CHEMICAL CONTROL STUDIES WITH CORRELATIVE BIOLOGICAL FACTORS PERTAINING TO THE APPLE APHID, *APHIS POMI* DEGEER, IN SOUTHWESTERN MICHIGAN

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by

JORDAN BRADLEY TATTER

AN ABSTRACT

Submitted to the College of Science and Arts
Michigan State University of Agriculture and
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the requirements for the degree of

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Approved Ray Hutson

ABSTRACT

This research project considered three objectives: (1) To correlate biological factors of the apple aphid, *Aphis pomi* DeGeer, with: (2) The evaluation of several recently developed compounds suspected of insecticidal properties for the control of the apple aphid exposed to field conditions in Southwestern Michigan, and; (3) The development of a simplified method of collecting performance data on the control of *A. pomi*.

Populations of the apple aphid were observed to increase in proportion to host vigor. A definite preference by the apple aphid to actively growing tissue was noted. Continuous migration by aphids to newly-formed plant tissue occurred during the growing season. Infestations required control measures by mid-July and peak populations were recorded in mid-August.

A group of 28 materials were evaluated for control of the apple aphid on Twenty Ounce Pippin variety of apples. Outstanding materials were Dimethoate, Phosphamidon, Systox, Compounds 4402 and 5727. Systemic-type chemicals were superior to the surface-residual compounds in effectiveness for aphid control.

A simplified method for sampling parameter populations of apple aphids was devised. The system denoted as "count rate" was based on migration and feeding habits of the aphids. Statistical procedures for proof of significance were

applicable to count-rate data. The technique was rapid, accurate and practical for usage by commercial apple growers.

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INTRODUCTION

Three species of aphids commonly infesting the apple (*Pyrus malus* Linnaeus) in Southwestern Michigan are: the apple aphid, *Aphis pomi* DeGeer, the rosy apple aphid, *Anuraphis roseus* Baker, and the apple grain aphid, *Rhopalosiphum fitchii* (Sanderson).

On occasions rosy apple aphid populations have caused greater injury to an apple crop than the other aphid groups, but control measures are much less involved. Although apple grain aphids may appear in alarming numbers soon after bud burst, this species normally migrates from the apple to grain crops within three weeks after hatching, and is of no further consequence to the grower. Since the apple aphid usually remains on the apple host during the entire growing season, it presents a continuous control problem for orchardists. Population densities are influenced mainly by environmental conditions and reinfestation by migration from uncontrolled areas is a common occurrence.

One of the significant contributing factors to the increase in importance of the apple aphid has been the recent introduction of versatile chemicals for the control of orchard insects. Many predators and parasites have been destroyed in conjunction with varying proportions of their hosts, but because of the biotic potential of the apple aphid, specific controls have become necessary.

Prior to each growing season, several new compounds are provided by agricultural chemical industries for research personnel to evaluate. As part of this project, certain of these products were appraised in the field for aphicidal properties in anticipation of providing additional control measures for apple aphid infestations.

A fundamental knowledge of the life history and appearance of the test species is basic to any biological research program. Information on the biology of the apple aphid was obtained in this study in correlation with control measures.

The apple aphid was chosen for two reasons: because of the economic importance, and secondly, this insect was present in sufficient populations to permit a significant evaluation of chemical controls.

OBJECTIVES

The major objectives of this research were:

(1) To correlate the biological factors of the apple aphid, *Aphis pomi* DeGeer, with,

(2) The evaluation of several compounds suspected of insecticidal properties for the control of the apple aphid exposed to local field conditions, and,

(3) The development of a simplified method of collecting performance data on apple aphid control.

LITERATURE REVIEW

Synonymy. The specific determination of the apple aphid as Aphis pomi was credited to Charles DeGeer in 1773, according to Baker and Turner (1916). However, the species was redescribed in 1775 by Johann Christian Fabricius as Aphis mali as indicated by Baker and Turner (1916) and subsequently noted by Matheson (1919). Investigations by Parrott, Hodgkiss and Lathrop (1916) and by Matheson (1919) support the initial description of Aphis pomi DeGeer emphasizing that this specific name should be applied to the apple aphid. Personal correspondence with Miss Louise M. Russell of the United States Department of Agriculture, Agricultural Research Service, Entomology Research Division, a specialist in aphid identification, has verified this fact.

Origin and Distribution. The apple aphid is of European origin. First appearance in North America according to Matheson (1919) was recorded to be prior to 1854. This author based his opinion from an article by Fitch (1856) describing the life cycle of the apple aphid as observed in New York plantings. However, Fitch erringly applied the name Aphis avenae Fabricius, adding to the confusion on nomenclature. Metcalf, Flint and Metcalf (1951) stated that the apple aphid is distributed generally throughout the apple producing sections of North America. The first serious commercial infestations were reported by Hodgkiss (1919) to have occurred in New York State as early as 1897.

Plant Hosts. Matheson (1919) listed the following plant species as possible hosts of the apple aphid: apple, Pyrus malus Linnaeus; pear, Pyrus communis Linnaeus; wild crab, Pyrus coronaria Linnaeus; hawthorn, Crataegus oxyacantha Linnaeus; Mountain ash, Pyrus americana Marsh; and species of Cydonia and Crataegus. The author also observed the following varieties of apples as most susceptible to apple aphid injury: Twenty Ounce Pippin, Maiden Blush, King, Fall Pippin, Greening and Baldwin. An extensive listing of host plants of the apple aphid was complied by Patch (1923).

Type of Injury. Peairs (1950) stated that A. pomi injury to apple fruits was limited primarily to the period immediately following bloom. Injury to foliage was also an important factor at that time. During mid-summer apple aphids were more likely to be found on young trees and infesting new shoots than on mature apples or hardened vegetation. Early season injury by apple aphids was described by Matheson (1919) as a partial folding of the leaves. Parrott, et al. (1916) discussed the tendency of the stem-mothers to ascend the growing shoots, feeding continuously on tender leaves. Hodgkiss (1919) reported that in New York orchards the apple aphid was considered more important as a dwarfing and deformation agent on the growth of younger trees than as a major pest of mature apple trees.

An interesting observation made by Parrott, et al. (1916) was that during the latter part of summer the terminal portions of new growth appeared less able to withstand the feeding of apple aphids than earlier in the season. Extreme cases of infestation resulted in curled foliage, blackened by sooty fungus, with associated leaf drop and possible death of the terminal portion of the shoots.

Life History and Seasonal Activity. Smith (1900) was one of the first to present a concise account of the life cycle and habits of the apple aphid in America, although he referred mistakenly to the insect as Aphis mali Koch. Baker and Turner (1916) presented a factual account of the structural features and biology of the apple aphid, and a summary of this work is reproduced herein from Hottes and Frison (1931).

