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Calcium and Ethephon Effects on Tabasco Pepper Leaf and Fruit Retention and Fruit Color Development

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Abstract. **All possible combinations of ethephon at 0, 5000, 10,000, and 15,000 ppm, and calcium as $Ca(OH)_2$ at concentrations of 0, 0.01, 0.1, and 1 M were applied to Tabasco pepper *(Capsicum frutescens* L.). In the greenhouse, as ethephon rates increased, leaf retention percentages decreased. Over all ethephon rates, as $Ca(OH)_2$ concentration increased, Tabasco leaf retention percentages increased. Ethephon-induced fruit abscission was greatest in less-mature fruit. Overall fruit retention percentages were greatest when ethephon was applied with either 0.1 or 1 M $Ca(OH)_2$. In the field, when ethephon was applied without $Ca(OH)_2$, leaf and fruit abscission was so great that data could not be recorded. When ethephon was applied with 0.1 M $Ca(OH)_2$, percentages of orange and red fruit on the plant increased with an increase in ethephon rate. Chemical name used: (2-choloroethyl)phosphonic acid (ethephon).**

The action of ethephon on peppers (*Capsicum annuum* L. and *C. frutescens* L.) is affected by pepper type (1, 13), cultivar (2), crop maturity (2, 10, 14), number of applications (2), rate of application (1–5, 8), and air temperature (5, 14). The use of ethephon as a pepper fruit ripening agent, however, is limited by premature fruit abscission and defoliation (1, 2, 5, 8, 14).

Ethylene-induced abscission can be reduced by treatment with calcium (6, 7, 11, 12). Calcium not only increases ethephon solution pH (6, 7), but also maintains the integrity of cell walls and membranes in the abscission layer (11, 12). Fruit and leaf abscission of olive (7) and pecan (6) was reduced when calcium was applied with ethephon.

Tabasco pepper is widely used in red pepper sauce production. Past efforts to mechanically harvest red fruit (15) have demonstrated the need to increase fruit ripening uniformity. To date, there has been no work on the influence of calcium in combination with ethephon applications to either *C. annuum* or *C. frutescens*. The purpose of this study was to investigate the effect of various concentrations of calcium and ethephon on Tabasco fruit and leaf retention and fruit color development.

Materials and Methods

Greenhouse studies. Tabasco pepper was seeded in the greenhouse in Speedling trays in early Nov. and Dec. 1985. At 10 weeks, seedlings were transferred to 4-liter pots. When 10% of the pepper fruit had reached mature red stage (10, 14), ethephon and calcium [$Ca(OH)_2$] treatments were applied. Fruit color at time of treatment and at harvest was determined by using the Munsell Standard Color System (9), where minimum orange = 7.5YR, 7/12 and minimum red = 10R, 5/16. Spray treatments were 0, 5000, 10,000, and 15,000 ppm ethephon; 0, 0.01, 0.1, and 1 M $Ca(OH)_2$; and all possible combinations thereof. All treatment solutions were mixed and applied immediately to minimize calcium precipitation and volatilization of ethylene. Martin et al. (6) reported that ethephon solution pH adjustment between 2.0 and 8.0 with Ca sources did not alter pecan leaf abscission consistently; therefore, no attempt was made to standardize treatment solution pH in this study. Each experimental unit consisted of one plant per pot and was sprayed until run off with 150 ml of the treatment solution. All leaves and fruit were counted and fruit were graded for maturity on each plant before and after treatment application. Abscission measurements were taken 48 hr after treatment (5, 8) by collecting abscised fruit on plastic under all pots, and by counting leaves and fruit remaining on each plant. Leaf and green, orange, and red fruit retention were expressed as percentages and arcsin transformations were performed on all data prior to analysis.

A randomized complete block experimental design, blocked on time with 3-day spray intervals, was employed in the first greenhouse test. Treatment arrangement of the first experiment was a complete 4 × 4 factorial with three replications and was harvested in mid-April. During this study, a slight temperature gradient within the greenhouse was recognized. For this reason, the second greenhouse experiment was arranged in a split plot design with ethephon concentrations in the main plot and $Ca(OH)_2$ concentrations in the subplots with three replications. The second study was harvested in early May in the same manner as the first study. Air temperatures in the greenhouse at the time of treatments in both studies ranged from 22° to 34°C, typical of air temperatures in the field at the time of commercial Tabasco harvest.

