substantiates the findings of Singleton (3).

The results presented here indicate that not all degenerative corn mutants are effective in promoting the heterotic effects reported by Jones (2) and Singleton (3, 4). 'Pee Wee' crosses do not show increased heterosis in hybrids over similar hybrids made with P39 or C30. Certainly some major genetic change must have occurred when C30 mutated to 'Pee Wee'; evidently 'Pee Wee' did not accumulate factors increasing its combining ability to the extent that C30 did.

The ear size and seed yield of 'Pee Wee' is too small for it to be of value as a seed parent and the plant too short for use as a pollinator even if a suitable mate could be found. It is likely that the *rd* ^{pw} factor in 'Pee Wee' might prove useful in developing shorter corn as Singleton did (5) when he transferred the *rd* factor in C30 to several field corn inbreds.

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Interaction of Ethylene, Auxin, and Succinic Acid-2,2-Dimethylhydrazide in Apple Fruit Ripening Control.[1]

Norman E. Looney[2]

Canada Department of Agriculture

Research Station, Summerland, B. C.

Abstract. Succinic acid-2,2-dimethylhydrazide (SADH) was applied 3 times, at monthly intervals beginning 2 weeks after full bloom, to 'McIntosh' apple trees (*Malus sylvestris* L.). In the month preceding normal harvest, control and SADH treated trees were sprayed on 3 different dates with 2-chloroethylphosphonic acid (ethephon) as an ethylene source and/or 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP), a synthetic auxin. Fruit samples harvested one and two weeks after each treatment revealed that without SADH: 2,4,5-TP moderately advanced ripening as evidenced by enhanced ethylene production, softening, and respiration, but prevented fruit abscission; ethephon greatly advanced ripening, red color development and abscission; and 2,4,5-TP + ethephon resulted in a striking increase in coloration accompanied by the highest rates of respiration, ethylene production and softening, but no abscission. With previous SADH treatment the effect of the other materials was reduced or, as in the fruit coloring response to ethephon, delayed. SADH exerted a pronounced effect on endogenous ethylene formation. It is suggested that SADH specifically inhibits autocatalytic ethylene formation, possibly by maintaining membrane integrity.

Spring and summer applications of succinic acid-2,2-dimethylhydrazide (SADH) inhibit several facets of ripening in apple fruits (5,6,9). Earlier work has indicated that postharvest ethylene treatments reverse the SADH inhibition of the climacteric respiratory rise (5) but do not overcome to the same degree the suppression of endogenous ethylene production (6). Furthermore, another growth retardant, 2-chloroethyltrimethylammonium chloride (CCC) has been shown to have little or no influence on ripening when applied in the same manner as SADH (6).

These observations have led to speculation about the mode of action of SADH in the control of ripening. Both auxin biosynthesis and ethylene induction and biosynthesis have been suggested as sites for inhibition (5,6). To better understand the hormonal relationships important to ripening control, we employed pre-harvest applications of 2-chloroethylphosphonic acid (ethephon) as a tool to introduce ethylene to fruit on the tree (3,4,11), 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP) as a synthetic auxin applied prior to harvest, SADH as a ripening inhibitor, and postharvest ethylene as a ripening promoter.

Materials and Methods

Thirty 12-year-old 'McIntosh' trees were sprayed with 2500 ppm SADH[3] on May 26, June 26, and July 28, 1969. A like number of trees were set aside as controls. On August 12, August 25, and September 8, 500 ppm ethephon[4] was applied to different 3-tree blocks of both SADH-treated and control trees. In a like manner, 2,4,5-TP at 20 ppm was applied alone and in combination (but as a separate spray) with ethephon. Thus fruits with the following range of treatments were harvested one and two weeks after each of the 2,4,5-TP and ethephon treatments: Control, 2,4,5-TP, ethephon, 2,4,5-TP + ethephon, SADH, SADH + 2,4,5-TP, SADH + ethephon, and SADH + 2,4,5-TP + ethephon. One 3-tree control block provided fruit for comparison with all three 2,4,5-TP and ethephon spray series. Fruits harvested from the 3 trees of each treatment block were pooled and divided into 4 lots of about 1 kg each and placed in chambers for respiration analysis at 20°C. Two chambers received a constant flow of 200 ppm ethylene gas for the first 5 days of a 7-day holding period. Respiration measurements were made daily using a Fisher-Hamilton gas partitioner. At the end of the holding period the rate of endogenous ethylene production was determined with a Microtek 220 gas chromatograph and the fruits were evaluated for firmness, using a Ballauf pressure tester with an 11 mm tip. Acceptable commercial harvest maturity in control fruits was judged to occur about September 12.

