Vol. 4 Issue- 10, June 2024 (e-ISSN: 2582-8223)

JUST AGRICULTURE
multidisciplinary e-Newsletter

Manipulating The Ripening Process in Fruits Through PGRS and Its Implication on Commercial Horticulture

[1]Karobi Handique, [2]Nanhe Lal Saroj, [3]Khonang Longkho and [4]Surjit Moni Deka

[1&3]Assistant Professor, Faculty of Agricultural Sciences, Arunachal University of Studies, Namsai, Arunachal Pradesh-792103

[2] Assistant Professor, Department of Agriculture Science, SRM University, Delhi NCR, Sonipat, Haryana-131029

[4] Department of Biochemistry and Agricultural Chemistry, College of Agriculture, Assam Agricultural University, Jorhat, Assam-785013

ARTICLE ID: 37

Introduction

Plant growth regulators (PGRs) are organic compounds (other than nutrients) that, in minute amounts, stimulate, impede, or alter any physiological function in plants. Consequently, the application of plant growth regulators has led to notable advancements in fruit crop growth, yield, and quality. For many years, PGRs have been utilized in agriculture with great success to modify the characteristics of plant growth to increase output and profit for growers. In a variety of fruit crops, foliar-applied PGRs are frequently used to reduce fruit drop, improve fruit set, growth, and development, and thin out flowers and fruits. Even before plant hormone was discovered, plant growth regulators played a significant role in agricultural output.

Though there are a few noteworthy exceptions, the majority of these applications are limited to high-value horticultural crops rather than field crops. The ability to alter plant development makes plant growth regulators valuable. Plant growth regulators can be applied to alter the endogenous levels of plant hormone when they fall short of or exceed the threshold required to alter the pattern of plant development. Recent research indicates that the relative roles of plant hormones are not stage-specific and that many plant hormones act together in a complex network that regulates various aspects of fruit development. While some topics have received a great deal of interest, there are still a lot of unanswered questions regarding the regulation of hormonal networks and the interactions between distinct hormones during fruit growth, development, and other ripening processes.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Hormonal regulation of ripening of climacteric and non-climacteric fruits

The regulation of fruit maturity and ripening varies between fleshy, climacteric fruits and non-climacteric fruits. Several regulatory processes are involved in fruit ripening, which alters the physiological and metabolic attributes of ripening fruits. The aforementioned process entails the start of several genetic and metabolic processes. The concentration of pigments in fruits causes their color to vary as they develop. According to Klee and Giovannoni (2011) and Seymour *et al*. (2013), complex carbohydrates are converted to sugars, fruit acidity lowers as sugars build, flavor and fragrance chemicals accumulate, and cell wall dynamics change, resulting in either dehiscence or a softening.

The primary phytohormone regulating the softening, coloration, and flavor development of climacteric mature but unripe fruits is ethylene. Fruit treated with ethylene undergoes a faster shift from maturity to ripeness because climacteric fruits strongly activate their respiration and ethylene evolution during the ripening process. At the onset of ripening, respiration is not initiated in non-climacteric fruits. These fruits do not ripen more quickly when treated with ethylene, as they produce far less of it (Pech *et al*., 2012). It is clear that climacteric tomato fruits generate about ten times more ethylene than strawberry fruits, even though the computation of evolved ethylene is done differently. It was long believed that non-climacteric fruits did not evolve ethylene at all because of the small amount of ethylene they produced.

