percentage capsule set, and number of seeds in all cultivars. The effects of growth regulators and grafting were additive for flower numbers, percentage capsule set, and number of seeds. Chemical names used: (BA), (2, 4-D), (ethephon), (GA_3).

6. PGRs effect on yield attributed traits

IAA and GA_3 can increase fruit size with consequent enhancement in seed yield. It also increases the flowering, fruit set, (Gurdev *et al*., 1991). GA stimulated stem elongation increase dry matter accumulation (Hore *et al*., 1988) and enhance vegetable seed yield. It was noticed both the fruit number and fruit yield significantly affected hormones. In case of sowing times, in case of hormone, Ripen-15 produced the highest yield of okra (14.06 t ha G1) and control produced the lowest (10.06 t ha G1) yield of okra (Dilruba *et al*., 2009). In cluster bean spraying of thiourea 500 mg/l registered maximum number of pods plant^{-1}, weight of 1000 seeds and seed yield with good quality seeds (Satodiya *et al*., 2012).

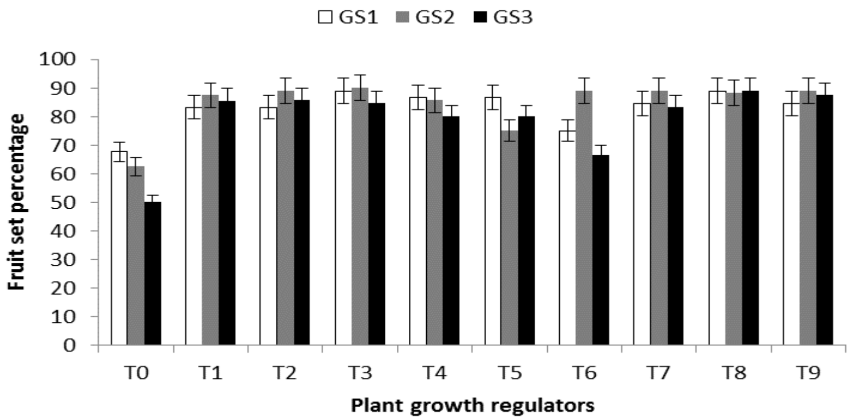
Effect of bio-regulators *viz*., *Triacontanol* @ 0.5 ml/ liter of water, NAA @ 50 ppm, GA @ 50 ppm and water sprayed at one, two and three times on growth and yield of fenugreek variety Rajendra Kanti. Spraying of Triacontanol @ 0.5 ml/liter water, NAA @ 50 ppm and GA @ 50 ppm gave significant effect on yield number of pods per plant (49.09), length of pod (10.82 cm), number of grains per pod (16.90) and yield (1.86 t/ha) (Singh *et al*., 2010). Effect of bio-regulators *viz*., *Triacontanol* @ 0.5 ml/ liter of water, NAA @ 50 ppm, GA @ 50 ppm and water sprayed at one, two and three times on growth of fenugreek variety Rajendra Kanti. Spraying of Triacontanol @ 0.5 ml/liter water, NAA @ 50 ppm and GA @ 50 ppm gave significant effect on yield and yield attributing character as compare to water sprayed. Maximum plant height (80.47 cm), number of branches per plant (7.04) was recorded by spraying Triacontanol @ 0.5 ml/l. Three sprays (at 25, 45 and 70 DAS) produced maximum plant height (79.92 cm), number of branches per plant (7.07) (Singh *et al*., 2010).

Significantly higher yield (17.62 q ha^{-1}) was observed in fenugreek with application of 60 kg phosphorus ha^{-1}. Foliar spray of naphthalene acetic acid (NAA) 20 ppm at 25 DASand 55 DAS resulted in significantly higher growth and seed yield (17.41 q ha^{-1}). The highest benefit: cost ratio (4.20:1) was observed for the treatment, 60 kg phosphorus ha-1 + NAA 20 ppm. (Gour *et al.,* 2009).

In bitter gourd, three concentrations each of GA_3 (25, 50 and 75 ppm), Ethrel (400, 500 and 600 ppm) and NAA (50, 100 and 150 ppm) were applied at three different stages namely S1 (2-leaf stage), S2 (2-leaf and flower initiation stage) and S3 (2-leaf, flower and fruit initiation stage). Application of GA_3 @ 25ppm significantly reduced number of days to first flower (40 days) and first harvest (54 days) at S3. Fruit set percentage was highest (90%) with similar application at S2; however, both fruit length and fruit diameter were highest with similar dose in plants sprayed at S2. Number of fruits and seed yield vine^{-1} was significantly higher among all the PGRs (GA_3, ethrel and NAA), when plants were sprayed with NAA @ 100 ppm at S2 and S1 (Muhammad *et al*., 2013).

