WHITE CUTWORM (EUXOA SCANDENS [RILEY]): SAMPLING AND BIOLOGY IN ASPARAGUS IN MICHIGAN

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ABSTRACT

WHITE CUTWORM (EUXOA SCANDENS [RILEY]): SAMPLING AND BIOLOGY IN ASPARAGUS IN MICHIGAN

By

Emmett Philip Lampert

Several non-destructive sample methods were evaluated with barrier-baited plots being the best for quantitative samples and open-baited plots being best for detection purposes.

Movement rates of overwintering larvae were calculated and a FORTRAN model was used to simulate the effect of treatment spacing on expected mortality. It shows that mortality can be selected by varying the between treatment spacing.

Adult flight behavior as measured by a blacklight shows better synchronization when time is changed from chronological to physiological time (degree-day--$°D_{50}$). Weather parameters were evaluated in the fluctuations in within year flight activity.

Temperature estimation at a field site was accomplished through regression analysis between a thermograph operated in a commercial field and the weather station in Hart, Michigan. Developmental information was used to allow calculations of weighted mean instars. This allowed aging of a population and when weighted mean instars are between 2.0 and 4.0 insecticide applications should be made if densities require treatment.

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Emmett Philip Lampert

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INTRODUCTION

On May 10, 1971 the initial report of significant cutworm damage in commercial asparagus was received from Oceana county, Michigan (Cress and Wells unpublished). Specimens were collected and identified as white cutworms, Euxoa scandens (Riley), and bristly cutworms, Lacinipolia renigera Stephens.

Since 1971 the damage caused by the bristly cutworms has decreased to an insignificant level. White cutworms, however, have been gradually increasing and by 1975 were present in economically damaging numbers in most of the commercial asparagus growing region of Oceana county.

Since the larvae are nocturnal feeders, feeding is not frequently observed. Larval feeding begins about one hour after sunset with the larvae climbing the asparagus spear and feeding on the tender spear tips and spear sides. This direct feeding results in an unmarketable spear due to insect damage and/or termination of normal spear growth.

Commercial asparagus plantings are most productive when planted in deep, loose, and light soil types (Commercial Growing of Asparagus 1971). Good examples of such soil types are mucks and loamy sands.

The larvae of the white cutworm are also most commonly found in sandy soils (Hudson and Wood 1930, Hardwick 1970, and

Bierne 1971). Because of this overlap in soil types it becomes more important to understand more of the biology and behavior of the white cutworm in an effort to reduce its damage to the asparagus industry.

Asparagus is an important vegetable crop in Michigan, with the 1975 production valued at 4.7 million dollars (1975 Crop Reporting Board). Acreage of asparagus in Michigan was reported at 18,493 acres in 1972, with commercial asparagus being grown in 22 counties (1972 Michigan Asparagus Survey). Unpublished blacklight trap records of Mr. John Newman show ten (45.45%) of these counties to have white cutworms present. However, only Oceana county has reported them as economically important. There is, therefore, a potential economic problem with the white cutworm to the asparagus industry.

Since asparagus is a perennial crop which requires several hundred dollars investment per acre before it can be harvested, a destructive larval sampling technique would not be tolerated by most farmers. Due to the unique nature of asparagus, a non-destructive larval sampling technique had to be developed.

It was with these factors in mind that a study was undertaken to: (1) more fully understand the biology of the white cutworm; (2) investigate feeding behavior of adults and larvae; (3) develop a non-destructive larval sampling technique; and (4) calculate movement rates to investigate various strip baiting strategies.

LITERATURE REVIEW

The white cutworm, Euxoa scandens, was first taxonomically categorized in 1869 by C. V. Riley (Riley 1869) upon the successful rearing of a previously unidentified moth. The larvae had been collected from mixed orchards of apples, pears, peaches, and cherries near Calumet, Illinois (Riley 1869). Dr. Riley designated it as the Climbing Rustic (Agrotis scandens); choosing the specific name scandens, which means to climb, because of the climbing tendencies exhibited by the larvae.

After going through a series of generic changes, scandens has been placed in the genus Euxoa. Hardwick (1970) has summarized the synonomy through 1970 with a brief abstract of each paper.

Slingerland (1895) proposed the present common name of white cutworm. He reasoned cutworms are commonly named by color or habit. Since many other equally common cutworms have exhibited a larval climbing tendency, he believed "climbing rustic" was too general for a common name. Therefore, owing to its pale color and white markings, he proposed "white cutworm" as a more appropriate common name.

Many keys are available for the larvae (Crumb 1932, Walkden 1950, Frost 1955) and for the adults (Forbes 1954, Hardwick 1966 and 1970) of E. scandens. Each contains a brief description of biology and damage.

The most comprehensive biological work has been done by Hudson and Wood (1930). They identified twenty of the known food hosts (Appendix A). From Appendix A it can be seen that the white cutworm larvae are omnivorous feeders, feeding on whatever is available. Of particular interest is the fact that most of the literature describes E. scandens as a fruit pest rather than a vegetable pest.

Parasites of the larvae include Copidosoma bakerii (Howard) (Hudson and Wood 1930) and Poecilanthrax willistonii (Coq.) which has been recovered from E. scandens in the western extremes of its range (Painter 1960). Parasitism by C. bakerii reached a maximum rate of about 20% in Oceana county in late May and early June in 1974 and 1975.

E. scandens is a northern univoltine species and is distributed from the Rocky Mountains east to the Atlantic Ocean, and from Nebraska and Colorado north to two specimens taken in the Northwest Territories (Hardwick 1970) (Figure 1). Hardwick (1970) presents an extensive list of moth collection records from the United States and Canada. In Figure 2 the known Michigan distribution of white cutworms from the personal records of Mr. John Newman is shown. The Michigan counties where asparagus is commercially grown are also shown in Figure 2.

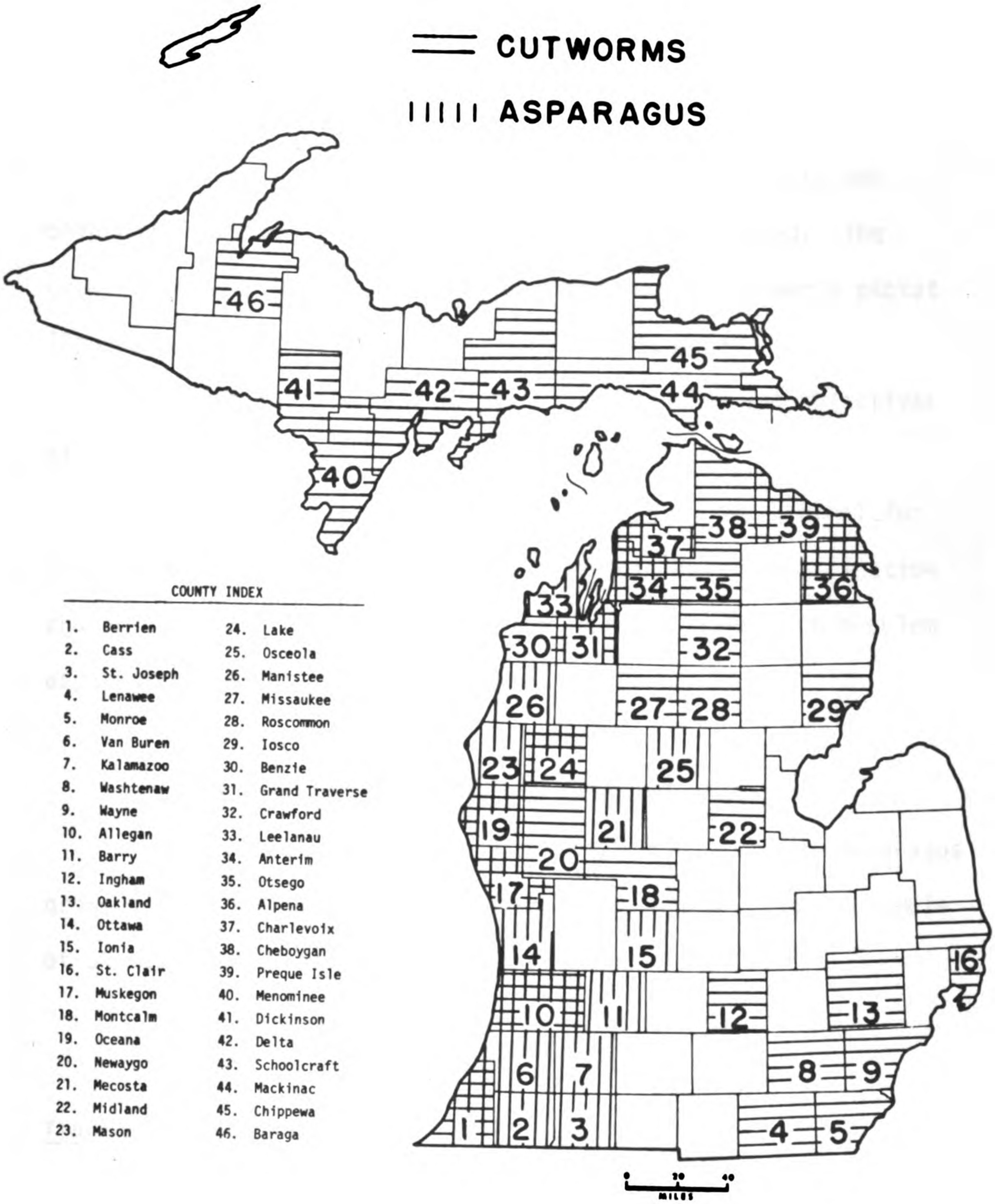

Figure 2. Known white cutworm distribution in Michigan and counties where asparagus is commercially grown.

METHODS AND MATERIALS

Questionnaire Survey

A list of the asparagus growers in Oceana county was obtained from the county extension agent, Edgar Strong. The growers on this list were then sent an asparagus grower's packet (Appendix B). Items included in this packet were:

1. An introductory letter of explanation and objectives of the questionnaire;

2. An "Asparagus Insect Identification and Control for 1975" fact sheet, which included a brief biology, identification characteristics, and control measures for the three main problem asparagus insects;

3. An asparagus questionnaire;

4. A self-addressed stamped return envelope.

This packet was then mailed to 327 Oceana county asparagus growers. A follow-up questionnaire was mailed to a random sample of 50 non-respondents.

Adult Sampling

Yearly Samples

Adult white cutworms were collected with two Ellisco^{R} general purpose, 15 watt blacklight insect traps in Oceana county. One trap was operated on the farm of Mr. Lyle Sheldon, eight miles west of Shelby; the second trap was operated on the farm of

Mr. Francis Hawley, two miles northeast of Shelby. Both traps were in operation from 1972 through 1975. Cyanogas[R] (American Cyanamid Corp.) was used as a killing agent. It was placed in small paper bags in the bottom of the blacklight trap and changed on two-day intervals. On one- or two-day intervals the moths were collected from the trap, dated, and allowed to dry. Once a week the collections were then mailed to M.S.U. for sorting and identification.

Hourly Samples

Information on hourly moth flight activity at the blacklight trap was obtained by collecting the trap contents on hourly intervals from 9:00 p.m. to 6:00 a.m. This was done on four separate occasions (July 9, 10, 18, and 25, 1975). The collections were labeled and stored in plastic bags until the following day when the white cutworm moths were sorted, sexed, and the collection time recorded.

Larval Sampling

A larval sampling technique was developed which incorporated a 5% apple-pomace bait formulation of Carbaryl (Sevin[R]). Sevin[R] was selected since it was the only insecticide registered for cutworm control in asparagus in Michigan.

The insecticide was used in three sampling designs:

1. Baited-barrier plots;

2. Open-baited plots;
3. Pitfall traps.

Baited-Barrier Plots

In the enclosed soil plots, seven circular plot sizes were used. These plot areas were 3, 6, 12, 24, 48, 96, and 192 square feet. The circumference was calculated for each of these areas and strips of four inch steel lawn edging were cut to form each circle. The ends of the lawn edging were then stapled together, centered over an asparagus crown, and then pushed one inch into the soil. Sevin[R] bait was spread evenly throughout the enclosed area and the number of dead cutworms were recorded the following days. Due to the rapid breakdown of Sevin[R], bait was reapplied on two-day intervals in all experiments.

Open-Baited Plots

Two sizes of open plots were evaluated. The largest plot was 15 feet by 15 feet and encompassed three asparagus rows (Figure 3). Sevin[R] bait was spread evenly throughout the plot and dead larvae were collected from the central square yard for the four following days. The remainder of the plot acted as an insecticide barrier about the desired sample area.

