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The effects of CaCl2 and aqueous seaweed extract foliar sprays on spider mite predator/prey status and on several aspects of fruit quality of 'McIntosh' apple trees.

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THE EFFECTS OF $CaCl_2$ AND AQUEOUS SEAWEED EXTRACT FOLIAR SPRAYS ON SPIDER MITE PREDATOR/PREY STATUS AND ON SEVERAL ASPECTS OF FRUIT QUALITY OF 'MCINTOSH' APPLE TREES

A Thesis Presented

By

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DEDICATION

This paper is dedicated to my wife, Norma, for her hard work and constant support of my efforts in graduate school and to my parents Dante and Gesuela Coli for their unswerving faith in my abilities.

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ABSTRACT

Sprays of $CaCl_2$ and an aqeuous seaweed extract (Cytex) were applied in 1977 and 1978 on 'McIntosh' apple trees (Malus domestica Borkh) on MM106 rootstock that received no insecticides or miticides with the exception of a dormant oil spray in 1977. Mite populations were not affected by the spray treatments in 1977. Cytex sprays at 2x concentration reduced 2-spotted mite and apple rust mite numbers in 1978 and the European red mite population was lowered by applications of $CaCl_2$. Limb circumference increase was suppressed both years by $CaCl_2$ sprays because of foliar burn and high mite numbers. In 1978, $CaCl_2$ sprays reduced foliar chlorophyll, fruit size, and fruit flesh firmness after storage at 32° F in air but increased red color, internal ethylene concentrations, preharvest drop, and brown core of fruits. Cytex sprays increased fruit set in 1978 and fruit flesh firmness both years.

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CHAPTER I

INTRODUCTION

Studies on integrated pest management of apple orchards have been directed in part, on pesticide and herbicide effects on target insects and mites and on the predator-prey status (1, 26, 55, 56, 88). However, materials other than pesticides and herbicides are sprayed on or under apple trees and can influence insect development. (36, 100). Succinic acid -2, 2-dimethylhydrazide (daminozide) can reduce aphid populations (47). Gibberellins were found to influence plant nutrition and mite populations at concentrations as low as 10 ppm (98). Many herbicides used in orchards are toxic to predatory mite species (56). Spray materials may thus affect the total orchard ecosystem and especially influence the predator/prey ratio in the tree (57, 87, 97). As a result, biological control may be inhibited by direct toxic effects to predators of applied chemicals or by elimination of alternate food sources which allow predator numbers to increase in the absence of preferred prey species (26, 53, 60, 84).

In Massachusetts 6 to 7 foliar sprays of $CaCl_2$ are being applied annually in many orchards to improve fruit calcium (Ca) levels (19, 20, 74). Little is known about $CaCl_2$ effects on tree vigor and productivity, some aspects of fruit quality, preharvest drop, and on the predator/prey status in the trees. Foliar sprays of certain marine algae species have a protective and/or a repellent effect on mites and aphids on peaches, beans, strawberries (15), and apples (35). Liquid extracts and wettable powders of these seaweeds are now readily available for use in orchards and warrant testing.

The objectives of this study were to evaluate the influence of foliar applications of $CaCl_2$ and Cytex, an aqueous extract of certain marine algae species on, 1) the predator/prey status in the tree; 2) the growth, productivity and nutrition of the trees; and 3) pre-harvest drop and fruit quality.

CHAPTER II

REVIEW OF LITERATURE

Spider mites are important pests of tree fruits and may cause severe damage to foliage of susceptible cultivars if not controlled (34). Severe damage can reduce leaf chlorophyll, reduce photosynthesis, reduce fruit size, increase pre-harvest drop, reduce bloom and fruit set in succeeding years, and cause a general decline in tree vigor (6, 8, 9, 26, 48, 53, 60, 71, 72, 118).

Apple cultivars vary in their susceptibility to mite feeding, with some such as 'Delicious', 'Northern Spy', and 'Golden Delicious' prone to rapid population increases (26). 'McIntosh' is believed to be less appealing to mites due to the hirsute nature of leaf surfaces (34), although Goonewardene *et al*. (45) found cultivars with less hairy leaves supported fewer mites than selections with an abundance of leaf hairs.

The major plant feeding mite species in Massachusetts commercial orchards are *Panonychus ulmi*, the European red mite, *Tetranychus urticae*, the two-spotted spider mite, and *Aculus schlechtendali*, the apple rust mite.

Populations of spider mites seldom reach damaging numbers in abandoned orchards as a varied complex of predators normally will exert a strong degree of biological control (26, 28). Certain major mite predators are susceptible to orchard insecticides (84), however, so that damaging species can reproduce rapidly in commercial orchards.

The major predator mite in Massachusetts apple orchards is Amblyseius fallacis (55, 56) commonly associated with T. urticae (68, 87), but able to prey as well on eggs or adults of P. ulmi and A. schlechtendali (28, 84). A. fallacis has the potential to bring about biological control of phytophagous species (25, 99). A. fallacis will also prey on A. schlechtendali, allowing predator numbers to increase early in the season or when preferred food sources are absent or few in numbers (26, 53, 117). Moderate apple rust mite numbers (< 300 per leaf) cause little harm to fruit trees and may act to reduce European red mite numbers by competitive displacement (27, 28, 38, 43).

Suggested tolerance levels to mite populations vary (16). The Michigan Integrated Pest Management program suggests that population densities of European red mite (ERM) or two-spotted mites of 15-20 mites per apple leaf or 200 apple rust mites per leaf can be tolerated up to 10-14 days before fruit production or tree vigor are adversely affected (26). However, miticide sprays are suggested when European red mite or two-spotted mites reach 7 per leaf (26). In contrast, Readshaw (94) set the damage level in apples at 100 mites per leaf. Croft, (25), working in southern California apple orchards, determined 10.5 prey per leaf, in the absence of predators, to be the level at which selective acaricide treatment is required.

Numerous apple storage disorders are related to fruit Ca levels, and sprays or dips with Ca solutions have proven to be effective in reducing these disorders (13, 14, 18, 19, 37, 41, 42, 81, 82, 102, 103).

Some Massachusetts apple growers claim that $CaCl_2$ treated 'McIntosh' apples are firmer at harvest (73). There is little data to affirm or negate this assertion, although Riley and Rolattukuoy (95) found that 'Golden Delicious' apples individually sprayed with $CaCl_2$ solutions over a period of 9 weeks prior to harvest, were 1.0 kg (2.2 pounds) firmer than untreated apples at harvest or after 9 weeks of storage. In contrast, Lord et al.(75) found that apples which had received 4 pounds (1.8 kg) of $CaCl_2$ every two weeks did not differ in firmness from the check after air storage.

Effects of Ca sprays on fruit color are not well documented, although workers in New Zealand found that sprays of $CaNO_3$ but not $CaCl_2$, retarded color development of 'Delicious' apples (24). Massachusetts commercial growers have reported that $CaCl_2$ sprays may increase preharvest drop (73). This could be in response to wound ethylene produced by the marginal foliar necrosis known to be associated with $CaCl_2$ sprays (13, 20). Hall and Ferree (49) have found that reductions in leaf area, of from 10-20% significantly reduced net phytosynthesis. Others have shown the relationship between leaf area, growth and quality of apples (50, 51, 79). The reduction in photosynthetic area caused by marginal foliar burn could also affect the spider mite predator/prey status, which is known to be postively correlated with tree chemical compositon and nutrient content (30, 31, 32, 96, 97, 110).

Kang and Chung (65) found decreasing emergence rates of *Drosophila melanogaster* on leaf disks floated on increasing concentrations of $CaCl_2$ solutions, therefore, a direct toxic effect is also a possibility. Further confirmation of $CaCl_2$ toxicity is work of Osman and Zohdy (88), who reported a 33% reduction of populations of Tetranychus arabicus (Attiah) 15 days after sprays of $CaCl_2$ were applied. Hislop et al.(56), however, using the slide dip technique of Abbott, found $CaCl_2$ at the 3 pounds per 100 gallon rate (0.04 kg/l) to be of low toxicity to a strain of Amblyseius fallacis, the major predatory mite found in Massachusetts commercial orchards.