Results

SADH inhibited ethylene production and the development of the respiratory climacteric. Control fruits not receiving added ethylene first displayed a respiratory rise and produced measurable amounts of ethylene with the harvest of August 11, 1969 whereas SADH treated fruits showed no ripening activity

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[3]Alar-85 supplied by Uniroyal 1966 Ltd., Elmira, Ontario.

[4]Amchem Products Inc., Ambler, Penn. Preparation 68-250 of 2-chloroethylphosphonic acid.

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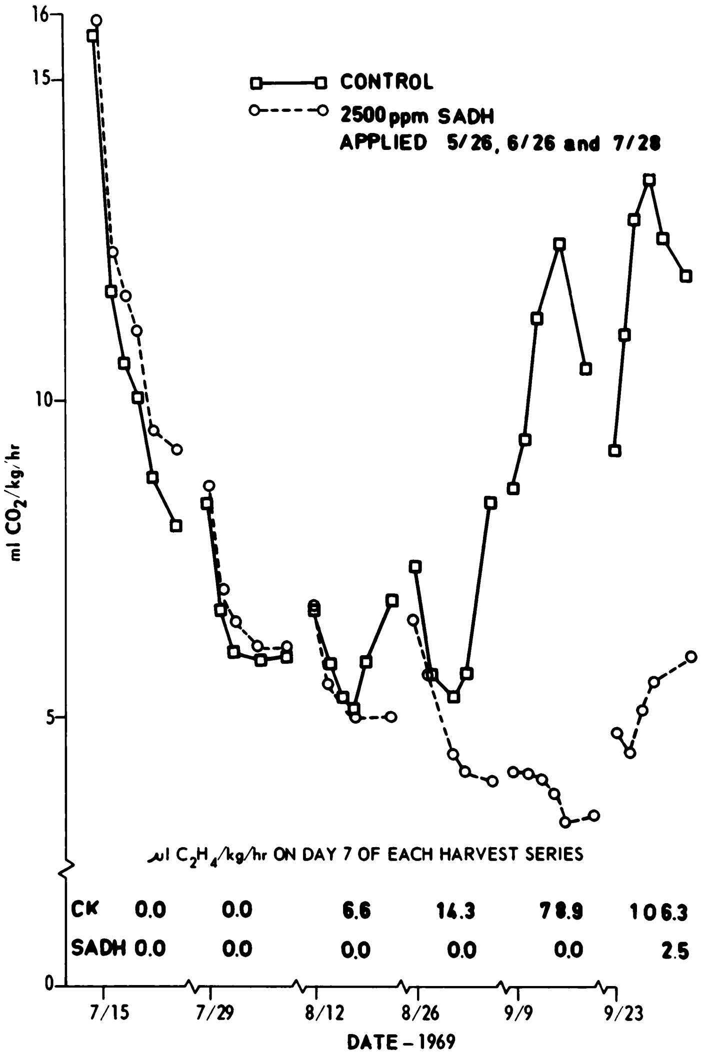

Fig. 1. Effect of SADH on carbon dioxide and ethylene production by 'McIntosh' apples harvested during the period of July 14 to September 22, 1969 and held for 7 days at 20°.

until the harvest of September 22 (Fig. 1).