The small plots, three feet by six feet, were used with three different placements within the rows: (1) between-two rows (Figure 4a); (2) perpendicular-to a row (Figure 4b); and (3) parallel-to a row (Figure 4c). Sevin[R] bait was spread evenly

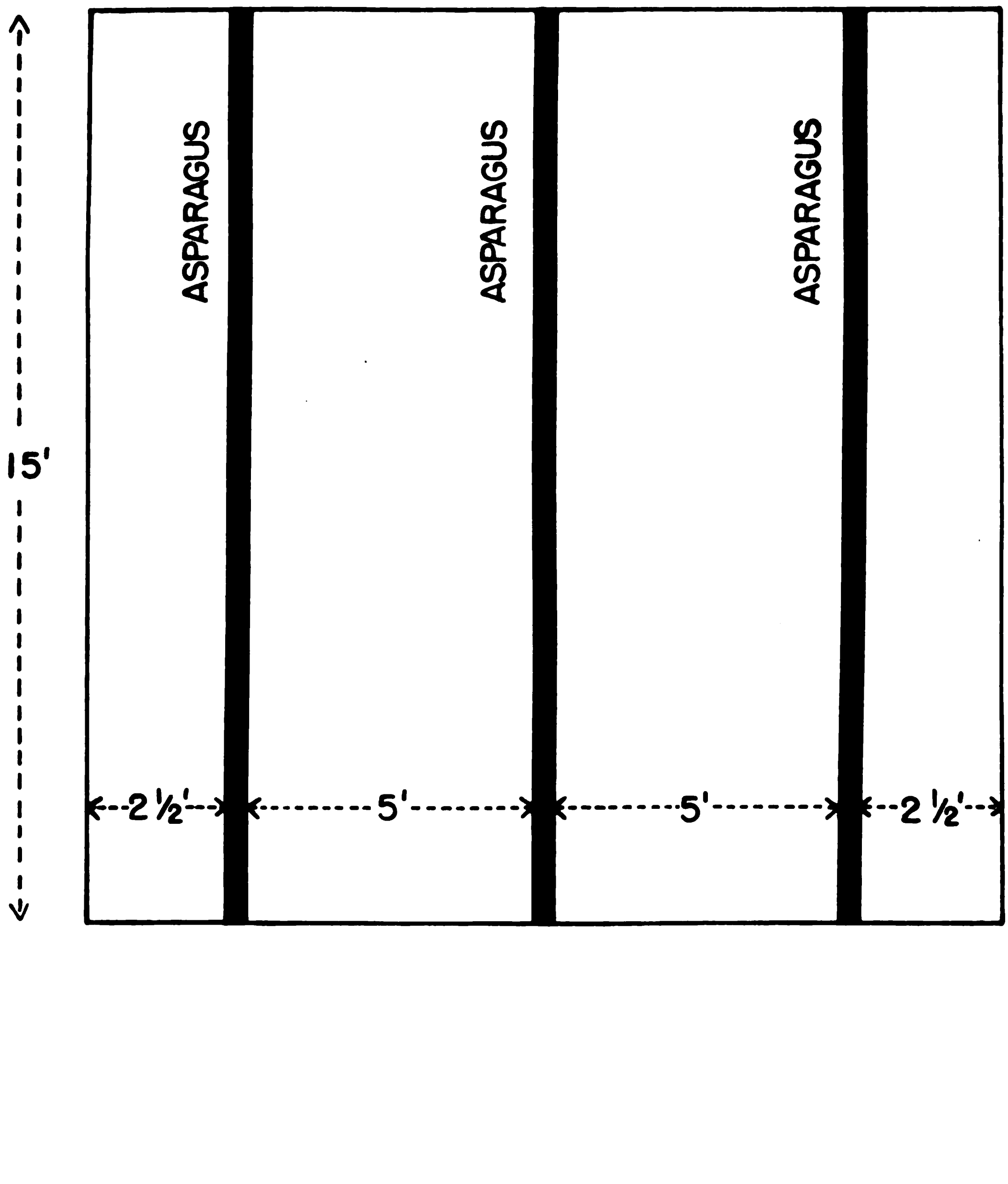

Figure 3. 15' by 15' white cutworm larval plots in asparagus.

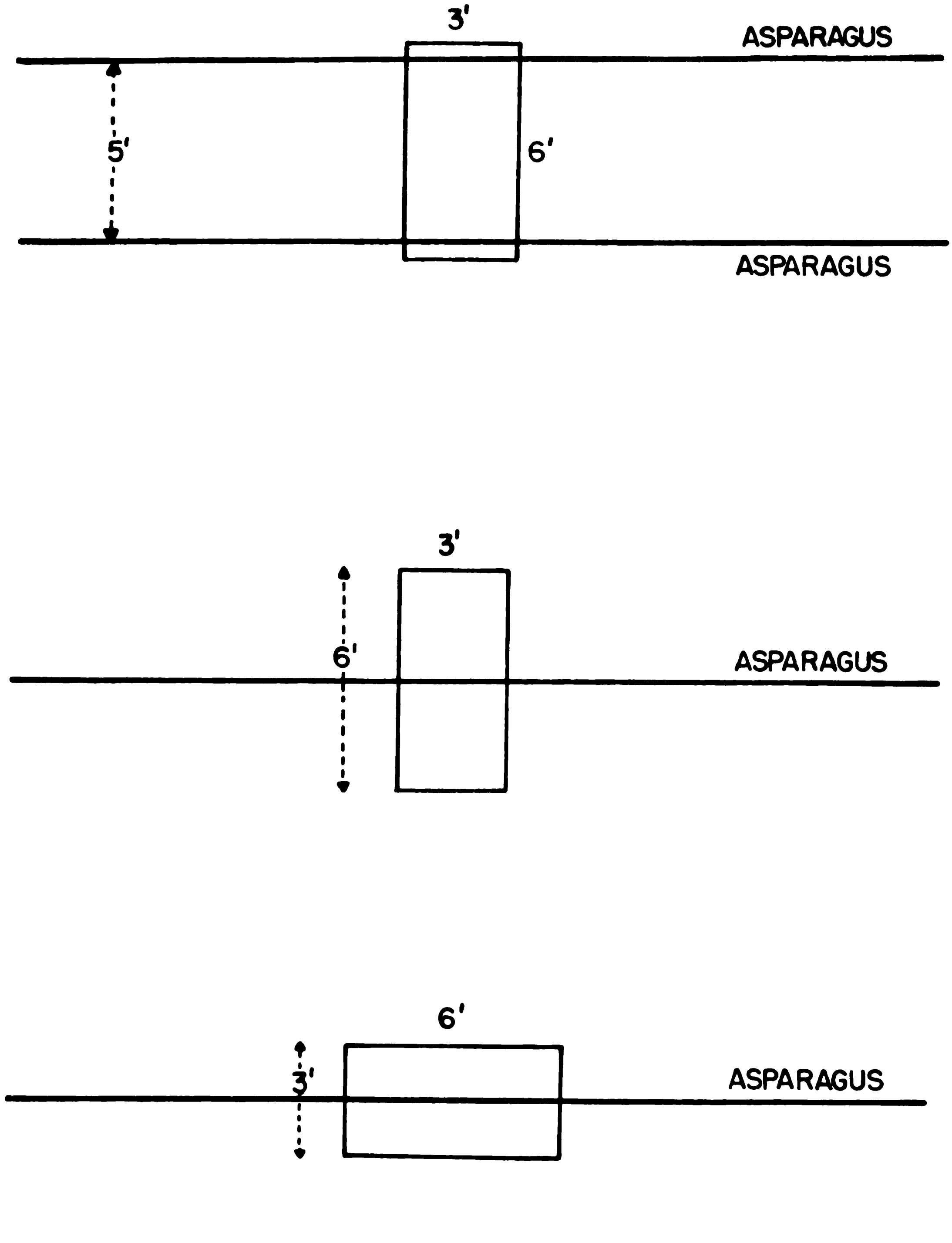

Figure 4. 3' by 6' white cutworm larval plots in asparagus - (4a) between two rows, (4b) perpendicular to a row, (4c) parallel to a row.

throughout the plot; the entire plot was examined for dead larvae on each of the following days.

Pitfall Traps

Two pitfall traps, two-cup plastic containers, were placed in each of three adjacent asparagus rows in holes made with a golf course hole cutter. The traps were set in the holes with their lips flush with the soil surface. Each trap site consisted of six traps, alternating a baited trap (1/4 inch Sevin^{R} bait) with an unbaited trap in each of the three rows.

Pitfall Trap Evaluation

To evaluate pitfall traps as a sampling tool, a test was conducted at the M.S.U. Botany Farm Research asparagus plots to check for larval attraction or repulsion to the pitfall traps. Four concentric circles with radii of one, two, three, and four feet respectively (Figure 5) represented the trap site. As close to 20% as possible of the first three circles were pitfall traps, whereas the fourth circle had pitfall traps two inches apart with barriers between them to prevent the white cutworms from escaping. Since no white cutworms were present in this site, no marking was necessary. Small groups of cutworms were released every hour in the center of the test area. Whenever a cutworm tumbled into a pitfall trap, the time and pitfall trap number were recorded and the specimen removed.

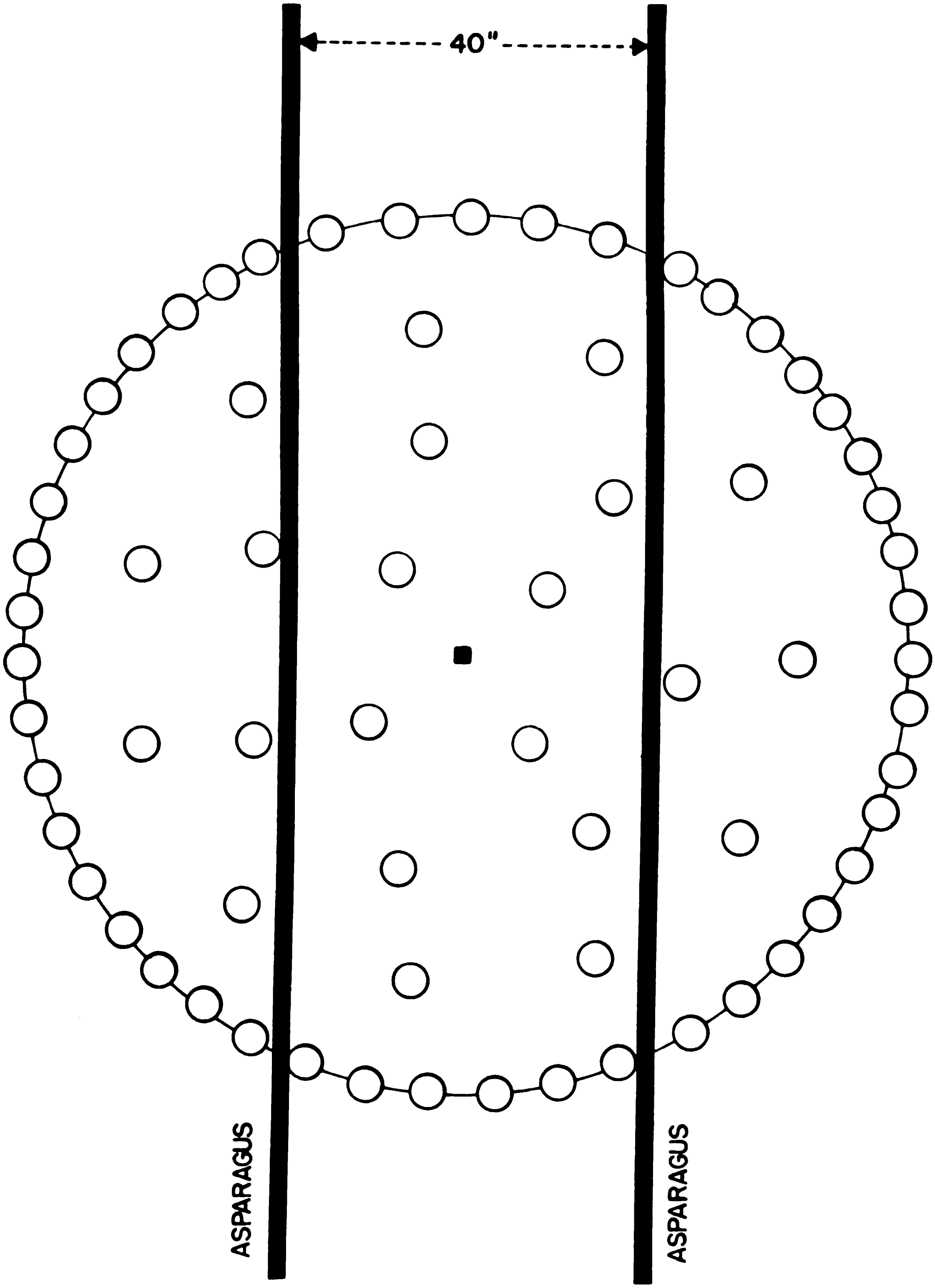

Figure 5. Test area for determination of attraction or repulsion of white cutworms to pitfall traps.

Oceana County White Cutworm Survey

An Oceana county white cutworm survey was taken in ten growers' asparagus fields. Growers were selected from the questionnaire responses; selecting those growers who (1) had agreed to cooperate; (2) had white cutworms in their asparagus; and (3) used few insecticides. Cooperators were given nine pitfall traps, collection vials, vial labels, forceps, and data sheets.

