Fruit Crops 1986:
A Summary of Research

The Ohio State University
Ohio Agricultural Research and Development Center

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CONTENTS

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ON THE COVER: Dr. Craig Chandler and Dr. Diane Miller examine strawberries in study of influence of shade at various times on plant growth and yield. This study is part of a larger effort investigating the effects of stress alleviation with mist cooling at several temperatures during runner formation.

Influence of Treatments at Planting on Trellised Apple Tree Performance[1,2]

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INTRODUCTION

The low trellis has been a productive and efficient management system for apple trees (4, 5, 8). This system has exhibited a greater tree efficiency in production of fruit vs. vegetative growth compared to both more intensive and less intensive systems (4, 5). On deep fertile soils, M9 rootstock is best suited to the low trellis system; however, significant tree losses have occurred with this rootstock due to a severe fireblight infection during the early cropping years (6). Thus, a rootstock more resistant to fireblight is needed.

Generally, trees on the trellis are developed by cutting or heading the tree below the bottom wire (18 inches) immediately following planting. This insures development of strong shoots to develop scaffolds on the lower wire (8). This process is repeated at each wire so it normally takes 4 years of optimum growth to cover the trellis with foliage. The procedure is of greater importance with cultivars such as spur habit 'Delicious' which only produce strong vegetative shoots close to the pruning cut, in contrast to other cultivars such as 'Golden Delicious' which tend to produce more shoots that often originate further from the pruning cut (3). In addition to the use of pruning to induce lateral shoots at the desired location, growth regulators containing cytokinins have been used (2, 7, 9) on trees in other training systems to induce branching.

The current study was carried out to determine if growth regulators or other cultural methods could be employed on newly planted trees for trellis management to shorten the time required to develop the fruiting canopy and initiate production.

MATERIALS AND METHODS

In April 1981, trees of 'Smoothee Golden Delicious', 'Lawspur Rome Beauty', 'Empire', and 'Oregon Spur Delicious' on M9 rootstock were planted 2m x 4m at the OARDC Mahoning County Farm, Canfield. In addition, trees of 'Smoothee Golden Delicious' on MAC9 (later named MARK) and M27 were also included in the planting.

Immediately after planting, the following treatments were applied: 1) check—headed at 40 cm (just below the bottom wire) with no additional treatment; 2) GA—headed at 40 cm with a spray of GA 4 + 7 (500 ppm) plus Regulaid (0.5%) applied on June 19 after growth

started; 3) notch—headed at 90 cm (just below the second wire) and a notch of bark removed above all buds in the 15 cm area below both the bottom and second wire at planting time; 4) Promalin—headed at 90 cm and Promalin (combination of N-(phenylmethyl)1 H-purin-6-amine and gibberellins GA 4 + 7) at 7500 ppm + Tween 20 in latex paint applied to the 15 cm area below both the bottom and second wires; 5) same as treatment 4, except 6-BA at 7500 ppm which is one of the components of Promalin was used instead of Promalin. The paint of each was applied with a brush within 30 minutes of mixing immediately following planting. The treatments were arranged as a split plot, with the four cultivars on M9 as whole plots and growth regulators as split plots with four replications.

The trees were trained as oblique palmettes on a four-wire trellis with 45 cm between wires. Sod middle and herbicide strip soil management was used and recommended pest control sprays were applied. Following leaf fall, the shoots were counted and length measured in the 15 cm section below each wire and also in the other portions of the tree. In subsequent years, a visual rating system was used to evaluate whether desirable shoots originated in the 15 cm area below each wire to provide scaffolds (origin) and also the relative vigor of these shoots. The percentage of the trellis space covered by foliage was calculated by multiplying tree height and spread and determining what percent this was of the 40,000 cm^2 allotted to each tree.

RESULTS

The treatment with 6-BA in latex paint increased the number of shoots in the painted area below both the top and lower wires compared to the notched and Promalin treatments and this resulted in more shoots on a whole tree basis (Table 1). Average shoot length was not greatly affected by the growth regulators. Average shoot lengths of all trees at the 90 cm heading height were shorter and more numerous compared to those headed at 40 cm. GA 4 + 7 had no influence on shoot growth of these trees. Total shoot growth did not differ among treatments.

There was no interaction between cultivar and treatment at planting. 'Empire' tended to have more shoots adjacent to and in the basal region below the bottom wire, while 'Lawspur' had the fewest shoots in these regions (Table 1). 'Smoothee' on M27 had shorter shoots adjacent to the second wire compared to 'Smoothee' on M9 or MAC9. On M9, 'Oregon Spur' had shorter shoots adjacent to the second wire than other cultivars. In comparison to other cultivars, 'Lawspur' tended to have fewer but longer shoots, and 'Empire' and 'Oregon Spur' tended to have a greater number of shorter shoots than .

TABLE 1.—Influence of Heading Height and Growth Regulator Treatment on Shoot Growth of Four Cultivars in a Newly Planted Trellis Planting at the OARDC Mahoning County Farm, 1981.

Treatment*	Heading Height (cm)	No. of Shoots Treated Level on Tree					Average Shoot Length Treated Level on Tree				Total Average Length	Total Length (cm)
		Second Wire	Mid	Bottom Wire	Base	Total	Second Wire	Mid	Bottom Wire	Base		
Check	40	0	0	5.0a†	1.9	6.9c	0	0	45.1a	10.9a	36.9a	234
GA	40	0	0	5.8a	1.9	7.8c	0	0	42.3a	12.8a	34.3a	248
Notch	90	5.5b	8.1a	3.4b	1.3	18.3b	23.5	13.9a	12.5b	12.3a	17.0b	302
Promalin	90 ·	5.7b	5.9b	3.3b	1.9	16.9b	26.2	10.1ab		3.6b	14.6b	233
6-BA	90	6.4a	8.1a	5.4a	2.6	21.6a	23.9	6.7b	8.2b	6.1ab	12.7b	259
Cultivar												
Smoothee/M9		3.7	4.2	4.7ab	1.5b	14.1ab	28.6ab	12.1abc	22.7	8.0	22.8abc	271b
Smoothee/MAC9		3.5	5.0	4.6abc	2.3b	15.5ab	30.9a	17.4a	28.4	12.1	29.6ab	386a
Smoothee/M27		3.7	4.6	4.9ab	1.7b	14.9ab	20.1cd	9.6bcd	23.2	9.9	20.9bcd	261b
Empire/M9		3.6	4.7	5.9a	3.5a	17.7a	22.8bc	5.9cd	17.4	4.7	14.1d	220bc
Lawspur/M9		3.4	2.9	3.1c	0.6c	10.2b	32.7a	13.8ab	28.3	10.8	30.5a ·	246b
Oregon Spur/M9		3.3	4.1	4.3bc	2.1b	13.9ab	14.9d	4.8d	22.7	10.3	16.3cd	189c

*Promalin 7500 ppm + Tween 20, 6-BA 7500 ppm + Tween 20 mixture 2 ml Tween 20, 71 ml Promalin or 6-BA brig to 190 ml volume of latex and water applied at planting (trees dormant). GA 4 + 7 + Regulaid 500 ppm spray (94.6 ml/gal) + 19 ml Regulaid and applied after growth started on June 17.

†Mean comparison, Duncan's multiple range test, 5% level.

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TABLE 2.—Influence of Heading Height and Growth Regulator Treatment the Year of Planting on Growth and Yield the Second Season of Three Cultivars on M9 Trained to a Trellis Management System.

Treatment	Heading Height (cm)	TC 1981 (cm)	TC 1982 (cm)	TC (cm)	Height (cm)	Spread (cm)	Bottom Wire* Origin	Bottom Wire Vigor	Second Wire Origin	Second Wire Vigor	Percent Cover	Yield lb/T	Yield Efficiency (lb/cm²)
Check	40	4.95	6.96	2.0	155b†	117	4.6a	4.0a	0.8b	0.6b	46.1	2.2b	0.72ab
Ga	40	4.87	7.21	2.3	155b	105	4.5a	3.6a	0.7b	0.4b	42.2	1.7b	0.46b
Notch	90	5.15	7.30	2.1	173a	115	3.7b	2.9b	3.6a	3.0a	50.8	4.2a	1.06a
Promalin	90	5.03	7.24	2.2	173a	116	2.8c	2.2c	4.2a	3.2a	51.4	2.2b	0.60b
6-BA ɛ	90	4.81	6.93	2.1	174a	105	3.3bc	2.4bc	4.1a	3.0a	47.1	2.8ab	0.79ab
Lawspur		4.79	6.38c	1.6c	163	100	3.7	2.4c	3.4a	2.4a	41.7	5.7a	1.72a
Smoothee		5.04	7.02b	1.9b	165	108	3.8	2.6bc	2.6b	2.0ab	46.3	3.3b	0.81b
Oregon Spur		5.12	7.93a	2.8a	169	113	4.1	3.8a	1.9c	1.4b	49.0	0.3c	0.06c
Empire		4.89	7.19b	2.3b	167	125	3.7	3.2b	2.8ab	2.5a	53.1	1.4c	0.31c

* Visual rating scale: Origin — 1 = no well-placed shoots for scaffolds to 5 = well-placed scaffolds; Vigor — 1 = weak or non-existent to 5 = vigorous, well-grown scaffolds.
† Mean comparison, Duncan's multiple range test, 5% level.

other cultivars. 'Smoothee' on MAC9 produced more total shoot growth the first season than the other cultivars and 'Oregon Spur'/M9 produced the smallest total growth.

At the completion of the second growing season after planting, trees headed at 90 cm were taller than those headed at 40 cm (Table 2). When the production of desirable shoots for permanent scaffolds was evaluated, heading at 40 cm resulted in more desirable shoots for the bottom wire, while heading at 90 cm resulted in more desirable growth at the second wire.

The application of growth regulating chemicals did not alter the general influence of pruning at the different heights. There was no difference in the percentage of the allotted space on the trellis covered by foliage following the second growing season. Yield/tree and yield efficiency tended to be highest in the notched treatment headed at 90 cm, but the differences were not significant when compared to the check headed at 40 cm and 6-BA headed at 90 cm treatments. There was no interaction between the growth regulator treatments and cultivars.

'Oregon Spur' had the largest trunk circumference and made the most growth compared to the other cultivars, while 'Lawspur' had the smallest trunk circumference and made the least growth during the second season (Table 2). 'Oregon Spur' had the most vigorous shoots adjacent to the bottom wire and the least vigorous on the second wire. 'Oregon Spur' and 'Empire' produced the smallest yields and had the lowest yield efficiency, while 'Lawspur' had the highest yield and efficiency.

There was no significant interaction between growth regulator and heading treatments and rootstock with 'Smoothee' (Table 3) and the results of the pruning and growth regulator treatments were similar to those for the other cultivars (Table 2). Trees on MAC9 had the largest trunk circumference in both 1981 and 1982 and trees on M27 the smallest. Trees on M9 and MAC9 did not differ in tree height and spread and both tended to be larger than trees on M27, with a similar pattern in the percentage of the trellis covered with foliage. Trees on MAC9 and M27 outproduced trees on M9 during the second season. Trees on M27 had the highest yield efficiency when judged by the amount of fruit produced for the amount of wood grown.

Following the third growing season (Table 4), the treatments continued to have similar effects such as greater tree height when headed at 90 cm, more desirable scaffold shoots on the bottom wire when headed at 40 cm and on the second and third wires when headed at 90 cm, but these differences were not as distinct as observed in the second year. Again there was no difference in the percentage of the allotted trellis space covered with foliage. A frost reduced yield so number of fruit/tree were counted with no difference among treatments. Again there was no significant interaction between treatments and cultivars or rootstocks.

'Oregon Spur' continued to produce the most desirable shoots on the bottom wire and 'Lawspur' the least desirable. There was no difference among cultivars in

TABLE 3.—Influence of Heading Height and Growth Regulator Treatment the Year of Planting on Growth and Yield the Second Growing Season of 'Smoothee Golden Delicious' on Three Rootstocks in a Trellis Management System.

Treatment	Heading Height (cm)	TC 1981 (cm)	TC 1982 (cm)	Growth (cm)	Height (cm)	Spread (cm)	Bottom Wire* Origin	Bottom Wire* Vigor	Second Wire Origin	Second Wire Vigor	Percent Cover	Yield (lb/T)	Yield Efficiency (lb/cm²)
Check	40	4.98	6.80	1.8	143	126	4.8a†	3.6a	1.4c	0.7b	45.8	3.0c	0.86bc
GA	40	5.07	7.14	2.1	151	114	4.7ab	3.7a	0.9c	0.6b	44.4	2.0c	0.56c
Notch	90	5.58	7.29	1.7	160	108	4.0b	2.0b	4.4a	2.7a	43.9	8.3a	2.09a
Promalin	90	5.19	6.69	1.5	147	95	3.0c	1.9b	3.7a	2.5a	36.9	3.2c	0.97bc
6-BA	90	5.00	6.93	1.9	159	103	3.7c	1.9b	3.7a	2.9a	41.6	4.7b	1.21b
M9		5.05b	7.02b	1.97a	165a	108ab	3.8	2.6	2.6	2.0	46.3a	3.2b	0.81b
MAC 9		5.54a	7.60a	2.06a	156a	126a	4.4	2.9	3.2	2.1	49.2a	4.7a	1.08b
M27		4.90b	6.27c	1.37b	135b	94b	3.9	2.3	2.7	1.5	32.1b	4.6a	1.52a

* Visual rating scale: Origin — 1 = no well-placed shoots for scaffolds to 5 = well-placed scaffolds; Vigor — 1 = weak or non-existent to 5 = vigorous, well-grown scaffolds.
† Mean comparison, Duncan's multiple range test, 5% level.

TABLE 4.—Influence of Heading Height and Applications of Growth Regulators at Planting in 1981 on Growth and Yield of Apples 3 Years Later Trained to a Trellis Management System.

Treatment	Heading Height (cm)	Trunk X-section Area (cm²)	Height (cm)	Spread (cm)	Bottom Wire*		Second Wire		Third Wire		Percent Area	No. Apples/Tree
					Origin	Vigor	Origin	Vigor	Origin	Vigor		
Check	40	8.2	172bc†	175	4.0a	3.4	2.5b	2.1c	1.8ab	1.8ab	75	5.9
GA	40	8.5	169c	155	3.8ab	3.2	2.6b	2.4bc	1.6b	1.7b	67	4.3
Notch	90	8.5	190a	159	3.5bc	3.1	3.5a	3.0a	2.3a	2.3a	76	6.4
Promalin	90	7.9	183abc	148	3.0c	3.0	3.7a	3.1a	2.3a	2.2a	68	4.6
6-BA	90	8.0	186ab	147	3.0c	2.9	3.8a	2.8ab	2.4a	2.1ab	70	2.8
Cultivar												
Lawspur		6.6c	178	141b	2.9c	2.8b	3.2	2.5	1.8	1.8	63.7	9.4a
Smoothee		8.2b	182	151b	3.4b	3.0b	3.3	2.7	2.2	2.1	70.0	3.6c
Oregon Spur		10.9a	187	155b	4.1a	3.6a	3.2	3.0	2.3	2.2	73.5	0.1d
Empire		7.7b	174	180a	3.5b	3.1b	3.3	2.6	2.0	2.0	79.4	6.3b
Rootstock (Golden Delicious only)												
M9		8.3b	182a	151b	3.4	3.0	3.3	2.7	2.2	2.1	70.0a	3.6
MAC9		9.4a	183a	176a	3.6	3.1	3.0	2.5	2.2	2.2	81.4a	5.3
M27		6.1c	157b	124c		2.7	2.9	2.6	1.8	1.8	49.9b	3.0

* Visual rating scale: Origin — 1 = no well-placed shoots for scaffolds to 5 = well-placed scaffolds; Vigor — 1 = weak or non-existent to 5 = vigorous, well-grown scaffolds.

† Mean comparison, Duncan's multiple range test, 5% level.

quality of shoots on the second and third wires (Table 4). 'Lawspur' was again the most productive, followed by 'Empire', 'Smoothee', and 'Oregon Spur'. The late blooming characteristics of 'Lawspur Rome' may have been partially responsible for its greater production during the frost damage of this season.

MAC9 resulted in the largest trees as determined by trunk cross-sectional area and spread (Table 4) and M27 resulted in the smallest trees by all parameters measured. Rootstocks had no influence on the desirability of the branching pattern at any level on the trellis. Trees on M27 covered only half of their allotted canopy space, while trees on the other stocks covered nearly 75%.

The growth regulator and heading height treatments had no influence on tree size or yield in 1984 or 1985 (Table 5). The cultivars all differed significantly in trunk cross-sectional area, with 'Oregon Spur' being the largest and 'Lawspur' the smallest. Average fruit size also differed among cultivars, with 'Oregon Spur' having the largest fruit and 'Smoothee' the smallest. In 1984 'Oregon Spur' had a lower yield than other cultivars, again reflecting the tardiness of 'Delicious' to begin production. There was no difference between trees on M9 and MAC9 in trunk cross-sectional area, while trees on M27 were smaller than on the other stocks. In 1985, trees on M9 had the highest yield/tree and trees on M27 the lowest, which probably reflected the difference in tree size.

DISCUSSION

Previous work (3) indicated that very few shoots would form on the trees of most cultivars below the 40 cm level if the trees were headed at 90 cm. However, in this study almost all trees of all cultivars formed a reasonable number of shoots at that level no matter what the treatment. It is unfortunate that non-treated trees headed at 90 cm were not included in this study, since there was little difference among treatments in number or length of shoots. It was expected that some trees headed at 90 cm would produce no usable shoots to develop scaffold limbs on the lower wire, even with treatment. Recent work indicates that cool temperatures (5°-10° C) during the shoot development period results in a dramatic increase in shoot production, even on cultivars not normally prone to developing shoots. The first 24 days of May following planting in 1981 had 19 days with a minimum at or below 10° C, which is cooler than normal, and this may explain the very desirable response obtained.

The conventional system of heading below the bottom wire did result in the most desirable shoots to develop the permanent scaffold system. This was true for both shoot origin and vigor. The slightly higher yield obtained on trees headed at 90 cm and treated by notching or 6-BA in paint in the second year was not carried over in subsequent years when higher yields were achieved. The large initial tree size achieved by heading at 90 cm did not result in significantly larger trees or more yield in the fourth or fifth year when significant yields occurred. Thus, there seems to be no commercial ad-

TABLE 5.—Influence of Heading Height and Applications of Growth Regulators at Planting in 1981 on Growth and Yield of Apple Trees 4 and 5 Years Later Trained to a Trellis Management System.

Treatment	Heading Height (cm)	1984			1985			
		Trunk X-section Area (cm²)	Yield lb/t	Yield Efficiency (lb/cm²)	Trunk X-section Area (cm²)	Av. Fruit wt. (g)	Yield lb/t	Yield Efficiency lb/cm²
Check	40	15.0	16.8	1.32	16.5	120	45.8	2.63
GA	40	14.5	13.1	1.06	17.1	122	43.9	2.43
Notch	90	15.4	16.3	1.20	17.4	138	49.8	2.69
Promalin	90	13.7	16.1	1.36	14.5	113	37.9	2.58
6-BA	90	13.8	15.3	1.30	16.8	121	50.2	2.47
Cultivar								
Lawspur		9.5d*	17.4ab	1.85a	11.9d	140bc	45.0bc	3.42a
Smoothee		15.2b	12.9ab	0.85b	18.9b	134c	53.3a	2.85b
Oregon Spur		20.7a	10.7b	0.55b	28.7a	160a	47.9ab	1.73d
Empire		12.5c	21.0a	1.75a	15.9c	149b	35.8c	2.24c
Rootstock (Golden Delicious only)								
M9		15.2a	12.9	0.42	18.9a	134a	53.3a	2.85
MAC9		15.9a	9.1	0.85	16.1ab	116b	44.4ab	2.85
M27		11.5b	13.2	0.63	14.4b	118a	38.9b	2.62

* Mean comparison, Duncan's multiple range test, 5% level.

vantage to change the recommended practice of heading below the bottom wire at planting to develop trees for the trellis system.

Numerous studies (3, 7, 8) have shown a dramatic increase in number of shoots from applications of Promalin or 6-BA applied as sprays or in lanolin paste to individual buds. Although a slight increase in shoot number occurred with 6-BA compared to notching or Promalin, the effect was not dramatic even though a very high (7500 ppm) concentration of 6-BA was used. In communicating with the manufacturer, concern developed that the 6-BA may have been partially inactivated or bound by components in the paint.

'Lawspur' (68.1 lb/tree) and 'Smoothee' (69.5 lb/tree) had slightly higher accumulated yields in the early years than 'Oregon Spur' (58.9 lb/tree) or 'Empire' (57.2 lb/tree). 'Oregon Spur' demonstrated less precocity than the other cultivars which follows the normal pattern for 'Delicious' strains. Although some differences in cultivars existed, all four of the cultivars in this study were adaptable to training to the trellis system of management. There was essentially no tree loss during the first 5 years. M9 and MAC9 produced essentially the same size tree, with trees on M27 being 18% smaller. Trees on M27 had not filled their allotted canopy space at 5 years of age, while trees on the other stocks had some fruiting wood on the top wire.

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Influence of Growth Regulators on Branching of Young Apple Trees

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INTRODUCTION

Studies with intensive orchards have shown that planting vigorous 1-year trees which have branched (feathered) in the nursery results in earlier production and greater yields (6, 8). A number of these studies used growth regulators to induce branching in the nursery, particularly on cultivars which didn't branch normally (4, 6, 9, 10). Removal of younger leaves has also been shown to induce lateral branching in nursery trees (3).

In the first few years in the orchard, cultivars such as spur habit Delicious may form many spurs, but many do not produce desirable side branches or secondary shoots on primary scaffold limbs. Other varieties such as Rome Beauty, Tydeman's Red, and Granny Smith form many "blind" or "naked" shoots without side branches. It would be very desirable for these cultivars during their young formative years to be able to induce side branches as has been accomplished with nursery trees. Several studies (2, 3) have shown successful induction of lateral branches on 1 to 3-year-old apple trees using growth regulating chemicals, but the results differed with cultivar, concentration of growth regulator, season, and time of application. The following three studies were conducted to determine the response under Ohio conditions.

MATERIALS AND METHODS

Study I: Three-year-old trees on M7 of Melrose, Lawspur, Rome Beauty, and Redchief Delicious (spur habit) were sprayed at petal fall (May 20, 1981) with the

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following treatments: 1) unsprayed control, 2) 6-BA (6-benzylamino purine) at 500 ppm + Alar [butanedoic acid mono (2,2-dimethylhydrazide)] at 1500 ppm, 3) Promalin [proprietary mixture of 6-BA and GA 4 + 7 (gibberellic acid)] at 500 ppm, 4) Promalin at 500 ppm + Alar at 1500 ppm, and 5) Alar at 1500 ppm. The trees were sprayed with a high pressure hand gun to the point of drip. The treatments were arranged as a randomized complete block with six whole tree replications. After leaf fall, the two largest scaffold limbs on each tree were selected for measuring limb circumference, terminal length, and laterals on 2-year wood. Fruit set was measured the following year.

Study II: In 1982, additional trees from the above orchard of Melrose and Redchief Delicious were sprayed to drip by knapsack sprayer with the following treatments: 1) unsprayed control, 2) 6-BA at 500 ppm, 3) Alar at 1500 ppm, 4) 6-BA at 500 ppm + Alar at 1500 ppm, 5) Promalin at 500 ppm, and 6) 6-BA at 500 ppm. Buffer X (0.05%) was used as a surfactant with 6-BA and Regulade (0.05%) with Promalin. Data were collected as described in Study I. The treatments were arranged as a randomized complete block with six replications.

Study III: In 1983, vigorous trees in their third leaf of Lawspur/M7 which exhibited considerable blind wood were sprayed when terminals averaged 5 cm in length with the following: 1) check, unsprayed control; 2) Buffer X at 0.05%; 3) 6-BA at 500 ppm; 4) 6-BA at 500 ppm; 5) Promalin at 300 ppm; 6) Promalin at 500 ppm; 7) Alar at 1000 ppm; 8) 6-BA at 300 ppm + Alar at 1000 ppm. Treatments with 6-BA also received Buffer X (0.05%) as a surfactant. The sprays were applied with a portable CO_2 sprayer on May 16. The

TABLE 1.—Influence of Growth Regulators on Shoot Growth of Three Cultivars During Their Third Leaf, OARDC, Wooster, 1981.

Treatment	Concentration (ppm)	Av. Shoot Length (cm) Terminal	Av. Shoot Length (cm) Lateral	Laterals/ Limb X-section (No./cm²)	Total Shoot Length (cm) Laterals	Total Shoot Length (cm) Laterals + Terminal	Percent Fruit Set 1982
Check		47.5a*	16.7ab	6.5a	221	269	43.9
6BA + Alar	500 + 1500	36.3c	14.2b	7.3a	208	245	44.1
Promalin	500	45.3ab	21.4a	6.4a	280	325	45.7
Promalin + Alar	500 + 1500	38.6bc	16.6ab	7.0a	229	268	43.0
Alar	1500	47.8a	18.6ab	5.0b	221	269	45.7
Cultivar							
Melrose		49.4a	23.0a	5.6b	293a	342a	45.3
Lawspur Rome		43.2a	18.9b	6.1b	214b	257b	39.2
Redchief		36.6b	10.7c	7.6a	189b	225b	48.0

* Main effect mean separation by Duncan's multiple range test, 5% level.

TABLE 2.—Influence of Branching Agents on Growth of Two Cultivars on M7 Rootstock in 1982 During Their Fourth Leaf.

Treatment	Rate (ppm)	Terminal Shoot Length (cm)	Laterals on 2-Yr Wood Total Branch (cm)	No.	Av. Length (cm)	Total Shoot Length/ Tree	No. Shoots/ Limb X-section
Check		48.0	204	12.0	19.8	252	6.4
6BA	500	60.1	200	11.5	20.5	260	5.8
Alar	1500	58.0	173	10.7	22.1	231	6.5
6BA + Alar	500 + 1500	53.9	193	11.6	21.2	247	6.7
Promalin	500	43.7	163	9.4	19.4	207	6.8
		NS	NS	NS	NS	NS	NS
Cultivar							
Melrose		69.3a	301a	8.7b	35.9a	370a	4.1b
Redchief		36.1b	72b	13.3a	5.3b	108b	8.8a

treatments were arranged in a randomized complete block design with seven replications.

RESULTS AND DISCUSSION

The application of 6-BA and Alar or Promalin and Alar caused a reduction in terminal shoot length, but Alar or Promalin alone had no effect. Alar by itself reduced the number of shoots per unit of limb cross-section, but in combination with either 6-BA or Promalin, shoot number was not influenced. Total shoot length or fruit set the following year were not influenced by the treatments. The application of 500 ppm of 6-BA to Lawspur Rome at petal fall resulted in the formation of many mummied fruits. Many clusters retained five small apples. These young trees had so few fruit in 1981 that no effort was made to make fruit measurements.

