DELAYING RIND SENESCENCE IN CITRUS FRUIT

MOHAMED ISMAIL
Scientific Research Director
Florida Department of Citrus
Lake Alfred, Florida

Citrus rind is the protective layer that encases the many varied and enticing qualities of citrus fruit; ranging from the delicate sweetness of tangerines to the robust taste of grapefruit. Throughout fruit growth and development, citrus peel with its distinctive layers of flavedo and albedo provides protection against an array of adverse environmental conditions and a myriad of biological predators. Yet it continues to protect the fruit against pathological and entomological agents which eventually brings an end to its functional life.

Senescence is the final stage of fruit growth and development. It brings about a plethora of deteriorative changes and disorders, all of which contribute to the weakening of peel structure and leads to the final demise of the fruit. Delaying peel senescence prolongs the life of citrus fruit and extends its value. This simple manipulation of the very final stage of fruit development is of immense economic importance to growers and consumers. Delaying rind senescence improves fruit quality and extends its marketing season, which potentially enhances the crop value, and contribute to growers' returns. Use of growth regulators is one of several tools which when properly utilized, enables citrus growers to extend the marketing season of citrus fruit beyond its usual bounds.

Plant Hormones

Plant hormones are chemicals produced by one part of the plant and transported to another part where they exert their action. They include auxins, cytokinins, gibberellins, ethylene, and abscissic acid. They affect such phenomena as cell division, differentiation and growth, seed germination, fruit set and senescence. Of all the plant growth regulators that have been discovered during the past century, gibberellins are most notable for their profound effects on plant growth and development and among the gibberellins, gibberellic acid (GA_3) has the most widespread commercial use.

Gibberellic acid was first discovered in rice plants infected with the fungus Gibberella fujikuroi. It caused rapid growth of the stem and inhibited flower and seed formation. Over 60 gibberellins have been identified in vascular plants and green algae. Among the many physiological and morphological influences of gibberellins are cell elongation, male flower formation, fruit set, inhibition of root formation and stimulation of auxins production. GA is approved for use on a number of crops that include seedless grapes, navel orange, Valencia orange, other round orange (all states except California) lemon/lime, tangerine hybrids, grapefruit, sweet cherry, strawberry, rhubarb, artichoke, celery, lettuce, melons, cucumbers, pepper, sweet potato and spinach (Anonymous, 1995). Coggins and Hield (1962) reported that potassium gibberellate retarded color development in the rind of navel oranges. Two years later, Coggins and Eaks (1964) reported gibberellins to reduce navel orange rind staining, stickiness, susceptibility to water spot, and rupture under pressure.

Delaying Rind Senescence in Grapefruit

Rind senescence in grapefruit can be quantitatively assessed by the change in the color of the flavedo from bright yellow to almost orange. Peel color can be effectively measured using the Hunter color and color difference meter (Ferguson, 1982) expressed as the ratio of a to b values. The "a" value measures redness when positive and green when negative, while the "b" value measures the yellowness when positive and blueness when negative. A pale yellow grapefruit rind usually has an a/b ratio of -0.1 to +0.1.

GA has been reported by Dinar et al (1976) to delay color development in 'Marsh' seedless grapefruit. 2,4-dichlorophenoxy acetic acid (2,4-D) effectively reduced fruit drop when applied separately or in combination with GA. Color differences between treated and control fruit were statistically significant, through May. They were most pronounced in December, January and February and diminished as the season progressed. Similar results were reported by Ferguson et al (1982). GA delayed the development of overripe color in 'Marsh' seedless grapefruit, increased peel puncture strength and reduced fruit decay. The effectiveness of preharvest applications of GA in delaying peel senescence was enhanced when the fruit were dipped after harvest in solution containing 1000 ppm GA and 500 ppm 2,4-D. Neither GA, nor 2,4-D however, have been reported to have any significant effect on juice quality, e.g. total soluble solids and % acid.

