A STUDY OF THE EFFECT OF INGREDIENTS IN INSECTICIDES ON THE BEHAVIOR OF THE JAPANESE BEETLE

DISSERTATION

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CONTENTS

<u>Section I</u>

<u>Section II</u>

<u>Section III</u>

LIST OF TABLES

Section I

Section II

Section III

Section IV

List of Figures

A STUDY OF THE EFFECT OF INGREDIENTS IN INSECTICIDES ON THE BEHAVIOR OF THE JAPANESE BEETLE

INTRODUCTION

The Japanese beetle (*Popillia japonica* Newman) is a major insect pest of great economic importance throughout a large eastern area of the United States. There is in all entomological literature no better example perhaps of an alien insect's response to a favorable new environment. The Japanese beetle has been known as a pest in Japan for many years. However, as it existed along with native parasites, it was held in check and had never been a pest of serious importance.

Dickerson and Weiss (1) are quoted as to the status of this insect in Japan:

> Mr. C. H. Uchida was kind enough to translate accounts of this insect as given in two Japanese textbooks. The first one is that given by S. Matsumura in his *Japanese Insect Pests*, part 2, p. 247. He states that the beetles do considerable damage to string beans, grapes, and certain wild beans; that the adults emerge in June and remain until September; that they are attracted by lights and controlled by hand picking and spring and fall plowing. The other account is that given by A. Fukatani in *Practical Methods of Destroying Insects on Horticultural Plants*, p. 325.....He also states that control is effected by jarring the beetles off the plants into a dish of oil and water; by jarring them from trees to a cloth spread below; by spraying with Paris Green and Bordeaux mixture and by the use of Vaporite in the soil, also that the use of organic manure and especially compost should be avoided.
>
> From these two accounts it is evident that *Popillia japonica* is regarded as a pest in Japan.

The beetle was probably introduced into the United States in the larval stage in soil around iris roots imported from Japan. From a single focus of infestation at a New Jersey nursery, where it was first discovered in August, 1916, the beetle spread rapidly. Britton and Johnson (2) note that at the time of the discovery of the beetle the infestation was confined to an area of a few hundred yards; in 1917, the infestation covered 2.7 square miles. By 1937, more than 100,000 square miles of the eastern United States was under federal quarantine because of this pest.

ECOLOGICAL CONSIDERATIONS

The amazing success of the Japanese beetle in its new environment is due to several ecological factors. Ecology has been defined as "the relationship of an organism to its environment." In the case of the Japanese beetle, the insect has been endowed by nature with a ravenous phytophagous appetite and a high biotic potential. These two factors together with the introduction of the insect into an environment with an abundance of food and an absence of most natural enemies, were ecologically responsible for the rapid population increase in the United States.

Life History and Feeding Habits of the Japanese Beetle

In Maryland the adult beetles begin to emerge from the sod lands about the second week in June. The time of emergence varies with the latitude and the weather conditions. Once emergence has started, the beetles continue to emerge in ever increasing numbers until the peak population is reached about the third week in July. From this time they decrease in numbers until by mid-September they are rarely seen, although a few stragglers may be found in sunny fields even after the first frosts.

The adult beetles are known to feed on more than 260 species of plants. They feed particularly on many of the small fruits, ornamental shrubs, shade trees, and flowering garden plants grown around the average home, garden or orchard. For this reason, the study of control methods began almost simultaneously with the appearance of the Japanese beetle in Maryland. Extensive investigations into the life history and into the control of the beetle have been made by the entomologists of the University of Maryland for over twenty years.

Sweet, or canning, corn is one of the major crops of the Maryland farmer. Corn silk is one of the favorite foods of the Japanese beetle. The Japanese beetle is important in the economics of canning corn production, not because of the amount of corn or plant foliage that it devours, but because by cutting the silks it prevents pollination and the subsequent development of the kernels. Unfortunately, the critical time of silking and pollination coincides with the peak period of Japanese beetle population. Coon (3) demonstrated that if the corn silk could be protected for seven hours after pollination, the kernels would be well fertilized, and a full ear of corn would develop. Langford, Rothgeb and Cory (4) advocated late planting of corn to assure that the silking period occurred after the emergence peak of the beetles. They suggested the following planting dates for northern Maryland:

Long season corn	May 25 to June 1
Medium season corn	June 1 to June 7
Short season corn	June 7 to June 14

Farmers cannot follow the above schedule with sweet corn because the time of planting is determined by the canner, who must arrange the planting dates so that all the corn does not arrive at the canning stage at the same time. For this reason, the corn may be silking at the time when beetle population is the greatest. The farmer must depend, therefore, on insecticides to control the Japanese beetle. The most satisfactory insecticides developed for this purpose, to date, is DDT. One pound of DDT (100%) dissolved in a solvent and properly applied is sufficient to control the beetles on an acre of corn. However, the residue of DDT is long lasting and creates a problem for the grower who wishes to feed the treated fodder to dairy cows or to beef cattle. For this reason the search for new and better insecticides for the spraying of corn has continued.

THE PROBLEM

Hadley and Hawley (5) call attention to the fact that although the Japanese beetle is known to feed on approximately 260 different plants, it shows a very definite preference for certain plants. Why, for example, are grape and raspberry leaves reduced to a skeletonized condition by the feeding beetles while dewberry and gooseberry leaves are left unharmed? The ecological factors involved in the feeding of the Japanese beetle are determined largely by attractant and repellent substances in the plants on which the beetle feeds.

While studying the mortality of beetles in corn fields treated with DDT, the observer noted that there were apparently more beetles feeding in the fields the day after the insecticide had been applied than before. The apparent influx of beetles into the treated field suggested that their feeding habits were influenced by the insecticide applied to the foliage.

Do insecticides or do any of the ingredients of insecticides, have properties that would attract or repel insects? Should the manufacturer of insecticides consider more carefully what killing agent he selects, what solvent he uses to dissolve the killing agent and what emulsifier he adds when he formulates an insecticide for the market?

This dissertation is a study of experiments designed to answer these questions.

METHODS AND MATERIALS USED IN 1950

The Japanese beetle was chosen as the test insect to be used in the experiment because it was available in large numbers; it was known to have a well developed olfactory sense and field observations of its behavior had aroused the questions that are the problems in this study.

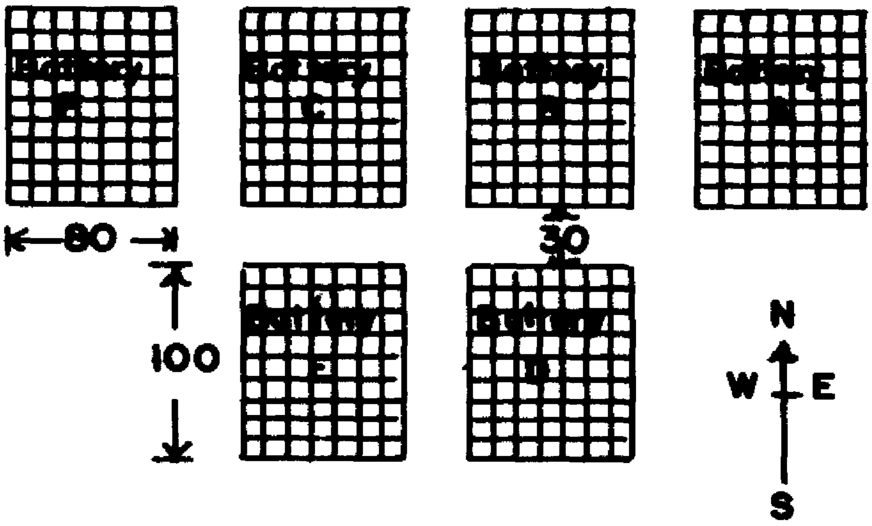
Since the problem was to determine the effect of insecticides and of ingredients used to formulate insecticides on the feeding of the Japanese beetle some method of measuring the response had to be devised. Dethier (6) classifies stimuli as chemical and physical. Insecticides are stimuli that can affect the feeding of the Japanese beetle in one of two ways — chemically or physically. That is, the odor of the insecticide could by the effect on the olfactory sense organs attract or repel the beetle, or the presence of the insecticide on the plant could be physically attractive or repulsive to the tactile sense organs of the insect. It was impractical to make large scale observations by treating the food plants with insecticides and then counting the number of insects on the plants because of the restless nature of the Japanese beetle. (Note. However, this was tried on a limited scale in 1951. See page 50.) Therefore, a trapping experiment was chosen as the most logical method of obtaining the data.

Early in July, 1950, when the annual flight of the Japanese beetles had begun, six batteries of standard Japanese beetle traps were placed in a large pasture at the University of Maryland experimental farm. Each battery was composed of 80 traps, subdivided into four replicates of 20 traps. Each replicate was composed of 18 traps containing a test material and two check traps, one containing a standard attractant material, the other an empty bait bottle. The standard attractant was the Japanese beetle bait used throughout the state of Maryland in the summer of 1950, and it was included in the battery as a standard of measure with which the test materials could be compared. The empty bottle was added to the battery to check whether the beetle was attracted or repelled by the test materials or whether they entered the traps through chance. The purpose of the replication was to reduce the experimental errors and to provide an estimate of the size of these experimental errors. The replicates were arranged in eight rows of ten traps with a ten foot interval between traps. An arbitrary interval of 30 feet was established between the batteries of traps (See Fig. I). Each test material was moved to a new position within the battery daily to overcome placement effect (See Fig. 2). Forty cubic centimeters of the solution to be tested was placed in a standard, wide mouth, glass bait bottle, a wick inserted and the bottle placed in the trap. A quart Mason jar mounted beneath the trap collected all beetles that entered. The Mason jars were inspected daily and emptied. If the number of beetles collected was estimated by visual inspection to be 100 or less, a physical count was made. If the number was greater than 100, the beetles were transferred to a graduate cylinder, and a graduated scale used to determine the number. The scale had been calibrated in earlier experiments and it had been determined that a close approximation to the actual number could be obtained by this method. The collection of beetles began on July 10, 1950, and was discontinued on August 20, 1950, when the population became so low that further collection of data would have been useless. In theory, Japanese beetles flying over the experimental area would be guided to attractant materials and away from repellent materials. The attractant or repellent value of the materials was determined from the number of beetles collected from the traps.

The experiment was divided into the following tests:

1. In Batteries A and B (See Tables I and II) the response of the Japanese beetle to certain ingredients of insecticides was tested by using the ingredients as baits.
2. In Batteries C and D (See Tables III and IV) the response of the Japanese beetle was tested when four cc of a standard attractant was added to 36 cc of each test ingredient.
3. In Battery E (See Table V) the response of the Japanese beetle was tested when 10 cc of a solution of 52 grams of technical DDT dissolved in 100 cc of xylene was added to 30 cc of each ingredient tested in Battery A.
4. In Battery F (See Table VI) the response of the Japanese beetle was tested when exposed to the killing agents used in some of the newer insecticides.

FIGURE 1. The Arrangement Of The Experimental Traps In The Field. (1950)



SCALE □ = 20feet

FIGURE 2. The Daily Pattern Of Rotation Of The Traps In The Battery. (1950)

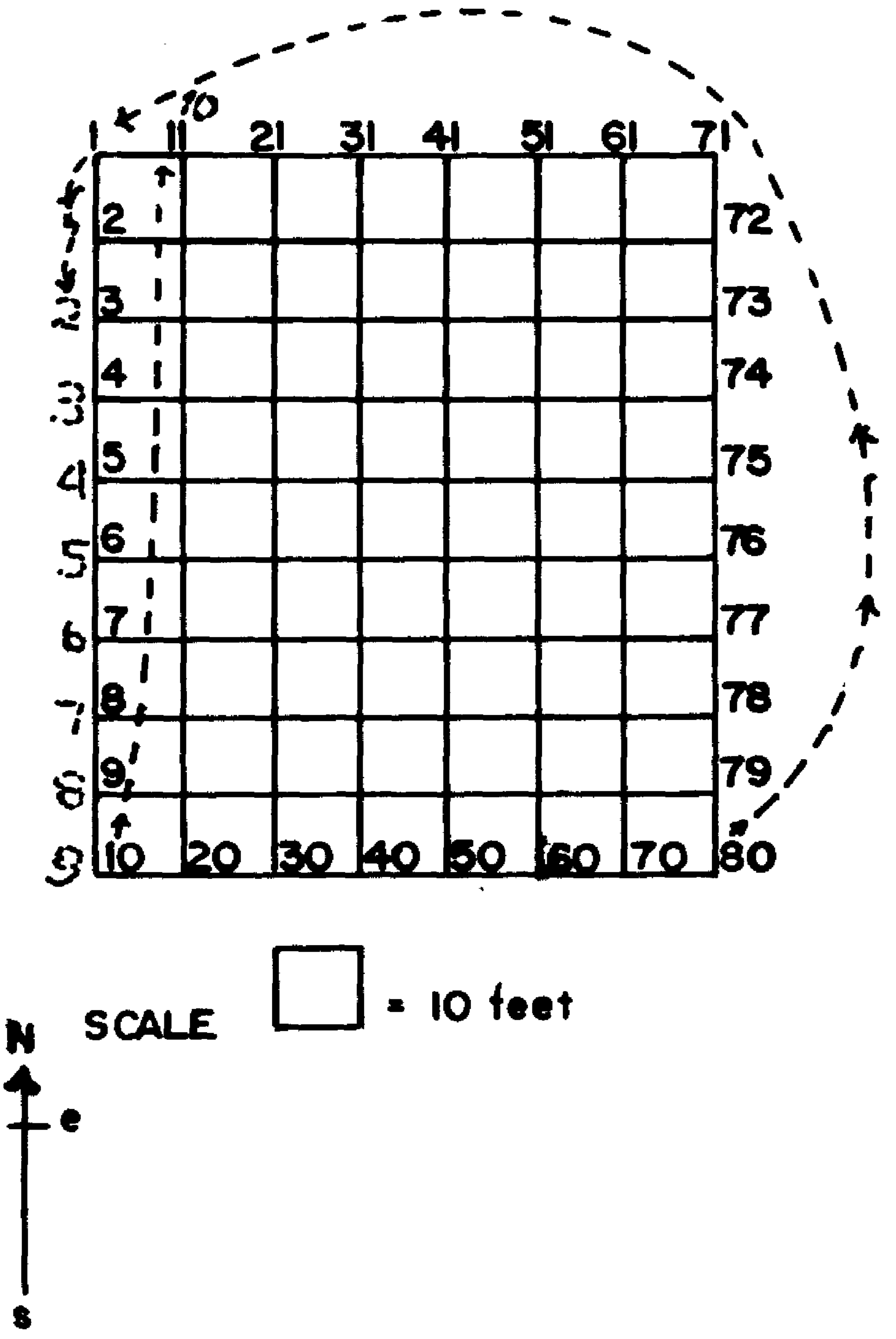


TABLE I

BATTERY A - The composition of a battery designed to test the attractant or repellent value of certain ingredients of insecticides.