Redchief had shorter terminal and lateral shoots and produced more laterals per unit trunk cross-section than the other cultivars. Melrose had a greater total shoot length than the other cultivars. The interaction between cultivars and treatments was significant for total shoot length. This indicated that Promalin alone resulted in more total shoot growth on Melrose, but this effect was not evident with the other cultivars. The variability in response from tree to tree was great and the consistent increase in branching observed in other studies (2) was not observed on these trees. Although no precipitates were observed with 6-BA, others (2) have reported that surfactants are necessary to keep 6-BA in solution. Thus, these were used in subsequent years.

In 1982 (Study II), the addition of surfactants did not significantly improve the branching response on 4-year-old Melrose and Redchief Delicious (Table 2). None of the growth regulator treatments significantly altered the branching pattern or shoot growth. Melrose again produced the longest shoots, while Redchief produced the greatest number of shoots.

In 1983, vigorous third leaf Lawspur Rome Beauty trees which exhibited a significant amount of blind wood were treated. Although it seemed obvious in the field that Promalin at 500 ppm markedly improved the branching of these trees, statistical treatment of the data indicated no significant difference due to the tree to tree variation. Rome Beauty trees typically exhibit a lot of "naked wood" and other difficult to branch cultivars, such as Paulared or Northern Spy, also responded poorly to similar treatments (2).

It was disappointing that the growth regulator treatments used in these studies did not consistently increase branching as reported by others (2, 3). Timing of the sprays and the amount of growth present during ap-

TABLE 3.—Influence of 6BA, Promalin, and Alar on Branching of Lawspur/ M7A Trees in 1983 (Hartzler's Orchard).

Treatment	Rate (ppm)	Terminal Length (cm)	Laterals on 2-Yr Wood Av. Length (cm)	No.	Total Shoot Length (cm)
Check		73.7	45.4	7.9	325
Buffer X		65.2	45.8	9.4	425
6BA	300	59.8	38.6	11.4	434
6BA	500	66.1	41.2	10.3	432
Promalin	300	64.0	42.3	9.8	415
Promalin	500	61.9	41.7	11.5	481
Alar	1000	58.8	34.8	11.4	385 .
6BA + Alar	300 + 1000	64.8	37.3	11.3	410

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plication were consistent with other studies. Studies with nursery trees have indicated that early season cool temperatures stimulated branching (1), but the current studies and others (2, 3) were conducted over a period of years, minimizing adverse weather effects. Promalin has been labeled to induce branching in young trees and has been successful at a number of locations. However, experience in Ohio indicates that it is not always successful.

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Influence of Growth Regulators
on Scarf Skin of Rome Beauty Apples

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INTRODUCTION

The whitish gray appearance of scarf skin has become a marketing problem in years when it develops to serious levels. Previous work indicates that changes in environmental conditions alter the expression of scarf skin, but the individual weather parameter most closely associated with increased scarf skin could not be identified (7). Nutritional factors such as high peel levels of Mn and Al and high N levels in leaves and fruit peel are associated with increased levels of scarf skin (6, 7). Fungicides, particularly benomyl, applied during the critical period for scarf skin development (the 30-40 days following petal fall) increase scarf skin (4, 5, 8, 9). Factors which changed the immediate environment around the fruit reduced fruit size and nearly eliminated scarf skin (7). The growth regulator gibberellic acid 4 + 7 (GA 4 + 7) caused a reduction in scarf skin (5) but did not eliminate it.

The present series of studies were conducted to determine the effect of several growth regulators on fruit size and scarf skin on trees which received no benomyl during the critical period for scarf skin development.

MATERIALS AND METHODS

Study 1: Law Rome Beauty trees on MM106 with a history of severe scarf skin located in a commercial orchard near Rogers, Ohio, were treated with GA - 4 (gibberellic acid), GA - 7, or an equal combination of GA 4 + 7. Each GA type was applied by dipping four clusters/tree at petal fall (PF), PF + 10, and PF + 20 days. The treated clusters were compared to an untreated control and clusters were enclosed in aerated plastic bags which have dramatically reduced scarf skin in previous studies (5, 7). All treatments were on each treated tree and arranged in a randomized complete block, with 10 replications.

Study 2: Clusters on separate trees in the orchard described above were dipped in 20 ppm of GA 4 + 7 at the following times: PF, PF + 10, PF + 20, PF + 30, and PF + 40; in addition, clusters were treated multiple times, receiving two, three, four, or five applications at the times described. Five clusters on each tree received each treatment in a randomized complete block, with 10 replications.

Study 3: Additional trees in this orchard were selected and limbs were sprayed with Alar at 125 or 250 ppm beginning at PF, with one, two, three, four, five, or six applications. Single applications of Alar at 500 ppm, 750 ppm, and 1500 ppm were also compared to an untreated control. Limbs were sprayed at pink (May 10), PF, PF + 10, PF + 20, PF + 30, and PF + 40 days with a CO_2 sprayer to drip. The treatments were arranged (five limbs/tree and three trees/replicate) as a randomized complete block, with eight replications.

Study 4: Gallia Beauty trees on M26 planted in 1968 at OARDC were treated with the following growth regulator sprays in 1984: 1) check, untreated control; 2) Alar at 750 ppm applied 10 days after full bloom (FB); 3) Alar at 1500 ppm applied FB + 10 days; 4) Alar at 1500 ppm applied 60 days pre-harvest; 5) 6BA (N-(phenylmethyl)-1 H purin-6-amine) at 50 ppm applied FB, FB + 10, FB + 20, and FB + 40; 6) treatments 3 + 5; and 7) treatments 4 + 5. The whole tree sprays were applied with a high pressure handgun to the point of drip. The treatments were arranged as a randomized complete block, with six replications.

Study 5: Lawspur Rome Beauty trees planted in 1979 had three fruiting clusters/tree dipped with either 0.5 ppm or 1.0 ppm 245-TP at PF. GA 4 + 7 at 20 ppm was then applied at 10-day intervals at one, two, three, or four times beginning at petal fall (May 24) at OARDC. The treatments were arranged as a randomized complete block on 12 replicate trees.

A corollary study on 15 additional trees had three clusters/tree/treatment dipped in 5 ppm or 10 ppm 245-TP at petal fall. GA 4 + 7 at 20 ppm was then applied by dipping at the following times PF, PF + 10, PF + 20, PF + 30, or PF + 40 for a total of 13 treatments with the untreated control. The treatments were arranged as a randomized complete block, with 15 replications.

Study 6: Law Rome Beauty trees on MM106 with a history of severe scarf skin located in a commercial orchard near Rogers, Ohio, were used in this study. Three to five lower scaffold limbs per tree were selected so that growth regulator sprays could be applied with minimal drift to adjoining limbs. The treatments were applied as a factorial with 0, 5, or 10 ppm of GA 4 + 7 and the following six growth regulator treatments: 1) check, no spray applied; 2) Alar (butanedioic acid mono(2,2-dimethylhydrazide) applied at 125 ppm; 3) Alar at 250 ppm; 4) Alar at 500 ppm; 5) 245-TP (2-(2,4,5-trichlorophenoxy) propionic acid) applied at 2 ppm; and 6) 245-TP at 2 ppm plus Alar at 250 ppm. Thus, 18 limbs composed a replication, with a total of nine replications in the study. Sprays were applied at pink (May 6, 1984, and April 23, 1985); petal fall (PF);

TABLE 1.—Influence of Types of Gibberellic Acid on Fruit Size and Scarf Skin of Law Rome Beauty Apples, Rogers, Ohio, 1983.

Treatment*	Rate (ppm)	Weight/ Fruit (g)	Scarf[†]
Check	0	202a	4.1a
GA4	5	209a	3.9a
GA4	10	193ab	4.0a
GA4	20	196a	3.7abc
GA4	40	190ab	3.3cd
GA7	5	199a	4.0a
GA7	10	188ab	3.9a
GA7	20	190ab	3.8ab
GA7	40	171b	3.3bcd
GA4+7	5	203ab	3.7abc
GA4+7	10	187ab	3.6abcd
GA4+7	20	190ab	3.1d
GA4+7	40	188ab	3.2cd
Plastic Bag		122c	1.1e

* Treatments applied by dipping fruit clusters in the solution at petal fall (PF), PF + 10 days and PF + 20 days.
[†] Scarf rating: 1 = no scarf to 5 = severe scarf.

PF + 10; and PF + 20 days with a CO_2 sprayer to the point of drip. The treatments were applied to the same limbs in 1984 and 1985.

Fruit set and flower density were determined annually on each limb and at harvest. Fruit size and degree of scarf skin on the green side of each fruit of a 15 fruit sample/limb were determined.

Study 7: Because environmental conditions had been shown to influence scarf skin development (7), fruiting clusters on separate trees in the orchard described in Study 6 were dipped in simulated acid rain solutions with the following pH values: 1) untreated control; 2) pH 5.6; 3) pH 5.1; 4) pH 4.6; 5) pH 4.0; 6) pH 3.5; 7) pH 3.0; 8) pH 3.0 plus enclosure in an aerated plastic bag; and 9) pH 4.0 plus enclosure in a plastic bag. Five clusters on each tree were dipped, with each treatment repeated at the following times: PF, PF + 10, and PF + 20. Deionized water was acidified with

TABLE 3.—Influence of Rates and Number of Times of Dipping Fruit Clusters in Alar on Fruit Size and Scarf Skin Development of Law Rome Beauty Apples, Rogers, Ohio, 1984.

Alar Rate (ppm)	No. of Sprays*	Wt/ Fruit (g)	Scarf Rating[†]
Check	0	209	3.2
125	1	198	3.1
	2	180	3.3
	3	199	3.1
	4	200	3.3
	5	208	3.2
	6	203	2.9
250	1	194	3.2
	2	192	3.0
	3	194	3.2
	4	200	2.9
	5	203	3.3
	6	198	3.4
500	1	190	3.2
750	1	201	3.2
1500	1	206	3.1

* Clusters were dipped at pink (May 10); PF, PF + 10, PF + 20, PF + 30, and PF + 40.
[†] Scarf rating: 1 = no scarf to 5 = severe scarf.

a mixture of sulfuric acid and nitric acid, which corresponded to the relative concentrations found in naturally produced acid rain.

RESULTS

GA7 at the highest concentration of 40 ppm caused a reduction in fruit size, but the other types and rates of GA had no effect on fruit size (Table 1). As in past studies (5, 7), the plastic bag caused a significant reduction in fruit size and the elimination of scarf skin. Generally, as the concentration of all forms of GA increased, scarf skin decreased, but one form did not appear superior to the others in the reduction in scarf skin. The applications of GA were not as successful in reducing scarf skin as the plastic bag and even the

TABLE 2.—Influence of Time and Number of Applications of GA4+7 (20 ppm) on Fruit Size and the Development of Scarf Skin on Law Rome Beauty Apples, Rogers, Ohio, 1983.

Time of GA4+7 Application	Weight/Fruit (g)	Scarf
Check	192	3.70a[†]
PF	207	3.68a
PF, PF + 10	211	3.61ab
PF, PF + 10, PF + 20	182	2,84c
PF, PF + 10, PF + 20, PF + 30	212	3.23bc
PF, PF + 10, PF + 20, PF + 30, PF + 40	195	2.84c

* Five clusters/tree dipped in 20 ppm GA4+7 on 10 replicate trees. PF = May 18, 1983.
[†] Scarf rating: 1 = no scarf to 5 = severe scarf. Means separated by Duncan's multiple range test, 5% level.

TABLE 4.—Influence of Growth Regulator Sprays on Fruit Color, Size, and Quality of Gallia Beauty Apples on M26, 1984, Wooster.

Treatment	Timing	Color*	Scarf[†]	Average wt (g)	Firmness (kg)	SS (%)	Percent Set
Check		3.1	3.5	224	5.8	13.1	68.0
Alar 750	FB + 10	3.2	3.5	218	5.7	13.0	75.4
Alar 1500	FB + 10	3.0	3.4	225	5.8	13.3	71.6
Alar 1500	60 Preharv.	2.9	3.4	212	5.4	13.5	60.0
6BA 50	FB, FB + 10, FB + 20, FB + 40	3.3	3.7	232	5.6	13.2	66.1
Treat 3+5		3.2	3.6	241	5.8	13.6	48.9
Treat 4+5		3.1	3.5	236	5.7	13.3	51.7

* Color rating: 1 = 100% red to 5 = 50% red.
† Scarf rating: 1 = no scarf to 5 = severe scarf.

highest concentrations failed to reduce scarf to the level of 2.5 chosen as acceptable commercially.

Applications of GA 4 + 7 at PF or PF and PF + 10 days had no effect on scarf skin, but three or more applications reduced the level of scarf skin (Table 2). Multiple applications had no significant influence on fruit size. The influence of GA 4 + 7 on reducing russet was enhanced by multiple applications (3, 11) and this study indicates that when scarf skin is severe, multiple applications are necessary for a significant reduction. Unfortunately, multiple applications didn't reduce scarf skin to the level of 2.5 chosen as commercially acceptable.

Applications of Alar had little effect on either fruit size or the level of scarf skin (Table 3). This is surprising, since other studies have shown that Alar applications of 1500 ppm early in the season reduced fruit size. Multiple applications of either 125 or 250 ppm had no influence on fruit size or level of scarf skin. It was hoped that a slight reduction in fruit size and the corresponding reduction in scarf skin normally associated with smaller fruit (5) might be achieved with these treatments. In previous years, the control fruit in the orchard normally had a scarf skin level of nearly 4.0 compared to 3.2 in 1984. The elimination of early season benomyl sprays and moderation of nitrogen applications employed by the grower may have been responsible for the reduced level of scarf skin.

The use of Alar at various times and the combination with 6-BA had no effect on fruit size or scarf skin levels on young Lawspur trees at Wooster (Table 4). The growth regulator treatments also failed to influence fruit color, firmness, soluble solids, or percent set on these trees.

Work in Virginia (2) indicated that 245-TP caused a significant reduction in russet of Golden Delicious apples and also reduced fruit size. Since scarf skin and russet have many similarities in the beginning stages of their expression (1, 5, 10), it was decided to test the influence of 245-TP on scarf skin development. Concentrations of 5 or 10 ppm of 245-TP and subsequent applications of GA 4 + 7 had no influence on scarf skin but did negatively influence fruit size (data not presented). Lower rates of 0.5 and 1 ppm which had

been successful in reduction of russet had little effect on fruit size or level of scarf skin (Table 5). Increasing the number of applications of GA 4 + 7 to four during the critical period for development of scarf skin tended to reduce scarf skin, but the effect was not significant. The level of scarf skin was relatively low in these trees, and treatments which normally reduce scarf skin have little effect when it is near the commercially accepted level of 2.5.

It was hoped that the effect of GA in slightly reducing scarf skin found previously (5) and confirmed in Table 1 could be enhanced by combining with other growth regulators which may also have potential. However, no interaction occurred when spray applications of GA 4 + 7 and 5 or 10 ppm were applied with Alar or 245-TP over 2 years (Table 6). The combination of 245-TP and Alar in 1984 reduced fruit size, but had no influence on scarf skin. Generally as the concentration of GA 4 + 7 was increased, scarf skin was slightly reduced in

TABLE 5.—Influence of 245-TP on Fruit Size and Development of Scarf Skin on Lawspur Rome Beauty Apples, 1984, Wooster.

245-TP* (ppm)	Number of Applications GA4+7 (20 ppm)	Weight/Fruit (g)	Scarf[†]
Check	0	168	2.8
0.5	0	147	2.2
1.0	0	117	1.8
0.5	1	138	2.3
1.0	1	173	3.0
0.5	2	140	1.8
1.0	2	133	1.7
0.5	3	141	2.2
1.0	3	114	1.5
0.5	4	124	2.3
1.0	4	121	2.3
0.5	5	132	1.6
1.0	5	159	2.2

* Treatments applied by dipping whole clusters beginning at petal fall (May 24, 1984) and at 10-day intervals.
† Scarf rating: 1 = no russet to 5 = severe russet.

TABLE 6.—Influence of Growth Regulator Treatments on Fruit Size, Development of Scarf Skin, Fruit Set, and Relative Density of Flowers and Fruit of Law Rome Beauty Apples, Rogers, Ohio.

Treatment	Rate ppm	1984					1985				
		Weight g/Fruit	Scarf*	Fruit Set (%)	Flowers/ cm²	Fruit/ cm²	Weight g/Fruit	Scarf*	Fruit Set (%)	Flowers/ cm²	Fruit/ cm²
Check	—	224a	3.3	49.1	4.1	2.3	224ab	3.0a	52.4	8.3	4.3
Alar	125	226a	3.2	49.5	4.6	2.2	229ab	2.8bc	55.7	8.3	4.4
Alar	250	214ab	3.0	44.8	4.9	2.1	223ab	2.9ab	57.4	7.1	3.9
Alar	500	219ab	3.1	49.9	4.7	2.2	219b	2.7c	68.4	7.9	4.7
245-TP	2	214ab	3.1	56.7	5.3	2.7	233a	2.9ab	68.0	7.2	4.6
245-TP+Alar	2+250	207b	3.0	54.2	5.1	2.6	225a	2.7c	66.6	7.2	4.5
GA4+7											
0		215	3.2a	52.1ab	4.9	2.5	232a	2.9a	54.6b	7.7ab	3.8b
5 ppm		222	3.0b	45.4b	5.3	2.2	227a	2.8ab	60.3ab	8.3a	4.7a
10 ppm		215	3.1ab	53.6a	4.6	2.4	218b	2.7b	69.3a	6.9b	4.7a

* Scarf rating: 1 = no scarf to 5 = severe scarf.

TABLE 7.—Influence of Various Levels of Acid Rain on Fruit Size and Scarf Skin Development of Law Rome Beauty Trees, 1984, Rogers, Ohio.

pH*	Weight/ Fruit g	Scarf†
Check	193bc	3.9ab
5.6	220a	4.1ab
5.1	213ab	3.7b
4.6	205abc	4.2ab
4.0	211ab	4.3a
3.5	193bc	3.9ab
3.0	214ab	4.1ab
3.0 + bag	160d	1.5c
4.0 + bag	188c	1.8c

* Clusters were dipped in the acid rain solutions at PF + 10, PF + 20, and PF + 30 days.
† Scarf rating: 1 = no scarf to 5 = severe scarf.

both 1984 and 1985, which confirms earlier work (Table 1). Alar at 500 ppm applied four times reduced fruit size in 1985 and the 125 and 500 ppm rates and the combination of 245-TP and Alar slightly reduced the level of scarf skin. Flower and fruit density on the treated limbs were not influenced by Alar or 245-TP. GA 4 + 7 tended to increase fruit density in 1985.

Multiple applications of acid rain during the critical period for scarf skin development had no influence on either fruit size or scarf skin (Table 7). Enclosing the cluster in an aerated plastic bag again decreased both fruit size and scarf skin. Acid rain at pH 3.0 caused a greater reduction in fruit size than acid rain at a pH of 4.0, but even in the bags acid rain had no effect on scarf skin.

A general conclusion to be drawn from this series of studies is that GA 4 + 7 can significantly reduce, but not eliminate, scarf skin when it is severe. Generally three or more sprays during the critical period for development (PF + 30 days) will be required for a positive effect. In years when the scarf skin is less severe, these sprays will have little effect.

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Influence of Fungicides on Scarf Skin on Gallia Beauty

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INTRODUCTION

Scarf skin of Rome Beauty has been shown to be due to cell separations which leave gaps or air spaces between cells several cell layers deep in the skin tissue, causing the visual whitish-gray appearance (2). The most critical period for scarf skin formation is the 30 to 40 day period following petal fall, with the early portion of this time period being more critical than the latter portion (1). Full-season fungicide programs of benomyl or dikar increased the amount of scarf skin (1). Hickey (3, 4) has also shown that some fungicides, particularly benomyl, cause opalescence or scarf skin of Rome Beauty.

Since the critical period for development of scarf skin is also one of heavy and consistent fungicide usage, the following study over 2 years evaluated a number of fungicide programs on scarf skin development.

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TABLE 1.—Apple Spray Trial — 1984.

Treatment	Rate Product/A (Based on 400 gal/A)	Timing	Av. Fruit wt (g)	Scarf Rating
DPX-H6573 40%EC	71 ml	14-day schedule starting ½ inch green	198abc	3.0
XE-779 25WP	91 grams	Full schedule	111e	3.0
Bravo 500F followed by	4 gal	¼ inch green thru petal fall	136bcde	3.6
Captan 50WP	6 lb	Petal fall start, full season program		
Vangard 10WP +	6 oz	Full schedule	127bcde	3.2
Captan 50WP	3 lb			
CGA-71818 10WP +	10 oz	Full schedule	122cde	2.7
Captan 50WP	3 lb			
Rubigan followed by	6 oz	Full schedule thru primary scab	129bcde	2.9
Captan 50WP	6 lb	Full schedule		
Difolatan DG followed by	25 lb	¼ inch green to petal fall	170a	3.1
Dithane M-45 80WP	6 lb	Cover sprays		
Funginex 1.6EC +	40 oz	Kickback within 3 days	139bcd	2.7
Polyram 80WP	3 lb			
Bayleton 50WP +	2 oz	Full season	118de	3.0
Captan 50WP	4 lb			
Topsin M 4.5F +	10 fl oz	Full season	142bcd	3.1
Baycor 50WP	4 oz			
Dikar 80WP followed by	8 lb	½ inch green thru petal fall	151ab	2.9
	6 lb	Remaining covers		
Dithane M-45 80WP +	8 lb	½ inch green thru petal fall	147abc	3.3
Bayleton 50WP followed by	2 oz			
Dithane M-45 80WP (alone)	6 lb	Remaining covers		

MATERIALS AND METHODS

Various season-long fungicide programs were applied to 16-yr-old Gallia Beauty trees on MM106 in the OARDC Plant Pathology orchard at Wooster. The fungicides used in 1984 and 1985 are listed in Tables 1 and 2. They were applied to four single tree replicates arranged in a complete randomized block design. Trees were sprayed to run-off with a handgun at 450 psi. At harvest, 25 fruit/tree were selected at random and average size and degree of scarf skin were determined as previously described (2).

RESULTS AND DISCUSSION

In 1984, the scab level in the untreated control was so severe that the fruit were distorted too badly for scarf skin analysis. Compared to a standard program of Dikar, average fruit size was reduced by XE-779 and the Bayleton + Captan programs (Table 1). Generally, there was very little influence of the various fungicides on scarf skin level with the exception that the program of Bravo 500F + Captan tended to increase the level; however, variation was great enough that this difference was not significant.

In 1985, the following fungicides tended to reduce fruit size: Topas, RH3386 + Dithane; A-815; Bayleton + Captan; and Benlate + Manzate + oil (Table 2). Compared to the unsprayed control, the level of scarf skin was increased by the following fungicide programs: Topas + Mancozeb and Benlate + Manzate + oil. The influence of Benlate in early sprays during the critical period for scarf skin development confirms previous studies (1, 3, 4). It should be noted that the use of Benlate late in the season after the critical period (Treatment 22) did not cause a significant increase in scarf skin development.

The most important conclusion from this work is that most of the fungicides in these tests had little or no influence on scarf skin development. It is important to note that the ergosterol biosynthesis (sterol inhibitors), which provide excellent scab control as well as curative activity, appeared to have no effect on scarf skin. These fungicides include: DPX-H6573 (Nustar), XE-779, CGA-71818, Rubigon, Funginex, Bayleton, Baycor, Topas MZ-61, RH-3866, and A-815.

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TABLE 2.—Influence of Various Fungicide Programs on Fruit Size and Scarf Skin Development of Gallia Beauty in 1985 (Plant Pathology Fungicide Trial).

Treatment	Rate Product/ 100 gal		Timing	Av. Fruit wt (g)	Scarf Skin
Check	—		--------	225a	2.5b
Rubigan EC followed by	1.5	oz	¼ inch green thru primary scab	195abcde	3.0ab
Captan 50W	1.5	lb	Remaining covers		
Rubigan EC plus	1.5	oz	¼ inch green thru primary scab	201abcd	2.7b
Ortho X-77 followed by	4	oz			
Captan 50W	1.5	lb	Remaining covers		
Rubigan AS followed by	1.5	oz	¼ inch green thru primary scab	211abc	2.7b
Captan 50W	1.5	lb	Remaining covers		
Rubigan AS plus	1.5	oz	¼ inch green thru primary scab	209abc	3.2ab
Ortho X-77 followed by	4	oz			
Captan 50W	1.5	lb	Remaining covers		
Topas MZ-61 followed by	1	lb	72 hr curative thru primary scab	199abcde	3.6a
Mancozeb 80W	6	lb	Remaining covers		

TABLE 2. (continued)—Influence of Various Fungicide Programs on Fruit Size and Scarf Skin Development of Gallia Beauty in 1985 (Plant Pathology Fungicide Trial).

Treatment	Rate Product/ 100 gal		Timing	Av. Fruit wt (g)	Scarf Skin
Topas MZ-61	1	lb	Full schedule	166e	2.4b
RH-3866 (40W) followed by	2.5	oz	½ inch green thru 2nd cover	182cde	3.0ab
Dithane M-45 (80W)	1.5	lb	Remaining covers		
RH-3866 (40W) plus	1.25	oz	½ inch green thru 2nd cover	220ab	3.0ab
Dithane M-45 (80W) followed by	1.5	lb			
Dithane M-45 (80W)	1.5	lb	Remaining covers		
XE779	23	g	Full schedule	202abcd	2.9ab
XE779 (25W) plus	23	g	Full schedule	212abc	2.5b
Captan 50W	12	oz			
A-815 (50W)	4	oz	72 hr curative thru primary scab then full schedule	188bcde	2.7b
A-815 (50W) plus	4	oz	72 hr curative thru primary scab then full schedule	200abcde	3.1ab
Dithane M-45	12	oz			
Baycor 50W plus	4	oz	72 hr curative thru primary scab	217abc	2.7b
Captan 50W followed by	1	lb			
Baycor 50W plus	2	oz	Remaining covers		
Captan 50W	1	lb			
Bayleton 50W plus	2	oz	Full schedule	168de	2.6b
Captan 50W	4	oz			
DPX-H6573 (20DF)	17.79	ml	Full schedule	201abcde	2.7b
DPX-H6573 (20DF) plus	8.99	ml	Full schedule	209abc	2.4b
DPX-965 (50DF)	2	oz			
DPX-H6573 (20DF) followed by	17.79	ml	½ inch green thru primary scab	210abc	3.1ab
Benlate 50W plus	3	oz	Remaining cover sprays		
Manzate 200 (80W)	12	oz			
Benlate 50W plus	3	oz	72 hr curative thru primary scab	186bcde	3.6a
Manzate 200 (80W) plus	12	oz			
70 sec oil followed by	1	qt			
Benlate 50W plus	3	oz	Remaining covers		
Manzate 200 (80W)	12	oz			

Little Relationship Between Root Pruning and Winter Injury

JAMES R. SCHUPP and DAVID C. FERREE[1]

INTRODUCTION

On Dec. 24, 1983, much of the United States suffered unusually cold temperatures. At the OARDC in Wooster, the temperature dropped from −15.6° C to −25° C, with high winds and no snow cover. The damage to fruit trees over the state was considerable, particularly young trees 4 and 5 years old which just produced their first or second crop. The following report summarizes injury to trees in several experimental plantings at the OARDC which were involved in root pruning studies. Prior work on root pruning does not comment on its relationship to winter injury (1).

