4. Jaworski, C. A., B. B. Brodie, N. C. Glaze, S. M. McCarter, J. M. Good and R. E. Webb. 1973. Research studies on field production of tomato transplants in southern Georgia. U. S. Dept. Agric. Prod. Res. Rpt. 148.
5. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. *Plant Dis. Rptr.* 48:692.
6. Ko, W. and F. K. Hora. 1971. A selective medium for the quantitative determination of *Rhizoctonia solani* in soil. *Phytopathology* 61:707-710.
7. Lopez, C. R. and U. L. Gonzalez. 1973. The effects of fungicides and fumigants applied to soil of onion seedbeds. *Proc. Tropical Region, Amer. Soc. Hort. Sci.* 17:277-284.
8. McCarter, S. M. and R. H. Littrell. 1970. Comparative pathogenicity of *Pythium aphanidermatum* and *Pythium myriotylum* to twelve plant species and intraspecific variation in virulence. *Photopathology* 60:264-268.
9. ———, C. A. Jaworski, A. W. Johnson and R. E. Williamson. 1976. Efficacy of soil fumigants and methods of application for controlling southern blight of tomatoes grown for transplants. *Phytopathology* 66:910-913.
10. Nash, S. M. and W. C. Snyder. 1962. Quantitative estimations by plant counts of propagules of the bean root rot *Fusarium* in field soils. *Phytopathology* 52:567-572.
11. Rhoades, H. L. 1969. Nematicide efficacy in controlling sting and stubby-root nematodes attacking onions in central Florida. *Plant Dis. Rptr.* 53:728-730.
12. Sumner, D. R. 1974. Ecology and control of seedling diseases of crucifers. *Phytopathology* 64:692-698.

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Effects of Harvest Date and Ethylene Concentration in Controlled Atmosphere Storage on the Quality of 'McIntosh' Apples[1]

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Abstract. **'McIntosh' apples (*Malus domestica* Borkh.) were harvested on 3 different dates and stored in controlled atmosphere (CA) storage with less than 1, 10 or 500 ppm ethylene. After 5 and 8 months of storage the fruits which had been harvested 5 to 6 days before the onset of the climacteric were less ripe and had less breakdown than fruits harvested after the onset of the climacteric. The fruits harvested at the preclimacteric stage had either comparable or slightly better eating quality but less red color than fruits harvested later. High levels of ethylene had slight but statistically significant negative effects on firmness and acidity of early harvested fruits judged by sensory evaluation after 5-month storage plus 7-day holding and by objective evaluation after 8-month storage plus 1- or 7-day holding at 21°C. An attempt was made to find a method to estimate the physiological age of preclimacteric apples. The minimum treatment time required for 10 ppm ethylene to trigger the onset of the climacteric at 21°C is judged to be promising.**

Recent studies have indicated that ethylene promotes the ripening and senescence of apples under CA and low pressure conditions (1, 3). 'McIntosh' apples harvested at the preclimacteric stage remained firmer and less ripe in CA with low ethylene levels than those in CA with high ethylene levels (4, 5, 6). Little information about the effects of harvest date and ethylene levels in CA on the eating quality of the fruits was reported by these authors. The main purpose of this study was to study these factors.

Since harvesting at the preclimacteric stage is reported to be a necessary condition for 'McIntosh' apples to be benefited by ethylene removal in CA (5), a way to predict the time of the onset of the climacteric is desirable. Methods to verify whether or not an apple is preclimacteric are available. They include measuring CO_2 production (9), measuring ethylene production (7, 9), and measuring internal ethylene concn of the harvested fruits.[2] However, methods for estimating the physiological age of preclimacteric apples in terms of how near they are to the natural onset of the climacteric are still lacking.

Materials and Methods

The effect of 3 harvest dates (Sept. 11, 17 and 22) and 3 levels of ethylene (<1, 10, and 500 ppm) in CA storage on the condition and quality of 'McIntosh' apples were tested with a factorial design. Each of the 9 treatments had duplicate samples for 5-month and 8-month assessments. Each sample contained 50 fruits harvested from 3 adjacent mature trees (16–17 fruits from each tree). The fruits were stored in 19-liter (5 gal.) jars (50 fruits/jar) in a continuous flow CA system at 2.2–3.3°C as previously reported (5). The atmospheres were maintained at 3% O_2 – 3% CO_2 and the appropriate concn of ethylene within ± 10% error. At the end of 5-month and 8-month storage the fruits were transferred from each jar to paper bags and placed in 21°C air. Evaluations of the condition and quality of the fruits were made 1 and 7 days after the transfer.