Rep 1	Rep 2	Rep 3	Rep 4	Material	Type
A 1	A 21	A 41	A 61	Kerosene (Regular run) Fuel Oil No. 1	Solvent
A 2	A 22	A 42	A 62	Kerosene (odorless)	Solvent
A 3	A 23	A 43	A 63	Fuel Oil No. 2	Solvent
A 4	A 24	A 44	A 64	Solvent	Solvent
A 5	A 25	A 45	A 65	Velsicol AR 50 (B-18756)	Solvent
A 6	A 26	A 46	A 66	Velsicol AR 55	Solvent
A 7	A 27	A 47	A 67	Velsicol AR 60	Solvent
A 8	A 28	A 48	A 68	Vapona D-43	Insecticide
A 9	A 29	A 49	A 69	Benzene	Solvent
A 10	A 30	A 50	A 70	Xylene	Solvent
A 11	A 31	A 51	A 71	Deobase	Solvent
A 12	A 32	A 52	A 72	Sovacide s/v 544-B	Solvent
A 13	A 33	A 53	A 73	Sovacide s/v 544-C	Solvent
A 14	A 34	A 54	A 74	Sun Solvent	Solvent
A 15	A 35	A 55	A 75	Insecticide base (Shell)	Solvent
A 16	A 36	A 56	A 76	E-407 R (Shell)	Solvent
A 17	A 37	A 57	A 77	Ultracene	Solvent
A 18	A 38	A 58	A 78	Cyclohexanone	Synergist
A 19	A 39	A 59	A 79	*Standard bait	Bait
A 20	A 40	A 60	A 80	Empty	Check

* Formula:

anethol........................	8 parts
eugenol........................	1 part
phenyl ethyl acetate...........	1 part

TABLE II

BATTERY B - The composition of a battery designed to test the attractant or repellent value of certain ingredients of insecticides.

Rep 1	Rep 2	Rep 3	Rep 4	Material	Type
B 1	B 21	B 41	B 61	Mineral Oil	Solvent
B 2	B 22	B 42	B 62	Mineral Oil (extra heavy)	Solvent
B 3	B 23	B 43	B 63	Mistol (light)	Solvent
B 4	B 24	B 44	B 64	Atlas Span 85 (Batch 2097A)	Emulsifier
B 5	B 25	B 45	B 65	Atlas G-1276 (Batch 3945A)	Emulsifier
B 6	B 26	B 46	B 66	Atlas Tween 20 (Batch 554A)	Emulsifier
B 7	B 27	B 47	B 67	Atlas Span 20 (Batch 2352A)	Emulsifier
B 8	B 28	B 48	B 68	Triton X-100	Emulsifier
B 9	B 29	B 49	B 69	Atlas G-1276 (Batch 3072)	Emulsifier
B 10	B 30	B 50	B 70	Atlox	Emulsifier
B 11	B 31	B 51	B 71	Ethofat 242/25 (lot 451)	Emulsifier
B 12	B 32	B 52	B 72	Ethoneen s/15 (lot 436)	Emulsifier
B 13	B 33	B 53	B 73	Arqua 0-2C (lot 6297)	Emulsifier
B 14	B 34	B 54	B 74	Tenlo-400 (Griffin)	Emulsifier
B 15	B 35	B 55	B 75	Nonisol-210	Emulsifier
B 16	B 36	B 56	B 76	Literite T	Emulsifier
B 17	B 37	B 57	B 77	Methoxychlor (50%) 10 gms. + 30 cc Mineral Oil	Insecticide
B 18	B 38	B 58	B 78	Lindane 10 gms. + 30 cc Mineral Oil	Insecticide
B 19	B 39	B 59	B 79	*Standard Bait	Bait
B 20	B 40	B 60	B 80	Empty	Check

* Formula:

anethol........................8 parts
eugenol........................1 part
phenyl ethyl acetate...........1 part

TABLE III

BATTERY C - The composition of a battery designed to test the attractant or repellent value of certain ingredients of insecticides with four cc of a standard attractant added to each test ingredient.

Rep 1	Rep 2	Rep 3	Rep 4	Material 36 cc	Adative 4 cc
C 1	C 21	C 41	C 61	Kerosene (Regular run)	Standard bait
C 2	C 22	C 42	C 62	Kerosene (odorless)	Standard bait
C 3	C 23	C 43	C 63	Fuel Oil No. 2	Standard bait
C 4	C 24	C 44	C 64	Solvent	Standard bait
C 5	C 25	C 45	C 65	Velsicol AR 50	Standard bait
C 6	C 26	C 46	C 66	Velsicol AR 55	Standard bait
C 7	C 27	C 47	C 67	Velsicol AR 60	Standard bait
C 8	C 28	C 48	C 68	Vaponia D-43	Standard bait
C 9	C 29	C 49	C 69	Benzene	Standard bait
C 10	C 30	C 50	C 70	Xylene	Standard bait
C 11	C 31	C51	C 71	Deobase	Standard bait
C 12	C 32	C 52	C 72	Sovacide 544-B	Standard bait
C 13	C 33	C 53	C 73	Sovacide 544-C	Standard bait
C 14	C 34	C 54	C 74	Sun Solvent	Standard bait
C 15	C 35	C 55	C 75	Insecticide Base (Shell)	Standard bait
C 16	C 36	C 56	C 76	E-407 R (Shell)	Standard bait
C 17	C 37	C 57	C 77	Ultracene	Standard bait
C 18	C 38	C 58	C 78	Cyclohexanone	Standard bait
C 19	C 39	C 59	C 79	*Standard bait	
C 20	C 40	C 60	C 80	Empty	Check

* Formula:

anethol......................8 parts
eugenol......................1 part
phenyl ethyl acetate.........1 part

TABLE IV

BATTERY D - The composition of a battery designed to test the attractant or repellent value of certain ingredients of insecticides with four cc of a standard attractant added to each test ingredient.

Rep 1	Rep 2	Rep 3	Rep 4	Material 36 cc	Addative 4 cc
D 1	D 21	D 41	D 61	Mineral oil	*Standard bait
D 2	D 22	D 42	D 62	Mineral oil (Heavy)	Standard bait
D 3	D 23	D 43	D 63	Mistol	Standard bait
D 4	D 24	D 44	D 64	Atlas Span 85 (2097A)	Standard bait
D 5	D 25	D 45	D 65	Atlas G-1276 (Batch 3945A)	Standard bait
D 6	D 26	D 46	D 66	Atlas Tween 20(Batch 554A)	Standard bait
D 7	D 27	D 47	D 67	Atlas Span 20 (Batch 2352A)	Standard bait
D 8	D 28	D 48	D 68	Triton X-100	Standard bait
D 9	D 29	D 49	D 69	Atlas G-1276 (Batch 3072)	Standard bait
D 10	D 30	D 50	D 70	Atlox	Standard bait
D 11	D 31	D 51	D 71	Ethofat 242/25	Standard bait
D 12	D 32	D 52	D 72	Ethoneen s/15	Standard bait
D 13	D 33	D 53	D 73	Arquao O-2c	Standard bait
D 14	D 34	D 54	D 74	Tenlo-400 (Griffin)	Standard bait
D 15	D 35	D 55	D 75	Nonisol - 210	Standard bait
D 16	D 36	D 56	D 76	Literite T	Standard bait
D 17	D 37	D 57	D 77	Rhothane lp cc + 30 cc xylene	
D 18	D 38	D 58	D 78	Penphene 10 cc + 30 cc xylene	
D 19	D 39	D 59	D 79	*Standard bait	
D 20	D 40	D 60	D 80	Empty	Check

* Formula:

anethol....................	8 parts
eugenol....................	1 part
phenyl ethyl acetate......	1 part

TABLE V

BATTERY E - The composition of a battery designed to test the effect of DDT on the attractant or repellent value of ingredients of insecticides.

Rep 1	Rep 2	Rep 3	Rep 4	Material 30 cc	Addative 10 cc
E 1	E 21	E 41	E 61	Kerosene (regular run) Fuel Oil No. 1	[1] DDT Solution
E 2	E 22	E 42	E 62	Kerosene (odorless)	DDT Solution
E 3	E 23	E 43	E 63	Fuel Oil No. 2	DDT Solution
E 4	E 24	E 44	E 64	Solvent	DDT Solution
E 5	E 25	E 45	E 65	Velsicol AR 50 (B-18756)	DDT Solution
E 6	E 26	E 46	E 66	Velsicol AR 55	DDT Solution
E 7	E 27	E 47	E 67	Velsicol AR 60	DDT Solution
E 8	E 28	E 48	E 68	Vapona D-43	DDT Solution
E 9	E 29	E 49	E 69	Benzene	DDT Solution
E 10	E 30	E 50	E 70	Xylene	DDT Solution
E 11	E 31	E 51	E 71	Deobase	DDT Solution
E 12	E 32	E 52	E 72	Sovacide s/v 544-B	DDT Solution
E 13	E 33	E 53	E 73	Sovacide s/v 544-C	DDT Solution
E 14	E 34	E 54	E 74	Sun Solvent	DDT Solution
E 15	E 35	E 55	E 75	Insecticide base (Shell)	DDT Solution
E 16	E 36	E 56	E 76	E-407R(Shell)	DDT Solution
E 17	E 37	E 57	E 77	Ultracene	DDT Solution
E 18	E 38	E 58	E 78	Cyclohexanone	DDT Solution
E 19	E 39	E 59	E 79	[2] Standard bait	
E 20	E 40	E 60	E 80	Empty	Check

1. The DDT solution was made by dissolving 52 grams of technical DDT in 100 cc of xylene. Ten cc of the solution was added to 30 cc of the test material.

2. Formula:

anethol	8 parts
eugenol	1 part
phenyl ethyl acetate	1 part

TABLE VI

BATTERY F - The composition of a battery designed to test the attractant or repellent value of the killing agent used in certain insecticides.