MATERIALS AND METHODS

The orchard planted in 1979 on M7A rootstock contained 80 trees of each of the following cultivars: Redchief Delicious, Lawspur Rome, and Smoothee Golden Delicious. A total of 160 trees of Melrose were planted in guard rows. Six independent observers surveyed the orchard, rating each tree with the following scale: 10 = no injury to 1 = severely injured, approaching death.

Melrose trees were in an experiment to study the effects of root pruning at different stages of growth. In 1983, 35 4-year-old trees and 20 3-year-old trees were selected for uniformity and assigned one of the following root pruning treatments: 1) control — no root pruning, 2) dormant — March 24, 3) full bloom — May 4, 4) June drop — June 27, and 5) preharvest — August 24.

Treatments were arranged as a randomized complete block with seven and four replications of the 4 and 3-year-old trees, respectively. The roots were pruned with a sharpened subsoiler mounted in an offset fashion on a tractor. The pruning cuts were made on two sides of the tree at 50 cm distance from the trunk and to a depth of 35-40 cm. In July 1984, winter injury to the trees was rated, as described previously.

An adjoining block planted in 1981 compared Empire, Lawspur Rome Beauty, Smoothee Golden Delicious, and Redchief Delicious in the following three management systems: 1) recommended spacing with conventional training and pruning; 2) spaced at half the recommended spacing with an application of 1500 ppm of daminozide 2 weeks following full bloom, plus a summer shearing of new growth in early August; and 3) spaced at half the recommended spacing and annually root pruned at full bloom to a depth of 30-40 cm at 50 cm from the trunk. The treatments were arranged in a randomized complete block, with four replications and three trees of each treatment per replication. Winter injury was rated as described previously.

RESULTS AND DISCUSSION

Winter injury resulting from −25° C temperature on Dec. 24, 1983, was characterized by trunk splitting, bark necrosis, shoot die-back, death of terminal buds, small chlorotic leaves, and poor fruit set or deformed fruit. Redchief was by far the most sensitive of the cultivars and 100% tree mortality was observed with this cultivar on M7A. Golden Delicious was judged to be least damaged, while Lawspur Rome and Melrose were more severely damaged but not statistically different from each other (Table 1). Additionally, it was noted that the Lawspur Rome had set a full crop of fruit, but these were very small and sunburned from lack of protective leaf canopy. Melrose set very few fruit and close observation indicated that many flower buds on this cultivar were killed and had abscissed.

Melrose trees which were dormant root pruned in March 1983 received higher injury ratings than the controls or those root pruned at a later stage of growth (Table 2). This may have been because this treatment is especially effective in reducing shoot growth and leaf size (2) so that the observers may have attributed these effects to winter injury. The experimental mean for this

TABLE 1.—Winter Injury to Four Cultivars on M7A Rootstock.

Cultivar	Winter Injury Rating
Golden Delicious	8.5a*
Melrose	6.7b
Lawspur Rome	5.6b
Redchief	− −†

* Mean separation by LSD = .05. Means followed by the same letter are not significantly different.

† Redchief suffered 100% mortality and thus could not be rated.

TABLE 2.—Effects of Root Pruning at Different Stages of Growth on Winter Injury to Melrose/M7A Apple Trees.

Growth State when Root Pruned	Winter Injury Rating	
	4-Yr-Old Trees	5-Yr-Old Trees
Control	3.5	7.2b*
Dormant	3.7	5.4a
Full Bloom	5.5	7.2b
June Drop	5.7	6.5ab
Preharvest	4.2	7.3b

* Mean separation by LSD = .05. Means followed by the same letter are not significantly different.

[1]Graduate Research Associate and Professor, respectively, Dept. of Horticulture.

TABLE 3.—Expression of Winter Injury as Influenced by Apple Cultivar and Orchard Management System.

Cultivar	Normal Spacing and Training	Alar + Summer Hedging	Root Pruned
Smoothee	8.5abc*	8.7ab	9.0a
Lawspur	7.1d	8.4abc	8.0abcd
Empire	8.5abc	7.7bcd	8.7ab
Delicious	7.1d	7.6cd	8.5abc

*Mean separation by Duncan's multiple range test at 5%.

study was 6.72, identical to the average rating for all Melrose in this orchard, which further indicates that root pruning had little or no effect on winter hardiness.

Similar to the evaluation of the M7A orchard, Lawspur Rome and Delicious had more winter injury than Smoothee Golden Delicious. Empire was rated the same as Smoothee. Root pruning improved the rating of Delicious slightly, but had no effect on the other cultivars.

The trees described in this study were those most damaged by the cold temperatures. Winter injury was observed in other orchards, but was more scattered and random in nature. These young trees were just coming into bearing, or had just produced their first significant crop, which was a particularly sensitive growth stage

to the 1983 freeze. Weed control in these orchards resulted in bare ground around the trees when the trees received the low temperatures. It was concluded from these studies that root pruning has little or no effect on early winter hardiness of apple trees.

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Performance of Two Apple Cultivars on M8 and M9 Interstems on Antonovka

D. C. FERREE, R. M. MCCONNELL, and J. C. SCHMID[1]

INTRODUCTION

The search continues for smaller, more efficient apple trees which are free-standing and productive. A number of investigators (1, 3, 4) have proposed that inserting an interstem of dwarfing rootstock such as M9 between a well-anchored rootstock and the scion cultivar has potential to produce small free-standing trees. Normally M9 or C6 are the dwarfing interstems employed (3), but M8 has been tried (1) and a recent report compared M9 and M27 (4). The present study was initiated to determine the relative yield efficiency of M9 and M8 interstems on two apple cultivars.

MATERIALS AND METHODS

Trees of 'Empire' and 'MillerSturdeespur Delicious' using a 6-inch interstem of M9 or M8 on Antonovka seedling rootstock were compared to trees on semi-standard MM111. The trees were planted in 1975 at a spacing of 8' x 16', with 10 replicate trees of each combination, at the OSU/OARDC Branch in Jackson. Soil management utilized sod row middles with herbicide strips and commercially recommended pesticides were used. The trees were fertilized annually with ⅛ lb of ammonium nitrate/tree per year of tree age.

RESULTS AND DISCUSSION

The harvestable crop was in 1979 with trees on M8 interstem producing significantly less than trees on either M9 interstems or MM111 (data not presented). Both interstems resulted in significantly more root suckers/tree when compared to MM111. The scion cultivar had no effect on rootsucker production (Table 1). Trees on M8 interstems consistently produced more suckers/tree than on M9; however, the difference was not statistically significant. The potential for the interstem to cause rootstocks to produce rootsuckers has been previously reported (3, 4). Generally, the longer the interstem the greater the amount of suckers. The potential for suckering is particularly great on rootstocks which have a tendency to sucker normally (3). In a trial comparing Antonovka seedling rootstocks with MM111 and Ottawa 11, there was little difference in suckering potential under M9 interstems (2).

'MillerSturdeespur Delicious' was generally smaller than 'Empire', likely due to its spur habit and compact nature. The larger 'Empire' trees out-produced 'Delicious' in this trial, but there was no difference in tree efficiency either judged by the relative amount of fruit produced for the amount of wood (TCA) or by pro-duction per unit of canopy. This result was rather surprising, because 'Empire' is considered a very productive cultivar, while 'Delicious' is generally less productive (unpublished data).

MM111 produced the largest trees by all the parameters, being 61 or 52% larger than M8 and M9 interstems, respectively (Table 1). Being larger, trees on MM111 out-produced either interstem combination, but MM111 trees had a much lower productive efficiency. Trees on M8 interstems were smaller in height and spread than trees on M9. Although trunk cross-sectional area was not significantly different, M8 tended to be smaller than M9. The yield/tree and yield efficiency (fruit/amount of vegetative growth) of trees on M8 were less efficient than on M9. Thus, M8 had no advantages and would not be preferred as an interstem over M9.

Tree loss over 10 years was minimal and no more than two trees of the original ten of any combination were lost. It was very difficult to maintain a central leader in the interstem trees, particularly with 'Empire'. The leader tended to have little growth and then would fruit heavily and bend over. As a result, the trees tended to have a bush habit at maturity compared to true central leaders on the MM111.

Based on the tree size after 10 years of growth, the following would be the suggested planting distances: 'Empire' on MM111, 15' x 23', interstems 10' x 18'; 'MillerSturdeespur' on MM111, 10' x 18', interstems 8' x 16'. The smaller tree size of M9 interstems would permit intensive planting and thus have the potential to out-produce trees on MM111 by 34% on a per acre basis. However, when planting interstems, the potential for severe tree loss to fireblight must be recognized (3).

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TABLE 1.—Performance of 'Empire' and 'MillerSturdeespur' Apples on MM111 and Interstems of M8 and M9 on Antonovka Seedling Rootstock Planted in 1975 (Jackson, Ohio).

Cultivar	Suckers/ Tree	Height (m)	Inrow	Across Row	Average	Truck Cross Sectional (TAC cm²)	lb/t	lb/ cm² TCA	lb/ Canopy*	Projected†
'Empire'	25.1a	3.0a	3.3a	4.0a	3.7a	130.3a	475.7a	4.2a	45.5a	2050
'MillerSturdeespur'	25.3a	2.7b	2.9b	2.7b	2.8b	93.7b	374.8b	4.4a	52.5a	2507
Stock										
MM111	6.5b	4.0a	3.5a	4.4a	3.9a	178.7a	503.2a	2.9c	31.7c	2060
M8/Antonovka	37.5a	1.9c	2.9b	2.7c	2.8b	70.4b	296.4b	4.2b	51.5b	1983
M9/Antonovka	28.6a	2.5b	3.0b	2.9b	2.9b	86.9b	476.2a	5.7a	64.0a	3086

*lb/canopy = accumulated yield (tree ht × av. spread).

† Projected calculated in 42 lb bu/a based on actual tree size in 1985.

Air Sprayer Jet Deflection by Travel or Wind: as Predicted by Computer

R. D. FOX, R. D. BRAZEE, and D. L. REICHARD[1]

INTRODUCTION

Orchard air sprayers use air jets to transport droplets of pest control agents into tree foliage. Air sprayer jets (ASJ's) are significantly affected by external flows such as wind or apparent wind due to sprayer travel. Brazee et al. (1) and Fox et al. (2) developed a computer model of a sprayer which included wind or travel effects on the ASJ's. ASJ velocities and deflected paths predicted by the computer model agree with values measured for 1/12-scale model sprayers. The 1/12-scale physical models were mounted in a wind tunnel which was used to simulate cross winds. In this article, the computer model is used to calculate paths of two typical ASJ's acted upon by a range of travel speeds, wind velocities, and directions.

METHODS AND MATERIALS

We selected two sprayer types with about equal power requirements, but with different outlet widths and outlet air velocities. Table 1 is a list of important sprayer characteristics for each model.

These sprayers are compared for travel speeds of 2, 5, and 10 mph and wind velocities of 0, 5, and 15 mph coming from four directions or azimuths. Sprayer position is defined by the inset at the upper left-hand corner of each figure; only one side of the sprayer is used. Azimuths used for the calculations were from the front, from the left, and from the front-left and front-right. The computer model requires a target point for calculation purposes; the target point was 10 feet from the sprayer centerline and 6 feet above the ground.

RESULTS

Figures 1, 2, and 3 are top views of ASJ centerline paths calculated with the computer model. Numbers adjacent to predicted centerline locations are jet veloc-

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ities in mph at that location. ASJ directions at these locations are along a line connecting data points.

Figure 1 shows that when sprayer model 1 travels at 10 mph, the centerline path is deflected nearly 80° from its initial direction when deflection is measured at the 21.7 mph point. Model calculations indicate that this ASJ would not be able to transport spray droplets beyond 10-12 ft perpendicular to the line of travel of the sprayer centerline. From studies with an air foil field crop sprayer, Goelich (3) plotted paths of suspended spray for sprayer travel speeds of 0.6, 3, 4.7, and 6.2 mph. His results were similar to those shown in Fig. 1.

Figure 2 gives plotted paths of ASJ's for sprayer model 1 traveling at 5 mph and subjected to wind speeds of 0, 5, and 15 mph. Wind direction was perpendicular to the jet at the outlet, i.e., directly into the operator's face. Results were similar to travel speed effect observed in Fig. 1; wind speed from this direction adds directly to the travel speed effects in deflecting the jet. Therefore, in these simulations, wind speed plus travel speed produce the same results as an equal travel speed without wind.

Figure 3 displays plots of sprayer jet paths for sprayer model 1 at 5 mph and acted on by a 5 mph wind from directions of 45, 270, and 315° as shown in the figure. Wind directions are measured clockwise from the sprayer travel direction. We predict that wind from 45° will combine with travel effect to deflect the jet back toward this sprayer before the jet centerline reaches a point 10 ft perpendicular to the sprayer centerline. Wind from 270° (from the operator's left) tends to reduce deflection effects of travel. Winds from behind the sprayer tend to reduce travel speed effects on deflection of the jet even more, depending on relative magnitude.

Figures 1 and 3 each have one plot of the simulated path of the jet centerline of sprayer model 2. The plots show that jets from lower air-volume flow rate sprayers, but requiring equal power, will be affected more by wind than jets from higher air-volume flow rate sprayers.

This simulation study shows that sprayer travel can

TABLE 1.—Air Sprayer Jet Parameters.

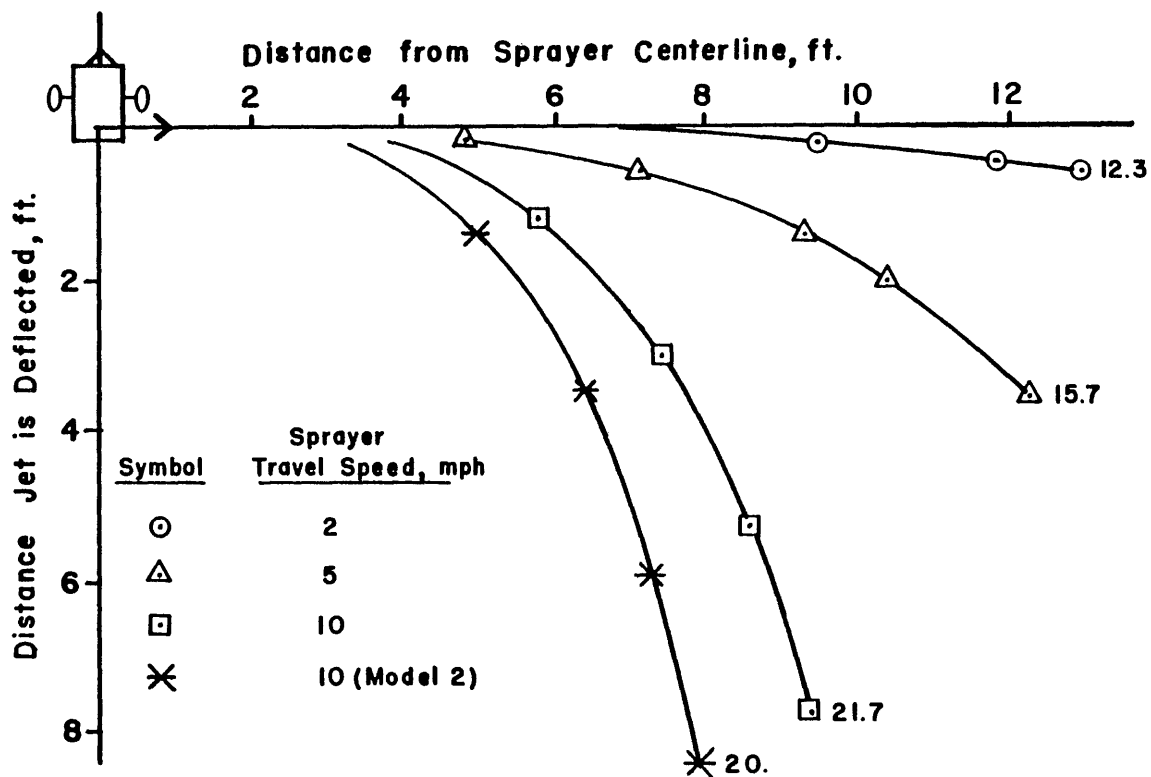| Model Number	Outlet Diameter (inches)	Outlet Width (inches)	Spray Angle (degrees)	Outlet Air Velocity (mph)	Air Flow Rate at Outlet (cfm)	Air Power at Outlet (kw)
1	36	6	120	100	24,240	8
2	20	2	120	175	7,900	8

FIG. 1.—Sprayer air jet centerline plots predicted by the computer model for three sprayer travel speeds and zero wind velocity. Values are calculated for a target point 10 feet away from the sprayer centerline and 6 feet above ground. Numbers by curves represent maximum jet velocities at that location.
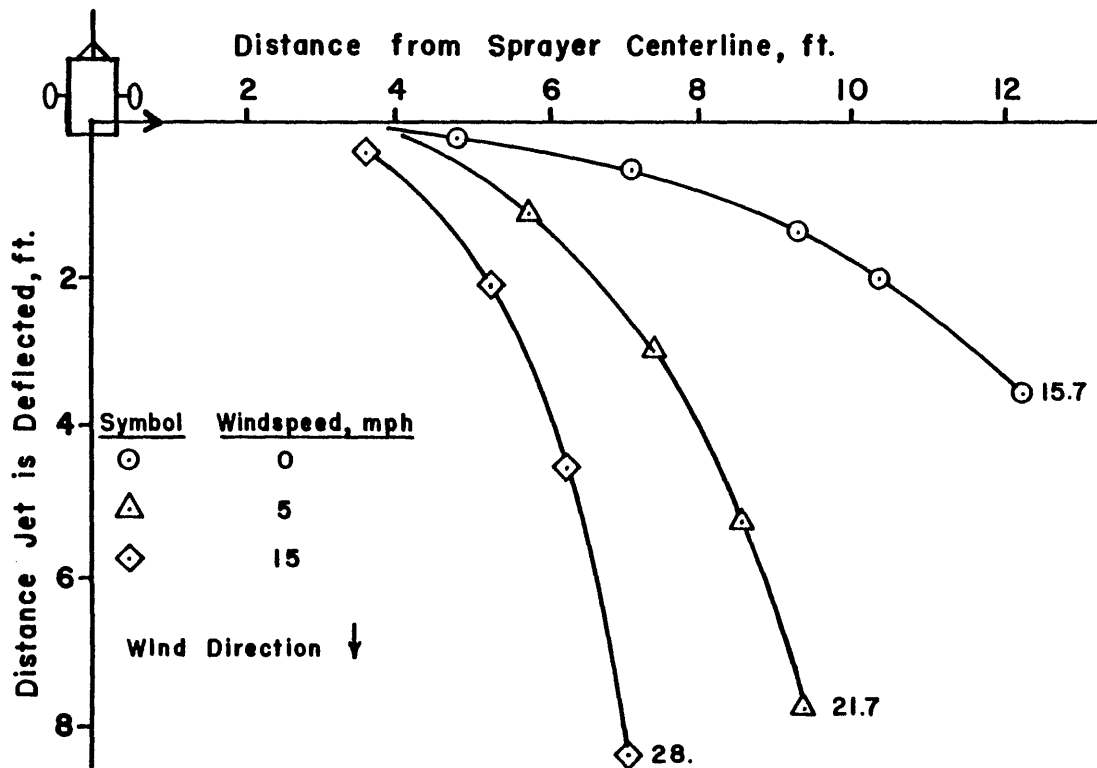

FIG. 2.—Air sprayer jet centerline paths for three wind velocities normal to the direction of the jet at the outlet and sprayer model 1 travel speed of 5 mph. Target point and velocity numbers are defined in Fig. 1.
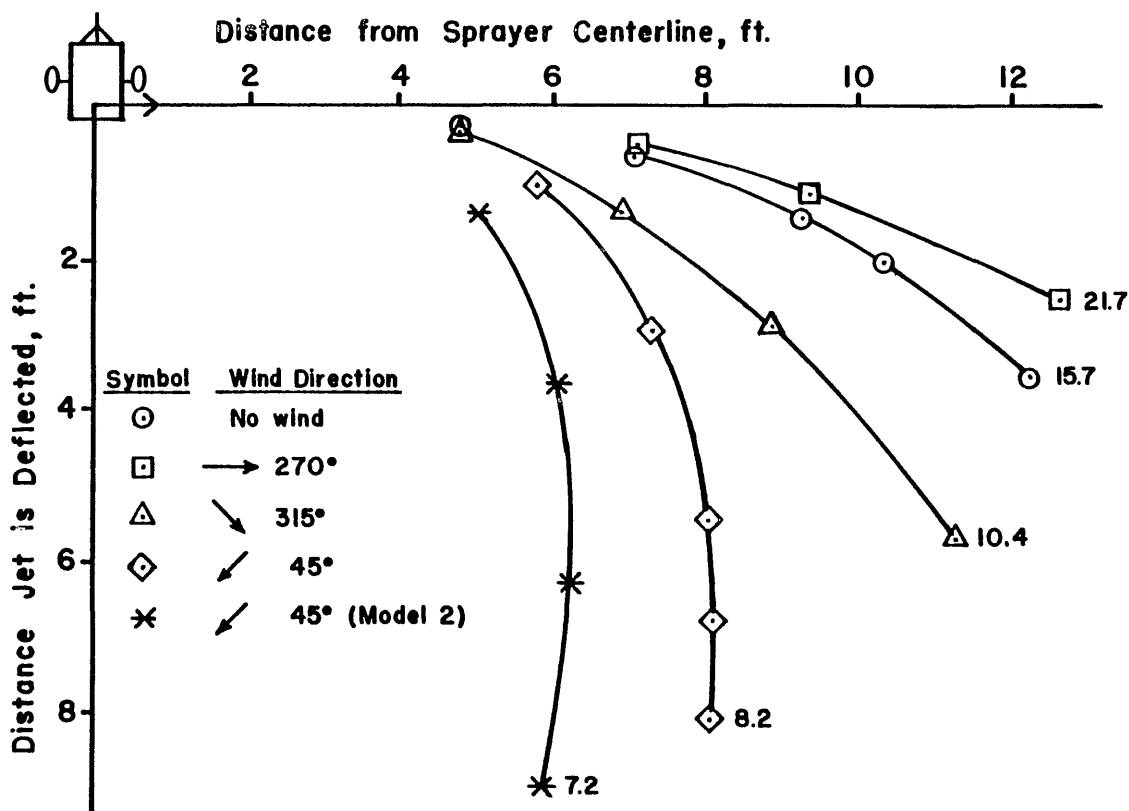
FIG. 3.—ASJ centerline paths for four wind directions, with sprayer travel speed and wind speed each at 5 mph for both models. Target point and velocity numbers are defined in Fig. 1.

greatly deflect ASJ's and reduce the distance which jets penetrate into the ambient air mass. Because sprayer jets transport pest control material into plant foliage, coverage is likely to be decreased if jets are deflected more than 45° at a distance of 10 ft from the sprayer. Figures 1-3 can be used to estimate conditions which will produce large deflections.

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Measuring Atmospheric Water Vapor

R. D. BRAZEE and R. D. FOX[1]

INTRODUCTION

Water vapor makes up only 1 to 2% by weight of the atmosphere, but this small portion has major effects on weather owing to its latent energy. The amount of water vapor in moist air can be expressed as relative humidity, wet-bulb temperature, dew-point temperature,

TABLE 1.—Definitions of Psychrometric Terms.

1. **Dry-bulb temperature:** Air temperature measured in a properly shaded and ventilated shelter.
2. **Wet-bulb temperature:** The temperature measured by a wetted thermometer at equilibrium with moisture in air. This is achieved by blowing air over a thermometer covered with a wet wick, such as a sling-psychrometer.
3. **Dew-point temperature:** The lowest temperature to which moist air can be cooled at a constant pressure without condensation.
4. **Relative humidity:** The ratio of actual water vapor pressure to saturated vapor pressure at the same temperature.
5. **Saturation:** The maximum amount of water which can be contained by air without condensation. Warm air can hold more water vapor than cold air.
6. **Absolute humidity:** Ratio of mass of water vapor to mass of dry air; humidity ratio.
7. **Specific humidity:** Ratio of mass of water vapor to mass of moist air.
8. **Enthalpy:** Sum of internal energies of a fluid system.

absolute humidity, or in other ways dependent on needs. These parameters, along with atmospheric pressure and air temperature, define the psychrometric state of a moist atmosphere. The parameters are related, and if atmospheric pressure and two other parameters are known, all psychrometric state parameters can be calculated.

Psychrometric charts are widely used to determine the state of a moist atmosphere. These charts can now be simulated with a microcomputer to permit convenient calculation of all psychrometric parameters of interest. This article outlines terms used to quantify water vapor in the atmosphere, cites sources of equations interrelating psychrometric parameters, lists data input options for the program PSYCHRO, and gives an application example.

THE PROGRAM AND TERMINOLOGY

The psychrometric program PSYCHRO is a menu-driven BASIC program which uses psychrometric regression and equations developed by Brooker (3) [also published in ASAE Standards (1)] to calculate psychrometric states. In addition to atmospheric pressure, psychrometric parameter-pairs which can be entered into the program can be chosen from the following list: TATD, TATW, TARH, TAAH, TAPV, or TWRH, where:

TA = Dry-bulb temperature, ° C or ° F;
TD = Dew-point temperature, ° C or ° F;
TW = Wet-bulb temperature, ° C or ° F;

[1]Research Leader and Agricultural Engineer, respectively, Agricultural Research Service, U. S. Dept. of Agriculture, Wooster, Ohio.

```
PSYCHROMETRIC STATE                    Date: 05/05/86 Time: 06:01:00
   Total  pressure: 29.9 in Hg


                     Temperature             Saturation vapor pressure
                      (F Deg)                      (in Hg)
  Dry-bulb........    80........                   1.03
  Wet-bulb........    50........                    .363
  Dew-point.......    1.43........                  .0408

  Relative humidity....     .0396
  Absolute humidity....     8.5E-04 Lb water/lb dry air
  Specific humidity....     8.48999999E-04 Lb water/lb air
  Specific volume......     13.6 cu ft/lb dry air
  Enthalpy of mixture..     20.2 BTU/lb dry air
```

FIG. 1.—Results calculated by psychrometric program with given values of dry-bulb (TA) and wet-bulb (TW), temperatures of 80° and 50° F, respectively.

RH = Relative humidity, (0.02-0.99);

AH = Absolute humidity, kg water/kg dry air or lb water/lb dry air; and

PV = Dew-point saturation water vapor pressure, inches hg, psi, mm hg

The input and additional output parameters are defined in Table 1.

APPLICATION AND DISCUSSION

Figure 1 is an example of results displayed or printed by PSYCHRO. The parameter-pair entered in this example were TA = 80.0° F and TW = 50° F, with barometric pressure PA = 29.92 inches hg.