Use of GA and 2,4-D is not a substitute for good cultural practices, most importantly irrigation. Gilfillan (1973) reported that moisture stress brought about by inadequate irrigation reduced the effectiveness of GA and 2,4-D in reducing peel puffiness and fruit drop under South Africa's conditions. In Florida, however, no differences were reported between irrigated and non-irrigated trees treated with the growth regulators. This may have been due to rootstock and environmental variables.

Growth regulators exert their action at very low concentrations. Phytotoxicity may result from use of higher than recommended concentrations. The following recommendations were offered to ensure successful results (Tucker et al, 1996):

Precisely follow label directions and do not exceed recommended rates, as tree defoliation can result.

2. Spray volumes of 250 gallons per acre or greater are recommended as more concentrated sprays have not been evaluated in Florida.
3. Avoid tank mixing of plant growth regulators (PGR's) with nutritionals, oils and additives with known penetrating properties. Enhancing the penetration of PGR's may stimulate higher uptake rates. If a surfactant is to be added, use the one recommended on the product label.
4. PGR's should not be applied to trees under stress conditions or when freeze threat is imminent.
5. Avoid application of GA and 2,4-D to young trees.
6. Past research and field observations have shown that fruit held for extended harvest periods has the effect of reducing the subsequent crop size, and inducing alternate-bearing cycles.

7. Check and adjust pH of water to between 6 and 7 if needed. Higher pH inhibits intake of GA.
8. Apply GA when fruit is at 50% color break or better. Late applications run the risk of interfering with flower bud differentiation and may reduce next season's bloom.
9. Avoid early harvesting of treated blocks. Treated fruit my be more difficult to harvest and may require excessive degreening.

To effectively improve quality of late season grapefruit, growers are advised to select groves that have proven history of good fruit holding capabilities. Although GA and 2,4-D have been proven effective in delaying rind senescence and extending the season for good quality grapefruit, the treatments have not been proven effective in retarding seed sprouting or affecting internal juice quality. It is imperative that growers monitor grapefruit held for late season harvesting for seed germination, internal drying and acid content to ensure maximum benefits from delayed harvesting.

Effect of Ga & 2,4-D on Rind Senescence of Navel Oranges

GA is widely used on California navel oranges to delay rind senescence, reduce water spotting, rind staining, tacky surface, puffy rind and rind rupture under pressure. GA application also helps delay harvesting and extend the season.

In Florida, preharvest application of GA and 2,4-D is not very common. However, GA has been reported to significantly delay peel color development for approximately two months beyond normal harvesting time (Ismail and Wilhite, 1992). However, it did not affect internal juice quality. Applying the growth regulators in October was more effective in delaying color development than November or December applications. It is recommended that treated fruit be closely monitored for internal dryness and acid levels to determine optimal harvesting time.

Effect of GA and 2,4-D on 'Minneola' Tangelo

'Minneola' tangelo is one of the most popular citrus varieties, especially for gift fruit shippers. Fruit are usually oblate to ovate with a prominent neck. Collapse of the area around the neck is very common. This is usually followed by dehydration and discoloration at the stem-end referred to in the trade as "black eye". The effect of Gibberellic acid and 2,4-D on peel quality on 'Minneola' tangelos grown in Florida was extensively evaluated. Data developed by the author were instrumental in obtaining a 24 (C) special local need label.

Results of research conducted during the 1983 to 1985 seasons indicated that GA at 10 ppm is effective in delaying peel color development and the onset of stem-end rind breakdown in 'Minneola' tangelos. The growth regulators were applied in July and December, or in both July and December to evaluate their effect on rind color, total soluble solids % acid, stem-end rind breakdown (SERB) and decay.

Applying GA, 2,4-D and GA + 2,4-D in July had no effect on peel color or internal maturity parameters, namely total soluble solids and percent acid of 'Minneola' tangelos harvested in January, February or March (Tables 1, 2, 3, & 4). When GA was applied in December or in both July and December, it delayed rind color development, but had no effect on total soluble solids or percent acid. The effect of GA on peel color was still evident in fruit harvested in March following the December application (Table 4).

