Short Communication

Levels of Endogenous Ethylene in Attached Citrus Fruits

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In fruits of the climacteric type, in general, ethylene production is associated with the onset of ripening of the fruits, since it increases dramatically at the same time or just prior to the respiratory rise.¹⁾ On the other hand, fruits of the non-climacteric type, *e.g.* citrus fruits, show no respiratory rise and no ethylene production at the ripening stage. In a previous paper²⁾ and other reports,^{3,4)} it has been reported that no ethylene production was observed in detached or postharvest citrus fruits of some varieties at the ripening stage. In the present work, the seasonal changes of endogenous ethylene levels within citrus fruits which were attached to the plant were investigated.

The three varieties of citrus fruits used in this experiment were as follows: *Citrus unshiu* Marcov. var. *Praecox* Tanaka cv. Okitsu-wase (*Wase satsuma mandarin*), *Citrus junos*

Tanaka (Yuzu) and *Citrus aurantium* Linn. var. *cyathifera* Y. Tanaka (Daidai). Fruits were obtained from the Kochi Fruit Tree Experimental Station. The experiment was carried out from July to December in 1980. Fruits attached to the plant or postharvest fruits were submerged in water and then the internal gas was withdrawn with plastic syringes from the fruits according to a previous paper.⁵⁾ Five fruits were used to collect gas samples, hence the data of gas levels represent the averages of 5 fruit samples. The fruits wounded by inserting the needle of a syringe were removed. Ethylene and CO₂ were analyzed by gas chromatography according to a previous paper.²⁾

The results are shown in Table I. On July 4 the endogenous ethylene levels in the three varieties of fruits were more than 1000 ppm, and thereafter they decreased. In citrus fruits the physiological fruit drop occurs from May to July, and the period of maximum drop is around the middle of June. The data for 1980 are summarized in Table II. The number of fruits abscised diminished with a decrease of endogeneous ethylene level. The author also observed considerable ethylene production and respiratory rise in young fruits harvested from May to July in this experiment as well as in the previous experiment.²⁾ From these results it is suggested that these high levels of ethylene accelerate separation of the fruit from the calyx to cause the physiological fruit drop.

TABLE I. CHANGES OF ENDOGENOUS LEVELS OF ETHYLENE AND CARBON DIOXIDE IN FRUITS OF *Wase SATSUMA MANDARIN*, YUZU AND DAIDAI

Levels of ethylene and carbon dioxide are expressed as ppm and percent, respectively.

Date	<i>Wase satsuma mandarin</i>		Yuzu		Daidai	
	C ₂ H ₄	CO ₂	C ₂ H ₄	CO ₂	C ₂ H ₄	CO ₂
July 4	1850	2.3	1040	3.2	3450	2.6
18	222	1.4	132	2.7	105	1.6
25	72.7	1.2	33.0	2.3	27.7	1.1
Sept. 4	0.1	1.0	0.1	1.5	0.1	0.9
Oct. 8	96.3	0.3	99.7	0.5	0.2	0.5
Nov. 1	6530	0.9	2140	0.9	2620	1.3
Dec. 3	10200	0.5	—	—	—	—
13	—	—	6570	0.3	13900	0.3

TABLE II. CHANGES OF THE NUMBER OF FRUITS
ABSCISED DURING PHYSIOLOGICAL
FRUIT DROP

The figures are expressed as the average number a day in each period.

Period	<i>Wase satsuma</i> mandarin	Yuzu	Daidai
May 26~31	357	4	39
June 1~10	432	24	59
11~20	100	22	66
21~30	10	6	87
July 1~10	13	2	53
11~20	7	0	19
21~31	3	0	4
Aug. 1~15	0	0	1

TABLE III. ENDOGENOUS ETHYLENE LEVELS IN
POSTHARVEST FRUITS OF *Wase SATSUMA*
MANDARIN, YUZU AND DAIDAI

Date	<i>Wase satsuma</i> mandarin	Yuzu	Daidai
Attached fruits			
Oct. 8	96.3	99.7	0.20
Harvested fruits ^a			
Oct. 9	2.1	0.04	0.11
10	0.03	0.04	0.08
11	0.14	0.11	0.17
12	0.20	0.09	0.15
13	0.13	0.14	0.10

^a Fruits were harvested on Oct. 8 and stored at room temperature.

Fruits before July were too small and tight to withdraw the internal gas for analysis.

On September 4 the endogenous ethylene levels in the three varieties of fruits were only 0.1 ppm. The most interesting period in the present study was on and after October 8. On October 8 the endogeneous ethylene levels of *wase satsuma* mandarin and yuzu attached to the plants began to increase exceedingly again, while the increase in that of daidai was delayed a few weeks. Finally in December endogenous ethylene levels of all fruits reached as high as 6000~14000 ppm. No ethylene could be detected on and after September 4 in the case of postharvest fruits as reported before.²⁾ Table

III shows the change of levels of endogenous ethylene in fruits detached or harvested on October 8. The fruits harvested were left at room temperature. Table III indicates that when the fruits at the ripening stage were separated from the plant the internal level of ethylene diminished rapidly, thereafter ethylene was not produced so much any longer. This suggests that the materials involved in biosynthesis of ethylene may be translocated continuously from the leaves to the fruits at the ripening stage. On the other hand, there is the fact that the fruits at the young stage from May to July show the ability to still produce ethylene after harvest.²⁾ This may result from either the presence of ethylene precursors such as 1-aminocyclopropanecarboxylic acid (ACC) enough to produce a large amount of ethylene,⁶⁾ or that of plant hormones such as auxin or cytokinin to activate ethylene biosynthesis. The endogenous levels of CO₂ decreased with the increase of fruit age, and seemed not to correlate with those of ethylene.

The relationship between the day of color break of fruits and their endogenous ethylene levels was then examined. *Wase satsuma* mandarin started coloring on September 29, yuzu on October 16 and daidai on November 18. The concentration of ethylene necessary to cause the color break is likely lower in *wase satsuma* mandarin than in yuzu and daidai, because the color break of *wase satsuma* mandarin had already occurred when the ethylene concentration reached about 1000 ppm on October 8, while that of yuzu did not although its endogenous ethylene level had increased to about 100 ppm. Daidai was still not in the ripening stage on that day as the ethylene concentration was only 0.2 ppm. The color break that is one of the ripening phenomena occurred after the rise of endogeneous ethylene in yuzu and daidai.

These results show that although the respiratory rise does not occur in the attached citrus fruits at the ripening stage a steep increase of the internal ethylene level occurs just as in the climacteric-type fruit, in other

words, they may require continuous high levels of ethylene to be performed for the ripening process on the plant.

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