These types of fruit also differ in the immediate cycle of ethylene generation. It rises in non-climacteric fruits only after ripening. It is also known that the mechanisms of IAA production alter during the completion of tomato fruit maturation (Epstein *et al*., 2002). This raises the question of how auxins, either alone or in combination with ethylene, contribute to the ripening of fruit. It is noteworthy that, in contrast to most fruits, where auxin content diminishes as ripening progresses, in peach fruits auxin synthesis in the pericarp was observed until day 100 following pollination, coinciding with the climacteric state and active production of ethylene (Trainotti *et al*., 2007). Genes encoding ACC oxidase and the ethylene receptor ETR2 are expressed in response to ethylene. On the other hand, auxin alone induces the genes of ACC synthase and another ethylene receptor from the ETR2 family that are generated during fruit softening. Consequently, the control of the ethylene signaling pathway is influenced by both hormones. At the same time, auxin triggers the production of both the two aspects of its

JUST AGRICULTURE
multidisciplinary e-Newsletter

signal system, Aux/IAA, as well as its own biosynthesis via inducing the tryptophan synthase beta subunit.

In addition to influencing each other's regulatory pathways, ethylene and auxin together have the ability to regulate the expression of the following genes: four Aux/IAA genes, three ARF genes from the auxin signaling system, and two genes encoding TIR1 auxin receptors, one of which is expressed in mature fruits and the other during the transition to ripeness. Furthermore, the combined action of these hormones can suppress the genes encoding signaling components for two auxin receptors, two Aux/IAA, and two ARF genes (not shown in the design) (Trainotti *et al*., 2007). It should be noted that a number of genes, including those encoding the auxin-synthesis-related enzyme indole-3-glycerol phosphate synthase, the ethylene receptor gene ETR1, and one ARF, were shown to be insensitive to either ethylene or auxin. So, it is evident that an advanced system of interactive control by two phytohormones, auxin and ethylene, is engaged in at least one fruit species, ensuring to ripen.

The flavor that ripe apple fruits absorb is regulated by the enzyme's alcohol acyltransferase and ethylene-induced lipoxygenase, which catalyze the synthesis of hexanal and hexenal (Zhu *et al*., 2005). Melon fruits produce volatile aromatic esters under the influence of ethylene (Pech *et al*., 2012). Bright fruit color is produced by ethylene activating phytoene synthase and β-lycopene cyclase, two enzymes that create carotenoids and anthocyanins (Marty *et al*., 2005; Klee and Giovannoni, 2011). Given that these alterations have been noted in relation to the response of many hormones, ethylene and ABA appear to be the primary factors governing ripening (McAtee *et al*., 2013). Because it plays a major part in the climacteric fruit ripening process, ethylene is still the hormone that has been studied the most (Bapat *et al*., 2010).

Multiple lines of evidence indicate that during the ripening process of climacteric fruits, there is a crosstalk between ethylene and indole-3-acetic acid (IAA). This idea is further supported by the following observations: (i) in fruits of both species, there is a concomitant increase in IAA and ethylene production; (ii) in genes for ethylene biosynthesis (ACS2, ACS4, and ACO1, for example) and signaling (ETRs and ERFs, for example) auxin up-regulates these genes in fruits (Trainotti *et al*., 2007). The nature of auxin action during this crosstalk appears to be complex, though. Auxin is very low or not detectable in the pericarp or locular tissue, so high levels of the hormone in seeds are primarily responsible for the high auxin concentration during the early ripening phase. Additionally, ripening-associated GH3 genes are thought to lower the free IAA concentration, which may be the reason for the low auxin levels in the remaining fruit tissues. Furthermore, it was shown that even IAA biosynthesis may cause IAA conjugation by boosting the expression of members of this gene family. This was suggested by the up-regulation of numerous GH3 genes, including GH3.1, GH3.5, GH3.9, and GH3.17 in the strawberry seed tissues with high auxin levels (Kang *et al*., 2013).

ABA appears to have a greater function during ripening in non-climacteric fruits when there is no surge in ethylene production during this time (McAtee *et al.,* 2013). It has been observed that any treatment that restricts the increase in ABA content that occurs during ripening in fleshy fruits would also hamper the induction of ripening. The greatest ABA level in tomato and peach fruits occurs before the climacteric ethylene production. Research has demonstrated that ABA stimulates ethylene biosynthesis by up-regulating the genes involved in ethylene biosynthesis, which in turn increases ripening (Sun *et al*., 2012). Similarly, the simultaneous elevation of ABA in siliques developing has been associated with ethylene-mediated stimulation of Arabidopsis dehiscence (Kanno *et al*., 2010).