> "The life history of Aphis pomi may be briefly outlined as follows; The egg is laid upon tender twigs of the apple, though occasionally it is laid upon the bark of the older twigs. It is light yellow when laid, but later changes to shining black. Development for a few days is very rapid, after which the egg rests for the winter. When revolution of the embryo is completed in the spring, an increase in temperature will cause the egg to hatch. Before this revolution a high temperature only tends to destroy it. Early in April the egg hatches by a uniform splitting over the insect's head.
>
> The stem mother is wingless and becomes mature in about 10 days. She produces live summer forms, both winged and wingless, with the winged ones predominating. There are 9 to 17 generations of the summer forms at Vienna, Va. After the second generation the wingless forms always outnumber the others, but winged forms may occur in every generation. They become rare toward the end of the season. On the other hand, a wingless line may be carried from the stem mother to the egg. A third form, the intermediate, may occur throughout the summer.
>
> The wingless sexes begin to appear about the 1st of September. They occur in all generations, from the eleventh to the nineteenth, inclusive, and

> probably also in the ninth and tenth.
> The summer wingless forms and the oviparous females, which live longer than the males, remain on the trees at Vienna, Va. until the leaves drop, usually about the middle of November.
> Mating commences toward the close of September, one male usually serving more than one female. Both sexes feed. The oviparous female may lay infertile eggs if not reached by a male, and these eggs do not become black. The fertile egg develops to the resting stage before the first heavy frosts; otherwise it may be winterkilled and will not hatch to a stem mother the following spring."

Further examinations were made by Parrott et al. (1916), Hodgkiss (1919) and Matheson (1919). Information derived from these studies closely paralleled that of Baker and Turner (1916). Brittain (1915) made the remarkable observation that on several varieties of apples A. pomi eggs hatch at the time the buds break. This phenomenon may vary despite identical environmental conditions for different varieties according to Matheson (1919). He also stated that the apple aphid was the major aphid pest of apples, because it was the only species that remained on the host throughout the growing season. Other species commonly migrate to alternate plant hosts soon after bloom.

Natural Control. Steiner (1944) noted that the toxicity of DDT to certain parasites and predators had caused sufficient reduction of the natural enemies of apple aphids to allow increases in aphid populations. Metcalf, et al. (1951) listed lady beetles, syrphid flies and aphid lions as common predators of the apple aphid.

The latter authors stated that control problems became complicated during cool, damp seasons, since A. pomi increases more rapidly than its enemies when exposed to these conditions.

Host Resistance Factors. Varietal specificity and host resistance was first observed by Gilchrist, an associate of Fitch, and reported by Fitch (1855) early in the recorded studies of the apple aphid in North America. Matheson (1919) discovered variances in A. pomi populations on different varieties of apples in the same orchards and attributed this to a resistance factor.

Cultural Control. Certain cultural methods of control were proposed by Hodgkiss (1919). These included wide spacing of trees, removal of succulent water-sprouts during the growing season and the use of sod in orchards to aid in reducing the amount of tender tissue available for feeding.

Chemical Control. Peterson (1919) conducted one of the first extensive studies of chemical control of the apple aphid. Among the materials investigated were fish oil soap, laundry soap, lime-sulfur, various petroleum oils, and nicotine sulfate. From this basic research nicotine sulfate in combination with lime-sulfur became the standard control measure.

Since the advent of synthetic organic insecticides during the early 1940's the previous standard compounds for control of A. pomi have become obsolete. Dormant sprays

were not sufficient to prevent summer population increases of apple aphids according to Cutright (1953). He evaluated several chemicals during the growing season, concluding that certain organic insecticides were the most efficient for aphid control. Glass and Chapman (1955) reported that parathion, malathion and Diazinon were toxic initially to the apple aphid, but lacked extended residual activity. This work also emphasized the effect of systemic insecticides as illustrated by Demeton (Systox) and Meta-Systox which were effective for three weeks in preventing reinfestation.

Recent investigations by Garman (1959) who evaluated combinations of insecticides and fungicides for control of insects and diseases, showed the complex nature of present day pest control. He concluded that control, fruit quality, cost and safety of the materials are important factors in profitable orchard practices.

Madsen and Bailey (1959) screened a group of new compounds involving an original technique of evaluation. They determined the actual number of living aphids on the third leaf from the terminal tip of an infested new shoot. Comparisons of mean values were made statistically for the various treatments but significant differences were not determined.

MATERIALS USED

The author wishes to express his appreciation of the organizations that contributed the chemicals used in this study.

1. Diazinon (O,O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothioate).
   25 per cent wettable powder; Geigy Chemical Corporation.

2. Dibrom (O,O-dimethyl O-(2,2-dibromo-1,2-dibromoethyl) phosphate).
   8 pounds per gallon emulsifiable concentrate; California Spray-Chemical Corporation.

3. Dimethoate (O,O-diemethyl S-methylcarbamoylmethyl) phosphorodithioate).
   4 pounds per gallon soluble concentrate; American Cyanamid Company.

4. Endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a, 5,6,7,8,8a-octahydro-1,4,5,8-endo-endo dimethanonaphthalene).
   75 per cent wettable powder; Corona Chemical Division, Pittsburgh Plate Glass Company.

5. Ethion (O,O,O',)'-tetraethyl S,S'-methylene diphosphorodithioate).
   25 per cent wettable powder; Niagra Chemical Division, Food Machinery and Chemical Corporation.

6. Ethyl Guthion (O,O-diethyl S-(4-oxo-3H,1,2,3-benzotriazine-3-methyl) phosphorodithioate).
   2 pounds per gallon emulsifiable concentrate; Chemagro Corporation.

7. Guthion (O,O-dimethyl S-(4-oxo-3H-1,2,3-benzotriazine-3-methyl) phosphorodithioate).
   1.5 pounds per gallon emulsifiable concentrate; Chemagro Corporation.

8. Korlan (O,O-dimethyl O-(2,4,5-trichlorophenyl) phosphorothioate).
   2 pounds per gallon emulsifiable concentrate; The Dow Chemical Company.

9. Malathion (O,O-dimethyl S-(1,2-bis-carboethoxyethyl) phosphorodithioate).
   25 per cent wettable powder; General Chemical Division, Allied Chemical Corporation.

10. Methyl Trithion (0,0-dimethyl(p-chlorophenylthio) methyl phosphorodithioate).
25 per cent wettable powder; Stauffer Chemical Company.

11. Parathion (0,0-diethyl 0-p-nitrophenyl phosphorothioate).
8 pounds per gallon emulsifiable concentrate; California Spray-Chemical Corporation.

12. Phosdrin (0,0-dimethyl 0-1-methoxycarbonyl-1-propene-2-yl phosphate).
2 pounds per gallon emulsifiable concentrate; Shell Chemical Corporation.

13. Phosphamidon (0,0-dimethyl 0-(2-chloro-2-diethylcarbamoyl-1-propene-2-yl) phosphate).
4 pounds per gallon emulsifiable concentrate; California Spray-Chemical Corporation.

14. Phostex (mixture of bis(dialkyloxyphosphinothioyl) disulphides).
8 pounds per gallon emulsifiable concentrate; Niagra Chemical Division, Food Machinery Corporation.

15. Ryania (Ryania speciosa).
100 per cent wettable powder; S.B. Pennick and Company.

16. Sevin (1-naphthyl-N-methy carbamate).
50 per cent wettable powder; Union Carbide Chemicals Company, and 4 pounds per gallon emulsifiable concentrate; Stauffer Chemical Company.

