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Effects of Growth Regulators on Ripening and Abscission of Pimiento and Paprika Peppers[1, 2]

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Abstract. **Ripening of pimiento and paprika peppers (*Capsicum annuum* L.), tested at 2 locations, was accelerated by (2-choroethyl)phosphonic acid (ethephon) when applied close to normal fruit maturity. Potential chemical ripeners of Buckman Laboratories, BL-2142 (Poly[oxyethylene(dimethylimino)-ethylene(dimethylimino)ethylene dichloride]) and BL-2143 (Poly[hydroxyethylene(dimethylimino)-ethylene(dimethylimino)methylene dichloride]) slightly enhanced ripening of pimiento, but had little or no effect on paprika. Ethephon (1500 to 3000 ppm) applications induced defoliation and fruit abscission in pimiento and paprika, especially at later stages of fruit development. Extractable red color of dehydrated paprika was improved by ethephon and BL-2143 at 1000 mg/liter.**

Ethephon enhances ripening and intensifies red color of bell (3, 4, 6, 8), chili (8), pimiento (5, 7), jalapeno (1), and paprika peppers (9). Applications of high ethephon concentrations caused extensive defoliation and fruit drop in bell pepper (3, 4). Pod removal is easier with ethephon-treated chili, pimiento, and bell peppers (8). Pimiento and paprika peppers produce fruit successively throughout the season; thus, at harvest, plants contain fruits of various stages of ripeness. Mechanical harvesting is being considered to reduce high production costs imposed by multiple harvesting of peppers, but nonuniform fruit sizes and stages of ripeness can seriously reduce harvesting efficiency. Utilizing the red color acceleration and abscission properties of chemicals, such as ethephon, once-over mechanical harvest may be more practical. In field experiments at 2 locations, effects of ethephon and 2 potential ethylene-producing chemical ripeners, BL-2142 and BL-2143 (Buckman Laboratories, Inc., Memphis, Tenn.) were investigated on: a) production and concentrated ripening of pimiento and paprika peppers; b) extent of fruit ripening enhancement at different developmental stages; c) fruit abscission and its possible advantages to mechanical harvesting; and d) color intensity of dehydrated paprika.

'Truhart Perfection' pimiento pepper plants were grown in the field at Attapulgus and Tifton, Ga., in the spring of 1979. Each treatment plot (2.75 × 1.8 m) consisted of 12 plants in 3 rows separated by border rows and border plants. Ethephon at 0, 500, 1500, and 3000 mg/liter, BL-2142 and BL-2143 at 0, 500, 1000, and 2000 mg/liter solutions were sprayed on the plant surface to run-off when 20–30% of the fruit were completely red ripe (12 and 14 weeks from transplanting at Attapulgus and Tifton, respectively). A second application was made at both locations 5 days after the first.

'California Mild' and 'Kalspice' paprika pepper plants were grown in the field at Attapulgus, Ga., in plots (4.6 × 0.9 m) of 12 plants in a single row separated by rows of border plants. Chemical treatments were 500 and 1000 mg/liter each of ethephon, BL-2142, and BL-2143, plus an untreated control. The pimiento experiments were randomized complete blocks with 4 replications, and the paprika experiment was a split-split-plot design with 2 cultivars as main plots, 3 chemicals as subplots and chemical concentrations as sub-subplots with 4 replications. Abscised pimiento fruit of different sizes: small (31–40 mm), medium (41–60 mm), and large (61–80> mm in diameter) and paprika fruit (regardless of size) were counted from application to harvest. All fruits were hand-harvested on July 31 and Aug. 15 at Attapulgus and Tifton, respectively. Fruits of each size class were categorized into ripeness stages: completely green, breaker, and red.

Red ripe paprika fruits were dehydrated, ground, and analyzed for extractable pigments using the AOAC procedures (2). Absorbance of pigments was determined at 460 nm, using acetone as blank. Absorbance of color solution was determined at 465 nm, using American Spice Trade Association (ASTA) standard, and color index units were calculated by applying ASTA conversion factors (2).

Total number of marketable fruit (small, medium, and large) produced at Attapulgus were significantly reduced by ethephon (500 and 1500 mg/liter), BL-2142 (all concentrations), and BL-2143 (1000 and 2000 mg/liter) (Table 1). In Tifton, however, only BL-2143 (2000 mg/liter) significantly reduced total number of marketable-size pimiento fruit. Plants treated with BL-compounds were much greener with lesser defoliation than ethephon-treated plants at both locations. BL treatments apparently slowed down the rate of fruit development, resulting in high numbers of undersized fruit (<30 mm in diameter) at harvest.