A 25-fruit sub-sample from each 50-fruit sample was used for each evaluation. The 25 fruits were displayed as a group for sensory evaluations by 6 or 7 experienced apple taste panelists. Each panelist visually evaluated the composite sample for surface color, ground color, gloss, and overall appearance. Then each panelist tasted 3 apples for firmness, sweetness, acidity, astringency, aroma, overall flavor and aroma, overall ripeness, and overall eating quality without considering the color and appearance factors. A 5-point scale was used for each item of the evaluation. For sweetness, acidity, and astringency evaluations a score of 3 represented adequacy; scores of less than 3 represented excess; and scores of more then 3 represented deficiency. For other items a lower score meant redder surface color, greener ground color, better appearance, firmer texture, less ripeness, or better flavor, aroma, and overall eating quality. After the sensory evaluation the fruits were

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[2]Dilley, D. R. undated. Warehouse procedure for determining ethylene in apple fruits – a fruit maturity indicator. Michigan State University Mimeograph.

objectively evaluated for firmness, soluble solids, and acidity by methods reported previously (5). Fruits with significant flesh browning judged by the author to be 'McIntosh' breakdown or senescent breakdown (8) were excluded from the objective evaluations.

'McIntosh' apples from 1 mature tree were harvested 5 times at 4-day intervals starting Sept. 1, 1976 for the study on physiological age. Immediately after harvest the fruits were divided into 3 groups. The internal ethylene of the first group containing 6 apples was measured as follows: An intercellular gas sample was extracted from each fruit by imposing a vacuum of 200 mm Hg for ½ min with an apparatus similar to that described by Beyer and Morgan (2). The ethylene concn in the gas sample was measured by a gas chromatography (Varian Aerograph Model 1860 with a flame ionization detector and 3.2 mm x 457.2 mm activated aluminum oxide column). The second group containing duplicate 5-apple samples was placed in two 3.8-liter glass jars with continuous air flow at 200 ml/min at 21°C. The CO_2 and ethylene production rates of apples in each jar were measured daily with an infrared CO_2 analyzer (Beckman IR-215) and a gas chromatograph (GC), respectively. The onset of the climacteric in these fruits was judged by the significant increase above an established minimum in ethylene and CO_2 production rates. The time interval in days between harvest and the onset of the climacteric was called the preclimacteric period. The third group of apples was held in 10 ppm ethylene mixed in air at 21°C and at 4-hr intervals duplicate 5-fruit samples were transferred from the ethylene containing air to the ethylene-free conditions described above. Previous observations indicated several hr of air flow were necessary to sweep away the ethylene trapped in the fruits from the treatment gas. No ethylene in the effluent air was detectable thereafter as long as the fruits remained preclimacteric. An ethylene level in the effluent air detectable by the GC (>5 ppb) would indicate an increased rate of ethylene production by the fruit and the onset of the climacteric. In order to standardize the procedure the ethylene content in the effluent from each jar was measured 8 to 12 hr after the transfer of the fruits from air with 10 ppm ethylene to air without ethylene. Thus, the minimum treatment time (in hr) required for 10 ppm ethylene to induce the onset of the climacteric of each sample was determined.

Results

Fruits harvested on Sept. 11 were clearly preclimacteric judging from their consistently low internal ethylene concn and 4–7 day preclimacteric period (Table 1). Those harvested on Sept. 17 were just at the beginning of the climacteric rise. Although the endogenous ethylene measured from the 6 fruits was not very high, no sample harvested on this date had a preclimacteric period of more than 1 day. Many fruits harvested on Sept. 22 were on the climacteric rise since they had high endogenous ethylene concn and high CO_2 production rates. Severe fruit abscission was also noticed from these trees by Sept. 22. Fruits harvested on Sept. 22 were slightly softer and had less acids than those harvested earlier (Table 1).