17. Systox (0,0-diethyl 0-(and S)-ethyl-2-thioethyl phosphorothioates).
2 pounds per gallon emulsifiable concentrate; Chemagro Corporation.

18. Thiodan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide).
50 per cent wettable powder and 2 pounds per gallon emulsifiable concentrate; Niagra Chemical Division, Food Machinery Corporation.

19. Trithion (S(p-chlorophenylthio) methyl 0,)-diethyl phosphorodithioate).
25 per cent wettable powder; Stauffer Chemical Company.

20. Compound 4402 (1,3,4,5,6,7,8-octachloro-3a,4,7,7a tetrahydro-4,7-methanophthalan).
1.25 pounds per gallon emulsifiable concentrate; Shell Development Company.

21. Compound 5539 (Not released).
2 pounds per gallon emulsifiable concentrate; Shell Development Company.

22. Compound 5727 (Not released).
1.25 pounds per gallon emulsifiable concentrate; Hercules Powder Company.

23. Compound 22408 (Bayer) (naphthaloximide 0,0-diethyl-phosphorothioate).
50 per cent wettable powder; Vero Beach Laboratories.

24. Compound 25141 (Bayer) (0,0, diethyl-0-p-methylsulforide-phenyl thionophosphate).
2 pounds per gallon emulsifiable concentrate; Vero Beach Laboratories.

25. Compound 29493 (Bayer) (0,0-dimethyl 0-(4-(methylthio)-m-tolyl phosphorothioate).
4 pounds per gallon emulsifiable concentrate; Vero Beach Laboratories.

26. Compound 30494 (Not released).
2 pounds per gallon emulsifiable concentrate; Geigy Chemical Corporation.

27. Compound 30686 (Bayer) (quinoxaline-2,3-trithio-carbonate).
50 per cent wettable powder; Vero Beach Laboratories.

28. VC-13 (0-2,4-dichlorophenyl 0,0-diethyl phosphorothioate).

8 pounds per gallon emulsifiable concentrate; Pennsylvania Salt Manufacturing Company of Washington.

EXPERIMENTAL PROCEDURES

A. Observations on the biology of the apple aphid.

Matheson (1919) reported that Twenty Ounce Pippin variety of apples appeared to be more susceptible to injury by the apple aphid than most other varieties. Preliminary to experimentation a block of Pippins with a past history of aphid infestations was inspected weekly beginning at petal fall. Water-sprouts on the scaffold limbs and new shoots at the periphery of the trees were examined to determine the presence of apple aphids.

Observations revealed that the stem-mothers would locate initially on the terminal tips of new growth shoots. Their parthenogenetic offspring would migrate progressively inward, infesting each leaf of recent growth in relationship to the population density. However, infestations seldom exceeded the fourth pair of leaves from the shoot tip.

By mid-July, apple aphids had populated the interior water-sprouts of the current season's growth through the third pair of leaves from the terminal tips. Peripheral shoots contained colonies of apple aphids through the second pair of leaves. The described amount of infestation would be considered serious by commercial orchardists.

B. Design of Experiment.

Because the block had received no specific aphicide treatments, and sufficient apple aphid populations existed, Experiment I[a] was initiated. This test consisted of 22 treatments (Table I) each replicated four times and randomized within the replications (Figure 1). A standard method of random selection of plots was used with allowances made for variable environmental characteristics in the orchard. The four replications were designed as single-tree plot systems including two controls per replicate.

Experiment II[b] consisted of 15 treatments (Table II) arranged as in Experiment I (Figure 2), with the exception of Compound 5727, which was supplied after the treatment design was established.

The treatments of Experiment I were applied between the hours of ten A.M. and two P.M., and those of Experiment II were applied betwee the hours of nine A.M. and one P.M. No precipitation occurred during either application (Table III).

All treatments were applied at a pressure of 400 pounds per square inch using a John Bean hydraulic-gun apparatus. Approximately 12 gallons of spray mixture were applied per tree. After the application of each treatment all parts of the spraying mechanism were rinsed with clean water. Complete coverage was obtained by spraying in a circular pattern around each plot.

(a) Materials applied July 19, 1959, at Watervliet(Berrien County), Michigan.

(b) Materials applied July 30, 1959, at Watervliet(Berrien County), Michigan.

C. Techniques of Evaluation of Control Measures.

Since this project involved considerable numbers of treatments, replications and small insect forms, a rapid technique for evaluation of chemical control which would be statistically sound was necessary. The problem of counting individual aphids live or dead was too time consuming; therefore, a count-rate method was devised that would provide for reliable evaluation.

Five new growth shoots on the scaffold limbs and five shoots on the periphery of each plot were examined visually. The first eight leaves of each shoot were separated into four pairs. If the first pair including the tip contained more living than dead apple aphids, a count determination of one was assigned. If more live than dead aphids existed on the second pair of leaves as well as the first pair, the terminal shoot received a rating of two, and continuously for the third and fourth couplet of leaves. Each terminal had a possible maximum rating of four in all cases. Criterion for death was the brown, dried remains of the aphids; all live forms were characteristically green in coloration. Since the count-ratings were made at frequent intervals, population changes were observed closely.

The data was taken at seven-day intervals beginning with a pre-spray count and continued for five weeks. A subsequent 10-day examination followed the last seven-day count. The intervals were chosen arbitrarily to closely approximate a standard spray schedule.

The count-rate data per plot were averaged, and an analysis of variance was made (Tables IV-V) based on a comparison among all means as devised by Tukey (1953).[1]

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1 Referenced from Snedecor, 1956 p. 290.

Table I. Materials, formulations, quantities and code numbers for Experiment I.

Material	Formulation[1]	Amount Active Insecticide Per 100 Gallons of Spray	Treatment Identification[2]
	(%)	(lb.)	(#)
Diazinon	25 WP	0.37	14
Dibrom	63 EC	0.50	5
Dimethoate	46 SC	0.25	1
Dimethoate	46 SC	0.50	2
Endrin	75 WP	0.25	17
Ethion	25 WP	0.50	11
Guthion	18 EC	0.30	12
Malathion	25 WP	0.50	19
Methyl Trithion	25 WP	0.37	15
Parathion	76 EC	0.25	20
Phosphamidon	49 EC	0.25	3
Phosphamidon	49 EC	0.50	4
Phostex	72 EC	0.50	6
Ryania	100 WP	4.00	18
Sevin	50 WP	0.75	13
Systox	26 EC	0.19	7
Thiodan	24 EC	0.50	10
Thiodan	50 WP	0.50	8
Thiodan	50 WP	1.00	9
Trithion	25 WP	0.37	16
Control	---	---	21, 22

1 WP= wettable powder; EC= emulsifiable concentrate; SC= soluble concentrate.

2 See Figure 1.

Figure 1. Plot Design of Experiment I.[1]

Rep. I	Rep. II	Rep. III	Rep. IV
22	2	1	22 Control
D*	17	D*	11 Ethion
D*	4	14	2 Dimethoate
10	20	22	19 Malathion
2	5	13	16 Trithion
17	6	19	20 Parathion
7	12	18	6 Phostex
4	22	3	14 Diazinon
6	P*	9	17 Endrin
12	11	2	18 Ryania
8	15	8	3 Phosphamidon
9	13	17	21 Control
18	16	10	13 Sevin
14	19	7	12 Guthion
19	9	11	15 Methyl Trithion
3	21	5	7 Systox
15	18	4	10 Thiodan
20	1	20	D*
16	10	6	8 Thiodan
21	D*	D*	P*
13	7	21	5 Dibrom
5	14	12	1 Dimethoate
1	3	15	9 Thiodan
11	8	16	4 Phosphamidon

[1] Each plot represents one tree; trees spaced 36 feet square.
*= Not in test; D= Red Delicious, P= Twenty Ounce Pippin.

