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CONTENTS

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ON THE COVER: Studies on summer pruning and mechanical shaping of fruit trees for high density orchards are being undertaken at the OARDC, Wooster. The Research Center acknowledges the financial support of the Ohio Fruit Growers Society in helping to secure the equipment shown on the cover.

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Performance of Selected Apple Cultivars on Semi-standard Rootstocks in Southern Ohio

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INTRODUCTION

Since most of Ohio's apple crop is sold for fresh consumption, the performance of new cultivars on various rootstocks must be continually evaluated to insure the greatest possible cropping efficiency. A complicating factor in establishing reliable cultivar recommendations is the influence of the different climatic regions of Ohio on cultivar performance.

The performance of selected cultivar/rootstock combinations in the following regions of Ohio have been summarized in past reports: North Central (1, 3), Northeast (5, 6), and Central (2). The only previous report from southern Ohio covered the performance of 12 strains of Golden Delicious on M26. Since trees in the southern part of Ohio bloom 10-14 days earlier than the northern areas and experience warmer temperatures during the growing and harvest periods, a more extensive evaluation of cultivar/rootstock performance in this area is needed.

MATERIALS AND METHODS

To evaluate the productive efficiency of various cultivars on several semi-standard rootstocks, a planting was established in 1969 at the Southern Branch of the Ohio Agricultural Research and Development Center at Ripley. The trees were planted in north-south rows at a spacing of 12' x 18' with 1-10 trees of each cultivar/rootstock combination which were completely randomized. The trees were trained as central leaders using limb spreaders and maintained with standard orchard practices. Yield/tree and trunk circumference were taken annually and in 1979 tree height and spread were determined.

RESULTS AND DISCUSSION

Spur cultivars on apple seedling rootstock averaged 20 and 35% larger trunk cross-sections than on MM104 and MM111, respectively (Table 1). Golden Delicious spur strains were generally more efficient than Delicious spur strains on all rootstocks. The spur strains of Golden Delicious had more russet than the standard and Frazier and Nugget tended to have

TABLE 1.—Tree Size and Production of Selected Cultivars on One of the Following Rootstocks: MM104, MM111, and Apple Seedling, 1969 Through 1979, Southern Branch, Ohio Agricultural Research and Development Center, Ripley.

Cultivar	No. of Trees	Ht. (ft)	Spread (ft)	Trunk Cross Section (cm^2)	Accumulated Yield/Tree (lb)	Efficiency* (lb/cm^2)
		MM104				
Ruby	6	19.6	13.3	186	1068	5.8
Wellspur	3	17.5	10.3	166	539	3.3
Frazier	7	16.1	10.8	164	725	4.6
Earlistripe	8	15.1	10.7	123	379	3.3
Hardispur	7	16.1	10.9	155	520	3.4
		MM111				
RedSpur	4	16.3	9.1	129	358	2.8
Sundale	6	16.3	11.4	129	599	4.8
Goldspur	6	15.6	9.7	115	675	5.7
Sturdeespur	5	16.7	12.0	147	523	3.6
		Apple Seedling				
Golden Delicious	2	19.8	15.8	318	1713	5.3
Starkrimson	6	16.5	12.5	187	432	2.3
Goldspur	6	15.5	12.9	158	875	5.7
Nugget	8	19.3	12.8	224	922	4.2
Skyspur	6	16.2	12.3	165	296	2.0
Red Rome Seeando	4	15.0	12.9	145	1011	7.1

*Yield/trunk cross-sectional area.

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TABLE 2.—Tree Size and Production of Selected Cultivars on M7 and MM106 Rootstocks, 1969 Through 1979, Southern Branch, Ohio Agricultural Research and Development Center, Ripley.

Cultivar	No. of Trees	Ht. (ft)	Spread (ft)	Trunk Cross Section (cm^2)	Accumulated Yield/Tree (lb)	Efficiency* (lb/cm^2)
			M7			
Gallia Beauty	6	16.5	12.3	160	1013	6.4
Ruby	7	17.5	12.1	181	1068	5.0
Double Red Jonathan	6	17.5	14.0	202	905	4.5
Wellspur	4	15.8	10.6	133	517	3.9
Barkley Red Rome	6	17.8	12.5	101	1119	5.9
			MM106			
Red Prince	5	18.2	14.8	198	1083	3.8
Red Queen	6	19.0	14.0	237	630	4.6
RedSpur	8	16.3	12.1	148	795	4.3
Ryan Red	8	17.8	13.0	179	958	4.6
Sundale	6	16.3	10.7	136	967	7.0
Quinte	3	18.0	16.3	329	1390	2.9
Goldspur	4	17.5	11.8	156	1126	7.2
Sturdeespur	6	16.4	12.6	167	643	3.9
Jonee	6	18.2	14.7	216	1293	6.0

*Yield/trunk cross-sectional area.

more russet than Sundale and Goldspur. Golden Delicious and Ruby were the highest producing cultivars and Skyspur Delicious the lowest yielding of the cultivars mentioned in Table 1. Tree loss on these rootstocks over a 10-year period was minimal as follows: MM104 (33 trees, 9% loss), MM111 (24 trees, 8% loss), and apple seedling (38 trees, 3% loss).

Golden Delicious, Mutsu (Table 3), Gallia Beauty, Barkley Red Rome, and Ruby (Table 2) were the most efficient and among the most productive trees on M7. Holiday and various strains of Delicious had the lowest efficiency and cumulative yields on M7 and were generally slightly more efficient and more productive on MM106. Although King Lucious was productive, the fruit quality was only fair and red coloration dull and unattractive. Mollies had large fruit size, a mild, sweet flavor, and generally could be harvested before Delicious. They may have a place in roadside sales, although the fruit were generally only 40-50% red. Jonee was a productive early strain of Jonathan that has promise. Smoothee had less russet and was slightly more efficient than Golden Delicious and these two standard habit strains were equal in production. The spur strains of Golden Delicious, Sundale, and Goldspur were smaller by nearly 18% than the standard strains, Golden Delicious and Smoothee. The spur strains had more russet and were no more efficient than the standard strains on MM106. These data agree with a previous report (4) on strains of Golden Delicious.

The average characteristics of all cultivars on M7 and MM106 are compared in Table 4. Trees on MM106 had 17% larger trunk cross-sectional areas and a 7% greater spread than trees on M7 and trees on MM106 maintained a faster growth rate as evidenced by a greater increase in trunk circumference (1978-1979). The allotted row space of 12'/tree was exceeded. (M7—14%, MM106—20%) by both rootstocks. The aisle (18') was overgrown and required summer pruning to permit normal harvest operations. Based on tree growth during the 10-year period, the planting distance for standard habit culti-

TABLE 4.—Performance of M7 and MM106 Rootstocks, 1969 Through 1979, Southern Branch, Ohio Agricultural Research and Development Center, Ripley.

	Rootstock	
	M7	**MM106**
Tree Size:		
Average Tree Height (ft)	17	18
Average Tree Spread (ft)	14	15
Average Trunk Circumference (cm)	49.1	52.1
Average Change in Trunk Circumference (cm)	3.9	4.2
Average Trunk Cross-Sectional Area (cm^2)	194	235
Tree Loss:		
Total Trees Planted	101	157
Total Trees Dead	10	4
Percentage Loss	9.9	2.5
Production:		
Average Yield/Tree/Year (lb)	83	100
Cumulative Yield/Tree (lb)	950	1119
Cumulative Yield/Acre (bu)*	3189	3277
Efficiency lb/cm^2	4.98	4.97

*Calculated using spacing based on average tree spread with an 8' aisle.

vars should be spaced 15' x 23' and 16' x 24' on M7 and MM106, respectively. Spur cultivars could be spaced 11' x 19' and 13' x 21' on M7 and MM106, respectively, for greatest management efficiency.

Yield efficiency was very similar between M7 and MM106 as judged by production/unit trunk cross-sectional area and calculated yield/acre. Average annual yield and cumulative yields/tree were slightly higher on the larger MM106 trees. Tree loss on both stocks was minimal in this planting, but observations of grower orchards would indicate more loss of trees on MM106 than on M7. This fact coupled with the slightly larger size of MM106 would make M7 the preferred rootstock for most Ohio soil types.

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TABLE 3.—Tree Size and Production of Six Standard Habit Delicious Strains and Eight Cultivars on M7 and MM106, 1969 Through 1979, Southern Branch, Ohio Agricultural Research and Development Center, Ripley.

	M7						MM106					
Cultivar	No. of Trees	Ht. (ft)	Spread (ft)	Trunk Cross Section (cm²)	Accumulated Yield/Tree (lb)	Efficiency (lb/cm²)	No. of Trees	Ht. (ft)	Spread (ft)	Trunk Cross Section (cm²)	Accumulated Yield/Tree (lb)	Efficiency (lb/cm²)
Delicious Strains												
Hi Early	2	18	15	227	680	2.96	6	18	15	227	857	3.79
Imperial	1	19	14	191	1249	6.51	6	19	14	225	848	3.75
Red King	5	18	12	163	554	3.35	7	19	14	212	838	3:95
Royal Red	6	16	13	157	593	3.83	3	19	15	227	873	3.95
Skyline Supreme	6	19	13	235	603	2.52	8	19	14	214	671	3.05
Topred	5	19	14	208	866	2.72	6	18	14	212	974	4.66
Other Cultivars												
Golden Delicious	5	17	13	163	1364	8.31	10	18	13	189	1453	7.74
Holiday	8	16	14	198	540	2.84	6	17	16	256	754	2.95
King Lucious	6	19	15	247	1073	4.32	6	18	15	251	1042	3.83
Melrose	6	19	15	200	687	3.47	5	20	14	289	858	2.98
Mollies	1	17	17	270	1062	3.92	5	16	15	194	945	5.21
Mutsu	1	15	11	103	583	5.62	5	18	16	294	1220	4.15
Red Rome	5	16	13	163	1024	6.43	7	16	13	171	1197	6.92
Red Stayman	6	17	14	211	1044	4.90	6	19	15	238	1364	5.98

Influence of Summer Pruning and Alar on Growth, Flowering, and Fruit Set of Jerseymac Apple Trees

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SUMMARY

Flower density of Jerseymac/M9 apple decreased with summer pruning. Fruit set was increased by pruning in June or repeated pruning in June, July, and August. Alar application in combination with pruning in June increased fruit set in the second season. Multiple summer prunings did not reduce shoot growth when compared to a single summer pruning.

INTRODUCTION

In many of the intensive plantings of recent years, the natural vigor of the scion/rootstock combination, soil fertility, and plant spacing have been mismatched and overcrowding has resulted. Dormant pruning may aggravate this problem by inducing increased vigor adjacent to the pruning cuts which in turn delays bearing.

Summer pruning has been suggested as a means of controlling vigorous trees. Early work in the United States revealed that summer pruning resulted in weak growth and tree devitalization when compared with dormant pruning of equal severity (1, 5). Summer pruning has been effectively used to manage intensive orchards in Europe for many years (9, 10). In addition to the devitalizing effect of summer pruning, several researchers (6, 8) have shown that flowering can be increased, particularly by pruning early in the growing season. However, pruning early in the summer results in more vegetative regrowth (2, 6, 7) than pruning in late summer.

Spray applications of Alar in combination with summer pruning have been tested on vigorous apple cultivars to reduce growth and enhance flowering, with varying results (3, 4). This study was initiated to determine the influence of timing and frequency of summer pruning in a Jerseymac planting exhibiting very vigorous growth.

MATERIALS AND METHODS

Trees of Jerseymac on M9 rootstock planted in 1975 in a grower orchard near Kingsville, Ohio, on a very fertile silt loam soil at a spacing of 2.44 x 3.66 m and trained on a four-wire trellis were used. The trees had filled their allotted space at the completion of the second growing season and were making 40-60 cm of terminal growth annually.

To test effects on containing vigorous growth, the following pruning treatments were applied at the mid-point of each month during the third and fourth growing seasons (1977 and 1978): 1) CK—unpruned, and pruning in 2) June, 3) July, 4) August, 5) June and August, 6) July and August, 7) June, July, and August. Additional treatments of Alar (2000 ppm) and Alar plus June pruning were made, with the spray applied in mid-June. Pruning cuts were made on all current season growth, leaving three to four leaves. On treatments with repeat pruning, second cuts were made on regrowth shoots by cutting them back to three leaves. The trees received no additional pruning during the dormant season. Treatments were arranged as randomized complete blocks with six single tree applications.

Length of 10 current season shoots/tree was measured after each growing season. This measurement included the length of the stub below the cut, plus regrowth on pruned shoots. Flower density and fruit were determined on two representative limbs/tree by counting flowers and fruit and measuring limb circumference. To study the influence of the localized effect of summer pruning on fruit set, six pruned shoots/tree or corresponding shoots on unpruned trees were tagged and flowers and fruit counted. Five independent raters evaluated degree of bloom in 1978 using a scale of 1 = no bloom to 10 = snowball bloom. The percent of pruned shoots with regrowth was determined by counting 20 pruned shoots/tree. Before harvest in 1978, three independent raters evaluated yield by using a scale of 0 = no fruit to 100 = full crop.

RESULTS AND DISCUSSION

The grower did not apply fertilizer to the very vigorous trees and permitted some weed competition during the third growing season (1977). These practices coupled with the rootstock influence resulted in a significant decrease in vegetative growth compared to previous seasons. Summer pruned shoots were generally shorter than unpruned controls (Tables 1 and 2). After the first year of pruning

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(1978), shoots pruned in August were shorter than those pruned in June and July (Table 1). However, after the second year of pruning, growth did not vary in relation to time of pruning (Table 2). As pruning was performed later in the summer, the percentage of shoots with regrowth decreased.

The number of flowers or fruit/cm of limb circumference was not influenced by 1 year of summer pruning. After two seasons, however, all pruning treatments reduced the number of flowers/cm limb circumference. Since Jerseymac produced flowers both terminally and in lateral buds on 1-year wood, a reduction in flowering would be expected. Lord *et al.* (6) reported a similar response for Cortland but not for Red Prince Delicious, which seldom flowers on 1-year wood.

Pruning in June or multiple pruning (June, July, and August) increased fruit set in both years on whole limbs. These data support the findings (6, 8) that fruit set can be increased by summer pruning during the first half of the growing season. Treatments did not affect fruit set on pruned shoots after 1 year. But, following 2 years of pruning, fruit set on pruned shoots was increased by multiple pruning (June and August or June, July, and August) and treatment with Alar plus June pruning.

Alar sprays were applied too late in the growing season to influence unpruned, vegetative growth in this study. There appeared to be no carryover effect the following year on vegetative growth. The combination of Alar and June pruning (Table 2) showed a trend toward greater fruit set than either treatment alone. Although not significant in either study, this trend also appeared in the data of Elfving and Forshey (4). Cartwright and Meakin (3) found no reduction in number of shoots produced

TABLE 1.—Influence of 1 Year of Various Times of Summer Pruning and Alar on Growth, Flowering, and Fruit Set of 4-Year-Old Jerseymac Apple Trees on M9 Rootstock, 1978.

Treatments	Average Shoot Length* (cm)	Pruned Shoots with Regrowth† (%)	Bloom Rating‡ (1-10)	Flower Clusters/cm Limb Circ.	Fruit/cm Limb Circ.	Fruit Set (%)	Fruit Set Pruned Shoots** (%)
Unpruned	22a††		6.5a	5.9a	0.5a	14c	16a
June	17b	67a	5.5bc	6.1a	1.3a	25a	21a
July	19ab	49b	4.3e	6.1a	0.7a	18c	20a
August	11d	16c	5.0cd	6.1a	0.9a	15c	12a
June and August	11d	47b	4.2e	5.7a	0.6a	17bc	14a
July and August	12cd	64ab	4.7de	6.0a	0.5a	15c	16a
June, July and August	16bc	67a	5.4bcd	5.7a	1.3a	24ab	9a
Alar (2000 ppm)	21ab		6.0ab	6.1a	0.9a	15c	14a
Alar (2000 ppm) + June	20ab	3c	5.4bcd	5.9a	0.6a	20abc	25a

*Total length of growth produced in 1977 (10 shoots/tree). Trees summer pruned in 1977 and 1978

†Percent of 20 pruned shoots/tree that had regrowth.

‡Average of five independent raters using scale: 1 = no bloom, 10 = snowball bloom.

**Flowers and fruit on six tagged shoots/tree that were pruned or corresponding shoots on unpruned trees

††Mean separation within columns by Duncan's multiple range (5 % level).

TABLE 2.—Influence of 2 Years of Various Times of Summer Pruning and Alar on Growth, Flowering and Fruit Set of 5-Year-Old Jerseymac Apple Trees on M9 Rootstock, 1979.

Treatments	Average Shoot Length* (cm)	Flower Cluster/cm Limb Circ.	Fruit/cm Limb Circ.	Fruit Set (%)	Fruit Set Pruned Shoots† (%)	Full Crop‡ (%)
Unpruned	25a**	13.9a	1.4bc	12c	15c	71b
June	17c	4.6c	2.2ab	88a	36abc	82a
July	19bc	6.7bc	1.8abc	27bc	23bc	70b
August	20abc	4.6c	1.1c	83ab	23bc	73b
June and August	17c	4.1c	1.2c	60abc	39ab	74b
July and August	20abc	5.2c	1.4bc	35abc	26bc	77ab
June, July and August	17c	4.7c	1.8abc	71ab	49a	82a
Alar (2000 ppm)	23ab	9.7b	1.7abc	25bc	24bc	82a
Alar (2000 ppm) + June	15c	5.7c	2.4a	53abc	47a	84a

*Total length of growth produced in 1978. Trees summer pruned in 1977 and 1978.

†Flowers and fruit on six tagged shoots/tree that were pruned or corresponding shoots on unpruned trees

‡Average of three independent raters using scale: 0 = no fruit, 100 = full crop.

**Mean separation within columns by Duncan's multiple range (5 % level).

when Alar spray was applied in July to Bramley's Seedling shoots pruned in June. In this study the percent of pruned shoots with regrowth was greatly reduced by a spray immediately following pruning (Table 1). Unfortunately, these data were not collected the second year.

A visual estimation of cropping following 2 years of the treatments indicated an increase in crop load with: 1) pruning in June; 2) pruning in June, July, and August; 3) an application of Alar alone; or 4) Alar in combination with June pruning. Elfving and Forshey (4) found a similar response to pruning in June either alone or in combination with Alar on the yield of young Delicious trees.

Although the desired reduction in vegetative growth occurred naturally in these trees, summer pruning in June increased fruit set and crop potential. Cartwright and Meakin (3) indicated that pruning Bramley's Seedling in June resulted in more lateral shoots that were fruitful and helped adapt this cultivar to intensive growing systems. Aselage and Carlson (2) indicated that June pruning of Jerseymac could not be recommended due to the large amount of regrowth. However, these investigators did not report information on flowering or fruiting. The results of this limited study indicate that fruit set of Jerseymac on M9 trained on a trellis was improved by summer pruning in June. Pruning more than once during the summer did not achieve any greater reduction in shoot growth than pruning a single time and would not be recommended.

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Influence of Promalin on Delicious in Ohio

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INTRODUCTION

Since the shape of Delicious apples produced in the West has been advertised and is recognized by consumers, fruit producers in other regions would like to be able to duplicate the elongated shape with pronounced lobes. The shape of an apple fruit is dependent on environmental conditions during the first several weeks after bloom. Several investigators have shown that Delicious apples were more conic and elongated if days were warm and clear and nights cool during this period (6, 9). High temperatures during this period result in flattened and oblate fruit. The presence of seeds also influences apple shape and if seeds are absent in carpels, asymmetric fruit develops (5). Bukovac and Nakagawa (1) found that asymmetric growth of apple could be induced with localized applications of gibberellins.

Promalin is a commercially available plant growth regulator containing the natural gibberellins A_4 and A_7 and the cytokinin 6-benzyladenine. Numerous investigators (2, 3, 4, 7, 8, 10) have shown that a combination of gibberellin and benzyladenine can increase the length to width (L/W) ratio and in some cases fruit weight (4, 8). Treatment of 'Delicious' apples resulted in more prominence of the points near the fruit calyx and improved 'typiness' (4, 7, 8, 10). Miller (4) found that the increase in 'typiness' in the warm growing area in Georgia did not appear to be of commercial significance, but the increase in fruit weight was significant. Looney (3) reported that calcium (Ca) concentration of the fruit and the incidence of "Spartan" breakdown was increased by sprays of gibberellin A_{4+7} and benzyladenine. Stembridge and Morrell (7) reported that fruit set was decreased by high concentrations and Miller (4) found yield was reduced an average of 2 bushels/tree in Promalin-treated trees.

Since both positive and negative influences of Promalin have been reported from various apple growing regions, studies were initiated in 1975 to evaluate its influence on apples in Ohio. Most of the studies were conducted in grower plantings representing various geographic sections of the state.

MATERIALS AND METHODS

In 1975 Promalin was applied to 7-year-old Red Prince Delicious trees on M26 at Wooster at petal fall with a hand gun to the point of runoff. Five uniform pairs of trees were selected, with one tree of each pair sprayed. The fruit length/width ratio, percent set, and yield/tree were recorded.

In 1977 trees on M7 at the Mahoning County Branch were treated with Promalin at 1.5 pints (pt)/acre dilute. The sprays were applied with an air blast sprayer at two stages of development—full bloom and petal fall. Frost caused a complete crop loss on Delicious and reduced the yields on the other cultivars. However, fruit set (150 clusters/tree) and fruit shape measurements were made on 10 fruit from each of 5 replicate trees of Jonathan, Melrose, and Golden Delicious. Fruit set and size were also collected on Miller Sturdeespur Delicious/MM106 in a grower orchard (Fuhrmann Orchard, Wheelersburg) sprayed when king blossoms were open with a Kinkelder sprayer at 1 pint/40 gallons (gal). Promalin-treated and untreated fruit of Red King Delicious from seedling trees in Collella Orchards in New Waterford were also sampled for fruit shape and fruit size distribution in a bin of fruit was determined.

In 1978 the influence of three rates of Promalin on Delicious was studied in the following commercial orchards by measuring fruit size, shape, set, and size distribution: Farm 1—Peace Valley Orchard, Starkrimson/seedling—19 years old, applied at 125 gal/A; Farm 2—Fuhrmann Orchard, Starkrimson/MM106—14 years old, applied at 40 gal/A; Farm 3—Apple Hill Orchard, Starking/seedling—13 years old, applied at 35 gal/A; Farm 4—Ohio Orchard Company, Starking/seedlings—20 years old, applied at 250 gal/A. All sprays were applied when king bloom was open at rates of 0.75, 1.0, and 1.5 pt to 10 trees at each concentration and compared to 10 unsprayed trees in each orchard.

In 1979 various combinations of Promalin and Alar (Table 6) were applied to 9-year-old Miller Sturdeespur Delicious in Moore Orchards, Oak Harbor, in an attempt to increase fruit set. The sprays were applied to runoff with a hand gun at king bloom or king bloom + 18 days. Fruit set, average fruit weight, and length to diameter ratio of 10 fruit/tree were recorded. The percentage of a full crop/tree

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[2] Appreciation is expressed to the following orchards for their support in parts of these studies.: Fuhrmann Orchard, Wheelersburg; Collella Orchard, New Waterford; Apple Hill Orchard, Mansfield; Ohio Orchard Company, Milford Center; Peace Valley Orchard, Rogers; and Moore Orchard, Oak Harbor. Appreciation is also expressed to Abbott Laboratories for supplying chemical and financial support for part of these studies.

was estimated by two independent observers. The treatments were arranged in a randomized complete block with eight replications.