Rep 1	Rep 2	Rep 3	Rep 4	Material	Addative
F 1	F 21	F 41	F 61	Toxaphene (50%) Hercules	
F 2	F 22	F 42	F 62	Toxaphene Tech. 10 gms.	+ 30 cc mineral oil
F 3	F 23	F 43	F 63	Toxaphene Tech. 10 gms.	+ 30 cc Xylene
F 4	F 24	F 44	F 64	Lindane (100%) (Ortho) 10 gms.	+ 30 cc Xylene
F 5	F 25	F 45	F 65	B HC (HCH) (High Gamma)	+ 40 cc Xylene
F 6	F 26	F 46	F 66	BHC (11.2%) (gamma)	+ 40 cc Xylene
F 7	F 27	F 47	F 67	BHC (11.2%) (gamma)	+ 40 cc mineral oil
F 8	F 28	F 48	F 68	Methoxychlor (50%) (Marlate)	+ 30 cc Xylene
F 9	F 29	F 49	F 69	Parathion (10%) 10 cc	+ 30 cc Zylene
F 10	F 30	F 50	F 70	Parathion (10%) 40 cc	
F 11	F 31	F 51	F 71	Velsicol (1068) Technical 40 cc	
F 12	F 32	F 52	F 72	Chlordane (48%) (Octa-Klor) 40 cc	
F 13	F 33	F 53	F 73	Chlordane (100%) (Octa-Klor) 40 cc	
F 14	F 34	F 54	F 74	Chlordane (100%) (Octa-Klor) 10 cc	+ 30 cc Xylene
F 15	F 35	F 55	F 75	Aldrin (23%) (Compound 118) 40 cc	
F 16	F 36	F 56	F 76	Rhothane 40 cc	
F 17	F 37	F 57	F 77	Penphane (EC-70) 40 cc	
F 18	F 38	F 58	F 78	Pyrethol Industrial Spray (.29%) 40 cc	
F 19	F 39	F 59	F 79	Standard bait	
F 20	F 40	F 60	F 80	Empty	

TABLE VII

JAPANESE BEETLES COLLECTED FROM BATTERY A - 1950 SEASON

Test Material		Sum	Percent
1	Kerosene (regular run) Fuel Oil No. 1	972	.67
2	Kerosene (odorless)	1303	.90
3	Fuel Oil.No. 2	919	.63
4	Solvent	855	.59
5	Velsicol AR 50 (B-18756)	742	.51
6	Velsicol AR 55	746	.51
7	Velsicol AR 60	582	.40
8	Vapona D-43	1405	.97
9	Benzene	1425	.99
10	Xylene	1073	.74
11	Deobase	1436	.99
12	Sovacide s/v 544-B	951	.66
13	Sovacide s/v 544-C	804	.55
14	Sun Solvent	810	.56
15	Insecticide base (Shell)	1809	1.25
16	E-407R (Shell)	1320	.91
17	Ultracene	2168	1.50
18	Cyclohexamone	3810	2.64
19	Standard Bait - 8 parts anethol; 1 part eugenol; 1 part phenyl ethyl acetate	118,464	82.38
20	Empty	2,196	1.52
	Total	143,792	99.87%

TABLE VIII

JAPANESE BEETLES COLLECTED FROM BATTERY B - 1950 SEASON

Test Material		Sum	Percent
1	Mineral oil	1848	1.095
2	Mineral oil (extra heavy)	2176	1.290
3	Mistol (light)	1248	.740
4	Atlas Span 85 (Batch 2097A)	1204	.713
5	Atlas G-1276 (Batch 3945 A)	1226	.726
6	Atlas Tween 20 (Batch 554 A)	1435	.850
7	Atlas Span 20 (Batch 2352 A)	3262	1.934
8	Triton X-100	1437	.852
9	Atlas G-1276 (Batch 3072)	1306	.774
10	Atlox	1213	.719
11	Ethofat 242/25 (lot 451)	1345	.797
12	Ethoneen s/15 (lot 436)	1405	.833
13	Arqua 0-2C (lot 6297)	2436	1.444
14	Tenlo - 400 (Griffin)	1728	1.024
15	Nonisol - 210	3146	1.865
16	Literite T	3442	2.041
17	Methoxychlor (50%) 10 gms + 30 cc mineral oil	2056	1.219
18	Lindane 10 gms + 30 cc mineral oil	3197	1.895
19	Standard bait	130,565	77.422
20	Empty	2964	1.757
	Total	168,639	99.990%

TABLE IX

JAPANESE BEETLES COLLECTED FROM BATTERY C - 1950 SEASON

Test Material		Sum	Percent
1	Kerosene (regular run)	20,764	2.960
2	Kerosene (odorless)	65,887	9.393
3	Fuel Oil No. 2	13,954	1.989
4	Solvent	48,076	6.854
5	Velsicol AR 50	6,649	.947
6	Velsicol AR 55	9,033	1.287
7	Velsicol AR 60	6,678	.952
8	Vaponia D-43	52,463	7,479
9	Benzene	79,371	11.316
10	Xylene	63,677	9.078
11	Deobase	74,840	10.670
12	Sovacide 544-B	8,969	1.278
13	Sovacide 544-C	6,389	.910
14	Sun Solvent	3,904	.556
15	Insecticide Base (Shell)	52,716	7.515
16	E-407 R (Shell)	8,970	1.278
17	Ultracene	55,667	7,936
18	Cyclohexanone	18,428	2.627
19	Standard bait - 8 parts anethol; 1 part eugenol; 1 part phenyl ethyl acetate	99,170	14.139
20	Empty	5,793	.825
	Total	701,390	99.989%

TABLE X

JAPANESE BEETLES COLLECTED FROM BATTERY D - 1950 SEASON

Test Material		Sum	Percent
1	Mineral oil	20,271	
2	Mineral oil (Heavy)	15,069	
3	Mistol	*	
4	Atlas Span 85 (2097A)	*	
5	Atlas G-1276 (Batch 3945A)	18,491	
6	Atlas Tween 20 (Batch 554A)	*	
7	Atlas Span 20 (Batch 2352A)	*	
8	Triton X-100	20,035	
9	Atlas G-1276 (Batch 3072)	*	
10	Atlox	21,826	
11	Ethofat 242/25	12,826	
12	Ethoneen S/15	15,816	
13	Arquao O-2c	2,867	
14	Tenlo-400	*	
15	Nonisol 210	*	
16	Literite T	*	
17	Rhothane 10 cc ≠ 30 cc xylene	1,122	
18	Penphene 10 cc ≠ 30 cc xylene	1,755	
19	Standard bait	84,033	
20	Empty	2,755	
		216,208	

* Data incomplete because of shortage of test material.

TABLE XI

JAPANESE BEETLES COLLECTED FROM BATTERY E - 1950 SEASON

	Test Material	Sum	Percent
1	Kerosene (regular run) Fuel Oil No. 1	940	.714
2	Kerosene (odorless)	1898	1.441
3	Fuel Oil No. 2	669	.508
4	Solvent	480	.364
5	Velsicol AR 50 (B-18756)	422	.320
6	Velsicol AR 55	535	.406
7	Velsicol AR 60	518	.393
8	Vapona D-43	1016	.771
9	Benzene	845	.641
10	Xylene	862	.654
11	Deobase	860	.653
12	Sovacide s/v 544-B	781	.593
13	Sovacide s/v 544-C	626	.475
14	Sun Solvent	559	.424
15	Insecticide Base (Shell)	1690	1.283
16	E-407 R (Shell)	1184	.899
17	Ultracene	1867	1.418
18	Cyclohexanone	1615	1.226
19	Standard bait - 8 parts anethol; 1 part eugenol; 1 part phenyl ethyl acetate	110,000	83.554
20	Empty	4,284	3.254
	Total	131,651	99.991

TABLE XII

JAPANESE BEETLES COLLECTED FROM BATTERY F - 1950 SEASON

Test Material		Sum	Percent
1	Toxaphene (50%) (Hercules)	5936	2.049
2	Toxaphene Tech. 10 gms. by weight	4983	1.720
3	Toxaphene Tech. 10 gms. by weight	1576	.544
4	Lindane (100%) (Ortho) 10 gms.	1453	.501
5	BHC (HCH) (High Gamma)	1131	.390
6	BHC (11.2%) (gamma)	1243	.429
7	BHC (11.2%) (gamma) *	1879	.648
8	Methoxychlor (50%) (Marlate) 10 gms.	2008	.693
9	Parathion (10%) 10 cc	629	.217
10	Parathion (10%) 40 cc	844	.291
11	Velsicol (1068) Technical 40 cc	2126	.734
12	Chlordane (48%) (Octa-Klor) 40 cc	2749	.949
13	Chlordane (100%) (Octa-Klor) 40 cc	4336	1.497
14	Chlordane (100%) (Octa-Klor) 10 cc	2742	.946
15	Aldrin (23%) Compound 118 40 cc	3227	1.114
16	Rhothane 40 cc	1916	.661
17	Penphene (EC-70) 40 cc	4852	1.675
18	Pyrethol Industrial Spray (.29%) 40 cc	8209	2.834
19	Standard bait	232,948	80.441
20	Empty	4799	1.657
	Total	289,586	99.990

TABLE XIII· A Graph Of Percentages Of Beetles Caught By Commercial Ingredients Of Insecticides (Battery A) 1950

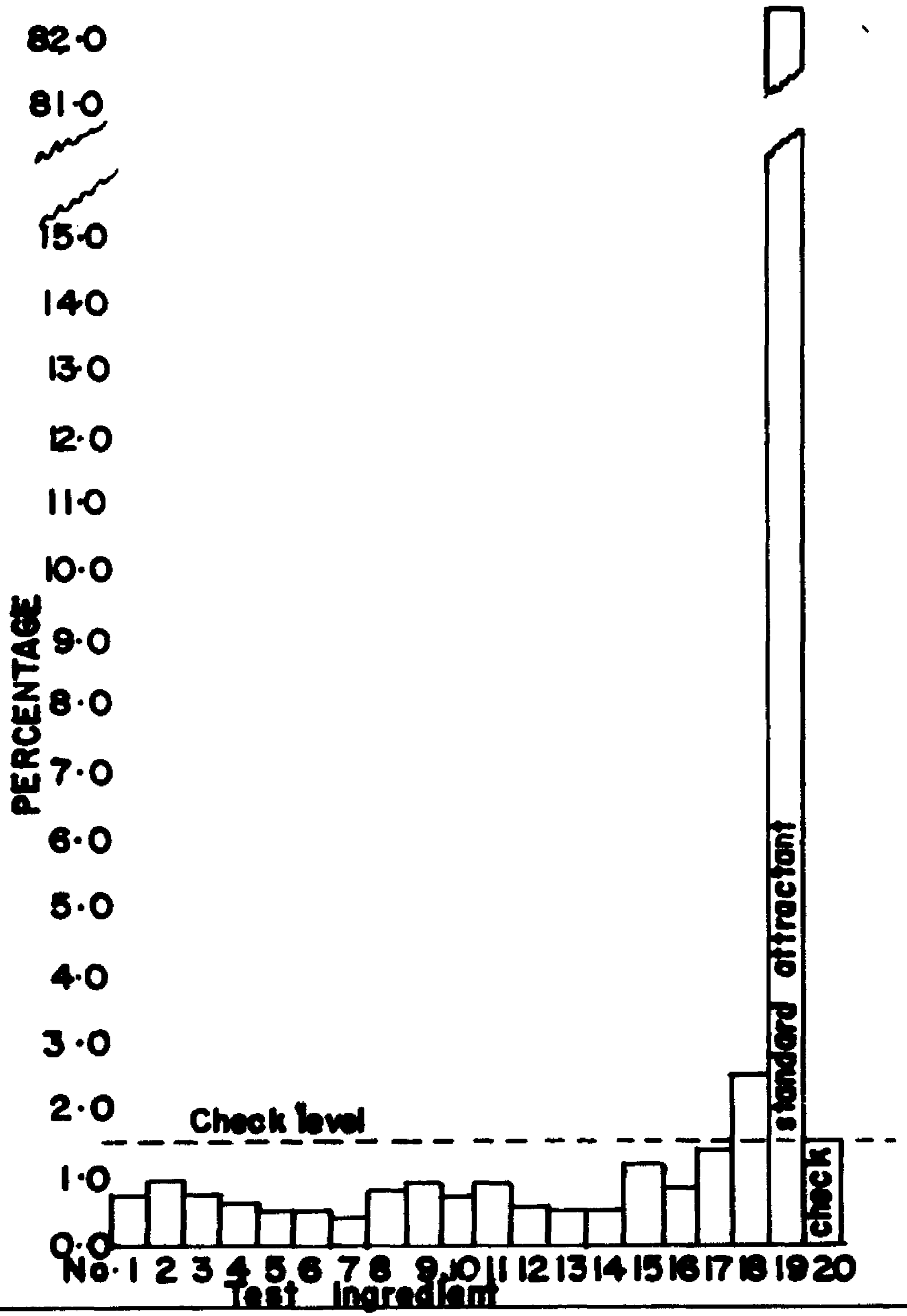


TABLE XIV. A Graph Of Percentages Of Beetles Caught By Commercial Grade Ingredients Of Insecticides (Battery B) 1950

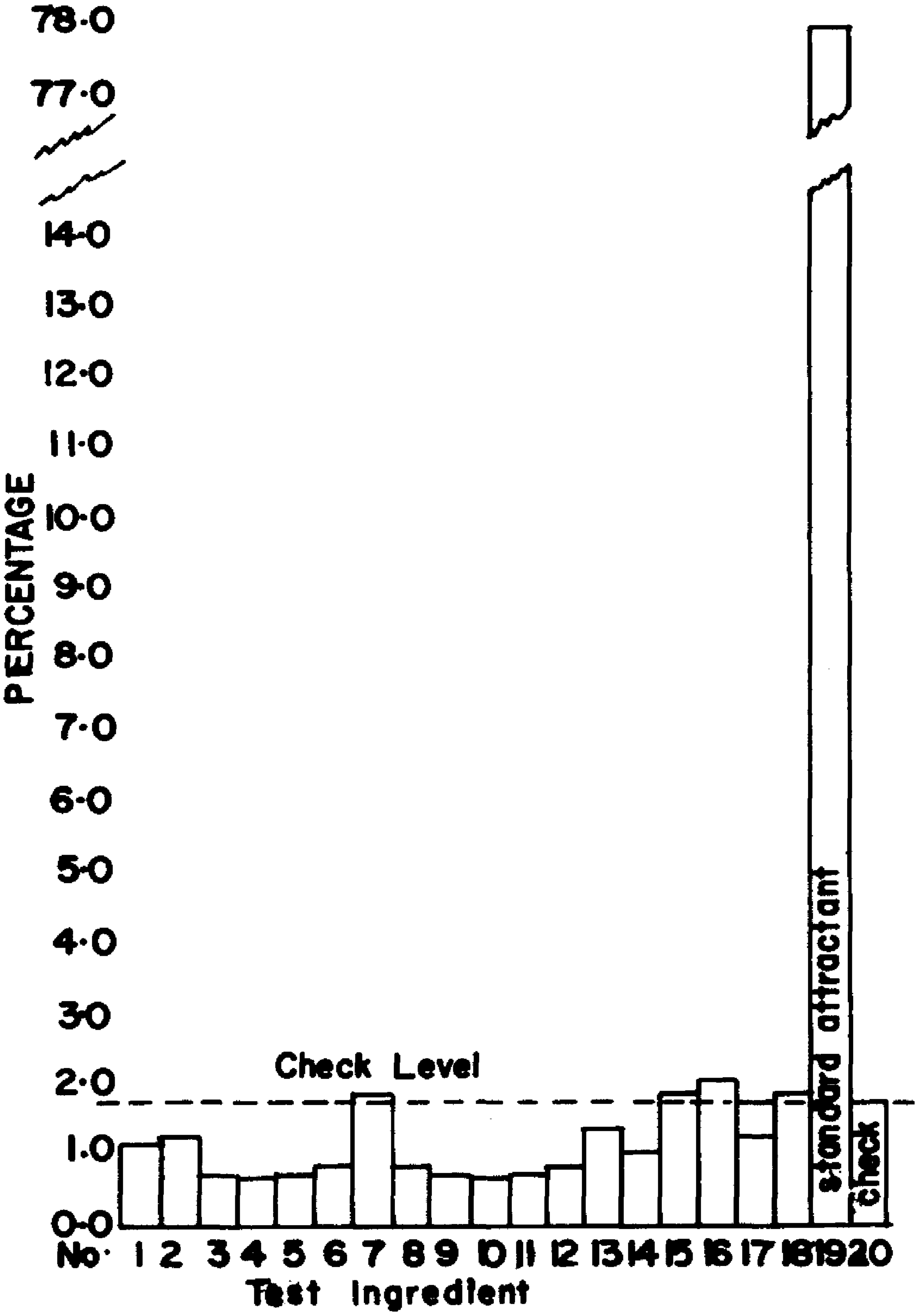


TABLE XV. A Graph Of The Percentages Of Beetles Caught By Commercial Ingredients Of Insecticides Plus Standard Bait (Battery C) 1950