Certain seaweeds, notably species of Laminaria, Fucus and Ascophyllum have been used for centuries in many parts of the world as a beneficial soil amendment and as fodder for animals (23, 44). Their analyses can vary with the source of the dried algal species (40, 66) and the time of year in which it is harvested (22). Foliar sprays of seaweed extracts can supply small amounts of over 50 different trace elements (104) as well as appreciable amounts (1-3% dry weight) of N, P, K, Mg and S (66). Significant amounts of carotene, Thiamine (B), Vitamin E and Vitamin B12 are present as well (104, 109). These heat sensitive vitamins would not be present in seaweed extracts made by high temperature alkaline hydrolysis, so for this reason, commercial extracts are generally prepared by low temperature aqueous extractions (89).

Maunter (83) reported finding antibiotic substances in seaweed extracts which could account for reports of increased shelf life of peaches (106) and storage quality of cherries (91) and apples (90).

Povolny reported a flesh firmness enhancement resulting from 0.8% sprays of commercial seaweed extracts in 'Cox's Pippin' and 'Matcino' apples.

Bently (10) reported growth promoting activity of freshly harvested algae, which would be in agreement with work of Williams (115) who detected a growth substance similar to IAA in Laminaria agardhii. Bently (11, 12) also determined the presence of unspecified indole compounds using thin layer chromatography on saponified extracts of commercially available aqueous aeaweed sprays. Mowat (85) and Jen (64) reported the presence of auxin-like compounds in commercial liquid extracts as well.

Evidence of gibberellin-like compounds in extracts of Ascophyllum nodosum order Fucacae was found by Williams et al.(115). Radley (92) confirmed the existence of a gibberellin-like substance in Fucus vesiculosis using a bioassay. Mowat and Reid (86) and Hussain and Boney (61) have indicated the presence of a cytokinin in algae of the genus Laminaria using a radish leaf bioassay.

Van Staden and Breen (113) found cytokinin-like activity in extracts from fresh water algae and Brain et al.(17) reported cytokinin-like growth promotion of carrot explants using a commercially available seaweed extract (Cytex). These authors confirmed cytokinin activity of this extract using tissue cultured cells of a cytokinin requiring strain of Atropa belladonna and also using radish leaf bioassay. They reported that the seaweed extract had a cytokinin activity capable of producing physiological changes even when applied at the low concentrations used in practice.

Mowat and Reid (86) found kinetin from 0.1 to 10 ppm in marine algae. Growth inhibitory substances also appear present in algae since Hussain and Boney (62) found water soluble compounds from Laminaria digitata which inhibited lettuce hypocotyl growth. Gas liquid chromatography revealed compounds similar to abscisic acid. A. nodosum extracts have exhibited a protective and/or repellent effect on mites and aphids when applied as a foliar spray to peaches, beans and strawberries (15) as well as apples (35). This may possibly be the result of endogenous cytokinins, since Shaeffers (100) reported smaller and fewer alate (winged) aphid offspring were produced on excised Fragaria leaf disks floated on N6-benzyladenine, a synthetic cytokinin. Abdahl-Rahman et al.(3) reported a concentration of 100 ppm cytokinin (mostly zeatin-like) in aqueous extracts of a commercially available seaweed extract (Cytex).

Mite populations are altered by endogenous tree nutrient and growth regulator content according to work of Scheuer (101), Henneberry (52) and Cutright (29). Others (108, 111) have established the direct relationship between high N levels and high aphid and mite populations. Asatur (5) found that fertility of female red spider mites was positively correlated with glutamic acid and threonine content of apple leaves and Terriere and Rajadkyakiska (110) reduced fecundity of two-spotted spider mites on metal-chelate treated leaves. Other workers (32) have found reduced spider mite fertility on strawberry leaves containing low levels of total N, protein N and free amino acids. Cytokinins are known to delay the decomposition of protein and chlorophyll in isolated leaves (70). This results in protein synthesis which utilizes free amino acids and N while sugars are consumed as energy sources (69) so that mite populations might be affected. Rodriquez and Rodriguez (96) and others (32) found that mite populations are influenced by levels of certain elements, although their results differed dramatically, apparently due to differences between species and cultivars of plants. Seaweed sprays, by supplying major and/or minor elements could influence mite numbers, corroborating work of Driggers (35) who observed reduced numbers of European red mites on trees sprayed with seaweed extracts added to the regular spray schedule. Kingman (66), however, under greenhouse conditions found no effect on mite and/or insect numbers, although a plant quality enhancement was observed.

CHAPTER III

MATERIALS AND METHODS

Trees selected for the study, initiated in 1977, were 8-year-old 'McIntosh'/Malling Merton (MM) 106. A randomized block design was used with 3-tree plots and 6 replications. The trees received a dormant oil spray at 2 gallons/acre (18.71/ha) in the spring of 1977, otherwise no insecticides or miticides were applied. All trees, including the controls received fungicide sprays as needed. The following spray treatments were applied in 1977 and 1978; (1) control-no treatment (2) Cytex-1.2 gal/acre (11.21/ha); (3) Cytex-2.4 gal/acre (22.41/ha); and (4) $CaCl_2$ - 3 pounds/acre (3.4 kg/ha). The Cytex and $CaCl_2$ sprays were applied bi-weekly, beginning about 3 weeks after petal fall, with a Bean hydraulic handgun sprayer at 250 p.s.i. until run off. No herbicides were applied, but the grass under the trees was mowed when required and let lie.

In 1978, 8 randomly located trees in the same block received either a regular spray program of Phosmet (Imidan) at 1/2 pound/acre (.56 kg/ha) plus fungicides as needed or Imidan plus Cytex at 1 gal/acre (9.4 l/ha) plus fungicides as needed. Timing of these sprays coincided with spray applications in the remainder of the orchard.

Composite leaf samples of 25 leaves per 3-tree replicate were obtained at 2 week intervals starting on June 2 in 1977 and June 7 in 1978. Thirteen leaves were selected randomly from the center tree in each 3-tree plot and six leaves from each of the 2 other trees in the plot. Trees that received Imidan or Imidan plus Cytex in 1978 were sampled at the same time as the other trees. Twenty-five leaves were selected randomly from each tree because they were single tree plots. Samples were kept refrigerated until brushed onto soap-coated glass disks using a mite-brushing machine. Numbers of motile red mite, two-spotted spider mites, apple rust mites and A. fallacis were recorded. Green apple aphid (Aphis pomi) and syrphid fly (several species) or cecidomyid (Aphidoletes aphidimyza) midge predators were monitored by counting motile aphids and predators on the second leaf of 18 terminals per tree-6 on the interior of the canopy, 6 on the outer perimeter and 6 on the upper portion.

Two limbs per tree of approximately equal size and vigor were selected and tagged. Circumference was measured at the base of the first spur or lateral branch on each limb prior to growth in May and after harvest. These branches were not pruned during the winter of 1977 or 1978 so as to not influence other data collections. Blossom clusters and fruit set were counted on these limbs in 1977 and 1978. Data was expressed both in terms of fruit per 100 blossom clusters and in fruit per cm limb circumference. Shoot growth was determined by measuring 25 terminals per tree after harvest. Observations were made of tree appearance, including severity of leaf burn from $CaCl_2$ sprays, leaf bronzing by mites, and damage by other insects. A composite leaf sample of 50 leaves per 3-tree replicate was taken before the first spray application and at harvest for analysis of nutrient content.

After drying and grinding, N content was determined by a modified Kjeldahl procedure and P, K, Mg and Ca by atomic absorption spectrophotometry using a Perkin-Elmer spectrophotometer.

Fifty leaves were sampled from the center of each 3-tree plot to determined chlorophyll content. The leaves were mid-way on current season's shoots and the shoots within arms length of the outside of the tree canopy. Chlorophyll extraction was done using acetone according to the methods of Arnon (4) and MacKenney (78).

Pre-harvest drop was recorded before and after the normal harvest date. Total drop was compared to total hand-picked yield.