Late harvest substantially increased the incidence of breakdown in storage (Table 2). The effect of ethylene concn on fruit breakdown was not statistically significant.

After 5 months of storage and a 1-day holding period at 21°C, early harvested fruits were firmer and had higher soluble solids and acidity than late harvested fruits (Table 3). The early-harvested fruits were judged by the taste panel to be less ripe, to have less aroma and poorer red color. However, the differences in overall eating quality among different treatments were not statistically significant. The ethylene in CA had a negative effect on fruit acidity significant at the 1% level, on aroma at the 5% level, and on ojbectively measured firmness and sensory evaluated ripeness at the 10% level (Table 3). No harvest/ethylene interaction effect on any quality factor was significant.

Similar apples were evaluated after an additional 6-day holding period at 21°C. At this evaluation the negative effects of ethylene and the harvest/ethylene interaction on sensory

Table 2. Effects of harvest date and external ethylene concn on the breakdown of 'McIntosh' apples in CA storage.

Date of harvest	Ethylene in storage gas (ppm)	Breakdown (%)[z] 5 months of storage	8 months of storage	Avg.
Sept. 11	<1	0	0	0
	10	2	4	3
	500	0	3	1.5
Sept. 17	<1	0	5	2.5
	10	2	7	4.5
	500	4	4	4
Sept. 22	<1	5	10	7.5
	10	9	21	15
	500	11	23	17
Level of significance				
Harvest date		*	**	
Ethylene		NS	NS	

[z]200 apples in each treatment; 100 each evaluated after 5 and 8 months of storage.

*, **, NS Significant at 5% (*); significant at 1% (**); not significant (NS), by F test.

Table 1. Values of selected maturity indices for 'McIntosh' apples harvested on 3 different dates.[z]

Date of harvest	Firmness[y] (kg)	Soluble solids[x] (%)	Acids[x] (as g malate in 100 ml juice)	Length of preclimacteric period[w] (days) Range	Mean	Internal ethylene[v] (ppm) Range	Mean
Sept. 11	7.1	10.5	0.615	4–7	5.25	0.10–0.15	0.13
Sept. 17	7.2	10.9	–	0–1	<1	0.15–0.21	0.18
Sept. 22	6.6	10.9	0.533	0–1	<1	0.10–30.50	10.18

[z]Fruits were harvested from the periphery of the same 3 trees on each date.

[y]Mean of 51 fruits, 17 fruits per tree, 2 measurements per fruit.

[x]Measured from the mixed juice extracted from 51 fruits, 17 fruits per tree.

[w]The length of period between harvest to the onset of the climacteric. Measurements were made from 6 samples, 5 fruits per sample, 2 samples per tree.

[v]Measured from 6 fruits, 2 fruits per tree.

Table 3. Effects of harvest date and external ethylene concn on the quality of 'McIntosh' apples after 5 months of CA storage and 1-day warm-up at 21°C.[z]

Date of harvest	Ethylene in storage gas (ppm)	Values of quality parameters objectively evaluated			Avg scores of quality factors subjectively evaluated by 7 taste panelists[y]							
		Firmness (kg)	Soluble solids (%)	Acids[x]	Surface color	Ground color	Overall appearance	Firmness	Acidity	Aroma	Ripeness	Overall eating quality
Sept. 11	<1	5.8 a[w]	11.1 a	0.415 a	3.50 a	2.43 b	3.07 ab	2.85 c	2.85 b	3.79 ab	2.71 c	3.07 a
	10	5.5 ab	11.0 ab	0.410 ab	3.22 ab	2.43 b	3.14 a	2.86 c	3.43 a	3.86 ab	2.79 c	3.36 a
	500	5.7 a	10.8 bc	0.403 ab	3.15 ab	2.36 b	3.00 abc	2.93 b	3.08 ab	3.57 b	3.00 bc	3.15 a
Sept. 17	<1	5.6 ab	11.1 a	0.410 ab	3.00 abc	2.88 ab	2.88 abc	2.86 c	2.82 b	3.63 bc	3.00 bc	3.19 a
	10	5.3 bc	11.1 a	0.393 bc	3.44 a	2.94 ab	3.06 ab	3.32 ab	3.07 ab	3.94 a	3.25 ab	3.50 a
	500	5.2 c	11.2 a	0.376 c	3.19 ab	3.01 ab	3.00 abc	3.38 a	3.00 ab	3.57 bc	3.32 ab	3.19 a
Sept. 22	<1	4.9 cd	10.8 bc	0.354 d	2.57 c	3.25 a	2.69 bc	3.44 a	3.25 ab	3.63 bc	3.32 ab	3.19 a
	10	5.1 c	10.6 c	0.339 de	2.82 bc	3.00 ab	2.88 abc	3.26 abc	3.07 ab	3.44 c	3.19 ab	3.13 a
	500	4.7 d	10.8 bc	0.319 e	2.44 c	3.14 a	2.57 c	3.57 a	3.32 a	3.44 c	3.38 a	3.32 a
Level of significance												
Harvest date		**[v]	**	**	**	**	*	**	NS	*	**	NS
Ethylene		+	NS	**	NS	NS	NS	NS	NS	*	+	NS
Harvest × ethylene		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Average of duplicates, 25 fruits per replicate in each treatment.