A trap site consisted of nine traps, with three traps placed 12 feet apart in a row in three alternate rows (Figure 6). Two inches of soapy water, which reduced surface tension and facilitated drowning of the captured insects, were placed in the traps. Cooperators were requested to check the traps daily, remove the captured white cutworms, and place them in labeled vials filled with FAA (50 parts H_2O, 47 parts 95% ETOH, 2 parts Formaldehyde, 1 part Glacial Acetic Acid). Weather information for the previous night was recorded on the data sheets (Appendix C). This information correspondence with the weather conditions present when the larvae were collected. On this sheet the cooperators were also asked to record field information for the present day, i.e. harvest, application of insecticides, etc.

On days when harvest occurred, the cooperators were requested to record the number of damaged spears in 40 of each of the three rows. Damaged spears were to be removed from the field.

Asparagus

Asparagus yield information was obtained from Dr. Hugh Price, M.S.U. Horticulture Department, and N. J. Fox and Sons

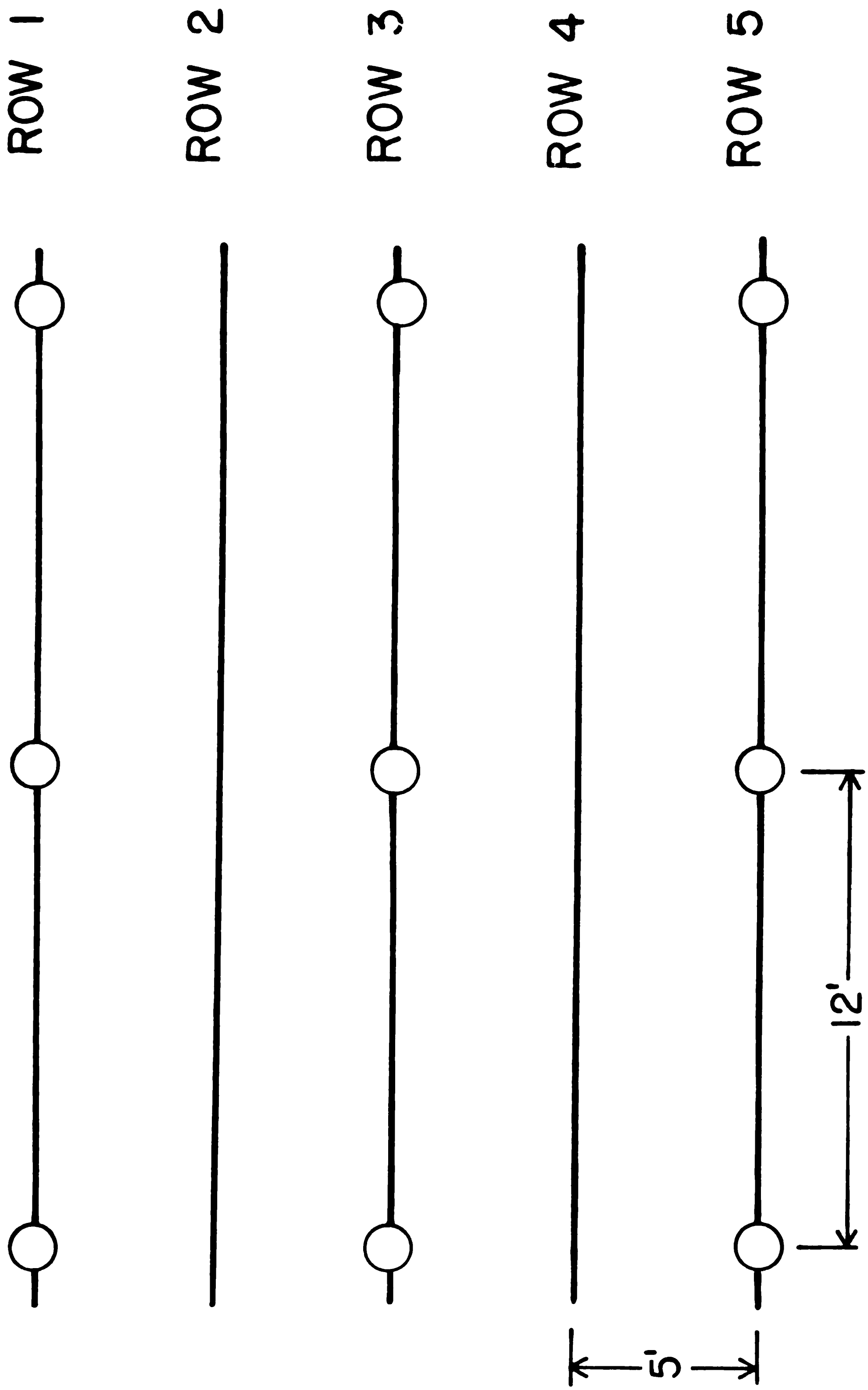

Figure 6. Asparagus cutworm survey pitfall trap plot design.

Processing, Shelby, Michigan. Dr. Price provided yield information on nine experimental varieties grown at the Sodus Experimental Farm, Sodus, Michigan (M.S.U. 1, Mary Washington, U.C. 66, U.C. 72, U.C. 309, U.C. 711, N.J. 44X22, N.J. 51X22, N.J. Improved).

N. J. Fox and Sons provided information on the number of spears in a 50, 100, 150, or 200 ounce sample based on sales receipts for the 1975 asparagus crop from a commercial field.

Larval Feeding Behavior

Nocturnal Observations

The locations of feeding larvae were recorded as feeding on spears or butts (unharvested portion of spears). Also recorded were all the spears and butts within a one foot radius of the observed larva. This allowed the calculation of a ratio of the number of cutworm larvae on spears and butts which could then be compared to the overall spear-butt ratio in the field.

Laboratory Experiments

Freshly harvested spears were cut into two three-inch sections, the tip of the spears being considered an experimental spear and the lower section considered an experimental butt. The basal ends of both were then dipped in melted beeswax to prevent subsurface feeding and moisture loss. Combinations of one spear and one butt, one spear and two butts, and two spears and one butt were then placed in a two-cup plastic container filled with one inch of moist sand. One larva was released in each container and feeding damage evaluated the following morning.

Larval Movement Rates

Diffusion coefficients, as described by Pielou (1969), were used by Casagrande (1975) in the development of a strip spray model for the cereal leaf beetle. Modifications in Casagrande's model were made such that the model could be used to evaluate movement of the white cutworm larvae. The model (Appendix D) functions on the following assumptions: (1) a bait insecticide (Sevin[R]) would be used and its band of application was limited to one foot in width; (2) any larva, which came within this treated band would stop, feed, and ultimately die; (3) the cutworms were actively moving about the fields for five hours per night. This assumption was based on field observations and movie evaluations which indicate larval activity for about five hours per night.

Diffusion coefficients (D) were calculated by (Pielou 1969):

$$D = \frac{r^2}{4T} \qquad (1)$$

where r = distance in feet larvae moved

T = hours required to move r distance.

Estimates of D were obtained in two manners: (1) from movies in the field and (2) from pitfall trap movement experiments.

Movies

A Minolta Autopak-8 D10 was used for nocturnal observations of larvae. The camera was equipped with an intervalometer, which allowed for time-lapse photography, and an AC rechargeable flash. The intervalometer allowed for selection of time between frame exposures (T). Thus, the only necessary variable was r, which could be measured by direct observation of the film. The movie camera was mounted on a tripod and focused on approximately one square yard of asparagus row in a commercial asparagus field. The mean distance the larvae moved between frames was calculated, from which individual larval diffusion coefficients were obtained. Diffusion coefficients obtained in this way were averaged and a mean diffusion coefficient was calculated for each night.

Pitfall Traps

A four-foot radius circle of 60 pitfall traps placed 1/2 inch apart was constructed at the M.S.U. Botany Farm asparagus research plots and served as the test area (Figure 7). Wooden one-foot stakes, placed between the pitfall traps, served as barriers to prevent the larvae from leaving the test areas. A single group of larvae (75 on June 18, 25 on June 19) was released at 10:00 p.m. in the center of the circle per night and the traps monitored until 1:00 a.m. Whenever a larvae tumbled into a trap, trapped larvae were removed and the trap number and time captured were recorded. In this fashion, an estimate for T was obtained since r was fixed at four feet. Individual larval diffusion

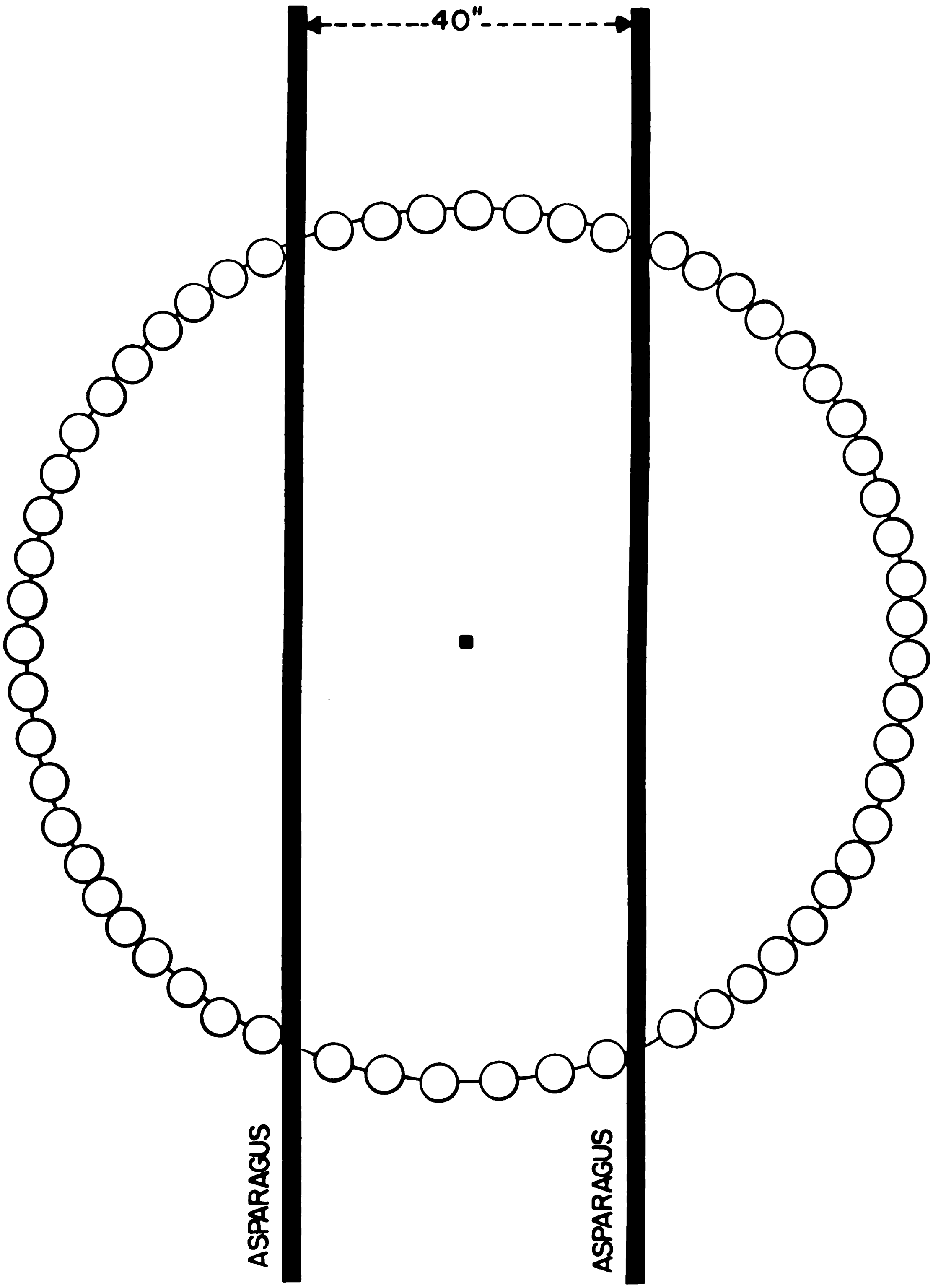

Figure 7. Test area for calculating movement rates for white cutworms.

coefficients were again calculated and their mean obtained for the experiment for each night.

RESULTS AND DISCUSSIONS

Questionnaire Survey

Of the 327 questionnaires initially mailed out, seven were returned to the sender due to various postal problems, i.e. no forwarding addresses, improper signatures, etc. Of the 320 questionnaires which reached the growers, 107 were returned for a response of 33.44%. The response to the follow-up 50 questionnaires was very poor; only seven responded for 14.00%. Due to the extremely poor response to the follow-up questionnaire, the normal statistical analyses for significant differences between first respondents and non-respondents were not performed since little faith could be placed in the results. Therefore, the two responses will be treated as one response of 35.63% reporting 3334 acres of asparagus. Extrapolation of 100% response estimates 1974 asparagus acreage in Oceana county as:

$$3334/35.63\% = 9357.28 \text{ acres} \qquad (2)$$

Since the statistical analyses were not performed, no further extrapolations to county totals will be attempted and the following discussion will deal only with the responses to the questionnaire.

Of the 114 responses, five or 4.39% were from counties other than Oceana (Mason and Mecosta) and ten or 8.77% had no asparagus. These responses will be omitted from the following discussion.

