PLANT GROWTH REGULATORS AND FRUIT QUALITY OF CITRUS

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Plant growth regulators are produced naturally by the plant or synthetically in the laboratory. Hormones, naturally occurring growth regulators, regulate physiological processes like rooting, shoot growth, flowering and fruit quality. Synthetic growth regulators mimic the action of hormones thereby altering the metabolism of the plant. Plant growth regulators have been in use for over 40 years in Florida, primarily in the packinghouse (degreening) and to delay preharvest fruit drop. They have become an important part of the fresh fruit production program in California and Australia for delaying peel senescence and preventing fruit drop for navel oranges and grapefruit held late into the season. Growers have not used growth regulators to a large extent in Florida, due to emphasis on production for the processing market. Following the severe freezes of 1983 and 1985, however, there has been increased interest in planting specialty fruit cultivars for the fresh fruit market. Moreover, high prices for fresh fruit during the past few years have prompted a renewed interest in using growth regulators to improve citrus fruit quality.

Major Groups of Plant Growth Regulators

Plant growth regulators can be separated into two main groups, growth promoters and growth inhibitors. The growth promoters include auxins, gibberellins, cytokinins and ethylene. Auxins, first discovered by Charles Darwin in the late 1800s, regulate cell elongation, rooting, fruit set, phototropism (movement toward light) and lateral bud break. The most common naturally occurring auxin is indoleacetic acid (IAA). Commonly used synthetic auxins include 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxy-acetic acid (2,4,5-T) used to prevent preharvest fruit drop, indolebutyric acid (IBA), a rooting hormone, and naphthalene acetic acid (NAA), a sprout inhibitor.

Gibberellins (GA) are a second group of growth promoters first discovered in Japan prior to the second World War. Rice plants infected with a fungus, *Gibberella fujikuroi*, grew abnormally tall and spindly due to production of gibberellins by the fungus. Gibberellins also promote seed germination, cell elongation and delay senescence of some tissues like the peel of citrus fruits. There are nearly 80 different naturally occurring GAs found in plants, but only a few have growth regulator activity. Commercial GAs are produced naturally using the fungus *Gibberella fujikuroi*.

Cytokinins (CK) are cell division factors first discovered in rapidly dividing cells during the 1950s. They also delay senescence of leaves and fruit. A number of natural CKs have been isolated from plants including Zeatin, or are produced synthetically, the most common of which is benzyladenine (BA). A compound containing GA and BA has been used successfully by apple growers to increase the length of the fruit; however, materials containing cytokinins alone have not produced consistently favorable results when used on citrus. Therefore cytokinins have very limited use in commercial citrus production in Florida.

Ethylene is unusual in that it is the only growth regulator occurring naturally as a gas. It promotes fruit ripening and color development in apples, bananas, tomatoes and other fruits. Citrus packers have used ethylene since the 1920s to degreen sweet oranges, grapefruit, tangelos and 'Temple' oranges. Ethylene also promotes fruit and leaf abscission.

A number of growth inhibitors have been isolated from plants and a few synthetic materials like maleic hydrazide and 2-chloroethyltrimethyl ammonium chloride (CCC), have become commercially important for retarding growth of ornamental plants. Maleic hydrazide was used to induce dormancy and increase cold hardiness in citrus during the 1960s; however, results were very inconsistent and this use has been abandoned. Abscisic acid (ABA) is the most widely studied naturally occurring inhibitor. None of these materials, however, has an effect on fruit quality of citrus.

Growth Regulators and External Fruit Quality

The primary effect of growth regulators is on external fruit appearance including color, texture, firmness, thickness of the peel and fruit size.

Color. Citrus fruit grown in subtropical regions like Florida may attain minimum internal quality standards before peel color becomes acceptable. Fruit may be colored naturally by degreening them in the packinghouse using 1-10 ppm of ethylene gas depending on cultivar. Ethylene promotes the breakdown of chlorophyll and the production of carotenoids. It also, however, promotes senescence of the peel and therefore must be used with caution. Degreening is used for sweet oranges, grapefruit and tangerines. Temperature and humidity conditions in the degreening room should be carefully controlled with optima being 85°C and 95% RH. Maintenance of optimum conditions retards peel softening, and allows for use of lower ethylene levels and less fruit damage.