[y]Each panelist evaluated the 25-fruit sample as a whole for color and appearance and evaluated 3 apples for other factors of eating quality. A 5-point scale (see text for meanings) was used.

[x]Titratable acids as grams malate in 100 ml juice.

[w]Mean separation within columns by Duncan's multiple range test at 5% level.

[v](**) significant at 1%; (*) significant at 5%; (+) significant at 10% level; (NS) not significant by F-test.

Table 4. Effects of harvest date and external ethylene concn on the quality of 'McIntosh' apples after 5 months of CA storage and 7 days holding at 21°C.[z]

Date of harvest	Ethylene in storage gas (ppm)	Values of quality parameters objectively evaluated			Avg scores of quality factors subjectively evaluated by 7 panelists[y]						
		Firmness (kg)	Soluble solids (%)	Acids[x]	Surface color	Ground color	Overall appearance	Firmness	Acidity	Ripeness	Overall eating quality
Sept. 11	<1	4.38 a[w]	11.2 a	0.362 a	2.88 b	3.01 b	3.00 c	3.44 c	2.88 b	3.75 b	3.07 b
	10	4.25 abc	11.1 ab	0.346 ab	3.13 ab	3.07 b	3.13 bc	4.00 a	3.32 a	4.00 ab	3.82 a
	500	4.35 ab	11.1 ab	0.344 ab	3.32 ab	3.07 b	3.32 ab	3.94 ab	3.32 a	4.00 ab	3.76 a
Sept. 17	<1	4.37 a	11.2 a	0.342 ab	3.32 a	3.38 ab	3.38 ab	3.75 b	3.19 ab	3.93 ab	3.44 ab
	10	4.14 bc	11.0 ab	0.330 ab	3.32 a	3.63 a	3.57 a	3.76 b	3.32 a	3.75 b	3.51 ab
	500	4.08 cd	11.1 ab	0.319 bc	2.88 b	3.44 ab	3.07 bc	3.75 b	3.19 ab	3.88 ab	3.44 ab
Sept. 22	<1	3.86 d	10.7 b	0.280 d	2.79 bc	3.15 b	3.16 b	4.00 a	3.36 a	4.07 a	3.86 a
	10	4.10 cd	10.7 b	0.288 cd	2.79 bc	3.65 a	3.36 ab	4.00 a	3.36 a	4.07 a	3.72 a
	500	3.99 cd	10.7 b	0.283 cd	2.43 c	3.64 a	3.14 bc	3.93 ab	3.36 a	4.08 a	3.72 a
Level of significance											
Harvest date		**[v]	**	**	**	**	NS	**	NS	**	+
Ethylene		NS	NS	NS	NS	+	NS	*	NS	NS	NS
Harvest × ethylene		*	NS	NS	NS	NS	+	*	NS	NS	+

[z]Average of duplicates, 25 fruits per replicate in each treatment.

[y]Each panelist evaluated the 25-fruit sample as a whole for color and appearance and evaluated 3 apples for other factors of eating quality. A 5-point scale (see text for meanings) was used.

[x]Titratable acids as grams malate in 100 ml juice.

[w]Mean separation within columns by Duncan's multiple range test at 5% level.