Application of GA and GA + 2,4-D in December effectively reduced the incidence of SERB in 'Minneola' tangelo harvested in February and stored for 2 and 4 weeks at 45°F (Table 5). Fruit from treated trees exhibited lower levels of decay compared to the controls after storage for 1 and 2 weeks at 70°F (Table 5). GA applied in December reduced the incidence of SERB decay in 'Minneola' tangelos harvested in March (Table 6).

Summary

Retardation of rind senescence of citrus improves fruit quality and extends its marketing season. Preharvest application of GA is effective in delaying peel senescence while 2,4-D is effective in reducing late season fruit drop. Neither compound has any significant effect on internal maturity of fruit, or seed sprouting in late season grapefruit. GA effectively delays the onset of stem-end rind breakdown in 'Minneola' tangelo and extends its season by approximately two months.

Table 1 Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid applied in July, December and July and December 1983 on external color, juice quality of 'Minneola' tangelos harvested January 12, 1984.

Treatment	Parameter			
	Color (a/b) ratio	% TSS[1]	% Acid	TSS/acid ratio
July Application				
1. Control	1.19ab	12.44	0.99	12.50
2. 10 ppm GA	1.13bcd	12.56	1.05	11.94
3. 20 ppm 2, 4-D	1.14bcd	11.82	0.97	12.22
4. GA + 2,4-D	1.18abc	11.94	0.97	12.14
December Application				
5. Control	1.14bcd	12.04	0.94	12.86
6. 10 ppm GA	0.83e	12.32	0.95	13.06
7. 20 ppm 2, 4-D	1.09d	12.12	0.97	12.60
8. GA + 2,4-D	0.80e	12.26	0.90	13.64
July + December Application				
9. Control	1.25e	12.62	1.01	12.64
10. 10 ppm GA	0.84e	12.20	0.92	13.22
11. 20 ppm 2, 4-D	1.10cd	12.26	0.96	12.90
12. GA + 2,4-D	0.85e	11.70	0.91	12.82
F-ratio	46.77**	1.85NS	1.73NS	1.53NS

Data analyzed by Duncan Multiple Range Test. Means followed by similar letters within columns are not significantly different.

[1] TSS = Total soluble solids
NS = No significant differences
** = Significantly different at the 1% level

Table 2. Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid applied in July, December and July and December 1983 on external color, juice quality of 'Minneola' tangelos harvested February 6, 1984.

Treatment	Parameter			
	Color (a/b) ratio	% TSS[1]	% Acid	TSS/acid ratio
July Application				
1. Control	1.45ab	13.18ab	0.96	13.92
2. 10 ppm GA	1.38ab	13.60a	0.97	13.52
3. 20 ppm 2, 4-D	1.43ab	12.40bc	0.84	14.78
4. GA + 2,4-D	1.43ab	12.34bc	0.89	13.94
December Application				
5. Control	1.38ab	12.42bc	0.88	14.32
6. 10 ppm GA	1.04c	12.80abc	0.88	14.74
7. 20 ppm 2, 4-D	1.38ab	11.86c	0.81	14.70
8. GA + 2,4-D	1.02c	12.28bc	0.87	14.18
July + December Application				
9. Control	1.48a	12.76abc	0.93	13.86
10. 10 ppm GA	1.07c	13.00ab	0.87	14.90
11. 20 ppm 2, 4-D	1.36b	12.62abc	0.88	14.34
12. GA + 2,4-D	1.04c	12.56bc	0.84	14.90
F-ratio	30.84**	2.24*	1.71NS	0.96NS

Data analyzed by Duncan Multiple Range Test. Means followed by similar letters within columns are not significantly different.

[1] TSS = Total soluble solids
NS = No significant differences
* = Significantly different at the 5% level
** = Significantly different at the 1% level

Table 3. Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid applied in July, December and July and December 1983 on external color, juice quality of 'Minneola' tangelos harvested February 20, 1984.

