Use of Ethephon as a Controlled Abscission Agent on Paprika Pepper

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Abstract. Mechanical harvest of paprika pepper (*Capsicum annuum* L.) produces a mixture of marketable and unmarketable fruit. Our objective was to increase the percentage of marketable red fruit in a once-over harvest by using ethephon to remove late-developing flower buds, blooms, and green fruit. Three experiments were conducted on field-grown plants in southwestern Oklahoma. We tested ethephon solutions of 0, 1000, 2000, 3000, and 4000 $\mu\text{L}\cdot\text{L}^{-1}$ as a one-time foliar application on various dates in September and October. Total dry mass of harvested fruit decreased linearly as ethephon rate increased in all experiments. Marketable fruit, as a percentage of total harvested fruit mass, increased linearly with ethephon rate in two of three experiments. Ethephon decreased the percent of total harvested fruit mass due to green fruit in all experiments. We recommend a single application of ethephon at about 2000 to 3000 $\mu\text{L}\cdot\text{L}^{-1}$ as a controlled abscission agent to increase the percentage of harvested red fruit in paprika pepper. The precise timing of the application will vary with the situation, but the last 10 days in September seemed an appropriate interval for southwestern Oklahoma. Chemical name used: (2-chloroethyl)phosphonic acid (ethephon).

Traditional hand harvests of sweet red pepper for processing as paprika result in a high percentage of marketable fruit, but are labor-intensive and expensive. Mechanical harvesting is essential to expand production of this crop (Bender, 1993; Palevitch, 1978). While a destructive mechanical harvest is efficient, the result is a mixture of marketable and unmarketable fruit. Unmarketable fruit reduce the value of the crop by diluting the intensity of the red pigment in the processed product. Unmarketable fruit often are separated from marketable fruit after harvest, but doing so requires time and increases costs.

One possible approach is to use ethephon to concentrate red fruit maturity (Batal and Granberry, 1982; Cantliffe and Goodwin, 1975). However, ethephon has given variable results as a fruit-ripening agent on pepper. The effectiveness of ethephon, when applied to pepper plants before harvest, varies with factors such as cultivar, rate, number of applications, and temperature (Beaudry and Kays,

1988; Rylski, 1986). We previously reported that ethephon had little value as a fruit-ripening agent for paprika pepper under our conditions (Cooksey et al., 1994).

An alternate approach to ethephon use was suggested by de Wilde (1971): "Eliminating unwanted blossoms or fruit at certain crop periods can also assure more uniform fruit maturity and thus reduce labor costs of multiple picking and separating maturity classes for marketing." Ethephon has been used to selectively remove floral buds in several crops, including apple (*Malus domestica* Borkh.) (Edgerton and Greenhalgh, 1969), *Camellia* (Woolf et al., 1995), and mango (*Mangifera indica* L.) (Galán Saúco et al., 1993). Ethephon also has been recommended for thinning developing fruit of 'Late Valencia' orange [*Citrus sinensis* (L.) Osbeck.] (Hutton, 1992). Bell pepper flower buds are known to abscise in response to ethephon (Tripp and Wien, 1989), but we found no reports of ethephon use as a controlled abscission agent for field-grown paprika pepper.

We hypothesized that ethephon would cause preharvest abscission of late-developing flower buds, blooms, and green fruit that would not develop into marketable fruit before frost. Our objective was to identify a combination of ethephon rate and application date that would increase the percentage of marketable paprika pepper fruit in a once-over harvest.