Field studies. Two studies were established in the field in

Table 1. Effect of the interaction of $Ca(OH)_2$ and ethephon on Tabasco leaf retention in the greenhouse.

	Leaves retained (%)				
Ethephon (ppm)	$Ca(OH)_2$ concn (M) 0	0.01	0.1	1	Significance
0	97	95	97	97	NS
5,000	57	56	87	93	L***Q**
10,000	8	12	86	93	L***C***
15,000	5	9	26	94	L***Q**C***
Significance	L***Q***C***	L***Q**	L***	NS	---

NS,**,***Nonsignificant or significant at the 1% or 0.1% levels, respectively. Linear (L), quadratic (Q), or cubic (C).

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Table 2. The effect of the interaction of $Ca(OH)_2$ and ethephon on Tabasco green, orange, and red fruit retention in the greenhouse.

Ethephon (ppm)	Fruit retained (%) $Ca(OH)_2$ concn (M) 0			0.01			0.1			1			Significance		
	Green	Orange	Red	Green	Orange	Red	Green	Orange	Red	Green	Orange	Red	Green	Orange	Red
0	100	100	100	100	100	100	100	100	90	100	100	100	NS	NS	NS
5,000	26	23	43	55	74	87	100	99	63	100	96	100	L***C*	L***Q**	L***C**
10,000	33	34	76	6	53	47	100	100	94	100	100	98	L***C***	L***C**	L***C**
15,000	22	47	67	29	61	55	89	90	85	100	99	95	L***	L**Q*C*	L*
Significance	L***Q***C**	L**Q***	Q**C**	L***Q***	L***Q***	L***	L*	NS	NS	NS	NS	NS	---	---	---

NS,*,**,***Nonsignificant or significant at the 5%, 1%, or 0.1% levels, respectively. Linear (L), quadratic (Q), or cubic (C).

Apr. 1986 by transplanting seedlings to plots arranged in a randomized complete block design. There were four replications with a split-plot treatment arrangement, with ethephon rates in the main plot and harvest dates in the subplots. Treatments were 0, 5000, 10,000, and 15,000 ppm ethephon, without the inclusion of calcium in the first study, and with 0.1 M $Ca(OH)_2$ in the second study. In late July, at ≈90 days after transplanting, ethephon and $Ca(OH)_2$ treatments were applied at first sign of fruit color. Sprays were applied at this time to ensure that only treatment effects would be observed in red fruit percentage data. All plots in both studies were sprayed until run off with ≈250 ml of solution per plant. At 4, 8, 12, and 16 days following spray application, Tabasco fruit were harvested. Peppers were sorted and graded for color as in previous greenhouse studies. Increases in the number of orange and red peppers were expressed as percentages of total harvest and data were transformed by arcsin prior to analysis.

Results and Discussion

Greenhouse studies. Pepper leaf and fruit retention response trends for the two greenhouse experiments were similar. The first experiment that used a randomized complete block design had a mean square error 2.26 times larger than the second experiment. For this reason, and because results of the two studies were similar, only the results of the more-efficient second study are presented and discussed.

Phytotoxicity was not observed at any level or combination of ethephon and $Ca(OH)_2$. No significant fruit ripening response (data not shown) was observed 48 hr after treatment. Observed treatment effects indicated, however, that 48 hr may have been insufficient for significant fruit color development to occur.

Ethephon and $Ca(OH)_2$ interacted significantly ($P < 0.05$) in their effect on Tabasco leaf retention (Table 1). At $Ca(OH)_2$ concentrations <1 M, when ethephon concentration increased from 5000 to 15,000 ppm, there was a very highly significant ($P < 0.001$) linear decrease in leaf retention percentage. At 1 M $Ca(OH)_2$, the influence of ethephon was not significant on Tabasco leaf retention. The data indicate, therefore, that the presence of Ca as $Ca(OH)_2$ offset ethephon-induced Tabasco leaf abscission. These data are consistent with other reports on olive (7) and on pecan (6).