Table II. Materials, formulations, quantities and code numbers for Experiment II.

Material	Formulation[1] (%)	Amount Active Insecticide Per 100 Gallons of Spray (lb.)	Treatment Identification[2] (#)
Ethyl Guthion	25 EC	0.50	6
Korlan	24 EC	0.50	11
Phosdrin	25 EC	0.25	2
Sevin	75 FC	0.50	12
Compound 4402	15 EC	0.50	4
Compound 5539	20 EC	0.50	5
Compound 5727	15 EC	0.50	13
Compound 22408	50 WP	0.50	7
Compound 25141	24 EC	0.50	8
Compound 29493	47 EC	0.50	9
Compound 30494	25 EC	0.50	1
Compound 30686	50 WP	0.50	10
VC-13	75 EC	0.50	3
Control	---	---	14,15

1 WP= wettable powder; EC= emulsifiable concentrate; FC= flowable concentrate.

2 See Figure 2.

Figure 2. Plot Design of Experiment II.[1]

			Rep. IV
			13 Compound 5727
		Rep. III	10 Compound 30686
	Rep. II	13	7 Compound 22408
	13	15	P*
	3	9	8 Compound 25141
	2	5	12 Sevin
Rep. I	10	4	15 Control
13	P*	12	6 Ethyl Guthion
3	8	6	1 Compound 30494
4	7	1	4 Compound 4402
9	15		
11			
15			
6	1		
7	12		
2	5	10	11 Korlan
8	14	11	3 VC-13
10	4	2	14 Control
12	11	8	D*
5	9	3	2 Phosdrin
1	6	7	9 Compound 29493
14		14	5 Compound 5539

[1] Each plot represents one tree; trees spaced 36 feet square.
*= Not in test; D= Red Delicious, P= Twenty Ounce Pippin.

Table III. Temperature and precipitation data, July 19-September 14, 1959, Benton Harbor Station, Michigan.[1]

Date	Daily Precipitation (inches)	Average Temperature (degrees Farenheit)
July		
19	.05	70
20	0	67
21	0	72
22	0	76
23	1.77	73
24	Trace	72
25	0	63
26	0	66
27	0	72
28	.36	78
29	.20	79
30	.09	80
31	0	72
August		
1	0	72
2	0	72
3	.27	71
4	Trace	72
5	0	75

[1] Climatological Data of Michigan, U.S. Department of Commerce, Weather Bureau. Volume LXXIV; Numbers 7,8,9, 1959.

Table III. (continued)

Date	Daily Precipitation (inches)	Average Temperature (degrees Farenheit)
August		
6	0	76
7	Trace	77
8	Trace	69
9	0	68
10	0	66
11	Trace	75
12	0	79
13	0	80
14	0	79
15	1.26	80
16	.13	75
17	.14	76
18	0	71
19	0	75
20	0	80
21	0	83
22	0	83
23	.10	83
24	0	79
25	0	79
26	0	82
27	0	80
28	0	78

Table III. (continued)

Date	Daily Precipitation (inches)	Average Temperature (degrees Farenheit)
August		
29	Trace	78
30	0	76
31	0	74
September		
1	Trace	68
2	0	70
3	0	73
4	0	72
5	0	75
6	0	81
7	Trace	81
8	.05	75
9	0	73
10	0	72
11	0	63
12	0	53
13	0	54
14	0	60

Month	Total Precipitation	Average Temperature
July	2.47 inches	73°F.
August	1.90 inches	76°F.
September . .	.05 inches	70°F.

EXPERIMENTAL RESULTS

The analylitical results of Experiment I and II are presented in Tables IV and V. An analysis of variance was performed using means derived from the count-rate determinations. The mean values presented in the tables depict the average leaf pairs containing more live than dead apple aphids and not actual numbers of insects per leaf.

Interpretation of the analysis of means for the respective treatments is facilitated by a lettering system corresponding to the significance of the results. This method provides for a rapid and accurate comparison of the individual results within a complex experiment designed to evaluate an extensive group of treatments.

Any two means within a specific interval may be compared by association of the adjoining letters. Results of treatments presented in conjunction with common letters are not significantly different at the five per cent level. Means sharing all symbols dissimilar are different significantly at five per cent. Treatments with greater mean values indicate inferior control to materials exhibiting lesser mean results, and significant differences may be ascertained readily by the letter system.

Graphic analysis of per cent reduction from controls and delineation of actual mean values for those treatments of Experiments I and II with initial effectiveness in excess of 80 per cent are presented in Figures 3 through 6.

Calculations of per cent reduction were based on the average of the control means and by a modified application of Abbot's Formula[1] for the use of count-rate determinations. The per cent reductions (Figures 3,5) were derived from the numerical values depicted in Figures 4 and 6 respectively.

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[1] per cent effectiveness

$$= \frac{(\text{count-rate control}) - (\text{count-rate treatment})}{(\text{count-rate control})} \times 100$$

Table IV. Mean number of leaf pairs with more live than dead apple aphids as determined for the various treatments of Experiment I.[1]