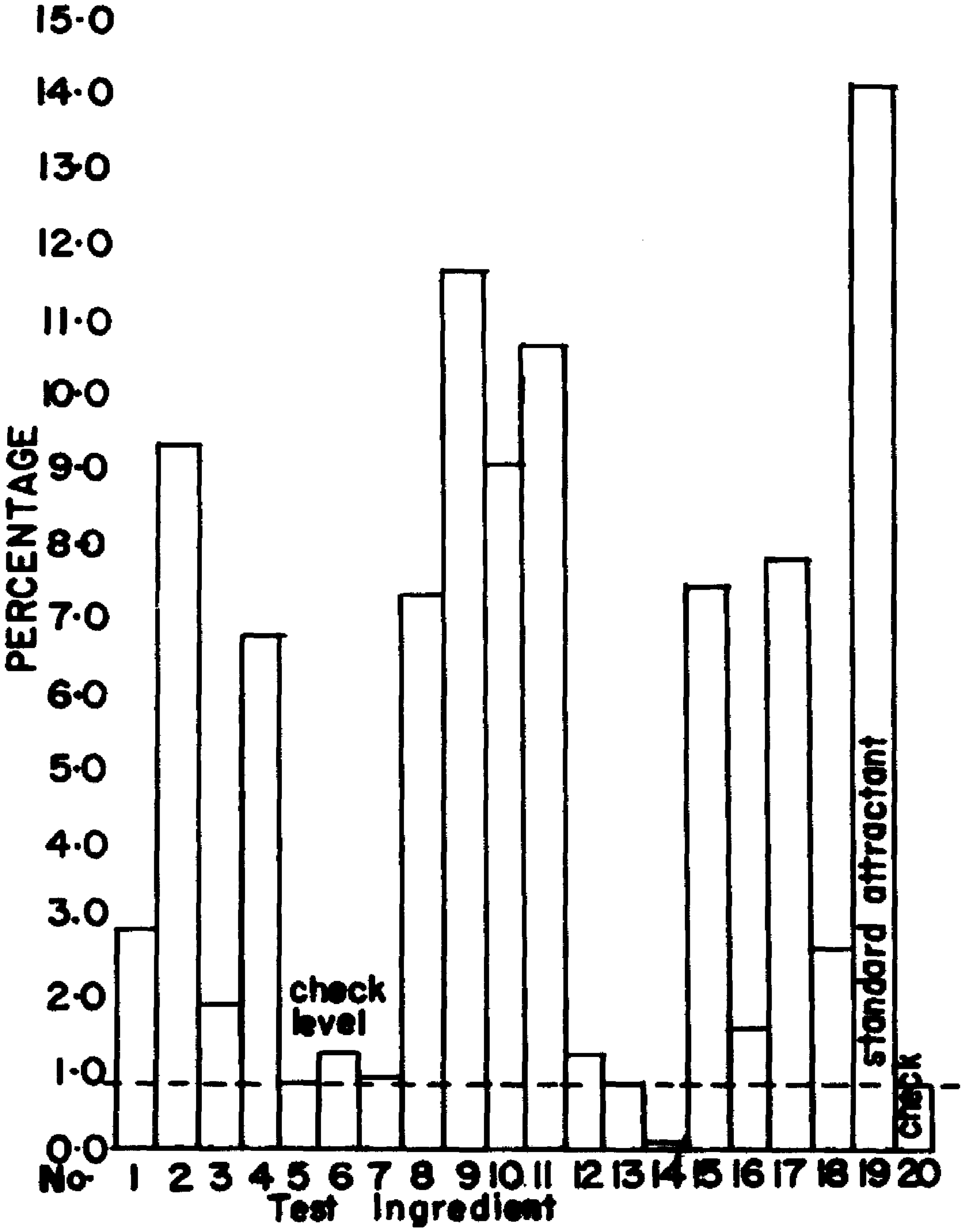


TABLE XVI· A Graph Of The Percentages Of Beetles Caught By Commercial Ingredients Of Insecticides With DDT· (Battery E) 1950

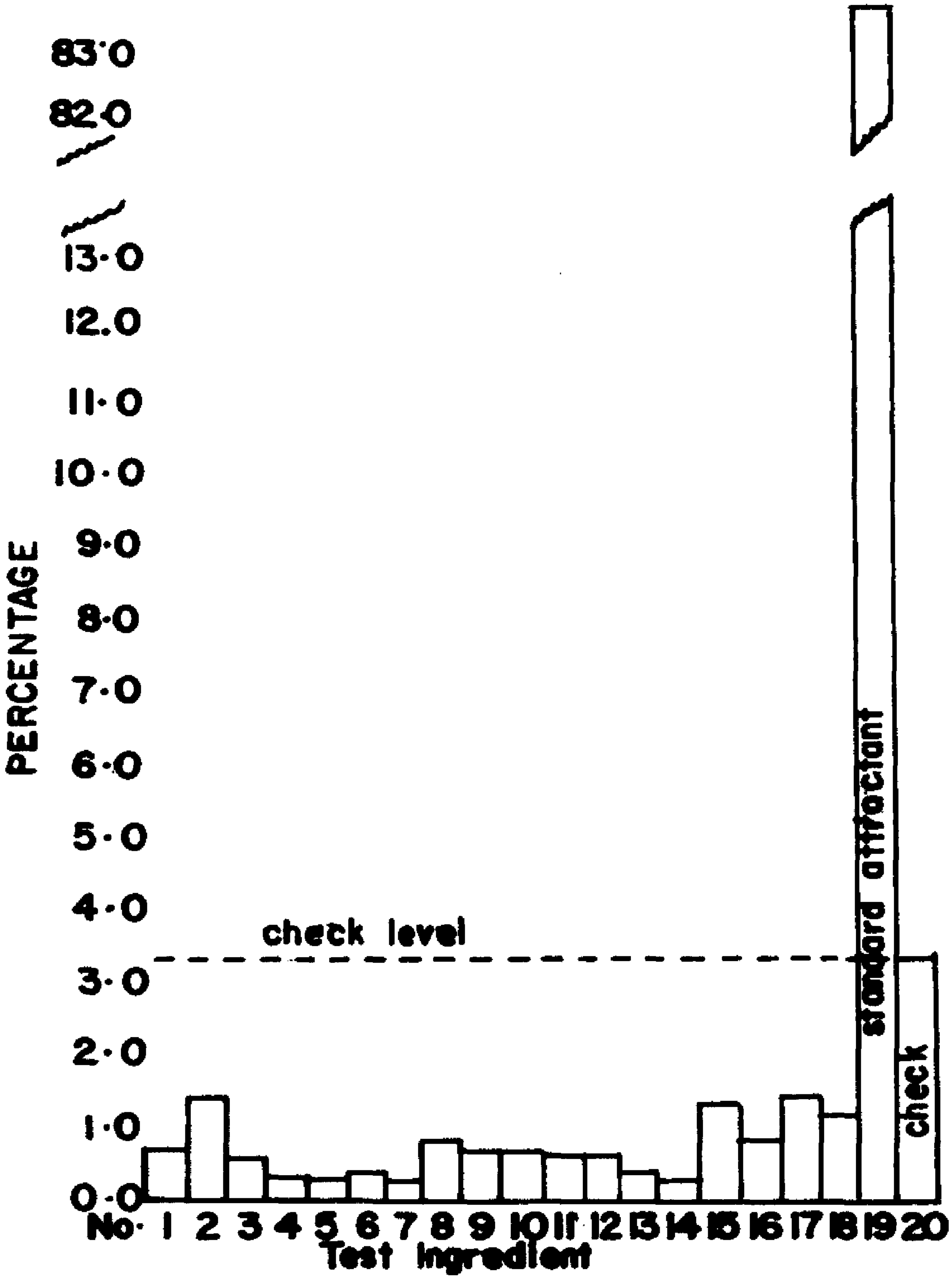
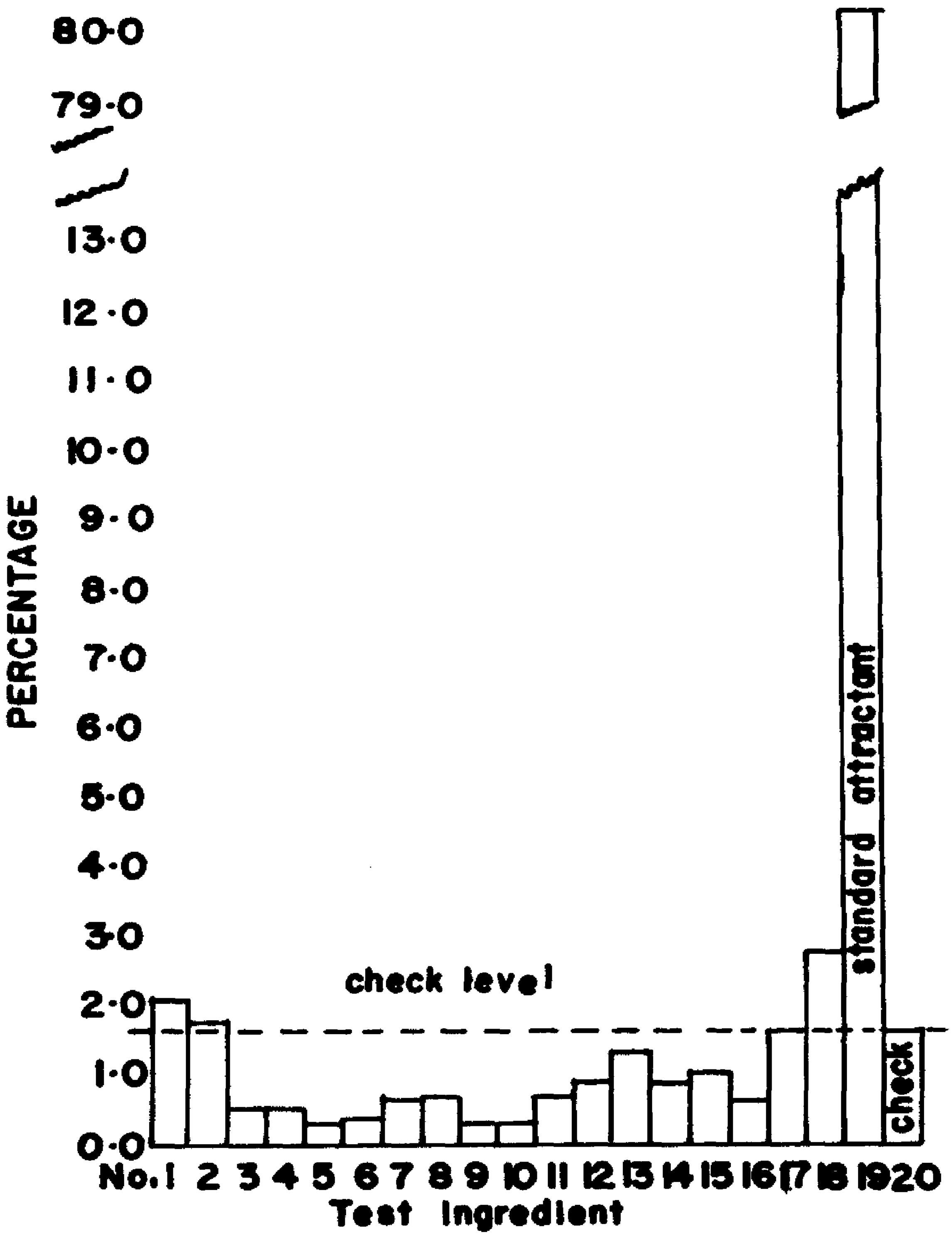


TABLE XVII. A Graph Of The Percentages Of Beetles Caught By The Killing Agent Used In Certain Insecticides. (Battery F) 1950



Discussion of Results for 1950

The original experiment was designed in the spring of 1950 and the field work performed and the data collected during the summer. In the course of analysis during the winter of 1950-51, it was discovered that an analysis of variance could not be made. It was noticed that the daily rotation of the samples to overcome placement effect had been in an orderly pattern instead of in a random manner. As a result, the standard attractant bait was always in the same relation to the two adjacent materials in the series, and the experimental error was so great that an analysis of variance was meaningless. These data were analyzed on a percentage basis, and the most promising of the test materials were selected for testing in a new experiment in the summer of 1951.

