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A REVIEW

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A new vista of plant bio-regulators in fruit crops

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ABSTRACT : A wide array of environment-friendly plant bio-regulators (PBRs) has received attention of researchers in horticulture. Bio-regulators, alternatively known as plant growth regulators (PGR) are natural or synthetic chemicals that affect the expression of biological responses in plant tissues. PBRs are used more extensively in tree fruit production than in any other horticultural or agricultural commodity, and they are essential for effective and profitable production. It plays an important role in growth and development of horticultural crops by sustaining their productivity and improving the quality of produce. The efficient utilization of plant bio-regulators can provide a dramatic change in fruit production despite all success in high density planting and improving quality yield and storage life of the fruits without any spoilage. Different plant bio-regulators like CPPU, salicylic acid, brassinosteroides, strigolactones, jasmonates, *etc*., have wide scope for exploration and application but are not widely accepted in commercial fruit production despite of their immense usefulness coupled with low hazard to human health.

KEY WORDS : PBR's, Propagation, Growth and development, Quality and yield.

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Plant bio-regulators previously called plant growth regulators. In 1992 at Jerusalem in the 7th international symposium the name changes from plant growth regulators to plant bio-regulators. The discovery of plant hormones and their ability to regulate all aspects of plant growth and development were defining moments in horticulture. The 1960s loom as the "Golden Decade" of plant hormones. New and exciting things were being learned about the gibberellins, the importance of ethylene suddenly surfaced, cytokinins were identified, and ABA was discovered. It was an exciting and an exhilarating time to be studying plant hormones. The 1970's did not result in the identification of any new classes of major hormones but pomologically it was a most active and important time. The use of daminozide was being fine-tuned, the plethora of uses of ethephon were being discovered. Amino-ethoxy vinyl glycine (AVG) was discovered, 6-benzyl amino purine (BA), GA alone and in combination were developed to improve fruit shape, fruit appearance and tree growth manipulation. The discovery or existence of brassinosteroids (Mitchell *et al*., 1970) and jasmonates (Ueda and Kato, 1980) occurred and their development continues today.

Lawes and Woolley (2001) examined the commercial use of plant growth regulators to regulate fruit development. Fruit trees are considered high value crops and even small modifications in production efficiency, product quality or enhanced cosmetic appeal have the potential to significantly increase product value. Use of PBRs is a unique fact of biotechnology and a new approach of manipulating plant biological activities for enhancing growth, yield, quality, nutritive value and also to reduce biotic and abiotic stress in plants. PBRs like jasmonic acid, its volatile ester methyl jasmonate (MJ), and other derivatives, collectively known as jasmonates (JA's), are ubiquitous signalling molecules which mediate plant responses to environmental stress such as wounding, and insect and pathogen attack (Wasternack, 2007).Though bio-regulators are commonly used to improve plant growth, development, pathogenic defense and productivity, the molecular mechanisms of their effects still remain to be fully elucidated.

Table 1 : Physiological responses that are currently regulated /influenced by PBR's.
Promotion of feathering and branching
Increase flower bud formation inhibit flower bud formation
Thinning by promotion of fruit/flower abscission
Retard pre-harvest drop
Improve fruit finish
Improve fruit shape
Vegetative growth control
Increase fruit set
Increase fruit red colour
Advance fruit ripening
Delay fruit ripening
Enhance rooting
Suppress growth of water sprouts
Improve stress tolerance

Greene (2010)

Aspects of PBR's in fruit production:

Propagation:

Much experimental evidence supports the concept that endogenous growth promoting and growth-inhibiting compound are involved directly in the control of seed development, dormancy and germination. Gibberellins comprise the class of hormones most directly implicated in control and promotion of seed germination. Abscisic acid appears to play a major role in preventing precocious germination of developing embryo in the ovule. IBA and NAA are more effective in induction of rooting than IAA. In guava cv. 'SARDAR'the maximum survival of stool was obtained with IBA (750 ppm) treatment (Singh *et al*., 1996). IBA is used most often to root of micro cuttings in a wide variety of species. Roy *et al*. (2012) confirmed that concentration of IBA (0.4 mg/lit.) stimulate rapid root formation during *in vitro* culture of papaya compared to Zeatin and NAA.

Flowering:

Use of plant bio-regulatorsfor induction or delaying in flowering in different fruit crops is differ as per the purpose of users so, it is necessary to keep in mind using of plant bio regulators as per it responses with different concentrations for induction of flowering . In many woody plants including fruits GA inhibits flower formation. In these cases growth retardants *viz.*, paclobutrazol, SADH which inhibits GA biosynthesis are used to promote flowering such as in pears and mango e.g. Application of paclobutrazol helps in restricting the vegetative phase and increasing the reproductive phase of mango (Baghel *et al*., 2004). Vijayalakshmi and Srinivasan, 2002 notified that soil application with 10 ml paclobutrazol resulted in the increase of panicle length, number of branches per panicle, number of hermaphrodite and male flowers in mango. Ethephon proved to be the most effective promoter of flower bud formation. However, its use on bearing trees was limited because ethephon also caused thinning (Byers, 2003). Many investigators concluded that a combination of damiozide plus ethephon was the appropriate combination to increase flowering. Crop regulation in guava 'Sardar' by reducing of crop load of rainy season crop through foliar application of NAA (600 ppm) produced maximum winter crop yield (Suleman *et al*., 2006).