Results (Surendra *et al*., 2006) indicated that among the growth regulators and micronutrients the foliar application of GA_3 (25 & 50ppm) at 60 DAS registered significantly higher fresh fruit yield over other treatments. The increase is due to increase in yield attributing components *viz*., total number of flowers, fruits plant^{-1}, fruit length, seed number fruit^{-1}, seed weight and harvest index. The benefit: cost ratio was higher with application of GA_3 (50ppm) over all other treatments.

Among PGRs, 2,4-D at 2 ppm was better for fruit set, number of fruits per plant, fruit length, number of seeds fruit^{-1}, seed weight fruits^{-1}, 1000 seed weight and fruit yield where as NAA at 40 ppm gave the highest



Source: Ghani, M. A. *et al.* (2013). *Pak. J. Life Soc. Sci.*, **11(3)** : 218-224.

Fig. 2 : Interactive effect of plant growth regulators and growth stages on fruit set in percentage bitter gourd. **S1** (2-leaf stage), **S2** (2-leaf and flower initiation stage) and **S3** (2-leaf, flower and fruit initiation stage).

leaf area index. PGRs were ineffective in promoting flowering and fruiting during winter season. GA_3 at 10 ppm exhibited maximum amount of ABA content. The treatments, 2 ppm 2,4-D, 5 ppm triacontanol, 40 ppm NAA and 10 ppm GA_3 produced 28.75%, 25.70%, 13.61% and 2.30% higher fruit yield over control, respectively. The highest net profit and B : C ratio were recorded in case of 2 ppm 2, 4-D. The use of GA_3 as foliar spray was not economical (Hilli *et al*., 2008).

Roy *et al*. (2011) conducted trail to study the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, *viz*., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54) and maturity (69.95) was recorded with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control (0 ppm GA_3) treatment. The application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the highest yield (45.22 kg/plot and 104.66 t/ha) was found from 50 ppm GA_3.

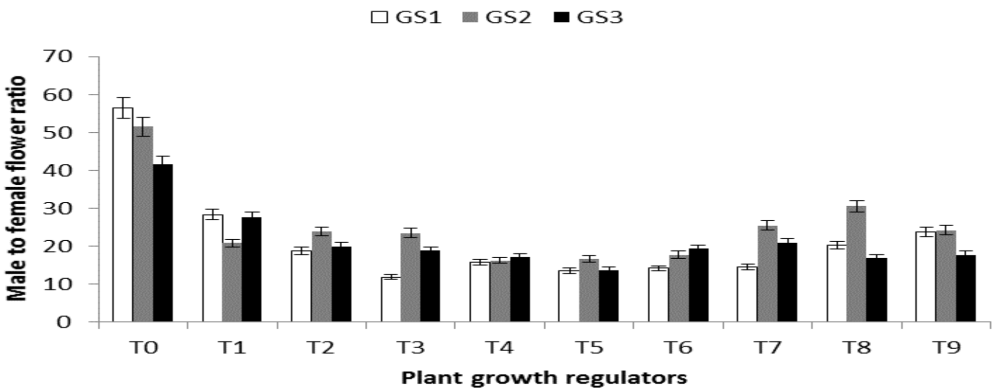
7. PGRs effect on sex expression

GA_3 (25 and 50 ppm) produced the female flowers at lower nodes and initiated early flowering, which consequently resulted in early yield. Besides, early yield by both concentration of GA_3, it also caused lower sex ratio along with greater number of fruits per plant followed by both concentrations of ethrel (250 and 500 ppm).The MH and NAA treatments were less effective for early and high yield as compare to GA_3 and ethrel treatments (Dixit *et al.* 2001). Two sprays of plant growth regulators were done at 2nd and 4th leaf stages in sponge gourd cv. 'Pusa Chikni'. The lowest number of male flowers (230.0), the highest number of female flowers (44.0) and lowest male: female sex ratio (1:5.26) was observed in ethrel 300 ppm treatment. The yield characters such as fruit length (25.95 cm) and diameter (16.50 cm) were observed maximum in treatment ethrel 300 ppm. Similarly, maximum fruit yield 23.90 t/ha was also observed in ethrel 300 ppm (Patel *et al*., 2010).