The result obtained in the summer of 1950 were based on a study of 432 samples involving approximately 1,655,216 Japanese beetles. The response to the tested materials is summarized by batteries in Tables VII to XII inclusive. The data are presented graphically in Tables XIII to XVII inclusive.

The Response of the Japanese Beetle to Certain Ingredients of Insecticides. The data presented in Tables VII and VIII indicate that none of the ingredients under test was highly attractant to the Japanese beetle when compared with the standard attractant.

The trap containing the standard attractant collected 82.38% of all beetles entering Battery A; the most attractant of the test materials was cyclohexanone, a synergist, which attracted 2.64% of the beetles. In Battery B, the standard attractant drew 77.42% of the beetles entering the battery; the most attractant test material was Literite T, an emulsifier, which attracted 2.04% of the beetles entering the battery. The repellent values of the ingredients were tested by comparing the percentage of beetles caught by the ingredients with the number of beetles caught by an empty check. In Battery A, the empty check caught 1.52% of the beetles; 16 of the test materials caught less beetles than the empty check. In Battery B, the empty check caught 1.75%; 14 of the test materials caught less beetles than the empty check.

The Response of the Japanese Beetle to the Test Ingredients with a Standard Attractant Added. When four cc of a standard attractant was added to 36 cc of each of the test materials, a clearer line was drawn between the attractant and repellent values of the materials. The results are shown graphically in Table XV. The standard attractant collected the greatest percentage of the beetles; but in Battery C (Tables IX and XV) the standard attractant collected 14.13% of the battery total catch as compared with 82.38% in Battery A. It was reasoned that if a test material was neutral per se then the addition of the attractant would greatly increase the catch of beetles. If a test material was attractant per se the catch of beetles would be increased in proportion to the amount of standard attractant added. If a test material was repellent the catch of beetles would be reduced in proportion to the masking effect of the attractant. Of the materials tested in Battery C, the solvents (See Table XV) odorless kerosene, "Solvent," benzene, xylene, deobase, Shell Insecticide Base and Ultracene were neutral ingredients as the Japanese beetle did not respond in either a negative or positive manner. The solvents, regular run kerosene, fuel oil No. 2, Velsicol AR 50, Velsicol AR 55, Velsicol AR 60, Sovacide 544-B, Sovacide 544-C, Sun solvent, and Shell E-407 were repellent ingredients.

The supply of some ingredients used in Battery D were exhausted before the experiment was completed. As the data were incomplete for this battery it was not included in the study of the results.

The Response of the Japanese beetles with DDT Added to the Test Ingredients. Since DDT was the killing agent most commonly used in spraying canning corn, a test was made to determine if this was influencing the behavior and feeding habits of the Japanese beetles in the corn fields. One part of a solution, made by dissolving 52 grams of technical DDT (100%) in 100 cc of xylene, was added to three parts of each of the test ingredients in Battery E. The results of these tests are presented in Tables XI and XVI. The results are not conclusive. With DDT added the beetles responded very much as they did to the test ingredients alone. A percentage graph (Table XVI) of the results differed very little from a percentage graph of the ingredients tested in commercial formulation (Table XIII).

The Response of the Japanese Beetles to Some of the Newer Insecticides. Battery F was used to test 18 samples of nine of the newer organic insecticides. The insecticides were tested in the commercial formulation if they were liquids. If they were solids, they were dissolved in xylene or mineral oil and the resulting liquid samples were tested. The results of these tests are presented in Tables XII and

XVII. The insecticides were repellent to the Japanese beetle although toxaphene and Pyrethol Industrial Spray were slightly more attractive than the empty check. Lindane, methoxychlor, parathion, and Rhothane were the most repellent of the materials tested.

Conclusions from the 1950 Season

1. The solvents, odorless kerosene, an unnamed "solvent," benzene, xylene, deobase, Shell insecticide base, Mistol, Ultracene, regular run kerosene, fuel oil No. 2, Velsicol AR 50, Velsicol AR 55, Velsicol AR 60, Solvacide 544-E, Sovacide 544-C, Sun solvent, and Shell E-407 R were repellent to the Japanese beetle.

2. The insecticides Vaponia D-43, lindane, benzene hexachloride, methoxychlor, parathion, and Rhothane were repellent to the Japanese beetle.

3. The insecticides toxaphene and Pyrethol Industrial spray were slightly attractant to the Japanese beetles.

4. The emulsifiers Atlas Span 85, Atlas Tween 20, Triton X-100, Atlas G-1276, Atlox, Ethofat 242/45, Ethoneen S/15 and Tenlo-400 were repellent to the Japanese beetle.

5. The emulsifiers Atlas Span 20, Nonizol 210, and Literite T were slightly attractant to the Japanese beetle.

Methods and Materials Used in 1951

The insecticide ingredients which produced the strongest response, whether negative or positive, in the experiments of 1950 were used as the basic materials for a continuation of the tests in the summer of 1951. The fundamental requirements of a well planned experiment are that it should yield a comparison of the different treatments and that it should provide a means of testing the significance of any observed differences. Anonymous (7) The experiment was designed for treating data obtained by an analysis of variance.

The question to be answered was: Do insecticides or any ingredients of insecticides attract or repel Japanese beetles? To answer this question three experiments were built on a group of 12 solvents, three emulsifiers and a check. The test materials were all ingredients common in the insecticide field today. They were:

No.	Name	Type
1	Sun Solvent	Solvent
2	Velsicol AR 50	Solvent
3	Velsicol AR 60	Solvent
4	Kerosene	Solvent
5	Fuel Oil No. 2	Solvent
6	Shell Solvent (E-407 R)	Solvent
7	Shell Insecticide Base	Solvent
8	Shell Helix Superior Oil	Solvent
9	Sovacide s/v 544-B	Solvent
10	Xylene	Solvent

No.	Name	Type
11	Sova Spray No. 2	Solvent
12	Deobase	Solvent
13	Atlas G-1276	Emulsifier
14	Emcol 74	Emulsifier
15	Emcol 77	Emulsifier
16	Empty bottle	Check

The three experiments were:

(1) The response of the Japanese beetle was tested to ingredients of insecticides in commercial formulations.

(2) The response of the Japanese beetle to 36 cc of the ingredient with 4 cc of a standard attractant was tested.

(3) The response of the Japanese beetle to 36 cc of the ingredient with 4 cc of a solution made by dissolving 52 grams technical DDT (100%) in 100 cc of xylene was tested.

The ingredients to be tested were exposed in standard bait traps arranged in randomized plots, and the response of the Japanese beetle to various materials was studied to determine which ingredients, if any, had attractant or repellent effect on the Japanese beetles.

In this experiment there are at least three independent sources of variance; these are location, treatment, and random error. It was known from the beginning of the experiment that the location of the tests, the direction of the wind, and the fluctuations of temperature would cause variation in the distribution of the test insects in the experimental area. Therefore, in order to obtain a more accurate estimate of the variance due to location, each test material was replicated four times. Replication reduces the experimental error, and it provides an estimate of the size of the error. The second source of variance is due to the difference in the test materials. Replication helps to secure an estimate of this variance. The third source of variance is that due to uncontrolled or unknown factors, and this is known as random or experimental error.

The field arrangement of the experiments for the summer of 1951 is shown in Figure 3. In order to minimize experimental error caused by location, and to confine the experiments to as small an area as possible, the replicated groups of test ingredients were arranged as a rectangle. The ingredients within the groups were randomized at the beginning of the experiments. A new randomization of the ingredients within the groups was made weekly (each Saturday) throughout the course of the experiments. The purpose of the random arrangement in the groups was to insure that no ingredient was favored; thus it provided an unbiased estimate of error. Three different treatments of the test ingredients were carried on simultaneously as part of the experiment. Each of the treatments was replicated four times to increase the degree of precision of the results. The design of the experiment is a form of randomized block trial; that is, the arrangement of the ingredients within the block and within the group is left purely to chance rather than arranged by a systematic plan which is apt to introduce error. Although the randomized block method of design controls the greater part of the variance due to location, it does not control all. Some random error still remains. Some reliable estimate of this random error must be made before a reliable comparison between the test ingredients can be made. This estimate of the random error was made by subjecting the data to an *analysis* of *variance.* "The analysis of variance consists essentially of taking the total variation and apportioning it to various known causes, leaving a residual portion ascribed to uncontrolled variation and therefore called experimental error." (Stark)[8].

The locations of the various parts of the experiments in Figure 3 are as follows:

Group		Replicate	
A	=	1	
D	=	2	A test of the ingredients
G	=	3	in commercial formulations
K	=	4	(64 samples)
B	=	1	
E	=	2	
H	=	3	A test of the ingredients
L	=	4	with DDT added. (64 samples)
C	=	1	
F	=	2	A test of the ingredients
J	=	3	with standard attractant
M	=	4	added. (64 samples)

Group	Replicate	
N		A group of 68 empty traps.
P		A group of 16 samples of standard attractants.

The experiments were conducted in a large pasture area at the University of Maryland Experimental Farm. The first data were taken on July 9, 1951, and the last on August 18, 1951. The experiments were ended because the number of Japanese beetles flying was so small that continuation of the experiments was not justified. In the summer of 1951 the three experiments involved 692 samples and approximately 231,980 Japanese beetles.

FIGURE 3. The Arrangement Of The Experimental Traps In The Field. 1951

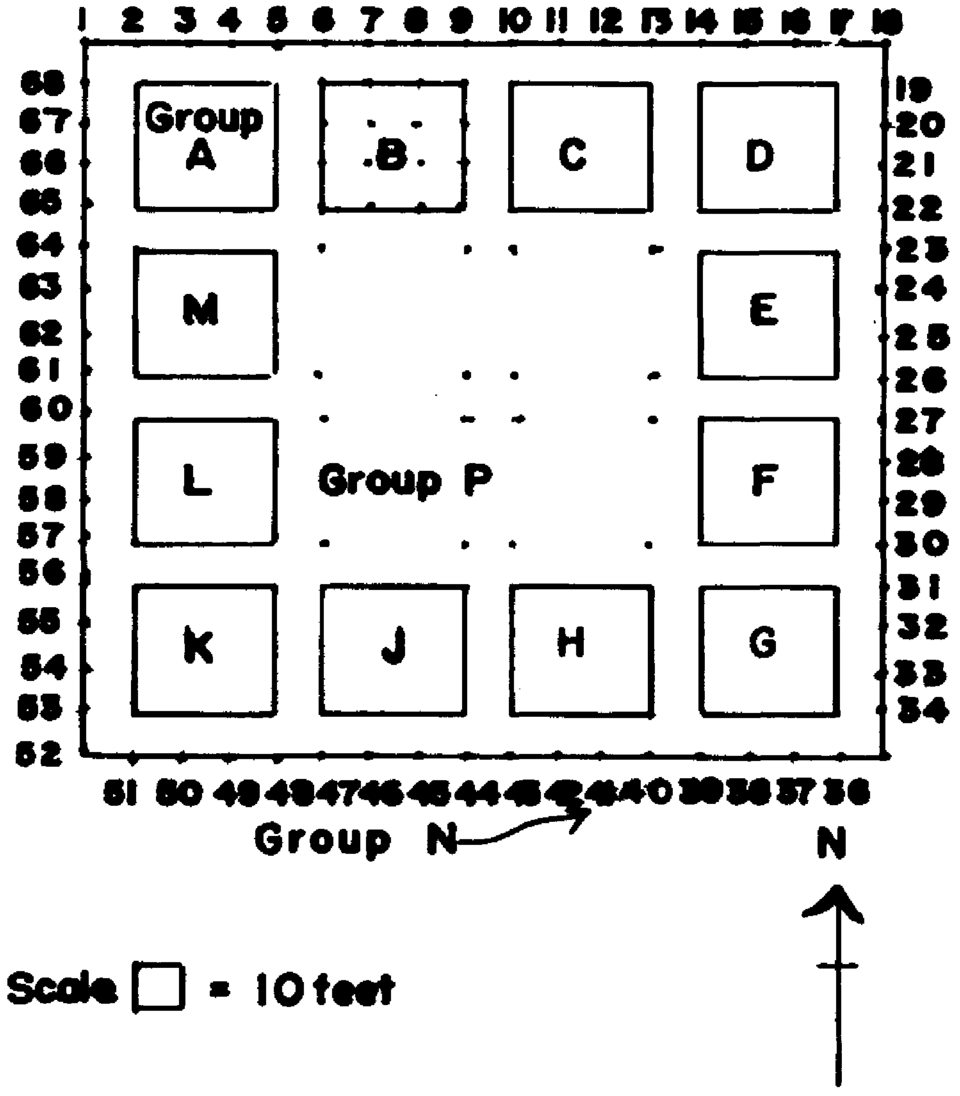


TABLE XVIII. A Graph Of The Number Of Beetles Caught By Commercial Grade Ingredients Of Insecticides. (Group A-D-G-K) 1951