A random 50-apple sample was taken per tree prior to harvest to determine fruit weight. The amount of red color per fruit was determined visually to the nearest 10% on 25 apples drawn from this sample. Flesh firmness of 10 uniformly sized apples was determined by using a Magness-Taylor pressure tester with a 7/16 inch head. Soluble solids were determined in 1978 on 10 fruit from each center tree in the 3-tree plots using a hand refractometer.

In 1978 six apples were harvested from the center tree of each plot on 3 sampling dates to determine treatment effect on the onset of the respiratory climacteric. A composite sample of 1 ml of internal gases was drawn from the core of two fruit while the fruit was momentarily submerged in water (76, 77, 105), a technique which is considered to yield a valid determination of internal ethylene gas concentration. Samples were then analyzed on a Varian Aerograph.

A bushel of randomly picked fruit was harvested from each tree, counted, weighed and placed in cold storage in air at 0° C. This sample was examined to determine the incidence of insect damage on the fruit. After 120 days of storage in 1977 and 97 days of storage in 1978, the fruits were removed and tested to determine flesh firmness using the Magness-Taylor pressure tester with a 7/16 inch head. Bitter pit, internal breakdown, brown core and scald were recorded after the fruits were held for 7 days at room temperature. All data were analyzed by computer using the BMD 08V analysis of variance program. Means were further separated using Duncan's New Multiple Range Test.

CHAPTER IV

RESULTS AND DISCUSSION

Treatment effects on mites and aphids.

Seasonal mean numbers of ERM, two-spotted mites, apple rust mites and predatory mites were not influenced by treatments in 1977 (Table 1). In 1978, European red mite numbers were lower on $CaCl_2$ trees than on the control trees and two-spotted mite numbers were reduced by Cytex at the 2x rate (Table 1). Two treatments reduced apple rust mite densities. The $CaCl_2$ and 2x Cytex trees contained fewer rust mites than those that received the Cytex at the 1x rate. *A. fallacis* densities were not influenced by treatments in 1978 (Table 1).

The trees sprayed with Imidan or Imidan plus Cytex did not develop significant amounts of leaf bronzing, although mite levels were higher than normally accepted tolerance levels. There were no differences between treatments regarding mite population (Table 2). No attempt was made to compare Imidan or Imidan plus Cytex trees with other treatments due to variations in mite sampling techniques and plot size.

Treatments had no effect on aphid numbers in 1977 or 1978 (Table 3). In both years, it was only possible to count aphids once since predators reduced their numbers to near zero after the first sample date of each year.

Population dynamics, 1977.

Populations of phytophagous mites did not reach potentially damaging levels based on the parameters of fruit quality studied, (Table 1) although moderate leaf bronzing was evident on most trees by mid-July.

Table 1. Mean seasonal spider mite and mite predator populations per 'McIntosh' leaf.

	P. ulmi		*T. urticae*		*A. schlechtendali*		*A. fallacis*	
Treatments	1977	1978	1977	1978	1977	1978	1977	1978
Check	0.8a[z]	36.2a	1.3a	1.8a	8.1a	136.1a	.50a	.13a
1x	1.2a	27.3ab	0.7a	1.3ab	14.3a	155.9a	.64a	.11a
2x	0.8a	29.9ab	0.9a	0.9b	10.4a	91.2b	.49a	.14a
$CaCl_2$	1.0a	23.0b	2.1a	1.6ab	14.0a	85.4b	.47a	.12a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

Table 2. The effect of Imidan or Imidan plus Cytex on seasonal mean numbers of phytophagous spider mites and the major phytoseiid predator on 'McIntosh' apple leaves[z]. 1978.

Treatments	*P. ulmi*	*T. urticae*	*A. schlectendali*	*A. fallacis*
Imidan @ 1/2 lb. per 100 gal.	1045a[y]	32a	3150a	1.6a
Imidan plus Cytex @ 1 gal. per acre	1026a	38a	2938a	3.5a

[z] Means represent total motile mites on 25 leaves per tree x 4 replicates x 7 sample dates.

[y] Mean separation within columns, using Duncan's new multiple range test, 5% level.

Table 3. The effect of $CaCl_2$ and Cytex foliar sprays on mean numbers of green apple aphids (<u>Aphis pomi</u>) and aphid predators in 'McIntosh' trees receiving fungicides but no insecticides or miticides.

Treatment	1977		1978	
	A. pomi	All predators	*A. pomi*	All predators
Check	42a[z]	0.08a	185a	0.56a
1x	82a	0.51a	297a	1.83a
2x Cytex	64a	0.14a	173a	0.56a
$CaCl_2$	61a	0.22a	201a	1.56a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

A. fallacis, the major phytoseiid predator, appeared to have achieved good biological control of harmful species, although pesticide spray drift from adjacent peach and apple blocks as well as an accidental spray contaminated with Imidan may have influenced results. ERM reached peak density of 2.5 mites per leaf on July 21 (Table 4) in trees receiving the 1x Cytex rate and dropped slightly thereafter. Red mite numbers increased gradually under all other treatments with peak densities being reached on September 1 in all but 1x Cytex trees. Two-spotted mite numbers reached a peak of 1.8 per leaf in 1x Cytex treated trees on July 7, nearly one month prior to check trees which contained 4.0 per leaf on August 2 (Table 4). $CaCl_2$ and 2x Cytex trees contained peak two-spotted mite numbers on July 21 (Table 4). Two-spotted numbers declined on all treatments for the rest of the season, apparently in response to increasing predator numbers. Apple rust mite densities were highest for all treatments on July 21 and gradually declined after this date (Table 4). Peak densities of A. fallacis were reached in 2x Cytex trees on August 2, which corresponds to the sharp decline in ERM and two-spotted mite numbers on this date (Fig. 1a). Highest per leaf numbers of A. fallacis were present in check, 1x Cytex and $CaCl_2$ trees on August 18 and these remained nearly constant through the September 1 sample date (Fig. 1a, 1b).

Population dynamics, 1978.

The year was ideal for ERM with high temperatures and light rainfall during June and July. These optimal environmental conditions with the withholding of early season oil sprays aimed at overwintering eggs,

Table 4. Average number of mites per leaf on seven sample dates in 'McIntosh' trees receiving $CaCl_2$ or Cytex foliar sprays but no insecticides or miticides. 1977.

Treatment	6/9	6/23	7/7	7/21	8/2	8/18	9/1
			European red mite				
Check	0.00a[z]	0.01a	0.15a	0.76a	0.79a	1.03a	2.49a
1x Cytex	0.01a	0.00a	0.18a	2.50a	2.00a	2.20a	1.70a
2x Cytex	0.00a	0.03a	0.19a	1.00a	0.51a	1.90a	2.20a
$CaCl_2$	0.00a	0.09a	0.27a	1.60a	1.10a	1.70a	2.00a
			Two-spotted mite				
Check	0.03a	0.19a	2.00a	2.50b	4.00ab	0.37a	0.19a
1x Cytex	0.01a	0.19a	1.80a	1.30b	1.30b	0.11a	0.08a
2x Cytex	0.04a	0.08a	2.00a	3.00b	0.64b	0.02a	0.10a
$CaCl_2$	0.01a	0.23a	1.80a	6.90a	5.50a	0.19a	0.08a
			Apple rust mite				
Check	0.00a	0.05a	1.50a	14.60c	10.10b	8.90a	21.60a
1x Cytex	0.00a	0.01a	4.10a	31.00ab	27.80a	14.70a	22.70a
2x Cytex	0.00a	0.23a	7.70a	19.20bc	16.60b	11.40a	18.00a
$CaCl_2$	0.00a	0.51a	8.00a	33.90a	19.00ab	17.00a	19.40a
			Amblyseius fallacis				
Check	0.00a	0.07a	0.11a	0.44a	0.73a	1.16b	1.00a
1x Cytex	0.00a	0.10a	0.12a	0.42a	0.83a	1.90a	1.10a
2x Cytex	0.01a	0.24a	0.07a	0.35a	0.90a	0.81b	0.88a
$CaCl_2$	0.00a	0.05a	0.12a	0.58a	0.40a	1.20b	1.10a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