PSYCHRO is written to guard against impossible situations. Note that in this example we selected a wet-bulb temperature near the minimum possible. Percent relative humidity is rarely as low as the 4% calculated here. If TW = 40° had been entered, an error message would have warned that the calculation could not be done.

Frost control studies, *e.g.*, Brazee *et al.* (2), show that dew-point temperature is an important indicator of how quickly air temperature drops and of the overnight minimum temperature reached. Instruments for measuring dew-point temperature are generally expensive, but wet-bulb temperature can be measured with a relatively inexpensive psychrometer. Dry-bulb and wet-bulb temperatures can be entered into PSYCHRO and dew-point temperature calculated. Dew-point temperature was used in a low-temperature prediction model presented by Brazee *et al.* (2).

The program PSYCHRO is available in Applesoft BASIC, either in DOS 3.3 or ProDOS versions. A copy of PSYCHRO and its operating instructions can be obtained by sending a blank diskette to the authors. For other systems, a program listing can be provided for modification by the user.

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A Prototypic Pollination Unit Made From Expanded Polystyrene

JAMES E. TEW and DEWEY M. CARON[1]

ABSTRACT

A prototypic design for a simple, expanded polystyrene pollination unit with a standardized adult bee population was developed. Polystyrene hives were evaluated for overwintering efficiency, spring season development, swarming propensity, transportation capabilities, and internal colony temperatures. Overwintered units and units started from packages were evaluated in Maryland and Alabama. Periodic evaluations of bee and brood populations indicated that polystyrene units overwintered in Alabama had greater populations than comparable colonies wintered in Maryland, but Maryland populations grew to similar numbers before the pollination season began. Managerial problems were encountered with internal foam colony temperatures during transportation as well as constant foam chewing by confined bees. However, in other areas tested, foam colonies favorably compared with control colonies.

INTRODUCTION

Colonies of honey bees *(Apis mellifera)* are frequently used to pollinate crops. Pollination services normally provided by bees are considered to be secondary to honey production by most beekeepers, even though crop pollination is more important to U. S. agriculture in general. Pilot studies were conducted to determine the feasibility of the development of a pollination unit with a standardized adult bee population which would only be used for pollination, with little emphasis on honey production. Such a unit would have to be inexpensive, simple, lightweight, and easily managed, even by non-beekeepers.

METHODS AND MATERIALS

Pollination Unit Construction

Initially, searches were conducted for expanded polystyrene containers from other disciplines. These unsuccessful searches resulted in prototype pollination units being constructed from bulk polystyrene sheets. Overall colony measurements were 30.2 cm high x 40.8 cm wide x 40.8 cm long. The square design facilitated compact stacking.

To prevent colonies from overheating, colony bottoms were covered with fiberglass window screening, which was attached with a combination of small nails and resin glue. Two foam pieces were positioned beneath

the colony to add support to glued joints, to assure air space for the screened bottom, and to provide attachment surfaces for screening (Fig. 1b). Resin glue was used to assemble the unit.

Comb Frame Construction

Comb frame top bars were cut from 19 mm (3/4") exterior plywood. Top bar length was the same as a standard top bar (48.2 cm, 19"). The elimination of standard bee space between top bars resulted in the formation of an outer hive cover (Fig. 1). Short end bars made of tempered masonite prevented bees from attaching comb to the inside colony walls.

An efficient, simple colony entrance was formed when frames were lifted and suspended at one end (Fig. 1). If a large entrance was necessary, all frames except the two outermost could be lifted. Normally, three frames lifted were. enough to allow free bee access.

Beeswax Comb Foundation

Combs in frames with no foundation or frames with foundation starter strips were easily broken when colonies were transported or individual combs were examined. The average gross weight when foundationless combs broke was 1.2 kg. Pilot studies indicated that common wired beeswax foundation which was stapled to top bars resulted in the most durable comb.

Colony Adaptations for Transportation

To prevent comb breakage, colonies containing newly constructed combs were inverted during transportation. Wooden slats across frames and the colony bottom were connected with elastic bands to hold frames in place during the inverting and transporting process (Fig. 1c).

Seasonal Development
of Established Experimental Colonies

Tests were conducted to determine if foam colonies could withstand winter conditions without special winterizing procedures. Four established foam colonies and four comparable control colonies in standard equipment were randomly selected to pass the winter in Maryland. A companion wintering study was conducted to determine if foam would winter appreciably better in a warm climate. Five foam colonies and five control colonies were transported approximately 800 miles to southeast Alabama for the warm climate wintering study. Additionally, tests were conducted to determine how well 3-lb packages of bees begun in the spring at both.the Alabama and Maryland locations would compete with other established test colonies. Eight foam colonies with control colonies were hived in Alabama and 25 foam colonies with control colonies were begun in Maryland.

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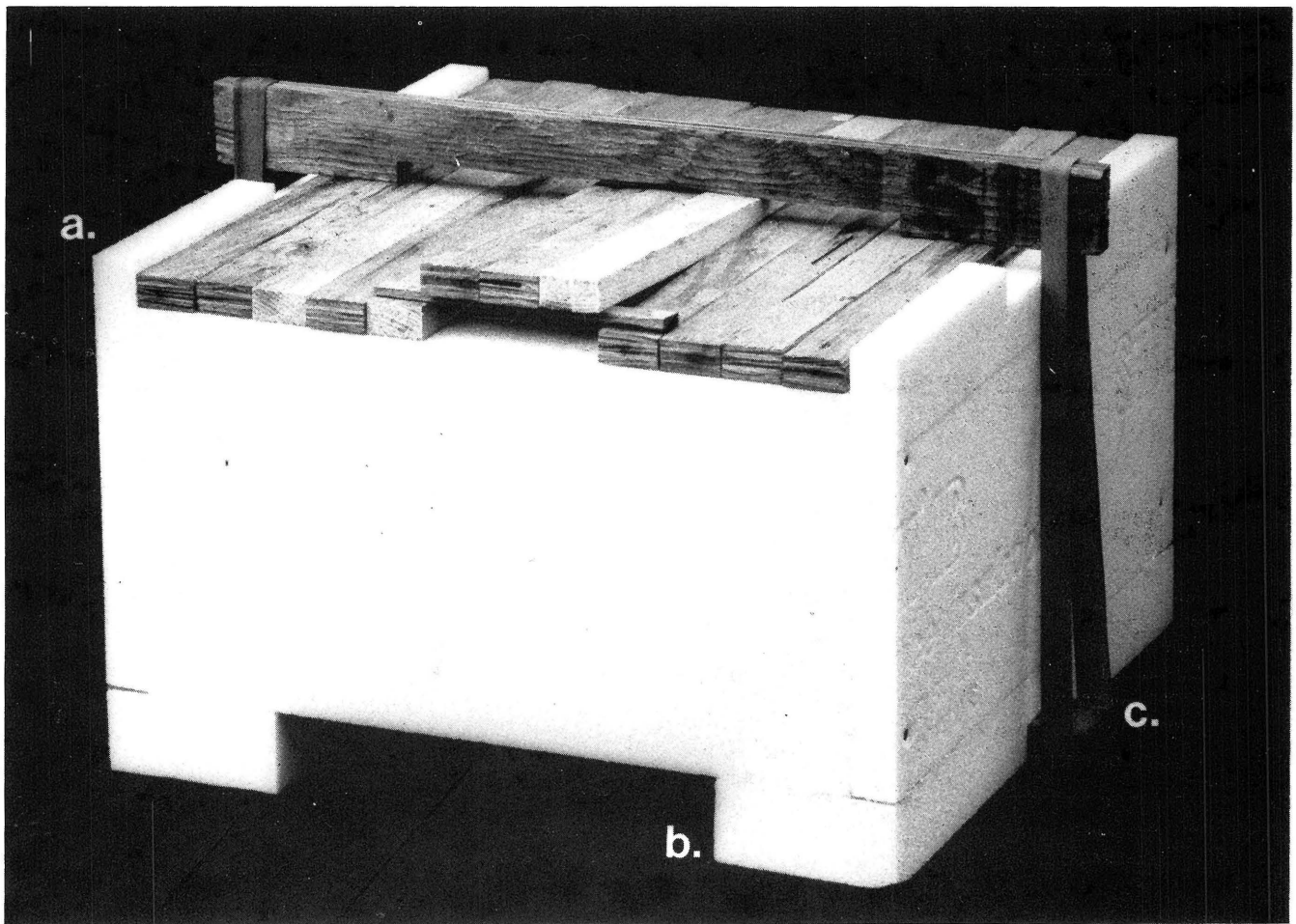
FIG. 1.—A complete polystyrene pollination unit.

Adult bee and brood populations were periodically determined in all colonies at both locations. Adult bee populations were measured by vacuuming bees from the hive and weighing them. While bees were held in vacuum cages, brood populations and honey stores were estimated.

Colonies were allowed to swarm to determine colony requirements for swarming. As expected, swarming occurred but was not excessive. Packages started in Maryland did not swarm during the study.

Expanded Polystyrene Ingestion Studies

Expanded polystyrene units were gnawed extensively by bees. Three 1-year-old queens in foam units became drone layers. Tests were conducted to determine if foam dust ingestion had a detrimental effect on caged honey bee workers.

RESULTS AND DISCUSSION

Overwintered Colonies

Alabama overwinter control colonies averaged 5.9 kg of adult bees and 4320.6 cm² of brood in June. Foam colonies wintered in Alabama had more adults, 3.6 kg,

but less brood than foam colonies wintered in Maryland (2355.5 cm² vs. 2850.9 cm² respectively). Maryland foam colonies averaged 2.68 kg of adult bees in June. Variations in June readings probably represent the ongoing population increase in colonies at the Maryland location. July measurements taken from Maryland foam colonies support this conjecture (3.1 kg bees and 2814.7 cm² of brood). Control colonies wintered in Maryland were the least productive, averaging 2.45 kg of bees and 1996.3 cm² of brood.

Colonies Started from Packages During Spring Months

Colonies were started from packages during March in Alabama and during April in Maryland. Colony measurements were taken in June. Results are shown in Table 1. As expected, Alabama colonies were more developed than Maryland colonies. However, no statistical differences were observed between tested and control colonies for brood and adult bee population means from each location. Maryland foam colonies had bee populations almost identical to control populations. As with Alabama colonies, Maryland colonies had more brood than control units, but differences were not significant (5160.6 cm² and 4989.7 cm², respectively).

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TABLE 1.—Colony Profile of Package Bees Installed in March (Alabama) and April (Maryland).

| | Alabama* | | Maryland† | |
	Foam	Control	Foam	Control
Bees	3.39 kg	3.58 kg	1.14 kg	1.16 kg
Brood	7116.90 cm²	6629.30 cm²	5160.60 cm²	4989.70 cm²
Honey	9.43 kg	13.9 kg	8.75 kg	6.00 kg

*Alabama = colonies started in March from 0.91 kg (3 lb) of adult bees at Dothan, Ala.; evaluated in June.

†Maryland = colonies started in April from 0.91 kg (3 lb) of adult bees at College Park, Md.; evaluated in June.

TABLE 2.—Profile of Tested Colonies which Swarmed from May 23 to June 20.

| | | Foam Means | | |
	Control Means	Overwintered*	Packages†	Combined Foam Means
Adult bees	3.7 kg	3.6 kg	3.4 kg	3.5 kg
Brood	7280.0 cm²	5613.5 cm²	7804.4 cm²	6709.7 cm²
Honey	9.5 kg	13.9 kg	9.4 kg	11.7 kg
Queen cells	7.3	9.7	8.0	8.85
Gross colony weight	37.5 kg	22.4 kg	17.2 kg	19.8 kg
Swarm weight	1.8 kg	1.4 kg	1.8 kg	3.2 kg
Percent of total colonies swarming	20.0%	---	---	26.9%

*Overwintered = colonies overwintered in Alabama and Maryland.

†Packages = colonies started from 0.91 kg of adult bees in Alabama.

TABLE 3.—Mean Numbers of Bees Dying After Being Confined in Ventilated Expanded Polystyrene Boxes for 3-Day Periods.

Box Number	Foam	Control
1	38.98	22.62
2	37.0	36.43
3	34.4	22.83
4	37.46	34.15
5	31.9	24.58
6	33.4	37.7
	$\overline{X}$ = 35.52*	$\overline{X}$ = 29.71

*Not significantly different from control mean at the 5% level (Duncan's multiple range test).

Swarming Studies

Swarming conditions were allowed to develop in foam and control colonies. Data are presented in Table 2. Colonies overwintered or started in Alabama along with colonies overwintered in Maryland were the test groups which approached swarming strength. Colonies started from packages in Maryland did not approach swarming strength. When compared with combined foam means, controls tended to have slightly higher brood and adult populations, but foam colonies had greater honey stores. Gross colony weights obviously were different. Foam colonies averaged 1.85 queen cells more per swarm than did control colonies. In addition to swarming more, foam colonies also absconded four times. No control colonies absconded. Since 16.8 kg was the lower swarming extreme, 16.8 kg was selected as the weight for a mature foam colony. Colonies were routinely kept at this weight for population control, swarm management, and transporting purposes.

Foam Ingestion Studies

A test was conducted to determine if bees could be forced to chew plastic containers by crowding test populations into small foam containers. Comparable bee populations were put into wooden containers. In theory, this plastic ingestion rate would compare to field feeding rates. Results are presented in Table 3. A "t" test analysis of foam (35.5) and control (29.7) means was not significant at P = .05.

Results of an earlier test indicated that high rates of foam dust force-fed to bees reduce longevity. The physiological reason is unknown at this point. However, bees stimulated to chew at approximated field rates did not show a decrease of life spans.

Temperature Observations

Since expanded polystyrene is an insulator material, seasonal measurements were taken to determine temperature differences in control and foam colonies. Ad-

ditionally, measurements were made during colony transportation to observe heat accumulation. Grand means for the entire monitoring season were 17.3° C and 19.5° C for foam and controls respectively. Means were not significantly different. Pearson's r was .957 (highly significant), indicating a high correlation between the two types of colonies as would be expected. Essentially, foam colonies were slightly cooler in the winter and slightly warmer in the summer, but differences were not significant.

Foam hives had to be transported in open trucks behind windbreaks. Temperature observations indicated that enclosed trucks caused foam colonies to become too hot, while open trucks cooled the colonies too much.

Colony Examination
and Manipulation Techniques

Foam hive construction differed from standard equipment. As the foam hive design evolved, several examination and manipulation techniques became useful. On occasions when quick estimations of colony strength were required (*e.g.*, grower evaluation for pollination), hives could be placed on end, thus exposing a view of the interior through the screen bottom. This same procedure was frequently employed during winter months to evaluate cluster strength and colony survival. If smoke was blown into the colony through the bottom, bees would quickly retreat from the area. An evaluation of comb construction or presence of swarm cells could then be made at a glance.

After a frame had been removed, it had to be held in one of two positions: as it was oriented in the hive or vertically. An empty deep hive body was necessary to temporarily hold frames while others were being examined. Overall, frame manipulation was a bit more difficult than standard frame manipulation. If foam colonies were used as intended, however, colony examinations would be performed infrequently.

Diseases and Pests

Periodic terramycin treatments prevented common bacterial diseases. However, other insect pests occasionally caused problems. Wax residue on screened bottoms of foam colonies was attractive to the Greater Wax moth *(Galleria mellonella)*. Wax moth larvae were always present in wax residue and occasionally attacked combs in weak or small colonies. Gallarisis occurred three times in foam units and one time in control colonies. Latent wax moth populations quickly destroyed combs in unoccupied hives.

On two occasions termites tunneled up through polystyrene walls and attacked wooden top bars. Simply moving infested colonies to new locations usually destroyed termite colonies.

CONCLUSIONS

Historically, bee colonies have been housed in wooden hives. Few studies have been conducted to determine the feasibility of housing hives in expanded polystyrene. The concepts tested indicated that foam hives produce comparable bee populations at different locations in the U.S. and that many other natural attributes such as swarming or overwintering are similar to colonies housed in standard equipment. Potential problems exist in areas of temperature control during transportation and constant chewing of foam structures by bees. The ease of management after establishment and the decreased weight of individual colonies, which resulted in easier movement within orchards, are positive features of expanded polystyrene pollination units.

Effects of Gibberellic Acid (GA$_3$) and Daminozide (Alar) on Growth and Fruiting of Himrod Grapes

G. A. CAHOON, M. L. KAPS, and S. P. PATHAK[1]

INTRODUCTION

Research on the effects of gibberellic acid (GA$_3$) on Himrod grapes was conducted as early as 1966 (8). During the period of 1968-80, experimentation was carried on at the Ohio Agricultural Research and Development Center on various cultural aspects of growing Himrod and Concord grapes (2, 3, 4, 6, 7, 9). Among these experiments were the individual, as well as combined, effects of nitrogen and potassium, daminozide (Alar)[2], and GA$_3$ (Pro-Gibb)[3] (9). The material presented here represents several experiments and highlights the response which can be obtained with the use of these two growth regulators.

MATERIALS AND METHODS

Four field experiments were conducted by Pathak in 1970-71 (9). In Experiment I, daminozide at 1,000 ppm was applied as a foliar spray. Unsprayed vines were retained as check plants. A randomized block design was used with four single vine replicates of two treatments for a total of eight vines. Himrod vines, 11 years old, were growing at the OARDC Southern Branch at Ripley.

In Experiment II, GA$_3$ at 100 ppm was applied (approximately 2 weeks post-bloom) at berry shatter to 5-year-old Himrod vines in a commercial vineyard near Cincinnati. Unsprayed vines were left as check plants. A randomized block design was used with four three-vine replicates of two treatments, for a total of 24 vines. X-77 at 0.25% concentration was used as a surfactant.

In Experiment III, the combined effect of daminozide and GA$_3$ applied to Himrod grapes was investigated. Daminozide at 1,000 ppm was applied at early bloom and GA$_3$ at 100 ppm was applied at berry shatter. Unsprayed vines were left as check plants. A randomized split plot design was used, with four three-vine replicates of the two treatments on two different training systems (Geneva double curtain and umbrella kniffin). A total of 48 vines were used. Vines were 6 years of age and located in a commercial vineyard near Cincinnati.

In Experiment IV, daminozide and GA$_3$ were applied in a factorial arrangement with nitrogen and potassium.

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[2]Alar, registered trade name of the Uniroyal Chemical Division of Uniroyal, Inc., Naugatuck, Conn. Alar contains 85% daminozide.

[3]Pro-Gibb, manufactured by Chemical and Agricultural Division of Abbott Laboratories, North Chicago, Ill.

Treatments were:
1. Control
2. Daminozide (Alar)
3. GA$_3$ (Pro-Gibb)
4. Daminozide + GA$_3$
5. Nitrogen
6. Nitrogen + Daminozide
7. Nitrogen + GA$_3$
8. Nitrogen + Daminozide + GA$_3$
9. Potassium
10. Potassium + Daminozide
11. Potassium + GA$_3$
12. Potassium + Daminozide + GA$_3$

A randomized block design was used with three single-vine replicates of 12 treatments for a total of 36 vines. Daminozide at 1,000 ppm and GA$_3$ at 100 ppm were applied at early bloom and berry shatter, respectively. Nitrogen at 1/2 lb actual N per vine and potassium at 1-1/2 lb actual K per vine were applied in a 4-foot strip underneath the vines during late winter. Himrod vines were 6 years of age and growing in a commercial vineyard near Waterford, Ohio.

The following data were collected in the above experiments: the lengths of two tagged shoots on each vine were measured prior to the application of daminozide and at weekly intervals thereafter; the number of leaves per tagged shoot was recorded at each measurement time; 20 mature leaves were selected randomly from each vine and fresh and dry weight measurements were recorded. At harvest, total yield and number of clusters from each vine were recorded. Five primary clusters were randomly selected from each vine; average cluster weight, volume, and size (length and width) were measured. One hundred berries were randomly picked from the five clusters for average berry weight and volume determinations. Ten berries were randomly selected for average berry size (length and width) measurements. The 100 berries were then crushed; the juice was collected and the volume was recorded. Percent soluble solids, titratable acidity, and pH were determined on the juice sample. One-way analysis of variance was run on all of the data.

Field experiments were conducted by Kaps in 1975-76 (7) at three locations in Ohio. Location I was at The Ohio State University research vineyard, Overlook Farm, near Carroll, Ohio. Locations II and III were in two commercial vineyards near Cincinnati. Daminozide and GA$_3$ were applied at early bloom and berry shatter, respectively, to Himrod at all three locations. Treatments were:

Vineyard 1			Vineyard 2			Vineyard 3		
Treatment	Daminozide (ppm)	GA$_3$ (ppm)	Treatment	Daminozide (ppm)	GA$_3$ (ppm)	Treatment	Daminozide (ppm)	GA$_3$ (ppm)
1	0	0	1	0	0	1	0	0
2	500	0	2	500	0	2	250	0
3	500	20	3	500	10	3	250	30
4	500	40	4	500	20	4	250	60
5	500	60	5	500	30	5	250	90
6	500	80	6	500	40	6	500	0
7	500	100	7	500	50	7	500	10
			8	500	60	8	500	20
			9	500	70	9	500	30
			10	500	80	10	500	40
			11	500	90	11	500	50
			12	500	100	12	500	60
						13	500	70
						14	500	80
						15	500	90
						16	500	100
						17	1000	0
						18	1000	30
						19	1000	60
						20	1000	90

A randomized block design was used with five single-vine replicates of the treatments for a total of 195 vines. Each vine was balance pruned to a 30 + 10 pruning formula in the dormant season prior to treatment, and the pruning weights were used in assigning treatments.

At harvest, total yield and number of clusters from each vine were recorded. Average cluster weight was determined from the yield data. Cluster weight and number per bud were determined from yield and pruning data. Two primary clusters were randomly selected from each vine. Cluster weight, length, and width were measured on the sample clusters and the data were averaged. Ten apical berries were randomly picked from sample clusters and their weight, length, and width were recorded and the data averaged. The sample clusters were crushed and the juice collected for analysis. Percent soluble solids, titratable acidity, and pH were determined on the juice sample.

A one-way analysis of variance was run on all data except pruning weight, which was run by least square analysis of variance. Treatment means were plotted against treatment levels and trends were observed.

RESULTS

Response Due to GA$_3$

Although some of the initial experiments with GA$_3$ were in conjunction with Alar, the individual response of GA$_3$ is presented first for clarity.

In Experiment II conducted in 1970-71, Pathak (9) found that the application of 100 ppm GA$_3$ on Himrod fruit increased berry size and thereby increased cluster size and yield (Fig. 1). When applied at berry shatter as a dilute spray, berry and cluster width, weight, and volume were increased. The number of berries per cluster and cluster length were not different from the control vines (Table 1). Shoot length was increased by GA$_3$ treatment. This was due to an increase in internode length, as there was no difference in leaf number between treated and non-treated vines (Fig. 2). It is also worthy of note that there was a significant increase in percentage juice, but not soluble solids or pH. GA-treated berries contained significantly less titratable acidity.

In Experiment IV, the effects of GA$_3$, nitrogen, potassium, and daminozide were investigated. Only the effects of GA$_3$ treatments at N$_1$K$_2$ levels are presented.

GA.100 P.P.M   CONTROL

FIG. 1.—Effects of GA$_3$ (100 ppm) on cluster characteristics of Himrod grapes (9, Expt. II).

TABLE 1.—Effects of GA on Cluster and Berry Characteristics of Himrod Grapes (9, Expt. II).

Treatments	Cluster				Berries per Cluster No.	Berry				Juice %	TSS %	pH	TA %
	Length cm	Width cm	Weight g	Volume ml		Length cm	Width cm	Weight g	Volume ml				
Control	14.25	7.63	110.25	207.50	679.18	1.38	1.31	1.62	1.50	66.40	15.50	3.15	0.57
GA	15.88	10.25	260.13	482.50	814.75	1.88	1.70	3.37	3.14	69.70	15.30	3.26	0.50
LSD (5%)	NS	1.00	95.50	191.03	NS	0.14	0.06	0.26	0.29	3.41	NS	NS	0.04

Measurements of shoot length and leaf number indicated that GA_3 at 100 ppm, applied at berry shatter, significantly increased both (Fig. 3). As shown by Fig. 4, yield per vine was increased from 2.7 to 4.6 kg per vine. This was the result of a much greater cluster weight, 93 g compared to 216 g. In terms of pounds, this was an increase from less than 1/5 lb to more than 1/2 lb per cluster. Increased cluster width and length both contributed to this difference. At the individual berry level, weight, length, and width were all significantly increased. Berry number per cluster was not significantly different from non-treated clusters.

Response Due to Daminozide and GA_3

Since the application of daminozide offers an additional dimension to the benefits derived from GA_3 alone, it is important that some of the known interrelationships be presented.

In Experiment IV, Pathak (9) observed that daminozide applied to mature Himrod vines at early bloom increased size and density of the cluster by increasing number of berries set and also the berry size (Figs. 5 and 6). Berry size increase of this magnitude is seldom observed on seeded grapes in the Eastern U.S. GA_3
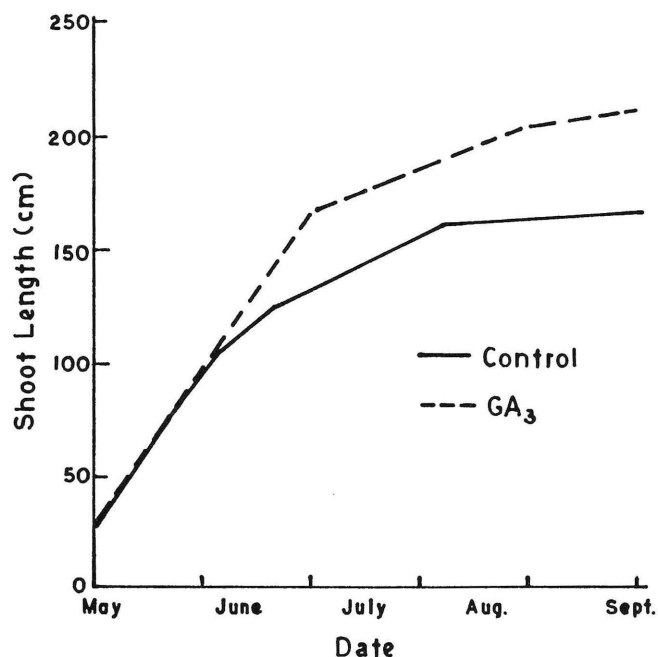
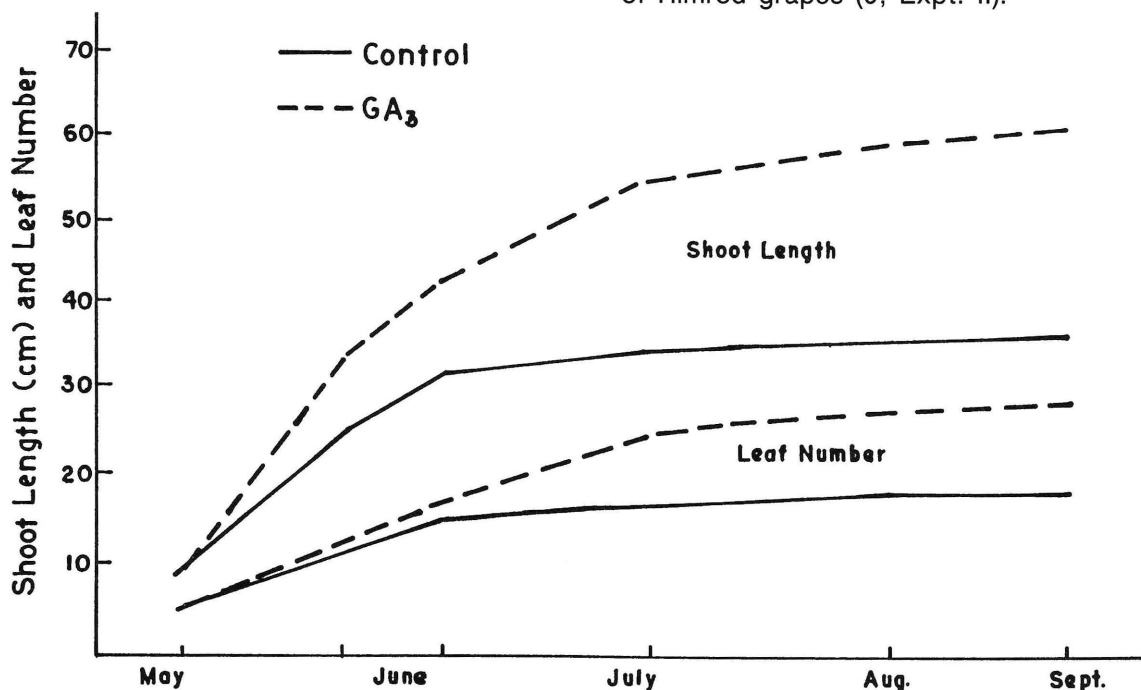FIG. 2.—Effects of GA_3 (100 ppm) on shoot length of Himrod grapes (9, Expt. II).