Material[4]	Mean Number of Leaf Pairs with more Live than Dead Apple Aphids at Various Intervals from Application[2] and Significant Differences Between Treatments[3]						
	(prespray)	(7 days)	(14 days)	(21 days)	(28 days)	(35 days)	(45 days)
Diazinon	1.65a	0.65bc	0.90bc	1.90b	2.33bc	2.43a	2.08ab
Dibrom	1.63a	0.58bcde	0.90bc	1.95b	2.44ab	2.18ac	2.10a
Dimethoate	1.55a	0.38cg	0.40c	0.95gh	1.50ij	1.83de	1.70eg
Dimethoate	1.48a	0.03fg	0.15c	0.93gh	1.23k	1.53f	1.53g
Endrin	1.70a	0.28cg	0.40c	1.60c	2.13ce	2.30ab	1.95acd
Ethion	1.65a	0.45cdef	0.58c	1.85b	2.28bcd	2.33ab	1.98acd
Guthion	1.48a	0.25cg	0.50c	1.38ce	1.98ef	2.20ac	1.85ae
Malathion	1.28a	0.25cg	0.70c	1.50cd	2.03def	2.23ab	1.93acd
Methyl Trithion	1.30a	0.63bcd	1.03bc	2.03ab	2.38ac	2.43a	2.03ac
Parathion	1.63a	0.60bcde	0.90bc	1.95b	2.20bce	2.30ab	2.00acd
Phosphamidon	1.55a	0.18eg	0.50c	1.33def	1.58hij	1.90cd	1.75def
Phosphamidon	1.60a	0.00g	0.28c	0.85h	1.23k	1.60f	1.58fg
Phostex	1.43a	0.93b	1.30ac	1.98b	2.44ab	2.40a	2.00acd
Ryania	1.45a	0.65bc	1.05bc	1.90b	2.38ac	2.38a	1.98acd
Sevin	1.68a	0.20dg	0.58c	1.53cd	1.88fg	2.15ac	1.90ae
Systox	1.78a	0.10fj	0.28c	1.10fgh	1.48ij	1.85de	1.80ce
Thiodan	1.28a	0.43cdef	0.63c	1.15eg	1.70ghi	2.00bcd	1.80ce
Thiodan	1.40a	0.35cg	0.58c	1.18eg	1.78gh	2.00bcd	1.83bce
Thiodan	1.45a	0.20dg	0.23c	0.95gh	1.40kj	1.68f	1.85ae
Trithion	1.25a	0.45cdef	0.78c	1.93b	2.28bcd	2.40a	1.88acd
Control	1.50a	2.13a	1.98a	2.10ab	2.40ac	2.25ab	1.98acd
Control	1.68a	1.98a	1.80ab	2.33a	2.63a	2.23ab	2.03ac

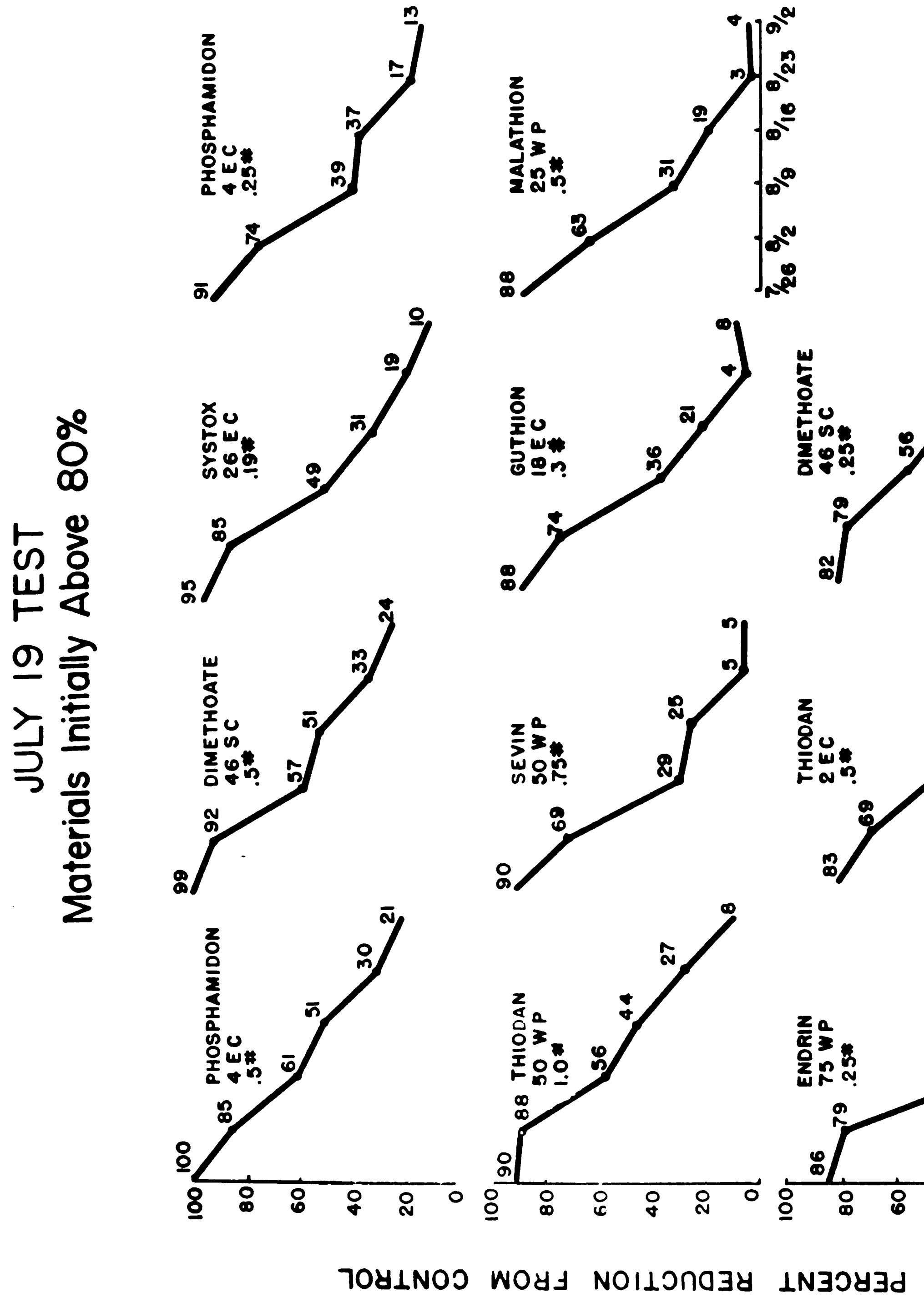
[1] Materials applied July 19, 1959.
[2] Data taken; July 19, 26; August 2, 9, 16, 23; September 2, 1959.
[3] Means not bearing a common letter are significantly different at the 5% level; means sharing any similar letter are not significantly different at the 5% level.
[4] Refer to Table I for formulations and dosages.

Table V. Mean number of leaf pairs with more live than dead apple aphids as determined for the various treatments of Experiment II[1]