Materials and Methods

Field experiments were conducted at SS Farms, Hydro, Caddo County, Okla. (≈ 85 km west of Oklahoma City). 'Oklahoma Paprika 50' ('PAP-50'), an advanced breeding line with an upright growth habit, was grown on a Pond Creek silt loam (fine-silty, mixed, ther-

mic Pachic Argiustoll) in 1992 and 1993. 'KS-1', a standard commercial cultivar, was grown on a Reinach silt loam (coarse-silty, mixed, thermic Pachic Haplustoll) in 1993. The Pond Creek soil was prepared with a broadcast, preplant-incorporated application of 56N–12P–46K ($\text{kg}\cdot\text{ha}^{-1}$) in 1992 and 20N–23P–0K ($\text{kg}\cdot\text{ha}^{-1}$) in 1993. The Reinach soil was prepared with a broadcast, preplant-incorporated application of 56N–25P–9K ($\text{kg}\cdot\text{ha}^{-1}$) in 1993. Additional fertilizer was used only on 'PAP-50' in 1993, when one topdressing with urea was made at first flowering to supply N at 56 $\text{kg}\cdot\text{ha}^{-1}$.

Both cultivars were direct seeded at 2–3 $\text{kg}\cdot\text{ha}^{-1}$ with 0.9 m between-row spacing. Plots were planted with raw seed on 10 Apr. 1992 and 25 May 1993 for 'PAP-50', and on 15 Apr. 1993 for 'KS-1'.

Weeds were controlled with a preplant application of napropamide [*N,N*-diethyl-2-(1-naphthalenyloxy)-propionamide] at 2.2 $\text{kg}\cdot\text{ha}^{-1}$ and cultivation in each study. No irrigation was used in 1992. Sprinkler irrigation was provided, based on subjective observations of soil, for all plots in 1993.

The design was a split-plot arranged in randomized blocks with four replications in each study. Ethephon application dates were main plots. Subplots (6 m long) were ethephon solutions of 0, 1000, 2000, 3000, or 4000 $\mu\text{L}\cdot\text{L}^{-1}$ sprayed on the pepper plants. Treatments were applied on 23 and 30 Sept. and on 9 Oct. in 1992. Average air temperatures ($^{\circ}\text{C}$) on these dates were 16, 17, and 16, respectively. Treatments were applied on 15, 20, and 26 Sept. and on 4 Oct. in 1993 to both cultivars. Average air means on these dates were 16, 26, 18, and 20 $^{\circ}\text{C}$, respectively. A CO_2 backpack sprayer calibrated to deliver 74 $\text{L}\cdot\text{ha}^{-1}$ was used. Guard rows were used to minimize the possibility of spray drift between plots. The first treatments were timed to occur about 5 to 6 weeks before the first expected hard frost ($\leq -2^{\circ}\text{C}$). Red fruits were present at the time of first ethephon treatment in each study, but quantitative data were not taken.

A single destructive harvest was made after a frost in each year to simulate grower practice. Dates of harvest were 9 Nov. 1992 ('PAP-50') and 8 Nov. 1993 (both cultivars). Plants in a 2.5-m section of each plot were cut by hand at soil level, counted, and placed in burlap sacks. All fruit on the ground beside the data rows, including those that abscised during harvest, were collected and counted separately. Fruit were removed from the plants in the laboratory. Fruit that were orange, green, bleached, or filled with fungi were classified as culls. Marketable fruit were leathery, partially dried, and deep red (termed "oxblood" in the trade). All plant material was dried at 48 $^{\circ}\text{C}$ for at least 7 days and weighed.

Representative samples of marketable fruit, with calyxes removed, were analyzed for extractable red pigment each year. Dried fruit samples were ground in a Wiley mill to pass through a No. 40 U.S. standard testing sieve (0.42 mm). Acetone extracts were analyzed for absorbance at 460 nm using a spectrophotometer (Shimadzu UV160A; Shimadzu,

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Table 1. Response of 'Oklahoma Paprika 50' pepper to ethephon treatments, Hydro, Okla., 1992. Dry masses are reported.