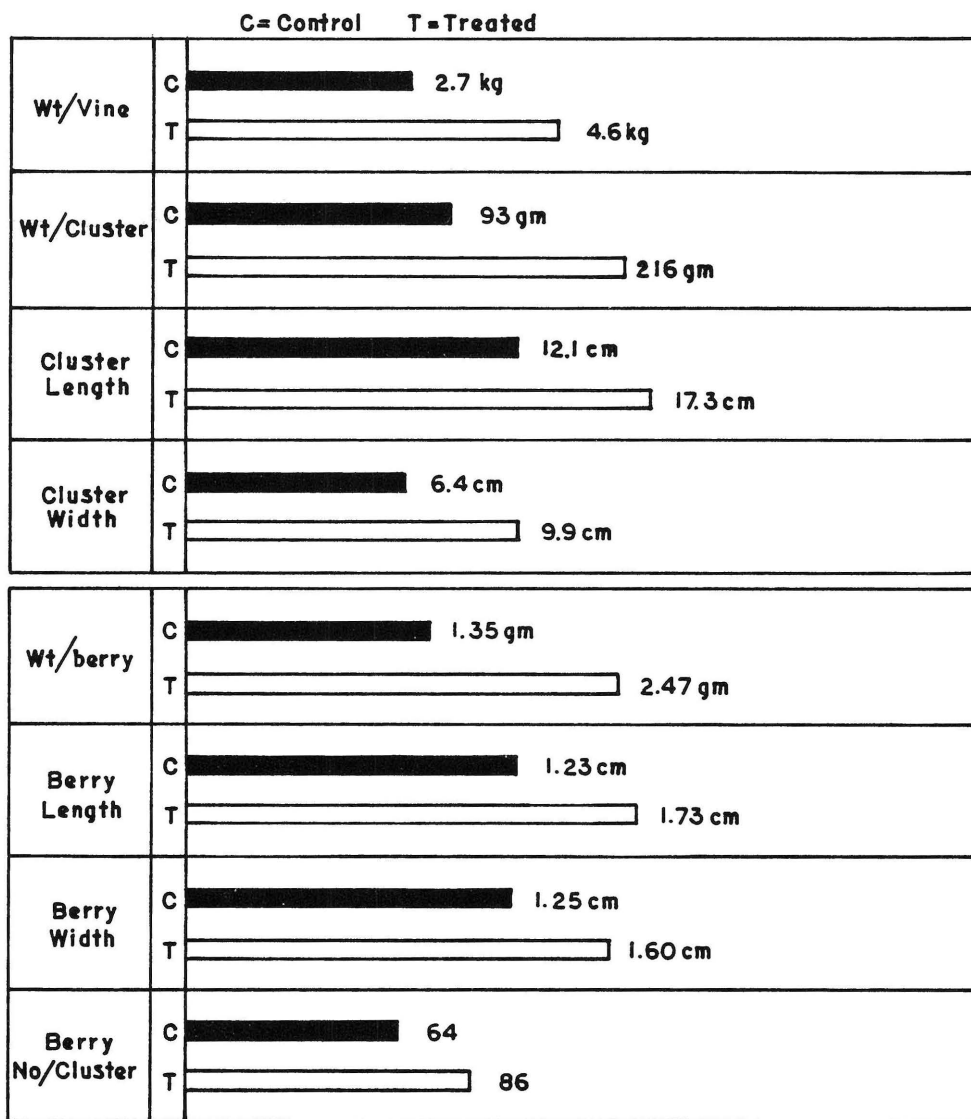FIG. 3.—Effects of GA_3 (100 ppm) on shoot length and leaf number of Himrod grapes (9, Expt. IV).

C= Control   T = Treated

Wt/Vine	C	2.7 kg
	T	4.6 kg
Wt/Cluster	C	93 gm
	T	216 gm
Cluster Length	C	12.1 cm
	T	17.3 cm
Cluster Width	C	6.4 cm
	T	9.9 cm
Wt/berry	C	1.35 gm
	T	2.47 gm
Berry Length	C	1.23 cm
	T	1.73 cm
Berry Width	C	1.25 cm
	T	1.60 cm
Berry No/Cluster	C	64
	T	86

FIG. 4.—Effects of GA₃ (100 ppm) on yield, cluster and berry size, and berry number of Himrod grapes (9, Expt. IV).
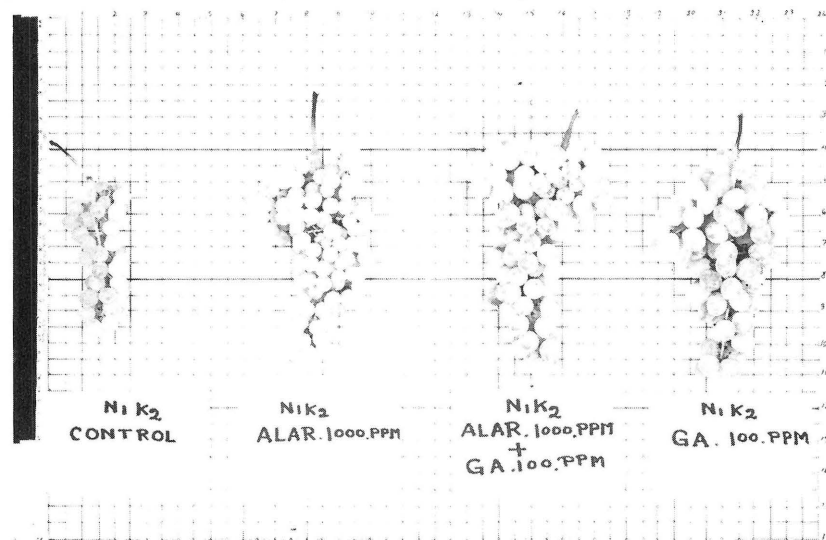
FIG. 5.—Effects of growth regulators daminozide (1,000 ppm) and GA₃ (100 ppm) on Himrod grape clusters (9, Expt. IV).

TREATMENTS :-

N₁ K₂ - CONTROL .

N₁ K₂ - ALAR 1000 P.P.M.

N₁ K₂ - GA 100 P.P.M.

N₁ K₂ - ALAR+GA .
            1000PPM 100 PPM.

FIG. 6.—Effects of growth regulators daminozide (1,000 ppm) and GA₃ (100 ppm) on Himrod berry size and shape (9, Expt. IV).
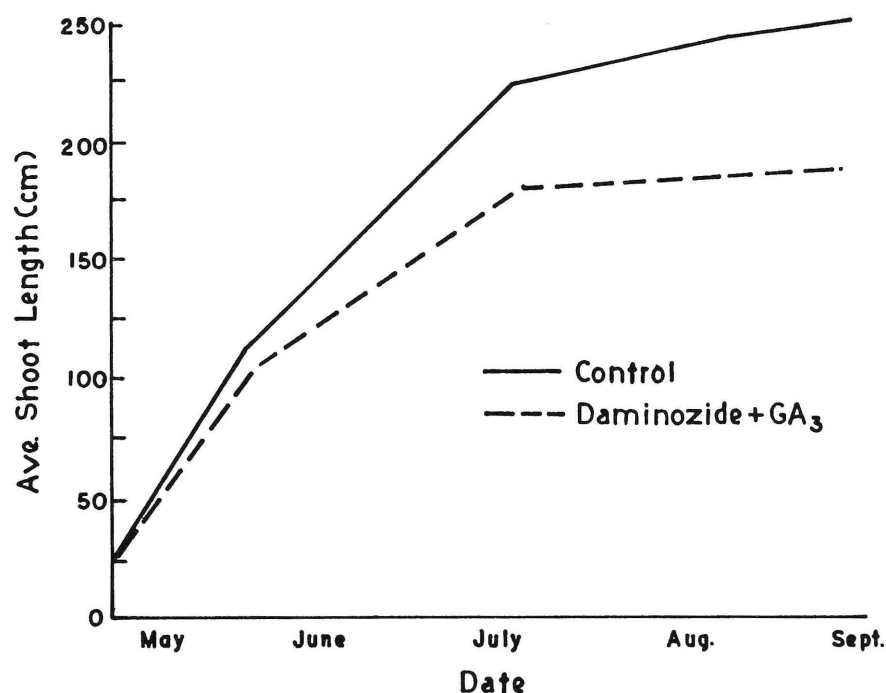
FIG. 7.—Effects of daminozide (1,000 ppm) and GA₃ (100 ppm) on shoot length of Himrod grapes (9, Expt. III).

applied at berry shatter stage increased the size of the cluster by increasing berry size. An increase in berry set due to GA₃ applied at shatter was somewhat doubtful. Daminozide and GA₃ both applied at the previously mentioned stages will result in larger berries and clusters than either applied alone (Fig. 5). It has been further verified that GA-treated berries will be more oval in shape than those treated with daminozide (Fig. 6).

In Experiment III, conducted under field conditions in a commercial vineyard, the application of 1,000 ppm daminozide at early bloom and 100 ppm GA₃ at berry shatter produced a decrease in overall shoot length (Fig. 7). However, when average number of leaves was com-

pared, there was no difference between the daminozide + GA₃ treated shoots and the control (Fig. 8).

Observations on fruiting characteristics showed that cluster length in this case was not significantly influenced by daminozide + GA₃ treatment. However, cluster weight, width, and number of berries per cluster were greater (Fig. 9). These increases occurred under both training systems (umbrella kniffin and Geneva double curtain). Growth of individual berries, as measured by weight, length, and width, was found to be greater in daminozide + GA 3-treated vines, irrespective of the training system (Fig. 9). The percentage juice content of berries, pH, and percentage titratable acidity
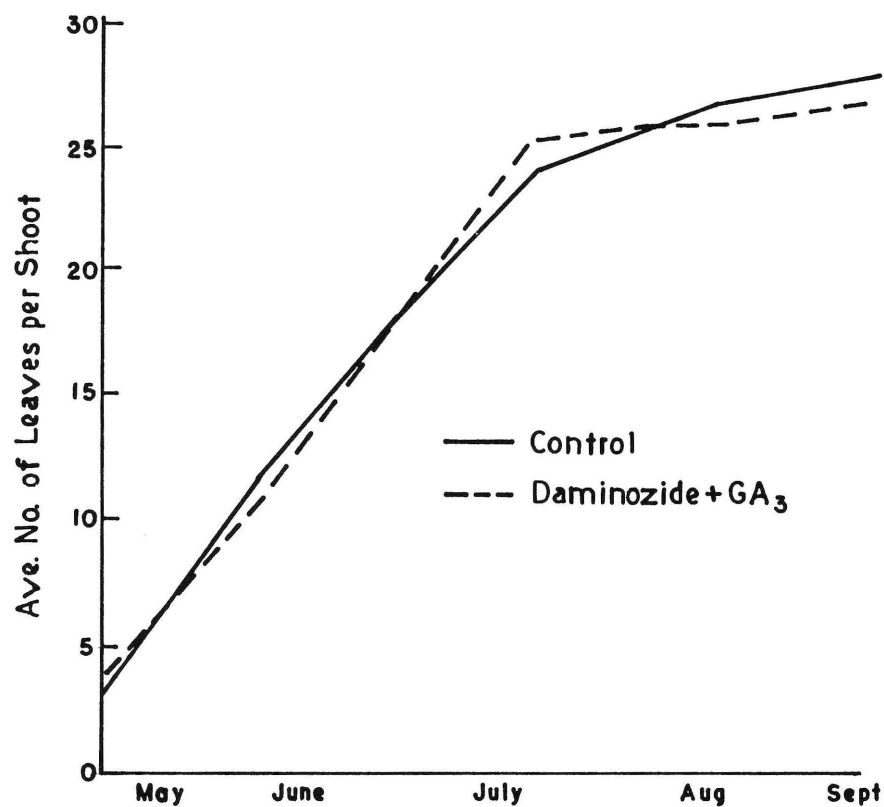
34

FIG. 8.—Effects of daminozide (1,000 ppm) and GA₃ (100 ppm) on number of leaves on Himrod grapes (9, Expt. III).
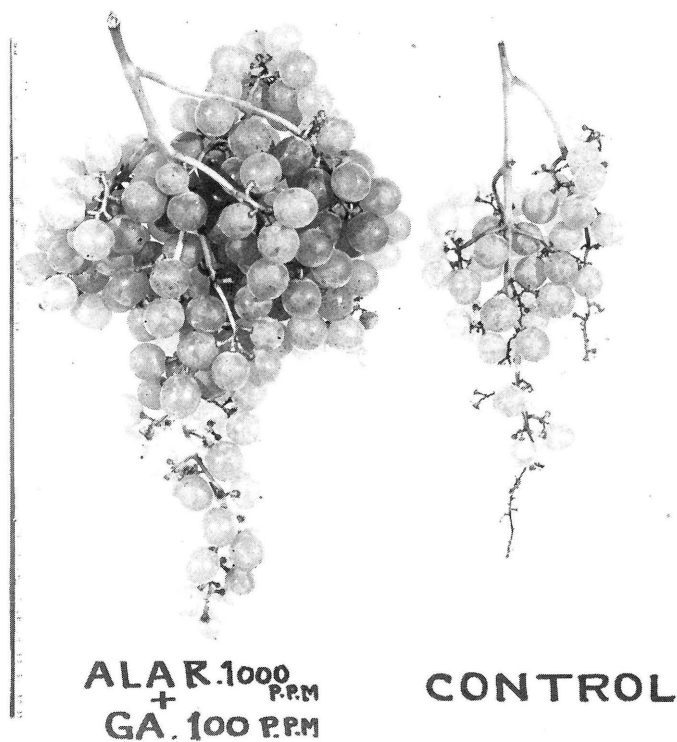

FIG. 10.—Effects of daminozide (1,000 ppm) and GA₃ (100 ppm) on cluster characteristics of Himrod grapes (9, Expt. III).
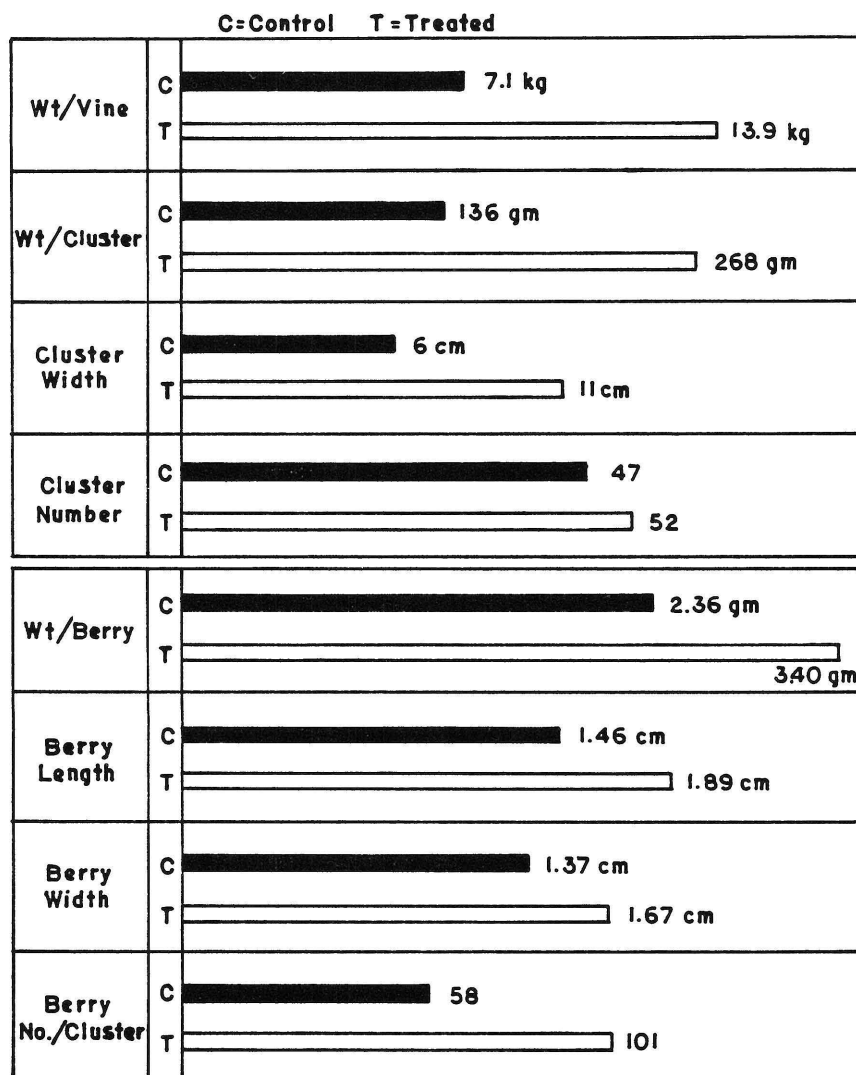
C=Control   T=Treated

Wt/Vine	C	7.1 kg
	T	13.9 kg
Wt/Cluster	C	136 gm
	T	268 gm
Cluster Width	C	6 cm
	T	11 cm
Cluster Number	C	47
	T	52
Wt/Berry	C	2.36 gm
	T	340 gm
Berry Length	C	1.46 cm
	T	1.89 cm
Berry Width	C	1.37 cm
	T	1.67 cm
Berry No./Cluster	C	58
	T	101

FIG. 9.—Effects of daminozide (1,000 ppm) and GA₃ (100 ppm) on yield, cluster and berry size, and number of Himrod grapes (9, Expt. III).

were not influenced to a significant extent in treated vines under either training system. Percent soluble solids decreased, however, following the application of daminozide + GA$_3$ to vines under both training systems. This is understandable, since yield (measured both as weight per vine and weight per cluster) was approximately twice that of the untreated vines (Fig. 9). Figure 10 illustrates these cluster differences.

Gibberellic Acid Concentration Experiments

Having established from the data presented that gibberellic acid (GA$_3$) does have the capacity to increase yield of Himrod grapes in commercial vineyards, research was initiated in 1975 to determine the concentration which would produce optimum vine response. It appears that the best time of application (berry shatter) has been well identified through previous research (1, 3, 5) and verified through the data just presented.

However, the concentrations used for Himrod and other Eastern cultivars (100 ppm) appears to be greater than for other cultivars, mostly those of *Vitis vinifera*.

In experiments conducted by Kaps in 1975-76 (7), GA$_3$ was applied at concentrations between 0 and 100 ppm in three commercial Himrod vineyards in central and southern Ohio. Since the previous work had shown a very beneficial effect of daminozide on fruit set, grapes of the experiments reported here had a basic rate of 500 ppm daminozide applied at early bloom to all treatments (except control) and varying rates of GA$_3$ applied at berry shatter.

As shown by Fig. 11, individual vineyards and vines within a vineyard varied considerably in their response to GA$_3$. However, it is important to note that in two of the three vineyards, the 70-100 ppm concentration produced the greatest yield per vine. In the third vineyard, the 100 ppm treatment produced the highest yields.
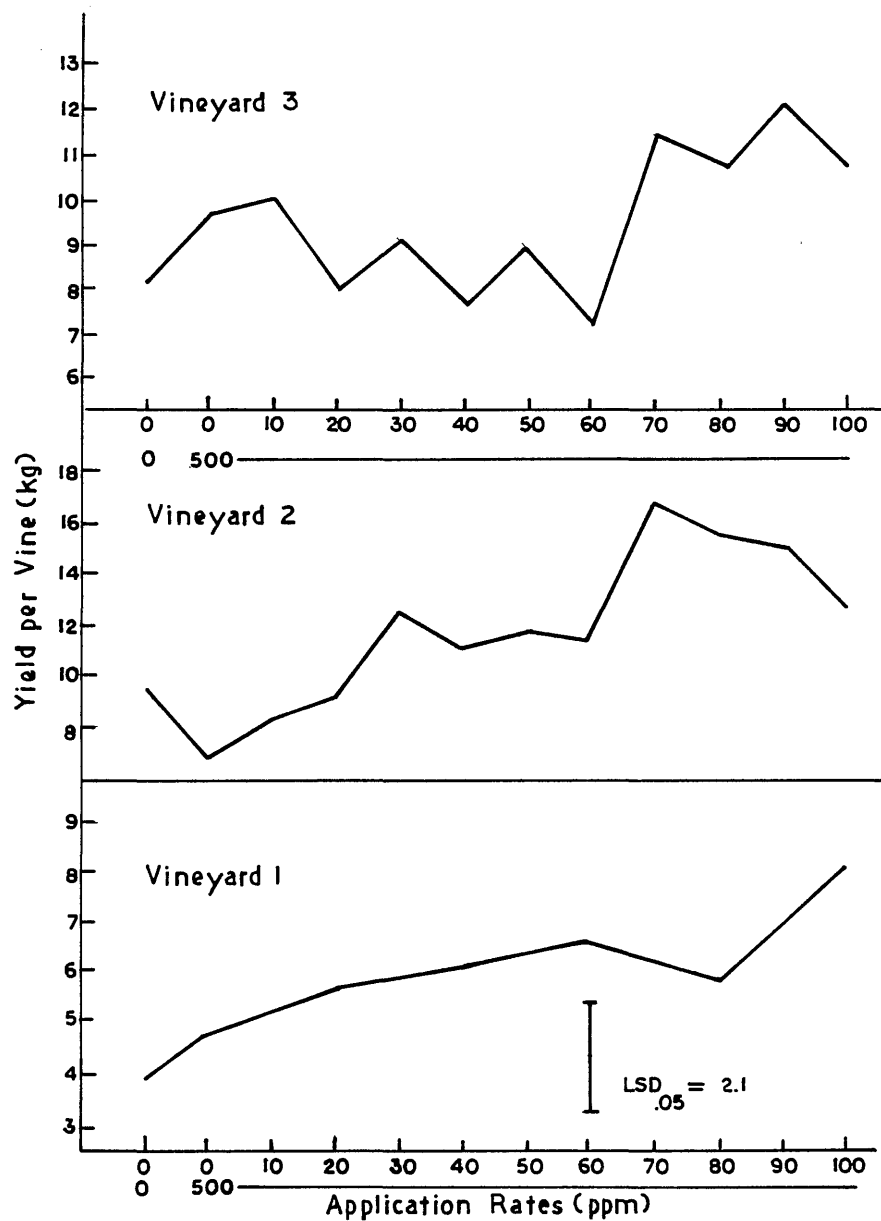
36

FIG. 11.—Total weight of Himrod grape clusters harvested per vine following treatment with varying rates of daminozide and GA₃ (7).
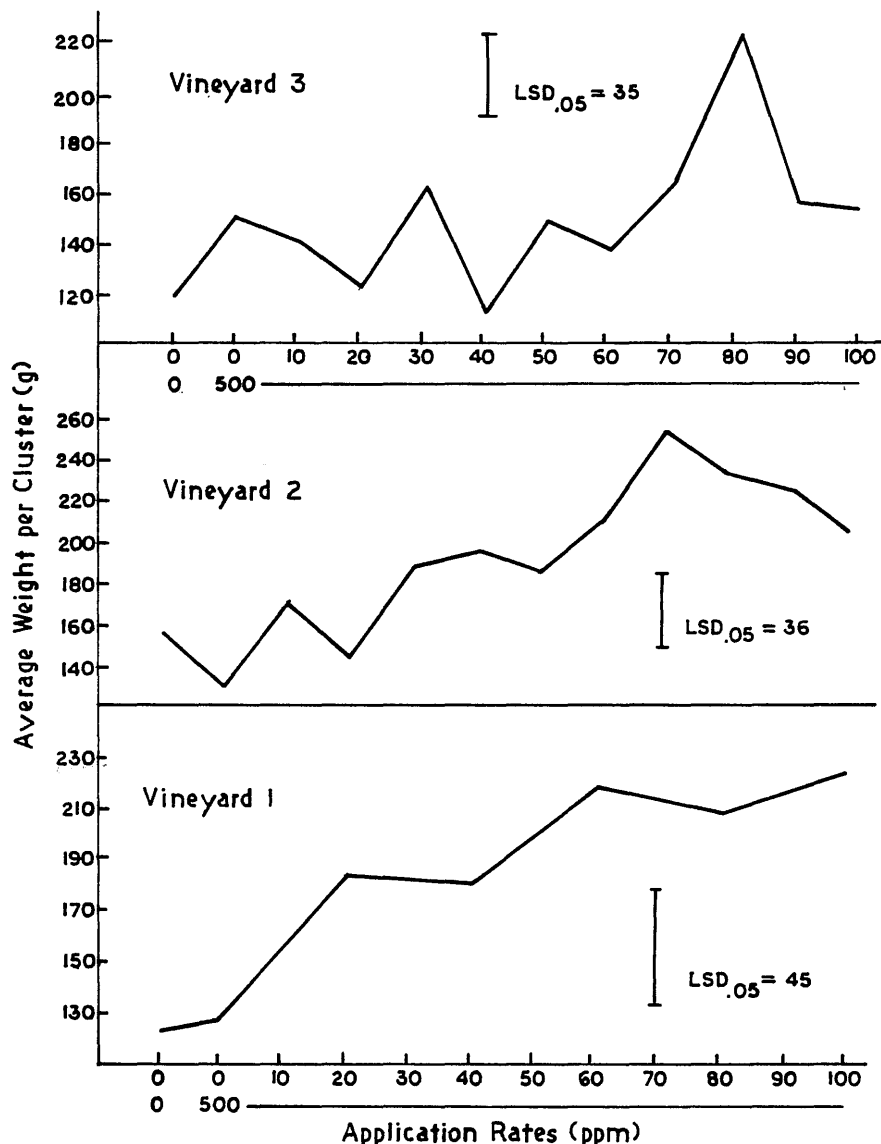
FIG. 12.—Average weight of Himrod grape clusters following treatment with varying rates of daminozide and GA_3 (7).