The number of marketable fruit harvested at Tifton was affected very little by the chemical treatments (Table 1); however, when compared to the control, marketable pimiento harvested at Attapulgus was significantly reduced by nearly all ethephon and BL-treatments. Reduction of harvested fruit by ethephon treatments can be attributed to the considerable loss of fruit by abscission. None of the BL-chemicals significantly affected fruit abscission at either location (Table 1). The percentage of abscised fruit increased as ethephon concentrations increased from 500 to 1500 mg/liter. Similar observations were made by Sims et al. (8)

Table 1. Effect of chemical ripeners on production of marketable size and abscission of pimiento pepper.

Treatment	Concn (mg/liter)	Attapulgus No. marketable fruit/ha (000) Total[z]	Attapulgus Abscised[y]	Attapulgus Harvested	Tifton No. marketable fruit/ha (000) Total	Tifton Abscised	Tifton Harvested
Control	0	255a[x]	6d	249a	263ab	10d	253ab
Ethephon	500	201bc	57c	144d	283ab	43c	240ab
	1500	206d	115b	91e	244bc	78b	166c
	3000	235ab	142a	93e	346a	125a	221bc
BL-2142	500	212b	4d	208b	301ab	18d	283a
	1000	200bc	4d	196b	307ab	13d	294a
	2000	202bc	6d	196b	253b	14d	239ab
BL-2143	500	232ab	5d	227ab	242bc	19d	223b
	1000	194bc	4d	190bc	228bc	14d	214bc
	2000	172c	4d	168c	186c	20d	166c

[z]Includes all mature green and red fruit of marketable sizes ≥ 31 mm in diam.
[y]Fruit of marketable sizes dropped prior to harvesting.
[x]Separation of means in columns by Duncan's multiple range test, 5% level.

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Table 2. Effect of ethephon on abscission of pimiento fruit of different sizes.

Ethephon concn (mg/liter)	Attapulgus			Tifton		
	% of all fruit abscised[z]	% abscised fruit by size		% of all fruit abscised	% abscised fruit by size	
		Small	Med		Small	Med
0	2c[y]	65a	35c	4c	60a	40c
500	28b	54b	46b	15b	49b	51b
1500	56a	47c	53a	32a	44b	56b
3000	60a	44c	56a	36a	35c	65a

[z]Includes all green or breaker fruit of small and medium sizes dropped before harvest. Number of green or red large fruit dropped was insignificant.
[y]Separation of means in columns by Duncan's multiple range test, 5% level.

on pod separation with higher rates of ethephon treatments.

Applications of 1500 mg/liter ethephon resulted in removal of over one-half and one-third of the fruit load at Attapulgus and Tifton, respectively (Table 2). As ethephon concentrations increased from 500 to 1500 mg/liter at Attapulgus and from 500 to 3000 mg/liter at Tifton, abscission of small fruit decreased, while the abscission of medium fruit increased. This indicates that abscission and fruit separation by ethephon are influenced by the physiological age of the fruit. The majority of fruit that dropped during the 20-day period following the first application was in the green and breaker stages.

Although the total number of ripe fruit harvested at Tifton was higher than at Attapulgus (Table 3), the average weight per fruit produced at Attapulgus was slightly higher than at Tifton. Thus, the yield of ripe fruit was nearly the same at both locations. 1500 and 3000 mg/liter ethephon treatments at Tifton significantly increased yield of ripe fruit over the BL-treatments and the untreated control. At both locations, the percentage of processable ripe fruit increased with an increase in ethephon concentrations. Similar results in bell pepper ripening tests were reported earlier (4, 6, 8). The increase in fruit ripeness due to 1500 and 3000 mg/liter ethephon applications over the control was attributed to the higher percentage of ripe fruit in medium-size and large-size categories (Table 3). However, ethephon treatments (1500–3000 mg/liter) at Tifton significantly increased the percentage of ripe fruit in the small size category (Table 3). Responses to BL-compounds were inconsistent. At Attapulgus, 2000 mg/liter BL-2142 and 1000 to 2000 mg/liter BL-2143 increased the percentage of ripe fruit in the medium size category. At Tifton, however, all concentrations of BL-2142 and BL-2143 significantly increased the percentage of ripe fruit in the medium and large size classes (Table 3).