Furthermore, aside from ABA, GA has been seen to postpone the ripening of several other fruits, including tomatoes, peaches, mangos, sapotas, and so on (Sudha *et al*., 2007). In general, several physiological factors those appear to be independent come together to form the ripening phase. The primary focus of early studies on fruit ripening was on ethylene, color changes, and cell wall dynamics, other ripening traits were given less consideration. There is evidence that certain hormones may regulate the ripening processes individually (McAtee *et al.*, 2013).

Implications of PGR's in commercial horticulture

- In lemons, GAs is used to postpone fruit ripening in order to boost fruit availability during the months of May through August, when output is low and demand is high. To postpone fruit harvesting and prolong fruit preservation, GA is given in November or December. Grapefruit and 'Navel' oranges are among the other citrus species for which postponing harvest is crucial. Fruit abscission can be managed with 2,4-D, but after fruit reaches maturity, there are changes related to the benefit of leaving the fruit on the tree longer so that harvesting can occur during a time when demand from consumers is highest.

- It has been reported that auxins are the cause of avocado fruit's inability to ripen on the tree. Before ripening to take place, the endogenous levels of fruit auxins represent a resistance component that must be deactivated. Fruit ripening is hastened when exogenous auxins are applied to its surface; however, ripening is slowed and ethylene levels are controlled when auxins are absorbed into the fruit tissue through the vascular system.
- Blueberry fruit ripens unevenly over a long period of time, requiring several harvests, which raises production costs. Three PGRs were tested for their effects on fruit ripening in rabbit eye blueberry cultivars, Premier and Powderblue: ethephon, abscisic acid, and methyl jasmonate. When 30–40% of the fruit on the plant reached ripeness, the ethylene-releasing PGR ethephon was applied at a dosage of 250 mg L-1. This hastened the ripening process, increasing the proportion of blue (ripe) fruit by 1.5–1.8 times in just 4–7 days following treatment in both cultivars. The results of this study collectively suggested that ethephon may hasten the maturity of rabbit eye blueberry fruit, hence reducing the number of fruit harvests.
- It has been discovered that diazocyclopentadiene (DCAP), a novel ethylene action inhibitor, prevents tomatoes and apples from ripening (Blankenship and Sisler, 1993).
- On "McIntosh" apples, ethephon with auxin (2, 4, 5-TP or NAA) accelerates ripening without reducing storage life.
- It has been discovered that postharvest treatment with 200 ppm of GA3 is particularly efficient in delaying the ripening of mangoes.
- According to Ye-mao *et al*. (2013), brassinosteroides may be involved in the early stages of fruit development and plays a significant role in the ripening of strawberry fruit.
- Ethephon 39% SL @192 ppm sprayed during fly pricking, when 10-15% of the berries have matured, aids in the consistent ripening of Arabica coffee berries.

Conclusion

Coordination and integration of numerous signaling events during plant growth are necessary for the regulation of complicated growth and the developmental process of plants. PGRs are an effective strategy for producing a variety of horticultural plants in greenhouses, fields, and nurseries. High output yields, improved crop production, and the incorporation of new technology are necessities in today's environment. In order to improve our understanding of plant physiology, future horticultural research—particularly that pertaining to the application of plant growth regulators in horticultural plants—will depend on the advancement of molecular and biotechnological techniques. It is important to look at new options when it comes to using plant growth regulators for other high-value crops including fruits, vegetables, and flowers. Applying these substances may be a useful strategy for minimizing the detrimental effects of stress on plant development. Furthermore, the various horticultural plants' yields can benefit from the alteration of the hormone balance. In the area of biotechnologies, new technologies have recently shown themselves to be effective tools.