RESULTS

A Promalin spray applied dilute at petal fall had little influence on L/W ratio and caused an unacceptable reduction in fruit set and yield/tree (Table 1) of Red Prince Delicious in 1975. In 1977 Promalin applications at petal fall of the king blossoms caused a reduction in fruit set of Jonathan and Melrose, while an application at full bloom (Table 2) had a tendency to increase fruit set of these cultivars. The effect of Promalin on fruit set of Golden Delicious was erratic, with a tendency toward increased fruit set at the petal fall application.

Promalin had no influence on the L/D ratio of fruit from any of the cultivars. Measurements in two grower orchards in 1977 revealed that fruit set of Delicious in Farm 1 (Table 3) was reduced and fruit size and L/D ratio tended to be increased in both orchards (Table 3—Farm 2).

In 1978 the influence of three rates of Promalin on Delicious was evaluated in four grower plantings selected because they represented various areas of Ohio. Promalin sprays tended (although not significantly) to decrease fruit set on three of the farms and cause a significant increase in fruit set in the planting in southern Ohio. In the planting from southern Ohio, fruit size was increased but the L/W ratio was similar to the fruit of the unsprayed controls. The L/W ratio was increased by the higher rates of Promalin in Farm 3 (North Central) and Farm 1 (Northeast) and unchanged in Farm 4 (Central).

TABLE 1.—Influence of Promalin on Fruit Shape, Set, and Yield of 7-Year-Old Red Prince Delicious on M26, Wooster, 1975.

	Fruit		Yield
Treatment	Length/Width	Percent Set	bu/Tree
Unsprayed	0.95	49.5	2.85
Promalin 1.5 pt/100 gal*	0.94	13.6	0.64

*Spray applied at petal fall to runoff with handgun.

The influence of the various rates of Promalin on average fruit size from a sample collected from the tree prior to harvest was variable. Fruit size distribution was determined by sizing one bin of fruit from each application rate. At Farm 3 (North Central), fruit size was increased by each rate of Promalin (Table 4), but only the 1 pt rate caused a noticeable increase in large fruit from Farm 4 (Central).

In 1979 Promalin and Alar sprays were applied to some young Delicious trees in a grower planting in northwest Ohio. Although not significant, there was a tendency for fruit set to be increased by an Alar spray 18 days after bloom, and the treatment receiving Promalin at bloom plus Promalin and Alar at 18 days resulted in the greatest increase in fruit set. Fruit size was reduced by any treatment receiving

TABLE 2.—Influence of Promalin on Fruit Shape, and Set of Three Cultivars on M7 Rootstocks, Mahoning County Farm, Canfield, 1977.

	Jonathan			Melrose			Golden Delicious		
		Promalin*			Promalin			Promalin	
	Check	Full Bloom	Petal Fall	Check	Full Bloom	Petal Fall	Check	Full Bloom	Petal Fall
Fruit Set (%)	21	34	2	24	44	2	154	106	173
Mean Fruit Length (cm)	5.77	5.83	5.74	7.03	6.63	6.62	5.93	6.23	5.49
Mean Fruit Diameter (cm)	6.65	6.67	6.71	6.71	8.35	7.96	6.50	6.78	6.64
L/D	0.87	0.87	0.86	0.84	0.83	0.84	0.91	0.92	0.93

*Promalin spray (1.5 pt/100 gal) applied dilute with airblast.

TABLE 3.—Influence of Promalin on Fruit Set, Size, and Shape of 'Delicious' Apples in Two Grower Plantings in 1977.

			Mean Fruit			
Farm*	Promalin Rate	Percent Set	Length	Diameter	Weight	L/D
1	Check	39	6.1	6.8	118	0.90
	1 pt/acre	29	6.2	6.7	127	0.92
2	Check		6.3	7.0		0.90
	1.3 pt/acre		6.7	7.3		0.92

*Farm 1—Millerspur/MM106 sprayed with 40 gal/acre, Wheelersburg; Farm 2—Red King/seedling sprayed dilute, New Waterford.

TABLE 4.—Influence of Promalin on Fruit Size Distribution of Delicious Apples in Grower Plantings.

	Application Rate (pt/100 gal)	Fruit Size Distribution (%)			
		1*	2	3	4
Farm 2† 1977					
Check		36	54	10	0
Promalin	1.3 pt/acre	53	43	3	1
Farm 3 1978					
Check		48	31	8	12
Promalin	0.75	54	24	7	15
Promalin	1.0	58	21	5	16
Promalin	1.5	56	25	4	15
Farm 4 1978					
Check		19	48	26	7
Promalin	0.75	21	51	24	4
Promalin	1.0	35	42	19	4
Promalin	1.5	16	27	40	16

*Size 1=2⅞" dia. +; Size 2=2⅝"-2⅞" dia.; Size 3=2¼"-2⅝"; Size 4=ciders (culls and smaller than 2¼").

†Farm 2—Red King/seedling, New Waterford; Farm 3—Starking/seedling, North Central Ohio; Farm 4—Starking/seedling, Central Ohio.

Alar except for the Alar spray at king bloom. Promalin applied at 0.5 pt/100 gal when king bloom was open resulted in an increase in L/W ratio while the other treatments had no influence on L/W. A rating of percent of a full crop on the trees prior to harvest indicated that Alar in combination with either 0.5 or 1.0 pt/100 gal of Promalin resulted in an increase in crop.

TABLE 5.—Influence of Promalin Sprays on Fruit Size, Shape, and Set of 'Delicious' Apples at Four Ohio Farms in 1978.

	Promalin Rate (pt/100 gal)			
Farm*	0	0.75	1.0	1.5
		Fruit Size (grams/fruit)		
1	152fgh†	138ij	128j	160defg
2	176b	198a	201a	190a
3	168bcde	147hi	162cdef	173bc
4	150gh	172bcd	175b	157efgh
		Length/Width Ratio		
1	0.90i	0.93gh	0.96def	0.95efg
2	0.97bcde	0.98bc	0.97bcde	0.98ab
3	0.94fg	0.92hi	0.98ab	1.00a
4	0.97bcd	0.96cde	0.96de	0.96bcde
		Percent Fruit Set		
1	30de	17e	17e	21e
2	37cd	74a	47bc	56b
3	17e	18e	17e	16e
4	21e	13e		12e

*Farm 1—Northeast Ohio, Starkrimson/seedling; Farm 2—Southern Ohio, Starkrimson/MM106; Farm 3—North Central Ohio, Starking/seedling; Farm 4—Central Ohio, Starking/seedling.

†Means followed by the same letter are not significantly different from each other, 5% level.

DISCUSSION

Since many growers of Delicious have experienced serious problems with inadequate set, one of the authors' major interests has been the influence of Promalin on fruit set. In 6 of the 10 studies reported here, fruit set was reduced. An increase in set occurred in one study. The most significant reductions in fruit set occurred when sprays were applied when all flowers were in petal fall. Applications earlier during the bloom period had less influence on fruit set. This supports the findings of Unrath (8) that the most effective period was between full bloom to petal fall. It may be possible to counter the adverse effects on fruit set by either adding or combining Alar in the spray program 15-18 days following full bloom (Table 6). Work will be continued to document this response in another year.

Fruit shape in 5 of the 11 studies reported here was changed by an increase in the length/width ratio. In three of these cases the influence was small and of questionable commercial value, but in two cases (Table 5, Farms 1 and 3) the influence was dramatic. However, these influences in Farm 1 were associated with a reduction in fruit set, and a visual inspection of the trees indicated a smaller crop on treated trees. In Farm 3 the number of bins of fruit from 10 trees was reduced in treated trees (untreated = 6.5 bins, 0.75 pt = 4.0 bins, 1.0 pt = 5.0 bins, and 1.5 pt = 2.6 bins.

Fruit size distribution from Farm 3 (Table 4) also indicated a shift toward larger fruit sizes, which is an expected response if fruit thinning occurred. Miller (4) reported a reduction in yield/tree asso-

TABLE 6.—Influence of Promalin and Alar on Fruit Shape, Size, and Set of Miller Sturdeespur Delicious Apples, 1979.

Treatment	Application Time		Percent Set	Fruit wt (g)	Length/ Width	Percent Full Crop
	King Bloom	King Bloom + 18 Days				
Check			37ab*	209a c	0.96bc	51cd
Promalin	1 pt		28b	195abc	0.98ab	46d
Promalin	0.5 pt		44ab	198ab	0.99a	56bcd
Promalin	0.5 pt	0.5 pt + A	54a	182d	0.97ab	63ab
Promalin	1 pt + A		38ab	182d	0.97ab	53bcd
Promalin	0.5 pt + A		41ab	182d	0.97ab	52cd
Promalin		1 pt + A	48a	186cd	0.98ab	67a
Alar†	A		38ab	200ab	0.94c	57abcd
Alar		A	47a	191bcd	0.95bc	59abc

*Means followed by the same letter are not significantly different from each other, 5% level.
†Alar spray at 1000 ppm.

ciated with an increase in L/D ratio and larger fruit size. Unrath (8) reported that all concentrations that improved fruit weight also reduced fruit set, but all trees inthese studies required fruit thinning.

In the Ohio studies little or no fruit thinning was required even on control trees, and in several years less than a full crop existed. Under these conditions of marginal cropping, Promalin must be used with caution and the possibility of reduced crop must be balanced against the possibility of increased price for larger fruit with the more acceptable elongated shape and pronounced lobes. Promalin has been successful in other regions of the country where adequate fruit set of Delicious is not a problem. If the fruit set problem in Ohio can be solved, Promalin may become an important management tool.

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The Effects of Overtree Misting for Bloom Delay on Soil Water Status, Net Photosynthesis, Transpiration, and Carbohydrate Levels of Apple Trees

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INTRODUCTION

Evaporative cooling for bloom delay is a new technique developed to prevent flower bud loss in the spring due to cold temperature injury. Research has shown evaporative cooling to be effective in delaying bloom 10 to 17 days in apples (1, 15) and 10 to 15 days in peaches and nectarines (3, 14).

Recent research has been directed towards designing water application systems that are more efficient and apply less water. Studies have indicated that sprinkler activation should be controlled by the existing environmental conditions within the orchard and not a pre-set time clock (2, 3, 14). Amount and time of water application for bloom delay have varied considerably from a low of 15 seconds to a maximum of 5 minutes (3, 14). The use of low pressure misting or fogging type nozzles has been shown to produce greater cooling and bloom delay than impact sprinkler nozzles (16). Temperature depression, the temperature difference between nonmisted and misted flower buds, has been as great as 34° C (1). Generally, however, temperature depressions (TD) have averaged 3° to 10° C (1, 14, 15).

As present one of the major limiting factors to the widespread adoption of misting for bloom delay is the large amount of water required and the effects of this water on the trees. Tree loss due to water logging of the soil and reduced fruit set and yield have been reported on bloom-delayed trees (3, 7, 15). Excessive water in the spring has been shown to reduce fruit set and photosynthetic rates of apple trees (8, 13). Studies have indicated that a salt precipitate accumulates on the bloom-delayed trees (1; 15) which may influence photosynthesis and carbohydrate levels.

MATERIALS AND METHODS

The study was conducted on a block of 'Golden Delicious' planted in 1972 in a Wooster silt loam soil. Water application was controlled by a thermostat and timer set to activate automatically when the ambient air temperature rose above 6° C. Water was applied for 1 minute out of 6. The mist system was activated on March 23 and ran until May 24 in 1978 and from March 20 until May 10 in 1979. Misting was discontinued in both years when the nonmisted trees reached full bloom.

Soil water content was measured on a weekly basis from beneath ten misted and ten nonmisted trees. Samples were collected by inserting a soil probe around the drip line of the trees and withdrawing a sample from 15 cm depth. The soil samples were immediately weighed, dried for 24 hours in an oven (105° C), and reweighed. The water content was expressed in gram water/gram soil (d.w.). Percent air space unoccupied by water was determined from the bulk and particle density and the water content of the soil.

Dormant MM111 rootstocks were placed in clay pots beside both misted and nonmisted trees in 1978 and allowed to develop. Net photosynthesis (Pn) and transpiration (Tr) were measured on these trees at full bloom of nonmisted and misted trees. Two readings were taken on May 24, one without washing the leaves and a second after washing the leaves with distilled water to determine what effect the salt precipitate build-up had on Pn and Tr. Measurements of Pn and Tr were made indoors, using an infrared gas analyzer (11).

Total nonstructural carbohydrates (TNC) of the current season's growth and the fibrous roots of the misted and nonmisted MM111 rootstocks were determined in 1978. Levels of TNC of dormant spurs on 'Golden Delicious' trees and spur leaves at full bloom and petal fall were determined in 1979.

Flower bud temperatures were monitored on 9 selected days in 1978 and 10 days in 1979 to represent a cross-section of weather. Temperatures were monitored in 1979 on 2 days during which rain fell and 2 nights. Flower bud temperatures were recorded by means of copper-constantan thermocouples attached to a Leeds and Northrup Speedomax 250 multipoint recorder.

RESULTS AND DISCUSSION

Full bloom was delayed 6 days in both seasons. Full bloom of nonmisted trees in 1978 was 2 weeks later than the 30-year average and in 1979 occurred

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on the date of the 30-year average (9). Total water application was 314 cm/ha in 1978 and 176 cm/ha in 1979.

Soil water content (SWC) was increased and percent air space (AS) was decreased under the misted trees (Table 1). Although more water was applied in 1978, SWC and AS were equal levels in misted and nonmisted soils at full bloom (May 24) of nonmisted trees. In 1979, SWC and AS did not return to equal levels in misted and nonmisted soils until 20 days after full bloom of the misted trees.

Based on other work (5, 6), the SWC and AS measurements did not indicate the soil was waterlogged and no standing water was observed in the orchard. However, deficient aeration during only 1 or 2 days, especially during bloom, can overshadow aeration conditions the remainder of the season (12). Tree death due to waterlogging in 1975 (15) and 1978 was undoubtedly the result of the early season changes in SWC and AS.

Alterations in the air-soil-root complex can influence nutrient uptake, fruit set and photosynthesis (8, 12, 13). Buchanan *et al.* (7) suggested that excess fruit abscission on bloom-delayed trees may have been due to a sudden water stress when the mist system was shut off. The reduced fruit set and yield may have been influenced by changes in soil water status. Relative water content of spur leaves was not affected by misting (9). Differences in the soil's drainage properties may explain why some studies (2, 14) have not reported reduced fruit set on bloom-delayed trees.

Misting had no apparent effects on net photosynthesis (Pn) and transpiration (Tr) of MM111 rootstocks (Table 2). The reported and observed salt build-up did not influence photosynthesis of the leaves of the rootstocks. Childers and White (8) completely submerged the roots of potted apple trees and reported Pn and Tr were reduced within 2 to 7 days after submergence; upon removal of the excess water, Pn and Tr recovered to presubmergence levels within 1 week. The rootstocks in this study were not submerged, although excessive water was a problem because appreciable death of misted rootstocks was noted in the field.

Total nonstructural carbohydrate levels were lower in current season's growth and fibrous roots of the misted than in nonmisted MM111 rootstocks (Table 3). Misting had no apparent effects on TNC levels of dormant spurs or spur leaves in 1979, and were similar to levels reported in other work (4). The lower TNC levels in the misted rootstocks were probably related to the effects of the excess water weakening the rootstocks. Lack of differences in TNC of the samples collected in 1979 suggests that carbohydrate reserves in mature trees were adequate

TABLE 1.—Influence of Misting for Bloom Delay on Soil Water Content and Percent Air Space Unoccupied by Water in a Wooster Silt Loam Soil in 1978 and 1979.

Date	Water Content ($g\ H_2O/g$ Soil)		Air-Space (%)		Precipitation Between Sampling Dates (cm)
	Misted	Nonmisted	Misted	Nonmisted	
1978 April 12	0.266a*	0.245a	17a	20a	
19	0.258a	0.245a	20a	19a	2.6
26	0.260a	0.244b	18a	20b	1.9
May 3	0.247a	0.211b	20a	24b	0
10	0.249a	0.225b	20a	23b	2.2
17	0.279a	0.258b	16a	18a	7.7
24	0.272a	0.260a	17a	18a	1.9
1979 March 22	0.235a	0.221b	21a	23b	
April 4	0.254a	0.252a	19a	19a	6.3
10	0.252a	0.251a	19a	19a	2.4
18	0.261a	0.236b	18a	21b	2.7
24	0.250a	0.201b	19a	26b	0
May 1	0.255a	0.235b	19a	21b	1.5
10	0.252a	0.207b	19a	25b	0.4
19	0.229a	0.196b	22a	26b	0.4
23	0.228a	0.197b	22a	26b	0
June 1	0.240a	0.228b	21a	22b	1.8
6	0.214a	0.220a	24a	23a	0.7

*Means within rows followed by different letters are significant at 5% level, Duncan's new multiple range test.

TABLE 2.—Influence of Misting for Bloom Delay on Net Photosynthesis (Pn) and Transpiration (Tr) of Washed and Unwashed MM111 Leaves and Percent Increase of Root Volume of Potted MM111 Rootstocks.

		Pn ($mg\ CO_2\ dm^{-2}\ hr^{-1}$)		Tr ($g\ H_2O\ dm^{-2}\ hr^{-1}$)		
Treatment	**Date**	**Washed**	**Unwashed**	**Washed**	**Unwashed**	**Root Volume (% Increase)**
Misted	5/24	5.23a*	6.03a	-0.94a	0.88a	9.3a
	5/31	17.14b		1.75b		
Nonmisted	5/24	4.84a	5.70a	0.73a	1.12a	14.5a
	5/31	16.38b		1.64b		

*Means within Pn, Tr, and Root Volume columns followed by different letters are significant at 5% level, Duncan's multiple range test.

TABLE 3.—Influence of Misting for Bloom Delay on Total Nonstructural Carbohydrates (TNC) of MM111 Rootstock Leaves and Fibrous Roots in 1978 and Dormant Spurs and Leaves at Full Bloom and Petal Fall of 'Golden Delicious' Apple Trees in 1979.

			TNC (% Dry Weight)	
Tissue			**Misted**	**Nonmisted**
MM111	Leaves		3.71a*	4.04b
	Roots		2.82a	5.26b
'Golden Delicious'	Spurs		4.15a	4.17a
	Leaves	Full Bloom	4.19a	4.12a
		Petal Fall	3.84a	3.85a

*Means within rows followed by different letters are significant at 5% level, Duncan's new multiple range test.

for the needs of the trees and were not influnced by misting.

Temperature depressions (TD) generally increased as the day progressed (Figure 1 A and B). Maximum TD occurred from 1100 hr until approximately 1530 hr, while minimum TD occurred in the early morning. Generally the average temperature depression was greater on the bud at 140 cm which was closer to the sprinkler nozzle. Differences in TD between 70 and 140 cm locations were likely due to water distribution patterns (15, 16) and higher incident radiation upon the 140 cm bud. The temperature depressions in this study were within the ranges reported by others (1, 14, 15).

Temperature depressions determined at night on May 7-8 and May 9-10 in 1979 averaged 25% lower than during the day (Figure 1 C and D). Temperature depressions began to decline around 2200 hr and reached a minimum around 0330 hr.

Two days were selected to measure temperatures when precipitation was falling and relative humidity was greater than 80%. There were essentially no differences between misted and nonmisted bud temperatures due to evaporative cooling (Figure 1 E and F). The temperature depressions on these days averaged 68% lower than those observed on sunny, clear days and 58% lower than on the 2 nights selected.

Since the design of the misting system in this study was such that it operated continuously even during periods of rainfall, the addition of some form of wetness or RH sensor should have reduced water application. Data from the 2 days' temperatures monitored in the rain show that the temperature depression did not exceed 2.5° C, and for considerable time there was no difference in bud temperatures in misted or nonmisted trees. The lack of large differences in temperatures during periods of rain strongly supports the necessity of an activating mechanism based on evaporative demand such as those designed in Kentucky (2) and New Zealand (17) for the misting system to be water efficient.

The choices between the possibility of less delay, water costs, and tree loss to waterlogging suggest that it would be better to shut the system off at night. Calculations based on hydrothermograph records covering the misting period showed that by shutting the system off at 2200 hr until 0600 hr, the number of hours of misting would have been reduced. The reduction would have amounted to a water savings of 59.7 cm/ha in 1978 and 47.7 cm/ha in 1979. Shutting the system off when RH equaled or exceeded 80% would also have reduced misting hours, further cutting the amount of water applied by 55 cm^3/ha in 1978 and 45.2 cm/ha in 1979. The total water applied utilizing two such activating mecha-

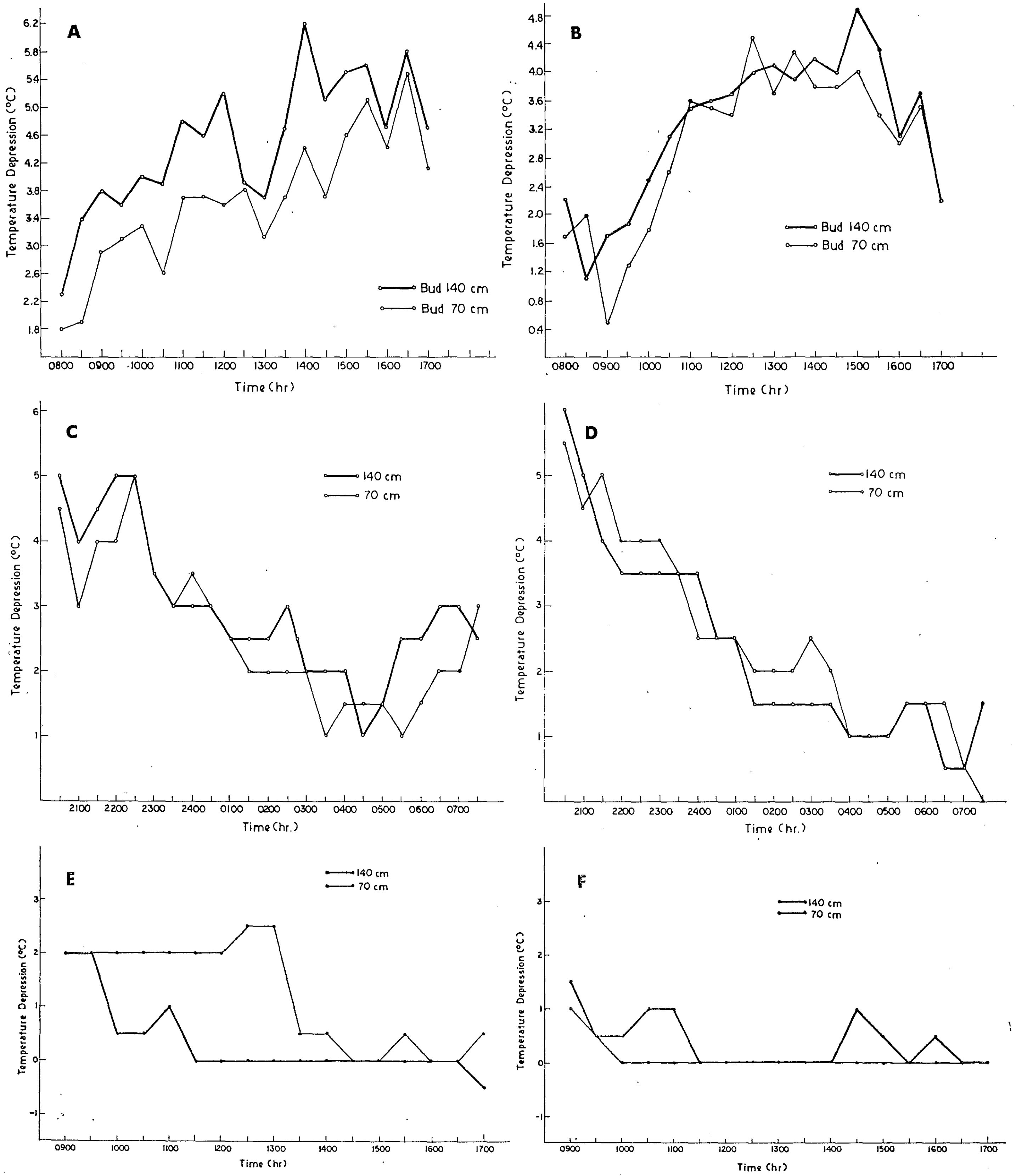

FIG. 1.—Influence of misting for bloom delay on temperature depression of flower buds at 70 and 140 cm. Season averages (A) 1978, (B) 1979; temperature depression at night: (C) May 7-8, (D) May 9-10; temperature depression during rainfall: (E) April 13, (F) April 26.

nisms would have been reduced to 199 cm/ha in 1978 and 83.3 cm/ha in 1979.