Variable	Abscised fruit mass (g·m ⁻²)			Harvested fruit (abscised excluded) mass (g·m ⁻²)				
	Marketable	Cull	Total	Marketable	Orange	Green	Bleached or fungi-filled	Total
Ethephon rate (μL·L ⁻¹)								
0	17	13	31	248	18	62	3	331
1000	19	15	34	291	19	50	3	363
2000	25	12	37	252	14	41	2	310
3000	25	14	38	258	15	33	2	308
4000	29	14	43	218	16	33	3	270
Response ^z	L**	NS	L**	NS	NS	L**y	NS	L**
Application date								
23 Sept.	25	14	38	268	15	41	3	327
30 Sept.	24	14	37	253	17	49	2	320
9 Oct.	21	13	34	240	17	43	2	302
Response	NS	NS	NS	NS	NS	NS ^y	NS	NS

^zL = linear; quadratic, cubic, and quartic effects were tested.

^yEthephon rate × application date interaction significant at $P \leq 0.05$. All other ethephon rate × application date interactions in this table were nonsignificant at $P \leq 0.05$.

NS, **Nonsignificant or significant at $P \leq 0.01$, respectively.

Kyoto, Japan) according to American Spice Trade Association (ASTA) method 20.0 (ASTA, 1968).

Composite fruit samples also were taken as described in our previous work (Cooksey et al., 1994); briefly, dry fruit masses were obtained from each plot for each classification (marketable, orange, green, and bleached or fungi-filled) and multiplied by 10%. Fruit (including calyxes) then were taken at random from each classification until the appropriate mass (10% of the total for that classification) was reached; fruit pieces were used as necessary. Samples from the four classifications were combined to create a composite sample for each plot. Composite samples were designed to determine whether ethephon treatments were reducing the dilution effect of unmarketable fruit on ASTA color readings. Composite samples were ground and analyzed as previously described for marketable fruit samples.

Data were evaluated with an analysis of variance. Trend analysis was used to partition

main effects of ethephon rate into linear, quadratic, cubic, and quartic components. A least squares means analysis also was performed in each year to compare individual ethephon rates to the control. If the main effect of ethephon application date was significant, means were separated using the least significant difference (LSD) at $P \leq 0.05$.

Results

'PAP-50', 1992. There were no differences in plant stands among the plots. The overall mean stand was 16 plants/m².

Total dry mass of abscised fruit increased linearly with ethephon rate, and this response was due to abscission of marketable fruit (Table 1). However, the dry mass of harvested marketable fruit was unaffected by ethephon. Total dry mass of harvested fruit decreased linearly with increasing ethephon rate, and this response was due to decreased yields of green fruit. Green fruit as a percentage of total harvested fruit mass also decreased linearly with

increasing ethephon rate, while the percentage of fruit that were bleached or fungi-filled showed a quadratic response (Table 2). The intensity of red pigment extracted from fruit was improved by ethephon for composite samples, but not for samples consisting only of marketable fruit (Table 2).

Main effects of ethephon application date never were significant in 1992 (Tables 1 and 2), but three ethephon rate × application date interactions were evident (Table 3). These interactions were due, in part, to an unexplained difference in green fruit yield between 30 Sept. and 9 Oct. in control plots. Otherwise, effects of ethephon application date seemed minimal in the interaction analyses.

'PAP-50', 1993. There were no differences in plant stands among the plots. The overall mean stand was 9 plants/m². Stands were reduced compared to 1992 because the planting date was later than optimum. The original 1993 study was destroyed by a storm.

Abscission of marketable fruit increased linearly with ethephon rate (Table 4), as in

Table 2. Response of 'Oklahoma Paprika 50' pepper to ethephon treatments, Hydro, Okla., 1992. Ethephon rate × application date interactions in this table were not significant at $P \leq 0.05$, except as noted.