Ethephon and 2,4,5-TP applied on August 12, 25, and September 8 to fruits with or without the previous SADH treatment increased the rates of respiration, endogenous ethylene production, and softening. Data for fruit harvested 2 weeks after each treatment best illustrate these effects (Table 1).

August 25 harvest. A climacteric respiratory pattern was evident in all samples treated with ethylene. Initial respiration rates, however, suggested differences in ripeness in the following order: 2,4,5-TP + ethephon > ethephon > 2,4,5-TP > Control ≥ all samples pre-treated with SADH. Values for endogenous ethylene production at the end of the ripening period followed in the same order and firmness values were in the reverse order. Ethephon and 2,4,5-TP tended to overcome the inhibitory effect of SADH on ethylene-stimulated ethylene production and softening (Table 1).

Samples not treated with ethylene displayed quite a different pattern except for those treated with only ethephon, 2,4,5-TP, or both. Control fruits ripened slightly whereas SADH-treated samples displayed essentially no ripening activity.

September 8 harvest. Fruits treated August 25 and harvested 14 days later differed from those treated on August 12 primarily in that with added ethylene, ethephon caused the highest rates of respiration and ethylene production but the addition of 2,4,5-TP appeared to have little influence on the behaviour of these more mature fruits. With previous SADH treatment, 2,4,5-TP as well as ethephon tended to increase ethylene production and reduce firmness. Ethylene induced a respiration climacteric in all lots (Table 1).

Without added ethylene the respiratory, ethylene production, and softening patterns confirmed the expected advance in maturity. All but the 'SADH only' lot displayed ripening activity at this harvest date and both 2,4,5-TP and ethephon enhanced ethylene production and softening, particularly in lots not pre-treated with SADH.

September 22 harvest. Ethephon enhanced respiration, ethylene production, and softening in these mature samples subjected to both postharvest environments although the effects were generally less striking than in earlier harvests. The ethephon treatment did result in a notable increase in ripening activity by SADH-treated fruit not subjected to postharvest ethylene treatment. The response to 2,4,5-TP was variable but even with fruits not treated with postharvest ethylene, 2,4,5-TP had less effect than was noted in earlier harvests (Table 1).

Other physiological responses to these treatments included an effect on fruit abscission and a marked effect on anthocyanin synthesis. Within 7 days of each ethephon treatment a high proportion of fruit had abscissed and by 14 days almost all fruits had dropped. Interestingly, the application of 2,4,5-TP to ethephon treated trees essentially negated this response. Likewise, previous treatment with SADH prevented ethephon induced abscission until the treatment of September 8 where almost 50% fruit drop was evident by September 22.

Both SADH and ethephon increased anthocyanin development (Table 2). Previously untreated fruit sprayed with ethephon on August 12 had less than 25% of the fruit surface displaying red color but by August 25 these samples (prevented from dropping with 2,4,5-TP) had developed 96% red color while control fruits had increased in color to only 37%. SADH-treated fruits sprayed with ethephon or ethephon + 2,4,5-TP had higher initial color (about 50%) but increased to only 74% indicating that in fruits treated at this time, SADH interfered with the coloring response to ethephon. This interference was not evident in later spray and harvest dates and in fact, the brightest red color (as opposed to the waxy and somewhat dull appearance of fruits picked in the later harvests from ethephon and ethephon + 2,4,5-TP treated trees) resulted from the SADH + ethephon and SADH + ethephon + 2,4,5-TP treatments. The 2,4,5-TP treatment alone or in combination with SADH and/or ethephon did not appear to influence color development except where abscission control aided fruit exposure to light.

Discussion

SADH delayed the climacteric and suppressed ethylene production in this study, confirming similar observations made earlier in this and other laboratories (4,6,9). The influence of and interactions among the other growth regulators in the control of ripening were no less striking but because of the limitations of this kind of study the physiological lessons are not easily extracted.