When the origin of this increase in yield is examined in these three vineyards (Fig. 12), it can be seen that an increase in the average weight per cluster was the primary correlating factor. Again, there is a strong i·dication that 70-100 ppm concentrations were best. ·igures 13 and 14 are averages of the three vineyards ·or yield per vine and weight per cluster. Although a liberal amount of license has been taken with these illustrations, the authors believe that they realistically represent the *type of response* which can be expected from daminozide and GA_3 under uniform conditions.

Data taken at location 3 (Fig. 15) shows that a complicating factor in interpreting the response to GA_3 is the reciprocal relationship which frequently exists between berry weight and berry number per cluster. For example, as berry number per cluster increases, the average berry weight decreases. This is a phenomenon which is very strongly present in studies of this type. Thus, although it must be concluded that GA_3 applied at shatter affected berry set very little, the variability among clusters and between vines was sufficiently great to affect the response of GA_3 on berry weight or berry size.

In 1975 (3), GA_3 treatments were applied at shatter at concentrations of 0, 50, 75, and 100 ppm. As shown in Fig. 16, these data are not characteristically different from those previously presented. However, it can be observed that cluster number again had a significant effect on the yield of the vines in the 75 ppm treatment. Thus, although cluster weight continued to increase between 75 and 100 ppm, the difference in cluster number significantly reduced overall yield between these two application rates. Perhaps the cluster weight relationship in this figure is the most important value to consider.
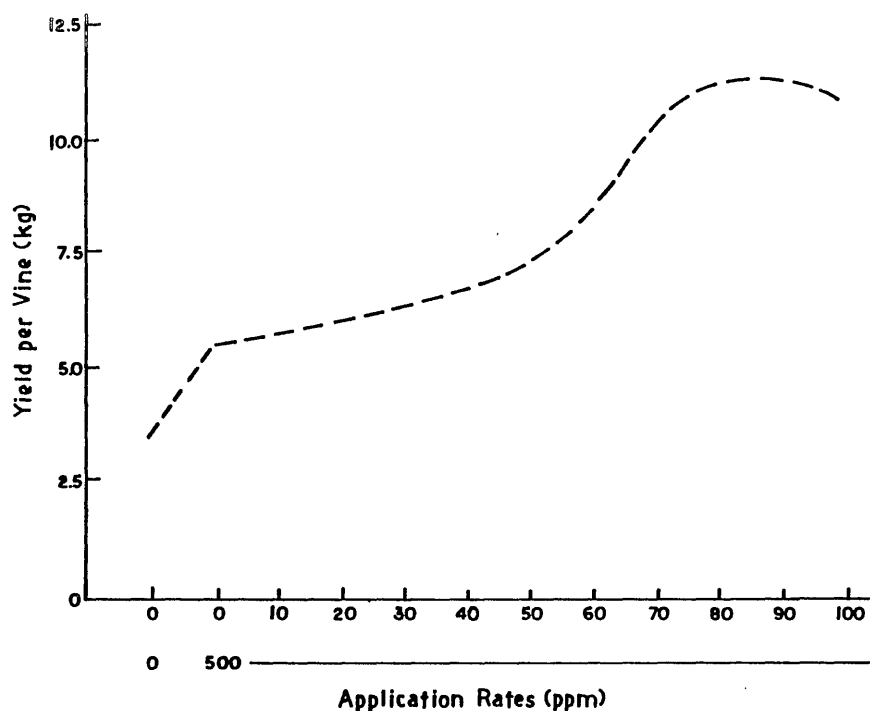
38

FIG. 13.—A theoretical daminozide-GA$_3$ yield response curve obtained by approximating data from three Ohio Himrod vineyards (7).
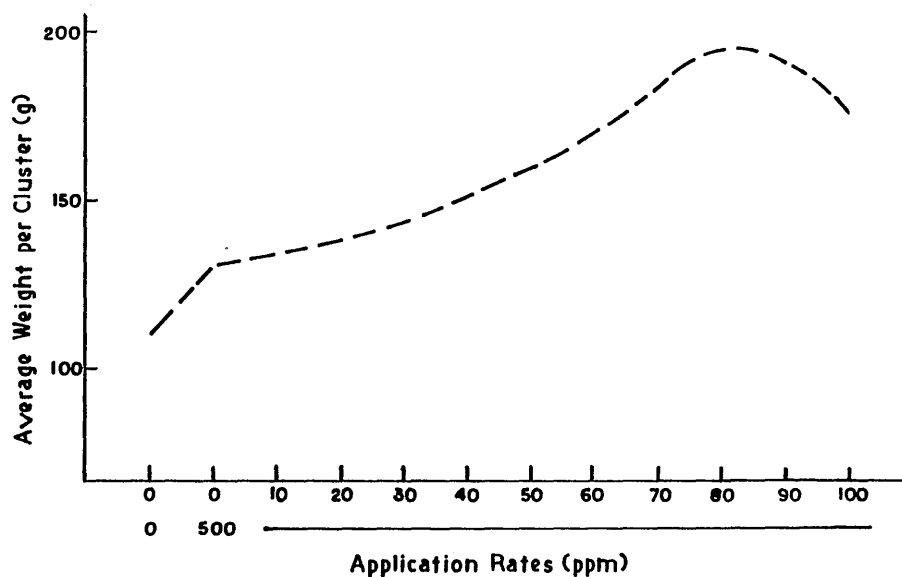

FIG. 14.—A theoretical daminozide-GA$_3$ cluster weight response obtained by approximating data from three Ohio Himrod vineyards (7).
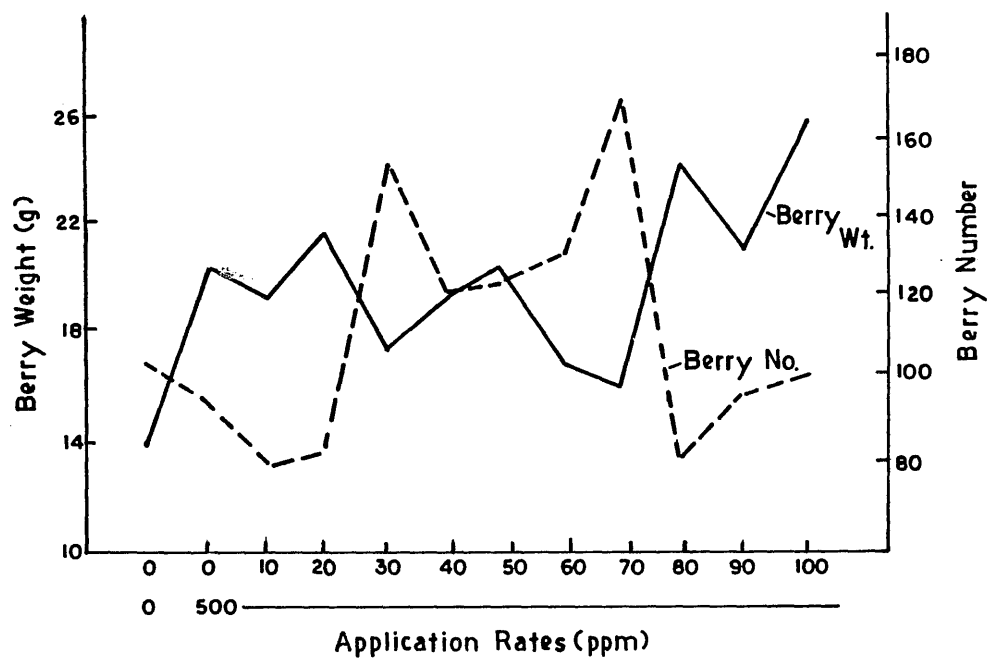
FIG. 15.—Relationship between berry weight and berry number in a Himrod vineyard treated with 0-500 ppm daminozide and 0-100 ppm GA₃ (7).
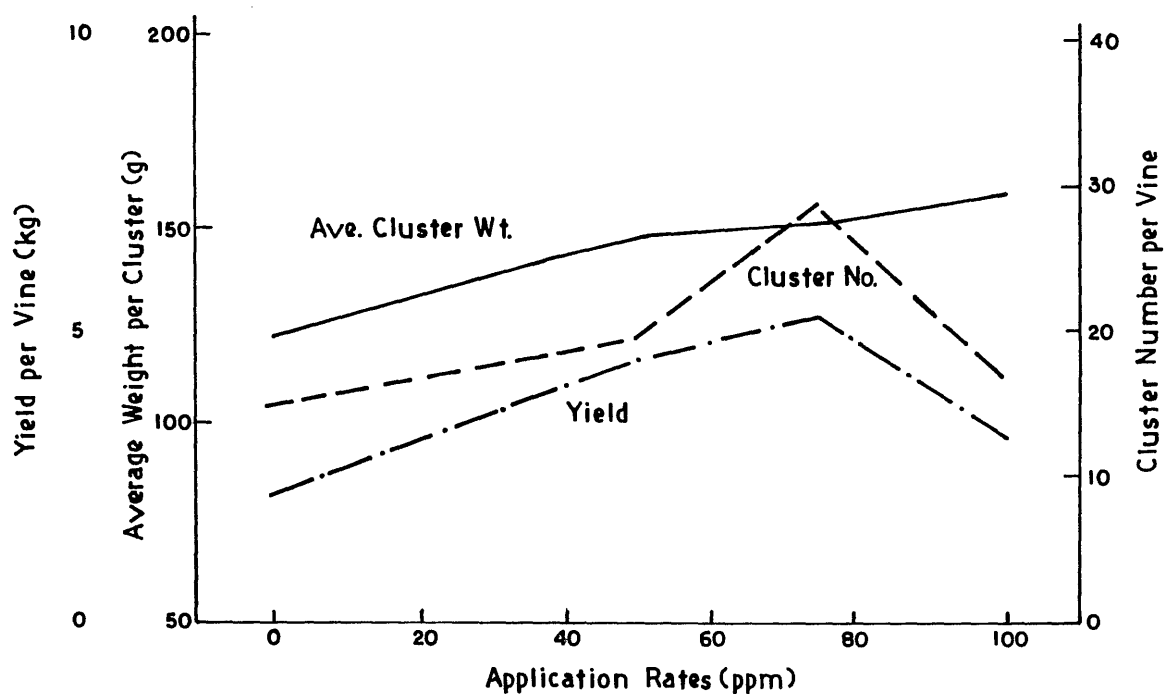

FIG. 16.—Effects of 0, 50, 75, and 100 ppm GA₃ on yield, cluster weight and number when applied to Himrod. grape vines (3).

SUMMARY AND CONCLUSIONS

It seems apparent from the data presented that the grape cultivar Himrod responds very favorably to applications of daminozide and gibberellic acid (GA_3). It is further apparent that the concentration levels for the most beneficial fruiting effect is between 70-100 ppm. There is some question as to whether the 100 ppm concentration is necessary in order to get maximum yield response from this cultivar. However, the studies referred to in the first part of this article appear to be quite valid in terms of a realistic, as well as a desirable, response to the growth regulator gibberellic acid. Application rates of daminozide for Concord have been established (4) and appear to be adequate for Himrod, although only a limited investigation on concentration was conducted here.

As far as future recommendations are concerned, it would appear that GA_3 application rates of at least 70 ppm and as high as 100 ppm should be used. It also appears logical from the data presented that concentrations beyond 100 ppm would offer little or no real advantage in terms of increased productivity, berry size, cluster size, etc. Depending on vine vigor, application rates of daminozide should be between 500 and 1000 ppm or 1 to 2 lb/acre.

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Development of an Action Threshold for Meadow Spittlebug on Strawberries

MARK A. ZAJAC and FRANKLIN R. HALL[1]

INTRODUCTION

The meadow spittlebug, *Philaenus spumarius* (L.), is a serious pest of strawberries throughout North America and Northern Europe (4, 6). A survey conducted by the Ohio Agricultural Research and Development Center in 1978 showed the insect to be the most frequently encountered insect pest of strawberries in the state of Ohio (2). Although the spittlebug has long been considered an aesthetic problem in "pick-your-own" strawberry operations, seldom has it been viewed as a serious economic pest; however, there is ever increasing evidence that nymphal feeding results in significant strawberry yield loss (1, 3, 5, 7).

Schuh and Zeller (5) reported that spittlebugs reduced the yield of strawberries in Oregon by 1 ton/acre. Losses of 30% of the fruit have been attributed to the insect in Canada (1). Halkka *et al.* (3) observed that 24 days of feeding by a single nymph resulted in a 34% reduction in strawberry weight yield per plant. In a 2-year field study conducted by Zajac and Wilson (7) on the cultivar "Redchief", strawberry yield was found to be negatively correlated with nymphal population density. Regression estimates suggested a loss in weight yield of approximately 0.2% per spittlebug nymph/ft².

A field study was initiated in 1984 to determine the correlation between nymphal spittlebug population density and yield of two strawberry cultivars, "Earlyglow" and "Allstar". Data collected were pooled with those obtained by Zajac and Wilson (7) for use in establishing an action threshold for pest management decision making.

MATERIALS AND METHODS

The experimental area consisted of a 2-year old strawberry planting located at the OARDC in Wooster. The field consisted of four rows each of the cultivars "Ear-

lyglow" and "Allstar" which were established in the spring of 1983, using the matted row system of planting. Crown densities at the initiation of this study were 20/ft² which was considered a full stand.

The study was initiated in late August 1984 when ovipositing spittlebug adults became active in the field. Wooden frame cages, covered with 18 by 16 mesh aluminum screening and measuring 3 x 6 x 2 ft, delineated 14 plots in each variety. Seven cages in each variety were infested with 125 adult spittlebugs collected from a nearby clover field; the remainder of the cages were left uninfested. Cages were removed in late November after the adults had died, and the plants were mulched with wheat straw. Mulch was removed in mid-spring when the plants broke dormancy. A sprinkler irrigation system was established to prevent frost damage and to supplement rainfall, and optimum crop management practices were employed throughout the duration of the study.

Nymphal population counts in a square foot area were collected in each plot just prior to adult emergence (May 25, 1985). These counts were used as an estimate of the spittlebug population density. Strawberry yield data were collected in each plot at 1 to 3-day intervals throughout the harvest season. Yield variables measured included the number of berries and total berry weight; from these data, the mean weight per berry was derived.

RESULTS AND DISCUSSION

Spittlebug infestation resulted in a significant reduction in strawberry weight yield, berry numbers, and mean weight per berry in the "Earlyglow" variety (Table 1). However, although nymphal population densities were found to be significantly higher in "Allstar" plots,

[1] Graduate Research Associate and Professor, respectively, Dept. of Entomology.

TABLE 1.—Comparison of Meadow Spittlebug Adult Infestation Densities* with Nymphal Densities and Yield Data of Two Strawberry Cultivars, Wooster, 1985.

Cultivar	Spittlebug Adults/ft²	Spittlebug Nymphs/ft²	Berry wt. (lb/A)	No. of Berries per Acre (x10⁻⁴)	Mean wt/Berry (g)
Earlyglow	0	5a†	26,927a	435a	6.20a
Earlyglow	5.6	158b	17,368b	344b	4.98d
Allstar	0	8a	29,355a	361a	8.11a
Allstar	5.6	212c	25,978a	378a	6.92b

* Adult populations refer to density at time of infestation the previous fall.

† Mean in each column followed by a letter in common are not significantly different (p<0.05), Duncan's new multiple range test.

TABLE 2.—Comparison of Meadow Spittlebug Adult Infestation Densities* with Nymphal Densities and Yield Data of the Cultivar "Redchief", Lafayette, Indiana.

Spittlebug Adults/ft²	Spittlebug Nymphs/ft²	Berry wt. (lb/A)	No. of Berries per Acre (x10⁻⁴)	Mean wt/Berry (g)
		1981		
0	3a†	14,374a	207	8.7a
1.4	23b	13,914abc	209	8.2b
2.8	43c	13,799bc	213	8.2b
5.6	22b	14,336ab	207	8.8a
8.3	61c	10,852c	176	8.0c
11.1	71c	11,786bc	189	8.0c
		1982		
0	11a	24,740a	486a	7.5a
2.8	92b	22,007ab	420ab	7.5a
4.2	131c	20,188b	401b	7.2b
5.6	121c	15,666c	359b	6.5e
6.9	145c	18,345c	393b	6.6d
8.3	136c	17,721c	370b	6.9c

* Adult populations refer to density at time of infestation the previous fall.

† Means in each column (within each year) followed by a letter in common are not significantly different (P<0.05), Duncan's new multiple range test.
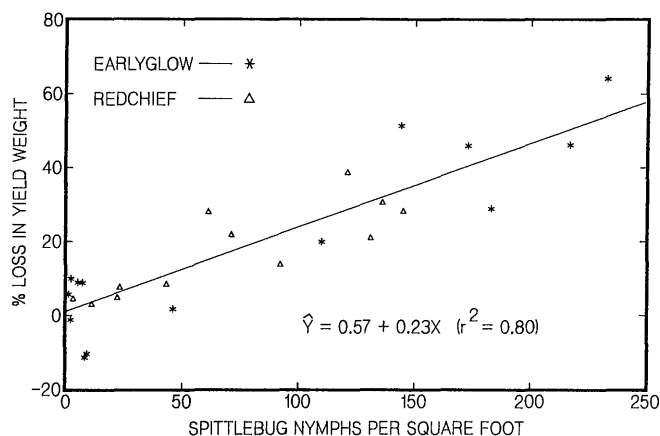

FIG. 1.—The relationship between percentage loss in strawberry weight of two cultivars ("Earlyglow" and "Redchief") and meadow spittlebug nymphal population densities.

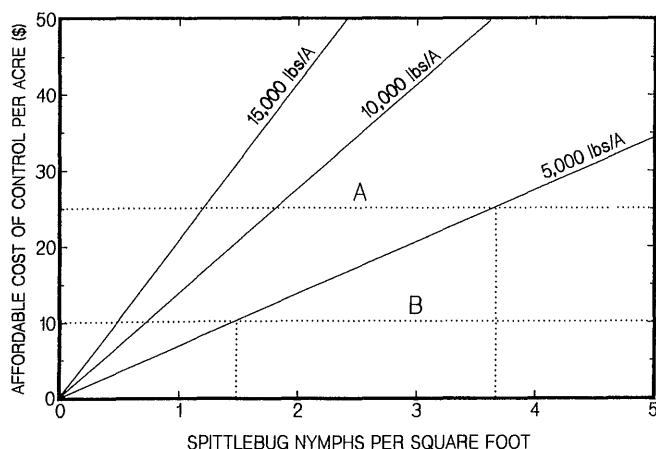$\hat{Y} = 0.57 + 0.23X$ $(r^2 = 0.80)$

FIG. 2.—Decision-making chart for meadow spittlebug control on strawberries.

infestation of this cultivar resulted in a substantial reduction in mean weight per berry only. Spittlebug treatments elicited a 36% reduction in yield weight in "Earlyglow" as compared to a 12% decrease in "Allstar". Initially, this threefold difference in spittlebug induced yield loss between cultivars was attributed to ripening season differences ("Earlyglow" being an early bearing variety whereas "Allstar" is a mid-season bearer). However, results obtained by Zajac and Wilson (7) on the midseason variety "Redchief" (Table 2) are in agreement with "Earlyglow" data. This finding suggests that "Allstar" may indeed exhibit some form of tolerance or resistance to spittlebug feeding.

Regression analysis showed a strong correlation ($r^2 = 0.83$) between strawberry weight yield and nymphal spittlebug population density in the variety "Earlyglow". Yield data were therefore transformed to a percentage loss using the regression function intercept as a base value for the conversion; this was done to allow a comparison between "Earlyglow" and the "Redchief" data of Zajac and Wilson. Regression lines were fitted for each above mentioned variety by regressing the percentage loss in yield weight on nymphal density. Subsequent tests on regression coefficients showed no significant differences between the two regression lines (P<0.01). Therefore, percentage data for the two varieties were pooled and a reduced model regression function was fitted (Fig. 1). The slope of this equation (0.23) represents an estimate of the percentage loss in strawberry yield weight attributed to one spittlebug nymph/ft².

The action threshold for spittlebug control will depend on several factors including the grower's production level, the cost of control, and the market value of strawberries. The grower can determine the need for control from the decision-making chart in Fig. 2. The chart is based on three grower production levels: 5,000 lb/A which represents approximately the state average,

10,000 lb/A which is considered a fair to good yield, and 15,000 lb/A which may be obtained with optimum crop management. In addition, the chart shows the cost per acre the grower can afford for control at each production level when the value of strawberries is 60 cents/lb.

STEPS IN DECISION MAKING

To use the decision-making chart, first estimate the cost of spittlebug control (chemical + application costs). Draw a horizontal line extending across the chart at the estimated control cost. The insect population density associated with a second line drawn vertically from the point at which the cost of control intersects the estimated production level is the action threshold (the pest population density at which control should be applied).

The cost of control will, of course, vary with the pesticide used, equipment, labor, etc., which will in turn affect the action threshold. For example, a single treatment with endosulfan 50 WP at a rate of 2 lb/A using a boom sprayer would cost approximately $25/A (Fig. 2, line A). The action threshold associated with this control cost at a production level of 5,000 lb/A would be approximately 3.6 nymphs/ft². However, if endosulfan were applied at the same rate but as a tank mix with a scheduled fungicide treatment, the cost of control would drop to $10/A, since application cost would be part of other crop protection costs (Fig. 2, line B). The action threshold would therefore be decreased to 1.5 nymphs/ft².

Once the action threshold has been determined, the grower must obtain an estimate of the actual spittlebug population density in the field. Counts should be made of the number of nymphs in a square foot area in five to ten randomly chosen sites per acre of strawberries. Samples should be collected at 2-week intervals beginning when the plants are in about 10% bloom. The nymphs will be quite small at 10% bloom (about the size of the head of a pin) and orange in color; in subsequent samples they may be as large as 1/4 inch in length and range in color from orange to green. On hot and dry or windy days, the insects will be at the bases of the plants and it will be necessary to spread the plants open and check the crowns and soil surface. On warm and humid or rainy days, the insects and their spittle masses (Fig. 3) may be easily seen on leaves and flower trusses. The insects and not just masses should be counted, since numerous nymphs may share the same mass. When the population estimate exceeds the action threshold, control should be applied at the first opportunity.

It must be kept in mind that the action threshold is continuously changing due to fluctuations in economic factors (*i.e.*, crop yields, production costs, and market prices). These fluctuations make the establishment of *exact* threshold values impossible. Furthermore, the *estimated* thresholds are conservative since they do not take into account "aesthetic" damage, which may be significant in "U-pick" operations. However, the decision-making chart presented in this paper is considered a realistic and practical tool for use in pest management programs.

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FIG. 3.—Aggregation of spittlebug nymphs in single spittle mass on strawberry flower truss.

Long-Term Yield of Selected Blackberry Cultivars and Selections in Southern Ohio

CRAIG K. CHANDLER, DONALD A. CHANDLER, and GREG L. BRENNEMAN[1]

INTRODUCTION

There has been interest in the thornless blackberry (*Rubus* sp.) as a new crop for southern Ohio, but concern about the crop's winter hardiness has limited commercial production to a few small plantings. To assess the potential of thornless and thorny blackberries for southern Ohio, various cultivars and selections have been evaluated at the OARDC Southern Branch, Ripley, since 1967.

MATERIALS AND METHODS

One to five plots of each clone were grown on a silt loam soil. Each plot consisted of four plants spaced 2.5 feet apart in the row with 15 feet between rows. Standard pruning, fertilization, and pest control practices (2) were followed. A stake by each of the thornless plants was used to support fruiting canes. Fruit was picked and weighed twice a week during the harvest season.

RESULTS AND DISCUSSION

In general, the semi-erect, thornless blackberry clones had a higher average yield and ripened over a longer

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period of time than the erect, thorny blackberry clones (Table 1). Of the thornless cultivars, Smoothstem, Hull Thornless, and Dirksen Thornless had relatively high average yields, but yield varied dramatically from year to year (Table 2). For example, Hull yielded more than 19,000 lb/acre in 1981 and less than 200 lb/acre in 1982 and 1984. Such wide fluctuations in yield—due primarily to winter injury to the fruiting canes—make it risky to grow sizable plantings of any of the currently available thornless blackberry cultivars.

A cooperative project between the Ohio Agricultural Research and Development Center and the U. S. Department of Agriculture is currently underway to develop thornless blackberry cultivars which are better adapted to the winters of Ohio and the surrounding region (1).

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TABLE 1.—Average Peak Picking Period, Average Yield, and Coefficient of Variation of Yield for Selected Blackberry Clones Grown at the OARDC Southern Branch, Ripley.

Clone	Plant Type*	Test Period	Av. Peak Picking Period	Av. Yield lb/acre)	Coefficient of Variation†
SIUS 64-21-6	S	1972-84	7/26-8/18	9,145	69
Smoothstem	S	1967-84	8/6-8/27	6,638	70
Hull Thornless	S	1976-84	7/24-8/21	6,563	105
C-62	S	1978-84	7/28-8/24	5,971	71
Dirksen Thornless	S	1972-84	7/23-8/22	5,844	54
C-58	S	1978-84	7/30-8/23	5,153	75
Thornfree	S	1967-84	8/1-8/23	4,776	64
Chester Thornless	S	1982-84	8/3-8/30	3,777	142
Black Satin	S	1976-84	7/30-8/23	3,191	94
C-33	S	1982-84	7/28-8/17	2,522	145
Darrow	E	1972-82	7/9-7/26	2,002	60
Cherokee	E	1973-83	7/9-7/27	1,613	86
C-55	S	1982-84	8/4-8/19	1,225	162
Comanche	E	1972-81	7/12-7/27	1,091	73
Ranger	E	1972-81	7/8-7/24	569	58

* S = semierect, thornless; E = erect, thorny.
† Coefficient of variation = (100) standard deviation/mean.

TABLE 2.—Yields of Selected Blackberry Cultivars Grown at OARDC Southern Branch, Ripley.

Year	Smoothstem	Hull Thornless	Dirksen Thornless	Chester Thornless
1967	2,412*			
1968	510			
1969	13,485			
1970	9,778			
1971	13,867			
1972	2,920		3,613	
1973	10,507		4,963	
1974	10,949		5,111	
1975	11,452		11,562	
1976	6,364	3,733	7,887	
1977	1,638	2,304	6,510	
1978	5,760	3,214	4,988	
1979	4,079	12,993	7,535	
1980	6,897	12,528	8,465	
1981	10,883	19,869	8,144	
1982	102	136	424	395
1983	7,681	4,276	6,397	9,973
1984	248	10	368	964

* lb/acre.