Problems with overtree misting for bloom delay have not been completely resolved and its use in Ohio is not recommended. The results of this study support previous findings (2, 14) that to achieve maximum cooling, sprinkler activation should be controlled by environmental conditions. A reduction in the amount of water applied may prove to be part of the solution to the reduced fruit set and yield of bloom-delayed trees.

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Effect of Orchard Heaters on Vertical Temperature Profiles

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This report is a summary of temperature-profile results obtained during three experiments with oil-fired orchard Spot[4] heaters. Temperature profiles were measured May 10, 1977 (77-03), May 18, 1978 (78-02), and May 5, 1979 (79-01).

ORCHARD SITE, INSTRUMENTATION, AND EXPERIMENTAL CONDITIONS

The site for Experiment 77-03 was an OARDC conventional peach orchard located on an east-facing slope of about 5%. Orchard dimensions were 60 meters (200 ft) in the N-S direction and 110 meters (330 ft) in the E-W direction. The heater density was 40 heaters per acre. The site of Experiments 78-02 and 79-01 was another OARDC orchard of mature dwarf apple trees located on a gentle west-facing slope. Orchard dimensions were 52 meters (180 ft) in the N-S direction and 88 meters (190 ft) in the E-W direction. Heater density in the apple orchard was 54 heaters per acre. At both sites, heaters were also placed just outside the perimeters of the orchards.

For each experiment, an adjacent unheated check orchard was used to obtain reference tempera-

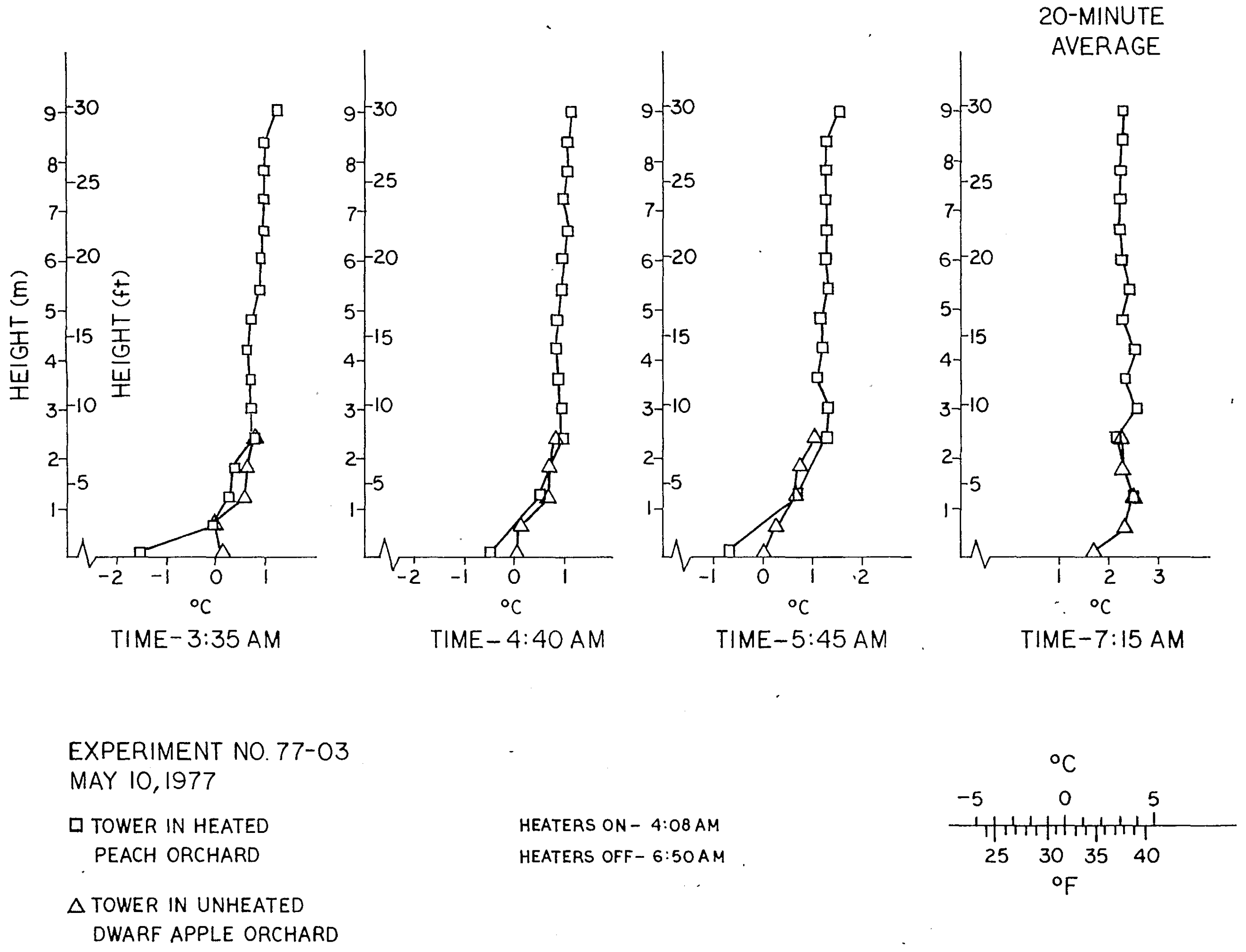

FIG. 1.—Air temperature profiles in heated and unheated orchard areas during nighttime operation of Spot heaters.

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ture profiles. For Experiment 77-03, reference profiles were obtained in an adjacent dwarf apple orchard. For Experiments 78-02 and 79-01, the check was an adjacent dwarf apple hedgerow system.

An aspirated, shielded thermocouple profile system described in the next article (2) was used for all temperature measurements. No temperature measurements were made within buds.

The experimental conditions were as follows:

Experiment 77-03: Experiment 77-03 was on May 10, 1977, from 12:55 a.m. to 8:00 a.m. The heaters were in full operation from 4:08 a.m. to 6:50 a.m. The weather was clear and calm, under light frost conditions, with little risk of bud damage even without heating.

Experiment 78-02: Experiment 78-02 was conducted on May 18, 1978, during a performance test of the newly relocated heater system, since no frost damage conditions were encountered during the spring of 1978. The experiment extended from 8:25 p.m. through 11:05 p.m., with the heaters in full operation from 9:58 p.m. to 10:40 p.m. Weather was clear at the beginning of the experiment, but full cloud cover developed at 9:15 p.m.

Experiment 79-01: Experiment 79-01 extended from 3:55 a.m. to 7:00 a.m., May 5, 1979. The heating operation was already in progress at the beginning of the experiment and continued until 6:30 a.m. Weather was clear and calm, with radiant frost conditions.

RESULTS AND DISCUSSION

Temperature profiles obtained during Experiment 77-03 are shown in Fig. 1. After the heaters were in full operation (4:08 a.m.), air temperatures measured in the orchard were not significantly higher than in the check orchard. The mean wind was about 0.7 meters/sec (1.6 mi/hr) from the north-northwest. At the end of the heating operation, temperature profiles in the heated and check orchards

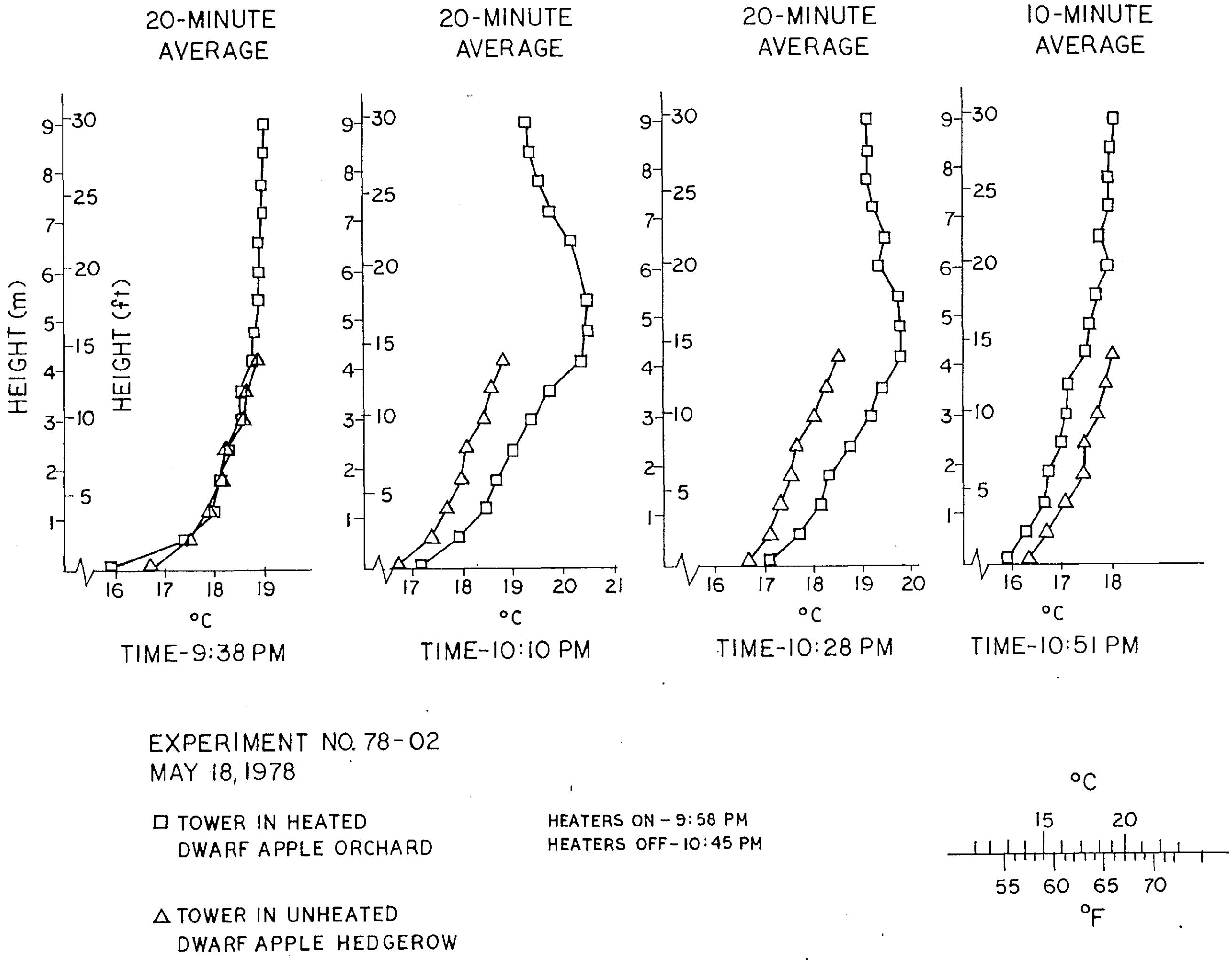

FIG. 2.—Air temperature profiles in heated and unheated orchard areas during nighttime operation of Spot heaters.

were nearly identical. Despite limited advection, there was sufficient atmospheric instability and buoyancy effect that a significant temperature increase could not be sustained by the heating system.

During Experiment 78-02, prevailing winds were northeasterly at 0.4 to 1.2 meters/sec (1-3 mi/hr) and check temperatures ranged from 15°-20° C (59°-68° F). The temperature profiles plotted in Fig. 2 were similar at all levels at both towers during the 1½ hours before heating commenced. After heating began (9:58 p.m.), temperatures in the heated orchard were typically 1°-2° C (1.8°-3.6° F) higher than the check temperatures. After heating ended, temperatures in the orchard fell slightly below the reference temperatures. The data acquisition periods during and following heating were too short to allow computation of 1-hour averages of temperature.

During Experiment 78-02, seed tufts were released into the air above a heater to aid visual observation of the airflow. There was evidence of a heat plume rising from the heater to a level of at least 6 meters (~20 ft). Heat plumes can cause a significant, systematic loss of heating effect at the orchard canopy level, in addition to the losses due to advection and dispersion by turbulence.

Temperature profiles from Experiment 79-01 are plotted in Fig. 3. Air temperatures in the heated orchard were about 2°-3° C (3.6°-5.4° F) higher than temperatures in the check orchard, the strongest heating effect observed in any experiments to date. After heating ended, temperatures in the orchard that had been heated fell below temperatures in the check orchard, as also observed in Experiment 78-02. The temperature depression indicates either a residual air flow due to heating that increases vertical mixing, or

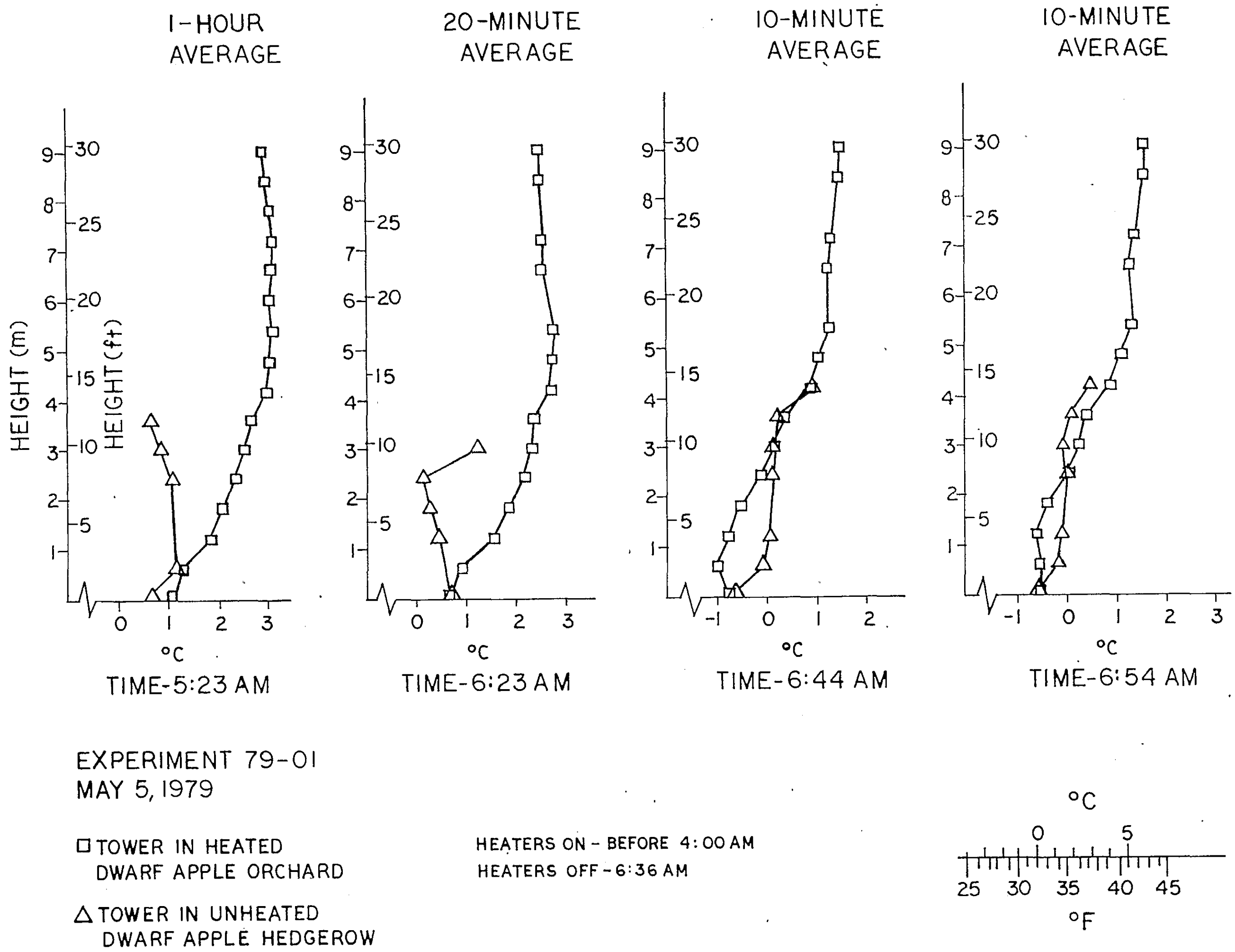

FIG. 3.—Air temperature profiles in heated and unheated orchard areas during nighttime operation of Spot heaters.

a cold air influx. Data analyses remain to be completed to determine whether such airflows occurred. Temperature profiles in Fig. 3 for 6:44 a.m. and 6:54 a.m. indicate that the lowest temperatures occurred after sunrise, prior to which heating had been ended. Radiation heat loss is usually greatest just before sunrise (1). Also, at sunrise, solar heating may increase vertical mixing which would tend to destroy a heated layer or else allow a cold air influx.

Temperature profile measurements in orchards to date indicate that the maximum temperature increase under Ohio conditions with oil-fired orchard heaters is 2°-3° C (3.6°-5.4° F). Weather conditions clearly influence the effectiveness of orchard heaters. Advection, strength of the temperature inversion, turbulence, and relative humidity (1) combine to determine the temperature increase that orchard heaters can sustain.

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The Effect of Orchard Heaters on Air Movement and Temperature

R. D. FOX,[2] R. D. BRAZEE,[3] and D. C. FERREE[4]

INTRODUCTION

Air movement and turbulence interact strongly with heat transfer processes in an orchard, either under natural conditions or when heating is applied for frost control. This report is a summary of two experiments conducted in the spring of 1976 to measure vertical profiles of air velocity and temperature in a peach orchard. One experiment was run during the daytime without heating, while the other took place during a frost-protection operation with oil-fired Spot[4] heaters. The air velocity data were analyzed to obtain mean wind velocity and root-mean-square (RMS) velocity. The importance of velocity measurements in studies of orchard microclimate is outlined by Brazee and Fox (1). The average, or mean, wind velocity profile can be used to estimate horizontal, or *advective,* heat transport. The RMS velocity is the same as the standard deviation used in statistics, and indicates the variability of the irregular, or turbulent, part of the wind velocity. The RMS velocities are used in estimating the rate of heat dispersion in the vertical and horizontal directions as the heat is being transported by advection.

ORCHARD SITE AND INSTRUMENTATION

The experimental site was at the OARDC, in a 2-acre peach orchard located on a 5% eastward-facing slope. Orchard dimensions were 60 meters (200 ft) in the N-S direction and 100 meters (330 ft) in the E-W direction. The trees were about 4.3 meters (14 ft) tall and were set in north to south rows, 6.7 meters (22 ft) on center in both directions. Eighty Spot heaters were set up in alternate rows in the peach orchard and around the perimeter of the orchard. Two towers (Nos. 3 and 4) were located in the peach orchard, and a third tower (No. 5) was placed in an adjacent unheated dwarf-apple orchard. Tower No. 4, where wind profiles were measured, was 56 meters (184 ft) from the west edge of the orchard and 27 meters (88 ft) from the south edge. The wind velocity probes were set at the eastern edge of a tree canopy. The peach trees were in early leaf stage with little foliage.

The system used for collecting and analyzing air flow data was reported by Fox *et al.* (2). Three-sensor constant temperature hot-film (CTHF) probes were used to measure wind velocities at 0.5, 1.7, 2.6, and 3.5 meters (1.6, 5.6, 8.5, and 11.5 ft) above the ground. A Gill 3-component propeller anemometer was also used at a point about 8.0 meters (26 ft) above the ground. Wind velocity data were recorded on magnetic tape for subsequent computer processing at the laboratory to obtain mean and RMS velocities.

Temperatures were measured with welded copper-constantan thermocouples that were shielded to minimize error due to radiation effect. Temperature profiles were recorded on paper tape for later computer analysis to obtain average temperatures for each measurement point. No temperature measurements were made within fruit buds.

DAYTIME EXPERIMENT

The daytime experiment (No. 76-07) was conducted from 9:17 a.m. to 3:17 p.m. on May 4, 1976. Weather conditions were clear and breezy, with temperatures ranging from 8° C to 14° C (46°-57° F). At the beginning of the experiment the wind was westerly, and during the day the wind direction changed slowly to southwesterly.

Mean wind velocity profiles within plant canopies have been fairly well established (3). The peach orchard of this experiment had an open layer between the ground and the lowest branches where it was possible for an airflow to be greater than within the foliage. In Fig. 1a, mean velocity observations from this experiment are plotted along with an idealized profile for the tree canopy. The azimuth of the mean wind was measured clockwise from north.

The mean vertical velocities shown in Fig. 1b are near zero except for the two observation points directly behind the tree. Velocities at both of these points indicated significant downdrafts, which suggest the existence of a circulation pattern in the drive space between tree rows. Such a circulation pattern must be persistent to attain the velocity magnitudes that were measured.

The mean and RMS air velocities were computed by three different methods of statistical analysis, and the results from all analyses are plotted in Figs. 1, 2, 4, and 5.

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[1] The authors are grateful to John T. Yoder, Jr. for encouragement in undertaking this work and with providing background information about frost protection.

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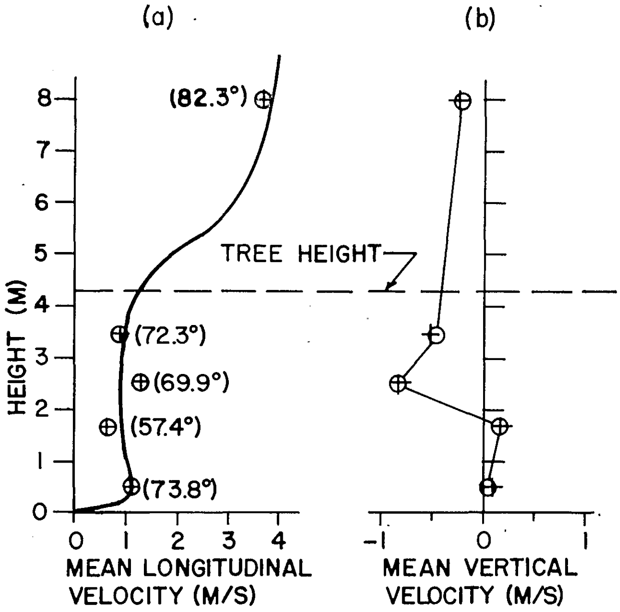

FIG. 1.—Profiles of mean velocities (in meters/sec) within and above a peach tree canopy during a 6-hr experiment. Symbols indicate results from two different methods of statistical analysis.