Several chemicals with auxin activity, including IAA, induce biosynthesis of ethylene (1,2,10). If a natural inducer of ethylene is required by mature apple fruits to initiate critical components of ripening, the physiological response to an exogenously applied inducer should be greatest before natural induction has occurred. The observation herein that the response to 2,4,5-TP diminishes with advancing maturity suggests that a native auxin induces normal ripening. However, a plausible alternative explanation is that the response to 2,4,5-TP-stimulated ethylene production diminishes as the ability for natural ethylene production increases with advancing maturity.

The fact that 2,4,5-TP continued to function effectively as

Table 1. Effect of harvest date and postharvest ethylene treatment on respiration, ethylene production and firmness values for 'McIntosh' apples previously treated with SADH and/or 2,4,5-TP and ethephon on Aug. 12, Aug. 25, or Sept. 8.

Harvest date	Treatment	Without ethylene treatment: Respiration rate[a] Initial	Final	Ethylene production[b]	Fruit firmness (kg)[c]	With added ethylene: Respiration rate[a] Initial	Final	Ethylene production[b]	Fruit firmness (kg)[c]
August 25	SADH	6.5	4.0	0.0a[d]	9.34d	6.6	11.2	3.2a	8.94c
	SADH + 2,4,5-TP	8.1	7.5	1.1a	9.25d	6.9	10.8	5.6a	8.30c
	SADH + ethephon	7.1	7.2	1.1a	8.44d	6.8	12.3	18.4a	7.17b
	SADH + 2,4,5-TP + ethephon	6.2	5.4	0.7a	9.62d	7.1	11.8	6.7a	8.16c
	Control	7.3	8.3	14.3b	7.48c	7.5	13.2	64.1b	6.40ab
	2,4,5-TP	8.9	14.3	73.8c	5.67b	8.6	12.8	73.6b	5.81a
	Ethephon	11.4	13.3	135.6d	5.62b	10.6	13.7	125.5bc	5.26a
	2,4,5-TP + ethephon	13.1	14.4	184.0e	4.90a	11.8	13.0	156.9c	5.17a
September 8	SADH	4.1	3.5	0.0a	8.85d	6.7	8.8	1.3a	7.66d
	SADH + 2,4,5-TP	6.5	5.0	5.6a	8.37d	6.0	9.0	4.8a	7.02cd
	SADH + ethephon	6.1	10.0	10.8a	6.59c	7.5	8.8	10.3a	6.69c
	SADH + 2,4,5-TP + ethephon	6.3	10.8	9.3a	6.55c	7.4	10.1	33.3ab	6.12bc
	Control	8.4	10.4	78.9b	5.56b	7.0	10.4	60.4b	5.33b
	2,4,5-TP	9.2	11.3	101.7c	4.40a	6.8	10.5	53.2b	5.15ab
	Ethephon	11.0	12.3	108.1c	4.84ab	12.4	13.1	135.4c	4.51a
	2,4,5-TP + ethephon	13.9	14.2	159.9d	4.74a	12.2	12.8	123.9c	4.64a
September 22	SADH	4.8	5.8	2.5a	7.85c	7.7	11.3	5.2a	6.74c
	SADH + 2,4,5-TP	5.1	6.6	4.3a	7.70c	7.0	11.2	12.2a	6.17d
	SADH + ethephon	6.7	9.7	12.4b	6.21b	9.1	11.9	15.5a	5.98cd
	SADH + 2,4,5-TP + ethephon	7.2	9.8	12.2b	6.67b	9.3	11.1	15.4a	5.60c
	Control	9.2	12.0	106.3c	4.35a	10.8	13.3	112.3b	4.05b
	2,4,5-TP	10.0	11.3	89.1c	4.43a	10.1	12.0	118.3b	4.22b
	Ethephon	12.9	12.0	126.7c	3.94a	14.3	11.7	144.4bc	3.97ab
	2,4,5-TP + ethephon	12.7	13.0	178.3d	3.57a	13.5	13.3	163.8c	3.27a

[a]Initial values (in ml CO_2/kg • hr at 20°) were recorded 24 hrs after harvest. Final values do not always represent the maximum value when a climacteric pattern was displayed.