Treatment	Parameter			
	Color (a/b) ratio	% TSS[1]	% Acid	TSS/acid ratio
<u>July Application</u>				
1. Control	1.51a	13.82	0.96	14.42
2. 10 ppm GA	1.49ab	13.24	0.99	13.40
3. 20 ppm 2, 4-D	1.37b	13.32	0.96	14.00
4. GA + 2,4-D	1.43ab	13.34	0.91	14.80
<u>December Application</u>				
5. Control	1.38b	13.24	0.98	13.48
6. 10 ppm GA	1.15c	13.50	0.96	14.02
7. 20 ppm 2, 4-D	1.39ab	13.26	0.88	15.32
8. GA + 2,4-D	1.16c	13.42	0.99	13.62
<u>July + December Application</u>				
9. Control	1.46ab	13.94	1.00	14.10
10. 10 ppm GA	1.25c	13.70	0.99	13.96
11. 20 ppm 2, 4-D	1.44ab	14.02	0.99	14.24
12. GA + 2,4-D	1.21c	13.26	0.98	13.70
F-ratio	11.76**	0.81NS	0.74NS	0.91NS

Data analyzed by Duncan Multiple Range Test. Means followed by similar letters within columns are not significantly different.

[1] TSS = Total soluble solids
NS = No significant differences
** = Significantly different at the 1% level

Table 4. Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid applied in July, December and July and December 1983 on external color, juice quality of 'Minneola' tangelos harvested March 5, 1984.

Treatment	Color (a/b) ratio	% TSS[1]	% Acid	TSS/acid ratio
<u>July Application</u>				
1. Control	1.50ab	13.92	0.87	15.98
2. 10 ppm GA	1.45ab	13.76	0.88	15.60
3. 20 ppm 2, 4-D	1.48ab	13.10	0.84	15.70
4. GA + 2,4-D	1.46ab	12.82	0.84	15.30
<u>December Application</u>				
5. Control	1.53a	13.38	0.87	15.40
6. 10 ppm GA	1.23c	13.32	0.91	15.56
7. 20 ppm 2, 4-D	1.45ab	13.22	0.81	16.20
8. GA + 2,4-D	1.23c	13.30	0.84	15.94
<u>July + December Application</u>				
9. Control	1.47ab	13.54	0.88	15.52
10. 10 ppm GA	1.25c	13.74	0.87	15.78
11. 20 ppm 2, 4-D	1.39b	13.68	0.84	16.34
12. GA + 2,4-D	1.22c	13.98	0.89	15.74
F-ratio	11.19**	.46NS	1.20NS	0.85NS

Data analyzed by Duncan Multiple Range Test. Means followed by similar letters within columns are not significantly different.

[1] TSS = Total soluble solids
NS = No significant differences
** = Significantly different at the 1% level

Table 5. Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid applied in July, December and July and December 1983 on stem-end rind breakdown (SERB) and decay of 'Minneola' tangelo harvested February 6, 1984 and held at 45°F and at 70°F.

	% SERB		% Decay			
Treatment	2 wk, 45°F	4 wk, 45°F	2 wk, 45°F	4 wk, 45°F	+ 1 wk at 70°F	+ 2 wk at 70°F
July Application						
1. Control	6.3abcd	21.7ab	0.0b	2.9abc	7.4abcde	22.8abc
2. 10 ppm GA	12.3ab	23.8a	1.1ab	4.7ab	12.1ab	33.2a
3. 20 ppm 2, 4-D	7.4abcd	20.1ab	1.1ab	2.3bc	12.0ab	28.6a
4. GA + 2,4-D	9.2abcd	17.7ab	0.6ab	2.3bc	7.4abcde	27.4ab
December Application						
5. Control	6.9abcd	25.1a	0.0b	0.6c	8.0abcde	26.9ab
6. 10 ppm GA	1.7d	4.0d	0.0b	0.0c	1.2e	7.4d
7. 20 ppm 2, 4-D	4.6bcd	18.9ab	0.0b	2.9abc	10.3abcd	32.6a
8. GA + 2,4-D	2.3cd	5.1cd	0.0b	2.8abc	4.5bcde	11.2cd
July + December Application						
9. Control	14.3a	27.4a	0.0b	2.3bc	11.4abc	33.7a
10. 10 ppm GA	6.3abcd	10.8bcd	0.0b	0.0c	3.9cde	13.8bcd
11. 20 ppm 2, 4-D	11.7abc	16.6abc	1.7a	5.9a	12.9a	33.2a
12. GA + 2,4-D	0.6d	2.9d	0.0b	0.0c	2.9de	8.6d
F-ratio	2.26*	4.57**	2.36*	3.53**	2.84*	4.97**