Figure 2 is a series of profiles of RMS velocities parallel, transverse, and vertical with respect to the mean wind direction. The largest RMS velocities occurred above the tree canopy at the 8-meter (26 ft) level. In the canopy, the largest RMS velocities occurred near the top and bottom of the tree canopy, in the shear layers where turbulence is generated. The lateral RMS velocity was nearly uniform within the tree-canopy layer and generally larger than the longitudinal RMS value, although the RMS velocity at the 3.5-meter (11.5 ft) level was slightly less than the RMS velocities at the lower levels. Vertical RMS velocities were greatest at the 2.6-meter (8.5 ft) and 3.5-meter (11.5 ft) levels.

Figure 3 is a series of plots of vertical profiles of temperatures at intervals from 10:00 a.m. to 1:00 p.m. The temperature profiles are shown at the midpoints of 1-hour averaging intervals. Canopy air temperatures on a sunny day are subject to the local distribution of solar radiation. The variation in temperatures measured on towers separated by only 50 meters (165 ft) was probably due to differences in solar heating effect at each tower site.

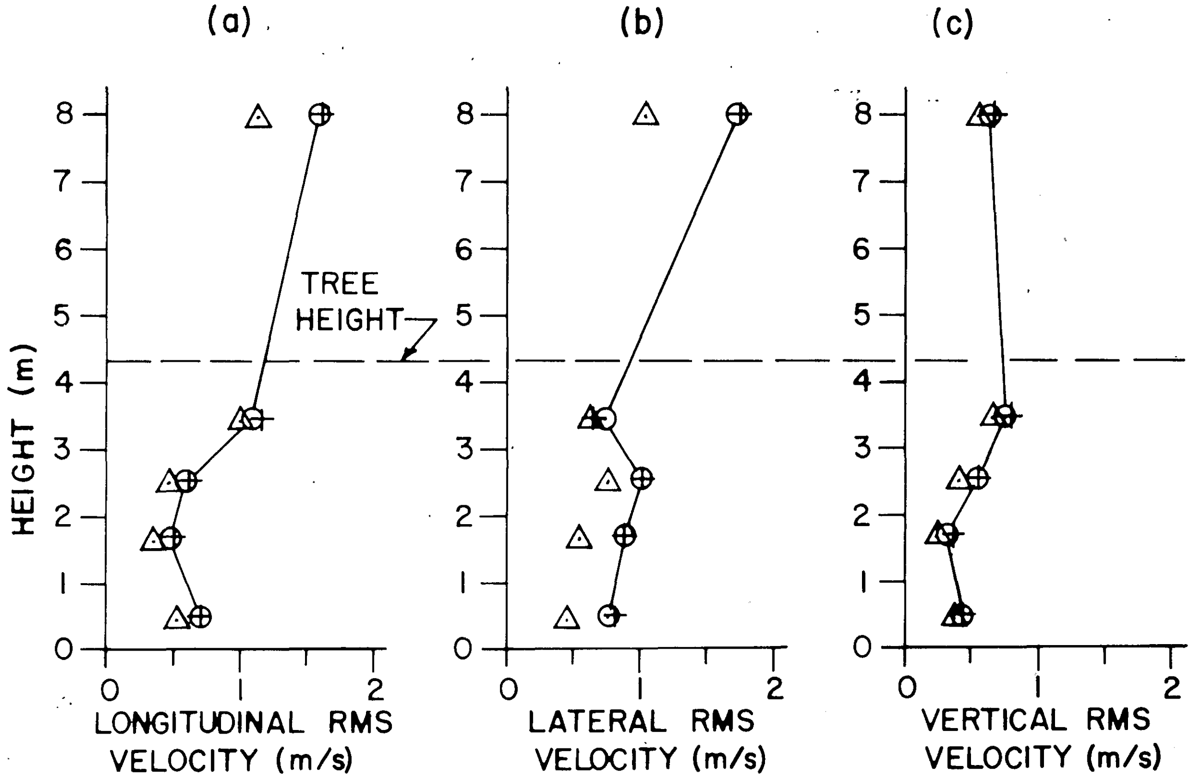

FIG. 2.—RMS (root mean square) velocity profiles (in meters/sec) within and above a peach tree canopy during a 6-hr experiment. Symbols indicate results from three different methods of statistical analysis.

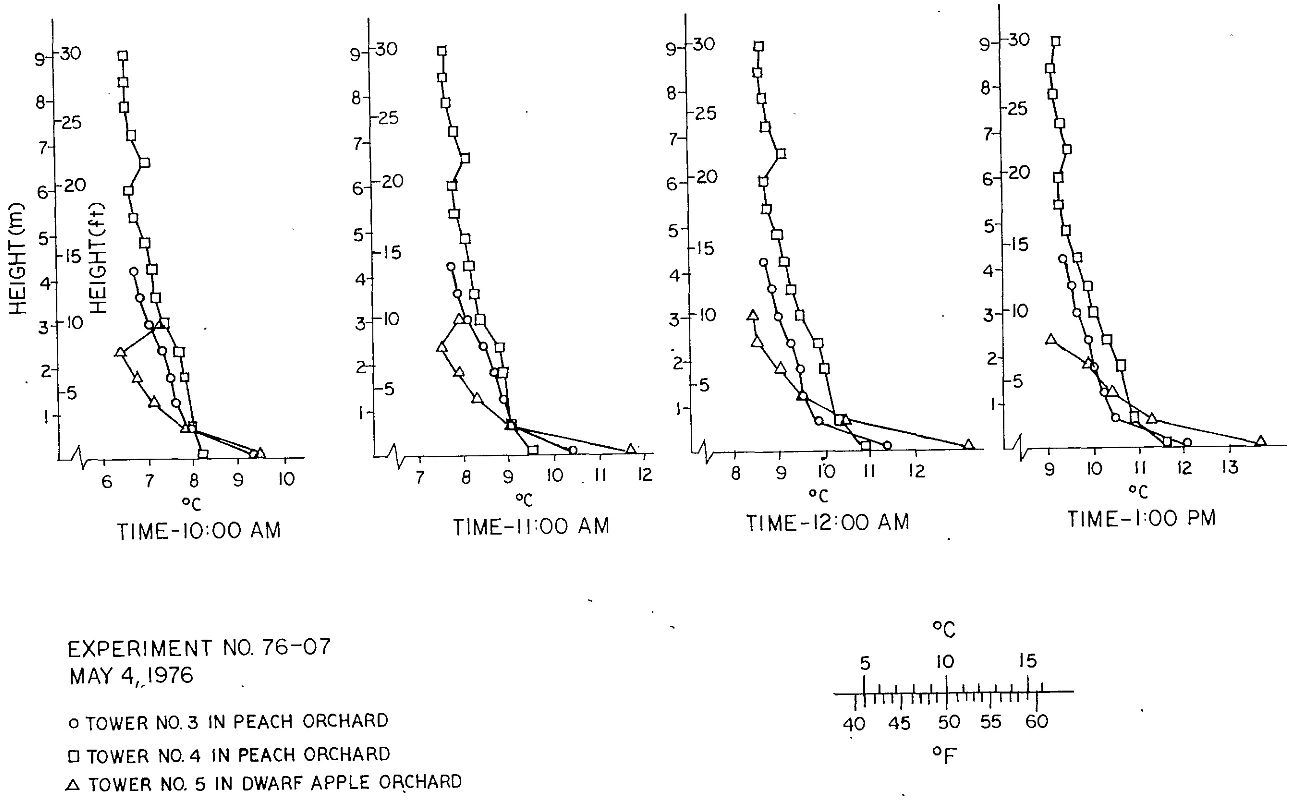

FIG. 3.—Air temperature profiles in an orchard area during the daytime.

NIGHTTIME EXPERIMENT

The nighttime experiment (No. 76-03) was conducted on April 12, 1976, in conjunction with frost-protection heating. Temperature profiles were recorded at Tower 5 in the unheated apple orchard for comparison of heating effect in the peach orchard.

Radiation frost occurred; winds were very light and remained nearly constant throughout the night. Thus, advective heat loss from the orchard should have been nearly constant during the experiment. Before heating was started, incipient frost was visible on the trees and grass. After a few minutes of operation the heaters had melted the frost, despite air temperatures below —5° C (23° F). Heavy frost was observed outside the heated orchard.

Figure 4 is a plot of the mean wind speed and direction over a 6-hour period at profile levels of 1.7, 2.6, and 3.5 meters (5.6, 8.5, and 11.5 ft). The mean velocities were greater than expected for radiation frost conditions. The mean vertical velocity at all observation points was upward, as expected with orchard heating in progress. The RMS velocity profiles displayed in Fig. 5 show values similar to the RMS velocities measured at the corresponding levels in the daytime experiment, as plotted in Fig. 2.

In Fig. 6, air-temperature profiles are compared among three tower locations. Two temperature profiles plotted in Fig. 6 were obtained from 1-hour averages, and two profiles were obtained from 20-min averages.

For much of the night, air temperatures in the heated orchard from 1-4 meters above the ground were raised by less than 1° C (1.8° F) at Tower No. 3 and by 1°-2° C (1.8°-3.6° F) at Tower No. 4, as compared with the unheated orchard. After 4:00 a.m., temperatures in the heated orchard were from 1°-2° C (1.8°-3.6° F) greater than temperatures at the corresponding levels in the unheated orchard.

An evaluation of the fruit-yield effectiveness of the frost protection operation associated with the nighttime experiment is not within the scope of this report. Most trees within and outside the protected area set fruit in 1976. Obviously, factors such as tree vigor and age, rootstock differences, and the physiological conditions within the fruit buds need to be considered, along with the microclimate, in evaluating economic frost protection.

COMPARISON OF DAYTIME AND NIGHTTIME AIR MOVEMENT

The synoptic weather conditions for the two experiments were clearly different. In particular, the prevailing wind was stronger during the daytime (Experiment No. 76-07) than during the night (Experi-

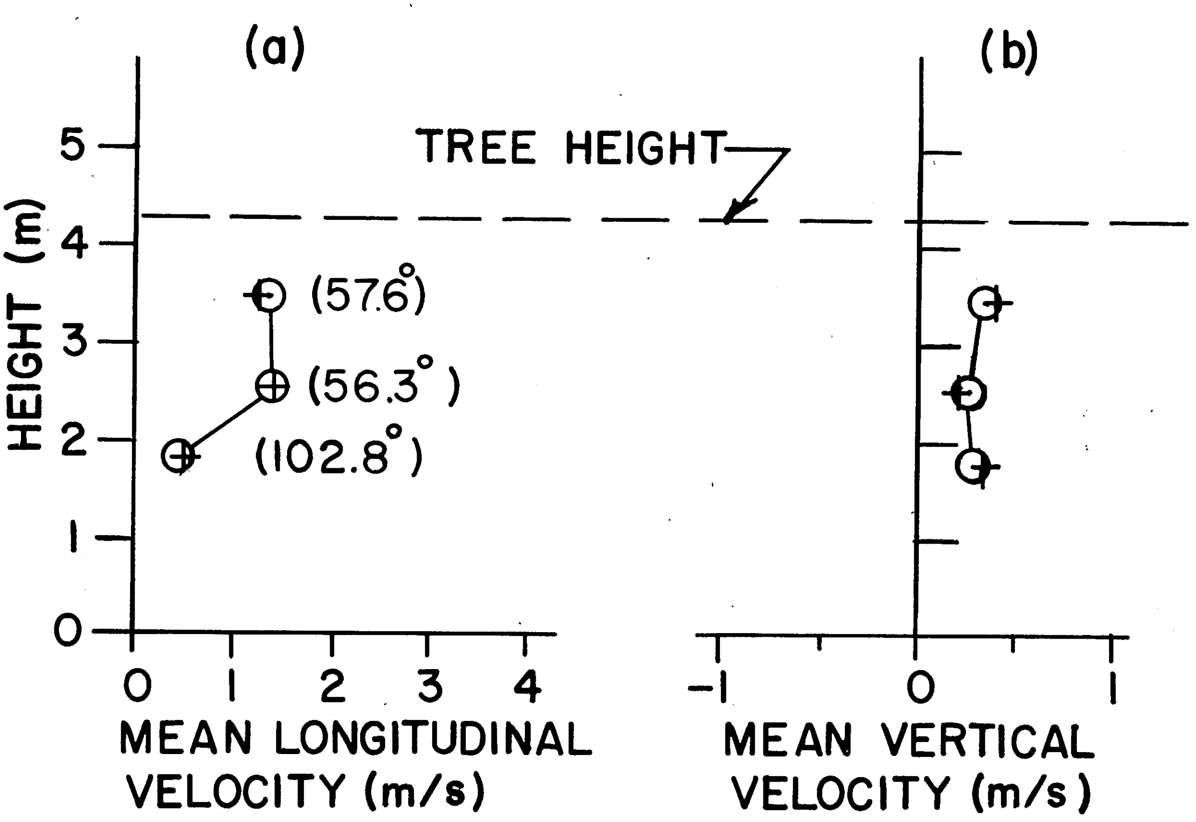

FIG. 4.—Profiles of mean velocities (in meters/sec) within and above a peach orchard during a 6-hr experiment. Symbols indicate results from two different methods of statistical analysis.

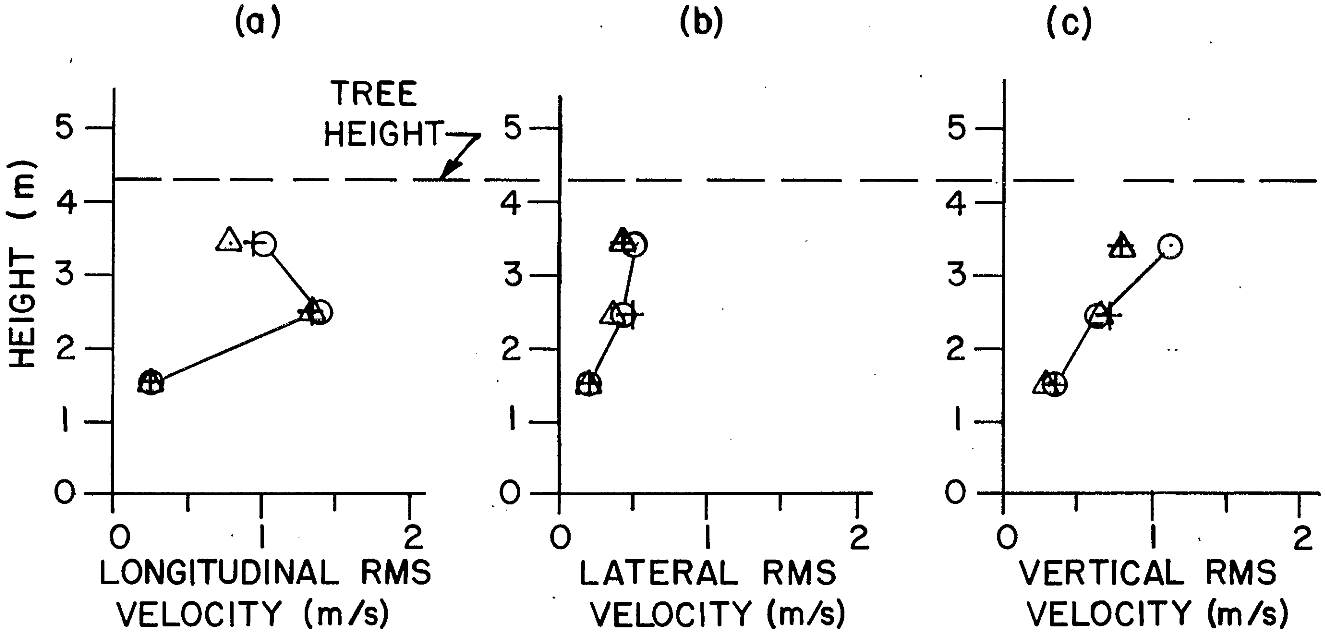

FIG. 5—RMS (root mean square) velocity profiles (in meters/sec) within and above a peach tree canopy during a 6-hr experiment. Symbols indicate results from three different methods of statistical analysis.

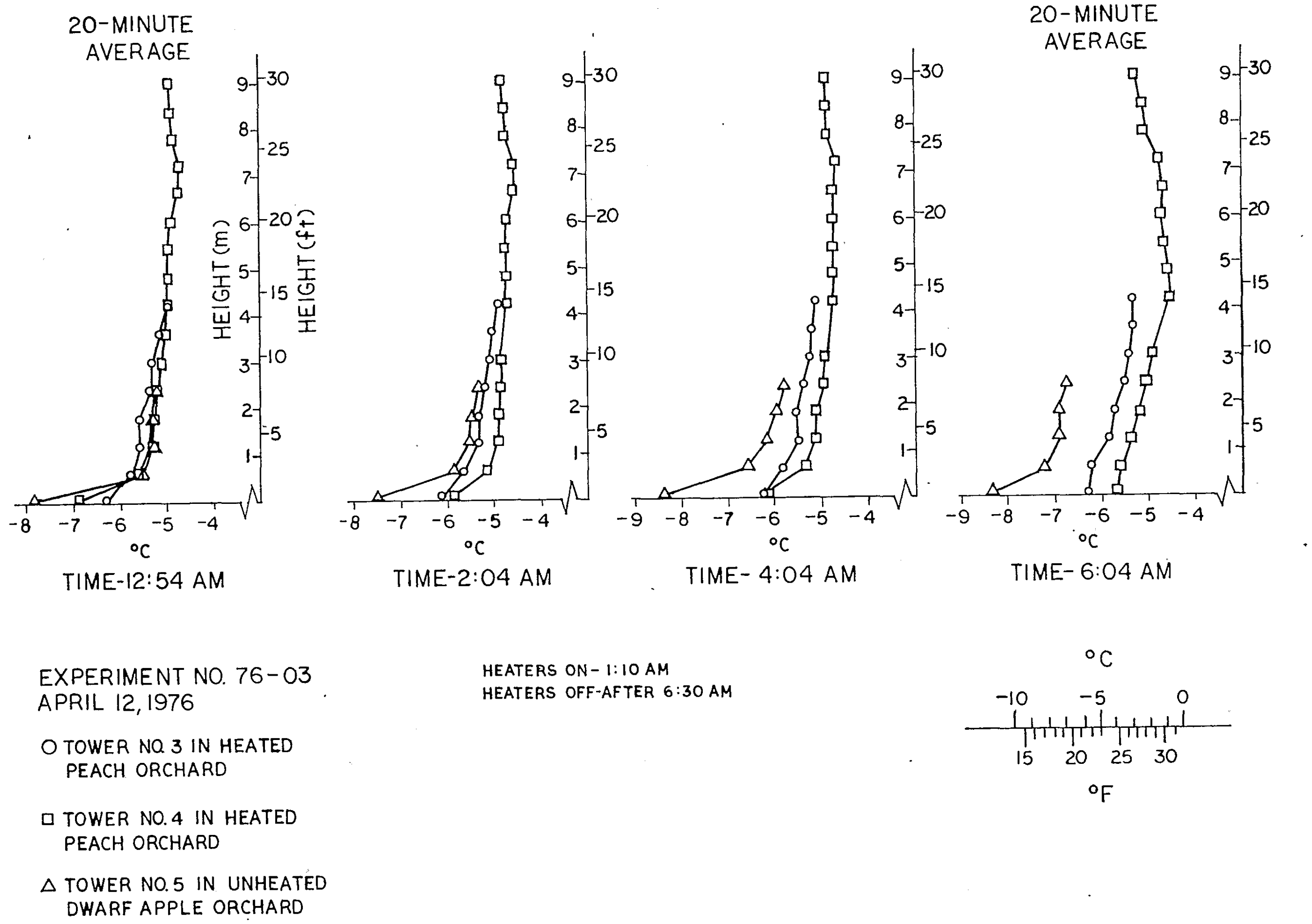

FIG. 6.—Air temperature profiles in heated and unheated orchard areas during nighttime operation of Spot heaters.

ment 76-03). Yet the results show that the mean-wind and RMS velocities were nearly the same during both experiments. However, other wind-velocity analyses not discussed in this report indicate a clear difference. The nighttime wind velocity fluctuations indicated that there was more energy in the long "wavelengths " of air motion, and less energy in the short wavelengths, than was found for the daytime observations. In physical terms, this meant that the night winds were more steady and changed slowly, while the daytime winds changed more quickly and frequently. The nighttime vs. daytime winds could be visualized as being similar to long swells vs. short, "choppy" waves in an ocean. The nighttime air movement indicates the predominance of buoyancy effect. The daytime air movement indicates stronger wind-shear effect than normally occurs under nighttime conditions.

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Organotins and Mite Control on Apples in Ohio

FRANKLIN R. HALL[2]

INTRODUCTION

Resistance of mites to newly developed acaricides has been a continuous problem wherever agricultural crops are grown. The mite resistance situation has been reviewed by Helle (6), Dittrich (2), and more recently by Herne *et al.* (7). In summary, resistance or cross-resistance has been detected in tetranychid mites to many organophosphates: organichlorines, *e.g.,* ovex and tetradifon; nitrophenols, *e.g.,* binapacryl; and formamidines, *e.g.,* chlorodimiform. To date, many classes of compounds have been usually available to growers, and thus the specific response of mites to acaricide applications differs within each agricultural area.

Herne *et al.* (7) recently reported that tetranychids have not developed resistance to organotins and Omite after consecutive applications of more than 5 years. Increased successful implementation of newly introduced IPM strategies should result in reduced reliance on repeated applications of acaricides. However, growers are faced with fewer choices of materials and if they rely too heavily on a few compounds, this lack of known resistance could change. For example, changes in the use of certain fungicides, which possess acaricidal properties, to those with non-acaricidal benefits are likely to bring about changes in the importance of mites in apple orchards. Croft and Hoyt (1), Hall (3, 4), and others have also noted "potential" for mite resurgence due to introduction of the new synthetic pyrethroids. Consequently, a continuous monitoring for mite resistance levels is needed.

Over the past few years, a number of Ohio growers have used Plictran (cyhexatin), an organotin, for the control of European red mite (ERM), *Panany-chus ulmi* Koch. Control of mites with this compound appeared to be more difficult in 1976 than earlier years. Consequently, in 1977 and 1978, a number of commercial orchards were surveyed in an attempt to establish whether there is resistance of red mite to tin-based miticides in Ohio.

METHODS AND MATERIALS

In 1977 and 1978, ERM adults were collected from a number of orchards in northern Ohio. Orchards chosen for sampling included those *with* and *without* a recorded use of organotin acaricides. Also included were orchards with both standard and dwarf apple tree plantings.