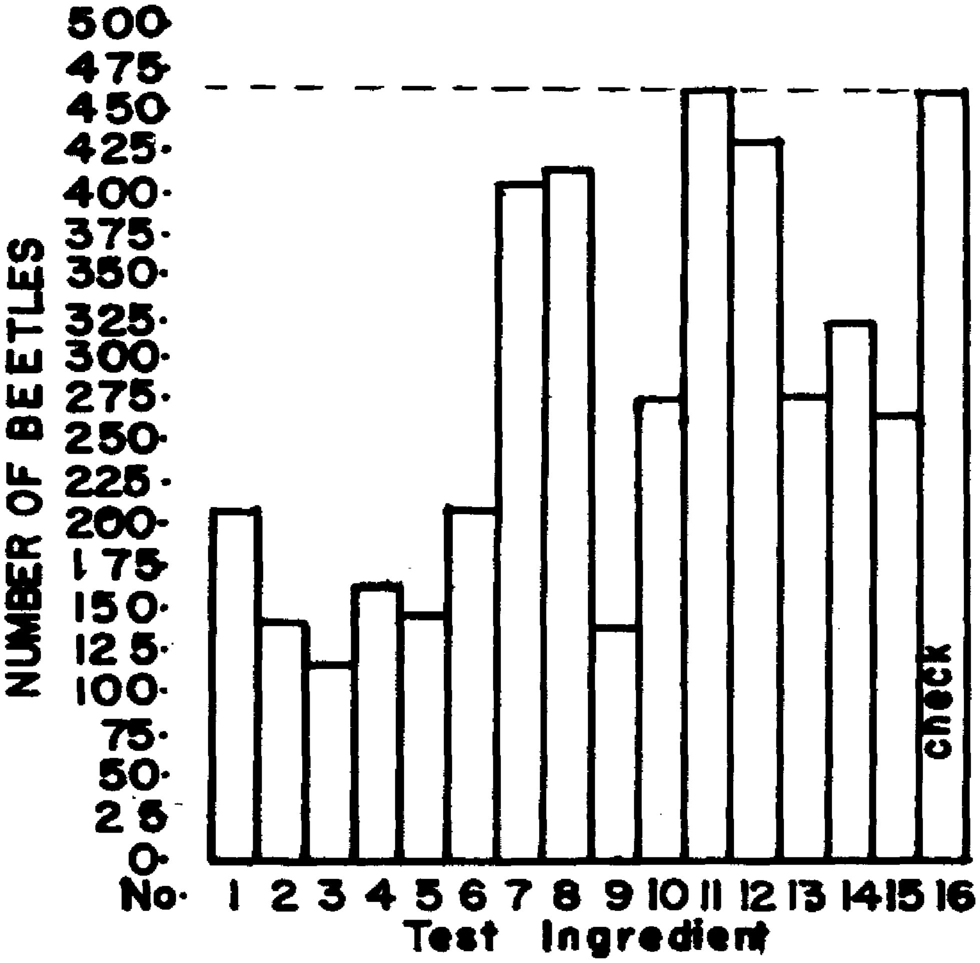


TABLE XIX. A Graph Of The Number Of Beetles Caught By Commercial Grade Ingredients Of Insecticides With DDT. (Group B-E-H-L) 1951

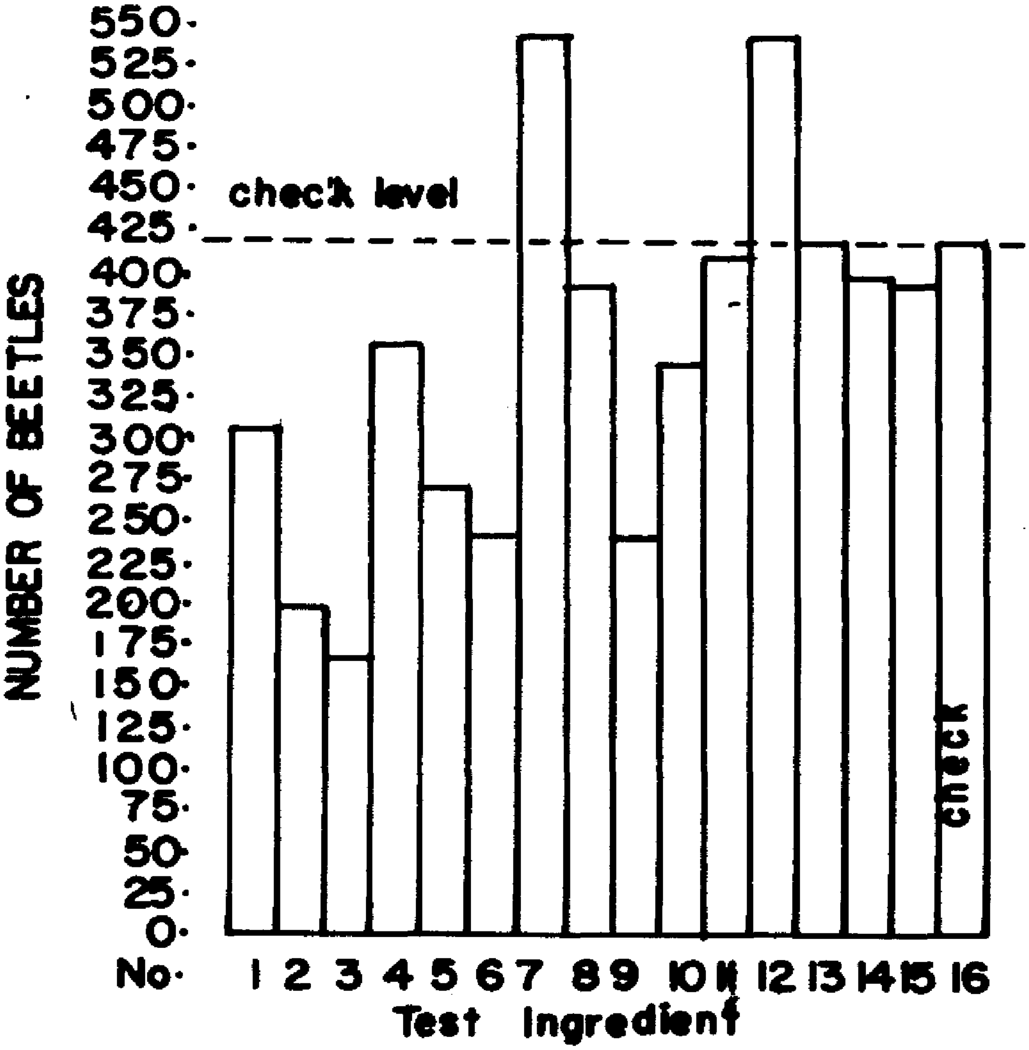


TABLE XX. A Graph Of The Number Of Beetles Caught By Commercial Grade Ingredients Of Insecticides Plus Standard Bait. (Group C-F-J-M) 1951

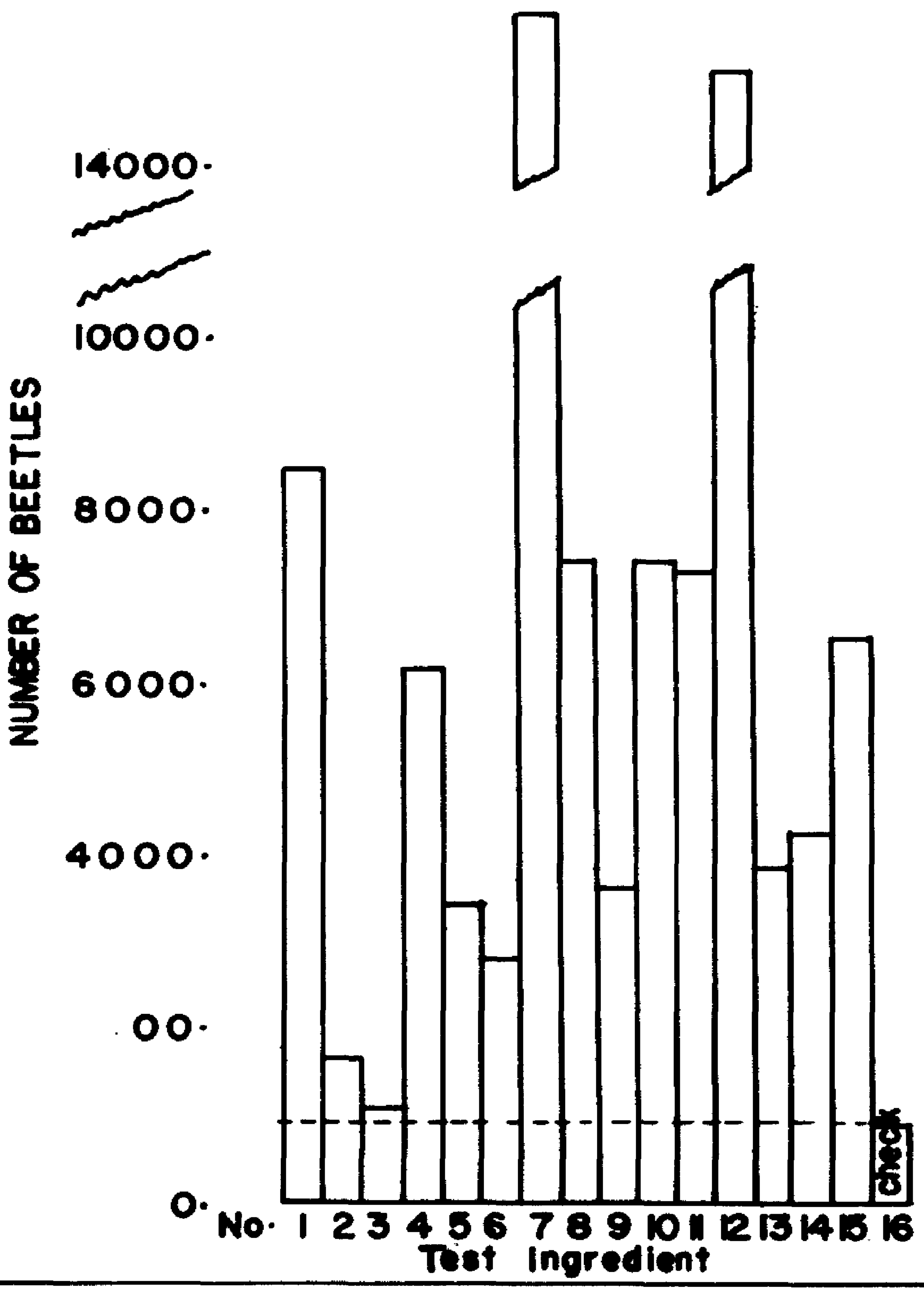


TABLE XXI

Data from Group A-D-G-K. A test of the attractant or repellent qualities of commercial ingredients of insecticides.

	Ingredient	Total beetles Sum
1	Sun Solvent	210
2	Velsicol AR 50	141
3	Velsicol AR 60	121
4	Kerosene	165
5	Fuel Oil No. 2	148
6	Shell Solvent (E-407 R)	210
7	Shell Insecticide Base	405
8	Shell Helix Superior Oil	415
9	Sovacide s/v 544-B	133
10	Xylene	275
11	Sova Spray No. 2	460
12	Deobase	430
13	Atlas G-1276	276
14	Emcol 74	324
15	Emcol 77	270
16	Empty bottle check	458
	Sum	4441

Difference required for significance between treatment totals at 5 per cent level 155.732

Source of Variation	D/F	Sum of Squares	Variance	F
Total	63	97,501.235	----	----
Treatments	15	57,268.235	3,817.882	5.106
Replicates	3	6,585.922	2,195.307	2.936
Error	45	33,647.078	747.712	----

TABLE XXII

, Data from Group B-E-H-L. A test of the attractant or repellent qualities of the commercial ingredients of insecticides with DDT added.

	Material	Sum
1	Sun Solvent	302
2	Velsicol AR 50	191
3	Velsicol AR 60	167
4	Kerosene	351
5	Fuel Oil No. 2	268
6	Shell Solvent (E 407 R)	238
7	Shell Insecticide Base	540
8	Shell Helix Superior	392
9	Sovacide s/v 544-B	235
10	Xylene	346
11	Sova Spray No. 2	408
12	Deobase	539
13	Atlas G-1276	423
14	Emcol 74	399
15	Emcol 77	390
16	Empty check	421
	Sum	5610

Difference required for significance between treatment totals at 5 per cent level 186.415

Source of Variation	D/F	Sum of Squares	Variance	F
Total	63	99,922.438	------	----
Treatments	15	49,224.438	3,281.629	3.063
Replicates	3	2,498.563	832.854	.777
Error	45	48,199.437	1,071.098	----

TABLE XXIII

Data from Group C-F-J-M. A test of the attractant or repellent qualities of the commercial ingredients of insecticides with a standard bait added.