Effects of ethephon applications on ripeness categories within each size class were more evident at Tifton than at Attapulgus. The percentage of red fruit gradually increased in the control plots as fruit size increased from < 40 mm to >80 mm in diameter (Fig. 1). Thus, the percentage of green fruit decreased, while the percentage of breakers remained unchanged in each size category. Ethephon treatments significantly altered this

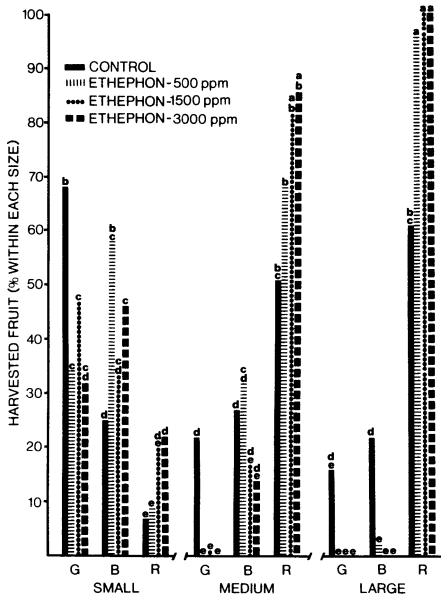

Fig. 1. Effect of ethephon on percentage of fruit in each ripeness stage: green (G), breaker (B), and red (R) within each size class: small (31–40 mm), medium (41–60 mm), and large (61–80> mm in diameter). Separation of means by Duncan's multiple range test, 5% level.

pattern by increasing the percentage of breakers and by reducing the percentage of green fruit in the small fruit category. Ethephon treatments also reduced the percentage of green and breaker fruit and gradually increased the percentage of red fruit as fruit size increased. For once-over harvest, a higher percentage of red fruit may be obtained from the remaining 15–30% of the medium breakers by delaying harvest. Osterli (6) suggested that field applications of ethephon should be at early stages of maturity to maximize ripening of bell pepper. Our results indicate that if ethephon is applied too early it may jeopardize total yield and reduce the size, which can be an important quality factor in pimiento processing.

Total number of paprika pepper fruit produced by the ethephon-treated plants were significantly less than those produced by the untreated plants (Table 4). The reduction in total yield may have been caused by the ethephon inhibition of flowering or by abscission of formed flowers, as reported by Worku et al. (9). BL-chemicals did not significantly reduce the total number of fruit produced. Applications of 500 to 1000 mg/liter ethephon also increased number of abscised fruit and reduced the number of harvested fruit (Table 4).

The percentages of the red-ripe paprika fruit was significantly increased by the ethephon treatments (Table 4). Worku et al. (9) also reported that 500 mg/liter ethephon enhanced ripening of paprika pepper by 14 days. But in this study, higher percentage of red ripe fruit was obtained at harvest time by using a higher concentration (1000 mg/liter) of ethephon. Although the total number or weight of harvested fruit from the ethephon-treated plants was significantly less than that

Table 3. Effects of chemical ripeners on ripeness and weight of pimiento fruit.

Treatment	Concn (mg/liter)	Total ripe fruit/ha		Percentage of ripe fruit			
		(000)	MT	All sizes	Small	Med	Large
				Attapulgus			
Control	0	80bc[z]	4.6a	32d	0a	25d	41d
Ethephon	500	84b	4.6a	58b	0a	38cd	50cd
	1500	85ab	4.0ab	94a	0a	70a	100a
	3000	93a	3.8ab	100a	0a	65a	100a
BL-2142	500	67d	3.6ab	32d	2a	39cd	59c
	1000	53e	3.0b	27d	5a	29d	83b
	2000	80bc	4.0ab	41c	4a	51b	47cd
BL-2143	500	64d	3.5ab	28d	0a	32cd	20e
	1000	74c	4.2ab	39cd	3a	42bc	45d
	2000	62d	3.3b	37cd	7a	40c	33de
				Tifton			
Control	0	99cd	4.8bc	39d	7bc	51d	62c
Ethephon	500	175b	5.5ab	73b	8b	68bc	97ab
	1500	159b	6.4a	96a	20a	82ab	100a
	3000	212a	6.2a	96a	22a	86a	100a
BL-2142	500	88d	4.6bc	31d	2c	74b	96ab
	1000	112c	5.4b	38d	3bc	64c	97ab
	2000	110c	4.7bc	46cd	8b	64c	90b
BL-2143	500	80d	3.9c	36d	2c	68bc	92ab
	1000	96cd	4.6bc	45cd	5bc	65c	91b
	2000	94d	4.2c	57c	5bc	66bc	94ab

[z]Separation of means in columns by Duncan's multiple range test, 5% level.

Table 4. Effects of ripening compounds on production, abscission, ripening, and color index of paprika pepper.

