SEASONAL VARIATION IN BONDING FORCE AND ABSCISSION OF CITRUS FRUIT IN RESPONSE TO ETHYLENE, ETHEPHON, AND CYCLOHEXIMIDE

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ABSTRACT

The bonding force between fruit and stem was measured during 1 season for 'Pineapple' and 'Valencia' oranges. In 'Pineapple,' it gradually increased during the summer reaching a maximum of 22.9 lb. in August. In November, it began to decline steadily reaching a minimum of 9.7 lb. in March. 'Valencia' orange fruit attained a maximm bonding force of 22.8 lb. in November. It began to decline in February, but did not go below 15 lb. during the summer. Retightening of mature fruit was initiated in August and continued through October. Ethylene, ethephon, and cycloheximide (CHI) accelerated abscission of 'Pineapple' oranges at most stages of growth and development. This stimulation was, however, at times obscured by increased sensitivity of fruit explants to abscission accelerating chemicals. This increased sensitivity was apparently associated with rind injury caused by rust mites.

INTRODUCTION

Abscission is a physiological phenomenon that is affected by many factors, one of which is age. As the chronological age of an organ increases, its responsiveness to an abscission accelerating agent also increases. This has been precisely demonstrated on intact bean leaves (3) and on blue lupine leaves (2). Burg and Burg (1) also reported an increase in the rate of ethylene induced banana fruit ripening with increased fruit age.

Fruit of some citrus cultivars are known for their ability to loosen naturally as they ripen, e.g., 'Pineapple' oranges; others, e.g., 'Valencia' are known for their ability to remain on the tree for long periods after ripening (8). Young 'Valencia' oranges (1.5 to 1.75 inches diameter) were reported to resist the abscission promoting action of ethylene, Ethrel, and CHI at concentrations effective in loosening fully mature fruit (9).

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No detailed chronology of changes in pull force and of responsiveness to abscission promoting agents at various times during fruit growth and development are available. Change in the pull force with time, of 'Pineapple' and 'Valencia' oranges, are presented with results of an attempt to determine the response of 'Pineapple' oranges to 3 abscission accelerators.

MATERIALS AND METHODS

Fruit from mature 'Pineapple' and 'Valencia' orange trees, grown on rough lemon rootstock, were removed with 3 to 4 inch stems. Samples of 20 'Pineapple' and 30 'Valencia' orange fruits were collected at 2 to 4 week intervals for measurement of fruit diameter and straight pull force needed for detachment of fruit from stem using a Chatillion tensiometer (7). The bonding force was monitored from June 13, 1969 to March 10, 1970 for 'Pineapple' and from July 2, 1970 to October 8, 1971 for 'Valencia' oranges.

Twenty fruit samples of 'Pineapple' orange, with 3 to 4 inch stems, were exposed to 10 ppm ethylene for 8 hr in 19.5 liter tightly closed glass jars. Other samples were treated by dipping in 300 ppm 2-chloroethylphosphonic acid (ethephon, Ethrel, or AnChem 68-240) or in 10 ppm cycloheximide (CHI) for 30 seconds. After treatment, stems were reclipped to a length of 2 inches and immersed in distilled water. Three days later, the pull force was measured on the same explants with a Chatillion tensiometer.

Effect of rust mite damage on abscission of 'Pineapple' oranges in response to ethylene, ethephon, and CHI.—Two groups of 'Pineapple' orange fruits were harvested during September, 1969. The first group had the characteristic russetted rind, caused by rust mites, covering half or more of the fruit surface. The other group was undamaged green fruit. Twenty fruit samples of damaged and sound fruit were treated with 10 ppm ethylene for 8 hr or dipped in 10 ppm CHI or 300 ppm ethephon for 30 seconds. The pull force was measured 3 days after treatment.

Ethylene production by green and russetted

'Pineapple' orange fruit.—Green and russetted 'Pineapple' oranges (2.6 inches in diameter) were collected in September. After washing and drying, the fruit were divided into three 5 fruit samples and placed in 1 gal glass jars. The jars were tightly closed and ethylene was measured in the jar atmosphere at 24 hr with a Varian Aerograph 1800 gas chromatograph using a 14 inch long x 1/8 inch i. d. alumina column maintained at ambient temperature.

Loss of fresh weight in sound green and rust mite damaged russetted 'Pineapple' oranges.—Samples of green and russetted fruit were harvested in September. They were washed, and dried, then paired according to size into 10 pairs of green and russetted fruit. Weights were determined, initially and at 2, 5, and 7 days thereafter.

Results and Discussion

Bonding force of 'Pineapple' orange fruit increased gradually during the summer reaching a maximum of 22.9 lb. in August (Fig. 1). The bonding force remained close to this maximum at least through the first few days in November. It then began to decline gradually and steadily until it reached a minimum of 9.7 lb. in March. Temperatures below 32°F were recorded on January 8, 9, 10, and 11, and again on February 4, 5, and 27, 1970 in the Lake Alfred area which may have had a speeding effect on the downward trend in bonding force.