Electronic Information Transfer

R. C. FUNT[1]

The Ohio State University has established itself as a leader in the use of electronics to provide information in biological, economical, and technological decisions. The Information Age is just beginning and this situation is very similar to agriculture when the first tractors were brought onto the farm to replace horses.

Electronics in agriculture can be computers, video players, telephones, sensors, weather stations, and infra-color sorters for apples. Many of these have been used in agricultural research, Extension, and industry for several years. With new technology, some instruments fail while others are refined and adapted into new ones.

Advances in technology started with the transistor in 1947 and then came microelectronics which made computers very powerful. The cost of the transistor has decreased a thousand-fold in 25 years and the speed of computer processing a million-fold. Video, voice, and data communications can be indexed, stored, manipulated, and converted at high speed. Video teleconferences provide full motion visuals by way of microwave, satellite, or fiber optic links to span great distances. Spanning several states can reduce costs.

Timely information can be transmitted, audiences can be interactive, and learning can be reinforced. Taped material can be available anytime. Data bases and electronic mail can allow complex educational material to be used at the pace and need of the client and at the same time support management decisions. While these will be useful, Extension delivery of articles to newspapers via electronic media will continue to grow. Specialized radio stations are serving selected population groups in rural America.

Telephone lines can deliver a wide variety of information to the client's home. Some data collected or processed by the home computer can be fed into software data bases for management decisions. Cellular radio technology allows mobile radio telephone transmission of information to portable computers carried in an Extension agent's or specialist's car.

In 1983, Dr. Mike Ellis at OARDC was one of the first to use electronics in forecasting apple scab and to show a reduction in the number of sprays with new chemicals. These sprays are being compared to standard programs to indicate economic benefits to growers. Now several computer models are available for fire blight, powdery mildew, etc. As this technology and decision-making software interacts, there will be an extensive amount of technology never before known to man.

There are communication problems to be solved before many farmers begin to use electronic instruments, computers, and similar devices. Scientists are working on the fifth and sixth generations of software and programs which allow you to talk to the computer. In Horticulture and Entomology, we are developing record systems together with software to accurately determine production costs. This is just the elementary stage to expert and artificial intelligence systems which will address difficult problems and emulate the reasoning process of specialists on the subject.

The North Central Computer Institute (NCCI) began in 1981 and was funded to accelerate computers and their use in Extension offices. It has established standards on software and hardware evaluations. Support has come from the Kellogg Foundation. This is the same source of funding for the CASH (Computerized Advisory Service for Horticulture) project which was given to Ohio State based on its innovation in electronics and its expertise in applying current technology into practical uses for agriculture.

In Ohio, nearly all county Extension offices have computers and will soon be able to contact OSU specialists by way of a central VAX system. In the near future, each county will also have a video tape player (VHS-video tape recorder) capable of showing new technology by color motion pictures. Satellite dishes may be established to receive live educational programs from OSU at 20 locations within the state. These electronics will bring OSU into your living room and aid farm management for you and your employees. The Cooperative Extension Service, nationwide, will adopt more of the emerging electronic technology to enhance program delivery.

The Extension Service has three functions: information, educational program delivery, and problem solving tasks. Clientele turn to the Extension Service for expertise, knowledge, and skills needed to solve problems arising on their farms, in their homes, and with their families. These three functions may overlap depending upon the type of program provided by specialists and agents.

To assist in maintaining existing programs and learning new programs, the OSU Extension Tree and Small Fruit Task Force established a pilot project to develop expertise in the five major districts in Ohio. Three special agents per district have received training since 1984 on fundamental cultural information. In the near future, as more software is developed, these agents will be trained in many new technologies.

During 1985 and 1986 you will see and hear more from the following persons: East District—Daryl Clark, Dale Bonnett, and Hank Bartholomew; Southwest District—Steve Bartels, Harold Schneider, and Jane Warner; Northeast District—Randy Zondag, Gary Bauer, and Rochelle Franks; South District—Bill Twarogowski, Ed Vollborn, and Joe McClanahan; and Northwest District—Ron Overmyer, Gerald Stanley, and Norm Moll.

A county extension agent in 1990 will probably do the following:

[1]Associate Professor, Dept. of Horticulture.

1) The agent will retrieve voice and text electronic messages received overnight.

2) He may request information from a state specialist. If there is no answer within an hour, the problem will be forwarded to a national extension network.

3) Next, the agent teleconferences with six other agents and summarizes a state report rather than sending materials through the mail.

4) The agent checks the weather forecast which is a result of artificial intelligence for agricultural applications.

5) A freeze alert for certain areas is suggested. A warning message is sent to fruit growers who subscribe to the service.

6) On the road, the agent uses a portable phone to call ahead before the next meeting, but also receives a call from a grower on an insect problem. The message is transferred to the county computer and put into the electronic mail system.

7) A computer controlled video-disk player is programmed to give three or four methods of pruning and the group can replay important factors. It also shows the performance, pack-out, and other data for making marketing choices.

8) A grower group comes by to use a computer program to solve financial management problems. This is used to secure a loan and provide suggested improvements in cash flow.

Electronic information transfer from the field to the computer, from the county agent to the state specialist, from the campus to the client's home, and from national experts will provide video films, data bases, and answers to many farm management questions as these evolve and change. New methods will allow easy use of these tools by nearly everyone. And just as tractors were unusual in the 1920's, by the year 2000 electronic tools will be so commonly used that our children will wonder what we ever did without them.

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A Summary of Research on Synthetic Pyrethroids and Mites in the Apple Orchard Ecosystem

FRANKLIN R. HALL[1]

INTRODUCTION

For the past several decades, organophosphorous insecticides have been used to control major apple pests (*i.e.,* codling moth, *Cydia pomonella* (L.); plum curculio, *Conotrachelus nenuphar* (Herbst); and apple maggot, *Rhagoletis pomonella* (Walsh)) in most fruit-growing areas of North America. Recently, a new group of insecticides, the synthetic pyrethroids, has become available for use in the apple orchard system. An assessment of what's on the market as well as those in research and development shows that several groups of synthetic pyrethroids are now available with various levels of insecticidal activity (Table 1).

Studies by Hall (4) showed seasonal applications of various pyrethroids were generally effective for controlling most major apple pests and were equal to or better than standard fruit insecticides used at 10-20 times AI of the pyrethroids. Although single sprays of the pyrethroids reduced apple aphid populations, these synthetics are less effective than diazinon on these pests and not as effective as fenitrothion and encapsulated parathion (methyl) on woolly apple aphid. In general, pyrethroids gave excellent control of leafminers.

In orchards where synthetic pyrethroids (*i.e.,* fenvalerate and permethrin) are being used, numerous accounts of phytophagous mite outbreaks have been recorded (3, 4, 5, 7). Several explanations have been given for these outbreaks. The usual explanation is that the elimination of predatory mites and insects by the synthetic pyrethroids allows phytophagous mite populations to grow unchecked. This paper summarizes a

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series of investigations on the relative toxicity of selected synthetic pyrethroids to European red mite, *Panonychus ulmi* (Koch) (ERM), and the twospotted spider mite, *Tetranychus urticae*, Koch (TSSM), and the resurgence phenomena of ERM common to many agricultural chemicals, but which had been exacerbated with the advent of the pyrethroids.

TOXICITIES OF SELECTED PYRETHROIDS

Laboratory experiments using the standard slide dip technique (7) were conducted for selected synthetic pyrethroids and an organophosphorous insecticide to establish dosage-mortality data for ERM and TSSM. After treatment, microscope slides containing mites were held under a photoperiod of LD 16:8 at 27° C and 95% RH for 24 hr before evaluation for mortality. Resulting mortality data were subjected to Finney's log-probit analysis. All chemicals tested were more toxic to ERM than to TSSM. The relative effectiveness of the chemicals against ERM based on LC_{50} values was fenvalerate > SD 47443 > flucythrinate > SD 41706 > permethrin (Ambush) > permethrin (Pounce) > phosmet. Relative effectiveness against TSSM based on LC_{50} values was fenvalerate > SD 47443 > permethrin (Ambush) > SD 41706 > fenpropathrin > permethrin (Pounce) > flucythrinate > phosmet.

Although LC_{50} values obtained in the laboratory are excellent for comparing different chemicals, different species, and different populations of the same species, data obtained do not relate well to actual field situations. Toxicity data obtained by keeping a mite immobile, stressed, and in direct contact with an insecticide for

TABLE 1.—Synthetic Pyrethroids in Various Stages of Research and Development.

Common Name	Trade Name	Manufacturer, Developer, or Licensee	Range Rate lb AI/Acre
fenvalerate	Pydrin	Shell	0.1-0.2
permethrin	Ambush	ICI	0.1-0.2
	Pounce	FMC	
cypermethrin	Ammo	FMC	0.025-0.1
	Cymbush	ICI	
flucythrinate	Payoff	American Cyanamid	0.025-0.1
fenpropathrin	Danitol	Chevron	0.2-0.4
fluvalinate	Spur	Zoecon	0.05-0.1
cyfluthrin	Baythroid	Mobay	0.01-0.05
resolved fenvalerate	Asana	Shell	0.025-0.05
bephenthrin	Brigade	FMC	0.04-0.2

24-48 hr, as is the case with the slide dip technique, represents an entirely different situation than does toxicity data obtained from field situations with mobile mites and incomplete spray coverage. Hall (4) found that TSSM females move out of areas of high synthetic pyrethroid residues to areas lower or completely absent of these residues. Because of these factors, synthetic pyrethroids at LC_{50} rates in the field may cause some phytophagous mite mortality, but would probably have far less effect on the overall population than that implied by these values.

Finally, applications of synthetic pyrethroids at current field rates have been shown to be quite toxic to predatory mites and insects (5). This reduction of predators, coupled with an almost negligible effect on phytophagous mites, may permit phytophagous mite populations to develop relatively unchecked, resulting in the outbreaks seen in the field. Reduction of predators does explain some of the mite buildup, but Hoyt *et al.* (5) and Hall and Iftner (unpublished data) have also shown that increasing synthetic pyrethroid rates in the absence of predators also increases the number of phytophagous mites; hence, other factors are involved.

DISPERSAL BEHAVIOR

In order to quantify the dispersal effects of pyrethroids on mites, laboratory studies were conducted using TSSM and sprays of fenvalerate, permethrin, phosmet, and water controls (7, 8). Fifteen female mites were placed on each of 28 lima bean plants (with dicotyledon leaves) and allowed to migrate to cover leaf surfaces. The pesticides and controls were each applied to seven different leaf surface combinations and observations were made of mite dispersal (up to 48 hr after treatment). Distinct differences in dispersal response were found between treatments in response to location of spray application and materials applied. Mites dispersed from treated areas to untreated areas in response to pyrethroids, whereas no dispersal response was shown by mites on surfaces directly sprayed with either phosmet or the water control. Movement was minimal where mites were not on surfaces in direct contact with spray materials. Disruption of feeding and changes in habitat selection beyond that of normal behavior were also noted by mites in response to pyrethroids. Of the two pyrethroids, fenvalerate had the more severe and lasting effect on mite behavior. Consequently, evidence from our laboratory study as well as field data (4, 8) would seem to support the proposed hypothesis of Hall (4) and Penman and Chapman (11) that the dispersal of phytophagous mites, resulting from the use of pyrethroids, is one of the factors involved in mite outbreaks after the use of these materials.

FEEDING BEHAVIOR

The effects of synthetic pyrethroids on the feeding behavior of TSSM were studied using a modified leaf disc technique (7). Four different concentrations of the pyrethroids fenvalerate and permethrin and of the organophosphorous insecticide phosmet were sprayed on Henderson lima bean plants in the laboratory. A water spray was used as a control. Leaf discs were taken from each treatment, including the control, at 2 hr, 1, 2, 4, 7, 11, and 14 days after treatment. One mite was placed on each disc, allowed to acclimatize, and then observed for 1 hr.

Mites on untreated and phosmet-treated discs spent an average 70-90% of the time feeding; mite behavior appeared to be unaffected either by water or phosmet. In contrast, mites often spent only 5-40% of the time feeding on discs treated with fenvalerate or with the higher rates of permethrin. In response to pyrethroid residues, mites exhibited hyperactivity, longer search periods and reduced feeding, reduced oviposition, and a preference for areas with lower residues. It was concluded that these changes in mite behavior may partially explain mite outbreaks in the field on apple trees following treatment with pyrethroids.

FECUNDITY AND
RATE OF DEVELOPMENT

Field studies have revealed that there appears to be a rate-related phenomenon occurring, *i.e.*, as the rates of fenvalerate and permethrin were increased, distinct increases in the number of phytophagous mites, particularly ERM, were recorded (4, 5, 6). This rate-related phenomenon has been noted to occur even in the absence of predators. Field observations also have revealed that there appear to be differences in the rate of development of ERM populations on apple trees treated with pyrethroids vs. those apple trees treated with various organophosphorous insecticides or those trees left untreated (6). In all instances where this difference was noted, mite populations on trees sprayed with the pyrethroids were found to be further advanced developmentally than mite populations on organophosphorous insecticide treated or untreated trees. Because of these two factors, laboratory studies were undertaken to determine the effects of fenvalerate and permethrin on TSSM fecundity and rate of development and how these factors may relate to the mite increases currently being seen in the field.

Permethrin treated lima leaf discs were found to have little or no effect on TSSM fecundity, whereas fenvalerate treated lima leaf discs significantly reduced TSSM fecundity. TSSM reared on permethrin and fenvalerate treated lima plants and then placed on untreated lima leaf discs had a significantly higher fecundity than mites reared on untreated lima plants. Permethrin and fenvalerate treated lima leaf discs also were found to shorten by 1-2 days the developmental period of TSSM taken from similarly treated plants (9).

Those offspring produced early contribute more to the growth rate than those offspring produced later (1). An increase in total fecundity would also cause an increase in mite numbers. In the TSSM fecundity studies, it appears that both these phenomena are taking place. Rate of development of a species is an important variable in influencing the intrinsic rate of increase. Wrensch (12) stated in terms of changes in the intrinsic

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rate of increase, a small change in the development rate can be approximately equal to a 10-fold change in total fertility. A shortening of the life cycle of 1-2 days over a number of generations as was seen in these studies could easily account for another partial or full generation of mites within a season. One extra generation could contribute to significant mite numbers depending upon conditions. A significant increase in the number of females being produced as was seen on fenvalerate-treated discs would also account for increases in mite numbers.

Although tests studying the effects of fenvalerate and permethrin on ERM have not produced increases in fecundity, shorter developmental periods have been demonstrated (6). In all of the ERM rate of development studies, a number of mites on permethrin and/or fenvalerate treated discs showed a 1-3 day shortening of the life cycle when compared to mites reared on untreated discs. This reduction in generation time could explain part of the mite increases seen in the field.

In Ohio, five complete broods of ERM are the normal number plus mites that form partial sixth, seventh, and eighth broods. It is quite possible that eight full broods occur in Ohio, especially if temperatures are near normal (2). In these studies, the average generation time for ERM on untreated discs was 13-16 days. Taking into account the five to eight broods a year and incorporating the 1-3 day shortening of the generation time seen in the author's studies, it is very likely that another partial or full generation of mites is generated within the season on trees sprayed with pyrethroids. The shortening of the life cycle also explains the differences in rate of development seen in the field.

From these studies on lima beans, it is suggested that the mite outbreaks on apple following pyrethroid treatments are also the result of two additional factors: 1) an accelerated developmental period, and 2) an increase in the fecundity of mites, particularly in their early adult life. Combining these two factors with the release of mites from predation by their natural enemies and the higher reproductive potential resulting from dispersal away from treated areas more fully explains the rapid increase in mite numbers seen in the field.

CONCLUSIONS

Clearly, the phenomenon of resurgence of spider mites following repeated applications of insecticides is complex and appears to be more dramatic with the use of the new synthetic pyrethroids. Our studies have shown not only direct toxicity effects on known predators, but a number of interactive phenomena involving direct toxicity to the mite, dispersal, feeding inhibition, as well as effects on fecundity and rate of development. Field populations are not generally studied in the detail necessary to explain how sublethal effects of a pyrethroid may affect the age structure of a population.

Studies are being conducted in this laboratory on: 1) cultivar tolerance to mite feeding, 2) the effects of cultivar quality on maximizing mite populations, and 3) pesticide application parameters including droplet distribution patterns and toxicant dose and formulation effects. The biological effect depends on the toxicolog-

ical properties of the AI, its formulation, and the concentration and pattern of the dose at the point of action. Target coverage and ultimate response of insect and mite pests are frequently not well correlated. This suggests that there is a lack of basic understanding of the dose transfer processes. Consequently, these studies should add to better understanding of the dose transfer process and how it relates to the biological response of a mite population in randomness and behavior. Clearly, these are very dynamic phenomena, and it will take a more intensive study of the physical and physiochemical parameters controlling the toxicant delivery to a site, its perception by a pest, and the varied biological responses of the target pest in order to improve usage of the new, more efficacious, agrochemicals.

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Controlling Apple Collar Rot: Effects of Fungicides, Soil Amendments, and Depth of Planting

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INTRODUCTION

Collar rot of apple is caused by *Phytophthora cactorum* (Leb. & Cohn.) and several other *Phytophthora* spp. Disease incidence is generally greater in heavy and poorly drained soils, which are common in Ohio. Differences in susceptibility of various apple rootstocks have been reported; however, few apple cultivars or commercially used clonal rootstocks are considered highly resistant, and the reports are inconsistent.

The most effective methods for controlling the disease have been the selection and use of resistant rootstocks and the selection of well-drained planting sites which are not conducive to disease development. Fungicide drenches or sprays applied to soil or infected portions of the tree have not provided adequate control. The introduction of fungicides such as metalaxyl (Ridomil 2E), which are systemic as well as highly effective against Pythiacious fungi, may be useful in providing chemical control.

Research at OARDC has shown that the percentage kill of 3-wk-old apple seedlings was significantly lower in a composted hardwood bark container medium than in a peat medium after inoculation with *P. cactorum* zoospores and oospores. In addition, sporangial production and zoospore viability was significantly lower in aqueous leachates from bark compost than in leachates from peat. These results suggest that composted hardwood bark may be useful in biological control of apple collar rot.

For years many apple producers have speculated that burying the graft union on susceptible apple rootstocks is beneficial in controlling collar rot. Nothing was found in the literature to substantiate this belief.

In 1979 the authors initiated a long-term study to evaluate the effects of preventive (preinfection) drenches of metalaxyl and captafol and preplant soil incorporation of composted hardwood bark on collar rot control. In addition, the effect of burying the graft union on rootstock infection by *P. cactorum* was also studied. The results of these studies are summarized in this paper.

MATERIALS AND METHODS

Rootstock and Planting Depth

A field study was established in May 1979 using 1-yr-old nursery whips of Golden Delicious apple trees on Malling-Merton 106 (MM106) rootstock or MM106 rootstock with an East Malling 9 (M9) interstem. The orchard was planted at OARDC Horticulture Unit II,

Wooster, on an old orchard site known to have a previous history of apple collar rot. Trees were planted with 3.0 m between trees and 5.5 m between rows in holes (61 x 61 cm) dug by a mechanical auger. Soil type was Wooster silt loam.

All trees were planted on one of the following roostocks and depths of planting: MM106 with graft union above soil line; MM106 with M9 interstem and lower graft union approximately 8 cm below soil line; and MM106 with M9 interstem and lower graft union above soil line. Hollow cylinders (collars) were cut from 20 cm diameter plastic pipe. One collar (20 cm long) was placed around the base of each tree and embedded 10 cm into the soil. Plastic collars were intended to maintain inoculum and moisture around the base or crown of the tree.

Soil Treatments

Composted hardwood bark (CHB) was obtained from Paygro, Inc., South Charleston, OH 45368. Trees were planted in a 1:1, v:v mixture of bark compost and soil removed from the planting hole (approximately 35 liters of bark). Metalaxyl (Ridomil 2E) and captafol (Difolatan 4F) were evaluated as fungicide drenches at the rate of 500 and 600 g/ml ai, respectively. Fungicides were applied in 1 liter of water inside the collar around the base of each tree. Application dates were: 19 July and 16 September, 1979; 18 April and 12 September, 1980; 15 April and 7 October, 1981; 30 April and 23 September 1982. Fungicides were not applied in 1983.

Inoculation with *P. cactorum*

One-half of all trees were inoculated with oospores of *P. cactorum*. Trees were inoculated by pouring 10 ml of a suspension containing 10,000 oospores/ml of water around the base of the tree, inside the collars. Inoculations were made on 20 July and 15 September, 1979, and 15 April, 1980. During dry periods, collars around all trees were flooded with water to insure high moisture levels around the crown of the tree. Collars were flooded approximately every 2 wk during the 1979 and 1980 growing seasons. Collars were removed from all trees in May 1981.

The development of collar rot symptoms was recorded throughout the growing season annually. At the end of the 1983 growing season, the majority of inoculated, nontreated trees were dead, and the experiment was terminated.

RESULTS AND DISCUSSION

Eighty-one percent of all inoculated, nontreated trees developed typical collar rot symptoms and died prior

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TABLE 1.—Effects of Metalaxyl, Captafol, Composted Hardwood Bark, and Graft Union Planting Depth on Percentage of Trees Killed After Inoculation with *Phytophthora cactorum*.

| Treatment and (Rate) | Rootstock and Graft Union Position* | | | | | |
| | MM106 Graft Union Exposed | | M9 Interstem/MM106 Rootstock Lower Graft Union Buried | | M9 Interstem/MM 106 Rootstock Lower Graft Union Exposed | |
	I†	NI	I	NI	I	NI
Composted hardwood bark (35 liters/tree in planting hole, 1:1 mixture with soil)	25‡	0	17	0	33	8
Metalaxyl (1 liter/tree of 500 ug ai/ml)	0	0	0	0	0	0
Captafol (1 liter/tree of 600 ug ai/ml)	8	0	0	0	0	0
Nontreated	92	8	83	25	67	17

* All trees were cultivar Golden Delicious and were 1-yr-old nursery whips at the initiation of the experiment (1979).

† I = inoculated; trees inoculated three times (on 20 July and 15 September, 1979, and 15 April, 1980) with 10 ml of a 10,000 oospore/ml suspension of *P. cactorum*. NI = noninoculated.

‡ All figures represent the percentage of trees killed by *P. cactorum* from 1980 through 1983 and are based on 12 single tree replications/treatment. Based on a log-linear contingency table model, the experimental factors of soil treatment and inoculation were highly significant ($P<0.01$), whereas rootstock and depth of planting were not ($P>0.50$).

to termination of the experiment (Table 1). Most trees died within the same growing season in which symptoms first appeared. This is not typical of apple collar rot in Ohio. In commercial orchards, trees initially show symptoms of foliar chlorosis and reduced terminal growth, then gradually decline and eventually die within a period of 2-3 yr. The rapid death of trees observed in this study was probably due to high levels of inoculum and wet soil conditions which favored disease development. The numbers of trees which died in 1979, 1980, 1981, 1982, and 1983 were 0, 2, 15, 17, and 12, respectively. Only 17% of all noninoculated, nontreated trees became naturally infected. *P. cactorum* was isolated from 38% of all trees with collar rot symptoms.

Significantly more trees developed symptoms and died in the untreated control than any other treatment. There were no significant differences between soil treatment with captafol and metalaxyl, and both fungicide treatments had significantly fewer infected trees than any other treatment. Soil incorporation of CHB resulted in significantly fewer infected trees than the control but significantly more infected trees than either fungicide treatment (Table 1).

Symptom development was not observed on any tree treated with metalaxyl and only one treated with captafol (inoculated on MM-106 rootstock) became infected. These results suggest that preventive fungicide drenches may be beneficial in controlling apple collar rot. Several reports have indicated that metalaxyl is effective in controlling Phytophthora crown or root rots on avocado, apple, and citrus. Postinfection curative activity of metalaxyl has been reported for *P. cactorum* on apple and *P. cinnamomi* on avocado. The authors' data suggest that metalaxyl may also provide good protectant activity against *P. cactorum* on apple. Captafol lacks systemic activity, and therefore it is unlikely

that it would provide postinfection curative activity. Captafol does appear to have good protectant activity against *P. cactorum* on apple.

Results in this study suggest that if protectant treatments are initiated prior to infection and continued on an annual basis, good control may be obtained. If treatment is initiated after infection has occurred, protectant fungicides will probably be of little value. One factor which could greatly reduce the effectiveness of protectant fungicides for collar rot control is that *Phytophthora* spp. may be introduced into the orchard in or on infected nursery stock.

Results in this study suggest that CHB may be beneficial in suppressing *P. cactorum* in the field. The incorporation of CHB into soil appeared to be effective in controlling collar rot; however, 25% of all inoculated trees in CHB became infected and died. This level of control would not be satisfactory on a commercial scale. However, the degree of control obtained in CHB may have been adversely affected by the high level of inoculum and moisture used in this study. Only one tree died in the noninoculated CHB treatment. The effectiveness of CHB as a biocontrol material for collar rot of apple needs further study.

Results also indicated that burying the graft union on susceptible rootstocks was not beneficial in controlling collar rot. The results from this study suggest that chemical control of apple collar rot can be obtained. The authors feel, however, that fungicide application should not be considered as the primary means of control. The development and use of more resistant rootstocks, combined with the selection of planting sites which are not conducive to disease development, remain the most effective and economical means of control. The use of fungicides, such as captafol and metalaxyl, within a total disease management program involving

resistant rootstocks, proper site selection, and clean nursery stock could aid in obtaining a higher level of disease control.

* * *

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Validation of an Electronic Unit
for Predicting Apple Scab Infection Periods

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INTRODUCTION

In Ohio, control of apple scab, a disease caused by *Ventura inaequalis* (CKe) Wint., is achieved primarily with protectant fungicide sprays. In a protectant program for primary scab control, fungicides are generally applied after every 7 to 10 days of new growth or 1 inch of rain. Applications are made irrespective of whether infection periods have occurred. In wet growing seasons, Ohio growers make up to 15 fungicide applications for scab control.

A curative spray program is an alternative to a protectant program. In a curative program, the fungicide is applied after the initiation of an infection period but before symptom development. Since W. D. Mills and his co-workers at the New York Agricultural Experiment Station published their findings on the environmental parameters necessary for scab infection, we have had the ability to monitor infection periods. Apple scab spray advisory programs have been developed based on Mills' system but aren't widely used by Ohio growers. One reason for poor grower acceptance of scab prediction systems has been the lack of fungicides with dependable curative activity up to 3 or 4 days after the initiation of an infection period. The introduction of the ergosterol biosynthesis inhibiting (EBI) fungicides, which have excellent curative activity, could make scab prediction more attractive because the newer compounds have the ability to control scab after identification of infection periods.

A computer program was developed to use weather monitoring data entered by teletype from remote locations to predict infection periods. However, the system was too costly and infection periods were often identified too late.

The advent of the microcomputer enabled Michigan State University scientists to combine electronic environmental monitoring sensors with a microcomputer designed to provide simple and rapid on-site identification of apple scab infection periods. The unit evolved into the commercial apple scab predictor manufactured and marketed by Reuter-Stokes, Inc., Cleveland, Ohio. The study summarized here was designed to determine the effectiveness of the apple scab predictor for scheduling several EBI fungicides which have post-infection control activity against apple scab. Field trials were conducted in 1982 and 1983 in OARDC research orchards.