Peel color may also be altered by application of ethylene to fruit on the tree. Dilute spray application of 200-300 ppm of ethephon (an ethylene releasing compound) 2-6 days before harvest improved peel color and decreased subsequent degreening time for 'Dancy', 'Nova', 'Lee' and 'Robinson' tangerines and 'Orlando' tangelo. Defoliation of 10-15% occurred a week following application at the 300 ppm rate, therefore caution should be exercised particularly when using ethephon on hot days or when trees are under moisture stress.

Delaying peel color development is also advantageous in some instances. Grapefruit held on the tree for late season harvest develop an uncharacteristic yellow-orange peel color suggestive of overmature fruit. Dilute spray application of 20 ppm gibberellic acid (GA_3) at color break delays the development of the off-yellow color making the fruit more attractive. Similarly, lemons develop a deep, yellow color when overmature. Application of 5-10 ppm of GA_3 prior to yellow color development delays this process and extends the harvest season. Gibberellic acid also effectively delays coloration of navel oranges when applied during December to January; however, it may prevent adequate peel color development if applied during August and September to navel oranges in Florida.

Peel texture and firmness. As fruits remain on the tree late in the season, peel texture becomes spongy and fruit become soft. Gibberellic acid has been used as an effective means of improving peel firmness, and decreasing postharvest brushing injury, decay, water spot and creasing for navel oranges grown in Australia. Dilute application of GA_3 to retard peel senescence has been used for many years to extend the harvest season of navel oranges grown in California. Application of GA_3 more than 13 weeks following bloom also improved peel firmness for Florida navel oranges. When GA_3 was applied during or shortly after bloom, however, an increase in fruit splitting has been observed on occasion. Currently, there is little interest among growers to extend harvest season of navels into January or February because of a strong early season demand. As acreage and supply of navel oranges increase, interest in extending the harvest season may increase.

The demand for premium quality grapefruit for the export market has produced renewed interest in extending the harvesting season for grapefruit using GA_3 to improve peel quality. Dilute application of 20 ppm GA_3 along with 10 ppm 2,4-D to prevent excessive fruit drop at color break has been a consistent means of extending harvest season of grapefruit into May and June. Gibberellic acid significantly improves peel texture and lessens incidence of soft or deformed fruit during long distance shipping.

Gibberellic acid, again applied along with 2,4-D as a stop drop, reduced incidence of black eye for 'Minneola' tangelos harvested in February and March. This study suggests the possibility of using this combination for improving external peel characteristics for other specialty fruits that may be held on the tree late into the season.

Fruit size. Fruit size is an important factor for any fresh fruit operation, particularly for tangerines and tangerine-hybrids. The primary reason for inadequate sizing is overproduction in a given season. Use of the growth regulators NAA or ethephon to thin the crop is an effective means of increasing fruit size of remaining fruit. Dilute application of 100-800 ppm NAA or 150-350 ppm ethephon reduced yields for 'Dancy' or 'Honey' tangerines but significantly improved fruit size, and returns to growers. No growth regulators are currently available that improve size without crop thinning, although studies from California in the 1950s showed increases in size of navel oranges sprayed with 2,4-D vs unsprayed fruit. The same effect has not been consistently observed in Florida.

Internal fruit quality factors

Internal fruit quality factors, total soluble solids, acid, color, juice content or seediness are not consistently affected by growth regulator application under Florida growing conditions. There are reports that GA_3 application reduced seed sprouting and granulation of late-season grapefruit. These effects cannot be consistently reproduced, however, and seem to vary from year to year. Biochemical studies on distribution of GA_3 in grapefruit suggest a very small percentage of the growth regulator is found in the juice or seeds.

Limitations for use of growth regulators

Growth regulators, if properly applied, can be effective in improving citrus fruit quality. However, margin for error is far less than that of other materials. Small errors in sprayer calibration or amount of material may cause leaf or fruit drop or inadequate fruit color development. Moreover, temperature and moisture conditions during application may alter effectiveness of some materials. Most growers are accustomed to applying relatively large quantities of spray materials to their trees and are skeptical that a few ounces of a growth regulator will elicit the desired response. This has prompted some people to apply far above recommended rates, with adverse effects. Finally, some growth regulators like 2,4-D have lost their registration due to concerns about product liability. The uncertain status of some materials has made it difficult for growers to develop a growth regulator program that is effective from year to year.

Future considerations

Growth regulators have been used for many years in Florida and worldwide to improve external fruit quality of citrus. Their major potential in Florida is for extending the harvest season of grapefruit and navel oranges and for improving peel color and fruit size of tangerines. When properly applied they can become a valuable addition to the fresh fruit program.

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