Field Age and Size Distribution

The 1975 age distribution of asparagus fields in Oceana county as reported from the questionnaires (Table 1) indicates the recent trend toward increased asparagus planting. This is shown by the fact that 41.15% of the total number of asparagus fields and 38.42% of the total acres are less than five years old. Asparagus reaches its maximum production by the age of 15 years (Price personal communication) and since about 84% of both acreage and number of fields were less than 15 years old, most of the asparagus fields were or soon will be of a highly productive age. It is interesting to note that the one-year fields make up a large percent of total fields (10.29) but a rather small percent of the total acres (4.74), thus indicating that many small fields were planted in 1974. According to Table 2, 54.73% of the total number of fields are less than ten acres but only 21.99% of the total acres. The importance of this is if a given number of acres are to be planted then by planting many small fields rather than a few large fields the county's density of fields will increase. As the field density increases, the probability of planting a field in or near a population of white cutworms increases. Since crops such as corn, potatoes, and others are planted too late in the spring for the larvae to feed on, the larvae tend to feed on weeds and other economically unimportant vegetation present in those fields.

Table 1. Asparagus field age distribution for 1975 as reported from questionnaires (A zero entry indicates no responses for that category).

Field Age (Years)	No. of Fields	% of Total Fields	Cumulative %	Acres in Age Class	% of Total Acres	Cumulative %
1	25	10.29	10.29	158	4.74	4.74
2	12	4.94	15.23	203	6.09	10.83
3	21	8.64	23.87	347	10.41	21.24
4	19	7.82	31.69	233	6.99	28.22
5	23	9.47	41.15	340	10.20	38.42
6	23	9.47	50.62	228	6.84	45.26
7	17	7.00	57.61	229	6.87	52.13
8	16	6.58	64.20	236	7.08	59.21
9	6	2.47	66.67	66	1.98	61.19
10	16	6.58	73.25	353	10.59	71.78
11	3	1.23	74.49	71	2.13	73.91
12	8	3.29	77.78	118	3.54	77.44
13	6	2.47	80.25	91	2.73	80.17
14	1	.41	80.66	10	.30	80.47
15	7	2.88	83.54	137	4.11	84.58
16	3	1.23	84.77	31	.93	85.51
17	3	1.23	86.01	41	1.23	86.74
18	2	.82	86.83	25	.75	87.49
19	0	0.00	86.83	0	0.00	87.49
20	9	3.70	90.53	106	3.18	90.67
21	1	.41	90.95	35	1.05	91.72
22	0	0.00	90.95	0	0.00	91.72
23	2	.82	91.77	11	.33	92.05
24	2	.82	92.59	71	2.13	94.18
25	8	3.29	95.88	138	4.14	98.32
26	2	.82	96.71	20	.60	98.92
27	0	0.00	96.71	0	0.00	98.92
28	1	.41	97.12	4	.12	99.04
29	0	0.00	97.12	0	0.00	99.04
30	4	1.65	98.77	20	.60	99.64
>30	3	1.23	100.00	12	.36	100.00

Table 2. Asparagus field size distribution for 1975 as reported from questionnaires (A zero entry indicates no responses for that category).

Field Size (Acres)	No. of Fields	% of Total Fields	Cumulative %	Acres in Age Class	% of Total Acres	Cumulative %
2	22	9.05	9.05	32	.96	.96
4	29	11.93	20.99	103	3.09	4.05
6	38	15.64	36.63	207	6.21	10.26
8	14	5.76	42.39	101	3.03	13.29
10	30	12.35	54.73	290	8.70	21.99
12	15	6.17	60.91	176	5.28	27.26
14	13	5.35	66.26	174	5.22	32.48
16	7	2.88	69.14	107	3.21	35.69
18	9	3.70	72.84	157	4.71	40.40
20	13	5.35	78.19	259	7.77	48.17
22	5	2.06	80.25	108	3.24	51.41
24	4	1.65	81.89	94	2.82	54.23
26	10	4.12	86.01	250	7.50	61.73
28	4	1.65	87.65	109	3.27	65.00
30	6	2.47	90.12	176	5.28	70.28
32	2	.82	90.95	62	1.86	72.14
34	3	1.23	92.18	101	3.03	75.16
36	4	1.65	93.83	140	4.20	79.36
38	2	.82	94.65	76	2.28	81.64
40	2	.82	95.47	80	2.40	84.04
42	2	.82	96.30	83	2.49	86.53
44	0	0.00	96.30	0	0.00	86.53
46	2	.82	97.12	90	2.70	89.23
48	1	.41	97.53	47	1.41	90.64
50	2	.82	98.35	100	3.00	93.64
>50	4	1.65	100.00	212	6.36	100.00

Special Distribution of Fields

Benona, Elbridge, Grant, Hurt, and Shelby--the five top asparagus growing townships--reported cutworm damage on 77.05%, 48.23%, 59.13%, 69.92% and 74.20% of their acres respectively (Table 3). These five townships contain 66.67% of the county's asparagus fields and 69.08% of the acres (Figure 8). It was apparent that most of the available farm land in Oceana county was limited to these five townships plus Clay Banks and Golden townships. The rest of the land in Oceana county was mostly state parks or Manistee National Forest. Therefore, by increasing the number of fields in the county, the density of fields in these townships will increase. As this happens, the probability of white cutworm presense will increase once again adding to its importance to the county.

The acres of asparagus with and without cutworm damage and number of fields in each of the county's soil types is given in Table 4. The primary soil was defined as the soil type which occupies most of the field and the secondary soil was the second most predominant soil type in the field. Of 243 fields, 102, or 41.98%, are on Emmet loamy sand or sandy loam; and 23, or 9.47%, are on Rubicon sand. Cutworm damage was reported on 58.96%, 73.12% and 84.49% of their reported acres respectively. For the primary soil type, 95.06% of the fields were on loamy sands, sandy loams, or sandy soils, and for the secondary soil 78.19% of the fields were on these soils. Since sandy soils are the preferred soil types for white cutworms (Hudson and Wood 1930, Hardwick 1970,

Table 3. Asparagus acreage and number of fields by townships and cutworm damage as reported from questionnaires (A zero entry indicates no response for that category).

TOWNSHIPS	CUTWORM DAMAGE							
	Reported		None Reported		Not Given		Total	
	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields
Benona	601	38	106	6	73	6	780	50
Clay Banks	27	3	66	4	0	0	93	7
Colfax	0	0	0	0	0	0	0	0
Crystal	115	4	78	5	0	0	193	9
Elbridge	218	11	234	15	0	0	452	26
Ferry	75	5	41	6	0	0	116	11
Colden	124	9	69	6	0	0	193	15
Grant	217	14	150	8	0	0	367	22
Greenwood	0	0	16	2	0	0	16	2
Hart	251	21	87	7	21	3	359	31
Leavitt	5	1	0	0	0	0	5	1
Newfield	31	2	0	0	0	0	31	2
Otto	85	10	9	1	0	0	94	11
Pentwater	0	0	0	0	0	0	0	0
Shelby	256	26	89	7	0	0	345	33
Weare	155	8	129	14	6	1	290	23
TOTALS	2160	152	1074	81	100	10	3334	243

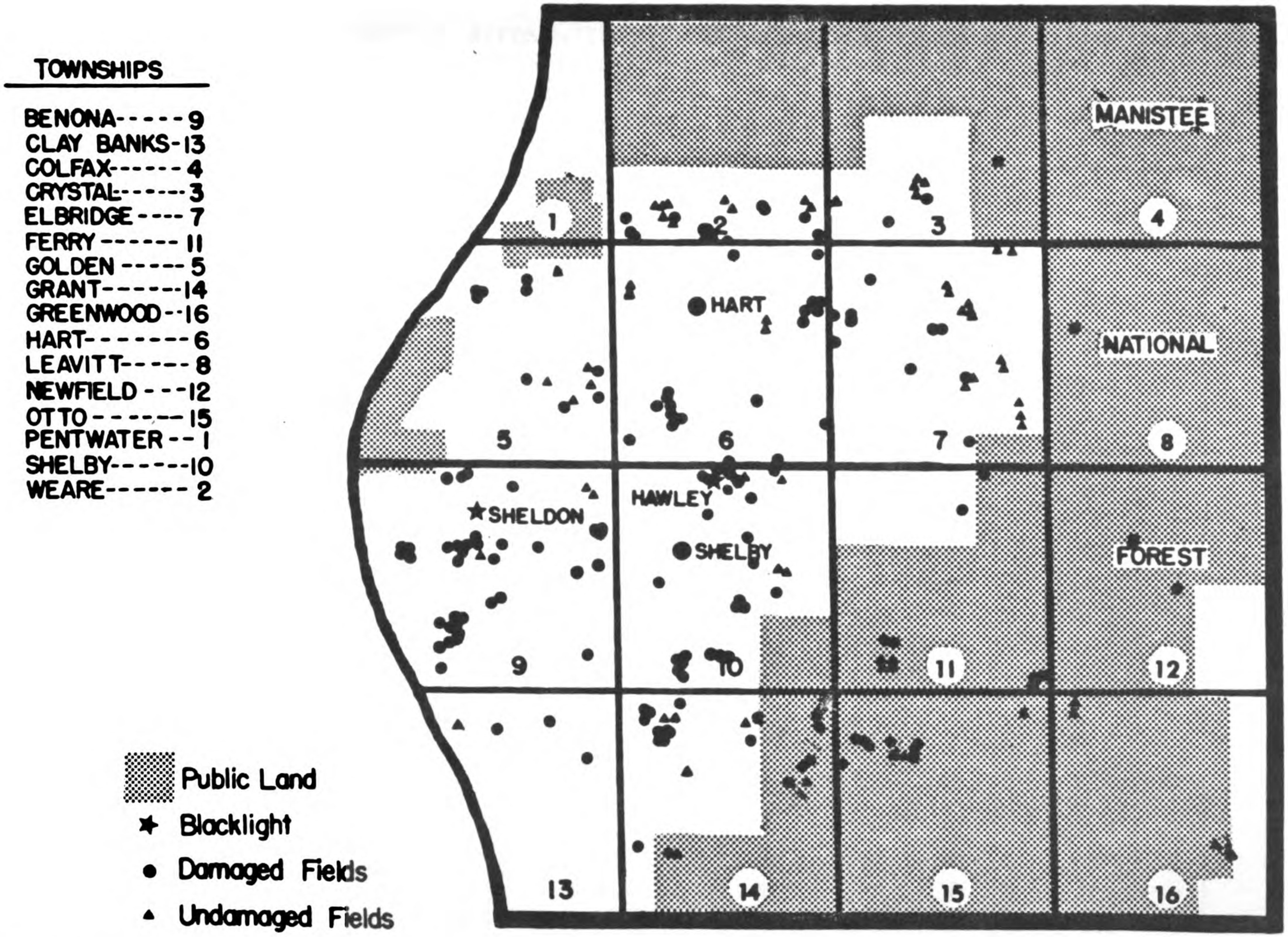

Figure 8. The townships of Oceana county showing the location of Hart, Shelby, the blacklight traps, the public land, and asparagus fields with and without cutworm damage.

Table 4. Number of acres, percent of acres with cutworm damage, and number of fields for the primary and secondary field soil type for each of Oceana county's soil types as reported from questionnaires (A zero entry indicates no response for that category).

SOIL TYPES	PRIMARY SOIL: Cutworm Damage					SECONDARY SOIL: Cutworm Damage				
	Reported (acres)	None Reported (acres)	Not Given (acres)	Percent	No. of Fields	Reported (acres)	None Reported (acres)	Not Given (acres)	Percent	No. of Fields
Antrim sandy loam	60	0	0	100.0	2	5	0	0	100.0	1
Arenac loamy sand	54	97	0	35.8	5	23	0	8	74.2	4
Arenac fine sandy loam	20	12	0	62.5	2	0	0	0	0.0	0
Bergland loam	24	0	0	100.0	1	0	0	0	0.0	0
Bridgman fine sand	0	61	0	0.0	3	12	20	0	37.5	2
Coventry silt loam	0	0	0	0.0	0	0	0	0	0.0	0
Eastport sand	0	4	0	0.0	1	0	0	4	0.0	1
Echo loamy sand	19	0	0	100.0	6	172	86	0	66.7	22
Emmet loamy sand	235	111	25	70.5	38	218	108	9	65.1	28
Emmet loamy sand Smooth phase	126	117	0	42.4	21	239	36	0	86.9	22
Emmet sandy loam	101	191	0	34.6	21	74	80	0	48.1	11
Emmet sandy loam Smooth phase	169	91	6	63.5	22	139	125	0	52.7	17
Granby fine sandy loam	6	0	0	100.0	1	36	0	0	100.0	2
Griffin sandy loam	0	34	0	0.0	1	50	16	0	75.8	2
Griffin sandy clay loam	0	0	0	0.0	0	0	0	0	0.0	0
Iosco sandy loam	0	0	0	0.0	0	0	0	0	0.0	0
Isabella sandy loam	0	0	0	0.0	0	0	0	0	0.0	0

Table 4. Continued.