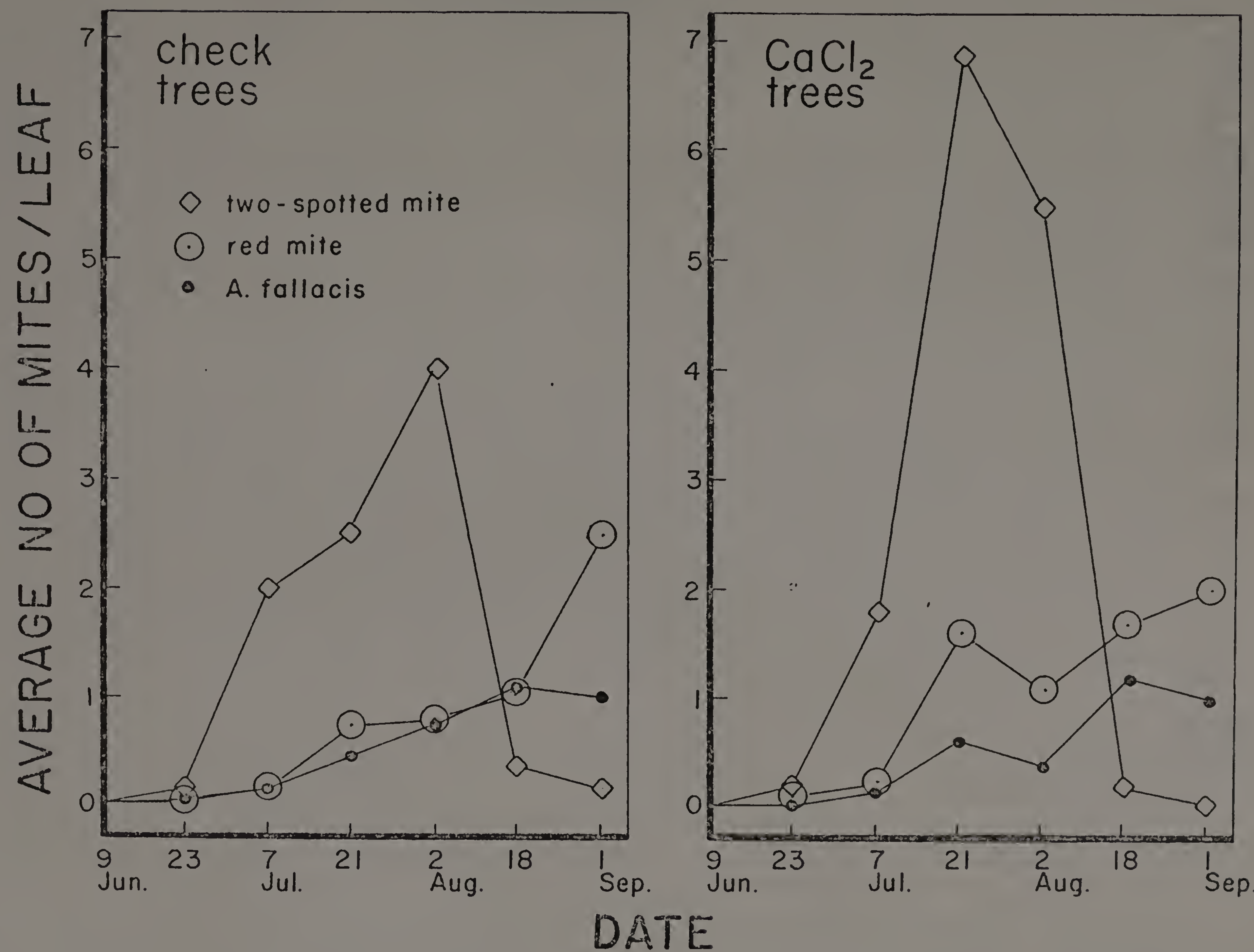

Figure 1a. Population dynamics of European red mite, two-spotted mite and _Amblyseius fallacis_ on 'McIntosh' apple leaves, Belchertown, MA. 1977.

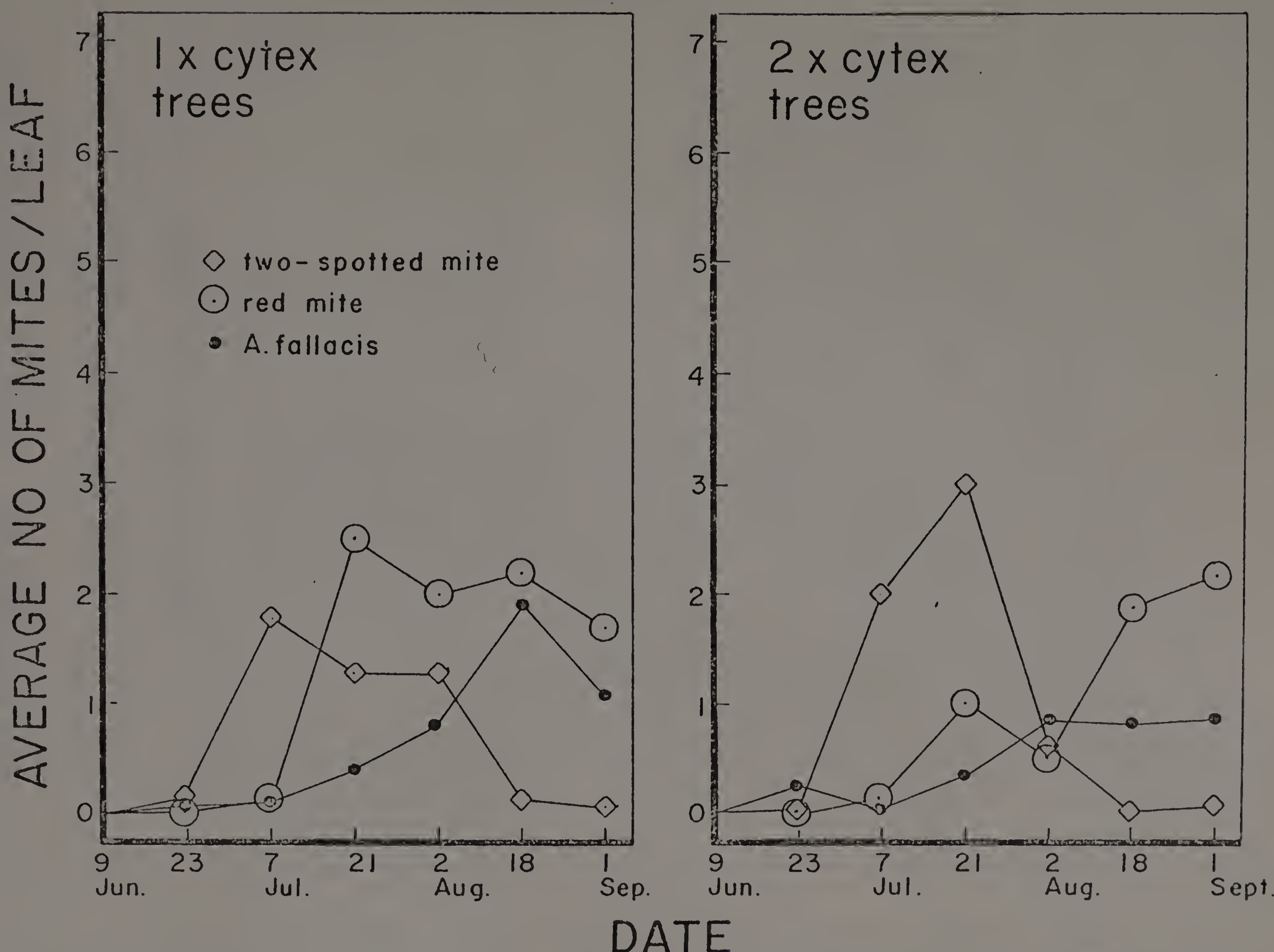

Figure 1b. Population dynamics of European red mite, two-spotted mite and *Amblyseius fallacis* on 'McIntosh' apple leaves, Belchertown, MA. 1977.