'Valencia' oranges (Fig. 1) exhibited maximum pull force of 22.8 lb. early in November, nearly 2.5 months after 'Pineapple' oranges reached their maximum. Pull force values close to this maximum were obtained through February. A gradual short period of decline in the pull force seemed to have taken place during March and April, following which no substantial loosening of fruit was noted. On the contrary, fruit retightening seemed to have been initiated in August and continued through at least the first week in October. Below freezing temperatures occurred on November 24 and December 27, 1970 and on January 20 and 21, 1971. This may have accelerated the rate of fruit loosening.

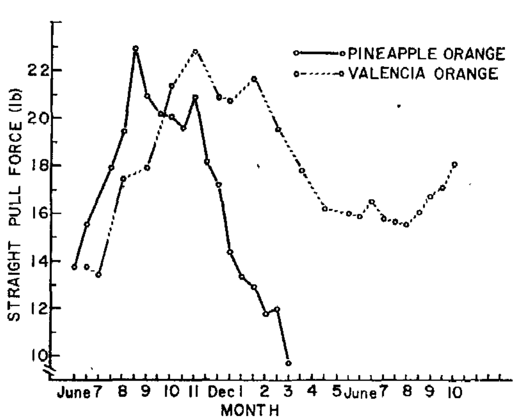

Figure 1.—Seasonal changes in pull force of 'Pineapple' oranges during 1969-1970 season and of 'Valencia' oranges during 1970-1971 season.

Data on the seasonal trend in pull force reflect cultivar differences between 'Pineapple' and 'Valencia' oranges. 'Pineapple' orange being a midseason cultivar exhibited higher bonding force values earlier in the season than the late maturing 'Valencia.' Furthermore, 'Pineapple' oranges underwent a steady decline in attachment force leading to fruit drop, while 'Valencia' fruit maintained an average bonding force above 15 lb., even at 18 months after full bloom. Another aspect in which 'Pineapple' oranges vary from 'Valencia' is their response to the synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D). 2,4-D inhibited abscission and reduced fruit drop of 'Pineapple' oranges but had no effect on 'Valencia' oranges in Florida (6). Regreening of 'Valencia' oranges in the spring and summer months is another area of difference between the 2 cultivars (4, 5). Such regreening was shown to be associated with a decline in ethylene production by the fruit (5). The increase in tree growth activities brought about by warm spring weather seems to halt and even reverse senescence of mature 'Valencia' oranges. This leads to blocking of fruit abscission and their remaining attached to the tree long after ripening. Cooper et al. (5) speculated that some unknown factors, antagonistic to ethylene, may move from the tree into the fruit causing their regreening. Such factor or factors, if present, could also result in keeping the fruit tenaciously bound to the tree beyond normal maturity.

Abscission of 'Pineapple' oranges at different stages of growth and development as influenced by ethylene.—'Pineapple' oranges exposed for 8 hr to 10 ppm ethylene in June and July (1.76 to 2.24 inches average diameter) did not abscise within 3 days after treatment (Table 1). At this stage, the fruit were dark green and almost free of rind blemishes, especially of rust mite damage. By the end of August when the fruit averaged 2.6 inches in diameter, it substantially loosened after 3 days in response to the same ethylene treatment. Even

Table 1. Effect of ethylene on abscission of 'Pineapple' orange fruit at various stages of growth and development during the 1969-1970 fruit season.

Sampling date	Fruit diameter (in.)	Bonding force (lb.) Initial	Bonding force (lb.) after 3 days: Control	Bonding force (lb.) after 3 days: 10 ppm ethylene
June 27, 1969	1.76	15.56	15.71	15.56
July 29, 1969	2.24	17.90	16.40	15.60
August 26, 1969	2.63	22.91	7.60	6.80
September 11, 1969	2.70	19.98	16.19	13.43
October 7, 1969	2.63	20.60	16.2	11.20
November 3, 1969	2.91	22.50	7.8	8.0
November 18, 1969	2.82	18.75	9.33	8.1
December 2, 1969	2.85	19.01	4.41	5.32
December 16, 1969	2.80	16.73	6.43	6.58
December 30, 1969	2.72	14.56	7.73	7.14
January 13, 1970	2.76	12.43	5.69	5.80

control fruit held in glass jars without ethylene abscised, apparently, under the influence of their own ethylene. Similar responses were exhibited by fruits treated during November, December, and January. Lack of abscission response to ethylene has been previously reported on young 'Valencia' oranges averaging 1.25 inches or more in diameter (9).