The effect of exogenous application of various levels of ethrel (500, 1000, 1500 and 2000 ìmol l^{-1}); (GA 15, 30, 45 3; and 60 ìmol l^{-1}) and (MH; 200, 400, 600 and 800 ìmol l^{-1}) on sex expression of bottle gourd (*Lagenaria siceraria*). Plants sprayed with distilled water were considered as control. Among all foliar agents, the response of GA and MH was found better. Exogenous application with 30 ìmol l^{-1} GA_3 3 maximally increased the pistillate flower production as compared to control. Moreover, the treatment produced maximum number of fruits plant^{-1} (22.24) and fruit weight plant^{-1} (6.31). However, foliar spray with different combinations of ethrel did not improve yield and yield contributing attributes (Hidayatullah *et al*., 2012). Plant growth regulators have profound influence on fruit production in cucurbits. It can modify growth and sex expression, improve fruit set and ultimately increase the yield in number of cucurbits.

8. PGRs effect on plant regeneration

When the proximal parts of cotyledons of winter squash from 4-day-old seedlings were cultured on induction medium composed of MS medium with 1 mg/l BA. After 3 weeks of culture in induction medium, 82 and 92% of explants from the two cultivars regenerated shoots. Adventitious shoots were sub-cultured on elongation medium composed of MS medium with 0.1 mg/l BA and the elongated shoots were successfully rooted in MS medium without growth regulators for 2



Source: Ghani, M.A. *et al.* (2013). *Pak. J. Life Soc. Sci.*, **11(3)** : 218-224.

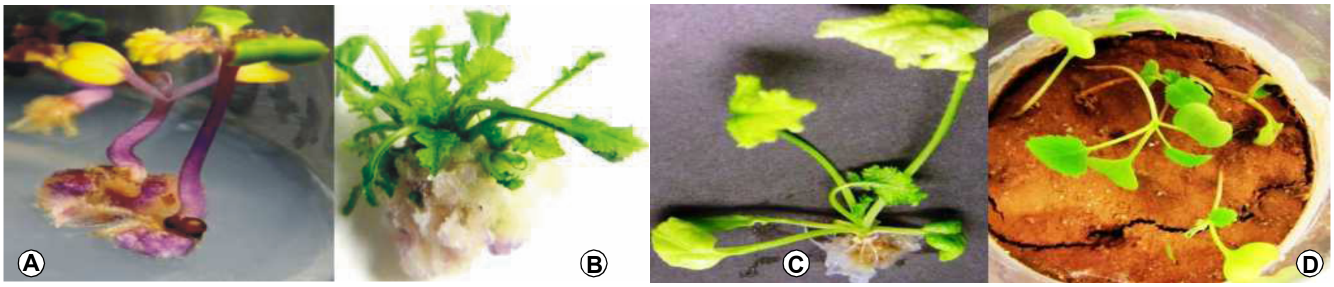
Fig. 3 : Interactive effect of plant growth regulators and growth stages on male to female flower ratio in bitter gourd. **S1** (2-leaf stage), **S2** (2-leaf and flower initiation stage) and **S3** (2-leaf, flower and fruit initiation stage).

weeks. Flow cytometric analysis revealed that most of the regenerated plants were diploid (Young *et al*., 2003). In order to study the *in vitro* callus induction and plant regeneration in the asparagus plant and indirect organogenesis in explants, it was found that the presence of two plant growth regulators NAA And BAP are necessary for seedlings regeneration and callus induction in asparagus. Treatment that leads to achieving the maximum amount of callus buds was MS medium supplied with 0.5 mg/lit of NAA and 1 mg/lit BAP, which leads to the production of 22 buds per explants. Two different levels of 2, 4-D were used for induce roots in regenerated seedlings. The best treatment was 1.25 mg/lit 2, 4-D with an average of 52% rooting in regenerated plants (Fazelzadeh *et al*., 2013). Resulted that the effects of plant growth regulators on spinach tissue culture were significant; moreover, the effects of explants were not significant except on the regeneration phase. The best medium for callous induction was MS media containing 1.5 mgl^{-1} IAA+2.5 mgl^{-1} GA_3. The best medium for shoot regeneration was MS media contained 0.5 mgl^{-1} NAA+2 mgl^{-1} GA_3. The best rooting medium was MS medium containing 0.5 mgl^{-1} IBA. Results presented inhibitory effect of GA_3 for callus and root formation; whereas; promote shoot development (Shojaei *et al*., 2010).