[v](**) significant at 1%; (*) significant at 5%; (+) significant at 10% level; (NS) not significant by F-test.

evaluated fruit firmness were significant at the 5% level (Table 4); the negative effects of late harvest and harvest/ethylene interaction on overall eating quality were significant at the 10% level; and the negative effect of ethylene on sensory evaluated firmness, acidity and overall eating quality was significant only for fruits harvested on Sept. 11 but not for those harvested later. Fruits harvested at the preclimacteric stage and stored in low-ethylene CA were less ripe and more acceptable to the taste panel than the fruits from other treatments (Table 4).

Due to a gas flow control failure in 2 jars, low oxygen injury developed before the end of 8 months of storage and these fruits were discarded. Consequently, the 8-month storage

Table 5. Effects of harvest date and external ethylene concn on the quality of 'McIntosh' apples after 8 months of CA storage followed by 1-day and 7-day holding at 21°C.[z]

Date of harvest	Ethylene in storage gas (ppm)	After 1-day holding: Firmness (kg)	After 1-day holding: Soluble solids (%)	After 1-day holding: Acids[y]	After 7-day holding: Firmness (kg)	After 7-day holding: Soluble solids (%)	After 7-day holding: Acids[y]
Sept. 11	<1	5.11 a[x]	10.9 ab	0.336 a	4.23 a	10.8 a	0.288 a
	500	4.37 b	10.6 bc	0.293 bc	3.89 bc	10.6 bc	0.266 b
Sept. 17	<1	4.35 b	11.1 a	0.319 ab	3.97 b	10.8 a	0.258 b
	10	4.35 b	10.8 abc	0.297 bc	3.90 bc	10.7 ab	0.260 b
Sept. 22	<1	4.51 b	10.5c	0.281 c	3.86 bc	10.6 bc	0.213 c
	10	4.52 b	10.6 bc	0.266 c	3.86 bc	10.3 d	0.214 c
	500	4.30 b	10.5 c	0.266 c	3.75 c	10.5 c	0.212 c

[z]Average of duplicates, 25 fruits per replicate in each treatment.

[y]Titratable acids as grams malate in 100 ml juice.

[x]Mean separation within columns by Duncan's multiple range test, 5% level.

results were analyzed according to a single factor experiment with 7 treatments instead of a factorial experiment with 9 treatments. The ethylene in CA storage had a significant negative effect on the firmness and on acid retention for fruits harvested at the preclimacteric stage (Table 5). This effect was not significant for later harvested fruits, however. No significant differences were detected by the taste panel. In no case did the delayed harvest or high ethylene levels in CA improve the fruit quality except that late harvest improved red color.

In the physiological age study, the internal ethylene concn in apples remained below 0.1 ppm until Sept. 9 (curve C of Fig. 1). There was a significant increase to 0.3 ppm on Sept. 13, just before the onset of the climacteric. By Sept. 17, the climacteric has started and the endogenous ethylene was increased to more than 10 ppm.