	Material	Sum
1	Sun Solvent	8460
2	Velsicol AR 50	1694
3	Velsicol AR 60	1188
4	Kerosene	6219
5	Fuel Oil No. 2	3539
6	Shell Solvent (E-407 R)	2803
7	Shell Insecticide Base	15,681
8	Shell Helix Superior Oil	7333
9	Sovacide s/v 544-B	3600
10	Xylene	7358
11	Sova Spray No. 2	7255
12	Deobase	15,108
13	Atlas G-1276	3915
14	Emcol 74	4296
15	Emcol 77	6527
16	Empty check	879
	Sum	95,855

Difference required for significance between totals at 5 percent level 725.429

Source of Variation	D/F	Sum of Squares	Variance	F
Total	63	80,167,600.5	------	------
Treatments	15	71,114,817.7	4,740,735.007	29.115
Replicates	3	1,725,581.8	575,193.933	3.532
Error	45	7,327,201.0	162,826.668	------

Figure 4. A Partial View of the Experiments in 1951. The view is from the northeast.

Figure 5. A Standard Japanese Beetle Trap Used in the Experiment.

Discussion of Results for 1951

The Response of the Japanese Beetle to Certain Ingredients of Insecticides in Commercial Formulations. The response of the Japanese beetles to the test ingredients is presented graphically in Table XVIII. In this graph none of the ingredients under test were attractant to the Japanese beetles; only one ingredient, Sova Spray No. 2, caught as many beetles as the empty check trap. Most of the ingredients were repellent to the beetles as they avoided the ingredients more than the empty check trap. These observed results were examined statistically by analysis of variance, and the results are presented in Table XXI. Of the solvents tested, Sun Solvent, Velsicol AR 50, Velsicol AR 60, kerosene, fuel oil No. 2, Shell Solvent (E 407R) Sovacide s/v 544-B, and xylene were significantly repellent to the Japanese beetle. The emulsifiers Atlas G-1276 and Emcol 77 were significantly repellent. Shell Insecticide Base, Shell Helix Superior Oil, Sova Spray No. 2, and deobase were neither significantly repellent or significantly attractant and were therefore considered as neutral materials to which the Japanese beetles did not respond.

The significant repellency shown by xylene at the 5% level was unexpected. Because xylene had been considered a "neutral solvent," it was used as the carrier in which technical DDT (100%) was dissolved to provide the solution in the test of DDT effects. However, as the DDT-xylene solution was used in the same proportion in each sample of the test group, it is believed that any experimental error produced by it would be equally distributed throughout the experiment.

'The Response of the Japanese Beetle to the Test Ingredients with 10 cc of a Solution Composed of 52 grams of Technical DDT Dissolved in 100 cc Xylene Added. The insecticide dichloro diphenyl trichloroethane or DDT, as it is commonly abbreviated, is the insecticide most widely used for treating corn to protect it from the Japanese beetle. Is it possible that DDT is attractant or repellent in itself to the Japanese beetle, or does DDT act as a synergist when used as the killing agent in an insecticide?

A group of 16 test materials, of the same ingredients as used in Groups A-D-G-K of the experiment, were formulated by adding to each sample 10 cc of a solution of 52 grams of technical DDT (100%) dissolved in 100 cc of xylene, to 30 cc of the test ingredient. These data are presented graphically in Table XIX and the results of the statistical analysis shown in Table XXII. In Table XIX, Shell Insecticide Base and deobase were attractant to the Japanese beetle; Velsicol AR 50, Velsicol AR 60, Shell Solvent (E-407 R) and Sovacide s/v 544-B were repellent to the Japanese beetle. In Table XXII Velsicol AR 60, Velsicol AR 50, and Sovacide s/v 544-B were significantly repellent. When the data of Table XXII are compared with the data of Table XXI, seven of the test ingredients that were repellent in Groups A-D-G-K are not repellent in Groups B-E-H-L where DDT was added. DDT has some attractant value. This is further borne out by a comparison of Table XVIII, the test ingredients without DDT, and Table XIX, the test ingredients plus DDT. The Japanese beetle response was consistently greater to all the test materials with DDT present except to

Shell Helix Superior Oil and Sova Spray No. 2. Whether DDT was attractant itself or was serving as a synergist could not be determined as a sample of technical DDT (100%) was not included. Further research is necessary before the exact response of the Japanese beetle to DDT is determined.

The Response of the Japanese Beetle to 36 cc of a Test Ingredient with 4 cc of a Standard Attractant Added. The response of the Japanese beetle to the ingredients under test, when a standard attractant was added to each in the ratio of four cc of attractant to 36 cc of the test ingredient, was investigated. The purpose in adding the standard attractant was to clarify whatever attractant or repellent qualities existed already. It was believed that the standard attractant would only make an ingredient that possessed attractant properties more attractant; if an ingredient was repellent, the repellent would modify the action of the standard attractant.

The results obtained are presented graphically in Table XX and statistically in Table XXIII. As would be expected, the Japanese beetles responded to the standard attractant in a most positive manner as shown by the increase in the number of beetles coming into the test ingredients. The Japanese beetles responded to the commercial ingredients, Shell Insecticide Base and deobase, in large numbers; this bears out the supposition that these two materials were neutral in effect. The remaining 13 test materials were repellent. The most pronounced repellent responses were shown to Velsicol AR 60, Velsicol AR 50, Shell Solvent E-407 R, fuel oil No. 2, Sovacide s/v 544-B and Atlas G-1276 in the descending order of repellency.

CONCLUSIONS FROM THE 1951 SEASON

1. The solvents: Sun solvent, Velsicol AR 50, Velsicol AR 60, kerosene, fuel oil No. 2, Shell Solvent E-407 R, Sovacide s/v 554-B, and xylene were significantly repellent to the Japanese beetle.

2. The emulsifiers: Atlas G-1276 and Emcol 77 were significantly repellent to the Japanese beetles.

3. Of the tested materials, Shell Insecticide Base, Shell Helix Superior Oil, Sova Spray No. 2, and deobase were neutral in appeal to the Japanese beetle.

4. With DDT added to the test series only Velsicol AR 60, Velsicol AR 50, and Sovacide s/v 544-B were significantly repellent.

5. The Japanese beetle response was consistently greater to the test material with DDT present except for Shell Helix Superior Oil and Sova Spray No. 2.

6. DDT was an attractant of a low order to the Japanese beetle.

7. The addition of a standard attractant to the test ingredients had only a relative effect in the response of the Japanese beetle. The test ingredients with standard attractant added were repellent, with the exception of Shell Insecticide Base and deobase.

TEST OF INGREDIENTS ON CANNING CORN (1951)

A second phase of the experiment in 1951 was the testing of the attractant or repellent value of the ingredients by applying them to canning corn in various stages of maturity. This was done in the following experiment.

A ten acre field of canning corn in which the Japanese beetles were feeding was selected. Check plots of 100 plants were selected and marked by red tags tied at the four corners of the plots. Similar plots of 100 plants so marked were selected and sprayed with one of the test formulations. A three gallon portable knapsack sprayer was used to apply the spray. The plant was sprayed thoroughly with especial attention paid to the tips of the silking ears. The experment was begun when the ears were in the early silk stage and the sprays were applied at intervals so that the last sprays were applied in the late silk stage of ear development. Six solvents and three emulsifiers were each mixed at a ratio of 1½ pints of solvent or emulsifier to 32 pints of water and applied to 100 plants in tests B. In test D the same test materials were applied but to corn in mid-to-late silk and at a ratio of one pint of solvent or emulsifier to 16 pints of water. In tests A and C the same test materials were applied but at a ratio of one pint of solvent or emulsifier plus 27 grams of 50% DDT wettable powder in 32 pints of water. In tests E1, 3, and 5 the formulation was one pint of a solvent, plus two ounces of Atlas G-1276 at a ratio of 16 pints of water. The number of beetles feeding in the check plots and in the test plots were counted at 24, 48, and 72 hour intervals after the sprays were applied. The ingredients tested and the results are shown in Table XXIV through Table XXVIII. Replication of these tests were not made.

DISCUSSION

An examination of the results shows the extremely erratic behavior of the Japanese beetle. The number of beetles varied widely in the check plots from day to day and from one part of the field to another.

The results of treatments of corn plots with formulations containing excessive amounts of solvents and emulsifiers are shown in Tables XXIV through XXVIII.

In the tests the number of beetles in the field plots were less 24 hours after treatment. In test plots B and D, in which the corn was treated with the solvent and emulsifiers, there was a notable drop in beetle population as compared with the numbers in check plots. This indicates that the test materials were repellent. In the plots treated with Shell Insecticidal Base and deobase, the beetle population remains relatively as high after treatment as before. The conclusion is that these two materials are neutral and do not prevent the beetles from returning to feed on the corn silk.

In test plots A and C, 27 grams of 50% DDT wettable powder is added to the same solvents and emulsifiers tested in test plots B and D. The results obtained are shown in Tables XXIV and XXVI.

The most obvious result was that DDT was an effective insecticide for killing Japanese beetles. After 72 hours the number of beetles in the test plots were few. Was this due to the insecticidal effect of DDT or was it a repellent effect? The answer is not clear. In only one test plot, C, was there an increase in beetles after treatment with DDT. This might indicate that low population is due to insecticidal effect of the DDT plus the repellent effect of the solvent.

In test plots E, the effect of Atlas G-1276, an emulsifier, on the solvents is shown in Table XXVIII. The number of beetles involved is not large, but in two of the three plots treated with Atlas G-1276 there is a substantial reduction in the beetle population. Atlas G-1276 has seemingly a strong repellent effect.

CONCLUSIONS

1. The solvents and emulsifiers tested were not attractant to the Japanese beetle when applied to growing canning corn. They had a repellent value as shown by a decrease in the beetle population in the sprayed plots

2. DDT is an efficient insecticide for control of Japanese beetles. The attractant or repellent qualities of DDT were not proven.

3. The emulsifier Atlas G-1276 was repellent to Japanese beetles entering canning corn fields to feed.

TABLE XXIV. THE RESPONSE OF JAPANESE BEETLE TO TEST INGREDIENTS WITH DDT APPLIED IN CORNFIELD.

(CORN SPRAYED IN EARLY-TO-MID SILK STAGE). (1951)

Ingredient	Dates Sprayed	NO. BEETLES IN CHECK PLOT Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.	NO. BEETLES IN TEST PLOT Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.
1A Velsicol AR 50 + DDT	Aug. 4	3	2		19	58	7		3
2A Velsicol AR 60 + DDT	4	3	2		19	29	2		6
3A Selvacide s/v 544-B + DDT	4	3	2		19	25	2		0
4A Atlas G-1276 + DDT	7	18	16		11	9	6		5
5A Emcol 74 + DDT	7	18	16		11	9	6		4
6A Emcol 77 + DDT	7	18	16		11	14	1		3
7A Shell Insecticide Base + DDT	7	18	16		11	18	8		3
8A Deobase + DDT	7	18	16		11	18	10		13
9A Helix Superior Oil + DDT	7	18	16		11	2	0		0

FORMULATION: 3 gallons water, 1 pint test material and 27 grams (50% DDT wettable powder)

TABLE XXV. THE RESPONSE OF JAPANESE BEETLES TO TEST INGREDIENTS APPLIED IN CORNFIELD. (CORN SPRAYED IN EARLY-TO-MID-SILK STAGE). (1951)

Ingredient	Dates Sprayed	NO. BEETLES IN CHECK PLOT Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.	NO. BEETLES IN TEST PLOT Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.
1B Velsicol AR 50	Aug. 3	73	84	62	60	25	15	9	25
2B Velsicol AR 60	3	73	84	62	60	57	18	7	21
3B Sevacide s/v 544-B	3	73	84	62	60	48	19	4	14
4B Atlas G-1276	3	84	62	60	81	29	34	34	28
5B Emcol 74	3	84	62	60	81	83	68	31	42
6B Emcol 77	3	84	62	60	81	86	23	37	70
7B Shell Insecticide Base	3	60	81		88	58	53		171
8B Deobase	3	60	81		88	58	66		69
9B Helix Superior Oil	3	60	81		88	63	37		58

FORMULATION: 3 gallons water and 1½ pints test material.

TABLE XXVI. THE RESPONSE OF JAPANESE BEETLES TO TEST INGREDIENTS WITH DDT APPLIED IN CORNFIELD.