Abscission of 'Pineapple' oranges at different stages of growth and development as affected by ethephon and cycloheximide.—Fruit were resistant to ethephon and CHI administered late in June (Table 2) but began to show substantial loosening response by the end of July. In August, when the fruit was 2.4 to 2.9 inches in diameter, and thereafter, their abscission response to ethephon and CHI was drastic. Control fruit dipped only in water containing 0.05% Triton X100 as a wetting

Table 2. Effect of ethephon and cycloheximide on abscission of 'Pineapple' orange fruit at various stages of growth and development during the 1969-1970 fruit season.

Date of harvest	Fruit diameter (in.)	Pull force (lb.) Initial	Pull force (lb.) after 3 days: Control	Pull force (lb.) after 3 days: Ethephon	Pull force (lb.) after 3 days: CHI
June 27, 1969	1.76	15.64	15.04	14.05	14.04
July 29, 1969	2.24	17.90	16.10	7.10	4.20
August 26, 1969	2.63	22.90	5.10	1.90	5.40
October 7, 1969	2.70	20.10	9.30	5.95	2.03
October 21, 1969	2.63	20.40	2.43	1.15	1.93
November 3, 1969	2.91	19.30	7.60	5.20	7.70
November 18, 1969	2.82	17.58	10.10	6.16	7.73
December 2, 1969	2.85	18.59	5.80	3.88	4.80
December 16, 1969	2.80	15.73	5.71	3.53	4.08
December 30, 1969	2.72	14.56	6.89	3.51	5.84
January 13, 1970	2.76	14.19	6.50	2.66	4.43

Table 3. Abscission response of sound and rust mite damaged 'Pineapple' orange fruits as influenced by ethylene, ethephon, and cycloheximide.

Treatment	Pull force (lb.) Undamaged fruit Initial	At 3 days	Russetted fruit Initial	At 3 days
Control		20.4		16.2
10 ppm ethylene	21.0	21.1	20.0	13.4
Control		21.2		15.8
300 ppm ethephon	21.0	11.0	20.0	2.9
10 ppm CHI		14.8		6.8

agent, exhibited considerable loosening after 3 days, indicating increased fruit sensitivity to mere excision.

The question then arose as to what had rendered these fruit explants extremely responsive. The most drastic change in fruit was the extensive rust mite damage on fruit harvested in August compared to those picked in July. The possibility that rind damage caused by rust mite might have interferred with the abscission response was investigated on fruit harvested in September. Extensively rust mite-damaged and sound fruit were compared (Table 3). Russetted fruit were found more responsive to the abscission accelerating effect of ethylene, ethephon, and CHI than were sound fruit. To explain this difference in response, 2 hypotheses were investigated:

1. Damage caused by rust mite may increase ethylene production of the fruit, thus leading to at least partial senescence believed to be necessary for abscission.
2. Damage caused by rust mite may increase rind permeability, thus permitting more of the abscission chemical to penetrate the fruit and effectively promote its abscission from the stem.

Experimental results showed very little difference in ethylene production of healthy green vs. russetted 'Pineapple' orange fruits (Table 4) collected in September (2.6 inches in diameter), However, this does not rule out an initial rise in ethylene production of russetted fruit shortly after mite infestation.

Table 4. Effect of rust mite damage on ethylene production of 'Pineapple' oranges.

Type of fruit	Ethylene production (μl/kg/hr)
Damaged	0.021
Sound	0.026

Table 5. Effect of rust mite damage on fresh weight loss of 'Pineapple' oranges.

Type of fruit	Fruit diameter (in.)	% loss in fresh weight* Time after picking (days) 2	5	7
Damaged	2.82	5.00	10.58	13.84
Sound	2.85	2.37	4.80	6.24

*Average of 10 fruits.

The fact that rust mite damage increases rind permeability was clearly demonstrated by the difference in fresh weight losses over a period of 7 days (Table 5). Rust mite-damaged fruit showed more than twice as much loss in fresh weight as did sound, green fruit. Most of the loss in fresh weight must have been due to moisture loss as indicated by the shrivelled appearance of the rust mite-damaged fruit in comparison with the turgid appearance of healthy green fruit. It, therefore, appears that rind damage caused by rust mites may accelerate abscission of excised fruit by facilitating the penetration of applied abscission chemicals. Although no difference in ethylene production by rust mite damaged vs. healthy fruits was observed, indications are that russetted fruit are more senescent than green fruit based on observed degreening and advanced ripening of fruit affected by insect bites. It is also doubtless that other stress conditions could have interferred with the abscission response of these fruit. Temperature and humidity have been shown to have pronounced influence on abscission of 'Hamlin' orange in response to CHI (10) under greenhouse conditions. It has also been noted that long periods of drought seem to adversely affect the abscission activity of CHI on 'Valencia' oranges. Such variables would undoubtedly cause some inconsistency in fruit response to a given abscission chemical under field conditions.

In summary, seasonal changes in pull force were presented for 'Pineapple' and 'Valencia' oranges. Results of treatments of 'Pineapple' orange fruit explants with abscission promoting chemicals indicated the possibility of an indirect role of rind damage caused by rust mites in acceleration of abscission.

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