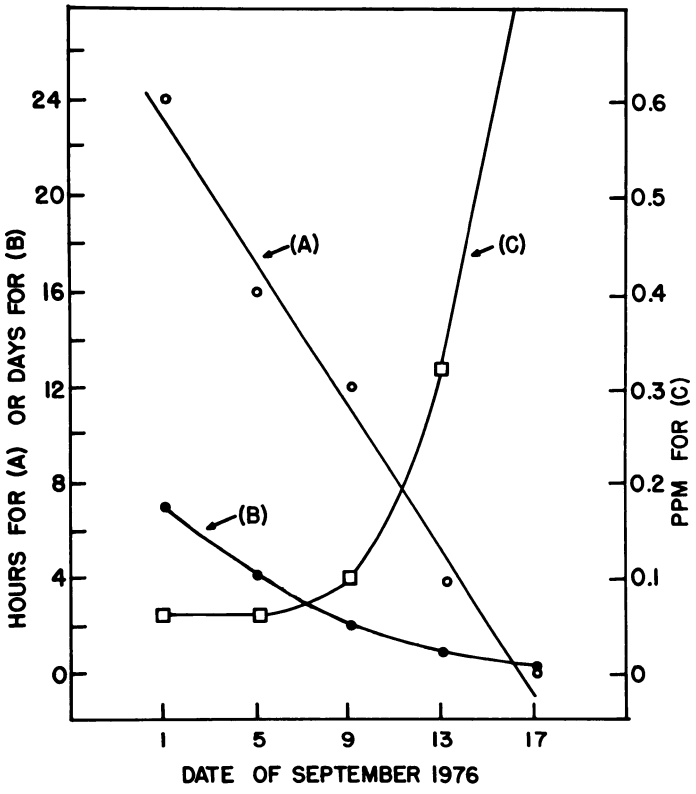

Fig. 1. Some physiological changes of 'McIntosh' apples during maturation. (A): The minimum treatment time required for immediate ethylene ripening response. (B): The length of the preclimacteric period of harvested fruits. (C): The concn of internal ethylene.

As the age of the fruits increased the length of the preclimacteric period of harvested apples decreased (curve B of Fig. 1). However, the change was rather slow and curvilinear with time.

Based on internal ethylene concn and the rates of CO_2 and ethylene production the natural onset of the climacteric occurred after Sept. 13 and before Sept. 17. The closer to the date of the natural onset of the climacteric the shorter treatment time was required for 10 ppm ethylene to trigger an immediate onset of the climacteric (curve A of Fig. 1). A linear correlation existed between the minimum treatment time required to trigger the onset of the climacteric (MTT) and the harvest date in Sept. The linear regression was $Y = 24.7 - 1.5X$ with Y representing MTT and X the date. The correlation coefficient was –0.99. The predicted date of the onset of the climacteric according to this equation was Sept. 16. If we take Sept. 16 as the date of the normal onset of climacteric, Y as the length of preclimacteric period (days before Sept. 16) of unharvested fruits, and X as MTT, a linear regression equation $Y = -0.3684 + 0.6579X$ was obtained.

Discussion

Reduced ethylene levels in CA storage improved firmness retention and retarded ripening of early-harvested 'McIntosh' apples in 1975-76 (5). The ethylene effect was less significant in this present study (1976-77). The seasonal variation in ethylene response might be related to differences in the general keeping quality of the fruits. The fruit firmness was 4.7 – 5.8 kg in 1976-77 (Table 3) compared with 3.6 – 4.6 kg in 1975-76 (5) after 5 months of storage. The firmness was 4.3 – 5.1 kg in 1976-77 compared to 3.2 – 3.7 kg in 1975-76 after 8 months of storage. Lougheed et al. (6) also noticed that lowered ethylene often but not always resulted in significantly firmer fruits.

One of the concerns about picking preclimacteric 'McIntosh' has been the eating quality. Our data indicates that after 5 to 8 months of storage the fruits picked several days before the onset of the climacteric had either similar or slightly better eating quality than those picked later. While late picked apples might have better eating quality shortly after harvest, they tend to become overripe and more susceptible to breakdown disorders during long term storage. After storage the late picked fruits had no better quality except for the redder color. From a practical point of view, a method to improve the surface red color of early harvested 'McIntosh' is highly desirable. The solution may be to spot pick fruits from the periphery of trees, modified tree training and pruning, and/or other means

to enhance red color formation without stimulating ripening.

Another concern is how to predict the onset of the climacteric if our aim is to harvest the fruits just several days before that physiological event. A great variation in maturity among fruits on the same tree was noticed. Our judgment probably should be based on a small but significant fraction of early maturing fruits. In this study the onset of the climacteric meant the time when at least 1 fruit in each of the duplicate 5-fruit samples had an elevated CO_2 and ethylene production rates. An initial several-fold increase in internal ethylene prior to the start of the climacteric might be a useful signal. Unfortunately the signal comes too late to be of great practical value. Furthermore, measuring the length of preclimacteric periods of harvested fruits is too time consuming to be practical. The correlation between the minimum treatment time required for 10 ppm ethylene to trigger the climacteric (MTT) and the length of the preclimacteric period may be more useful. The time required to determine the MTT was about 2 days for very immature fruits, but was less than 24 hr for fruits harvested 1 week prior to the natural onset of the climacteric.