Leaves were collected at random, placed into bags in chilled containers, and brought to the laboratory for study. Standard dip tests were performed using double stick Scotch tape on microscope slides. ERM adults (20/slide) were placed upside down on the tape with a fine artist brush and slides were dipped for 3 seconds in solutions containing Plictran (cyhexatin) 50 WP @ 2 oz/100-gallon concentration. The slides (three-four replications) were drained of excess solution on paper toweling and placed on petri dishes in laboratory chambers for 24 hr for observation. Chambers were maintained at 27° C, 50% R.H., and 12/12 hr light regime.

Using lima bean leaf discs (½-inch diam.) on wet cotton in petri dishes, various sizes and numbers of droplets (Plictran 50 WP @ 2 oz/100 gal) were placed on one side of the discs by a microapplicator and microsyringe. Adult twospotted spider mites *(Tetranychus urticae* Koch) [TSSM] adults ♀'s (10/leaf disc and 4-6 replications) were placed on the leaf discs and observations made of mortality, fecundity, and reaction of mites to dried deposits over 24 hr.

In another experiment using completely dipped lima bean leaf discs, individual TSSM adult ♀'s were observed over a 1 hr time period for changes in feeding behavior. Leaf discs (½-in diam.) were dipped in solutions containing Omite 30 WP (1 lb/100 gal), Plictran 50 WP (4 oz/100 gal) and water, allowed to dry for 2 hr and placed on wet cotton in petri dishes. Individual TSSM adult ♀'s were placed on the discs and feeding behavior was observed for 1 hr. The experiments were replicated four times.

RESULTS AND DISCUSSION

In Table 1, there were no significant differences in mortality of mites among orchard sites in both 1977 and 1978 tests. In all of these tests, Plictran was utilized at a 2 oz rate (per 100 gal) which is 50-75% below the label recommendation of 4-8 oz/100 gallons. In each case, high mortality of ERM was obtained as was the case in other 1978 tests (Table 2). Orchard H mites showed a slight increase in tolerance to Plictran. This decrease in mortality, although statistically significant, is still not what would be expected if true resistance of ERM to Plictran was present. If the rate of Plictran was increased to 8-12 oz/100 gallons without an increase in ERM mortality, then resistance or at least tolerance would be suspected be-

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[1]Thanks are extended to John Gregory for his technical assistance and cooperation in these studies.

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cause of a loss in sensitivity to this 6-fold increase in material. Orchard H has had a history of mite control problems. However, orchards CAN, SR, and MO have all used Plictran over the past 4 years and have not experienced this problem.

To obtain control of very active and tiny organisms such as mites, growers must obtain good coverage and even distribution of the pesticide throughout the trees. Hall (5) recently discussed the most important factors governing "coverage" within different apple plants and noted that it was this "even" distribution that is a major factor in success or failure of a chemical. As noted by Hall (5), the major factors governing good coverage include:

1. Ground speed—2.3 mph for most plantings.
2. Nozzles—new and checked periodically.
3. Pressure—functional gauges.
4. Air velocity/air volume—airways clean and rpm's at correct rates.
5. Dosage—"a little more for good measure" is wasteful.
6. Wind—below 10 mph or do it later.
7. Temperature and relative humidity—high T and low RH will diminish low volume deposition.
8. Cultivar and pruning—open CV's and good pruning aid spray deposition patterns.
9. Tree spacing, height, and size—adjustments should be made for the target size or density.

Other factors include keeping the sprayers functional and clean, *i.e.,* operating pressure gauges and speedometers. Inadequate attention to proper calibration techniques, worn nozzles and excessive ground speed are probably the *most common problems* encountered by private consultants throughout the country. Inadequate pruning is a frequent reason for lack of mite control. In addition, excess speed of travel for the tree size, sprayer size, and the degree of pruning is also a frequent combination of factors in many orchards. Using a minimum rate of miticide is an objective of growers. *However,* the use of a minimum rate of miticide when populations of 10-20 adult mites/leaf and a large number of eggs and nymphs are present on the foliage is not going to do the job.

The problems of poor spray distribution are illustrated by data shown in Tables 3 and 4. The effect of different droplet densities of Plictran resulted in changes in the number of feeding scars and eggs/leaf disc as well as an increase in the number of adults found off the leaf disc. Repellency by deposits of various acaricides is well known but is amply displayed in this experiment.

TABLE 1.—Mortality of European Red Mite from Slide Dip Tests of Plictran (2 oz/100 gal), 24 hr After Treatment.

Location	Mean Percent Mortality* 1977	1978
Test No. 1		
Snyder	100 a	95 a
SR—Standard	85 a	90 a
SR—Dwarf	95 a	85 a
Snyder—Check	5 b	6 b
Test No. 2		
Snyder	89 a	95 a
SR—Standard	96 a	95 a
MO—Standard	100 a	88 a
Snyder—Check	12 b	10 b

*Within each test, means followed by the same letter do not differ at the .05 level of significance (DNMRT).

TABLE 2.—Mortality of European Red Mite from Slide Dip Tests of Plictran (2 oz/100 gal), 24 hr After Treatment (1978).

Location	Mean Percent Mortality*
Test No. 3	
Snyder	91 a
CAN	98 a
Snyder—Check	15 b
Test No. 4	
Snyder	95 a
CAN	97 a
H	65 b
Check	7 c

*Within each test, means followed by the same letter do not differ at the .05 level of significance (DNMRT).

TABLE 3.—Effects of Different Droplet Residues of Plictran (2 oz/100 gal) on the Behavoir of Twospotted Spider Mite 24 hr After Treatment.*

Droplet Pattern per Leaf Disc	Mean No. Feeding Scars per Leaf Disc	Mean Percent TSSM off Leaf Disc	Mean No. Eggs per Disc
1 – 5 μl	> 50 a	16.7 b	16.3 a
5 – 1 μl	> 50 a	20.0 b	22.8 a
10 – ½ μl	45 a	40.0 a	22.0 a
Complete leaf dip	11 b	46.7 a	9.5 b
Check	> 50 a	0.0 c	25.3 a

*Means in columns followed by same letter are not significantly different at .05 level (DNMRT).

TABLE 4.—Feeding Behavior of TSSM Adult ♀'s After Leaf Dip Treatments with Acaricides.*

Treatment and Rate/100 gal	Percent Feeding of TSSM After** 0 hr	24 hr
None	64.5 a	62.7 a
Omite 30 WP 1 lb	32.6 b	42.0 b
Plictran 50 WP 4 oz	30.7 b	30.3 c

*Observations over a 1 hr period of time; mean of four replications.

**Means in columns followed by same letter are not significantly different at .05 level (DNMRT).

Observations in feeding behavior (Table 4) also showed that the adult mite exhibits a reduction in actual feeding in response to acaricide deposits. The reduction in feeding of adult TSSM to Plictran deposits remained higher than Omite 24 hr after treatment of leaf discs.

In conclusion, it must be assumed that coverage in the orchard is not going to be perfect and thus results are dependent upon the mite moving across deposits of the acaricide. As shown in these studies, mites do respond negatively to Plictran deposits and if deposits are only sparsely distributed throughout the foliage, the mites could avoid the deposits and continue to increase in number. Although no resistance of ERM to Plictran in contact tests was evident in these tests, there might be a change in sensitivity to organotin deposits in field populations; *i.e.,* enhancement of avoidance behavior. However, this was not specifically tested in these studies. Low volume applications of acaricides to areas of high mite populations will continue to result in "control problems" because of the contribution of any number of the aforementioned "coverage factors". Studies of behavioral effects of various acaricides and combinations in various droplet arrays are being continued in an attempt to determine the most effective orchard use patterns.

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Model of the Air Sprayer

R. D. FOX,[1] R. D. BRAZEE,[2] D. L. REICHARD,[3] and F. R. HALL[4]

INTRODUCTION

Air velocity and turbulence patterns from orchard air sprayers control the droplet carrying and impingement functions and the ultimate distribution of spray material on fruit trees. Consequently, an understanding of key parameters of the air sprayer help to improve the efficiency of the spray deposition process on target foliage. A mathematical model of the orchard air sprayer jet (ASJ) was developed based on a theory of turbulent fan jets. The model consists of a set of equations that can be used to calculate the air velocity at any position in the sprayer air jet, for any wind condition or sprayer travel speed. The input variables that must be defined for the model are sprayer outlet radius, outlet width, air velocity at the outlet, and the ambient wind speed and direction. Derivations of the equations for the model are outlined by Brazee *et al.* (1) and Fox *et al.* (3). Measurements of air velocities produced under calm weather conditions by two air sprayers were reported by Fox *et al.* (4) and are in good agreement with the model. This report is a summary of the experimental measurements used to test the sprayer model.

EQUIPMENT AND PROCEDURES

Stationary Sprayer Experiments

The sprayer air velocities were measured outdoors over a large concrete pavement (see Fox *et al.* (4) for details). Air velocities were measured at numerous points with constant temperature hot-film (CTHF) anemometers to obtain transverse profiles (parallel to the horizontal centerline of the sprayer outlet) at various distances from the sprayer outlet. Transverse profiles were required to locate the axial, or maximum, velocity in the jet at a given distance from the outlet. The maximum velocity is usually expected to occur at the outlet centerline. However, some air sprayers do not discharge the air jet in a direction exactly perpendicular to the sprayer. The Myers 2A36[5] sprayer used in these experiments discharged the air jet at an angle of about 10°-15° toward the front of the sprayer.

Moving-Sprayer Experiments

The equipment and procedures used in the moving sprayer portion of this experiment are described in detail by Reichard *et al.* (7) and Brazee *et al.* (2). Air-velocity profiles were measured for the Myers 2A36 sprayer traveling past an instrument tower in an open field. To investigate the degree of velocity reduction due to jet-deflection effect, data were used for the sprayer traveling 4.2, 5.5, and 8.1 kilometers/hr (2.5, 3.5, and 5.0 mi/hr) at horizontal distances of 1.5, 3.0, and 4.6 meters (5, 10, and 15 ft) from the anemometer sensors. The velocity measurement points at 0.4, 1.6, 2.5, and 3.4 meters (1.5, 5, 8, and 11 ft) above the height of the sprayer centerline were selected for analysis. The measured velocities were compared with velocities predicted from the model. In the sprayer model, it is assumed that the range of spray delivery is reduced by jet deflection either due to crosswind effect or sprayer travel speed.

The model reference directions for the experiment were defined as: 1) the direction parallel to sprayer travel, 2) the direction of the radial line from the centerline of the sprayer outlet to the sensor location, and 3) the inclined, upward direction perpendicular to the first two directions. Resultant velocities were calculated as vector sums of the velocities in the directions specified above. Under ideal conditions there would be no flow in the upward-inclined direction. The direction and magnitude of the resultant ASJ velocity at a particular location were estimated from the maximum resultant velocity.

Effect of Travel Speed on Pesticide Deposit

The effects of sprayer travel speed on spray deposit patterns were also studied. Details of those experiments are reported in an article by Reichard *et al.* (6) elsewhere in this circular.

RESULTS AND DISCUSSION

Stationary Sprayer Experiments

As shown in Fig. 1, axial velocities measured for the Myers 2A36 sprayer agree closely with velocities predicted from the model for an ideal fan jet with similar outlet dimensions and velocities. The results show that velocities in air sprayer jet diminish rapidly beyond the outlet through interaction with the atmosphere. However, within 0.5 meter of the sprayer outlet, measured axial air velocity was found to increase as distance from the sprayer increased, as was also observed by Randall (5). This effect is probably due to a sustained pressure at the outlet that is partial-

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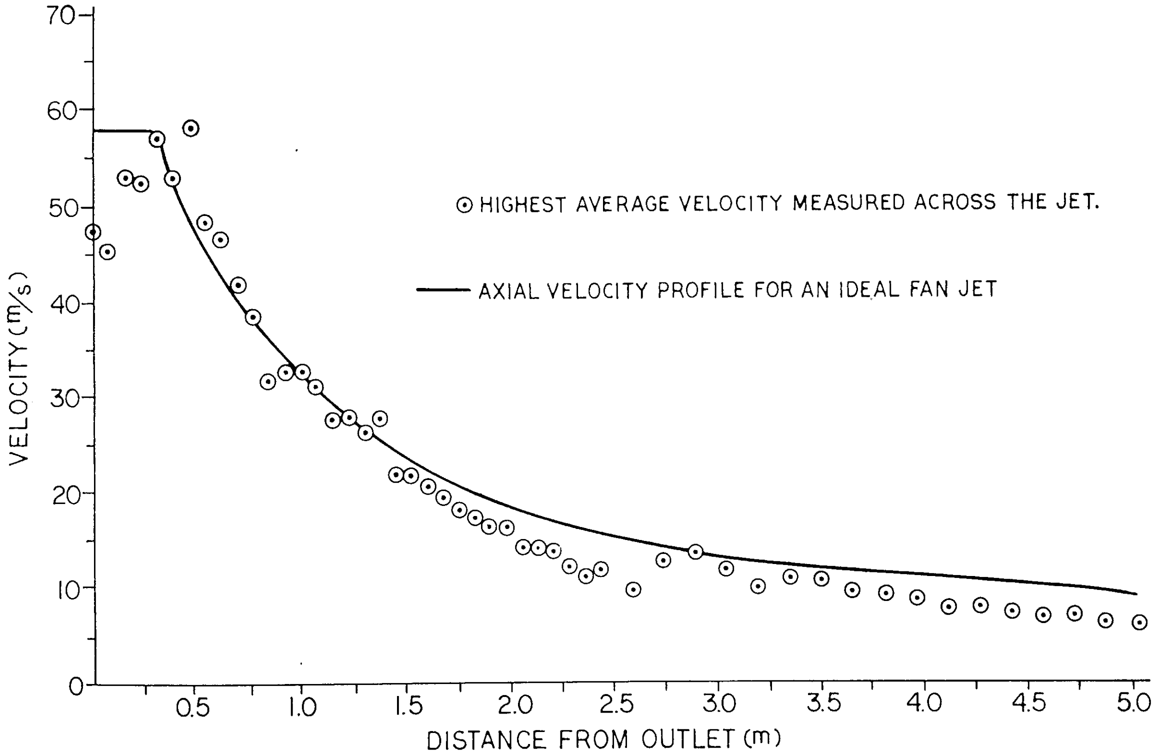

FIG. 1.—Effects of distance from outlet on highest average jet velocity for the Myers 2A36 sprayer.

ly changed into kinetic energy as the air emerges from the outlet. Beyond the region of increasing velocity, the jet entrains ambient air and disperses, which results in a rapid decrease in velocities. At greater distances from the outlet, the wind or atmospheric turbulence may affect the jet and further reduce the air velocities.

Moving Sprayer Experiments

In the moving sprayer experiments, travel of the sprayer in effect generated a constant crosswind acting upon the jet. An effort was made to conduct these experiments when the ambient wind speed was low. However, each experimental series required several hours to complete and the actual wind velocity varied from 0.5 to 1.5 meters/sec (1 to 3.4 mi/hr) at 1.5 meters (5 ft) above the ground and from 1.5 to 3.0 meters/sec (3.4 to 6.7 mi/hr) at the height of 4.5 meters (15 ft). The wind direction was generally opposite that of the air sprayer jet. The effects of the ambient wind were neglected in the moving-sprayer model calculations.

Predicted and measured air velocities for the Myers 2A36 sprayer are plotted in Fig. 2. For comparison, a portion of the same information shown in Fig. 1 for the stationary sprayer tests is also plotted in Fig. 2. The reference distances plotted in Fig. 2 were the actual radial distances from the circular sprayer outlet to sensors located at four different levels. In Fig. 2, the change in the measured velocity magnitude for a given change in sprayer travel speed was, in most instances, about twice as great as had been calculated from theory.

Effect of Travel Speed on Pesticide Deposit

Table 1 is a listing of the amounts of pesticide deposited on target slides by an air sprayer moving past sampling towers. The outlet-to-targets distances of 3.1, 3.5, and 4.3 meters were actual radial distances to targets at levels of 1.5, 3.0, and 4.6 meters (5, 10, and 15 ft), respectively.

At the shortest outlet-to-target distance (3.1 meters), there was no significant difference in deposit among the three travel speeds. At the middle outlet-to-target distance (3.5 meters), there was no signifi-

TABLE 1.—Effects of Travel Speed on the Amount of Pesticide Deposited on Slide Targets.

		Mean Deposit of Permethrin (µg/cm²)		
		Distance from Outlet to Target		
Travel Speed km/h	mi/hr	3.1 meters (10.0 ft)	3.5 meters (11.5 ft)	4.3 meters (14.0 ft)
3.2	2	0.896	0.832[a]*	0.653[a]
6.4	4	1.02	0.874[a]	0.276[b]
9.7	6	0.671	0.260[b]	0.095[c]

*Means followed by the same letter are not significantly different at the 5 % level of probability.

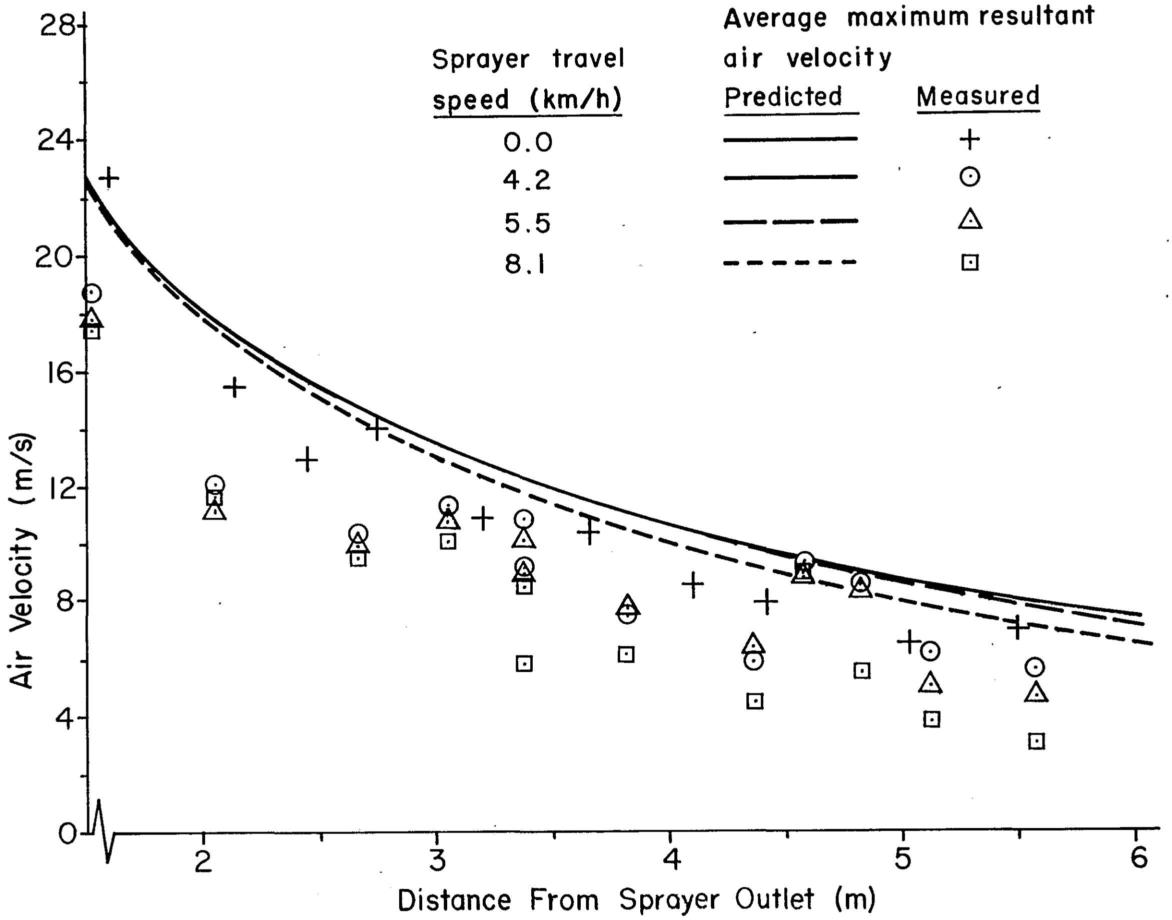

FIG. 2.—Effects of sprayer travel speed and distance from sprayer on the average maximum air velocities produced by an air sprayer.

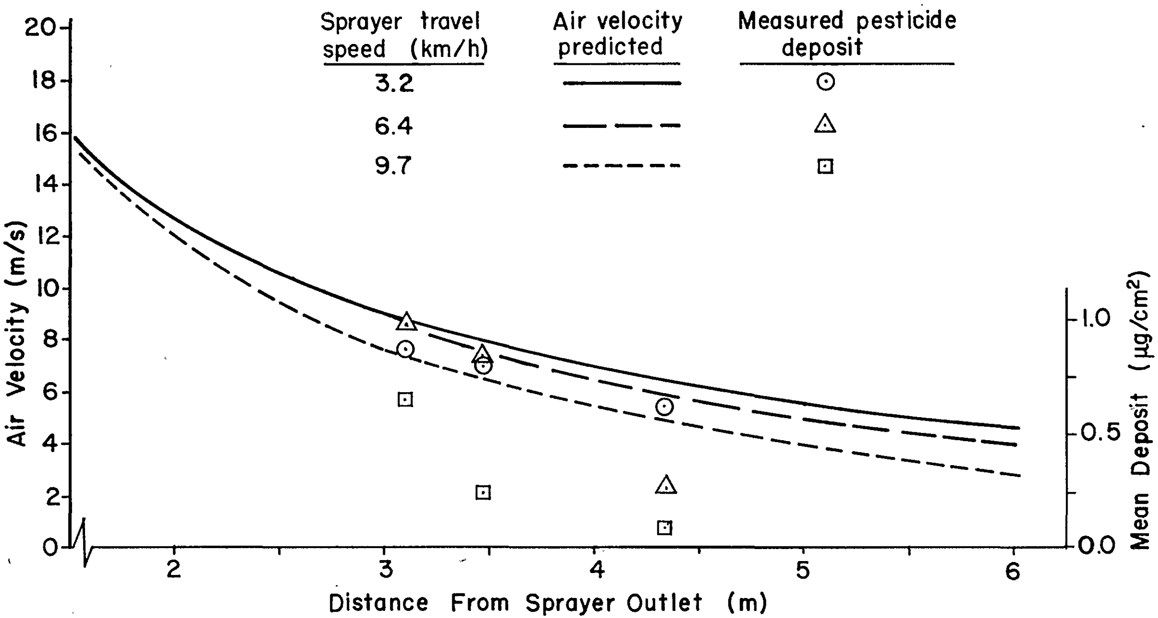

FIG. 3.—Effects of sprayer travel speed and distance from sprayer on the amount of pesticide deposited on target slides.

cant difference in deposit between the 3.2 and 6.4 km/hr (2 and 4 mi/hr) travel speeds, but both produced significantly higher deposits than the 9.7 km/hr (6 mi/hr) speed. At the greatest outlet-to-target distance (4.3 meters), the deposits for the three travel speeds were significantly different and deposit decreased as travel speed increased.