SOIL TYPES	PRIMARY SOIL Reported (acres)	None Reported (acres)	Not Given (acres)	Percent	No. of Fields	SECONDARY SOIL Reported (acres)	None Reported (acres)	Not Given (acres)	Percent	No. of Fields
Isabella loam	75	5	0	93.8	4	10	10	0	50.0	3
Kalkaska loamy sand	384	100	61	70.5	37	314	61	4	82.9	26
Kalkaska loamy sand Broken phase	54	0	0	100.0	3	49	34	0	59.0	4
Kent silt loam	10	0	0	100.0	1	42	27	0	60.9	4
Maumee loam	8	0	0	100.0	1	8	0	6	57.1	2
Montcalm sandy loam	38	7	0	84.4	8	33	0	0	100.0	6
Munuscong sandy loam	4	1	0	80.0	3	1	0	0	100.0	1
Newton loamy sand	31	9	0	77.5	2	43	18	0	70.5	6
Newton sandy loam	0	0	0	0.0	0	8	0	0	100.0	1
Ogemaw sandy loam	54	0	0	100.0	4	18	0	25	41.9	2
Oshtemo sandy loam	116	0	0	100.0	4	67	62	0	51.9	5
Ottawa loamy fine sand	0	0	0	0.0	0	65	0	0	100.0	3
Ottawa loamy fine sand Rolling phase	0	0	0	0.0	0	0	0	0	0.0	0
Ottawa fine sandy loam	0	0	0	0.0	0	0	0	0	0.0	0
Otto fine sandy loam	0	0	0	0.0	0	0	0	0	0.0	0
Plainfield sand	37	18	0	67.3	3	40	18	0	69.0	5
Roselawn loamy sand	49	0	0	100.0	8	51	7	0	87.9	10
Roselawn loamy sand Smooth phase	29	35	0	45.3	3	0	35	0	0.0	1

Table 4. <u>Continued</u>.

SOIL TYPES	PRIMARY SOIL: Reported (acres)	PRIMARY SOIL: None Reported (acres)	PRIMARY SOIL: Not Given (acres)	PRIMARY SOIL: Percent	PRIMARY SOIL: No. of Fields	SECONDARY SOIL: Reported (acres)	SECONDARY SOIL: None Reported (acres)	SECONDARY SOIL: Not Given (acres)	SECONDARY SOIL: Percent	SECONDARY SOIL: No. of Fields
Rubicon sand	136	29	0	82.4	12	150	55	0	73.2	14
Rubicon sand Broken phase	131	20	0	86.8	11	68	20	0	77.3	7
Saugatuck sand	0	0	8	0.0	1	10	40	0	20.0	4
Sparta loamy sand	0	0	0	0.0	0	0	0	0	0.0	0
Wallace fine sand	0	0	0	0.0	0	0	0	0	0.0	0
Wallkill loam	0	0	0	0.0	0	0	0	0	0.0	0
Warners loam	0	0	0	0.0	0	0	0	0	0.0	0
Washtenaw sandy loam	0	0	0	0.0	0	17	67	0	20.2	4
Weare fine sand	0	0	0	0.0	0	0	0	44	0.0	2
Greenwood peat	0	0	0	0.0	0	0	0	0	0.0	0
Rifle peat	0	62	0	0.0	1	0	16	0	0.0	1
Carlisle muck	37	0	0	100.0	3	123	27	0	82.0	7
Houghton muck	0	0	0	0.0	0	0	0	0	0.0	0
Kerston muck	10	0	0	100.0	1	22	0	0	100.0	2
Burned muck Over clay	0	0	0	0.0	0	0	0	0	0.0	0
Burned muck Over sand	0	0	0	0.0	0	0	0	0	0.0	0
Dune sand	0	0	0	0.0	0	0	44	0	0.0	2
Not Given	53	62	0	46.1	9	53	62	0	46.1	9

Bierne 1971), one will note that much of the asparagus is grown on soils very close to the preferred soil type of the white cutworm.

Fertilizers Used in Asparagus

Fertilizers used by asparagus growers are listed in Appendix E1. Nitrogen, potash, lime, and phosphorous were the most commonly used fertilizers and were used on 35.03%, 50.57%, 56.64%, and 41.99% of the reported acres respectively. No significant relationship was found between fertilizers and presence of cutworm damage (χ^2_4 = 2.15, p >.750).

Pesticide Use in Asparagus

Insecticides used for cutworm control (Table 5) indicate dieldrin was the most frequently applied insecticide (2412 acres or 72.35%) while formulations of Sevin[R] were second (1665 acres or 49.94%). Dieldrin, a pre-emergence insecticide, must be applied in the early spring before any asparagus has emerged and Table 6 shows that 2295 acres (68.84%) were treated in the spring whereas only 93 acres (2.79%) were treated in the fall.

Insecticides used to control other insects (Appendix E2) include: Sevin[R] formulations which were used on 2632 acres (78.94%), dieldrin spray used on 314 acres (9.42%), chlordane wettable powder used on 186 acres (5.58%), and methoxychlor used on 23 acres (.69%). Sevin[R] formulations were the most frequently used insecticide for insects other than cutworms, of which the primary use was to control the two types of asparagus beetles (asparagus growers personal communication).

Table 5. Insecticides used for cutworm control and acres and number of fields for each insecticide as reported from questionnaires (A zero entry indicates no response for that category).

INSECTICIDE	CUTWORM DAMAGE							
	Reported		None Reported		Not Given		Total Per Insecticide	
	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields
Sevin Dust	205	12	57	8	13	2	275	22
Sevin Bait	73	5	0	0	44	2	117	7
Sevin Spray	1007	74	285	16	81	5	1373	95
Dieldrin Sp	1629	109	762	51	21	3	2412	163
Methoxychlor	23	2	9	1	0	0	32	3
Chlordane	45	1	51	1	0	0	96	2
Not Given	312	23	207	17	6	3	525	43

Table 6. Season of year when cutworm insecticides applied and acres and number of fields for each season as reported from questionnaires (A zero entry indicates no response for that category).

SEASON	CUTWORM DAMAGE							
	Reported		None Reported		Not Given		Total	
	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields
Fall	33	4	60	5	0	0	93	9
Spring	1549	108	652	47	94	7	2295	162
Fall & Spring	511	36	201	23	N/A*	2	712	61
Not Given	67	4	161	6	6	1	234	11
TOTALS	2160	152	1074	81	100	10	3334	243

* acreage for these fields not reported

Herbicides and fungicides used in asparagus (Appendix E3) in 1974 were Princep^R, Dowpon^R, Karmex^R and 2, 4-D and they were used on 2538 acres (76.14%), 999 acres (29.96%), 535 acres (16.05%) and 189 acres (5.67%), respectively. The fungicides used were Dithane^R, Polyram^R, Manib^R and Zineb^R and they were used on 381 acres (11.43%), 348 acres (10.44%), 278 acres (8.34%) and 206 acres (6.18%) respectively.

Fungicides were not extensively used; apparently growers do not consider rust an important problem or were unaware of its presence in their field. Since little interest was given to the asparagus fields after harvest was completed, the latter was probably the case.

Degree of Tillage in Fields

A significant difference was observed between cutworm damage in no-till asparagus and cutworm damage in tilled asparagus ($\chi^2_1 = 9.15$, $p < .005$), with more damage than expected in the no-till fields and less than expected in the tilled fields. Possible explanations for this include: (1) higher larval mortality in the tilled fields due to mechanical and physical injury; (2) exposure of larvae by tillage to predation by birds and other predators; (3) better incorporation of insecticide into the soil which adds to its efficacy; or (4) reduction of weeds through tillage, which are alternate larval hosts.

No significant difference was found between tillage and presence of the three main weeds-milkweed, sandbur, and grasses (quackgrass and crabgrass) (Appendix E4, $\chi^2_2 = 3.70$, $p > .100$). Field experiments by Dr. Putman (personal communication) have indicated a significant inverse relationship between weed presence and tillage. This was apparently due to stirring of the weed seed reservor in the soil and exposing seeds to germinating conditions.

No significant relationships were observed between these weeds and the presence of cutworm damage (Appendix E5; $\chi^2_2 = .43$, $p = .750$). Since no significant relationships were found, one can conclude weeds and cutworm damage were not related and the decrease in damage in the tilled field was probably due to a combination of mechanical and physical factors--exposure to predators, larval injury, or incorporation of the insecticides in the soil.

Adjacent Crops

Woods and shrubs, grasslands, fence rows and neighbors' asparagus were the most common asparagus field borders; bordering 45.27%, 40.74%, 22.22% and 21.81% of the fields respectively (Appendix E6). Apple, cherry, peach, and pear trees bordered 16.46%, 12.35%, 7.41% and 6.17% of the fields respectively. The importance of these adjacent crops is that they provide the moths with diurnal hiding locations other than the fields. Diurnal hiding places were sought on several occasions, but no significant numbers of adults were ever found. Very few were found in the asparagus fields relative to those collected in the blacklight traps which makes these border fields the apparent diurnal hosts for the resting moths.

Methods of Harvest

Of the 3334 acres reported, the following summarizes the harvest methods given in Appendix E7:

Harvest Method	Acres	% of Acres
Hand	2814	84.40%
Mechanical	291	8.73
Not Harvested	57	1.71
Not Given	172	5.16

Due to all the land labor used in harvesting asparagus, the overhead incurred by the growers was very high and losses must be kept minimal to insure an operational profit.

Drainage and Irrigation

No significant differences were found between cutworm damage on the field considered well drained and those poorly drained, 84.77% and 4.94% of the fields respectively (Appendix E8, $\chi^2_1 = .35$, $p > .500$). Most of the fields were not irrigated (90.54%, Appendix E9). Again no significant differences were found between cutworm damage in irrigated and non-irrigated fields ($\chi^2_1 = .33$, $p > .500$). It appears as though moisture level has no effect upon cutworm damage, even though larvae are always found in well-drained sandy acres.

Adult White Cutworm

Yearly Sampling for Adults

In Figure 9 the blacklight trap catches from Oceana county from 1973 to 1975 are shown (Appendix F). The initial moth catches

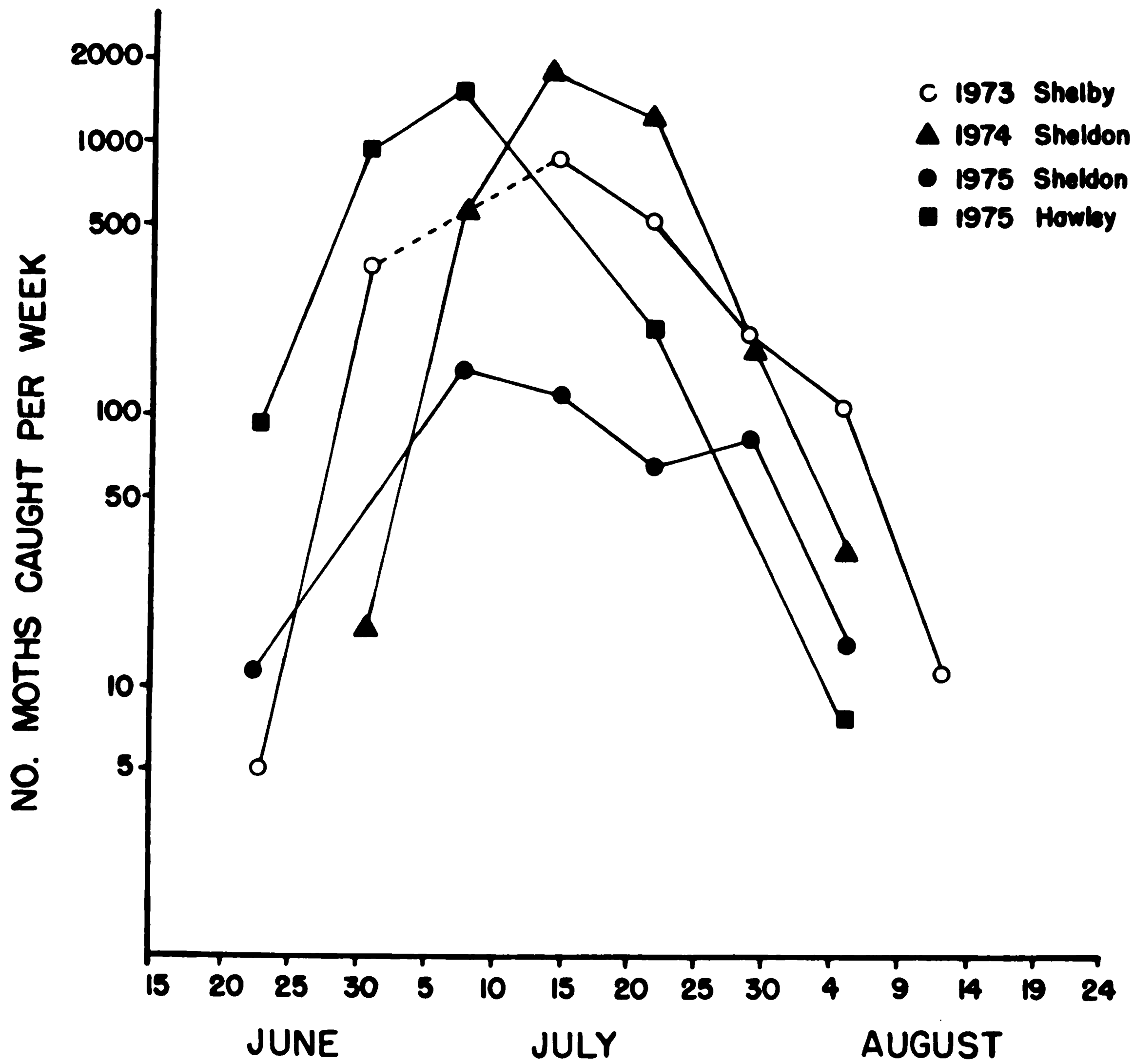

Figure 9. Weekly blacklight trap catches of white cutworms from Oceana county.

were taken on June 18, 1973; June 24, 1974; June 19, 1975 for the Hawley trap; and June 20,1975 for the Sheldon trap. When plotting catch against chronological time, there was considerable variation in the flight curves. In 1975 the peak blacklight trap catches were about ten days earlier than in both 1972 (Insect Alerts)[1] and in 1974. The peak catch for 1973 was unknown due to a campus postal strike in July. This prevented all but first-class mail from reaching campus, which included the blacklight collections. When postal services resumed, the samples had deteriorated and could not be identified; therefore, the flight records for 1973 are incomplete.