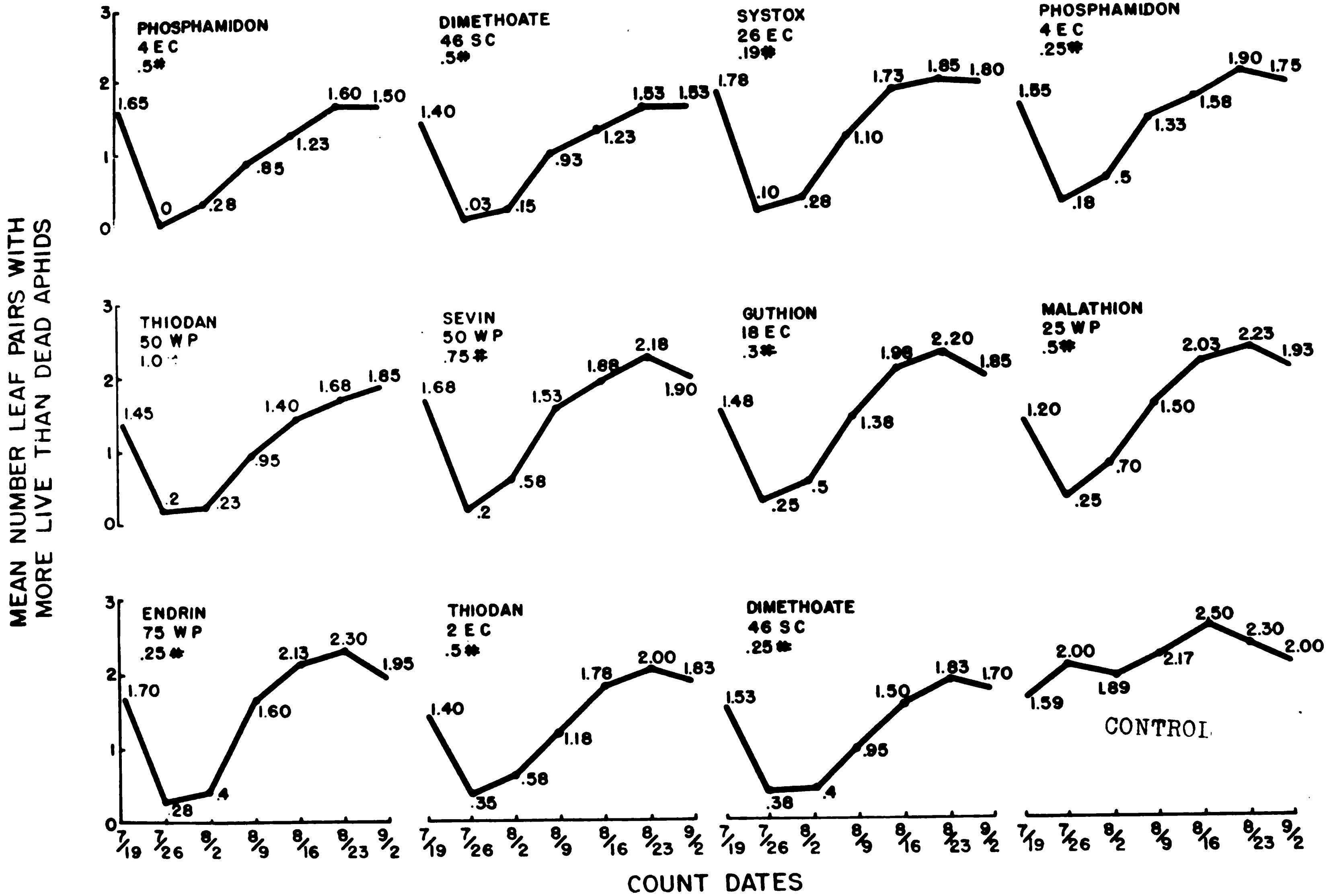
Material[4]	Mean Number of Leaf Pairs with more Live than Dead Apple Aphids at Various Intervals from Application[2] and Significant Differences Between Treatments[3]						
	(prespray)	(7 days)	(14 days)	(21 days)	(28 days)	(35 days)	(45 days)
Ethyl Guthion	1.42a	0.08d	1.12d	1.70ef	1.78de	1.75bc	0.58a
Korlan	1.35a	0.15d	1.32cd	1.92ce	2.00bc	1.88ac	0.50a
Phosdrin	1.60a	0.18d	0.60e	1.75de	1.75de	1.88ac	0.58a
Sevin	1.52a	0.05d	0.75e	1.42fg	1.68e	1.70ce	0.50a
Compound 4402	1.48a	0.18d	0.70e	1.25g	1.32g	1.58e	0.58a
Compound 5539	1.48a	0.20d	0.75e	1.70ef	1.75de	1.75bc	0.55a
Compound 5727	1.18a	0.08d	0.78e	1.38g	1.50f	1.58e	0.45a
Compound 22408	1.60a	1.28b	2.08b	2.25ab	2.08ac	1.95a	0.48a
Compound 25141	1.45a	1.15b	2.05b	2.38ab	2.25a	1.92ab	0.60a
Compound 29493	1.60a	0.40d	1.52c	2.05bcd	1.92cd	1.78ac	0.50a
Compound 30494	1.55a	0.38d	1.40c	1.82de	1.82de	1.82ac	0.50a
Compound 30686	1.32a	0.72c	1.52c	2.18ac	2.08ac	1.85ac	0.50a
VC-13	1.52a	1.10b	2.05b	2.35ab	2.00bc	1.88ac	0.50a
Control	1.60a	1.55a	2.38a	2.32ab	2.10ac	1.90ab	0.58a
Control	1.55a	1.60a	2.35a	2.42a	2.18ab	1.90ab	0.65a

1 Materials applied July 30, 1959.
2 Data taken; July 30; August 6, 13, 20, 27; September 3, 13, 1959.
3 Means not bearing a common letter are significantly different at the 5% level; means sharing any similar letter are not significantly different at the 5% level.
4 Refer to Table II for formulation and dosages.

Figure 3. Experiment I, per cent reduction from controls for those materials with initial effectiveness above 80 per cent.