The sprayer used in the deposition experiments was a Myers Model T-33. The characteristics for the T-33 sprayer were used in the sprayer model to obtain the family of air velocity curves plotted in Fig. 3 for the three travel speeds. The scale of the mean-deposit axis of Fig. 3 was selected so the 1.02 $\mu g/cm^2$ value was on the theoretical velocity curve at the 3.1 meters (10.1 ft) outlet-to-target distance. Thus, it was possible to compare the effects that both travel speed and distance from the sprayer had on the amount of pesticide deposited (Fig. 3) with the effects that these same variables had on the measured air velocities (Fig. 2). A comparison of Figs. 2 and 3 shows that measured air velocities and deposits both decreased as travel speeds and distances from the outlet increased.

Randall (5) measured the effects of travel speed and distance from sprayer on air velocities and on pesticide deposit. His results for three small air sprayers were similar to the results of this research. Sprayer travel speed had a greater effect on air velocities produced by air sprayers than was predicted by the sprayer model developed here, but the air jet velocities delivered by stationary sprayers were close to the predicted values.

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Effects of Application Equipment Variables on Spray Deposition by Orchard Air Sprayers

D. L. REICHARD,[1] F. R. HALL,[2] and H. R. KRUEGER[2]

SUMMARY

The effects of several variables on deposition by an orchard air sprayer were measured. Sixty gpa produced significantly higher total deposit than either 24 or 12 gpa rates. There was no significant difference in total deposits between 100 and 200 psi, but 50 psi produced significantly lesser total deposit. The highest blower rpm produced significantly higher total deposit than any of the other blower rpm. Residue deposits on targets at the 15 ft height decreased as travel speed increased.

INTRODUCTION

It is desirable to achieve pest control with the minimum amount of pest control agent, pollution to the environment, and energy requirement. Several application equipment variables influence the deposition of pesticides on targets, but few data are available regarding the effects of these variables on deposition. During the summer of 1979, the authors measured spray deposits produced with various solution application rates, nozzle pressures, blower speeds, and travel speeds.

METHODS AND MATERIALS

A model T33 sprayer (F. E. Myers Company)[3] was used in all experiments. The sprayer mounts on the 3-point hitch of a tractor and is driven by the tractor PTO. It delivers about 18,700 cubic feet per minute (ft^3/min) of air at about 94 miles per hour (mph) from each side when driven by the PTO at 550 rpm. The sprayer is equipped with eight nozzles per side, but only six nozzles on the right-hand side were used—the top and bottom nozzles were shut off. All nozzles (Spraying Systems Co.) produced hollow cone spray patterns and all except the TX2.5 nozzles were disc-core type.

Table 1 shows the nozzles, pressures, solution and pesticide rates, PTO and travel speeds used in all experiments. Permethrin (Ambush 2E) was used in all experiments, each of which was performed on a different date.

To determine deposition, all sprays were directed toward glass microscope slides (1 x 3 in) fastened with clips on vertical poles at heights 5, 10, and 15 ft above ground. The slides were extended from the poles with the 1-inch long side vertical and the 3-inch long sides parallel to the side of the sprayer. Five poles with slides were placed 1 ft apart in a line parallel with and 10 ft (horizontal distance) from the line of travel of the nozzle on the horizontal centerline of the sprayer.

Following each of the five passes (replicates) for each treatment, the slides at each height were re-

TABLE 1.—Variables Used in Experiments.

Experiment Variable	Nozzles	Gage Pressure (psi)	Solution Rate* (gpa)	Pounds Active Permethrin* (per A)	PTO Speed (rpm)	Travel Speed (mph)
Application rate	D4-23	200	60	0.224	550	2
	D1.5-13	200	24	0.224	550	2
	TX2.5	200	12	0.224	550	2
Nozzle pressure	D4-23	200	42	0.224	550	2
	D6-23	100	42	0.224	550	2
	D4-25	50	42	0.224	550	2
PTO rpm	D4-23	200	42	0.224	580	2
	D4-23	200	42	0.224	500	2
	D4-23	200	42	0.224	400	2
	D4-23	200	42	0.224	300	2
Travel speed	D4-23	200	42	0.224	550	2
	D4-23	200	21	0.112	550	4
	D4-23	200	14	0.075	550	6

*Based on spraying both sides of rows 20 ft apart.

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moved from the poles and the residues were flushed with acetone into a sample bottle. The residues were analyzed with a model 2500 Tracor gas chromatograph within 48 hours after each experiment. The residue data reported here are the mean micrograms per square centimeter ($\mu g/cm^2$) on both sides of the glass slides.

Treatments were tested for significant statistical differences by Duncan's multiple range test.

RESULTS AND DISCUSSION

The highest application rate, 60 gallons per acre (gpa), produced a significantly (5% level) higher overall deposit over the three heights than either 24 or 12 gpa. Figure 1 shows examples of the mean deposits on slides at 5, 10, and 15 ft heights for 12 and 60 gpa. The highest gpa rate produced significantly higher deposit at the 5-ft height than any other treatment at any height. The lowest gpa rate produced significantly higher deposit at the 15 ft height than either of the 24 or 12 gpa rates at the same height.

According to unpublished droplet size data from the Spraying Systems Co., the D4-23 nozzles would produce drops with a mass median diameter considerably larger than those produced by either the D1.5-13 or TX2.5 nozzles. Apparently the total volume of drops conveyed to the 15 ft height was less with the D4-23 nozzles than with the TX2.5 nozzles. Obviously, nozzles should be selected for a sprayer so its air jet will be able to convey and effect impingement of the droplets at the top of the target. Nozzles should also be selected so that the volume of spray reaching the various target areas of the tree provides adequate coverage of the foliage.

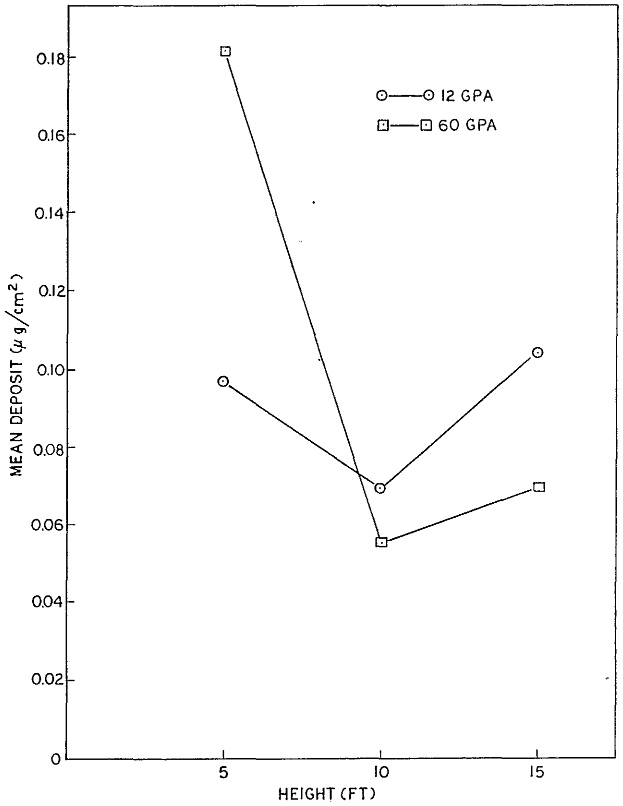

FIG. 1.—Comparison of residue deposits on slides for application rates of 12 and 60 gpa.

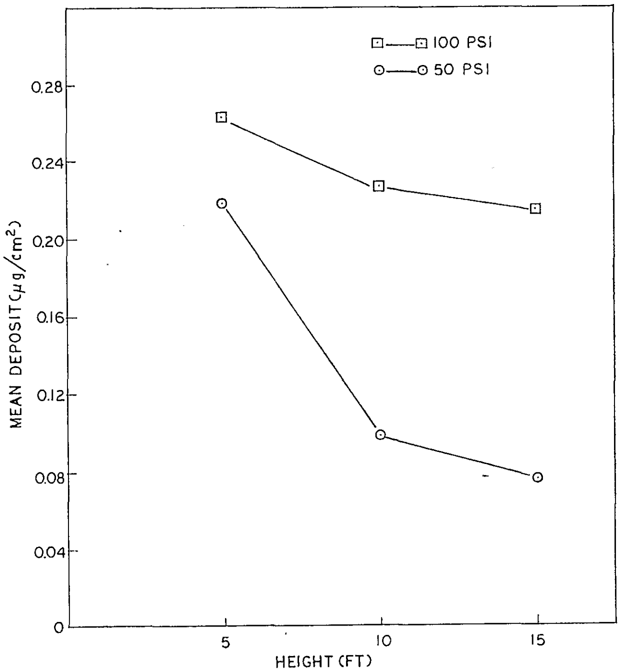

FIG. 2.—Effects of 50 and 100 psi pressures on residue deposits on slides.

Figure 2 shows the effect of nozzle pressure on deposition on slides at 5, 10, and 15 ft heights. There was no significant difference in total deposit over all heights between 100 and 200 psi (pounds per square inch) pressures. The 50 psi pressure caused lower mean deposits at all heights and significantly lower total deposit over all heights than the 100 and 200 psi pressures. For the liquid flow rates and air jet velocities in this experiment, 50 psi pressure was too low, but there was no apparent advantage in using pressures higher than 100 psi.

Nozzle pressures lower than those commonly used with orchard air sprayers would reduce the rate of wear of nozzle orifices, and in many cases cost of the pump and other sprayer components. To spray the same gallons per minute (gpm) at lower pressures with the same type of atomizer requires the use of larger orifices which produce sprays with larger mean diameter drops.

Ideally, a sprayer should distribute the pesticide uniformly over the target while consuming the minimum possible amount of power. Since the input power to a blower varies about directly as its rpm

TABLE 2.—Effect of PTO Speed on Deposition on Glass Slides at 5, 10, and 15 Feet Above Ground and 10 Feet (Horizontal Distance) from Air Outlet.

PTO Speed (rpm)	Blower Power (hp)	Air Flow Rate (ft^3/min)	Air Velocity (mph)	Mean Deposit ($\mu g/cm^2$)
580	39	39300	99	0.298^{a*}
500	25	33900	86	0.252^{b}
400	13	27100	68	0.245^{b}
300	6	20300	51	0.232^{b}

*Means followed by same letter are not significantly different at the 5 % level.

cubed, the power requirement decreases very rapidly as rpm decreases. Table 2 shows the approximate blower power requirements, air flow rates, and velocities at the outlet for PTO speeds of 580, 500, 400, and 300 rpm. The actual blower rpm was about four times the PTO rpm.

Table 2 also shows the mean of the total deposit on slides at 5, 10, and 15 ft heights for the four different PTO rpm. The mean deposit decreased as the blower speed decreased, and the 580 rpm PTO speed produced a significantly greater deposit than any of the other PTO rpm.

Figure 3 shows the amounts of mean deposits on the slides at 5, 10, and 15 ft heights for the four PTO rpm. The amount of deposit decreased as blower speed decreased at the 5 ft height. The 580 rpm PTO speed produced significantly greater deposits at the 5 ft height than any of the other PTO rpm and it produced deposits at both the 10 and 15 ft heights that were not sigificantly different from the greatest amount of deposits produced by other speeds. The data indicate that to provide the maximum deposit at the distances from the sprayer used in this experiment, the T33 sprayer should be operated at about 580 rpm PTO speed. Brazee *et al.* (1) and Fox *et al.* (3) have developed equations that can be used by sprayer engineers to develop sprayers providing the desired air jet velocities with minimum input power.

Figure 3 also shows the trend toward decreased deposits as height increased. Obviously, a different nozzle arrangement around the outlet would be required to provide a uniform distribution over the three heights. Ideally, the amount of deposition varies inversely as the distance from the nozzle, and to obtain equivalent deposits at twice the distance requires twice the flow rate at the nozzle.

Fox *et al.* (2) developed equations to determine the effects of travel speed and wind on sprayer air jets, and Reichard *et al.* (4) measured air velocities delivered by air sprayers traveling at various speeds. Both publications show that increased travel speed causes decreased air jet velocity.

The authors measured the effects of travel speed on deposition. The same tank mix was used for all

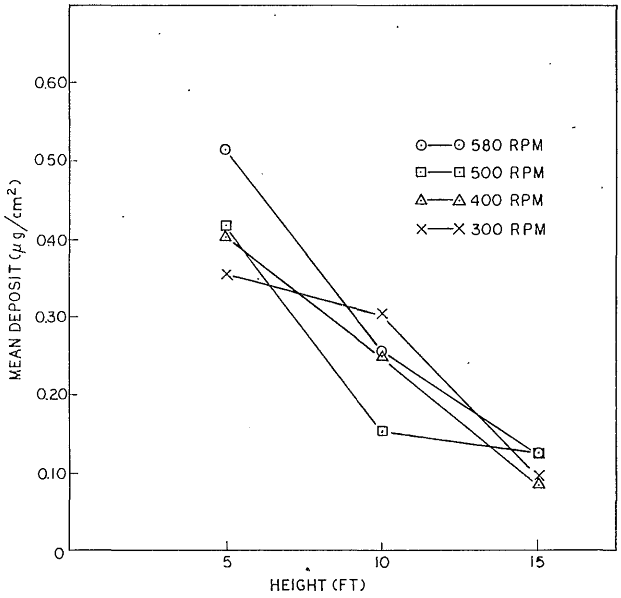

FIG. 3.—Effects of PTO rpm on residue deposits on slides.

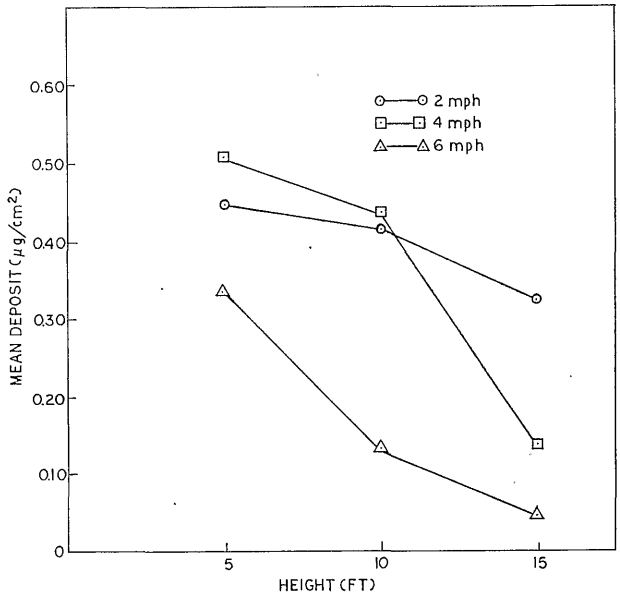

FIG. 4.—Effects of travel speed on residue deposits on slides.

travel speeds, and the residue data were adjusted to account for the difference due to travel speed. Figure 4 shows the amounts of deposition on the slide at 5, 10, and 15 ft heights for 2, 4, and 6 mph travel speeds. At the 15 ft height, all three travel speeds produced significantly different amounts of deposit. The 2 mph speed produced nearly seven times as much deposit at the 15 ft height as the 6 mph speed. There was no significant difference among deposits due to travel speed at the 5 ft height. At the 10 ft height, there was no significant difference in deposits between 2 and 4 mph travel speed, but the 6 mph travel speed caused significantly lesser deposit. Travel speed greatly influenced deposition—especially at the 15 ft height.

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Fungi Associated with Moldy-Core of Apple and Their Location within Fruit

MICHAEL A. ELLIS[1] [2]

INTRODUCTION

The weather conditions during the 1979 growing season provided excellent conditions for development of most apple diseases. High levels of scab, caused by *Venturia inaequalis,* and fireblight, caused by *Erwinia amylovora,* were present in most orchards around the state. Conditions that favor scab and fireblight development also favor the development of moldy-core or Alternaria core rot. Under conditions of high humidity and mild temperatures during late spring, many fungi can infect the fruit of open-calyx varieties such as Red Delicious (5, 7). These fungi enter the calyx and colonize the core or carpel area. Once inside the fruit, conditions for their growth and reproduction are excellent and they are protected from fungicide application. Disease incidence has been reported to be greater in apples that have been damaged by late spring frost so that seeds do not develop normally (5).

Fruit affected with moldy-core have a black to gray fungus growth over the seed and carpel walls (Figs. 1 and 2). In some seasons more than 50% of stored Red Delicious apples have been affected. Occasionally the infection continues into the outside flesh and appears externally as a brown rot, but rotting of the flesh is not common (1).

Several Ohio growers experienced high levels of moldy-core in several varieties during the 1979 season. Affected fruit appeared normal when harvested and sold but when cut in half, fungus growth was observed in the core and many consumers assumed that the fruit was rotten. Thus, moldy-core is a factor reducing apple fruit quality in Ohio. The purpose of this study is to determine the fungi associated with moldy-core in Ohio, and their location within the fruit.

MATERIALS AND METHODS

Fruit of the varieties Red Delicious, Quinte, Vista Bella, Melba, and July Red were collected at harvest. Apples of each variety were handpicked from the tree or picked off the ground where they had dropped. Only firm fruit without external signs of decay were selected.

Dropped and handpicked fruit of each variety were cut in half and the number of fruit with visible mycelia in the core was recorded. Isolations from half of each cut fruit were made from a seed, carpel

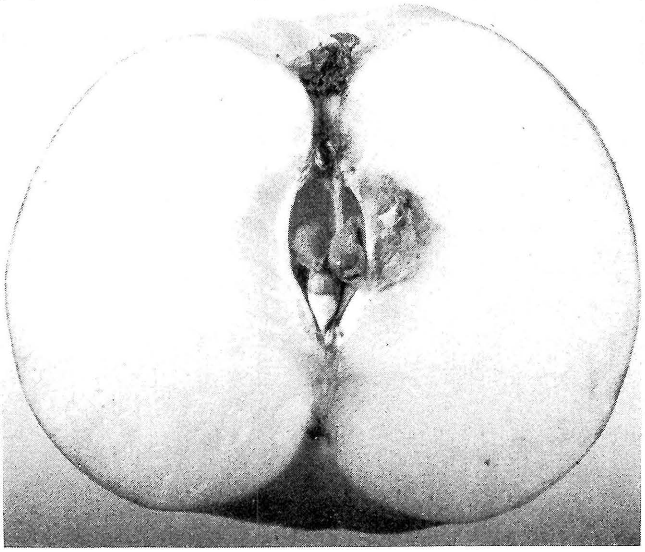

FIG. 1.—Cross-section of fruit with moldy-core. Note the dark fungal growth over seeds and carpel wall.

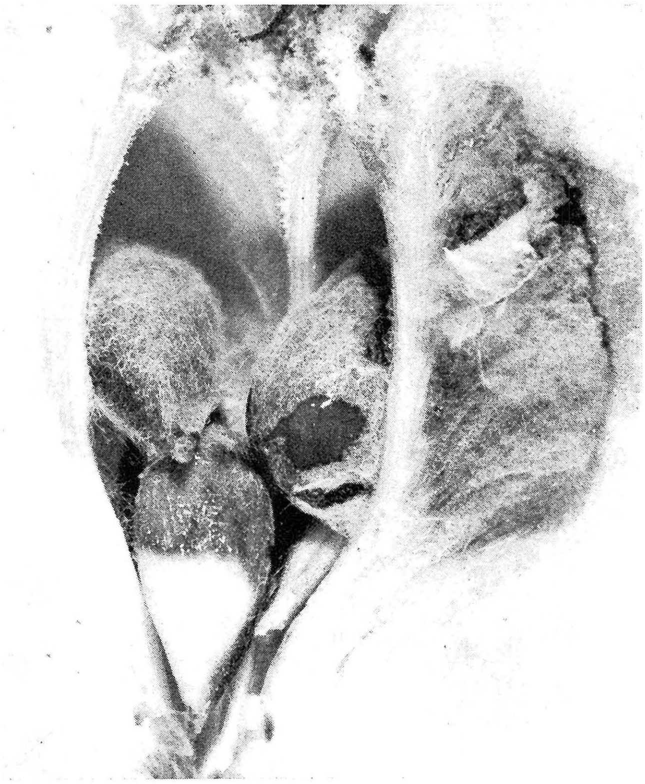

FIG. 2.—Close-up of the core region of Figure 1.

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[2] The author wishes to thank Allen and Bob Sage, Chardon, Ohio, for supplying fruit and R. M. Ritter for his technical assistance in this study.

wall, and flesh ¼ inch outside the carpel wall. One seed and tissue sections from each fruit were surface disinfected by soaking in a 0.25% sodium hypochlorite solution for 30 seconds, then rinsed in sterile distilled water and plated on potato dextrose agar in petri plates.

After 5 days the presence of fungi was recorded. Isolations from distinctively different fungal colony types were made and the fungi were identified to genus.

RESULTS AND DISCUSSION

The following genera of fungi were isolated from the cores of fruit: *Alternaria, Botrytis, Candida, Cladosporium, Coniothyrium, Fusarium, Gloeosporium, Eppicoccum, Penicillium, Phoma, Sporothrix,* and *Trichoderma.* Ninety-eight percent of all fungi isolated were *Alternaria* spp. *Alternaria alternata* was the most prevalent species. Visible mycelia in the core region was always that of *Alternaria.*

The number of fruit with visible mycelia was greater in dropped than in handpicked fruit for all varieties tested (Table 1). Even when fruit had no visible mycelia, the majority of cores were colonized by *Alternaria.* This suggests that fungal growth in the core region may have some effect on fruit drop. It has been reported that infected fruit may mature and color faster in the orchard (5).

The percentage of handpicked fruit of the varieties Red Delicious, Quinte, and Melba with visible mycelia in the core suggests that moldy-core is a significant factor affecting apple fruit quality in Ohio. The extent to which the disease is present in the state is not known and undoubtedly varies between seasons and locations, depending on environmental conditions.

No fruit tested showed any signs of external rot, and visible mycelia appeared to always be restricted to within the carpel wall. Isolations from fruit indicate that *Alternaria* is restricted to within the carpel wall (Table 2). Of 500 fruits tested, *Alternaria* was recovered from cores (either seed or carpel wall) of 426. *Alternaria* was recovered from the flesh ¼ inch outside the carpel wall of only two fruits. The results of this study indicate that at time of harvest moldy-core is a disease restricted almost entirely to the core and has little effect on the flesh or edible portion of the fruit. The effects of moldy-core on apple fruit during storage need to be determined.

One factor that may account for an increased incidence of moldy-core is the absence of fungicide application during bloom. In the past, fungicides were routinely applied during bloom. Bloom sprays were stopped by many growers due to reports that certain fungicides adversely affect apple pollen germination and fruit set (3, 4, 6). Brown and Hendrix (2) recently reported that fungicides recommended for

TABLE 1.—Number of Fruit with Visible Mycelia (Moldy-core) and Number of Fruit from which *Alternaria* **spp. Was Isolated from the Core Region.**

	Fruit with Visible Mycelia*		Fruit from which *Alternaria* was Isolated from Core	
Variety	Dropped	Handpicked	Dropped	Handpicked
Red Delicious	33	13	47	39
Quinte	45	22	50	48
Melba	30	9	48	39
Vista Bella	12	0	46	36
July Red	10	0	39	34

*All figures based on 50 dropped or handpicked fruit of each variety. Dropped = firm fruit (with no indication of rot) lying on the ground beneath the same tree where handpicked fruit were obtained.