By changing the time axis to degree-days (°D) (Baskerville and Emin 1969), which measure physiological time rather than chronological time, much of the variations were removed from the flight curves causing better synchronization (Figure 10). Degree-day accumulations were calculated from the Hart, Michigan weather station for 1973 to 1975 (Appendix G1). Since the actual flight threshold was unknown, 50°F was chosen as the base temperature from which to accumulate °D (Thompson 1966). On a physiological time scale, the range of initial catch was from 625° D > 50°F to 675° D > 50°F, which was not that much better than chronological time. However, there was better synchronization of the flight curves with degree-days rather than chronological time.

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[1]Insect Alerts are published by the Cooperative Extension Service of Michigan State University.

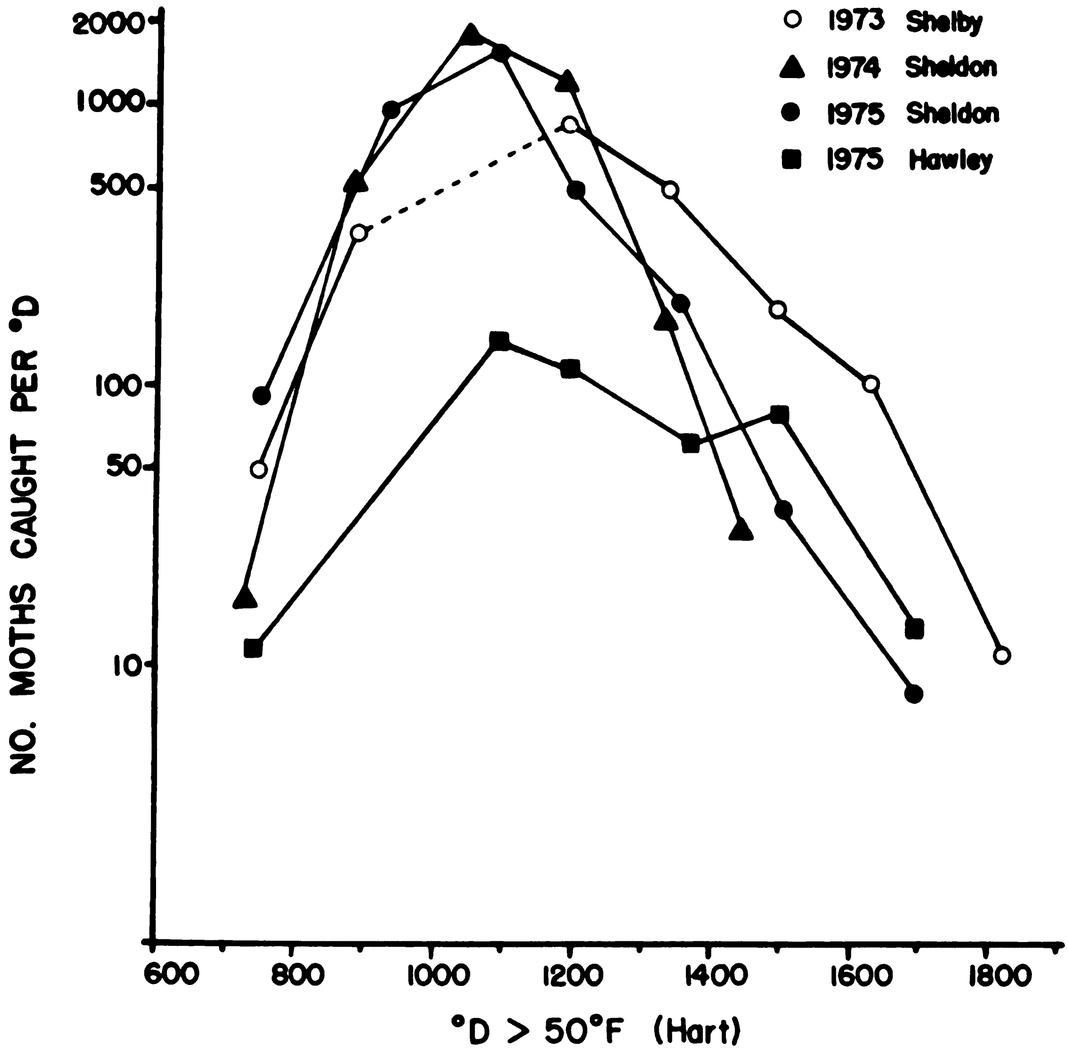

Figure 10. Blacklight trap catches of white cutworms per degree-day from Oceana County.

Weather Parameters and Flight Activity

Since a blacklight trap is passive, movement of the insect to the trap is required for the insect to be collected. Flight activity and movement of the moths then become important when evaluating blacklight trap catches. Williams (1940) and King (1962) have stated that the number of insects caught on a given night was not a function of population or activity, but rather both. Weather factors were the major reasons for flight activity fluctuations in their studies.

In an effort to relate the importance of weather parameters to white cutworm moth activity, a series of correlations were computed between adjusted daily catch and weather parameters (Table 7). Daily catch was calculated by dividing catch during a time interval by the number of days in that interval.

A significant positive correlation was found between the two trap's catches. This was not surprising, since the traps were only seven miles apart and in similar habitats. The Sheldon trap showed a significant positive correlation with relative humidity, but no correlation was shown for the Hawley trap. This was quite unexpected, since other authors (Cook 1921 and Hanna 1968) have shown increasing relative humidity to increase flight activity of certain Lepidoptera.

For the Hawley trap, there was a significant inverse correlation between daily catch and barometric pressure, but again, no correlation was shown by the other trap. (This inverse correlation would indicate that as the barometric pressure increases,

Table 7. Correlation coefficients for 1975 daily white cutworm moth catches for Hawley's and Sheldon's blacklight traps with several measured environmental factors.

Parameter	BLACKLIGHT	
	Sheldon	Hawley
Sheldon's Trap	1.000	.380*
Relative Humidity (Muskegon)	.336*	-.245
Percent Sky Cover (Muskegon)	.016	.065
°D per day (Hart)	.051	-.299
Minimum Air Temperature (Hart)	-.0001	-.193
Maximum Air Temperature (Hart)	.200	-.188
Average Air Temperature (Hart)	.112	-.211
Barometric Pressure (Muskegon)	.014	-.620**
Rainfall (Hart)	-.114	.011

* significant at 5% level

** significant at 1% level

n = 43

the catch decreases.) Williams (1940) stated that the effects of barometric pressure were complicated and difficult to understand, but may partially be explained by the fact that as the barometric pressure rises, the air generally becomes warmer and drier. Hanna (1968) has shown that low temperatures and high relative humidities favor flight activity of the black cutworm *Agrotis ipsilon* (Hufnagel), thus possibly explaining the inverse correlation between barometric pressure and daily moth catch.

Sex Ratio of Blacklight Collected Moths

Sexing of the moths collected at the Sheldon blacklight trap for 1974 (Figure 11) and 1975 (Figure 12) revealed that more males than females were collected. The ratio of females to males for 1974 and 1975 was 1 to 3.46 and 1 to 2.99, respectively. Possible explanations for this include: (1) the male population was greater than the female population; (2) males were more attracted to blacklight traps; or (3) once a female was trapped, she emitted pheromones and attracted males.

From the data available, there was no way to determine if males were more attracted to the blacklight trap or if a trapped female attracted males. From sexing pupae, (Cheng 1970) which were laboratory-reared from field collected females, the sex ratio was 1 to 1.05 females to males. If this was an indication of the true field population, then the sex ratios were approximately equal.

As a check on the hypothesis that males were more attracted to the blacklight trap, moths were collected on milkweed blossoms

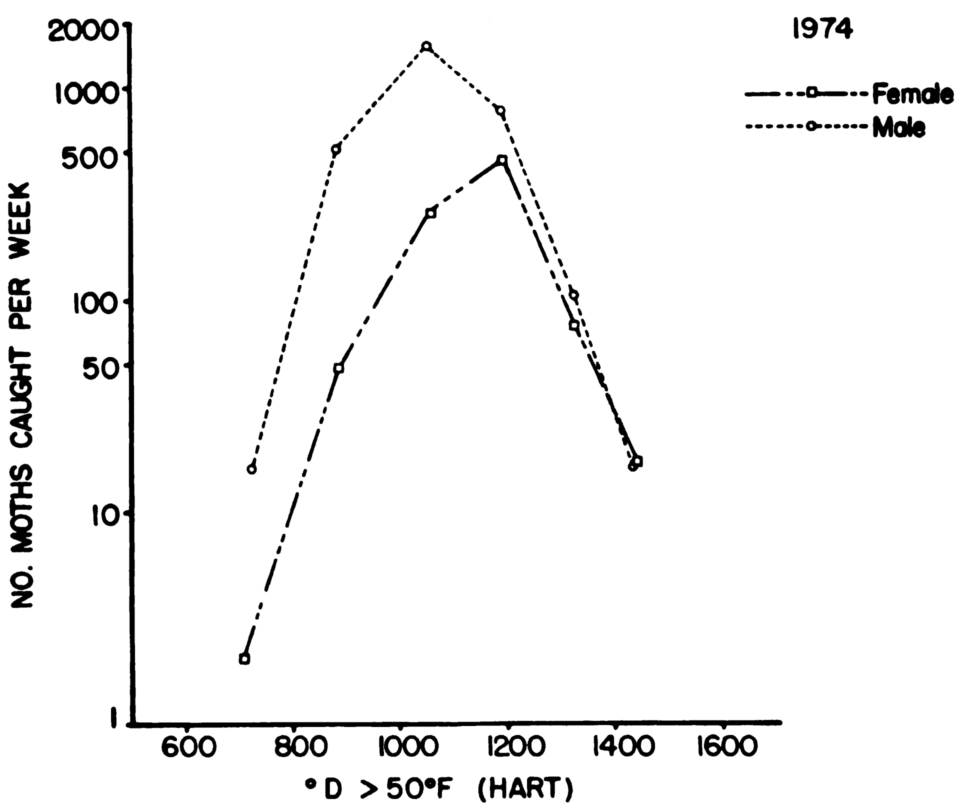

Figure 11. Number of male and female moths caught per week at the Sheldon blacklight trap for 1974.

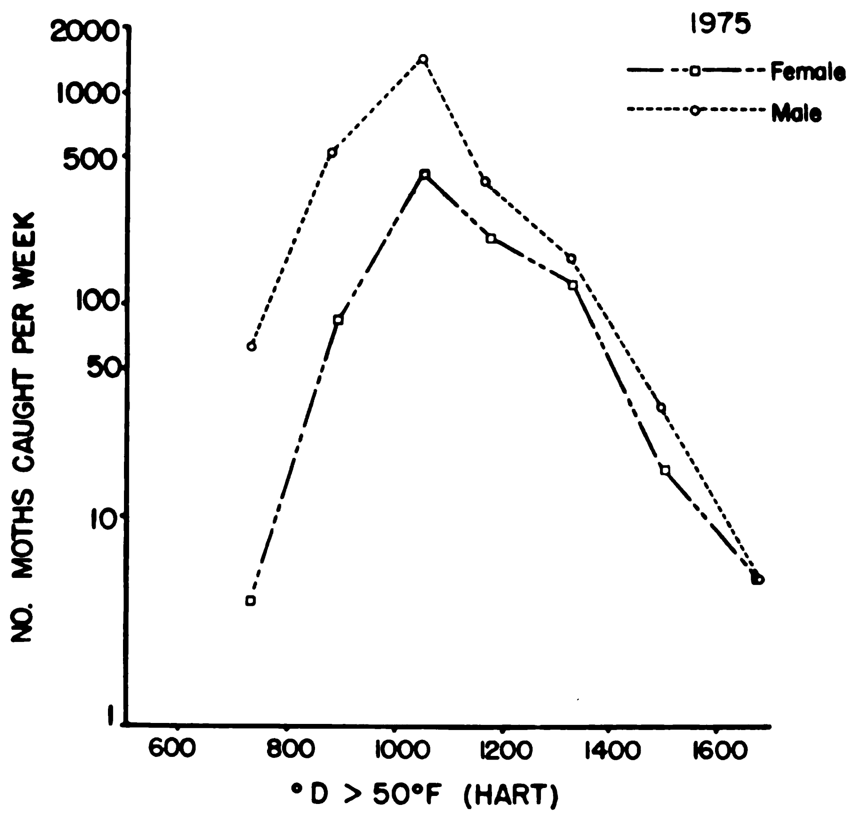

Figure 12. Number of male and female moths caught per week at the Sheldon blacklight trap for 1975.

and at the blacklight trap on July 9, 1975. Females were more abundant than males at the milkweed blossoms (ratio of 1 to .58), whereas males were more abundant at the blacklight trap (ratio of 1 to 1.90). It appears as though males were more active at the blacklight trap, whereas females were actively feeding.