Literature Cited

1. Bangerth, F. 1975. The effect of ethylene on the physiology of ripening of apple fruits at hypobaric conditions. Colloques Internationaux C. N. R. S. 238. 183-188.
2. Beyer, E. M., and P. W. Morgan. 1970. A method for determining the concentration of ethylene in the gas phase of vegetative plant tissues. *Plant Physiol.* 46:352-354.
3. Forsyth, F. R., and C. A. Eaves. 1975. Ripening of apples in C.A. storage, low or high ethylene and medium or high humidity levels. Colloques Internationaux C. N. R. S. 238. 67-72.
4. ———, ———, and H. J. Lightfoot. 1969. Storage quality of McIntosh apples as affected by removal of ethylene from the storage atmosphere. *Can. J. Plant Sci.* 49:567-572.
5. Liu, F. W. 1977. Varietal and maturity differences of apples in response to ethylene in controlled atmosphere storage. *J. Amer. Soc. Hort. Sci.* 102:93-95.
6. Lougheed, E. C., E. W. Franklin, S. R. Miller, and J. T. A. Proctor. 1973. Firmness of McIntosh apples as affected by Alar and ethylene removal from the storage atmosphere. *Can. J. Plant. Sci.* 53:317-322.
7. Smith, R. B., E. C. Lougheed, and E. W. Franklin. 1969. Ethylene production as an index of maturity for apple fruits. *Can J. Plant Sci.* 49:805:807.
8. Smock, R. M. 1977. Nomenclature for internal storage disorders of apples. *HortScience* 12:306-308.
9. Wilkinson, B. G. 1961. A simple method for following the climacteric in apples. *J. Hort. Sci.* 36:197-201.

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Residues of Acephate and Methamidophos in Greenhouse Tomatoes[1]

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Abstract. **Acephate was applied to greenhouse tomatoes (*Lycopersicon esculentum* Mill.) as single and multiple applications, and residues on the fruits were determined several times after treatment. Immediately after application, residues of acephate averaged 0.46, 0.83, and 1.81 ppm for plots receiving 0.56, 1.12, and 2.24 kg/930 liter solutions, respectively. By day 7 residues of acephate, averaged over all rates, were 5.4% of day 0 values. Residues of methamidophos, a metabolite of acephate, were detected in all samples except those for day 0, but differences between rates and days after application were not significant. A statistical comparison of residue data showed that total residues (acephate plus methamidophos) were significantly greater after spraying once a week for 4 weeks than after a single application.**

Acephate (*O,S*-dimethyl acetylphosphoramidothioate) and its primary metabolite methamidophos (*O,S*-dimethyl phosphoramidothioate) are effective for controlling a wide variety of insect pests (2, 4). Because of its low mammalian toxicity and effectiveness, there is considerable interest in obtaining registration of acephate on greenhouse tomatoes. Therefore studies were designed to determine the disappearance rate of acephate and methamidophos from tomato fruit after application at several rates to greenhouse tomatoes and to compare residue levels from single and multiple spray applications.

Materials and Methods

First expt. Acephate was applied once to 6 plots of greenhouse tomatoes in the fall of 1974. Each plot contained 5 'Michigan-Ohio Hybrid' plants. Spray solutions containing 0.56, 1.12, and 2.24 kg ai of acephate (75% SP formulation) per 930 liters were applied with a constant-pressure CO_2 sprayer. Spraying pressure was 1.2 kg/cm^2, and the plants were sprayed to runoff (equivalent to 930 liters/ha). An untreated control was maintained in each replication. A 1-kg sample of red fruit was taken from each plot in 2 replicates 1, 2, and 4 days after application. Samples were packed in insulated boxes containing dry ice for transport to the laboratory where they were stored at −18°C until analyzed 6 weeks later.

Second expt. Applications were made to 9 plots of greenhouse tomatoes in the spring of 1975. Each plot contained 8 'Manapal' plants. Untreated controls were included. Formulation of acephate and rates and method of application were identical to those employed in expt. 1. Samples weighing 1 kg were taken at 0, 1, 2, 3, 4, and 7 days after application in each of 3 replicates.

Immediately after the day 7 sampling, 3 additional weekly sprays were applied at the same rates and to the same plots. Samples were taken at 2, 3, and 4 days after the final (4th) application. Sample wt and processing before analysis were

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