allowed ERM populations to rise dramatically (Table 1, 5) and reach potentially damaging levels by early July. Peak red mite numbers were reached in all trees July 28 with check trees averaging a high of 105 mites per leaf (Table 5). Moderate to severe leaf bronzing from mite feeding was evident in most trees by this time but those that received $CaCl_2$ showed the severest damage due to a combination of mite feeding and marginal burn characteristic of $CaCl_2$ sprays (13, 20). Cool temperatures and 6.5 inches (16.5 cm) of rain from July 28 to August 8 may have caused the sharp drop in ERM, two-spotted mite, and rust mite numbers observed on the August 10 sample date (Table 5), although A. fallacis was not affected in a similar fashion. Perhaps, due to their mobility, predatory mites were able to return to the tree canopy in sufficient numbers so that their numbers did not appear to have been influenced by the heavy rainfall. It also is possible that phytophagous mite species may have declined due to an exhaustion of food supply (29). Other workers (32, 59, 63) have correlated declines in rust mite and other eriophyid species with high temperatures and low humidity, conditions which were absent in this orchard in early August. Perhaps a combination of these factors was responsible for the observed population decline. Two-spotted mite numbers were slow to increase in 1978 and had not reached one per leaf on July 13 (Table 5). Interspecific competition with ERM and rust mites may have prevented T. urticae from becoming established in the tree canopy early, although peak numbers were reached in the control, 1x Cytex and $CaCl_2$ trees in late July-early August, as in 1977 (Fig. 2a, 2b). Mean seasonal numbers were

Table 5. Average number of mites per leaf on seven sample dates in trees receiving $CaCl_2$ or Cytex foliar sprays but no insecticides or miticides. 1978.

Treatment	6/15	6/29	7/13	7/28	8/10	8/24	9/8
			European red mites				
Check	0.8a[z]	3.2a	46.4a	105.4a	53.7a	31.7a	12.3a
1x Cytex	0.6a	1.9a	27.0b	67.6b	50.2a	28.4a	15.5a
2x Cytex	1.7a	1.9a	27.6b	90.6a	51.7a	21.7a	13.8a
$CaCl_2$	1.5a	1.1a	19.7b	54.7b	45.6a	27.8a	10.6a
			Two-spotted mites				
Check	0.0a	0.0a	0.1a	6.7a	3.8a	1.7b	0.0a
1x Cytex	0.0a	0.1a	0.0a	7.2a	1.3b	0.83b	0.0a
2x Cytex	0.0a	0.0a	0.8a	0.6c	0.9b	4.1a	0.1a
$CaCl_2$	0.0a	0.0a	0.0a	3.3b	4.9a	3.4a	0.0a
			Apple rust mites				
Check	1.1a	4.2a	168.6a	393.9b	232.9a	146.7a	5.3a
1x Cytex	1.5a	6.2a	125.5b	664.6a	178.9ab	108.1a	6.9a
2x Cytex	3.9a	2.9a	106.2b	279.2c	149.9bc	89.4a	6.6a
$CaCl_2$	1.5a	6.1a	148.2b	211.6d	118.6c	102.1a	9.4a
			Amblyseius fallacis				
Check	0.01a	0.01a	0.08a	0.16a	0.29a	0.24bc	0.12a
1x Cytex	0.0a	0.0a	0.11a	0.19a	0.24a	0.13c	0.05a
2x Cytex	0.0a	0.01a	0.05a	0.16a	0.21a	0.35ab	0.05a
$CaCl_2$	0.0a	0.0	0.03a	0.05a	0.37a	0.45a	0.05a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

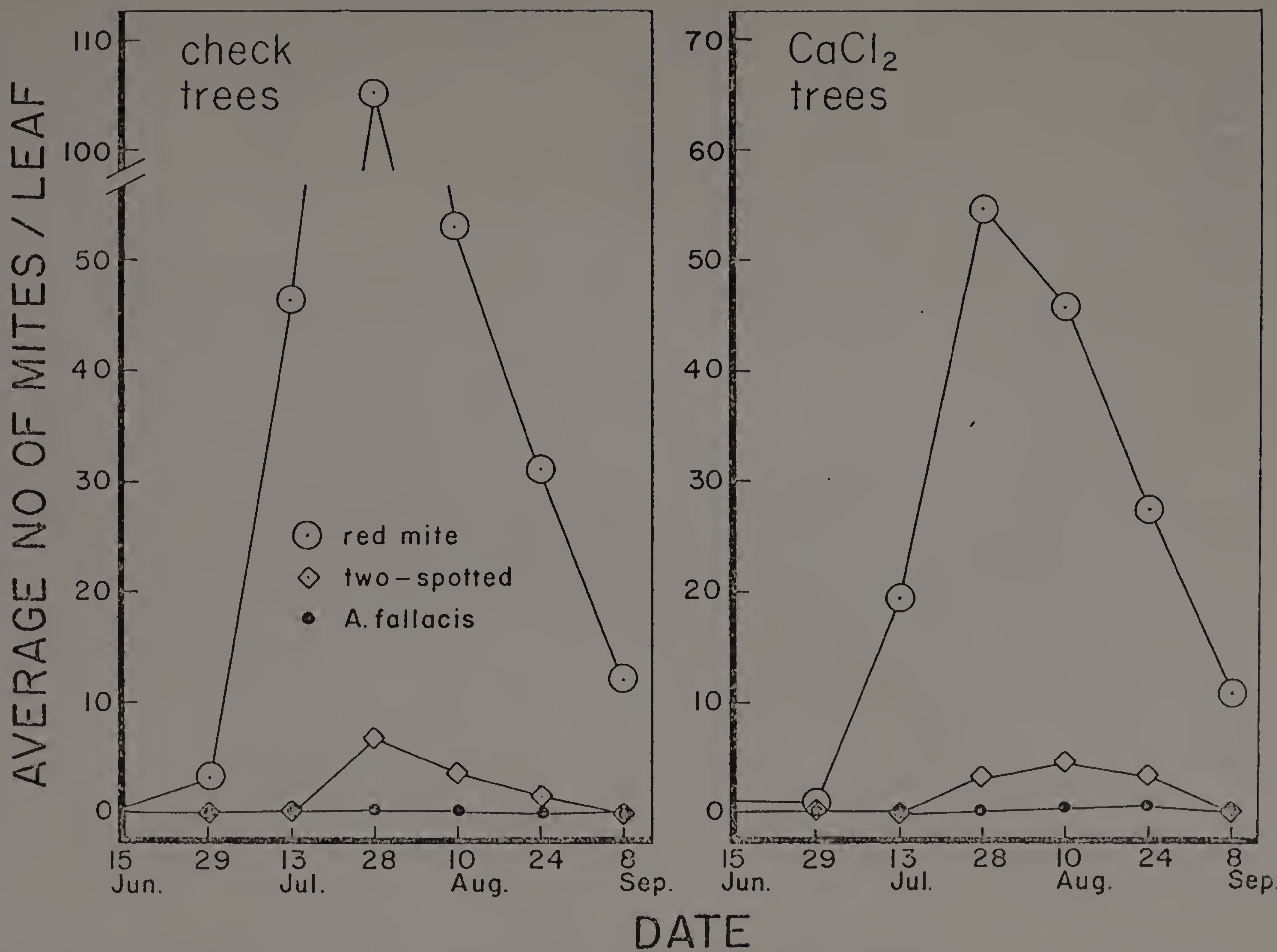

Figure 2a. Population dynamics of European red mite, two-spotted mite and Amblyseius fallacis on 'McIntosh' apple leaves, Belchertown, MA. 1978.