[b]Rate of endogenous production (in μl C_2H_4/kg • hr) recorded after one week in respiration chambers.

[c]After one week in respiration chambers.

[d]Means for any one harvest date not followed by the same letter differ significantly (P=.05).

Table 2. Percent of red coloration on 'McIntosh' apples as affected by harvest date and growth regulator treatments. Ethephon and 2,4,5-TP treatments preceded each harvest date by 2 weeks. SADH was applied on May 26, June 26, and July 28, 1969.

Treatment	Aug 25	Sept 8	Sept 22
Control	37a[y]	61a	86a
Ethephon + 2,4,5-TP	96c	98b	100b
SADH	62b	72a	89a
SADH + ethephon + 2,4,5-TP	74bc	99b	100b

[y]Means in each column followed by different letters differ significantly (P=.05).

an abscission controlling agent reaffirms the belief that the physiology of abscission and fruit ripening in apples are not in all ways analogous.

In contrast to 2,4,5-TP, ethephon does not induce the biosynthesis of ethylene but simply breaks down to form ethylene in the treated tissue (3,11). It is not surprising, therefore, that the response to ethephon is quicker than that to 2,4,5-TP. But like 2,4,5-TP, the response to ethephon lessened with advancing fruit maturity. In more mature fruits the ability for natural endogenous production increased and the response to ethephon diminished by comparison. Nonetheless, the continuing effectiveness of ethephon in promoting endogenous ethylene production indicates that ethylene must be considered a potent promoter of endogenous ethylene formation.

An interesting response to ethephon was the striking increase in color development. Since ethylene gas applied postharvest to 'McIntosh' apples of the same physiological age held in constant flow chambers did not increase in red coloration, it must be assumed that either some tree effect or light conditions present in the orchard, or perhaps both, combine with the ethephon treatment to promote coloring. It is noteworthy that the coloring response to ethephon was almost equally evident in all parts of the tree canopy and over the entire fruit surface, suggesting that light was not of exclusive importance.

Treatment with SADH suppressed the effects of 2,4,5-TP, ethephon, postharvest ethylene and all combinations of these treatments so decisively that it is probably risky to draw conclusions from the responses which were noted. Edgerton and Blanpied (4) also found that SADH suppressed the respiratory and ethylene production responses to ethephon and 2,4,5-TP. However, even with previous SADH treatment a clear pattern developed in the response to the other regulators indicating advancing fruit maturity. With the exception that SADH interfered with the effect of the earliest ethephon spray in increasing skin color, it did not appear to exert a strong influence on fruit maturity.

Rhodes et al. (9) concluded that even the reduced ethylene production associated with the SADH treatment was sufficient to initiate enzyme processes associated with ripening. With this we concur. However, the rate at which these ripening changes proceed seems to be related to another important part of the normal ripening syndrome; autocatalytic ethylene production. In the present study 2,4,5-TP induced ethylene production by relatively immature fruits and both ethephon and postharvest ethylene treatment promoted ripening throughout the experiment as evidenced by higher rates of respiration and softening. SADH did not prevent these materials from causing some ripening, including some endogenous ethylene formation, but in all cases it greatly reduced the extent of this activity.

These data suggest to the author that SADH is a potent inhibitor of autocatalytic ethylene production in ripening apples. In accord with previous discussion and speculation on the subject (5,6,9) this effect is probably mediated through hormonal control mechanisms. Pratt and Goeschl (8) have proffered that autocatalytic ethylene production may be attributed to progressive deterioration of cell membranes. It is conceivable that SADH could influence ripening by altering or controlling certain physical properties of the protoplasm. This possibility is supported by reports of increased drought and cold tolerance in some plants treated with this retardant (7).