(CORN SPRAYED IN MID-SILK STAGE) (1951)

Ingredient	Dates Sprayed	NO. BEETLES IN CHECK PLOT				NO. BEETLES IN TEST PLOT			
		Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.	Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.
1C Velsicol AR 55 + DDT	Aug. 8	66	72	86	84	206	10	8	28
2C Velsicol AR 60 + DDT	8	66	72	86	84	264	18	22	20
3C Sovacide s/v 544-B + DDT	8	66	72	86	84	294	8	0	0
4C Atlas G-1276 + DDT	8	66	72	86	84	144	20	8	8
5C Emcol 74 + DDT	8	66	72	86	84	264	30	14	8
6C Emcol 77 + DDT	8	66	72	86	84	290	18	8	10
7C Shell Insecticide Base + DDT	8	66	72	86	84	420	76	120	132
8C Deobase + DDT	8	66	72	86	84	194	16	4	0
9C Helix Superior Oil + DDT	8	66	72	86	84	206	48	34	52

FORMULATION: 3 gallons water, 1 pint test material and 27 grams (50% DDT wettable powder)

TABLE XXVII. THE RESPONSE OF JAPANESE BEETLES TO TEST INGREDIENTS APPLIED IN CORNFIELD. (CORN SPRAYED IN MID-TO LATE-SILK STAGE) (1951)

		NO. BEETLES IN CHECK PLOT				NO. BEETLES IN TEST PLOT			
Ingredient	Dates Sprayed	Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.	Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.
1D Velsicol AR 50	Aug. 8	254	204	228	90	246	84	70	98
2D Velsicol AR 60	8	254	204	228	90	214	58	22	42
3D Sovacide s/v 544-B	8	254	204	228	90	274	58	2	0
4D Atlas G-1276	8	254	204	228	90	84	28	38	32
5D Emcol 74	8	254	204	228	90	272	144	36	54
6D Emcol 77	8	254	204	228	90	276	118	16	2
7D Shell Insecticide Base	8	254	204	228	90	520	416	228	184
8D Deobase	8	254	204	228	90	294	252	212	162
9D Helix Superior Oil	8	254	204	228	90	182	192	210	20

FORMULATION: 2 gallons water and 1 pint test material

TABLE XXVIII. THE RESPONSE OF JAPANESE BEETLES TO TEST INGREDIENTS APPLIED IN CORNFIELD. (CORN SPRAYED IN LATE SILK STAGE) (1951)

Ingredient	Dates Sprayed	NO. BEETLES IN CHECK PLOT				NO. BEETLES IN TEST PLOT E			
		Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.	Before Spraying	After Spraying: 24 hrs.	48 hrs.	72 hrs.
1E Velsicol AR 50	Aug. 10	204	228	90	58	204	8	14	14
2E Velsicol AR 50 + Atlas G-1276	10	204	228	90	58	204	6	16	12
3E Velsicol AR 60	10	204	228	90	58	204	10	14	54
4E Velsicol AR 60 + Atlas G-1276	10	204	228	90	58	204	0	2	0
5E Sovacide s/v 544-B	10	204	228	90	58	204	70	53	16
6E Sovacide s/v + Atlas G-1276	10	204	228	90	58	204	8	22	8

FORMULATION: For tests 1E, 3E, and 5E - 2 gallons water, 1 pint test material.
For tests 2E, 4+, and 6E - 2 gallons water, 1 pint test material and 2 oz. Atlas G-1276.

SUMMARY

The Japanese beetle is a pest of great economic importance in the eastern part of the United States. These insects, by feeding in large numbers on the cornsilk at the time of pollination, prevent the fertilization of the kernels and their subsequent development. To protect canning or sweet corn during this critical period of development it is customary, in Maryland, to treat the corn with an insecticide. Because it is relatively inexpensive, has a residual effect and produces a rapid knock down, dichloro diphenyl trichloroethane, or DDT as it is commonly known, has been used most commonly for this purpose. The large number of Japanese beetles observed in cornfields the day after treatment with DDT suggested that the insecticide or some ingredient of the insecticide was attracting the beetles to the field.

In 1950 and 1951 a number of the common solvents, emulsifiers, oils, and insecticides were tested in a series of field experiment for attractant or repellent properties. The ingredients tested were subjected to three treatments, i.e. commercial formulations alone and in combination with standard attractants or DDT.

The response of the Japanese beetles to the test materials as compared with the response to the check materials was used to determine the attractant or repellent value. The results of the testing for the summers of 1950 and 1951 are summaries in Table XXIX.

In the commercial formulation most of the materials tested in 1950 were repellent to the Japanese beetle.

The solvents, odorless kerosene, an unnamed "solvent," benzene, xylene, deobase, Shell Insecticide Base, Mistol, Ultracene, regular run kerosene, fuel oil No. 2, Velsicol AR 50, Velsicol AR 55, Velsicol AR 60, Sovacide 544-B, Sovacide 544-B, Sovacide 544-C, Sun Solvent and Shell E-407 R were repellent. The insecticides, Vaponia D-43, lindane, benzene hexachloride, methoxychlor, parathion, and Rhothane were repellent. The insecticides, toxaphene and Pyrethol Industrial Spray were slightly attractant. The emulsifiers, Atlas Span 85, Atlas Tween 20, Triton X-100, Atlas G-1276, Atlox, Ethofat 242/45, Ethoneen 5/15 and Tenlo-400 were repellent. The emulsifiers, Atlas Span 20, Nonizol 210, and Literite T were slightly attractant.

In the tests of 1951, the solvents, Sun Solvent, Velsicol AR 50, Velsicol AR 60, kerosene, fuel oil No. 2, Shell Solvent E-407 R, Sovacide s/v 544-B, and xylene were significantly repellent to the Japanese beetle. The emulsifiers, Atlas G-1276 and Emcol 77, were significantly repellent. The solvents, Shell Insecticide Base, Sova Spray No. 2, deobase, and the oil Superior Oil were neutral materials to which the beetle did not respond.

The killing agent DDT or dichloro diphenyl trichloroethane, when added as 10 cc of a solution, made by dissolving 52 grams of technical DDT in 100 cc of xylene, to 30 cc of the test ingredient did not have a measurable influence on the behavior of the Japanese beetle. In 1951 DDT added in the same proportion was an attractant of a low order. That is, the Japanese beetle response was consistently greater to the test materials with DDT present, except to Shell Helix superior oil and Sova Spray No. 2. With DDT present, only Velsicol AR 60, Velsicol AR 50, and Sovacide s/v 544-B were significantly repellent. Further testing will be necessary to determine the exact status of DDT.

With a standard attractant added to the commercial formulation of the test ingredients the solvents, regular run kerosene, fuel oil No. 2, Velsicol AR 50, Velsicol AR 55, Velsicol AR 60, Sovacide 544-B, Sovacide 544-C, Sun Solvent and Shell E-407 R were repellent in the tests of 1950. The Japanese beetles did not respond in either a negative or positive manner to odorless kerosene, "solvent," benzene, xylene, deobase, Shell Insecticide Base, Ultracene or to the insecticide Vaponia D-43. These eight ingredients were of such a low order of repellency that they were completely masked by the standard attractant. In 1951 Shell Insecticide Base and deobase with the standard attractant attracted beetles in large quantities. The remaining 13 test materials were repellent. The most pronounced repellency was shown to Velsicol AR 60, Velsicol AR 50, Shell Solvent E-407 R, fuel oil No. 2, Sovacide s/v 544-B and Atlas G-1276 in descending order of repellency.

A second phase of the experiment in 1951 was the testing of the attractant or repellent value of the ingredients by applying them as sprays to canning corn in various stages of maturity. In test plots B & D in which corn was treated with solvents and emulsifiers there was a notable decline in beetle population when the test plots were compared with the numbers in the check plots. In the plots treated with Shell Insecticide Base and deobase, the beetle population remained relatively the same after treatment as before. The conclusion was that these two materials were neutral and did not prevent the beetles from returning to feed on the corn silk. The beetles avoided the DDT treated plot, but whether this was due to the insecticidal effect or a repellent effect of the DDT was not determined.

The results of the experiments do not support the hypothesis that Japanese beetles are attracted into cornfields by the insecticide on some ingredient of the insecticide used in the treatment of the fields. Most of the ingredients tested were repellent and would discourage the Japanese beetle from entering the treated fields. The results do suggest that the problem is more complex from an ecological and practical viewpoint than was thought at the beginning of the experiment.

TABLE XXIX.--A SUMMARY OF THE RESULTS OF EXPERIMENTS TO DETERMINE THE ATTRACTANT, REPELLENT, OR NEUTRAL PROPERTIES OF SELECTED INGREDIENTS OF INSECTICIDES.

R = repellent
N = neutral
A = attractant

Tests of 1950

Ingredient	Tested Alone			+ DDT			+ Standard Bait		
	R	N	A	R	N	A	R	N	A
Solvents									
Sun Solvent	X						X		
Velsicol AR 50	X				X		X		
Velsicol AR 60	X				X		X		
Kerosene	X				X		X		
Fuel Oil No. 2	X				X		X		
Shell Solvent E-407 R	X				X		X		
Shell Insecticide Base	X				X			X	
Sovacide s/v 544-C	X				X		X		
Sovacide s/v 544-B	X				X		X		
Xylene	X				X			X	
Deobase	X				X			X	
Kerosene odorless	X				X			X	
Velsicol AR 55	X						X		
"Solvent"	X				X			X	
Benzene	X				X			X	
Mistol	X								
Ultracene	X				X			X	
Emulsifiers									
Atlas G-1276	X								
Atlas Span 85	X								
Atlas Tween 20	X								
Triton X-100	X								
Arqua o-26	X								
Atlox	X								
Ethofat 242/45	X								
Ethoneen 5/15	X								
Tenlo-400	X								
Atlas Span 20			X						
Nonisol 210			X						
Literite T			X						

TABLE XXIX (Continued)

Tests of 1950 (Cont.)

Ingredient	Tested Alone			+ DDT			+ Standard Bait		
	R	N	A	R	N	A	R	N	A
Oils									
Mineral oil (light)	X								
Mineral oil (heavy)	X								
Synergist									
Cyclohexanone			X						
Insecticides									
Toxaphene			X?						
Lindane	X								
Benzene hexachloride	X								
Methoxychlor	X								
Parathion	X								
Velsicol (1068)	X								
Chlordane	X								
Aldrin	X								
Rhothane	X								
Penphene	X								
Pyrethol Industrial Spray			X?						
Vaponia D-43	X			X				X	

Tests of 1951

Ingredient	Tested Alone			+ DDT			+ Standard Bait		
	R	N	A	R	N	A	R	N	A
Sun Solvent	X			X?			X		
Velsicol AR 50	X			X			X		
Velsicol AR 60	X			X			X		
Kerosene	X			X?			X		
Fuel Oil No. 2	X			X?			X		

TABLE XXIX (Continued)

Ingredient	Tested Alone			+ DDT			+ Standard Bait		
	R	N	A	R	N	A	R	N	A
Shell Solvent E-407 R	X			X?			X		
Shell Insecticide Base		X				X		X	
Shell Helix Superior Oil		X		X?			X		
Sovacide s/v 544-B	X			X			X		
Xylene	X			X?			X		
Sova Spray No. 2		X		X?			X		
Deobase		X				X		X	
Atlas G-1276	X				X?		X		
Emcol 74	X?				X?		X		
Emcol 77	X				X?		X		

Field Tests on Canning Corn - 1951

Ingredient	Tested Alone			+ DDT			+ Atlas G-1276		
	R	N	A	R	N	A	R	N	A
Velsicol AR 50	X			X			X		
Velsicol AR 60	X			X			X		
Sovacide s/v 544-B				X			X		
Atlas G-1276		X		X					
Emcol 74	X			X					
Emcol 77	X			X					
Shell Insecticide Base		X		X					
Deobase		X		X					
Helix Superior Oil	X	X		X					

BIBLIOGRAPHY

1. Dickerson, Edgar L., and Weiss, Harry B. "*Popillia japonica* Newm; a Recently Introduced Japanese Pest." *Canadian Ent., 50* (1918), pp. 217-221.

2. Britton, W. E., and Johnson, J. P. "The Japanese Beetle in Connecticut." Conn. Agri. Exp. Sta. Bull. 411 (1938), pp. 457-486.

3. Coon, B. F., "Duplicating Japanese Beetle Injury in Field Corn." J. Econ. Ent., 37 (1944), pp. 253-257.

4. Langford, G. S, Rothgeb, R. C., and Cory, E. N. "Relation of Planting Dates of Corn and Japanese Beetle Injury." J. Econ. Ent., 37 (1944), pp. 253-257.

5. Hadley, C. Y., and Hawley, I. M. "General Information about the Japanese Beetle in the United States." U. S. Dept. Agri. Cir. 332 (1934), p. 10.

6. Dethier, Vincent G. Chemical Insect Attractants and Repellents. Philadelphia: The Blakiston Co., 1947, p. 289.

7. Anonymous. "Some Principles Involved in a Well-Plannted Experiment." Ohio Agri. Exp. Sta., Dept. of Ent., Pub. Series No. 13, p. 6.

8. Stark, F. C. "The Analysis of Variance." Dept. of Hort., Univ. of Md. (1949), p. 4.

AUTOBIOGRAPHY

I, James Russell Foster, was born in Springfield, Kentucky, January 9, 1910. I received my secondary school education in the public schools of the city of Springfield, Kentucky. My undergraduate training was obtained at The University of Kentucky, from which I received the degree of Bachelor of Arts, with a major in zoology in 1933. I received the degree Master of Science from the University of Kentucky in 1935. While in residence at the University of Kentucky, I taught zoology as a graduate laboratory assistant and served as the Curator of the Museum of Anthropology and Archaeology. In 1936, moved by economic necessity, I began work as a Junior Archaeologist with the Tennessee Valley Authority and spent the next five years in intensive field and laboratory research on the North American Indian. In the autumn of 1938 I attended the University of Chicago for one quarter. In 1941, I was called into active duty as an officer in the United States Army where I served in the states and overseas until released in the spring of 1946. In June 1946, I entered the Graduate School of Ohio State University and began studying for the degree Doctor of Philosophy. While in residence at Ohio State University, I acted as a research assistant during the year 1947-48. In June 1948, I was employed by the Department of Entomology of the University of Maryland as a research entomologist. At the University of Maryland I continued my studies by taking off-campus research.

In August 1951, I was recalled to active duty by the United States Army. In September 1952, I sailed for Korea where I served with the 45th Infantry Division. In September 1953, I rejoined the staff of the Department of Entomology at the University of Maryland as an assistant professor of entomology.