The influence of the interaction of $Ca(OH)_2$ and ethephon on Tabasco fruit retention is shown in Table 2. At 0 and 0.01 M levels of $Ca(OH)_2$, retention of green, orange, and red fruit significantly declined as ethephon concentration increased. At 0.1 and 1 M $Ca(OH)_2$ levels, with one exception, ethephon did not affect Tabasco fruit retention. There was no significant difference ($P = 0.38$) between main effects of $Ca(OH)_2$ at 0.1 and 1 M levels on overall fruit retention. Fruit retention means over ethephon and $Ca(OH)_2$ were 72%, 79%, and 81% for green, orange, and red fruit, respectively. The data indicate, therefore, that Tabasco fruit retention was influenced by the physiological age of the fruit, an observation also made by others (1) working with pimiento peppers. Fruit retention increased as $Ca(OH)_2$ concentrations increased in a manner similar to leaf retention.

Field studies. Greenhouse data analysis indicated that there was no significant difference in fruit retention percentages between 0.1 and 1M $Ca(OH)_2$. For this reason, and because maintaining 1 M $Ca(OH)_2$ in solution was of major concern, the 0.1 M level was selected to study further its effect with ethephon on fruit color development in the field.

When ethephon was applied with no $Ca(OH)_2$, both leaf and fruit drop in the field were so great that no data on increases in fruit color development could be collected. This observation further supports leaf and fruit retention results of greenhouse studies reported in Tables 1 and 2. Data in Table 3, therefore, only concern ethephon influences with 0.1 M $Ca(OH)_2$.

Ethephon rate and time after treatment interacted significantly for both orange and red fruit percentages observed on the plant ($P < 0.01$ and $P < 0.001$, respectively). When no ethephon

Table 3. The influence of 0.1 M $Ca(OH)_2$ and ethephon on Tabasco fruit color development over a 16-day period as measured by the increase in percent orange and red fruit in the field.

Ethephon (ppm)	Orange fruit (%) Days after application 4	8	12	16	Significance	Red fruit (%) Days after application 4	8	12	16	Significance
0	0.2	0.3	3.3	9.0	L*	0	0	0	0	NS
5000	4.8	16.5	18.5	31.0	L***	0	0.8	3.7	20.8	L***Q**
10,000	6.5	20.0	25.0	32.4	L***	0.2	0.3	5.4	22.9	L***Q**
15,000	11.1	25.8	38.1	39.8	L***Q*	0.4	5.0	10.3	36.4	L***Q***
Significance	L**	L***	L***	L***Q*C*	---	NS	NS	L*	L***C*	---

NS,*,**,***Nonsignificant or significant at the 5%, 1%, or 0.1% levels, respectively. Linear (L), quadratic (Q), or cubic (C).

was applied, orange fruit percentage increased in linear manner from 0.2% to 9.0%; however, as expected there was no natural ripening of fruit to the pure red stage (Table 3). As time following treatment application increased to 16 days, orange and red fruit color development increased. This response supports treatment trends observed, but not measured, in previous greenhouse work. Over all harvest times, there was a significant linear increase in orange fruit as ethephon concentration increased. Red pepper fruit percentages were not significantly influenced by ethephon rate at 4 and 8 days following treatment application. At 12 and 16 days following treatment, however, increasing concentrations of ethephon increased the percentages of red fruit on the plants in a significant linear manner.

As observed in the greenhouse, ≈10% of the green fruit had abscised by day 4 in the field following 15,000 ppm ethephon and 0.1 M $Ca(OH)_2$ application. Furthermore, on day 16 in the field following 15,000 ppm ethephon application, an ≈10% drop of red Tabasco fruit also was observed. Unlike the greenhouse, however, there was no noticeable leaf abscission at any time following application of 15,000 ppm ethephon.

Tabasco pepper leaf and fruit retention trends were generally similar in both greenhouse and field studies. In the greenhouse, inclusion of calcium, as $Ca(OH)_2$, at the 1 M level significantly reduced ethephon-induced leaf abscission at all ethephon rates. There were, however, no significant differences in fruit retention percentages between 0.1 and 1 M $Ca(OH)_2$. Ethephon had its greatest effect on green fruit abscission. In the field, 5000, 10,000, and 15,000 ppm ethephon applications with 0.1 M $Ca(OH)_2$ resulted in 51.8%, 55.3%, and 76.2% total orange and red fruit on the plant, respectively (Table 3). The difficulties associated with ethephon use are well-recognized. This study indicates, however, that the inclusion of 0.1 M $Ca(OH)_2$ in ethephon sprays can overcome undesired Tabasco leaf and fruit abscission, while increasing fruit color development on the plant.

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