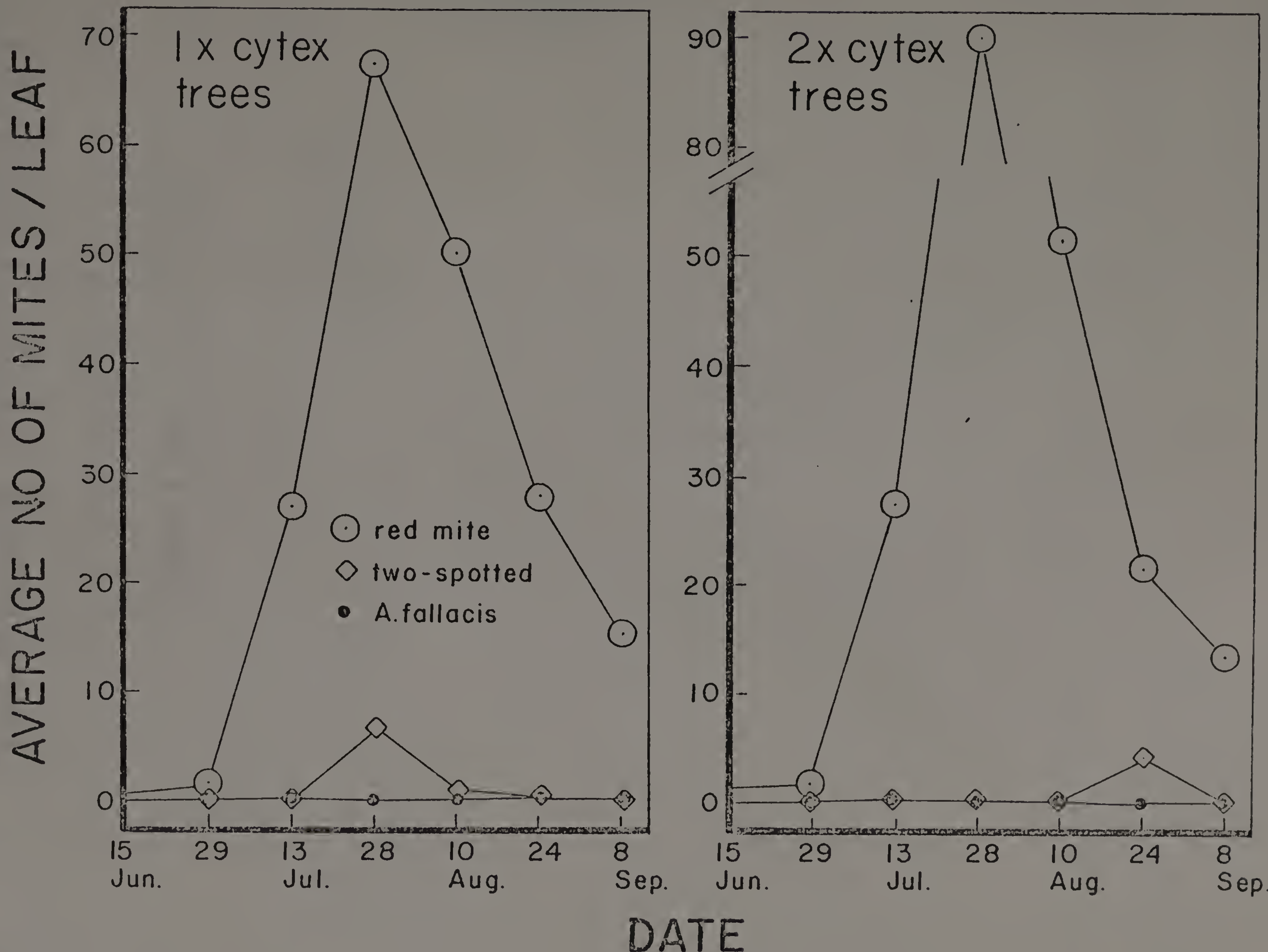

Figure 2b. Population dynamics of European red mite, two-spotted mite and <u>Amblyseius fallacis</u> on 'McIntosh' apple leaves, Belchertown, MA. 1978.

similar in both years, despite the slow emergence of *T. urticae* from the ground cover (Table 1). Peak densities of *A. schlechtendali* were present under all treatments on July 28, with check trees sustaining an average of 394 mites per leaf. $CaCl_2$ trees had fewest rust mites per leaf, with an average of 212 per leaf. There appears to have been no competitive inhibition of red mite numbers by these intermediate to high rust mite populations. Our data indicates that peak populations in both species in most cases were present in the same trees, a finding which is at variance with work of Croft and Hoying (27) and Glass (43). Numbers of *A. fallacis* increased slowly in 1978 despite a plentiful supply of *A. schlechtendali*, an alternative food source (117), and never exceeded 0.5 per leaf under any treatment. Check and 1x Cytex trees had peak predator populations on August 10 while 2x Cytex and $CaCl_2$ trees reached peak numbers on August 24 (Fig. 2a, 2b). The absence of larger numbers of *A. fallacis* in the trees may have been due to their preoccupation with *T. urticae* in the ground cover (not sampled).

Prey/predator ratios.

Programs directed at integrated control of mites in Michigan, New York and Massachusetts rely on prey/predator status rather than mere presence of a certain level of phytophagous mites. Some workers (26) feel that a prey/predator ratio of 7.5 to 1 would appear to be potentailly favorable for control by the predator. Other workers report that the predacious mite *Typhlodromus occidentalis* (25) is capable of biological control of phytophagous species if prey/predator ratio is 10:1 or less in early summer.

Treatments had no effect on ERM/A. fallacis ratios in 1977 or 1978 and on two-spotted/*A. fallacis* ratios in 1977 (Tables 6, 7). $CaCl_2$ trees had a more favorable two-spotted mite/predator ratio in 1978 when compared to the check, although this may merely reflect the difficulty that two-spotted mites had in becoming established in the tree canopy rather than a true treatment effect. $CaCl_2$ does not appear however, to be toxic to *A. fallacis*, although a reduction of red mite numbers was observed in 1978.

Vegetative growth.

Shoot growth was similar among treatments (Table 8) inspite of differences in mite density in 1978 (Table 9) and leaf burn from the $CaCl_2$ sprays in 1977 and 1978. This is possible because leaf burn in both years and high mite numbers in 1978 occurred in early July or later when extension growth was virtually completed. It is surprising that the combination of mite damage and foliar burn failed to cause a greater reduction in limb circumference increase on the $CaCl_2$-treated trees (Table 8). This is particularly true in 1978 when the control and Cytex-treated trees appeared to recover from early mite injury as has been noted by Hoyt (59), whereas on the $CaCl_2$-treated trees spray damage and mite injury became progressively worse.

Leaf elemental content.

N, P, K, Ca or Mg levels did not vary among treatments either year (Table 10). Mite densities varied independently of N and differences in mite populations had no effect on the percentage of N (Table 10).

Table 6. The effect of $CaCl_2$ and Cytex foliar sprays on European red mite/predator ratio in 'McIntosh' trees receiving fungicides but no insecticides or miticides.

Treatments	Sampling dates, 1977							
	6/9	6/23	7/7	7/21	8/2	8/18	9/1	Season mean
Check	0	.45	2.8	7.4	1.3	1.1	2.6	2.2a[z]
1x Cytex	0.17	.73	3.8	11.0	1.7	1.2	1.5	2.9a
2x Cytex	0	.38	3.3	5.6	1.2	1.5	2.2	2.0a
$CaCl_2$	0	.51	4.7	20.7	10.1	2.2	2.5	5.8a

	Sampling dates, 1978							
	6/15	6/29	7/13	7/28	8/10	8/24	9/8	Season mean
Check	18.7	78.7	939.4	1537.0	390.9	470.8	188.5	517.7a
1x Cytex	22.8	47.3	355.3	1160.7	392.4	310.1	310.3	371.3a
2x Cytex	45.2	54.7	480.4	1538.6	371.3	165.8	260.0	416.6a
$CaCl_2$	38.3	26.8	346.8	1053.8	242.7	72.7	234.8	288.0a

[z] Mean separation within columns using Duncan's new multiple range test, 5% level.

Table 7. The effect of $CaCl_2$ and Cytex foliar sprays on two-spotted mite/predator ratios in 'McIntosh' trees receiving fungicides but no insecticides or miticides.