Data analyzed by Duncan Multiple Range Test. Means followed by similar letters within columns are not significantly different.

* = Significantly different at the 5% level ** = Significantly different at the 1% level

Table 6. Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid applied in July, December and July and December 1983 on stem-end rind breakdown (SERB) and decay of 'Minneola' tangelos harvested March 5, 1984.

		% Decay	
Treatment	% SERB	6 days at 70°F	14 days at° 70F
<u>July Application</u>			
1. Control	55.52a	78.8a	85.1a
2. 10 ppm GA	60.16a	79.8a	86.1a
3. 20 ppm 2, 4-D	59.84a	79.0a	86.9a
4. GA + 2,4-D	49.54a	79.8a	84.7a
<u>December Application</u>			
5. Control	54.62a	84.7a	87.5a
6. 10 ppm GA	25.04c	57.0bc	61.6bc
7. 20 ppm 2, 4-D	51.80a	71.0ab	85.1a
8. GA + 2,4-D	28.08c	39.5cd	45.4c
<u>July + December Application</u>			
9. Control	55.24a	78.3a	80.0a
10. 10 ppm GA	33.88bc	45.5cd	55.0c
11. 20 ppm 2, 4-D	48.42ab	72.8ab	78.6ab
12. GA + 2,4-D	20.10c	36.6d	44.2c
F-ratio	7.92**	8.35**	7.72**

Data analyzed by Duncan Multiple Range Test. Means followed by similar letters within columns are not significantly different.

** = Significantly different at the 1% level

Literature Cited

1. Anonymous, 1995. ProGibb® 4%; Plant Growth Regulator Solution. EPA Reg. No. 275-61. EPA Est. No. 33762-1A-1. List No. 5016. Abbott Laboratories 3/95, AG4913/R1.

2. Coggins, C. W., Jr., and H. Z. Hield. 1962. Navel orange fruit response to potassium gibberellate. Proc. Amer. Soc. Hort. Sci. 81:227-230.

3. Coggins, C. W., Jr., and I. L. Eaks. 1964. Rind staining and other rind disorders of navel orange reduced by gibberellin. California Citrog. 50 (2):47.

4. Dinar, H. M., A. H. Krezdorn and A. J. Rose. 1976. Extending the grapefruit harvest season with growth regulators. Proc. Fla. State Hort. Soc. 89:4-6.

5 Ferguson, Louise, M. A. Ismail, F. S. Davies, and T. A. Wheaton. 1982. Pre- and postharvest gibberellic acid and 2,4-dichlorophenoxyacetic acid applications for increasing storage life of grapefruit. Proc. Fla. State Hort. Soc. 95:242-245.

6. Gilfillan, I. M., W. Koekemoer and J. Stevenson. 1973. Extension of grapefruit harvest season with gibberellic acid. Proc. 1st World Citrus Conf., Murcia-Valencia Spain. 3:335-341.

7. Ismail, M. A. and D. L. Wilhite. 1992. Effect of gibberellic acid and postharvest storage on quality of Florida navel oranges. Proc. Fla. State Hort. Soc. 105:168-173.

8. Tucker, D. P. H., A. Wheaton, L. G. Albrigo, S. Futch, and M. A. Ismail. 1996. Plant growth regulator use strategies for delayed grapefruit harvest. Packinghouse Newsletter. No. 178. Citrus Research and Education Center, University of Florida, Lake Alfred, Florida.