Fruit set and development:

The PBRs that contribute in increasing fruit set in different fruit crops have been subject of research and

Table 2 : Different PBR's effect on germination

Sr. No.	Fruit crop	PBRs	Concentration	Effect	References
1.	Jackfruit	GA_3	100 ppm	Germination (95.33%)	Singh *et al*., 2002
2.	Pomegranate	IBA	2000 ppm	Maximum number of primary root (13.24), maximum survival percentage (81.33%)	Upadhyay and Badyal (2007)
3.	Aonla	GA_3	500 ppm	Highest seed germination (75.50%)	Rashmi *et al.*, 2007
4.	Papaya (Honey Dew)	GA_3	Ms+GA_3 2.0 mg/lit	Highest germination (61.33%)	Beniwal *et al*., 2005
5.	Acid lime	GA_3	MS+GA_3 0.5 mg/lit	Maximum germination (72.16%)	Verma *et al.*, 2007

field testing since long. The exogenous application of auxin and gibberellins in most of cross-pollinated fruit crops help in preventing early fruit abscission by substituting to some extent, the normal endogenous production of the same. Apart from auxins and gibberellins, the growth retardants, ethylene inhibitors, polyamines and mixture of bioregulators have been found to increase fruit set. The phytohormone brassinosteroid plays an important role in various aspects of plant physiological responses including cell elongation and division, vascular differentiation, flowering, pollen development and photomorphogenesis (Clouse, 2011). Several reports have also shown that brassinosteroids are involved in fleshy fruit development and ripening of grape berry (Symons *et al*., 2006). Pre-pollination applications of putrescine (1.0 and 0.01 mM) positively affect fruit set in 'Housui' after hand-pollination (Mora *et al*., 2004).

Fruit sprayed with GA_3 (100 ppm) have retained maximum number of fruits in 'Amrapali' due to the beneficial effect of GA_3 in delaying the formation of abscission layer. GA spray might have triggered auxin level and nullified the action of ABA consequently retained more fruit (Rani and Brahmachari, 2004). Pear fruit treated with NAA (20 ppm) have strong effect on fruit set and development (Chen *et al*., 2012).Among different concentration of GA_3, ethrel, CCC, PP_{333} the maximum number of fruit set and yield of Plume cv. 'RED BEAUTY' was noted in ethrel @200 ppm and GA_3 @ 200 ppm, respectively (Saini and Sharma, 2010).

Fruit drop:

Abscission of mature fruit before harvest is a problem in many fruit crops producing countries. Increasing production and the desire for orderly fresh fruit marketing have made ontree storage of fruit an economic necessity. The synthetic auxin 2, 4-D is often incorporated into citrus production practices to reduce preharvest drop of mature fruits. 2, 4-D has a documented history of controlling mature citrus fruit drop in many citrus producing regions of the world (Coggins and Hield, 1968). A recent survey by Coggins found 2, 4-D in commercial use in at least nine countries (El-Otmani *et al*., 2000). The screening for fruit drop controlling compounds in pome fruit production has been extensive (Miller, 1988) but NAA remains in widespread use. Whereas, research on reducing mature fruit drop has not been as extensive as in pome fruit, perhaps due to the widespread efficacy of 2,4-D, several other compounds have been studied. One of the first reports of auxin analog use in citrus was that of 100 $mg \cdot L^{-1}$ naphthalene acetamide applied to reduce mature fruits. AVG is a naturally occurring compound which blocks ethylene synthesis and limits pre-harvest drop. The commercial formulation of AVG, Retain, and has become an essential tool in managing harvest of 'McIntosh' apple in the Northeastern USA (Robinson, 2006). PBRs such as NAA, GA_3, and CPPU sprayed to 'Arumani' mango trees at 14 days after blooming which results that CPPU (1-(2-chloro-4-pyridyl)-3-phenylurea) at 10 ppm, gave the best result in increasing fruit retention, number of fruit per cluster, fruit weight, volume and leaf area (Notodimedjo, 2000).

Fruit quality and yield:

Application of plant bio-regulators resulting in better quality and yield in fruit crops because it had improved the internal physiology of developing fruit in terms of better supply of water, nutrients and other compounds vital for their proper growth and development which resulted in improved size, quality and ultimately greater yield. Recently (Sharma and Belsare, 2011) reported that foliar application of boron at 0.2 per cent and CPPU @10 ppm reduced extent of fruit cracking and increased fruit size, fruit weight and juice contents were noticed with CPPU @ 5 ppm in pomegranate cultivar 'G-137'. Fruits of kiwifruit cv. 'ALLISON' dipped in 10 ppm CPPU solution 14 days after full bloom gave highest fruit yield, better size and quality fruits (Chandel and Devi, 2010). Ethylene and ethylene generators, advance eating ripeness of bananas (Bartholomew and Criley, 1983), intensify surface colour of apples (Looney, 1971), and reduce damage during mechanical harvesting by promoting abscission of sour cherries (Looney and Mc Mechan, 1970).