Variable	Distribution of total harvested fruit mass (abscised excluded) by color categories (%)				Harvested fruit color	
	Marketable	Orange	Green	Bleached or fungi-filled	Composite ^z (ASTA) ^y	Marketable (ASTA)
Ethephon rate (μL·L ⁻¹)						
0	74	6	20	0.9	103	179
1000	79	6	14	0.8	110	183
2000	80	5	14	0.7	113	181
3000	83	5	11	0.6	122	178
4000	80	6	13	1.2	120	187
Response ^x	NS ^w	NS	L**v	Q*	L**	NS
Application date						
23 Sept.	81	5	13	1.0	116	183
30 Sept.	78	6	16	0.6	112	183
9 Oct.	78	6	15	0.9	113	178
Response	NS ^w	NS	NS ^v	NS	NS	NS

^zComposite samples consisted of 10% (by dry mass) random fruits from each of the four fruit color categories, including calyxes, from each plot (see text for details). Calyxes were removed for the separate analysis of marketable fruit.

^yASTA = American Spice Trade Association color units (1968).

^xL = linear, Q = quadratic; cubic, and quartic effects were tested.

^vEthephon rate × application date interaction significant at $P \leq 0.05$.

^wEthephon rate × application date interaction significant at $P \leq 0.01$.

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Interactions of ethephon rate $\times$ application date on paprika pepper, Hydro, Okla.²

Application date	Ethephon rate ($\mu\text{L}\cdot\text{L}^{-1}$)				
	0	1000	2000	3000	4000
<i>Harvested green fruit mass ($\text{g}\cdot\text{m}^{-2}$)</i>					
23 Sept. 1992	66 ab	46 b-d	24 d	26 d	41 b-d
30 Sept. 1992	80 a	57 a-c	42 b-d	31 cd	34 cd
9 Oct. 1992	41 b-d	47 b-d	58 a-c	43 b-d	24 d
LSD ($P \leq 0.05$)			31		
<i>Harvested marketable fruit (% of total harvested fruit mass)</i>					
23 Sept. 1992	74 a-d	84 a-c	88 a	87 a	72 b-d
30 Sept. 1992	66 d	76 a-d	82 a-c	84 a-c	82 a-c
9 Oct. 1992	81 a-c	78 a-d	70 cd	77 a-d	86 ab
LSD ($P \leq 0.05$)			15		
<i>Harvested green fruit (% of total harvested fruit mass)</i>					
23 Sept. 1992	20 ab	11 ab	8 b	8 b	18 ab
30 Sept. 1992	26 a	17 ab	13 ab	10 b	12 ab
9 Oct. 1992	13 ab	15 ab	22 ab	16 ab	9 b
LSD ($P \leq 0.01$)			16		
<i>Abscised marketable fruit mass ($\text{g}\cdot\text{m}^{-2}$)</i>					
15 Sept. 1993	8 g	14 e-g	21 c-e	28 bc	45 a
20 Sept. 1993	8 g	12 e-g	14 e-g	25 b-d	32 b
26 Sept. 1993	7 g	8 g	9 g	10 fg	10 fg
4 Oct. 1993	11 e-g	8 g	12 e-g	16 d-g	20 c-f
LSD ($P \leq 0.05$)			11		

²Data are from 'Oklahoma Paprika 50' in 1992 and 'KS-1' in 1993. Within each variable, means in the entire array followed by the same letter do not differ according to the interaction least significant difference (LSD) at the indicated level of probability. These LSD values compare differences between ethephon rate subplots for different application date main plots. The following LSD values may be used to compare differences between ethephon rate subplots for the same application date main plot: 23, 14, 13, and 11 for the four variables, respectively.

1992. However, the numerical increase was small, and unlike 1992, the dry mass of abscised cull fruit decreased quadratically as ethephon rate increased. The net result was a quadratic decrease in total dry mass of abscised fruit as ethephon rate increased.

Total dry mass of harvested fruit decreased linearly with increasing ethephon rate, and this response was due to decreased yields of green fruit (Table 4). Green fruit as a percentage of total harvested fruit mass also decreased linearly and quadratically with increasing ethephon rate (Table 5). Concomitantly, marketable fruit as a percentage of total harvested fruit mass increased linearly with ethephon rate. The intensity of red pigment extracted from fruit was improved by ethephon for composite samples, but not for samples consisting

only of marketable fruit (Table 5), as in 1992.