MATERIALS AND METHODS

In 1982, all fungicide treatments were applied to four single-tree replicates of 'McIntosh', 'Delicious', and 'Golden Delicious' cultivars on MM 106 rootstock arranged in a randomized complete block design. The 13-year-old trees were spaced 12 feet apart with 28 feet between rows. Soil type was Wooster silt loam. Trees were sprayed to runoff with fungicide in 400 gallons of water per acre with a handgun at a pressure of 450 psi. Apple scab infection periods were determined by the Reuter-Stokes apple scab predictor (ASP) and verified by using a deWit leaf wetness meter and a hygrothermograph in conjunction with the Mills table.

The following EBI fungicides and rates in formulated product per acre were applied 72 and 96 hours after the initiation of predicted infection periods: bitertanol (Baycor 50% WP, 1 lb); fenerimol (Rubigan 1 EC, 12 fluid oz); and etaconazole (Vangard 10% WP, 60 oz).

Upon termination of primary scab infection periods June 20, protectant cover sprays of benomyl (Benlate 50% WP, 1 lb) plus captan (captan 50% WP, 4 lb) were applied to all curative treatments. Baycor at 1 lb and captan at 8 lb were applied in standard full-season protectant programs for comparison.

The 72 and 96 hours after infection treatments were applied on May 10 and 11, May 22 and 23, June 4 and 5, and June 18 and 19, respectively. Curative treatments were not repeated for 7 days even if additional infection periods were predicted. Protectant cover spays were applied to treatments in the curative program on June 30, July 9 and 21, and August 9 and 12. Application dates and growth stages of treatments applied in the standard protectant program were: April 20 (half-inch green); April 28 (tight cluster); May 4 (pink); May 11 (full bloom); May 18 (petal fall); May 25 (first cover); June 2, 15, 22, and 30; July 9 and 21; and August 9 and 26.

Percentage of leaves with primary scab lesions was determined from five cluster leaves per cluster for each of 10 clusters per tree on June 10. Percentage of leaves with secondary scab lesions was determined from all terminal leaves for each of 10 shoots per tree Sept. 7-19. Percent of fruit infected was determined for 100 fruit per tree on Sept. 21 and 23.

The 1983 trial was conducted the same as in 1982 except 'Delicious' cultivar was not included and triforine (Funginex 1.6 EC) was included in the curative program. Captan was also tested in the curative program at 72 hours after the initiation of an infection period and in a standard protectant program. Upon termination of the curative program on June 2, protectant cover sprays of benomyl (1 lb) plus mancozeb (Manzate 200 80% WP, 6 lb) were made to all treatments in the curative program.

The 72 and 96 hours after infection treatments were applied April 9-10; May 1-2, 14-15, 22-23; and June 1-2, respectively. Protectant cover sprays were applied to treatments in the curative program June 13 and 29; July 5, 18, and 28; August 18; and Sept. 6. Application dates and growth stages of treatments applied in the standard protectant program were: April 8 (half-inch green); April 15 (tight cluster); April 25 (open cluster); May 5 (pink); May 11 (full bloom); May 18 (petal fall); May 26 (first cover); June 2, 13, and 28; July 5, 18, and 28; August 18; and Sept. 6.

Primary leaf scab counts were made June 15. Secondary leaf scab counts were made Sept. 6-8 and percent fruit infected was determined Sept. 19-21.

For both years, analysis of variance was used to evaluate the effect of fungicide treatment on scab. Each cultivar was analyzed separately. Differences of means were tested with Duncan's new multiple range test (EPR = 0.05).

RESULTS AND DISCUSSION

The scab predictor recorded 10 primary scab infection periods in 1982 and 14 in 1983. All infection periods were verified. In both years, disease incidence was high. Primary scab lesions first developed on foliage approximately 10 days after the first infection period in 1982 and 14 days after the first infection period in 1983.

The mean temperatures and wetness durations recorded by the predictor were very similar to those recorded by the deWit meter and hygrothermograph.

In both years, the EBI fungicides provided excellent scab control when applied 72 hours after the initiation of predicted infection periods. However, captan applied at 72 hours in 1983 did not provide satisfactory control. The failure of captan applied at 72 hours indicates the greater post-infection activity of the EBI fungicides. We suspect the limited control exhibited by captan in the curative program was due to protectant activity against subsequent infection periods during the 7-day period after application.

When applications were made 96 hours after the initiation of infection periods, control was still excellent with bitertanol, etaconazole, and fenarimol. Triforine did not provide satisfactory control at 96 hours. Chlorotic flecks were common on leaves of trees treated at 96 hours. No sporulation was observed in these chlorotic flecks, while typical sporulation was observed in the captan treatment applied at 72 hours, triforine at 96 hours, and in the control. These chlorotic flecks were believed to be scab lesions that were inactivated before they could fully develop.

Excellent control was achieved with all treatments applied in the protectant program. In most cases, only slight differences in control were observed between the curative and protectant programs. However, four and

TABLE 1.—Data on Infection Periods Collected from the Apple Scab Prediction Unit, and Fungicide Application Dates for the Curative and Protectant Program in 1982.

Wetness or Infection Period	Severity*	Av. Temp. °C	Wetness Duration	Date	Fungicide Application†
Wetness	None	7.2°	15 hr 00 min	April 20	½″ green (protectant)
Wetness	None	13.3°	8 hr 30 min	April 26	
Wetness	None	4.4°	25 hr 30 min	April 27	
				April 28	Tight cluster (protectant)
				May 4	Open cluster (protectant)
Infection	Moderate	11.67°	17 hr 00 min	May 7	
				May 10	Curative application‡
				May 11	Full bloom (protectant)
				May 28	Petal fall (protectant)
Infection	Moderate	16.1°	19 hr 30 min	May 19	
Infection	High	16.1°	44 hr 00 min	May 20	
				May 22	Curative application
Infection	High	18.3°	33 hr 00 min	May 23	
				May 25	First cover (protectant)
Infection	Low	17.2°	10 hr 00 min	May 28	
Infection	Moderate	18.3°	21 hr 30 min	May 29	
Infection	Moderate	16.7°	16 hr 00 min	June 1	
				June 2	Second cover (protectant)
				June 4	Curative application
Infection	High	13.3°	31 hr 30 min	June 5	
Infection	Moderate	18.9°	15 hr 00 min	June 9	
Infection	High	17.8°	36 hr 50 min	June 15	Third cover (protectant)
				June 18	Curative application

* The instrument records the severity of each infection period as low, moderate, or high.

† The curative program was terminated on 20 June, and all treatments received five additional protectant applications of fungicide.

‡ Dates listed under curative application are for 72 hr after the initiation of an infection period. 96 hr applications were made 24 hr later but are not listed in the table.

three fewer sprays were made in the curative program in 1982 and 1983, respectively.

Table 1 lists data on infection periods recorded by the scab predictor and fungicide application dates for both the protectant and curative programs in 1982. An examination of this table reveals how four fungicide applications were saved. Three protectant applications (half-inch green, tight cluster, and open cluster) were made prior to the first infection period. Although three wetness periods occurred during this period, none were infection periods, and fungicide application was not required. By disregarding infection periods which occurred within 7 days after curative applications, additional sprays were saved. The same general results were obtained in 1983.

The economic advantages of reducing the number of spray applications through the use of EBI fungicides need to be studied. The reduction of any pesticide application may be beneficial to the environment. Disease prediction or "forecasting" systems such as the one studied here offer an alternative to prophylactic applications of fungicide in standard protectant programs.

It is also important to note that in growing seasons with excessive rainfall in Ohio, many conscientious growers with extensive protectant programs still endure significant losses to scab. Improper timing of fungicide applications is at least partially responsible. A moni-

toring program such as used in this study could greatly improve the timing of fungicide applications by warning growers on a protectant program when scab pressure is high. If they are concerned that their protection is not adequate, they can still apply a curative compound.

Especially in dry growing seasons, a curative spray program for scab could reduce the number of fungicide applications. In wet seasons, a curative program may not reduce the number of applications, but may be beneficial in improving the timing of fungicide applications.

In summary, the data from this study indicate that: 1) the scab predictor is as effective as the Mills table in predicting scab infection periods under Ohio conditions, and 2) the EBI fungicides at the rates tested control apple scab when applied within 72 hours after the initiation of an infection period, and 3) all except triforine will provide good control when applied up to 96 hours after infection.

* * *

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Epidemiology and Control of Strawberry Leather Rot

G. G. GROVE, M. A. ELLIS, and L. V. MADDEN[1]

INTRODUCTION

Leather rot of strawberry fruit, caused by the fungus *Phytophthora cactorum* (Leb. and Cohn) Schroet, is a serious disease of the cultivated strawberry (*Fragaria* x *ananassa* Duch.). The disease was first reported in 1924 in a number of southern states.

In Ohio, the disease was not reported previously and was not considered economically important until 1981. Excessive rainfall during May, June, and early July 1981 resulted in heavy disease losses to Ohio's strawberry crop of about 1500 acres. Several growers reported crop losses as high as 50% which were due primarily to leather rot.

In initial surveys for disease incidence in Ohio, it became obvious that most growers did not recognize leather rot in their plantings. Most growers assumed the fruit was rotted by *Botrytis cinerea* pers. ex fr. (gray mold) or was simply overripe. The inability of growers to recognize the disease led the authors to believe that leather rot was probably a much more common and serious problem than most growers thought. Because of the lack of information about the disease, experiments were initiated to study the epidemiology of strawberry leather rot and to develop methods for its control.

EPIDEMIOLOGY

This research was designed to study the following portions of the leather rot disease cycle: 1) how the pathogen *(P. cactorum)* survives or overwinters in strawberry fields in Ohio, 2) how the pathogen is spread or dispersed within the field, 3) what environmental factors are necessary for fruit infection in the field, and 4) what environmental conditions promote sporulation of the pathogen on infected fruit in the field, and thus provide inoculum for secondary spread of the disease. The following is a summary of the results.

Overwinter survival of *P. cactorum* in strawberry fields. The authors' observations indicate that strawberry fruit infected with *P. cactorum* eventually dry to form hard, shriveled mummies. A series of experiments was conducted to determine if infected, mummified fruit could serve as a source of overwintering inoculum for leather rot during two winters. Mummies were either left exposed at the soil surface or buried 0.39 inch (1 cm) beneath the soil inside nylon mesh pouches. These were placed in the field July 1 and retrieved April 15 during both years of testing, resulting in a 9-month exposure period. Upon retrieval of the mummies, observations were made for the presence of *P. cactorum*.

P. cactorum was recovered from all infected fruit mummies following 9 months' burial beneath or expo-

sure at the soil surface. Germinating oospores were observed in all overwintered mummified fruit within 14 days after placement in water. Numerous papillate sporangia characteristic of *P. cactorum* were observed microscopically at the distal portions of germ tubes emerging from oospores. Indirect germination (production of zoospores) of several sporangia was also observed. These sporangia were connected to oospores by germ tubes.

These results suggest that *P. cactorum* can overwinter as oospores in mummified, infected strawberry fruit. Oospores have been reported to be long-term survival propagules for *P. cactorum* which are highly resistant to cold, dry conditions. The mean soil temperatures for the winter months ranged from 27 to 41° F (−3 to 5° C). It should be noted that the temperatures during the winter of 1983-1984 were abnormally low, and the soil was frozen for at least 3 months. These long-term, adverse conditions make it highly unlikely that *P. cactorum* survived as sporangia or mycelia in mummified fruit tissue. In addition, only oospores were observed in tissues from overwintered mummies. Based on these observations, it was concluded that oospores are the most probable survival propagules of *P. cactorum* in strawberry fields under Ohio conditions.

The implications of mummified fruit as a potential source of primary inoculum for leather rot are obvious. In areas where leather rot is a serious problem, sanitation (removal of infected fruit) may be important in disease control.

Dispersal or spread of *P. cactorum* in strawberry fields. Prior to these studies, it was believed that *P. cactorum* only infected strawberry fruit in direct contact with soil. During the Ohio leather rot epidemic of 1981, the authors observed that infection of fruit without soil contact was quite common. Fruit found in the top of the row canopy, 12 inches (30.5 cm) or more above the soil surface, were infected. In addition, where epidemics occurred, disease spread was very rapid. These observations suggested that initial fruit infection and subsequent spread of the disease involved more than fruit contact with soil. We suspected that rain splash or other means of water dispersal were important in leather rot development. Studies were conducted to demonstrate the role of water-splashing in the dispersal of infected propagules of *P. cactorum*.

Splash dispersal was demonstrated by releasing water drops from various heights onto infected strawberry fruit adjacent to petri plates containing selective media. Impact of the water drops readily dispersed sporangia, zoospores, and fungal mycelia (all of which are infective propagules of *P. cactorum*) from the surface of infected fruit to the adjacent petri plates. *P. cactorum* colonies formed on petri plates up to 47.2 inches (120 cm) away from the infected fruit. A multiple regression model described the number of colonies as a function of dis-

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tance from the infected fruit and water drop velocity at impact. There was a negative gradient of colonies away from the infected fruit; thus, the number decreased as distance increased. In addition to lateral spread, colonies also were observed in plates placed at 11.8 inches (30 cm) above the infected fruit.

Splash dispersal from plant-to-plant also was demonstrated. Potted plants with immature (green) fruit were positioned 11.8 inches (30 cm) away from a plant with infected fruit. Water drops were released so that they impacted on infected fruit. The resulting splash off the surface of infected fruit carried infective propagules of P. cactorum to the surface of healthy fruit on adjacent test plants. Test plants were then removed and incubated in the greenhouse for 3 days. All exposed fruit on these test plants developed leather rot symptoms.

Results of these studies demonstrated that P. cactorum can be readily dispersed from the surface of infected to healthy strawberry fruit by splashing water. These results help to explain how the disease spreads so rapidly. In these studies, the pathogen was disseminated about 4 feet by simply impacting droplets of water onto the surface of infected fruit. It is highly probable that the pathogen would be disseminated over much greater distances during rainstorms associated with high winds. The impact of large water droplets from overhead irrigation could result in an effective method of disseminating infective propagules of P. cactorum, and thus spreading of the disease.

Environmental conditions (temperature and wetness duration) necessary for strawberry fruit infection by P. cactorum. Prior to these studies, the environmental conditions necessary for strawberry fruit infection by P. cactorum had not been studied. These studies involved a series of fruit inoculations under controlled conditions in growth chambers. Nine constant temperatures between 43 and 86° F (6 to 30° C) were tested. Upon completion of each inoculation test, fruit were examined for leather rot symptoms and P. cactorum was isolated from all infected fruit.

The results clearly indicated that wetness duration and temperature are significant factors influencing the infection of strawberry fruit by P. cactorum. Infection only occurred in the presence of free water. The source of free water can be rain, irrigation, or dew. Infection level (number of fruit infected) increased with each increase in wetness duration (0 to 5 hours) at all nine temperatures tested. For each wetness duration, infection level increased up to the optimum temperature of 70° F (21° C) and then declined. At temperatures between 63 and 77° F (17 and 25° C), 2 hours of wetness resulted in more than 80% infection.

Environmental conditions necessary for sporulation (production of sporangia) of P. cactorum on the surface of infected strawberry fruit. Once fruit infections have occurred in the field, dissemination of the pathogen and thus the spread of the disease is dependent upon the production of sporangia on the fruit surface. After sporulation has occurred and numerous sporangia are present on the fruit surface, they can be easily disseminated to healthy fruit by water splash. Studies were conducted to determine the temperature and wetness durations necessary for sporangial production on the surface of infected fruit, and to develop a model predicting sporangial production at different temperatures and wetness durations.

Infected strawberry fruit were incubated under various combinations of wetness duration and temperature. The results indicated that a film of free water is necessary for sporangia production on the surface of infected fruit. Sporangia production increased with increased wetness duration from 3 to 24 hours between the temperatures of 55 and 82° F (12.5 and 27.5° C). The most favorable temperatures for production of sporangia were between 59 and 77° F (15 and 25° C), with the optimum temperature of 68° F (20° C). Sporangia were formed at wetness durations as short as 3 hours at temperatures of 59 and 77° F (15 and 25° C), but required greater than 12 and 6 hours of wetness duration at 55 and 82° F (12.5 and 27.5° C), respectively. Sporangia were not produced at 50 and 86° F (10 and 30° C).

A proposed disease cycle for strawberry leather rot. Based on these results, the following disease cycle for strawberry fruit leather rot is proposed.

The fungus survives the winter as thick-walled resting spores, called oospores. These form within infected fruit as they mummify. The oospores can remain viable in soil for long periods of time. In the spring, oospores germinate in the presence of free water and produce sporangia in which zoospores are generally produced. The zoospores have a flagella and can swim in a film of water. In the presence of free water on the fruit surface, zoospres germinate, forming a germ tube which penetrates and infects the fruit. In later stages of disease development, sporangia are produced on the surface of infected fruit under moist conditions. The disease is spread by splashing or wind-blown water from rain or overhead irrigation. Sporangia and zoospores are carried in water from the surface of infected fruit to healthy fruit where new infections occur. Thus, under the proper environmental conditions, the disease can spread quickly.

The optimum temperatures for infection are between 63 and 77° F (17 and 25° C). As the duration of the wetness period increases, the temperature range at which infection can occur becomes much broader. As infected fruit dry up and mummify, they fall to the ground, and lie at or slightly below the soil surface. Oospores formed within the mummified fruit enable the fungus to survive the winter and cause new infections the following year, thus completing the disease cycle.

CURRENT CONTROL RECOMMENDATIONS

Properly timed applications of fungicides before and during harvest are extremely important in reducing losses from fruit rot. Because fruit rots may be caused by several different fungi, and because many of the newer and most effective fungicides are very specific as to what fungi they control, the proper identification of fruit rots is critical to successful strawberry produc-

tion. Knowing which type of fruit rot or rots are present in the planting enables the grower to select the proper fungicide or fungicide combination for optimum control. The following practices should aid in reducing losses from several fruit rot diseases.

- Select a planting site with good soil drainage and air circulation. Plants should be exposed to direct sunlight. Plant rows with the direction of the prevailing wind to promote faster drying of foliage and fruit.
- Mulch strawberry plants with straw or other material to reduce fruit contact with soil.
- Proper spacing of plants and timing of fertilizer applications are important. Excessive applications of nitrogen fertilizer can produce an excessive amount of foliage. Shading of fruit by thick foliage prevents rapid drying of fruit and creates ideal conditions for disease development.
- Pick fruit frequently and early in the day (as soon as plants are dry). Cull out all diseased fruit, but do not leave them in the field.
- Handle fruit with care to avoid bruising.
- After harvest, refrigerate fruit promptly at 32 to 50° F (0 to 10° C).
- Adjust timing of irrigation so that foliage and fruit dry as soon as possible. Water should be applied in mid-morning or early afternoon. This practice may not be ideal for obtaining the desired amount of supplemental water needed, but should aid in reducing disease development and spread. Obviously, irrigation for frost control must be timed accordingly.

Where leather rot is a problem, a good fungicide spray program is essential to control. It is important to remember that the conditions which favor leather rot development are also favorable for development of gray mold, caused by *Botrytis cinerea*. Gray mold and leather rot are commonly found in the same planting or even on the same plant. In growing seasons where both diseases are present, the fungicide spray program must be capable of controlling both of them. It is important to note that the most effective and commonly used fungicides for control of gray mold (*i.e.,* Benlate, Topsin-M, and Ronilan) are not effective against leather rot. Research in Ohio indicates that until new fungicides with efficacy against leather rot are labeled, the use of broad spectrum protectant fungicides such as captan, thiram, or folpet in combination with either Benlate, Topsin-M, or Ronilan should provide the best control of both fruit rots.

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Grove, G. G., L. V. Madden, and M. A. Ellis. 1985. Influence of temperature and wetness duration on sporulation of *Phytophthora cactorum* on infected strawberry fruit. Phytopathology, 75:700-703.

Grove, G. G., L. V. Madden, and M. A. Ellis. 1985. Splash dispersal of *Phytophthora cactorum* from infected strawberry fruit. Phytopathology, 75:611-615.

Grove, G. G., M. A. Ellis, and L. V. Madden. 1985. Overwinter survival of *Phytophthora cactorum* in infected strawberry fruit. Plant Dis., 69:514-516.

Research on Cane Diseases
of Thornless Blackberry in Ohio

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INTRODUCTION

In the past decade, there has been considerable interest in Ohio production of thornless blackberry (*Rubus* spp. hybrid). The cultivars 'Hull', 'Dirksen', and 'Thornfree' have been introduced and planted commercially on a limited scale. Evaluation of the thornless blackberry indicated that these cultivars had great potential in terms of field and fruit quality.

However, a problem surfaced in 1976 when stem cankers appeared on the majority of plants in an experimental planting at the OARDC Southern Branch in Brown County. Cankers were primarily on second-year canes. In most cases, the portion of the cane above the canker either died or was extremely weak and failed to produce marketable fruit.

In 1977, a 1-acre commercial planting of 'Hull' in the same area of the state had nearly all canes affected with these cankers and the grower subsequently destroyed the planting. Since that time, several other small plantings in southern Ohio have been removed because of the disorder.

MATERIALS AND METHODS

In 1981, research was initiated in the Department of Plant Pathology to determine the cause of the cankers on thornless blackberry.

The following fungi were isolated from naturally occurring cankers: *Alternaria* spp.; *Botryosphaeria obtusa* (Schw.) Shoemaker; *Cytospora* sp.; *Epicoccum purpurescens* Ehrenb. ex Schlecht.; *Fusarium* spp.; *Gno-*

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monia rubi (Rehm) Winter; *Leptosphaeria coniothyrium* (Fuckel) Sacc.; and *Pestalotiopsis* sp.

RESULTS

Of the fungi isolated, only *B. obtusa*, *G. rubi*, and *L. coniothyrium* (anamorph; *Coniothyrium fuckelii* Sacc.) were pathogenic. All three fungi produced characteristic cankers on inoculated canes in both field and greenhouse tests and all were consistently re-isolated from diseased tissues. Length of the cankers caused by each fungus varied between cultivars and time of inoculation; however, canker lengths produced by each fungus were uniform for a given cultivar and time of inoculation.

Table 1 summarizes canker ratings obtained in 1982 tests. Similar results were obtained in 1983 tests. In all cankers with a rating of 1 (discoloration up to 1 cm), the fungus was isolated from apparently healthy tissue up to 2 cm beyond the margin of the canker.

All three fungi have been previously associated with *Rubus* spp. However, only *L. coniothyrium* has been reported to cause cane blight on blackberry. Although *G. rubi* has been commonly associated with cankers on blackberries, its pathogenicity has not been demonstrated. *B. obtusa* has been reported on a variety of woody hosts under numerous synonyms. An association with *Rubus* has been reported.

Under natural conditions in the field, all three fungi were commonly found on the same cane, and cankers produced by each fungus were difficult to distinguish. Typical cankers caused by *L. coniothyrium* were initially dark red to reddish purple with dark purple irregular borders. Eventually the cankers turned gray (Fig. 1).

TABLE 1.—Canker Length Ratings on Three Thornless Blackberry Cultivars Inoculated in the Greenhouse or Field with *Leptosphaeria coniothyrium*, *Gnominia rubi*, and *Botryosphaeria obtusa* (1982).

Fungus	Greenhouse Dec. 15, 1981	Field April 15, 1982 First-year Canes			Field July 15, 1982 Second-year Canes		
	TF*	TF	D	H	TF	D	H
Leptosphaeria	2†	3	2	2	3	2	3
Gnominia	1	1	1	1	3	2	2
Botryosphaeria	2	1	1	2	3	1	2

* Canker rating system: 0 = no discoloration, 1 = discoloration less than 1 cm, 2 = discoloration from 1-3 cm, and 3 = discoloration more than 3 cm away from the point of inoculation.

† Three inoculations were made on each of three canes per cultivar. Cultivars inoculated were TF = 'Thornfree'; D = 'Dirksen'; and H = 'Hull'.
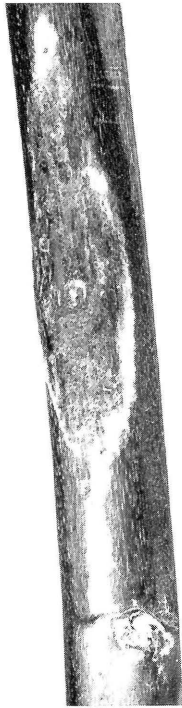
FIG. 1.—Canker on thornless blackberry (cv. Hull Thornless) caused by *Leptosphaeria coniothyrium*. Typical symptoms on second-year cane.

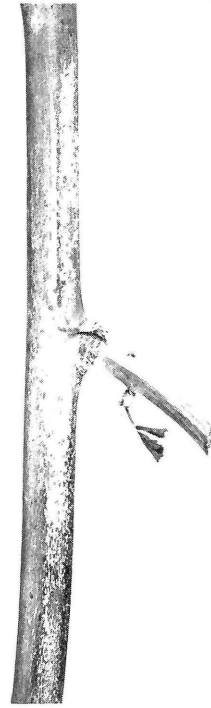FIG. 2.—Canker on thornless blackberry (cv. Hull Thornless) caused by *Gnominia rubi*. Typical symptoms on second-year cane.

Those produced by *G. rubi* were whitish gray but did not typically have distinct borders (Fig. 2). Cankers produced by *B. obtusa* had dark brown centers with regions of lighter brown or gray scattered throughout. These cankers also had very dark brown to purple irregular borders (Fig. 3).

Second-year fruiting canes appeared to be more susceptible than first-year primal canes (Table 1). In most field plantings where disease was severe, second-year canes were heavily infected and nonproductive, whereas first-year canes often appeared healthy. These observations suggest the possibility of predisposition to infection due to winter injury.

Although the effects of winter injury were not studied, a number of observations have indicated that it may be an important factor in disease development. For example, the cankers appear most severe in Ohio following winters with excessively cold temperatures and are less severe following mild winters. In addition, the more winter-hardy thorn-type cultivars (*i.e.*, Darrow) rarely became infected even when grown adjacent to severely infected thornless cultivars. Future studies need to be conducted to determine the effects of winter injury on disease development.

Commercial production of these cultivars of thornless blackberry in Ohio will not be possible until effective means of controlling these canker diseases are developed.
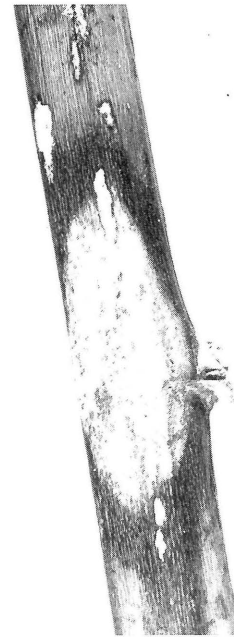

FIG. 3.—Canker on thornless blackberry (cv. Hull Thornless) caused by *Botryosphaeria obtusa*. Typical symptoms on second-year cane.

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