Control of vigour:

Various growth retardants have been used to restrict the vegetative growth of plant such as AMO 1618, ancymidol, paclobutrazol, B-Nine, chlormequat etc. The reduction in vegetative growth by growth retardants is due to the systemic inhibition of GA_3 biosynthesis pathway at the sub-apical meristem, which ultimately reduced cell elongation and rate of cell division and decreased the shoot growth. These growth retardants also inhibit the gibberellin precursor by blocking the oxidation of entkaurene to ent-kaurenoic acid. Chanana and Gill (2007) suggested that minimum trunk growth, height and spread were effectively controlled by using paclobutrazol 8ml/ tree in peach cv. 'EARLY GRANDE' and also in mango cv. ALPHANSO 10g a.i. per tree reduced tree size effectively (Murti *et al*., 2001). For several decades, auxin and cytokinin were the only two hormones known to be involved in the control of shoot branching through apical dominance, a process where the shoot apex producing auxin inhibits the outgrowth of axillary buds located below. Recently, this branching inhibitor has been shown to belong to the strigolactones, a group of small molecules already known to be produced by roots, exuded in the rhizosphere and as having a role in both parasitic and symbiotic interactions (Rameau, 2010).

Medjdoub *et al*. (2005) reported that a new chemical compound prohexadione-Ca (Pro Ca) @ 200 mg L^{-1} act as a growth inhibitor in the vigorous red apple cultivars 'Fuji' and 'Royal Gala'.

Canopy management:

Different plant growth hormones include in the dwarfing mechanism (Canopy management). And it is possible by applying the different growth hormones to the plant other than present in plant itself. Cytokinin is synthesized partially in the roots and translocated through the xylem to shoot tip or developing buds where it influences growth. In dwarfing apple rootstocks cytokinin concentration in the xylem sap below the graft union is at least fourfold higher than above the graft union (Jones, 1984). This indicates that the graft union has yet clearly undefined role to limit the transport of solutes, including cytokinins in the xylem sap**.** Abscisic acid is a hormone that increase markedly in leaves of water stressed plants and apparently is synthesized in the plastids of the leaves (Milborrow, 1978). Abscisic acid like compounds were reported to be higher in dwarf apple trees (Yadava and Dayton, 1972). Brar (2010) reported that paclobutrazol @ 500 ppm having highest growth retardation effect in guava.

Post-harvest quality:

Many climacteric fruits, such as banana, apple, peach, pear etc. are harvested when fully mature, and ripening is controlled while the harvested fruit is under storage. Control is exercised mainly by regulating the level of ethylene. Excessive ethylene production by ripening fruits result in early deterioration of fruit quality and shelf -life. Ethylenes levels can be regulated to some extend by the use of inhibitors of ethylene (AVG, AOA) and/or ethylene action (e.g., silver thiosulfate 2, 5-norbornadiene, trans-cyclo octane). However, use of these compounds in the food industry is not acceptable; moreover, silver is a heavy metal. The search for more acceptable alternative has led to the use of cyclopropane compounds, especially 1-methylcyclopropane (1-MCP), which is an odourless gas effective in small doses. The uniform or early ripening , firmness for long shelf life of fruits are also a needful things which can be overcome by PBR's. Ye-mao *et al*. (2013) reported that brassinosteroides plays an important role in strawberry fruit ripening, and may be involved in early fruit development. Ahmad *et al.* (2013) found pre-harvest spray of SA at 8 mM effective to increase the fruit firmness, soluble solid content, titratable acidity, sugars and organic acids of 'Lane Late' Sweet Orange (*Citrus sinensis* L.) during cold storage. The use of ethylene response inhibitors such as amino, ethoxy-vinyl glycine (AVG) and 1-methylcyclopropene (Sisler and Serek, 2003), and genetic manipulation targeting ethylene biosynthetic genes has identified distinct roles of ethylene in controlling different ripening characteristics in different fruits.

Conclusion :

Detailed knowledge of the mechanism of action and advance use of existing bio-regulators will not only aid the search for new products, but will be useful in predicting possible secondary effects of potentially market-able compounds in terms of their effects on the environment. The exogenous application of bio-regulators might, therefore, act as a powerful tool not only for enhancing the growth, productivity, quality of fruits but also in combating the ill effects generated by various biotic and abiotic stresses in plants in the near future. There by aiding to enhance potential crop yield and alleviating hunger and malnutrition in the ever-increasing human population of the world.Future research needs, therefore, require a better understanding of the mechanism responsible for developmental processes in plants at the cellular and molecular levels, and a more comprehensive description of the specificity of bio-regulators in mediating key biochemical steps.

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