Hourly Sampling for Moths

A relative estimate of hourly moth activity, as measured by a blacklight trap (Figure 13), indicates males to have a unimodal and females a bimodal flight activity. Male activity gradually increased to a peak of about 30% (Table 8) of the total males collected from 1 a.m. to 2 a.m. Female activity increased rapidly to a first peak between 10 p.m. and 11 p.m. of about 24% than slowly declined to about 6% caught between 2 a.m. and 3 a.m. The second peak occurred between 4 a.m. and 5 a.m. with about 18% of the females caught during that hour. Females became more active about the blacklight trap earlier in the evening than males.

A possible explanation for this difference in flight activity could be that moths coming into the fields from their daily hiding sites were attracted to the blacklight trap. Females, once they had reached the fields, were more attracted to feeding and ovipositing. Males, however, were continually attracted to the blacklight. Once the females had finished feeding or ovipositing, they started leaving the fields, returning to their daily hiding places and were again collected in the trap, thus explaining the second peak.

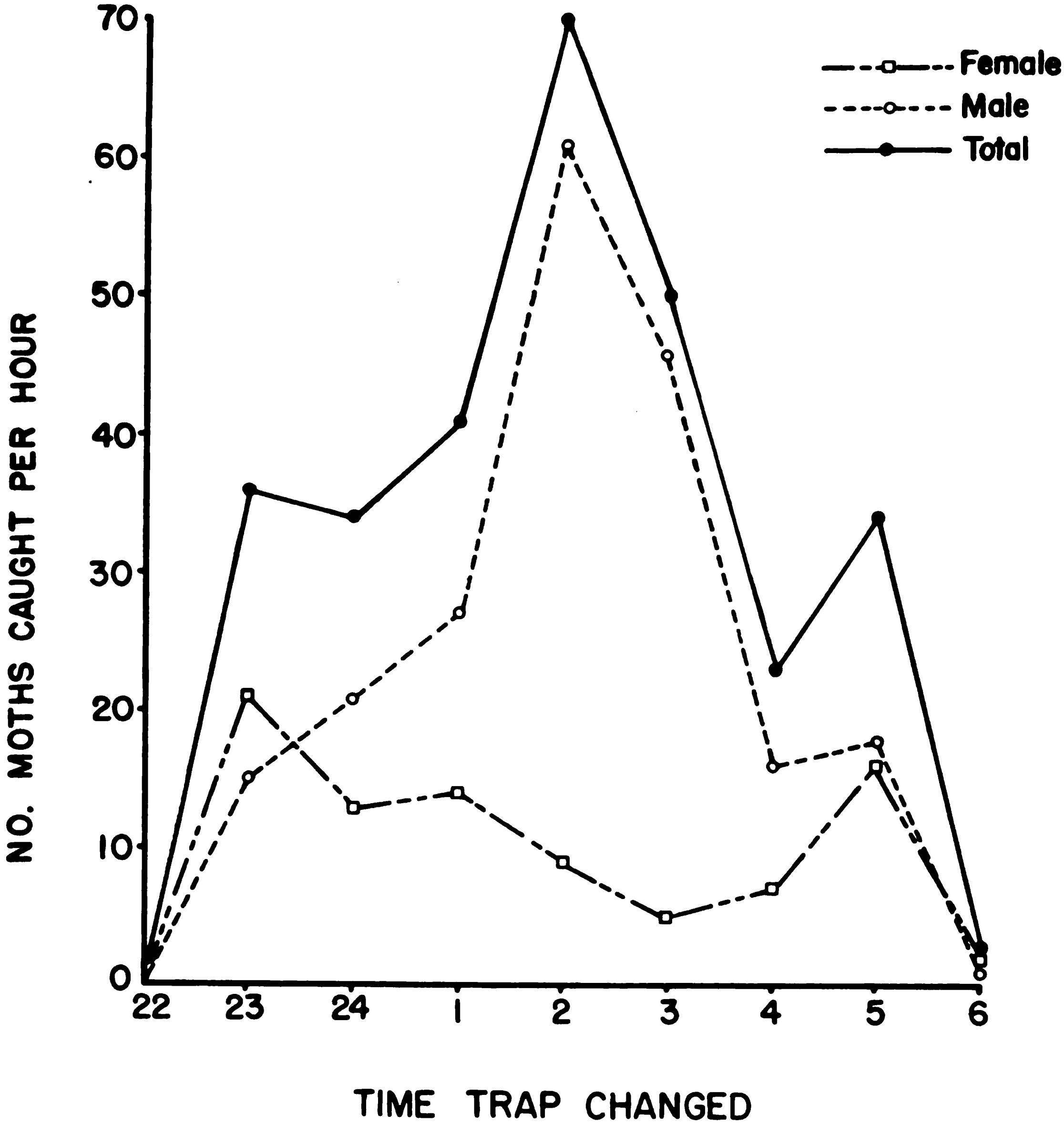

Figure 13. Total hourly moth catches from the Sheldon blacklight trap for July 9, 10, 18, and 25, 1975.

Table 8. Summary of total moths caught per hour from the Sheldon blacklight trap for July 9, 10, 18, and 25, 1975.

Time Hours	Hourly Catch			Percent of Nightly Catch		Percent of Total Catch per Hour		
	Female	Male	Both	Female	Male	Female	Male	Both
21-22	1	0	1	100.00	0.00	1.14	0.00	.34
22-23	21	15	36	58.33	41.67	23.86	7.35	12.33
23-24	13	21	34	38.24	61.76	14.77	10.29	11.64
24-1	14	27	41	34.15	65.85	15.91	13.24	14.04
1-2	9	61	70	12.86	87.14	10.23	29.90	23.97
2-3	5	45	50	10.00	90.00	5.68	22.06	17.12
3-4	7	16	23	30.43	69.57	7.95	7.84	7.88
4-5	16	18	34	47.06	52.94	18.18	8.82	11.64
5-6	2	1	3	66.67	33.33	2.27	.49	1.03
	88	204	292					

Another possible explanation could be that early in the evening both males and females are attracted to external stimuli, i.e., blacklight traps, milkweed blossoms, etc. After they have aggregated at these stimuli, mating occurs. Once mated, the females became less interested in external stimuli and more interested in feeding and ovipositing. After oviposition and feeding, the females were once again attracted to external stimuli and were again caught in the blacklight trap.

Since no data is available to support either of these statements, no definite conclusions can be drawn.

Larval White Cutworm

Instar and Population Age Determination

Figure 14 shows the frequency distribution of headcapsule widths of field-collected and laboratory-reared white cutworm larvae (fed on a diet obtained from Drs. Dupre and McLeod of Agriculture Canada, Appendix H). Larvae were measured with an ocular micrometer in a Wild^R microscope, with the small larvae measured at 50x and the large at 25x. Overlap in headcapsules increased as the instars increased, and was the greatest between the laboratory fourths and the field collected fifth instars. Due to this overlap, exact separations into instars were impossible. Based on this data, the most probable ranges of instar headcapsules are given below.

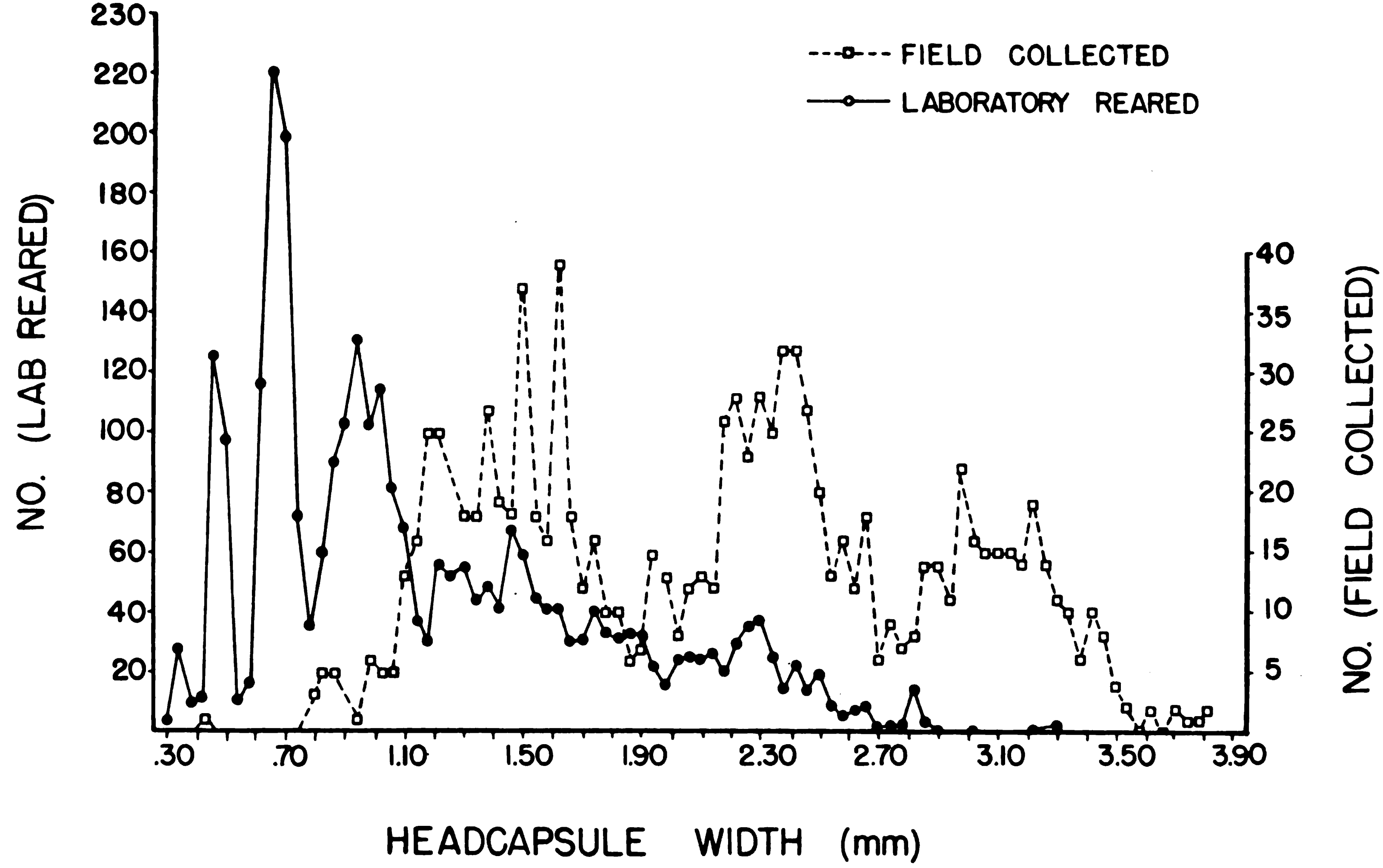

Figure 14. Frequency distribution of headcapsule width measurements from laboratory reared (n = 2923) and field collected (n = 1053) white cutworm larvae.

Instar	Head Capsule Width (mm)
1	Less than .39
2	.39 to .52
3	.53 to .78
4	.79 to 1.12
5	1.13 to 1.86
6	1.87 to 2.70
7	Greater than 2.70

Once the instars have been determined, the population can then be aged. Fulton (1975) describes a method for determining weighted mean instars (WMI) for the cereal leaf beetle; also included was a discussion on calculation of WMI for insects with unequal instar durations. WMI can then be calculated by:

$$WMI = \sum_{i=1}^{7} i\, P_i\, N_i \Big/ \sum_{i=1}^{7} P_i\, N_i \qquad (3)$$

where P_i = proportion of the duration of larval development represented by instar i.

Exact developmental times for the white cutworm were unknown; however, information on development (Appendix I) indicates that developmental time was not equal for all instars. Values of P would than have to be calculated for each instar. Since the developmental time for seventh instars was combined with pupation time, they would first have to be separated before P_i could be calculated. The two were separated as follows. A linear regression was calculated between temperature and time required for seventh instar and pupal development. Only those temperatures with equal photoperiods were used in the regression.

$$Y = -.027 + .00071\ X \tag{4}$$

where Y = percent development per day

X = rearing temperature in °F

r^2 = .935

The total number of days required for seventh instar and pupal development at 80°F was then obtained from the reciprocal of the percent development per day (33.88 days). From this the known time for pupal development at 80°F was subtracted (16.92 days $\pm$ 5.49 [S^2], n = 25) to obtain a seventh instar developmental time of 16.96 days. A proportion of seventh instar developmental time (16.96) to total developmental time (33.88) was then calculated (.50). The seventh instar and pupal developmental times were then multiplied by this proportion, thus yielding seventh instar developmental time. Once the seventh instar developmental time had been calculated, P values were calculated for each instar and are listed below:

Instar	P
1	.087
2	.080
3	.086
4	.110
5	.152
6	.165
7	.349

WMI from field collected larvae (Appendix J) were then calculated for the different collection dates and are shown in Figure 15.