	Sampling dates, 1977							
Treatments	6/9	6/23	7/7	7/21	8/2	8/18	9/1	Season mean
Check	.67	1.7	19.6	20.0	6.2	.36	.20	6.9a[z]
1x Cytex	.33	1.9	14.2	5.1	1.7	.12	.08	3.4a
2x Cytex	1.2	.83	12.0	6.8	1.8	.07	.14	3.3a
$CaCl_2$	.33	1.2	26.1	114.9	6.1	.18	.15	21.3a

	Sampling dates, 1978							
	6/15	6/29	7/13	7/28	8/10	8/24	9/8	Season mean
Check	0	.17	3.4	75.8	18.5	19.2	.13	16.7a[z]
1x Cytex	0	.17	.18	68.7	9.6	7.8	.02	12.3ab
2x Cytex	0	.17	11.9	4.7	4.6	22.6	.17	42.2ab
$CaCl_2$	0	0	.04	73.8	17.0	8.5	.02	6.3b

[z] Mean separation within columns using Duncan's new multiple range test, 5% level.

Table 8. The effect of $CaCl_2$ and Cytex foliar sprays on shoot growth and limb circumference increase of 'McIntosh' trees receiving fungicides but no insecticides or miticides[z].

	Shoot growth (cm)		Limb circumference increase (cm)	
Treatments	1977	1978	1977	1978
Check	32a[y]	26a	1.66a	.90a
1x Cytex	33a	25a	1.43ab	.84a
2x Cytex	32a	26a	1.60a	.72ab
$CaCl_2$	33a	23a	1.05b	.63b

[z] Trees received an accidental spray contaminated with Imidan July 15, 1977.

[y] Mean separation within columns, using Duncan's new multiple range test, 5% level.

Table 9. The effect of $CaCl_2$ or Cytex foliar sprays on mean seasonal numbers of phytophagous spider mites and the major phytoseiid predator Amblyseius fallacis on 'McIntosh' leaves.

	P. ulmi		T. urticae		A. schlechtendali		A. fallacis	
Treatments	1977	1978	1977	1978	1977	1978	1977	1978
Check	19.2a[y]	905.5a	34.1a	44.4a	26.2a	4216.4a	12.6a	3.2a
1x Cytex	33.0a	683.8ab	17.3a	33.4ab	47.5a	3108.6a	16.8a	2.6a
2x Cytex	21.3a	747.4ab	21.4a	22.6b	34.0a	2278.7b	12.7a	3.0a
$CaCl_2$	24.3a	574.4b	53.7a	41.2ab	45.3a	2134.7b	11.8a	3.4a

[z] Means represent total motile mites on 25 leaves per three-tree replicate x 6 replicates x 7 sample dates.

[y] Mean separation within columns, using Duncan's new multiple range test, 5% level.

In contrast, other researchers have noted that insect and mite numbers varied directly with leaf N levels (32, 97, 98, 108) and that N was reduced by high mite numbers (60, 67). Ca levels were abnormally low in 1977 (Table 10) perhaps due to excessive washing of leaf samples prior to drying. Awad and Kenworthy (7) reported that Ca content of apple leaves was higher in late than early summer. This occurred only in leaves from 2x Cytex trees in 1977 (Table 10). In 1978, Ca remained low, but increased from first to last sampling date, with $CaCl_2$ trees having highest Ca content, although this trend was not significant. Awad and Kenworthy (7) also reported that Mg content of apple leaves increased during the growing season. We found that Mg in leaves from $CaCl_2$ trees was lower in September than in June (Table 10). This may have been due to severe foliar injury leading to a net reduction in chlorophyll, a Mg containing molecule (Table 11).

Bloom and fruit set.

$CaCl_2$ and both Cytex treatments applied in 1977 reduced the amount of bloom per cm limb circumference in 1978 (Table 11). Fruit set was highest on trees that received 2x Cytex the previous season but this difference was not related to differences in mite densities in 1977 (Table 9). However, workers at Clemson (104) have reported increased fruit set of certain vegetables from aqueous seaweed extracts applied at bloom. Varga (114) found kinetin, which is present in seaweed extracts (3) increased fruit set of pears. Martin *et al.*(80) increased fruit set and the length/diameter ratio of 'Delicious' apples with a 500 ppm cytokinin spray applied 3 days after petal fall.

Table 10. Levels of certain elements in 'McIntosh' apple leaves that received fungicides but no insecticides or miticides[z].

Treatments	N (%)		P (%)		Ca (%)		K (%)		Mg (%)	
	June[y]	Sept	June	Sept	June	Sept	June	Sept	June	Sept
					1977					
Check	2.3a[x]	2.1a	.28a	.18a	.57a	.52a	1.6a	1.3a	.25a	.31a
1x Cytex	2.2a	2.0a	.25b	.18a	.55a	.33a	1.8a	1.5a	.25a	.27a
2x Cytex	2.3a	2.0a	.27b	.18a	.52a	.71a	1.7a	1.4a	.22a	.28a
$CaCl_2$	2.3a	2.0a	.24ab	.17a	.74a	.46a	1.7a	1.3a	.27a	.26a
					1978					
Check	2.6a	1.8a	.21a	.12a	.68a	.92ab	1.7a	.84a	.33a	.32a
1x Cytex	2.6a	1.9a	.23a	.12a	.63a	.90ab	1.7a	.86a	.32a	.32a
2x Cytex	2.5a	1.7a	.22a	.12a	.58a	.80b	1.7a	.84a	.30a	.30a
$CaCl_2$	2.6a	1.7a	.22a	.12a	.63a	1.04a	1.7a	.77a	.32a	.29a

[z] Trees received an accidental spray contaminated with Imidan on July 15, 1977.

[y] Sampling dates: 1977 - 6/1 and 9/8; 1978 - 6/13 and 9/29.

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

Table 11. The effect of $CaCl_2$ or Cytex foliar sprays on bloom, fruit set and leaf chlorophyll of 'McIntosh' trees which received fungicides but no insecticides or miticides[z].

Treatments	Blossom clusters/cm limb circ 1978	Fruit set/ cm limb circ 1978	Mean foliar chlorophyll (mg/l)[y] 1978
Check	14.58a	5.8b[x]	41.3a
1x Cytex	10.87b	7.6ab	42.5a
2x Cytex	13.41b	9.0a	40.4a
$CaCl_2$	12.93b	6.8ab	33.3b

[z] Trees received an accidental spray contaminated with Imidan on July 15, 1977.

[y] Chlorophyll extract performed Aug. 7, 1978.

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

Recently, Abdul-Rahman (2) reported increased fruit set in 'Delicious' using petal fall applications of Cytex. In trials in a Massachusetts commercial orchard in 1978, this author found increased fruit set in 'Royal Red Delicious' apples (Table 12) and increased length/diameter ratio in 'Standard Delicious' (Table 13) using 1x Cytex sprays at bloom and petal fall respectively. Grebnanowski (46) reported that $CaCl_2$ sprays increased bloom of apples, which is contrary to our findings (Table 11).

Preharvest drop.

In 1977, drop was greater from the 2x Cytex trees (Table 14). We are not able to suggest an explanation for this finding, although it is not believed to be due to differential mite feeding, advanced fruit maturity or foliar injury. Fruit drop was severe on the $CaCl_2$ trees in 1978 (Table 14), and is attributed to extensive foliar injury which hastened fruit maturity in response to wound ethylene. The severity of drop from $CaCl_2$ trees necessitated collection of data over a shorter period than in 1977 to have enough fruit remaining until harvest for storage.

Red Color.

The percentage of fruit surface with red color was similar among treatments at harvest in 1977 (Table 14). In 1978 the fruits from $CaCl_2$ treated trees had more red color than those from check trees (Table 14). This finding is at variance with work in New Zealand Orchards (24) where $CaCl_2$ had no effect on fruit color. Again, the

Table 12. The effect of Cytex and Ergostim foliar sprays on fruit set, fruit weight and L/D ratios of 'Royal Red Delicious' apples.