Treatment	Concn (mg/l)	Total fruit/ha (000)			Ripe Fruit		Color index[y]
		Produced[z]	Abscised	Harvested	(%)	(MT/ha)	
Control	0	417a[x]	12c	405a	49b	4.0ab	112b
Ethephon	500	310b	33b	277c	85a	4.7a	122a
	1000	291b	55a	236c	91a	4.5a	122a
BL-2142	500	379a	10c	369ab	56b	4.1ab	119ab
	1000	355ab	12c	343b	55b	3.8b	117ab
BL-2143	500	412a	14c	398ab	52b	4.1ab	118ab
	1000	352ab	19bc	333b	53b	3.2b	121a

[z]Includes all mature green and red pods measuring 7.5 cm long or longer.
[y]Weighted average of color readings based on extractable color intensity range, min 70 to max 137 ASTA units.
[x]Separation of means in columns by Duncan's test (P≤.05).

from the control, the yield of ripe fruit was equal to or greater than those of the control. Once-over mechanical harvesting would remove 91% of the fruit from treated plants vs. only 49% ripe fruit from untreated plants. The extractable color index readings (ASTA units) were also improved by ethephon as was suggested earlier (9), and by 1000 mg/liter concentration of BL-2143. Holding the breakers in storage at 25–30°C for a period ranging from 1–2 weeks completed normal color development acceptable to the processing trade. The green paprika fruit did not ripen during storage.

These experiments suggest that field applications of ethephon can be part of the overall production practices in the pimiento and paprika industry. Ethephon accelerated fruit ripening when applied to plants at stages closer to normal fruit maturity. Ethephon also increased fruit abscission when applied at later stages of fruit development. This concentrated ripening resulted in higher yields of usable fruit with improved quality for once-over harvesting of pimiento and paprika. Removal of green or immature fruit prior to harvest would certainly improve efficiency of mechanical harvesting. The BL-compounds showed some effects on ripening, but had no effect on fruit abscission. Ripening of pimiento and color intensification of paprika were induced by BL-compounds at the highest concentrations tested, but they also intensified foliage green color and slowed down the rate of fruit growth. These compounds apparently induced fruit ripening by ethylene action as in ethephon applications. However, a higher concentration than 2000 mg/liter and/or more frequent applications of BL-compounds may be required for a more consistent response.

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Sensitivity of Watermelons to Ethylene during Storage[1]

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Abstract. **'Charleston Gray' watermelons [*Citrullus lanatus* (Thunb.) Matsum & Nakai] exposed to various concentrations of ethylene (C_2H_4) for 3 or 7 days of storage at 18°C deteriorated rapidly. Exposure to C_2H_4 reduced the rind thickness and firmness of melons. Almost all of the melons exposed to 30 or 60 µl/liter ethylene for 7 days were unacceptable for consumption.**

Many shipments of watermelons are made in nonrefrigerated trucks, but when refrigeration is used, temperature is maintained between 10 and 21°C, depending on ambient temperature and length of transit time (1). Watermelons are not adapted to long storage. At low temperatures they are subject to various forms of chilling injury, and at high temperatures they are subject to decay. A recent study (2) indicated that 15.6° may be a better storage temperature than was recommended in U.S. Department of Agriculture Handbook 66 (5). Watermelons, particularly early in the season, are sometimes shipped in mixed loads with other produce or they may be stored in central warehouses near products that may emit C_2H_4.

Watermelons are usually harvested at their peak maturity, and flavor generally will not improve with storage. An increase in C_2H_4 production is associated with the respiratory peak and with the end of senescence after harvest (6). It has been reported that rind thickness decreases with increase in maturity and during storage (3), and that the degree of redness in melon color increases at certain storage temperatures (10). After watermelons reach optimum harvesting maturity, about 30 days after anthesis for Florida cultivars (4), soluble solids content (SSC) does not increase during storage (7, 11).

C_2H_4 is used to increase uniformity in ripening of fruits such as tomatoes (10), 'Honey Dew' melons (8, 9), and bananas. However, no information has been available on the response of watermelons to C_2H_4. A report from industry suggested that the quality of watermelons may be damaged by their exposure to C_2H_4; therefore, we conducted the research described herein to determine the effect of various C_2H_4 concentrations on fruit quality as affected by postharvest ripening during short-term storage.

'Charleston Gray' watermelons were commercially harvested near Leesburg, Fla. during May–June 1980 and 1981. In the 1980 tests, a commercial watermelon grader selected the melons for fully ripe or slightly underripe categories. The melons were then

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