TABLE 2.—Recovery of *Alternaria* **spp. from Various Locations Within the Fruit.**

	Recovery of *Alternaria* spp.*					
	Dropped			Handpicked		
Variety	Seed	Carpel Wall	Flesh	Seed	Carpel Wall	Flesh
Red Delicious	43	45	0	37	39	0
Quinte	46	48	1	44	46	0
Melba	43	46	1	36	37	0
Vista Bella	42	44	0	32	34	0
July Red	36	38	0	31	33	0

*All figures based on 50 dropped or handpicked fruit of each variety. Dropped = firm fruit (with no indication of rot) lying on the ground beneath the same tree where handpicked fruit were obtained.

apple disease control did not significantly affect fruit set, even when application rates were doubled. They also reported that bloom sprays were beneficial because they protected against several fruit rot fungi, especially those causing core rot. Further studies will be conducted to evaluate the effects of fungicide application during bloom on fruit set and fruit rots under Ohio conditions.

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Nutrient Content of Twelve French and American Hybrid Grape Cultivars Grown Under a Wide Range of Soil Conditions

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INTRODUCTION

Development of foliar analysis as a diagnostic technique for horticultural crops has been a matter of continuous research for many years in Ohio as well as elsewhere. Samples from fruit crops are now routinely sent to service laboratories by growers to aid them in determining their fertilizer needs. Foliar analyses are also used with as much zeal as ever by scientists attempting to identify those nutritional factors associated with optimum production and quality.

Because of their commercial importance, grapes were among the first fruit crops for which nutritional standards were developed. In California and Europe the cultivars used were those of *Vitis vinifera* species. East of the Rocky Mountains standards were developed for cultivars of *Vitis labrusca*—primarily Concord. Even though a plant analysis program has been available to Ohio grape growers since 1964 (2), many nutritional relationships still need further study and refinement.

Present standards are based primarily on research with Concord *(Vitis labrusca)*. Numerous other cultivars, especially the French hybrids, are now being planted throughout the Midwest and East. There is reason to believe that these standards cannot be applied to all of these cultivars with the same degree of accuracy. Thus, the question to be answered is, "Which cultivars of commercial importance have nutritional requirements different from Concord?"

MATERIALS AND METHODS

In order for nutritional standards to have proper meaning, consistent sampling and analysis procedures must be strictly followed and related to yield and productivity. In the present study, experimental plantings consisting of 12 cultivars were established in 14 southern Ohio counties during 1965-66 (Adams—1, Clinton—6, Clermont—5, Hamilton—7, Monroe—11, Washington—14, Athens—2, Meigs—10, Jackson—8, Lawrence—9, Scioto—12, Brown—3, Butler—4, and Warren—13).

The primary purpose of these vineyards was to extend grape research studies across a broad area with considerable variability in soil and climate but which in general was thought to have considerable acreage suitable for grape production. Sixty vines of each cultivar were randomly located in rows and placed at 2 locations in each vineyard (2-30 vine replications). The analyses reported are for an average of 30 vines/sample.

Between July 15 and August 5, 1968, 60 petioles of each cultivar were taken for analysis from each of the 2 replications in the 14 vineyards. These petioles were from recently matured leaves on fruiting shoots exposed to the sun. Samples were returned to the laboratory at Wooster, dried at 70° C, ground, and analyzed for the following essential nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), iron (Fe), boron (B), copper (Cu), molybdenum (Mo), and zinc (Zn). The resulting data were subjected to statistical analysis to determine differences among the cultivars and locations. During the summer and fall of 1969, visits were made by personnel from the USDA Soil Conservation Service under the direction of the State Soil Scientist.[2] Detailed information was compiled on each soil in each of the vineyards (3).

The study was terminated in 1970. At this time four vineyards were in their sixth, ten in their fifth, and one in its fourth growing season. Eleven of a possible 12 cultivars were established at each location, and represent cultivars that were considered at the time to have possibilities as both fresh and wine grapes.

In 1960 a vineyard was established at the Southern Branch, Ripley, with 39 cultivars. In 1964, varying degrees of visual potassium deficiency symptoms developed among these cultivars. Petiole samples were taken in mid-July, 1964 and 1965, and analyzed for 13 nutrient elements, including potassium. Cultivars were classified into groups according to the visual symptoms exhibited in 1964.

In August 1964, an initial potassium application of ½ lb per vine was made to all cultivars. However, deficiency symptoms were not alleviated until 1965 when 2 lb of potassium sulfate per vine was applied and irrigated into the soil with 2½ acre inches of water.

DESCRIPTIONS OF SOIL SERIES FROM THE 14 VINEYARDS

The following are brief but pertinent descriptions of the soil(s) of each vineyard according to series, texture, slope, wetness, pH, available moisture

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capacity, depth, permeability, general fertility, general vine vigor, and productivity.

Vineyard 1—Adams County (AD): Soil is a Nicholson silt loam. It has fairly good natural drainage but a dense fragipan in the subsoil limits the percolation of water and the passage of plant roots. Plant nutrient supply in the subsoil is medium. Soil erosion is a hazard on the more sloping east side of the plot. Nicholson soils occur on ridgetops in unglaciated areas of Adams and adjacent counties where the underlying bedrock is limestone or high lime shale. Soil pH is 6.3 at 20 inches and 6.0 at 40 inches. Vine vigor and yield were poor.

Vineyard 2—Athens County (AT): Two soil types are represented. Strongly sloping Gilpin silt loam occurs on about two-thirds of the vineyard. Gently sloping Zanesville silt loam occurs on the southwest part and comprises the remainder. Acid sandstone or siltstone underlies Gilpin soils at depths of about 2 feet and Zanesville soils at about 4 feet. A dense fragipan layer occurs at depths of about 2 feet in Zanesville soils, restricting the movement of water and roots. The supply of plant nutrients is low in the subsoil of both. These soils are extensive in the unglaciated region of southeastern Ohio. Soil pH at 20 inches is 5.0 for Gilpin and Zanesville. At 40 inches, pH is 5.5 for Zanesville, and bedrock for Gilpin. Vine vigor and yield were moderate.

Vineyard 3—Brown County (BR): Soil is Rossmoyne silt loam. It has fairly good natural drainage. A dense fragipan layer about 2 feet thick occurs below depths of about 2 feet, limiting percolation of water and restricting the plant rooting zone. Soil has low to medium supply of subsoil nutrients. It is an extensive soil in the better drained portions of the Illinoian age glaciated region of southwestern Ohio. Rossmoyne soils are underlain by glacial till which is leached to depths of 5 feet or more. Soil pH is 4.8 at 20 inches and 5.5 at 40 inches. Vine vigor and yield were moderate.

Vineyard 4—Butler County (BU): Miamian silt loam is the dominant soil in this vineyard. A strip of eroded Hennepin clay loam about 50 feet wide occurs on the slope along the west side. Both soils have good natural drainage. Compact, limey glacial till occurs below depths of 24 to 30 inches in Miamian soils and at depths of less than 12 inches in Hennepin soils. Plant nutrient supply in the subsoil is medium to high in both soils. Hennepin soils are thin and tend to be droughty. Miamian soils are extensive in the better-drained areas of the Wisconsin age glaciated region of central and western Ohio. Hennepin soils occur on steep slopes in this region and soil erosion is a hazard. Soil pH at 20 inches is 7.0 (neutral); at 40 inches it is 8+ (calcareous). Vine vigor and yield were exceptionally good.

Vineyard 5—Clermont County (CL): Rossmoyne silt loam is the dominant soil in this vineyard. The level area at the east end is Avonburg silt loam, a wet soil with somewhat poor natural drainage. Rossmoyne soils have fairly good natural drainage, but they have a dense fragipan layer below depths of about 2 feet, limiting percolation of water and restricting the plant rooting zone. These soils have low to medium plant nutrient supply in the subsoil. They are underlain by glacial till which is leached to depths of 5 feet or more and are extensive soils in the Illinoian age glaciated region of southwestern Ohio. Soil pH is 6.0 at 20 inches and 5.2 at 40 inches. Vine vigor and yield were good to excellent.

Vineyard 6—Clinton County (CC): Soil is a Russell silt loam. It has good natural drainage and medium to high plant nutrient supply in the subsoil. Limey glacial till occurs below depth of about 3 feet. The upper 2 feet of this soil formed in a very silty material called loess. This soil is extensive in the better-drained portions of the loess-covered Wisconsin age glaciated region of southwestern Ohio. Soil pH is 6.7 at 20 inches and 8+ (calcareous) at 40 inches. Vine vigor and yield were moderate.

Vineyard 7—Hamilton County (HA): Rossmoyne silt loam is the dominant soil in this vineyard. It has fairly good natural drainage. Cincinnati silt loam (eroded) occurs on the more sloping area at the north end. It is naturally well drained. Both soils have a dense fragipan horizon at a depth of about 2 feet which restricts the movement of water and plant roots. This layer is more pronounced in Rossmoyne than in Cincinnati soils. Both soils have low to medium subsoil nutrient supply, and overlie glacial till which is leached to depths of 5 feet or more. These soils are extensive in the better-drained portions of the Illinoian age glaciated region of southwestern Ohio. Soil pH is 5.5 at 20 inches and 5.0 at 40 inches. Vine vigor and productivity were excellent.

Vineyard 8—Jackson County (JA): The soil in this vineyard is an eroded Clymer loam. It is sloping to strongly sloping and has a soil erosion hazard. It has good natural drainage but a low plant nutrient supply. It is underlain by sandstone bedrock at depths of 2 to 3 feet. This soil occurs in scattered areas in the unglaciated region of southern Ohio. Soil pH at 20 inches is 5.5; at 40 inches it is 5.0. Vine vigor and yield were good.

Vineyard 9—Lawrence County (LA): Soil is a Huntington loam. It is deep with good natural drainage and high plant nutrient supply in the subsoil. It has a dark color and high organic matter content. This soil is extensive in the flood plains along the Ohio River and some of the major tributaries. Soil pH at 20 and 40 inches is 6.5. The entire vineyard is uniform in soil characteristics. Vine vigor and yield were good.

Vineyard 10—Meigs County (MG): Two soil types are represented. Tilsit silt loam occurs on the north two-thirds of the vineyard and Rarden on the south one-third. Both soils have fairly good natural drainage and low plant food supply on the subsoil. Rarden soils have reddish-brown clay lower subsoils and overlie acid shale. Tilsit soils have dense fragipan layers below depths of about 2 feet and overlie acid siltstone. Soil erosion is likely, especially on Rarden. These soils are extensive in the western portion of the unglaciated region of southwestern Ohio. Soil pH at 20 inches is 5.0 for Tilsit and 4.5 for Rarden. At 40 inches it is 5.0 for Tilsit and 4.5 for Rarden. Vine vigor and yield were poor (due to frost several years, comparison is not very valid).

Vineyard 11—Monroe County (MO): Three soil types are represented. The dominant type is Latham silt loam. It has a clay subsoil and is underlain by very acid gray shale at depths of 1½ to 3 feet on the sloping areas on the north half of the plot and on the nearly level area of the south half. Three small areas of Woodsfield silt loam occur in the middle portion of the plot, two along the east side an one along the west side. This soil has fairly good natural drainage and is underlain by red clay. Wellston silt loam occurs in a small area in the northwest corner of the plot, and Clymer silt loam in a narrow strip along the west side of the south half. Wellston soils are silty and Clymer soils are sandy. Both are underlain by acid sandstone. Except for Woodsfield, these soils have low plant nutrient supply in the subsoil. Woodsfield has medium fertility. These soils occur throughout the unglaciated region of southeastern Ohio. Soil pH at 20 inches is 5.0 for Wellston and Latham, 4.8 for Woodsfield, and 6.0 for Clymer. Soil pH at 40 inches or budbreak is 5.2. Vigor and yield were moderate to good.

Vineyard 12— Scioto County (SC): Coolville and Monongahela soils occur in this vineyard. They have fairly good natural drainage but both have subsoil layers which limit percolation of water and the passage of plant roots. The Coolville soil on the west one-fifth of the plot has heavy clay below depths of about 35 inches. Monongahela soils comprise the remainder of the plot. These have dense fragipan layers below depths of about 28 inches. Both soils are naturally low in subsoil nutrients and both occur in small areas throughout the unglaciated region of southeastern Ohio. The Coolville soils overlie acid shale and the Monongahela soils overlie old, acid water-deposited material. Soil pH at 20 inches is 5.3 for Monongahela and 5.0 for Coolville. At 40 inches it is 5.1 for Monongahela and 5.0 for Coolville. Vine vigor and yield were poor.

Vineyard 13—Warren County (WN): A dark-colored Dana silt loam occurs on the east one-third of this vineyard. A lighter-colored Xenia silt loam comprises about one-half of the plot. An eroded Miamian clay loam occurs on the more sloping area on the west side of the plot. Dana and Xenia soils have fairly good natural drainage and Miamian soils are well-drained. Limey glacial till occurs below depths of 3 feet in Dana and Xenia soils. It is as shallow as 2 feet or less in Miamian soils. All of these soils have medium to high subsoil plant nutrient supply. They are extensive in the Wisconsin age glaciated region of southwestern Ohio. Soil pH at 20 inches is 6.0 for Xenia and 7.0 for Dana. At 40 inches the pH for all soils is 8+ (calcareous). Vine vigor and yield were moderate.

Vineyard 14—Washington County (WA): Five soil types are represented. Zanesville silt loam occurs on gentle slopes on the east side, except for a small area of Gilpin silt loam at the south end. Acid siltstone bedrock underlies both soils. Bedrock is at depths of about 4 feet in Zanesville and 2 feet in Gilpin. Zanesville soils have a dense fragipan at about 2 feet that restricts the movement of water and roots. They have fairly good natural drainage. All other soils on the plot are well drained. On the strongly sloping portion of the plot, Wellston silt loam occurs on the north half, and Summitville and Muskingum silt loam on the south half. Wellston and Summitville soils overlie acid siltstone bedrock at depths of about 4 feet, and Muskingum soils at about 2 feet. Summitville soils have reddish-brown subsoils and medium plant nutrient supply in their subsoils. The other soils are yellowish-brown and have low plant nutrient supply in the subsoil. All of these soils are scattered throughout the unglaciated region of southeastern Ohio. Soil pH at 20 inches is 5.0 for all types. Soil pH at 40 inches is 5.0 for Zanesville and Summitville, 4.5 for Wellston, and bedrock for Muskingum and Gilpin. Vine vigor and yields were excellent.

RESULTS AND DISCUSSION

As might be expected, differences among vineyard locations when all cultivars were averaged were very significant for all elements and point up the wide range in soil and fertility conditions where vineyards are planted in Ohio (Table 1).

The nutrient content of all cultivars averaged from the 14 locations was equal to or higher than the

TABLE 1.—Average Nutrient Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

County	Percent Dry Wt					Parts per Million Dry Wt					
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Mo
1. Adams	1.16fg*	0.32ef	2.78cd	1.45cd	0.49cde	378c	56bc	31g	15cd	65cde	2.0cd
2. Athens	1.15fg	0.34ef	2.50def	1.11efg	0.36efg	206de	42bc	46cd	32b	61de	1.0de
3. Brown	1.61a	0.36de	3.36b	1.06fg	0.41def	174e	49bc	29g	20cd	78ab	2.2bcd
4. Butler	0.92i	0.35def	0.95h	2.05a	1.10a	116f	37c	54b	11d	54ef	3.1ab
5. Clermont	1.46bcd	0.28ef	3.08bc	1.34cde	0.39def	213de	92bc	37f	44a	45f	0.9de
6. Clinton	1.39cd	0.56a	4.16a	1.28cde	0.33fg	59f	142b	79a	15cd	81a	1.4de
7. Hamilton	1.51abc	0.35def	3.39b	1.22def	0.32fg	388c	70bc	44cde	14cd	52ef	0.9de
8. Jackson	1.09fgh	0.21g	1.98f	1.13efg	0.68b	344c	35e	41def	19cd	71abcd	1.8de
9. Lawrence	1.20f	0.49ab	2.62cde	1.51bc	0.50cd	63f	127bc	50bc	14cd	75abc	1.6de
10. Meigs	1.35de	0.41cd	3.51b	0.97g	0.26g	660a	33c	43def	20cd	72abcd	1.0de
11. Monroe	1.04ghi	0.30ef	1.49g	1.69b	0.78b	258d	82bc	38ef	17cd	67bcd	4.0a
12. Scioto	1.22ef	0.28ef	2.09ef	1.36cde	0.73b	592b	52bc	41def	24bc	65cde	2.2bcd
13. Warren	1.55ab	0.47bc	2.78cd	1.29cde	0.56c	68f	54bc	41def	16cd	63cde	2.8bc
14. Washington	1.02hi	0.20g	2.18ef	1.33cde	0.69b	241d	430a	40def	22c	79a	2.9bc
Mean	1.25	0.35	2.64	1.34	0.54	264	93	44	20	66	2.9
LSD .05	0.11	0.07	0.51	0.19	0.11	51	83	6	9	11	0.9

*Mean separation within columns by Duncan's multiple range test, 5% level.

recommended range of values presently in use and developed primarily for use for Concord (Table 2). Although some of these values, such as P and K, would be considered in the high range, they were not excessive. However, between vineyards (Table 1) and especially among cultivars within a particular vineyard (Tables 5-9), some extreme concentrations existed in several nutrient elements. Data obtained showing differences between vineyards indicated the overall nutritional conditions to be found in southern Ohio vineyards and the cultivars' relative ability to absorb and accumulate nutrients under these conditions.

As shown in Table 3, significant differences among cultivars were found to exist for 6 out of the 11 elements. Considering the broad range of soil conditions on which the cultivars were grown and even the soil variability within vineyards, this indicates that meaningful cultivar differences do exist.

Nitrogen: The mean for all cultivars at all locations of 1.26% N (Tables 1 and 2) fell within the recommended range presently in use (0.9-1.3%). Among the 14 vineyards (Table 1), significant differences were present, indicating the wide range of nitrogen conditions that existed. Although the average content for individual cultivars from all locations ranged from 1.39% for Himrod to 1.15% for Chelois, variability was such that no significant differences were found for nitrogen (Table 3). Within vineyards, only 4 out of the 14 did have significant nitrogen differences among the cultivars (Table 5). They were the vineyards in Adams, Clermont, Hamilton, and Monroe counties. Of the 4, Monroe county soil was the more variable (see soil description), but this was not reflected by greater variability among cultivar N means. The Butler county vineyard at 0.92% was the lowest in average N content. Baco noir, Alden, and Romulus were all below the 0.9% N level. But cultivars within this vineyard were not significantly different. The four vineyards that showed significant cultivar differences did not represent the highest or lowest in nitrogen content. Two of the four were, however, in the high range when compared to standard values. The mean N content of none of the vineyards or cultivars was in the low range.

Phosphorus: Strong cultivar differences were evident for this element (Table 3). The mean for all cultivars at all locations was 0.35% P, which would be considered high when compared to standard values (Table 2). Nine out of the 14 vineyards had significant phosphorus differences among the cultivars (Table 6). Nine vineyards also had average P contents above 0.30%. Three vineyards highest in P content were from Clinton (0.56%), Lawrence

TABLE 2.—Recommended July-August Petiole Nutrient Contents for Grapes (A) Compared to the Average Contents of 12 Cultivars Located in 14 Counties in Southern Ohio (B).*

Percent Dry Wt					Parts per Million Dry Wt					
N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Mo
A—July-August Recommended Range										
0.9–1.3	0.16–0.30	1.5–2.5	1.0–1.8	0.26–0.45	30–150	30–150	25–50	10–15	30–30	0.3–1.5
B—Average Content 14 Vineyards										
1.26	0.35	2.62	1.34	0.54	264	93	44	20	66	2.9

*Range used by Research Extension Analytical Laboratory, Wooster, Ohio, and developed primarily from research on Concord (**Vitis labrusca** Ln.).

(0.49%), and Warren (0.47%) counties. Two of the lowest were from Jackson (0.21%) and Washington (0.20%) counties. Only one of these five vineyards had significant differences among the cultivars although P content ranged quite widely. Averaging all locations (Tables 3 and 6), Himrod was found to have the highest P content (0.47%), followed by Baco noir (0.42%). Bokay (0.27%) and Aurore (0.28%) had the lowest average P content.

Potassium: Among the cultivars averaged over all locations, the K content of 2.64% (Tables 2 and 3) would be in the sufficient to high range by almost any standards in use today (1). Levels in the 3+% range exhibited by Himrod, Villard blanc, Romulus, and Buffalo would be considered luxury consumption (Tables 3 and 7). Catawba at 1.86% was significantly lower in potassium than 50% of the other cultivars.

Vineyards in Butler and Monroe counties (Table 1) had the lowest average potassium contents (0.95 and 1.49% K, respectively). Cultivars in the Butler county vineyard were all below 1.5% K, a value usually used to indicate the sufficiency level (Table 7). Seven out of the 11 cultivars had K levels below 1.0%. Steuben, Aurore, and Catawba had contents of 0.68, 0.70, and 0.71% K, respectively. Baco noir with a content of 1.47% K and Villard blanc with 1.39% K were significantly higher than most of the other cultivars. In the Monroe county vineyard, only two cultivars, Chelois and Bokay, had levels below 1% (0.87 and 0.80, respectively). Himrod, Romulus, and Villard blanc all had contents of 2% K or above. Values as high as 5.32% K were found in the Brown county vineyard for Romulus.

Additional Cultivar—Potassium Relationships

Pertinent information on the nutrient content of several American and French hybrid grapes was obtained at the Southern Branch of the Ohio Agricultural Research and Development Center, Ripley, during 1964-66. It strongly supports the supposition that there are differences in the ability of grape cultivars to take up potassium, and to exhibit visual symptoms of potassium deficiency. The inverse relationship between potassium and magnesium is also very evident.

Table 4 shows that when all cultivars were considered, the severity of visual symptoms increased as the potassium content decreased. Villard blanc, Baco noir, and Blue Eye did not exhibit visual deficiency symptoms but still varied considerably in their potassium content (1.49-0.52% K). Villard blanc and Baco noir were also cultivars with high K contents in the 14-county study. Cultivars such as Concord, Schuyler, and Van Buren exhibited only slight visual symptoms and their K content was well within the deficient range.

Two related cultivars, Himrod and Romulus, exhibited similar potassium deficiency symptoms but at rather high potassium contents (0.88 and 0.72%, respectively. Couderc 7120 was peculiar in that at both sampling dates, with and without adequate potassium, the foliar magnesium level was equal to or greater than the potassium content. Chelois also had a high Mg content on the 1966 sampling date.

The application of potassium to relieve potassium deficiency decreased the content of magnesium in the foliage of most cultivars. However, all cultivars with a low foliar content of potassium did not necessarily have a high magnesium content. When the potassium content of all cultivars was rated from low to high and correlated with magnesium content, the resulting relationship was not significant.

Essentially all cultivars with visual potassium deficiency symptoms showed the same general pattern—burning of the marginal leaves in severe cases and lighter leaf margins in milder cases, with the darker areas towards the center or midrib of the leaf.

Calcium: Average content for all cultivars at all locations was 1.34% (Table 2), which was well within the recommended range. Seven of 14 vineyards had significant cultivar differences (Table 8).