Treatments	Fruit per blossom clusters	Fruit per cm lumb circumference	Fruit weight (g)	L/D Ratios
Check	41.2b[z]	7.1b	109b	0.96a
Cytex, 2 pts/A full bloom	36.1b	6.4b	119ab	0.95a
Cytex, 4 pts/A full bloom	41.0b	7.6ab	125a	0.96a
Ergostim full bloom	38.3b	7.2b	117ab	0.97a
Cytex, 2 pts/A petal fall	56.8a	9.3a	128a	0.96a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

Table 13. The effect of Cytex and Ergostim foliar sprays on fruit set, fruit weight and L/D ratios of 'Standard Delicious' apples.

Treatments and timing	Fruit per 100 blossom clusters	Fruit weight (g)	L/D Ratios	Fruit per cm limb circ
Check	44.1a[z]	116a	.923b	6.85a
1x Cytex full bloom	41.0a	112a	.947a	6.52a
2x Cytex full bloom	43.7a	110a	.932ab	7.52a
Ergostim full bloom	45.6a	117a	.938ab	5.50a
1x Cytex petal fall	33.8a	104a	.937ab	6.55a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

additive effect of marginal leaf burn may be a factor here, since mite feeding typically results in poorly colored fruit (26, 71) and it is possible that the extensive leaf injury due to $CaCl_2$ sprays may have produced wound ethylene that hastened red color development in these fruits.

Soluble Solids.

Treatments had no effect on soluble solids in 1978, the only year in which data was collected (Table 14).

Fruit Size.

There were no differences in fruit weight among treatments in 1977 (Table 14). The fruits averaged 3 inches (76.2 mm) in diameter (data not shown) which indicated that 'McIntosh' trees under certain conditions can tolerate some damage from $CaCl_2$ sprays and mite bronzing and produce large apples. In contrast the majority of fruits from the $CaCl_2$ trees were smaller than 2-1/4 inches (57.2 mm) diameter in 1978 (data not shown). Average fruit weight was also reduced by $CaCl_2$ sprays (Table 14). Heavy mite feeding combined with reduced photosynthetic area from marginal leaf burn probably accounts for the reduction in fruit size. Hall and Ferree (48, 49) showed that a 10 to 20% reduction in leaf area results in a reduction of fruit size of apples. The control and Cytex trees, inspite of higher mite numbers than on the $CaCl_2$ treated trees, produced a high percentage of large fruits (Table 14).

Internal ethylene.

Ethylene concentrations were highest in the fruits from the $CaCl_2$

Table 14. The effect of $CaCl_2$ and Cytex foliar sprays on red color, soluble solids, fruit size and preharvest drop of 'McIntosh' apples which received fungicides but no insecticides or miticides[z].

Treatments	Red color (%)		Soluble solids (%)	Fruit size (g)		Preharvest drop (%)	
	1977	1978	1978	1977	1978	1977	1978
Check	57a[y]	63b	10.9a	192a	109a	28b	8b
1x Cytex	57a	63b	10.6a	190a	112a	34ab	14b
2x Cytex	56a	66b	10.1a	189a	111a	44a	14b
$CaCl_2$	55a	77a	10.5a	184a	95b	34ab	42a

[z] Trees received an accidental spray contamination with Imidan on July 15, 1977.

[y] Mean separation within columns, using Duncan's new multiple range test, 5% level.

trees when sampled on September 8, 1978 (Table 15). A concentration of 80 ppm ethylene has been reported in 'McIntosh' fruit prior to the peak of respiratory activity (21). Thus the $CaCl_2$ fruits had advanced further in their climacteric rise than the check or Cytex-treated fruits. On September 15, the Cytex treated fruits had lower ethylene concentrations than those from the check trees, perhaps due to experimental error. The $CaCl_2$ fruits had a noticeably higher ethylene content than check fruits, although this difference was not significant. Lack of significant differences probably can be attributed to heavy drop of the more mature fruit between sampling dates. By September 29, all treatments had advanced in the respiratory climacteric as indicated by the rather uniform levels of internal ethylene.

Fruit flesh firmness.

On the first harvest date in 1977, 2x Cytex increased flesh firmness, but the difference disappeared by the second harvest date (Table 16). In 1978 both concentrations of Cytex increased fruit firmness. This slight but significant flesh firmness increase is probably of no practical importance since the differences disappeared in storage. On the second harvest date in 1977, $CaCl_2$ fruits were softer, otherwise this treatment did not influence firmness (Table 16). It should be noted that although $CaCl_2$ fruits were not softer at harvest in 1978 than those from the control trees (Table 16), these fruits were significantly smaller (Table 14). Had it been possible

Table 15. The effect of $CaCl_2$ and Cytex foliar sprays on internal ethylene concentrations in 'McIntosh' apples on three sample dates.

	Internal C_2H_4 (ppm)			
Treatments	9/8/78	9/15/78	9/29/78	Season mean
Check	3.4b[z]	9.4a	61.4a	24.8b
1x Cytex	4.3b	0.2b	71.1a	25.2b
2x Cytex	2.9b	7.5a	92.4a	34.3b
$CaCl_2$	80.3a	60.5a	90.7a	77.2a

[z] Mean separation within columns, using Duncan's new multiple range test, 5% level.

Table 16. The effect of $CaCl_2$ and Cytex foliar sprays on firmness (kg) of 'McIntosh' apples at harvest and after storage at 0° C. in air.

Treatments	Firmness at harvest (kg)			Firmness (kg) after cold storage[z]	
	9/1/77	9/15/77	9/10/78	1977	1978
Check	6.61bc[y]	6.45a	6.76b	4.30a	6.42a
1x Cytex	6.82ab	6.64a	6.88a	4.37a	6.43a
2x Cytex	6.83a	6.55a	6.90a	4.29a	6.31a
$CaCl_2$	6.59c	6.38b	6.81ab	4.32a	6.22b

[z] Storage duration: 1977 - 120 days; 1978 - 97 days

[y] Mean separation within columns, using Duncan's new multiple range test, 5% level.

to test fruit of comparable size for all treatments, we believe that $CaCl_2$ treated fruit would have been softer, reflecting their advanced maturity.

Fruit condition after storage.

The Cytex and $CaCl_2$ treatments reduced bitter pit and brown core in 1977 (Table 17) and the $CaCl_2$ fruits had the least storage breakdown (Table 17). In 1978, bitter pit and breakdown were virtually non-existent and scald was not a problem in either year. $CaCl_2$-treated fruits had significantly more brown core than the checks in 1978, perhaps due to the advanced maturity of these fruit at harvest (39). Rasmussen however, (93), reduced the incidence of this disorder by leaving fruit at room temperature for 5 days prior to storage, a treatment which would hasten fruit maturation. Other workers (107) also have found brown core to be inversely related to maturity. Forsyth and Eaves (39) found reduced core browning in apples held in CA with low levels (10 ppm) of ethylene. Perhaps observed higher levels of ethylene in $CaCl_2$ treated fruit (Table 15) are related to the greater incidence of this disorder in 1978. The data in Table 17 refer only to the presence or absence of brown core after storage. Rating the severity of injury may have revealed more striking differences among treatments. In 1977, fruit were large, perhaps due to leaf N levels in excess of 2% dry weight, and in relatively poor condition prior to storage, with numerous bruises. The storage period of 120 days was unrealistically long for these

Table 17. The effect of $CaCl_2$ and Cytex foliar sprays on storage disorders of 'McIntosh' apples from trees receiving fungicides but no insecticides or miticides following air storage at 0° C[z].

Treatments	Bitter pit (%)		Brown core (%)		Breakdown (%)		Scald (%)	
	1977	1978	1977	1978	1977	1978	1977	1978
Check	8a[y]	1ab	28a	9b	33a	0	1a	0
1x Cytex	4b	2a	17b	17ab	39a	0	1a	0
2x Cytex	3bc	2a	18b	14ab	36a	0	2a	0
$CaCl_2$	1c	0b	20b	21a	11b	0	1a	0

[z] Storage duration: 1977 - 120 days; 1978 - 97 days.

[y] Mean separation within columns, using Duncan's new multiple range test, 5% level.

fruits, since a commercial grower would probably have released them for immediate sale. Fruits were nearer optimum size and condition in 1978 and could easily have been stored longer than 97 days, although N levels were again in excess of 2% dry weight.

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