References

Bapat, V. A., Trivedi P. K., Ghosh, A., Sane, V. A., Ganapathi, T. R. and Nath, P. (2010). Ripening of fleshy fruit: molecular insight and the role of ethylene. *Biotechnology Advances*, 28:94–107.

Blankenship, S. M. and Sisler, E. C. (1993). Response of apples to diazocyclopentadiene inhibition of ethylene binding. *Sylvia Postharvest Biology and Technology*, 3:95- 101.

Epstein, E., Cohen, J. D., and Solvin, J. P., (2002). The biosynthetic pathway for indole_3_acetic acid changes during tomato fruit development, *Plant Growth Regul*, 38:15–20.

Giovannoni J. J., Lee J. M., Chung M. M. and Fox, E. (2011). Molecular analysis of the developmental and hormonal systems regulating fruit ripening. *Acta horticulturae*, 884:41-50.

Kang, C., Darwish, O., Geretz, A., Shahan, R., Alkharouf, N. and Liu, Z. (2013). Genome-scale transcriptomic insights into early-stage fruit development in woodland strawberry *Fragaria vesca*. *Plant Cell*. 25:1960–1978.

Kanno, Y., Jikumaru, Y., Hanada, A., Nambara, E., Abrams, S. R. and Kamiya, Y. (2010). Comprehensive hormone profiling in developing *Arabidopsis* seeds: examination of the site of ABA biosynthesis, ABA transport and hormone interactions. *Plant Cell Physiology*, 51:1988–2001.

Klee, H. J. and Giovannoni, J. J. (2011). Genetics and control of tomato fruit ripening and quality attributes. *Annu. Rev. Genet.*, 45: 41–59.

Marty, I., Bureau, S. and Sarkissian, S., (2005). Ethylene regulation of carotenoid accumulation and carotenogenic gene expression in color contrasted apricot varieties (*Prunus armeniaca*). *J. Exp. Bot.*, 56: 1877–1886.

McAtee, P., Karim, S., Schaffer, R. and David, K.(2013). A dynamic interplay between phytohormones is required for fruit development, maturation, and ripening. *Front. Plant Sci*, 4: 79.

Pech, J. C., Purgatto, E. and Bouzayen, M., (2012). Ethylene and fruit ripening, *Ann. Plant Rev.*, 44: 275–304.

Seymour, G. B., Ostergaard, L. and Chapman, N. H. (2013). Fruit development and ripening, *Annu. Rev. Plant Biol.*, 64: 219–241.

Sudha, R. R., Amutha, S., Muthulaksmi, W., Baby, R., Indira, K. and Mareeswari, P. (2007). Influence of pre and post harvest chemical treatments on physical characteristics of sapota (*Achras sapota* L.) var. PKM 1. *Journal of Agricultural and Biological Science*, 3:450–452.

Sun, Y., Chen, P. and Duan, C. (2012). Transcriptional regulation of genes encoding key enzymes of abscisic acid metabolism during melon (*Cucumis melo* L.) fruit development and ripening. *Journal of Plant Growth Regulation*, 32: 233–244.

Trainotti, L., Pavanello, A., and Casadoro, G., (2007). Different ethylene receptors show an increased expression during the ripening of strawberries: does such an increment imply a role for ethylene in the ripening of these nonclimacteric fruits?, *J. Exp. Bot*., 56: 2037–2046.

Ye, M., Chai, Q., Zhang, L. T., Chun, Yu., Xing, L. Q., and Yuan, Y. S. (2013).Brassinosteroid is involved in strawberry fruit ripening. *Growth Regulation*, 69 (1): 63-69.

Zhu, K. L., Zhu, B. T. and Fu, D. T. (2005). Role of ethylene in the biosynthetic pathways of aroma volatiles in ripening fruit, *Russ. J. Plant Physiol.*, 52: 691–695.