Dry mass of harvested orange and green fruit tended to be lowest with the 15 Sept. application, and the total dry mass of harvested fruit was lowest with the 15 Sept. application (Table 4). The intensity of red pigment extracted from composite fruit samples was lowest with the 4 Oct. application (Table 5). There were no significant ($P \leq 0.05$) ethephon rate $\times$ application date interactions evident in this study.

'KS-1', 1993. The overall mean stand was 20 plants per m^2 . Plant stands did not differ among ethephon rate subplots, but there were differences among application date main plots. Stands averaged 21, 19, 18, and 21 plants/ m^2 for the 15, 20, and 26 Sept. and 4 Oct. plots, respectively. The least significant difference

($P \leq 0.05$) was 3. Analysis of covariance procedures were used to adjust the data from this experiment for possible effects of stand differences. Interactions between stand, ethephon rate, and spray date never were significant ($P \leq 0.05$) for any measured variable, so these interactions were pooled into the experimental error. Plant stand proved to be a significant factor for only four measured variables: dry mass of harvested orange and green fruit, total dry mass of harvested fruit, and orange fruit as a percentage of total harvested fruit mass.

Abscission of marketable fruit increased linearly with ethephon rate, while abscission of cull fruit showed a quadratic response (Table 6). The net effect was a linear and quadratic increase in total dry mass of abscised fruit with ethephon rate.

Total dry mass of harvested fruit decreased linearly as ethephon rate increased due to decreased yields of fruit in all color categories, except orange (Table 6). Green fruit as a percentage of total harvested fruit mass decreased linearly and quadratically with increasing ethephon rate (Table 7). Concomitantly, marketable fruit as a percentage of total harvested fruit mass increased linearly with ethephon rate. The intensity of red pigment extracted from fruit was improved by ethephon for composite samples and apparently also for samples consisting only of marketable fruit. However, a least squares means analysis of the marketable fruit samples (not presented) showed that only the 1000 $\mu\text{L}\cdot\text{L}^{-1}$ rate resulted in an ASTA value higher than that from control fruit.

The main effect of application date often was significant in the 'KS-1' experiment, due in part to the relatively high abscission and low yield resulting from the 15 Sept. application. The percent of total harvested fruit mass due to marketable fruit was numerically highest with the 15 Sept. treatment, but the actual dry mass of harvested marketable fruit was numerically lowest (Tables 6 and 7). There also was one significant ethephon rate $\times$ application date interaction in the 'KS-1' experiment (Table

Table 4. Response of 'Oklahoma Paprika 50' pepper to ethephon treatments, Hydro, Okla., 1993. Dry masses are reported. All ethephon rate $\times$ application date interactions in this table were not significant at $P \leq 0.05$.

Variable	Abscised fruit mass ($\text{g}\cdot\text{m}^{-2}$)			Harvested fruit (abscised excluded) mass ($\text{g}\cdot\text{m}^{-2}$)				
	Marketable	Cull	Total	Marketable	Orange	Green	Bleached or fungi-filled	Total
Ethephon rate ($\mu\text{L}\cdot\text{L}^{-1}$)								
0	9	24	32	67	82	50	27	225
1000	10	15	24	64	78	31	31	204
2000	9	13	22	77	77	29	27	210
3000	12	13	25	72	75	23	27	197
4000	15	18	32	73	73	22	27	194
Response ²	L*	Q**	Q**	NS	NS	L**Q**	NS	L**
Application date								
15 Sept.	10	17	26	64	64	25	23	176
20 Sept.	12	16	28	71	83	34	28	216
26 Sept.	10	15	25	76	79	28	30	214
4 Oct.	12	17	29	70	80	37	31	219
Response ²	NS	NS	NS	NS	12	8	NS	21

²L = linear, Q = quadratic; cubic, and quartic effects were tested.