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Effects of Water Quality on Canned Carrots, Sweet Cherries, and Apricots[1]

J. C. Chiang, B. Singh, and D. K. Salunkhe[2,3]

Utah State University, Logan

Abstract. The chelating agents, monocalcium disodium salt of ethylenediaminetetraacetic acid ($CaNa_2EDTA$) and sodium hexametaphosphate (Na-HMP), at 800 ppm, were used for canning 'Honey Sweet' carrots, 'Van' sweet cherries, and 'Large Early Montgament' apricots with water containing 0, 20, 40, 80, and 160 ppm of Ca and 20 ppm of magnesium. The control cans did not contain EDTA or Na-HMP.

The canned carrots, cherries, and apricots were stored at 70° or 100°F. Evaluations were made at 60-day intervals for 6 months. All 3 commodities had better organoleptic[4] acceptibility when they were canned with $CaNa_2$ EDTA or Na-HMP than the controls.

Carrots canned with $CaNa_2EDTA$ were firmer and retained better color than those canned with Na-HMP or the controls. The rate of loss of firmness and color increased with time of storage. Retention of firmness, volatile reducing substances, pH, and taste quality was improved in sweet cherries and apricots canned with $CaNa_2EDTA$ or Na-HMP.

The salts present in water used for canning fruits and vegetables affect the quality of the processed product. Firmness was retained better in beans (8), apples, pears, apricots, peaches (9), and tomatoes (10) when hard water containing Ca or magnesium was used for canning. Calcium salts have been used for canning tomatoes (11), green and red sweet bell peppers (6), and cauliflower and blanched apple slices (7). Kertesz (11) suggested that polygalacturonic acid or demethoxylated pectin combines with Ca and other elements to produce Ca pectate. These compounds lend additional firmness to the tissues, consequently, a better preservation of the original texture.

While the presence of some salt in water improves the quality of canned fruits and vegetables, an excess or even inclusion of other salts may cause harmful effects (12, 18).

Natural and industrial pollutants can make culinary water supplies unfit for food processing. Water in Utah and throughout much of the West contains substantial amounts of calcium, magnesium, iron, copper, sulfur and other minerals. Sulfur compounds in water can cause detinning and consequently corrosion of the cans. They precipitate due to polymerization and can cause scum and cloudiness in brine or syrup. Iron and copper compounds combine with tannins in fruits and can cause blackening. Sodium, calcium, and magnesium sulfates give bitter flavors to the processed fruits and vegetables. The calcium and magnesium chlorides cause hardness of water. All of these constituents will affect flavor quality of the processed products. Impurities cause processing problems and considerable economic loss, consequently, processors pay heavy penalties for using hard and raw water for food processing and consumers receive inferior quality products. To meet U. S. Public Health Standards, processing water can be softened by using either water softeners or ion-exchange resins. Home canners as well as commercial canners can benefit by using chemical water softeners.

Quality of fruits and vegetables canned in hard water may be improved by adding chelating agents to the canning water. These compounds sequester the trace metals that catalyze oxidative breakdown of food and thus can improve flavor, color, and texture of foods (19). They also prevent formation of insoluble metal salts which cause turbidity and other quality deterioration (2). One of the most commonly used chelating agents is ethylene diaminetetraacetic acid (EDTA). The chemistry, mechanism of action, and the role of EDTA in canning and food preservation have been well documented (4). The other groups of compounds which have been used as water-softeners are the polyphosphates (16, 18), Ca phytate (10), thiourea (3), and citric acid (5).

In this study, 500 ppm of $CaNa_2$ EDTA and Na-HMP were used with water containing different concentrations of Ca for canning apricots, sweet cherries, and carrots to determine their effects on color, titratable acidity, pH, firmness, volatile reducing substances, and organoleptic quality during storage for 6 months at 70° or 100°F.

Material and Methods

Food grade $CaNa_2EDTA$, Na-HMP, anhydrous $CaCl_2$, and

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[2]Graduate student, assistant professor, and professor, respectively of Department of Food Science.

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[4]Organoleptic is a synonym for 'sensory' when referring to examination by taste and smell by a panel of judges.