Cotyledon explants excised from seedlings germinated *in vitro*, an efficient plant regeneration system via organogenesis was established for bottle gourd (*Lagenaria siceraria*) maximum shoot regeneration was obtained when the proximal parts of cotyledons from 4-day-old seedlings were cultured on MS medium with 3 mg/l BA and 0.5 mg/l $AgNO_3$ under a 16-h photoperiod. After 3-4 weeks of culture, 21.9-0.7% of explants from the five cultivars regenerated shoots. Adventitious shoots were successfully rooted on a half strength MS medium with 0.1 mg/l IAA for 2–3 weeks. Flow cytometric analysis revealed that most of the regenerated plants derived from culture on medium with $AgNO_3$ were diploid (Han *et al*., 2004).

Leaf explants of squash (*Cucurbita pepo* L.) and melon (*Cucumis melo* L.) were pretreated initially with 113.1, 226.2 or 452.4 μM 2,4-dichlorophenoxyacetic acid (2,4-D), 46.5, 93 or 186 μM kinetin or a combination of both at the above concentrations, for 6, 24 or 48 h. After pretreatment, explants were transferred to an agar-solidified medium that was not supplemented with growth regulators or to a species-specific standard induction medium. Control explants from each species were incubated directly on the species-specific standard induction medium. Initial pre-treatment of squash explants with 186 μM kinetin and of melon explants with 226.2 μM 2, 4-D for 48 h significantly promoted the formation of somatic embryos, which developed further to the torpedo-shape stage and germinated. Under these conditions at least four plants can be regenerated per square centimeter of explant surface, thus achieving an increase over non-pretreated cultures of 143% and 130% for squash and melon, respectively (Kintzios *et al*., 2002).

A novel combination of plant growth regulators comprising (IBA), (BA) and (GA_3) in Murashige and Skoog basal medium has been formulated for *in vitro* induction of both shoot and root in one culture using cotyledonary node explants of guar (*Cyamopsis tetragonoloba*). Highest percentages of shoot (92%) and root (80%) induction were obtained in the medium containing (mg/L) 2 IBA, 3 BA and 1 GA3. Shoot regeneration from the cotyledonary node explants was observed after 10-15 days. Regeneration of roots from these shoots occurred after 20 to 25 days. The regenerated plantlets showed successful acclimatization



Source: Kaleem Ullah Kakar *et al.* (2014). *Sarhad J. Agric.*, **30(2)**.

Fig. 4 : A-D Regeneration and acclimatization of *B. rapa* var. *Turnip* plants from *in vitro* seed derived callus by applying different concentrations of PGRs. **A.** *In vitro* seed derived callus induction at the base of germinated seedlings after 10 days, where purple color shows the presence of anthocyanin, **B.** adventitious shoot induction from seed derived calli, **C.** rooted plant **D.** acclimatization.

on transfer to soil. This protocol is expected to be helpful in carrying out various *in vitro* manipulations in this economically and industrially important legume (Verma *et al*., 2013).*In vitro* plant regeneration involves different mechanisms for activation and regulation of certain enzymes at particular growth stage (Meratan *et al*., 2009 and Abbasi *et al*., 2011a). Induction of organogenic callus from explants culture is key step in *in vitro* plant propagation.

9. Parthenocarpy induction

Chowdhury *et al*. (2007) a experiment was conducted to find out the suitable PGRs for inducing parthenocarpic fruit in Kakrol (*Momordica dioicia*). Four plant growth regulators, *viz*. NAA and 2, 4-D, Cytokinine and GA_3 were sprayed at three stages (a day before anthesis, at anthesis, a day after anthesis). Out of four growth regulators 2, 4-D and fulmet induced parthenocarpic fruit development. Fruit set percent, final fruit weight, fruit length and fruit diameter varied significantly with different treatment combinations. 2, 4-D at 50 ppm when applied at anthesis showed better performance in inducing parthenocarpy.

Conclusion

Plant growth substances have key role in different physiological processes related to growth and development of vegetables and other crops. It is obvious that changes in the level of endogenous hormones due to biotic and abiotic stress alter the crop growth and any sort of manipulation including exogenous application of growth substances would help for yield improvement or at least sustenance of the crop. Hormones usually move within plant from a site of production to site of action. Phytohormones are physiological intercellular messengers that are needed to control the complete plant lifecycle, including germination, rooting, growth, flowering, fruit ripening, foliage and death. In addition, plant hormones are secreted in response to environmental factors such as abundance of nutrients, drought conditions, light, temperature, chemical or physical stress. Hence, levels of hormones will change over the lifespan of a plant and are dependent upon season and environment.

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