³If main effect of application date is significant, value shown is least significant difference, $P \leq 0.05$.

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 5. Response of 'Oklahoma Paprika 50' pepper to ethephon treatments, Hydro, Okla., 1993. All ethephon rate $\times$ application date interactions in this table were not significant at $P \leq 0.05$.

Variable	Distribution of total harvested fruit mass (abscised excluded) by color categories (%)				Harvested fruit color	
	Marketable	Orange	Green	Bleached or fungi-filled	Composite ^z (ASTA) ^y	Marketable (ASTA)
Ethephon rate ($\mu\text{L}\cdot\text{L}^{-1}$)						
0	29	37	22	12	64	204
1000	31	38	15	15	78	210
2000	37	36	14	13	79	204
3000	37	38	12	14	76	208
4000	38	38	11	14	88	208
Response ^x	L**	NS	L**Q**	NS	L**C**	NS
Application date						
15 Sept.	37	37	13	13	82	208
20 Sept.	33	39	16	13	80	206
26 Sept.	36	37	13	14	78	209
4 Oct.	32	37	17	14	68	205
Response ^w	NS	NS	NS	NS	8	NS

^zComposite samples consisted of 10% (by dry mass) random fruits from each of the four fruit color categories, including calyxes, from each plot (see text for details). Calyxes were removed for the separate analysis of marketable fruit.

^yASTA = American Spice Trade Association color units (1968).

^xL = linear, Q = quadratic, C = cubic; quartic effects were tested.

^wIf main effect of application date is significant, value shown is least significant difference, $P \leq 0.05$.

NS, **Nonsignificant or significant at $P \leq 0.01$, respectively.

3), which confirmed much marketable fruit abscission with the 15 Sept. application with ethephon at 3000 or 4000 $\mu\text{L}\cdot\text{L}^{-1}$.

Discussion

Abscission of marketable fruit increased with ethephon rate in all three experiments. Others have reported similar responses (Batal and Granberry, 1982; Conrad and Sundstrom, 1987). Cull fruit abscission was inconsistently affected by ethephon, but dry mass of harvested green fruit decreased as ethephon rate increased in all three experiments. This is indirect evidence that we were successful in meeting our objective of causing abscission of late-developing flower buds and blooms. Abscised flower buds were visible in the field each year following initial ethephon applications, even at 1000 $\mu\text{L}\cdot\text{L}^{-1}$. Also, few or no blooms were present on ethephon-treated plants at 7 to 10 d following the ethephon applica-

tions, in contrast to control plants which had many white blooms. However, it was not practical to record quantitative data on abscised organs in the field.

The total dry mass of harvested fruit decreased linearly as ethephon rate increased in all three experiments. However, the dry mass of harvested marketable fruit was unaffected by ethephon rate in both 'PAP-50' experiments. In the 'KS-1' experiment, a least squares means analysis (not presented) showed that despite the overall linear response, only the 4000 $\mu\text{L}\cdot\text{L}^{-1}$ rate resulted in a harvested marketable fruit yield lower than that from control plants. Thus, the marketable fruit abscission that occurred with ethephon treatments did not adversely affect harvested marketable fruit yield. Ethephon treatments had little or no effect on the dry mass of harvested orange fruit or fruit that were bleached or fungi-filled, in agreement with our previous findings (Cooksey et al., 1994). Therefore, the primary source of

the reduced total dry mass of harvested fruit with ethephon treatments was a reduction in the yield of green fruit, as we had hypothesized.

Marketable fruit as a percentage of total harvested fruit mass increased linearly with ethephon rate in two out of three experiments, while the percent of total harvested fruit mass due to green fruit decreased as ethephon rate increased in all three experiments. Similar findings were reported in other cultivars of *Capsicum annuum* by Cantliffe and Goodwin (1975).