TABLE 3.—Average Nutrient Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

Cultivar	Percent Dry Wt					Parts per Million Dry Wt					
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Mo
French Hybrids											
1. Baco noir	1.35	0.42ab*	2.82ab	1.75a	0.66a	285	70	47	25	67bc	2.62ab
2. Chelois	1.15	0.28de	2.19bcd	1.48b	0.64ab	311	108	41	16	51c	2.35abc
3. Aurore	1.18	0.28e	2.31bcd	1.42b	0.59abcd	287	116	43	19	62bcde	2.75a
4. Villard blanc	1.28	0.34bcde	3.20a	1.40bc	0.48bcde	213	200	48	20	57cde	1.54abc
American Hybrids											
5. Himrod	1.39	0.47a	3.16a	1.27bcd	0.62abc	287	75	46	23	83a	2.51ab
6. Romulus	1.28	0.38abc	3.13a	1.08d	0.45cde	292	70	38	24	69bc	1.36c
7. Bokay	1.28	0.27e	2.32bcd	1.27bcd	0.61abc	229	69	41	18	71bc	21.2abc
8. Alden	1.20	0.38abcd	2.78abc	1.40bc	0.40de	269	70	43	24	66bcd	1.46bc
9. Steuben	1.28	0.36bcd	2.30bcd	1.25bcd	0.45cde	267	82	44	17	73b	1.63abc
10. Bath	1.19	0.34bcde	2.09cd	1.45b	0.68a	191	81	50	19	70bc	2.46abc
11. Catawba	1.21	0.32cde	1.86d	1.04d	0.55abcd	257	53	38	15	55de	1.88abc
12. Buffalo	1.25	0.37abcd	3.21a	1.12cd	0.32e	261	101	42	24	71bc	1.52abc
Mean	1.26	0.35	2.64	1.34	0.52	264	93	44	20	66	2.0
LSD .05	NS	0.07	0.76	0.20	0.18	NS	NS	NS	NS	9.54	1.03

*Mean separation within columns by Duncan's multiple range test, 5% level.

In 8 of the 14 vineyards, Baco noir had the highest Ca content. Averaging all locations, calcium ranged from a high of 1.75% for Baco noir to a low of 1.04% for Catawba (Table 3). The content for Romulus was only slightly above Catawba at 1.08%, and was frequently lower in many of the vineyards. Calcium content was the highest in Butler county and the lowest in Meigs county (Tables 1 and 8), which correlates well with soil pH (see soil descriptions).

Magnesium: Average Mg content for all cultivars at all locations was 0.54%. This was higher than the recommended range of 0.26-0.45% (Table 2). Baco noir had the highest average magnesium content at 0.68%, while Buffalo had the lowest (0.32%) (Table 3). The average Mg content of 8 of the 12 cultivars was above 0.45%. The Butler county vineyard had a very high Mg content that averaged 1.10% for all cultivars (Tables 1 and 9). Several other vineyards had Mg contents ranging between 0.68 and 0.78%. Significant differences among cultivars did not exist in the Butler county vineyard, although the Mg content ranged from 1.30% for Bath to 0.90% for Bokay (Table 9). In fact, cultivar differences existed in only 4 of the 14 vineyards.

Manganese: Mean manganese levels among cultivars for all vineyards were not significantly different at 264 ppm (Table 3), but fell in the high range according to recommended values (Table 2). It has been observed for a number of years that grapes absorb large amounts of Mn under low soil pH conditions. The vineyard in Meigs county was significantly higher than all others at 660 ppm, followed by Scioto county with 592 ppm (Table 1). Soil pH in both vineyards is low. The pH of the Tilsit and Rarden soils making up the Meigs county plot is between 4.5 and 5.0 (see soil description). Lowest Mn content was found in Clinton county, with an average content of 59 ppm. Soil is a Russell silt loam with a pH of 6.7 or above. Vineyards in Lawrence, Warren, and Butler were not significantly different. Mn levels above 700 ppm were recorded for Aurore, Chelois, Alden, and Romulus in the Meigs county vineyards. Within vineyards, significant Mn differences existed in only 5 of the 14 locations. Cultivars differed between vineyards so much that no cultivar differences were of relative importance.

Iron: Average iron levels among cultivars from all locations ranged from 200 to 53 ppm, with a mean of 93 ppm (Table 3). All vineyards except one fell within the 30-150 ppm recommended range (Tables 1 and 2). Washington county vineyard iron levels averaged 430 ppm. The next highest vineyard was Clinton county with 142 ppm Fe. The lowest iron

TABLE 4.—Average Potassium and Magnesium Contents (Percent Dry Wt) of 30 Grape Cultivars Before and After Potassium Fertilization, July 11, 1964, and July 26, 1966.*

Class I **No Visual K Symptoms**	1964† K	1964† Mg	1966‡ K	1966‡ Mg
Villard Blanc (S.V. 12-375)	1.49	0.62	2.14	0.84
Baco noir	1.07	0.65	1.87	0.55
Blue Eye	0.52	0.80	1.12	0.89
Class II **Very Slight Visual K Symptoms**				
Aurore (S. 5279)	0.64	1.20	2.07	0.56
Concord	0.59	1.10	2.97	0.55
Schuyler	0.57	0.95	1.71	1.01
Van Buren	0.52	0.64	2.44	0.32
Class III **Slight Visual K Symptoms**				
Chelois (S. 19878)			0.83	1.42
Couderc 7120	0.85	0.85	1.16	1.19
Bokay	0.41	0.72	1.95	0.64
Sheridan	0.52	0.80	2.70	0.62
Seyve Villard 14287	0.54	0.91	0.84	1.02
Class IV **Slight to Moderate K Symptoms**				
DeChaunac (S. 9549)			2.84	0.79
Himrod	0.88	0.75		
Golden Muscat	0.48	0.87	2.00	0.65
Fredonia	0.45	0.83	2.23	0.58
Steuben	0.34	0.80	1.87	0.68
Seneca	0.61	0.81	2.61	0.71
Class V **Moderate K Symptoms**	1964 K	1964 Mg	1966 K	1966 Mg
Seibel 10096			3.06	0.35
Bath	0.41	0.93	1.10	0.96
Yates	0.37	0.60	2.11	0.51
Romulus	0.72	0.47	1.88	0.64
Class VI **Moderate to Severe K Symptoms**				
Chancellor (S. 7053)	0.68	1.42	2.24	0.94
Kendaia	0.52	0.91	2.84	0.53
Alden	0.43	0.56	1.75	0.48
G. 1547	0.29	0.45	2.53	0.54
Courderc 17	0.37	1.06	2.11	0.67
Ontario	0.52	0.86	2.68	0.66
Class VII **Severe K Symptoms**				
Seibel 8745			2.97	0.32
Verdelet (S. 9110)			3.19	0.48
N. Y. 18080	0.34	0.56	3.21	0.32
Naples	0.23	0.71	1.33	0.83
Buffalo	0.45	0.79	2.65	0.39
Catawba	0.39	0.56	2.82	0.33
Delaware	0.45	1.17	2.48	0.61
Niagara	0.52	0.87	3.00	0.50

*Deficient range for K = —1.0%; low = 1.41-1.10%; sufficient = 1.5% +; Deficient range for Mg = —0.14%; low = 0.25-0.14%; sufficient = 0.26% +.

†Before application of potassium.

‡1 year after application of 2 lb of potassium sulfate per vine.

levels were found in Meigs, Jackson, Butler, and Athens counties (33-42 ppm). However, significant differences existed only between the extremes as Fe levels varied considerably within cultivars. Only one cultivar averaged more than 150 ppm and that was Villard blanc (200 ppm).

Boron: Cultivar differences were not significant (Table 3). The average for all cultivars at all locations was 44 ppm, which placed it well in the sufficient range of 25-50 ppm (Table 2). Clinton county vines had the highest average Boron content (79 ppm), followed by Butler and Lawrence (54 and 50 ppm) (Table 1). Brown and Adams counties had the lowest B content at 29 and 31 ppm, respectively.

Copper: Copper values among cultivars ranged from 15 to 25 ppm, but were not significantly different (average = 20 ppm) (Table 3). Cu levels were well within or above the sufficient range (10-15 ppm) (Table 2). Between vineyards some differences did exist (Table 1). Clermont county had the highest average Cu content at 44 ppm, followed by Athens with 32 ppm and Scioto with 24 ppm. Butler county had the lowest average content with 11 ppm.

Zinc: Average content for all cultivars at all locations was 66 ppm (Tables 1 and 2), which was above the sufficient range (30-50 ppm). Himrod, as an average from all locations, had the highest content of Zn at 83 ppm while Chelois had the lowest at 51 ppm (Table 3). Clinton, Washington, Brown, Lawrence, and several other counties had average Zn contents more than 70 ppm. Clermont, Hamilton, and Butler counties were lowest in zinc with 45, 52, and 54 ppm Zn, respectively.

Molybdenum: Differences among vineyards as well as cultivars were found, although small in magnitude. The range among vineyards was 0.9 to 4.0 ppm. For cultivars 1.36-2.75 (Tables 1 and 3), no differences were projected, as all values fell within the sufficient to high range.

SUMMARY AND CONCLUSIONS

Some nutrient elements appeared to be absorbed differentially by some cultivars. There have been strong indications that service samples from French hybrids sent to the Ohio Foliar Analyses Laboratory were generally higher in N than others. From the

TABLE 5.—Average Nitrogen Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

Cultivar	Vineyard AD (1) %	AT (2) %	BR (3) %	BU (4) %	CL (5) %	CC (6) %	HA (7) %	JA (8) %	LA (9) %	MG (10) %	MO (11) %	SC (12) %	WN (13) %	WA (14) %	Mean
French Hybrids															
1. Baco noir	1.32	1.23	1.67	0.76	1.61	1.41	1.75	1.36	1.30	1.58	0.98	1.52	1.44	1.16	1.35
2. Chelois	0.94		1.52	0.92	1.20	1.10	1.24	1.12	0.95	1.29	1.07	1.16	1.51	0.93	1.45
3. Aurore	1.14		1.45	0.99	1.21	1.10	1.42	1.04	1.33	1.39	0.92	1.14	1.45	0.94	1.18
4. Villard blanc	1.24	1.13	1.80	0.93	1.19	1.36	1.66	1.15	1.19	1.45	1.11	1.36	1.61	0.98	1.28
American Hybrids															
5. Himrod	1.14	1.16	1.76	1.06	1.75	1.82	1.66	1.26	1.08	1.46	1.24	1.30	1.08	1.12	1.39
6. Romulus	1.40	1.29	1.76	0.84	1.45	1.52	1.39	0.99	1.18	1.28	0.98			1.12	1.28
7. Bokay	1.12	1.18	1.46	0.92	2.03	1.61	1.34	0.96	1.44	1.20	0.82	1.30	1.75	1.02	1.28
8. Alden	0.89	1.32		0.88	1.34	1.31	1.40		1.32	1.18	0.96	0.96	1.41	0.94	1.20
9. Steuben	1.26	1.05	1.59	1.00	1.33	1.37	1.75	1.15	1.33	1.20	1.02	1.10	1.66	1.10	1.28
10. Bath	1.08	1.01	1.50	0.95	1.50	1.32		0.94	1.02		1.13	1.22	1.38		1.19
11. Catawba		1.01	1.55	0.90				0.83	1.36	1.62	1.09	1.27	1.60	0.96	1.21
12. Buffalo		1.11	1.56					1.12	1.12	1.22		1.16	1.72	0.92	1.25
Mean	1.16	1.15	1.61	0.92	1.46	1.39	1.51	1.09	1.20	1.35	1.03	1.22	1.55	1.02	1.26
LSD .05	0.28	NS	NS	NS	0.39	NS	0.18	NS	NS	NS	0.21	NS	NS	NS	NS

TABLE 6.—Average Phosphorus Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

Cultivar	Vineyard AD (1) %	AT (2) %	BR (3) %	BU (4) %	CL (5) %	CC (6) %	HA (7) %	JA (8) %	LA (9) %	MG (10) %	MO (11) %	SC (12) %	WN (13) %	WA (14) %	Mean*
French Hybrids															
1. Baco noir	0.32	0.44	0.29	0.69	0.31	0.81	0.37	0.25	0.63	0.36	0.45	0.28	0.39	0.22	0.42ab
2. Chelois	0.21		0.36	0.27	0.17	0.36	0.22	0.24	0.48	0.42	0.23	0.21	0.47	0.15	0.28de
3. Aurore	0.27		0.33	0.24	0.21	0.40	0.29	0.15		0.34	0.26	0.22	0.37	0.17	0.28e
4. Villard blanc	0.22	0.36	0.38	0.39	0.19	0.57	0.32	0.17	0.54	0.37	0.22	0.26	0.54	0.18	0.34bcde
American Hybrids															
5. Himrod	0.58	0.36	0.50	0.41	0.44	0.83	0.52	0.22	0.55	0.55	0.42	0.34	0.48	0.34	0.47a
6. Romulus	0.42	0.41	0.41	0.34	0.40	0.57	0.66	0.19	0.44	0.44	0.33			0.25	0.38abc
7. Bokay	0.38	0.18	0.26	0.22	0.27	0.46	0.25	0.14	0.32	0.30	0.20	0.21	0.50	0.17	0.27e
8. Alden	0.29	0.36		0.39	0.26	0.52	0.38		0.57	0.45	0.31	0.24	0.46	0.19	0.38abcd
9. Steuben	0.33	0.30	0.43	0.31	0.27	0.58	0.42	0.24	0.62	0.36	0.26	0.27	0.46	0.19	0.36bcd
10. Bath	0.24	0.38	0.36	0.33	0.27	0.44		0.13	0.61		0.31	0.28	0.43		0.34bcde
11. Catawba		0.27	0.26	0.34				0.27	0.30	0.52	0.31	0.25	0.49	0.21	0.32cde
12. Buffalo		0.34	0.26					0.29	0.31	0.46		0.40	0.55	0.20	0.37abcd
Mean	0.32	0.33	0.36	0.35	0.28	0.56	0.35	0.21	0.47	0.41	0.30	0.28	0.47	0.20	0.35
LSD .05	0.07	0.11	NS	0.08	0.08	0.27	0.08	NS	NS	0.10	0.03	0.06	NS	NS	0.07

*Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 7.—Potassium Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

	Vineyard														
Cultivar	AD (1) %	AT (2) %	BR (3) %	BU (4) %	CL (5) %	CC (6) %	HA (7) %	JA (8) %	LA (9) %	MG (10) %	MO (11) %	SC (12) %	WN (13) %	WA (14) %	Mean*
French Hybrids															
1. Baco noir	2.58	2.61	2.18	1.47	3.20	5.55	3.98	2.48	3.58	3.47	1.55	1.29	2.73	2.07	2.82ab
2. Chelois	2.40		2.71	0.79	2.22	2.29	4.02	2.05	1.51	3.67	0.87	1.06	2.40	1.97	2.19bcd
3. Aurore	3.35		2.63	0.70	2.46	3.82	2.56	1.58		3.47	1.57	2.38	2.30	2.31	2.31bcd
4. Villard blanc	4.05	2.75	4.32	1.39	3.97	4.81	3.12	2.17	3.33	4.28	2.00	2.74	2.93	2.72	3.20a
American Hybrids															
5. Himrod	3.41	2.81	4.26	1.08	3.91	5.87	3.90	2.31	1.21	3.73	2.52	3.60	2.44	2.46	3.16a
6. Romulus	2.76	2.83	5.32	1.11	4.05	4.64	3.02	1.85	3.16	3.66	2.10			2.54	3.31a
7. Bokay	2.35	2.15	2.93	0.85	3.77	4.00	2.72	1.34	2.51	2.73	0.80	1.59	3.83	1.55	2.32bcd
8. Alden	2.54	2.76		0.71	2.37	4.10	3.39		2.55	3.40	1.68	2.86	2.50	2.99	2.78abc
9. Steuben	2.30	1.94	3.22	0.68	2.50	2.90	3.25	1.77	2.99	2.77	1.42	1.89	2.74	1.62	2.30bcd
10. Bath	2.15	2.28	3.45	0.89	2.36	3.39		1.54	2.05		1.32	1.71	2.03		2.09cd
11. Catawba		1.80	2.56	0.71				1.75	2.11	3.08	1.02	1.42	2.70	1.60	1.86d
12. Buffalo		3.05	3.45					2.77	2.44	4.40		2.64	4.00	2.54	3.21a
Mean	2.78	2.50	3.36	0.95	3.08	4.16	3.39	1.98	2.62	3.51	1.49	2.09	2.78	2.18	2.64
LSD .05	0.93	0.73	NS	0.44	NS	1.40	NS	NS	NS	0.47	NS	NS	NS	NS	0.76

*Mean separation within columns by Duncan's multiple range test, 5 % level.

TABLE 8.—Average Calcium Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

	Vineyard														
Cultivar	AD (1) %	AT (2) %	BR (3) %	BU (4) %	CL (5) %	CC (6) %	HA (7) %	JA (8) %	LA (9) %	MG (10) %	MO (11) %	SC (12) %	WN (13) %	WA (14) %	Mean*
French Hybrids															
1. Baco noir	1.68	1.53	1.50	3.12	1.86	1.86	1.47	1.23	2.03	1.24	2.49	1.62	1.56	1.14	1.75a
2. Chelois	1.84		1.30	2.06	1.41	1.05	1.37	1.31	1.94	1.08	1.55	1.22	1.30	1.73	1.48b
3. Aurore	1.11		1.46	2.16	1.37	1.54	1.22	1.12		1.19	1.61	1.38	1.31	1.35	1.42b
4. Villard blanc	1.48	1.32	1.00	2.03	1.26	1.48	1.43	1.40	1.41	0.99	1.83	1.44	1.17	1.39	1.40bc
American Hybrids															
5. Himrod	1.50	1.19	0.92	1.51	1.00	1.01	1.23	1.33	1.46	1.05	1.40	1.60	1.62	1.31	1.27bcd
6. Romulus	0.90	0.97	0.88	1.92	1.06	1.07	0.94	1.00	1.17	0.84	1.35			1.08	1.08d
7. Bokay	1.49	1.02	0.99	1.85	0.94	1.16	1.05	1.10	1.44	0.66	2.17	1.86	1.08	1.37	1.27bcd
8. Alden	1.64	1.04		2.76	1.46	1.26	1.28		1.57	1.12	1.73	1.27	1.26	1.24	1.40bc
9. Steuben	1.39	1.02	1.06	1.93	1.14	1.41	1.19	1.06	1.35	0.95	1.45	1.37	1.05	1.24	1.25bcd
10. Bath	1.33	1.23	0.86	2.05	1.94	1.09		0.97	1.69		1.62	1.13	1.48		1.45b
11. Catawba		0.83	0.65	1.51				1.00	0.89	0.82	1.22	1.01	1.09	1.31	1.04d
12. Buffalo		0.93	0.95					0.90	1.36	0.81		1.36	1.39	1.41	1.12cd
Mean	1.45	1.11	1.06	2.05	1.34	1.28	1.21	1.13	1.51	0.97	1.69	1.36	1.29	1.33	1.34
LSD .05	0.47	0.29	0.26	0.47	0.33	NS	NS	NS	0.37	NS	0.51	NS	NS	NS	0.20

*Mean separation within columns by Duncan's multiple range test, 5 % level.

TABLE 9.—Average Magnesium Contents (Percent Dry Wt) of 12 French and American Hybrid Grape Cultivars Grown in 14 Counties in Southern Ohio, 1968.

	Vineyard														
Cultivar	AD (1) %	AT (2) %	BR (3) %	BU (4) %	CL (5) %	CC (6) %	HA (7) %	JA (8) %	LA (9) %	MG (10) %	MO (11) %	SC (12) %	WN (13) %	WA (14) %	Mean*
French Hybrids															
1. Baco noir	0.86	0.38	0.75	1.03	0.44	0.45	0.45	0.80	0.50	0.33	1.15	1.18	0.43	0.72	0.66a
2. Chelois	0.58		0.46	1.24	0.57	0.31	0.25	0.73	0.79	0.22	0.97	0.72	0.66	0.94	0.64ab
3. Aurore	0.37		0.58	1.14	0.43	0.40	0.52	0.67		0.24	0.66	0.72	0.55	0.64	0.59abc
4. Villard blanc	0.33	0.42	0.32	1.00	0.31	0.30	0.54	0.77	0.41	0.21	0.75	0.62	0.38	0.53	0.48bcde
American Hybrids															
5. Himrod	0.48	0.49	0.44	1.00	0.36	0.36	0.27	0.90	0.68	0.46	0.67	1.15	0.84	0.94	0.62abc
6. Romulus	0.41	0.28	0.32	1.17	0.34	0.29	0.28	0.61	0.36	0.24	0.55			0.58	0.45cde
7. Bokay	0.44	0.49	0.40	0.90	0.22	0.29	0.31	1.01	0.53	0.37	0.99	0.86	0.42	1.14	0.61abc
8. Alden	0.58	0.26		0.91	0.36	0.26	0.28		0.28	0.25	0.45	0.59	0.47	0.48	0.40de
9. Steuben	0.30	0.31	0.41	1.21	0.26	0.39	0.23	0.48	0.45	0.22	0.47	0.74	0.43	0.56	0.45cde
10. Bath	0.46	0.50	0.34	1.30	0.65	0.33		0.58	0.94		0.95	0.69	0.68		0.68a
11. Catawba		0.28	0.22	1.09				0.58	0.35	0.23	0.70	0.64	0.66	0.70	0.55abcd
12. Buffalo		0.17	0.24					0.31	0.22	0.12		0.48	0.64	0.34	0.32e
Mean	0.49	0.36	0.41	1.10	0.39	0.33	0.32	0.68	0.50	0.26	0.78	0.73	0.56	0.69	0.52
LSD .05	NS	0.21	0.20	NS	NS	NS	NS	0.27	NS	0.11	NS	NS	NS	NS	0.18

*Mean separation within columns by Duncan's multiple range test, 5 % level

four cultivars selected in the present study, this difference did not materialize. Some vineyards averaged above 1.3% N (Table 1), but a study of cultivar differences from all vineyards did not show these values to be abnormal (Table 3). Baco noir and Villard blanc appeared to reflect higher N levels than Chelois or Aurore. But when vineyards lowest in N were considered, these differences were not that much higher.

Himrod appeared to absorb greater quantities of P than many other cultivars (0.47%). Baco noir also had a high P content (0.42%) as well as Ca (1.75%) and Mg (0.66%). Bokay and Aurore were at the low end of the scale for P with 0.27% and 0.28%, respectively.

Catawba, which has been assumed to have nutritional requirements similar to Concord, was significantly lower in K and Ca than many other cultivars in this study. Buffalo had the lowest content of Mg.

Although these data indicate some strong individual cultivar differences, neither the French nor American hybrids show trends that would set them apart from the standards already established.

The results obtained at the Southern Branch, Ripley (Table 4), indicated at least three things: 1) some cultivars were able to absorb more potassium from a similar environment than others; 2) some cultivars expressed visual K deficiency symptoms at a higher or lower K content than others; and 3) there was a wide range in the K/Mg ratio when the various cultivars were deficient in potassium. The relationship between K and Mg, although very evident in the petioles, did not in many instances result in a rapid decrease in Mg content upon the addition of potassium fertilizer.

In conclusion, although some significant cultivar/nutrient relationships were found, additional studies in a more controlled nutritional environment are needed to determine which cultivars actually have requirements different from the standards presently in use.

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North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Science and Education Administration/Agricultural Research, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Fremont, Sandusky County: 105 acres

Western Branch, South Charleston, Clark County: 428 acres