JULY 19 TEST
Materials Initially Above 80%



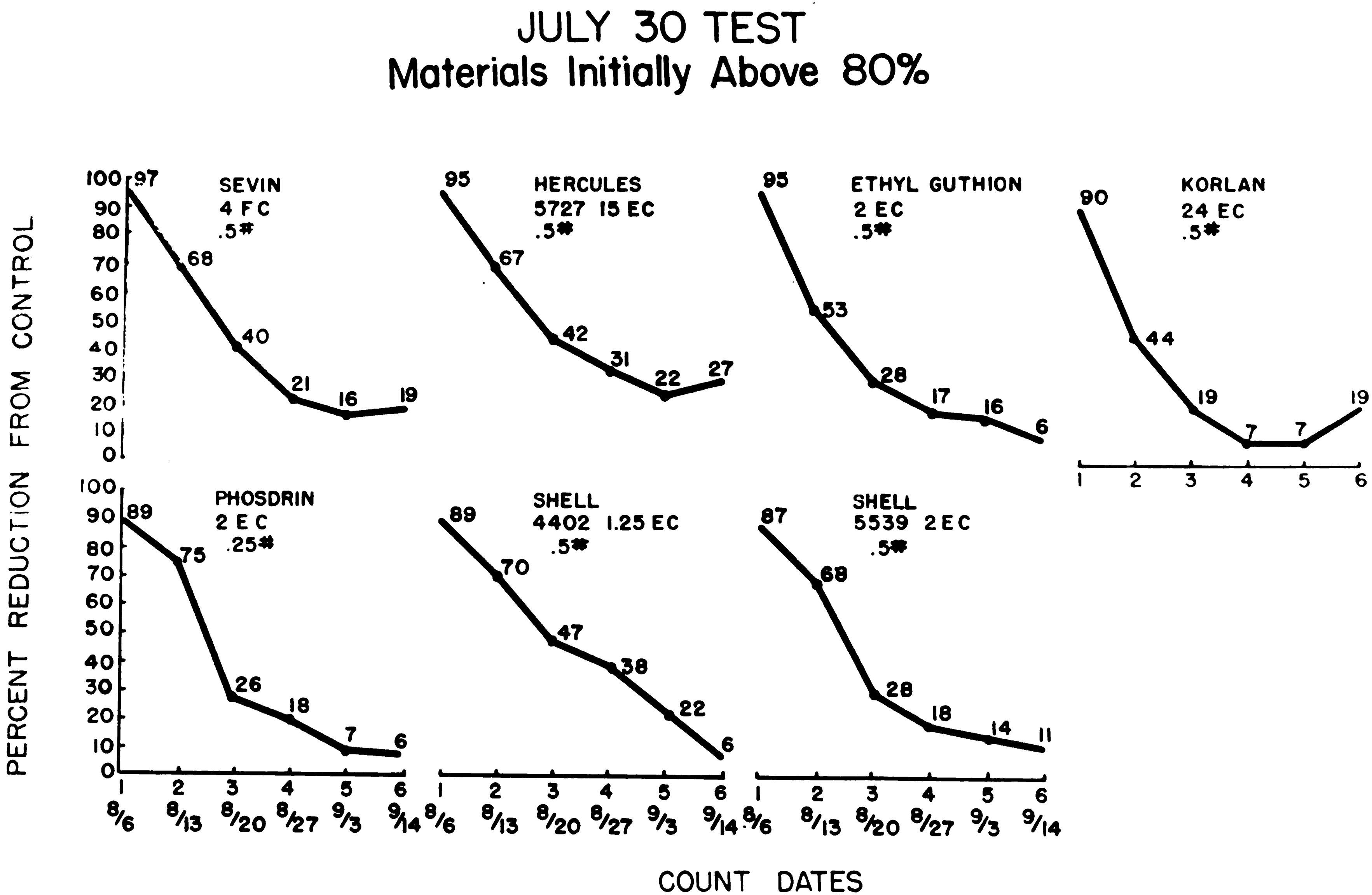


Figure 5. Experiment II, per cent reduction from controls for those materials with initial effectiveness above 30 per cent.

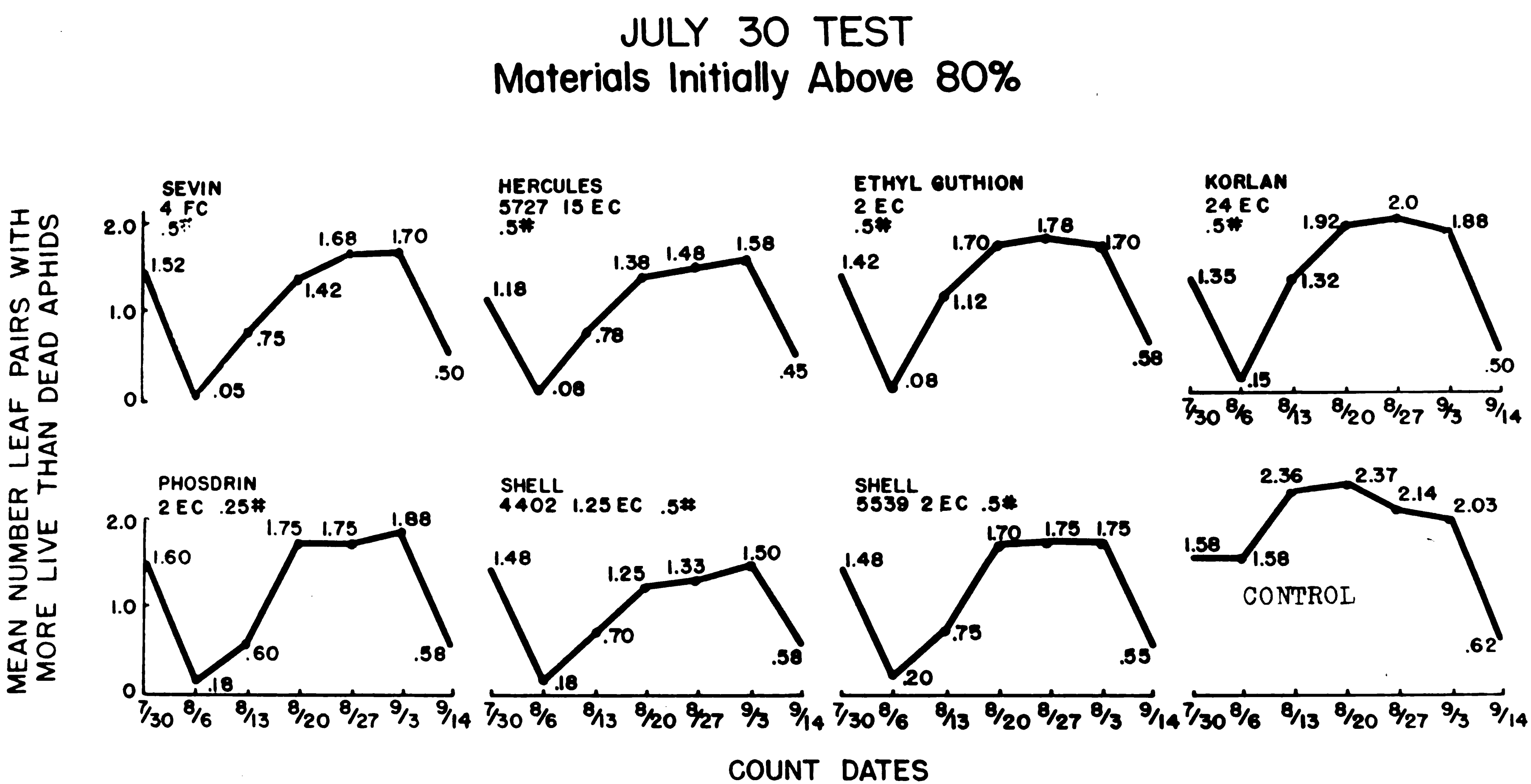


Figure 6. Experiment II, mean number of leaf pairs with more live than dead apple aphids for those materials with initial effectiveness above 80 per cent.

DISCUSSION

Biological Activity of *Aphis pomi* DeGeer. During the course of this study[1] observations were made on the biological activity of *A. pomi* in Southwestern Michigan. These facts are correlated with experimental evaluation of recently developed insecticides to provide additional knowledge of the control of the apple aphid.

Initial apple aphid populations were observed to be in the proposed test area during petal fall (May 15-22). By the first week in June, the aphids had infested the interior shoot growth, through the first pair of leaves from the terminal tip. Actual counts ranged from 10 to more than 100 aphid forms per leaf pair. Reproduction had taken place by early June because some of the apple aphids present were alates.

The experimental blocks had a history of serious infestations of this pest. Cultural practices, such as extensive dormant pruning, a perennial fertilization program, and sod-mulch-cultivation produced vigorous growth of new tissue each season. Combinations of these factors with the specific host relationship of the Twenty Ounce Pippin has created an ideal environment for apple aphids. Because of increasing populations in recent years specific controls have been required to prevent economic losses of fruit. Chemical choices were dormant oils and

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[1] May-September, 1959.

dinitro-compounds with the inclusion of aphicides during the growing season. The constant use of conventional dosages of parathion as a preventative measure for increases in aphid populations became less successful and more costly each year. The need for efficient aphicides had become important.