The altered distribution of fruit color categories due to ethephon treatments resulted in improved composite ASTA fruit color values in all three experiments. However, color sorting and removal of calyxes resulted in much higher ASTA values from samples containing only marketable fruit. Ethephon treatments also had little or no effect on the intensity of red pigment extracted from dehydrated mar-

Table 6. Response of 'KS-1' pepper to ethephon treatments, Hydro, Okla., 1993. Dry masses are reported.

Variable	Abscised fruit mass ($\text{g}\cdot\text{m}^{-2}$)			Harvested fruit (abscised excluded) mass ($\text{g}\cdot\text{m}^{-2}$)				
	Marketable	Cull	Total	Marketable	Orange	Green	Bleached or fungi-filled	Total
Ethephon rate ($\mu\text{L}\cdot\text{L}^{-1}$)								
0	8	24	32	246	45	89	18	398
1000	10	21	32	250	43	68	18	379
2000	14	20	34	236	42	59	16	354
3000	20	23	43	231	43	47	15	336
4000	27	28	54	216	38	46	15	315
Response ^z	L**y	Q*	L**Q*	L**	NS	L**Q*	L*	L**
Application date								
15 Sept.	23	26	49	213	35	44	14	306
20 Sept.	18	23	41	241	36	59	14	350
26 Sept.	9	18	27	252	46	72	16	387
4 Oct.	13	25	38	237	52	72	21	382
Response ^x	4 ^y	4	8	25	7	20	5	35

^zL = linear, Q = quadratic; cubic, and quartic effects were tested.

^yEthephon rate $\times$ application date interaction significant at $P \leq 0.05$. All other ethephon rate $\times$ application date interactions in this table were not significant at $P \leq 0.05$.

^xIf main effect of application date is significant, value shown is least significant difference, $P \leq 0.05$.

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 7. Response of 'KS-1' pepper to ethephon treatments, Hydro, Okla., 1993. All ethephon rate $\times$ application date interactions in this table were nonsignificant at $P \leq 0.05$.

Variable	Distribution of total harvested fruit mass (abscised excluded) by color categories (%)				Harvested fruit color	
	Marketable	Orange	Green	Bleached or fungi-filled	Composite ^a (ASTA) ^y	Marketable (ASTA)
Ethephon rate ($\mu\text{L}\cdot\text{L}^{-1}$)						
0	62	11	22	4	91	174
1000	66	11	18	5	99	187
2000	68	12	16	5	104	178
3000	69	13	14	5	111	176
4000	69	12	14	5	102	183
Response ^x	L**	NS	L**Q**	NS	L**Q**	C*
Application date						
15 Sept.	71	12	13	5	109	187
20 Sept.	69	10	16	4	101	174
26 Sept.	65	12	19	4	98	181
4 Oct.	62	14	19	6	98	176
Response ^w	5	2	NS	NS	NS	NS

^aComposite samples consisted of 10% (by dry mass) random fruits from each of the four fruit color categories, including calyxes, from each plot (see text for details). Calyxes were removed for the separate analysis of marketable fruit.

^yASTA = American Spice Trade Association color units (1968).

^xL = linear; Q = quadratic; C = cubic; quartic effects were tested.

^wIf main effect of application date is significant, value shown is least significant difference, $P \leq 0.05$.

ns, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

ketable fruit, in agreement with our previous findings (Cooksey et al., 1994).

We recommend ethephon at ≈ 2000 to $3000 \mu\text{L}\cdot\text{L}^{-1}$ to provide a favorable yield distribution of fruit color categories while minimizing the risk of excessive abscission. One aerial application at this rate would cost about \$16.00/ha. A target spray interval of the last 10 days in September seems appropriate for southwestern Oklahoma. The precise timing of the ethephon application will vary with the situation due to crop timing, which affects tissue maturity and temperature (Rylski, 1986; Woolf et al., 1995). Ethephon treatment will not substitute for color sorting of harvested fruit, but likely will simplify the process by decreasing the percentage of green fruit among all fruit harvested.

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