Actual counts of A. pomi populations were continued through June, but as infestations increased, counting procedures became cumbersome. Population densities of aphids resulted from prolonged migration of both alate and apterous forms to actively growing tissue. The adult aphids seldom were observed beyond the fifth pair of leaves from a terminal tip; consequently, active colonies of A. pomi were located consistently nearest the shoot tips. Parthenogenetic young invariably fed on newly expanded leaves, crowded between the tip and fourth pair of leaves. Factors such as migration, intense feeding and rapid plant growth have created the necessity of systemic compounds.

The method of population sampling used in these experiments was based on the biological activities of A. pomi, with special emphasis on feeding habits. The count-rate technique was designed for rapid evaluation of surface residual and systemic-type aphicides; and, also to provide a practical sampling procedure.

By mid-July count-ratings from the peripheral area of several trees averaged one and means of water-sprout counts equaled two. Since the population density had attained sufficient proportions to cause foliage and fruit injury the experimental treatments were applied.

The apple aphid is an economically important insect, generally being categorized as a nuisance pest. In the plots, the aphids were persistent. Wherever consistent control was not obtained several types of injury usually occurred. Excreted matter on fruits was the most serious. Fluid-like and sticky, this substance became discolored by a secondary fungus growth which reduced the market value of many fruits. Excessive feeding had caused terminal die back and leaf drop; and some fruit did not attain mature size or color as a direct result of aphid damage.

Therefore, since the apple aphid is considered more of a nuisance than a serious apple pest, it is logical to assume that control methods should not be disproportionate economically to the degree of injury.

Population densities of apple aphids had attained maximum values during mid-August (Figures 4, 6). This increase which was in opposition to the results of chemical treatments indicated an ideal testing of the materials. Infestations declined rapidly following the peak. The prime factors for these population decreases were lack of precipitation, temperatures in excess of the normal (Table III) and maturity of plant tissue.

<u>Evaluation of Chemical Controls</u>. A detailed statistical analysis was made of the treatment data. The application of significant difference constants to the ranked means of

treatments for the various intervals separating the means provided a rigorous statistical proof of the merits of the evaluated materials. This method will produce reliable conclusions from experimental results if the sampling techniques accurately represent the population.

A condensed description of analyzed data can be complicated by the many comparisons possible among the means of the treatments. Therefore, a lettering system was attached to the mean values. This method simplified the interpretation of the data in terms of significant difference.

Because Experiments I and II were autonomous no comparative conclusions were made. The experiments were not repeated because duplicate field and environmental conditions were unobtainable. However, the data from the statistical analysis permits reasonable expression of confidence that if the treatments were reproduced, comparable results would occur. Therefore, a quantity of insecticides was evaluated exposed to similar field conditions in the anticipation of providing a wide range of information concerning chemical control of apple aphids.

Materials with outstanding aphicidal properties from Experiment I (Table IV) were Dimethoate, Phosphamidon and Thiodan. Each of these chemicals provided commercial control through 21 days from date of application. Commercial control is defined herein as equivalent to 1.5 or less mean count rates. Increased dosages of Dimethoate and Phosphamidon were successful for at least four weeks. All materials with the exception of Diazinon, Dibrom, Methyl Trithion, Parathion, Phostex and Ryania produced control for 14 days after application. There were significant differences between Dimethoate and Phosphamidon and the controls at the 45 day interval, but in all treatments population densities exceeded commercial acceptability.

Dimethoate, Phosphamidon and Systox exhibited systemic qualities with extended residual activity, since plant growth dilution and continuous aphid migration eliminated the possibility of surface contact control. Results from the maximum rate of Thiodan indicated a possibility of systemic activity.

In Experiment II several compounds were tested for aphid control for the first time (Table V). Phosdrin and Sevin were established as standard materials for comparison.

Results were generally disappointing, since compounds 22408, 25141 and VC-13 were not effective. Ethyl Guthion, Korlan, Compound 29493, 30494 and 30683 produced partial control with ineffective residual activity seven days after application. Compound 5539 compared favorably with the standards, but acceptable control did not continue beyond two weeks. Only Compounds 4402 and 5727 exhibited extended aphicidal properties.

From these experiments examination of data[1] reveals the fact that surface-residual materials were limited in duration of control primarily because of plant growth and reinfestation. However, several of the compounds could be included satisfactorily in a commercial control program. The obvious

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[1] Refer to Tables IV,V and Figures 3,5.

choice should be systemics since the longevity of aphicidal properties reduces the necessity of frequent applications.

Method of Sampling. The accuracy in analysis of variance and subsequent application of statistical devices is dependent on the sampling method utilized for data collection. When the sampling techniques reflect a true random section of the parameter population, the statistical procedures will produce an accurate potrayal of the effects of the variable tested.

Madsen and Bailey (1959) reported on apple aphid control using total numbers of dead and live forms on a single leaf as criterion for evaluation. However, their method entailed extensive counting procedures and failed to account for translocation factors of systemic materials.

The technique applied in this research was an attempt to sample the entire population of apple aphids for each terminal. Because the count-rate method included the expanding terminal tips the system was applicable to cases of translocated materials.

Therefore, it would be reasonable to assume that since the count-rate method was rapid and reliable, the technique could have practical implications. Growers troubled by apple aphid problems in their orchards could estimate easily the necessity of chemical control by applying the principles of this method.

SUMMARY AND CONCLUSIONS

This investigation is briefly summarized as follows:

1. The biological activity of the apple aphid, Aphis pomi DeGeer, in a Southwestern Michigan orchard was observed during the growing season of 1959. Distribution and feeding habits were correlated with chemical control experiments.

2. A group of 28 insecticides were evaluated on Twenty Ounce Pippin variety of apples. Performance data were analyzed statistically; control merits were established by comparison of significant differences among the treatment means.

3. A rapid method of sampling parameter populations was developed to facilitate the evaluation of the chemicals for apple aphid control.

The following conclusions were drawn from the results of this research:

1. Apple aphids prefer feeding on succulent foliage and continuously migrate to newly expanded leaves.

2. The insect is economically important because of its persistent occurrence. Several types of injury result if consistent control is not obtained.

3. Aphid populations increased to treatment proportions by mid-July. Peak period occurred during mid-August. Infestations declined rapidly following the peak.

4. Insecticides outstanding for chemical control of the apple aphid were: Dimethoate, Phosphamidon, Systox, Thiodan, Compounds 4402 and 5727. None of the materials

tested demonstrated satisfactory control in excess of four weeks after treatment.

5. Chemicals exhibiting systemic properties with extended residual activity gave the best control. Surface residual compounds were limited in effectiveness by plant growth dilution and reinfestation.

6. Count-rate determinations represented an accurate sampling of the parameter population. Statistical procedures for proof of significance were applicable to count-rate data.

7. The count-rate method for evaluation of apple aphid control eliminates actual determinations of aphid numbers. Technique is rapid, accurate and practical for usage by commercial apple growers.

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