Larval Sampling with Barrier-Baited Plots

The expected row area was calculated for each of the seven plots, based on their radius, average row spacing (5 feet) and average row width (15 inches). Since no significant differences were found between the expected row areas and the observed areas (χ^2_6 = 10.75, p > .05), the rows selected were representative of the field and as such could be used in the experiments (Table 9).

Looking at Table 9, one will see that the number of larvae decreased rapidly through the test interval, with 82.54% being recovered after the first night. Due to a rain storm on the night of September 7, the larvae were less active. This, coupled with a reduction of the bait's efficacy due to deterioration by the rain, accounts for the decreased larval recovery on September 8.

Distribution of the dead larvae showed that 92.06% of all recovered larvae were within one foot of the center of the asparagus row. Since only about 25% of the asparagus field is actually row, little effort need be expended in sampling between rows to get an estimate of larval densities present in the field.

Estimates for the mean number of larvae per square foot of plot, per square foot of observed asparagus row, and per square foot of expected asparagus row after one day were calculated as .41 $\pm$ .52 (S), 1.26 $\pm$ 1.26 (S), and .86 $\pm$ .83 (S), respectively.

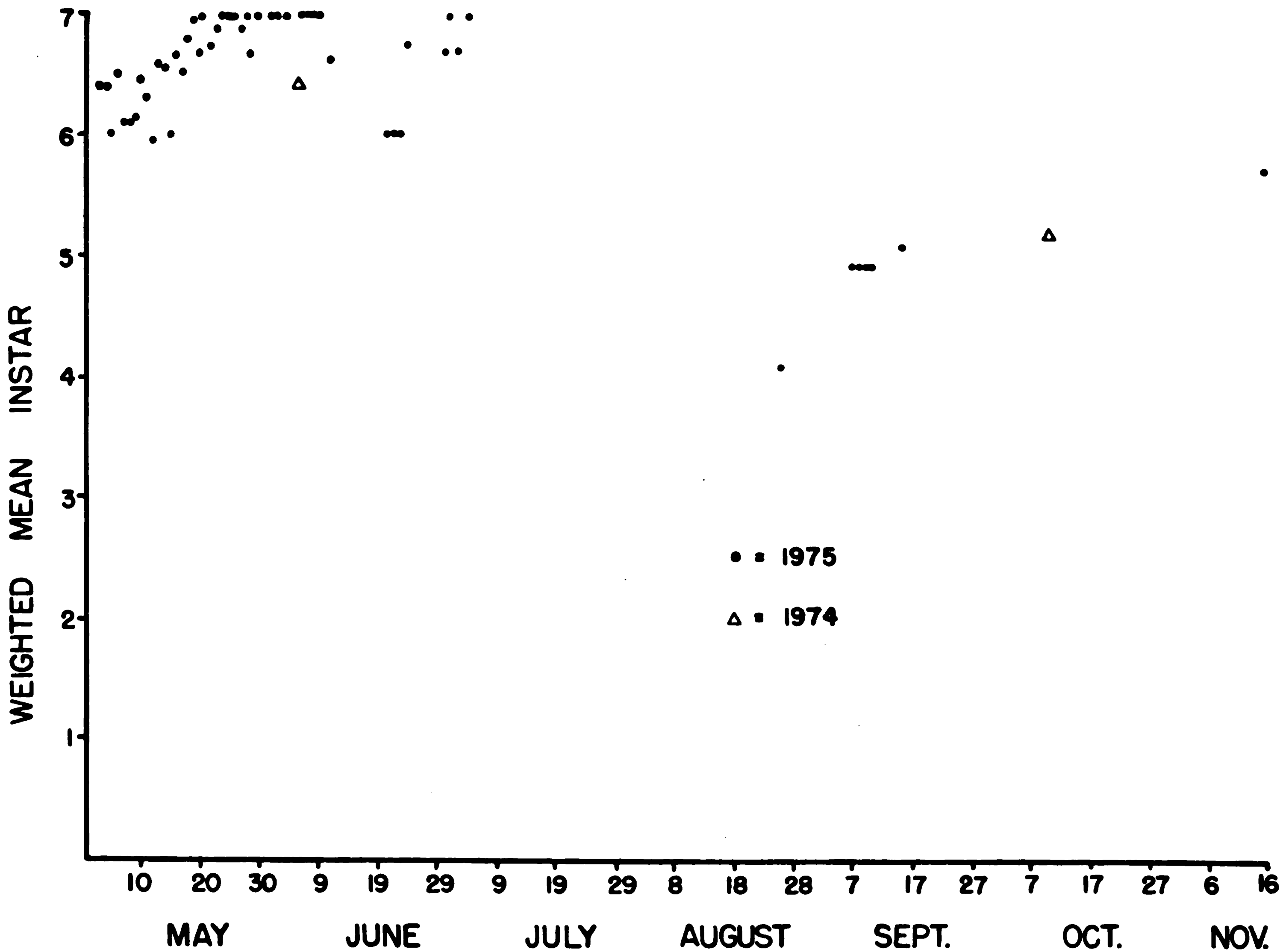

Figure 15. Weighted Mean Instar for field collected larvae for 1974 and 1975.

Table 9. Results of the baited barrier soil plots for quantative samples for white cutworms.

Plot	Plot Radius (ft)	Plot Area (sq ft)	OBSERVED Asparagus Row Area (sq ft)	OBSERVED % Total Area as Row	EXPECTED Asparagus Row Area (sq ft)	EXPECTED % Total Area as Row	DATE LARVAE COLLECTED 9/7	9/8	9/9	9/10	Total Larvae
1	.98	3	1.92	63.89	2.37	79.00	2	0	0	0	2
2	1.38	6	5.19	86.57	3.36	55.97	9	0	3	2	14
3	1.95	12	3.75	31.25	4.75	39.58	2	0	1	0	3
4	2.76	24	1.53	6.37	6.72	27.98	6	0	1	0	7
5	3.91	48	7.00	14.58	9.51	19.82	3	0	1	0	4
6	5.53	96	19.35	20.18	23.92	24.92	13	0	0	2	15
7	7.82	192	34.54	17.99	48.29	25.15	17	1	0	0	18
						TOTAL	52	1	6	4	63

Unfortunately, no replications of these plots were made and no significant differences were observed between the means.

From the mean number of larvae per square foot of asparagus row ($\bar{x}$) and its variance (S^2), the appropriate sample size (N) needed to bring the standard error of the mean within a fixed percent of the mean can be calculated by (Helgeson 1972):

$$N = S^2/S_{\bar{x}}^2 \tag{5}$$

Larval Sampling with Open-Baited Plots

A feature present in the open-baited plots not available in the barrier-baited plots is that larvae are capable of movement into the plot. Samples taken in this fashion include both the larvae present in the soil at the time the plot was treated plus those that move into the plot.

In an effort to use open-baited soil plots as a quantifiable sample method, large plots (15 feet by 15 feet) were tested. The entire plot was treated with Sevin[R] bait but only the central square yard was used as the sample unit. The six feet on each side thus acted as an insecticide barrier and prevented larvae from moving to the central sample yard.

Of the 67 larvae collected from these sample plots, only three were collected from the central square yard. The remaining larvae were collected in the six-foot insecticide barrier, of which 28 (77.78%) were collected on the first night. All larvae collected on subsequent nights were in the first three feet, thus indicating that the insecticide barrier was effective in preventing larvae from moving into the central square yard. However, the baited-barrier soil plots were more satisfactory for quantitative sampling since no assumptions about movement had to be made.

The advantage to the open-baited soil plots is that larvae moving through a baited area will stop and feed upon the bait and this makes an excellent larval detection technique. The large plots, however, were so large that examination of the plot for larvae required considerable time and almost all of the dead larvae were found within the outer three feet of the plot. Therefore, as a detection technique, this plot size was much too large and a smaller plot size (six feet by three feet) was considered.

The results of the small open-baited plots (Appendix K) are summarized in Table 10. The low density plots (1-5) received an additional fall insecticide application in 1974 which accounts for fewer larvae being collected. When the daily catches for the high and low density between-row plots (Figure 4a) are combined and compared to the perpendicular to a row (Figure 4b) daily catches, a highly significant difference ($t_{67} = 3.72$, $p = .00041$) was found. However, if one adjusts the catch according to the number of asparagus row feet per plot (six in the between-row plots and three in the perpendicular to row plots), no significant difference ($t_7 = 1.68$, $p = .10$) was found. This indicates that the number of dead white cutworms found was more related to the number of asparagus row feet in the plot rather than the area of the plot itself.

Table 10. Results of small open-baited plots (3 feet by 6 feet).

Plot-Row Relationship	Mean Larvae per Plot	Standard Deviation	Number of Observation
Between			
Low Density	1.20	1.23	10
High Density	7.27	5.96	15
Combined (Low & High)	4.84	5.52	25
Perpendicular	1.48	1.58	44
Parallel	1.40	.55	5

Five sets of paired plots were set up in the same location to test the importance of the asparagus row location in the plot to the number of dead larvae found. Each pair consisted of one between-row plot and one parallel to a row plot (Figure 4c). These plots both contained six asparagus row feet; however, the between-row plot consisted of two row segments each three feet long. Daily catches from these two plots were not significantly different from one another ($t_{18} = .25$, $p = .81$), which indicates the location of the asparagus row to the plot was not a factor in determining the number of larvae found.

Therefore, when using small open-baited plots for detection purposes, maximization of resources occurs when the asparagus row area in a plot is at a maximum.

Larval Sampling with Pitfall Traps

Pitfall traps were tested to determine white cutworm larvae attraction or repulsion at the M.S.U. Botany Research Farm (Table 11). The expected larval catch for a given radius (EC_R) was calculated by:

$$EC_R = PC_R \left(T - \sum_{i=1}^{R-1} EC_i\right) \qquad (6)$$

where PC_R is the proportion of the circumference that was pitfall traps for that radius and T is the total number of white cutworms released. Stated explicitly, the expected catch for any radius is the product of the proportion of the circumference that was occupied by pitfall traps and the total number of cutworms left to be trapped. No significant deviations were found between the observed catch and the expected catch ($\chi^2_3 = 6.296$, $P = .098$).

As one can see from Table 11, much of the total χ^2 comes from the final radius. The exact cause of this deviation from the expected catch is unknown, but is probably due to two causes. First, since the area of the test circles are increasing with the square of the radius, the area was increasing much faster than the radius. When this happens, the probability of a catch becomes more dependent upon area and less dependent upon the percent of the circumference that was occupied by pitfall traps. Second, there were also undoubtedly repellant effects caused by the barriers between the pitfall traps since they were quite reflective to the moonlight and the larvae are photonegative. This deviation was

Table 11. Results of the experiments for determination of white cutworm attraction or repulsion to pitfall traps.

Radius (inches)	Circumference (inches)	# Pitfall Traps	% of Circ. in Traps	LARVAE CAUGHT				Expected Catch	x^2 Contribution
				Trial 1	Trial 2	Trial 3	Total		
12	75.43	4	23.88	22	19	10	51	57.31	.695
24	150.86	7	20.91	17	8	9	34	38.18	.458
36	226.29	11	21.89	12	16	3	31	31.63	.003
48	301.71	47	70.16	18	22	17	57	79.19	5.141
			TOTAL CAPTURED	69	65	39	173		6.296
			TOTAL RELEASED	80	100	60	240		

of little concern since no barriers were used in conjunction with pitfall traps in the field.

Since no significant deviations were observed, this experiment has shown that pitfall traps could be used quite successfully as collection and detection tools for white cutworm larvae. This justified the further use of pitfall traps for sampling larvae.

Both unbaited and baited pitfall traps were used for larvae trapping. Pitfall traps were baited by placing one-fourth inch of Sevin[R] bait in the trap. The results of the pitfall traps (Table 12) show that a significant difference was observed between the number of cutworms caught per day per baited pitfall trap ($.54 \pm .89$[S]) versus unbaited pitfall trap ($.16 \pm .39$[S]) ($t_{172} = 3.69$, $p = .0003$). Thus, the baited pitfall trap was significantly better for detection of white cutworms than was the unbaited pitfall trap.

Comparison of Larval Sampling Methods

For quantitative samples the barrier-baited plots were more satisfactory than the open-baited plots. With open-baited plots the effects of weather parameters and larval age upon movement would have to be fully understood. However, with the barrier-baited plots no assumptions about movement were necessary to evaluate the results. The barrier-baited plots consisting of six square feet appeared to be the most desirable plot size. Plots larger than this incorporate too much row area and require the examiner to enter the plot to examine it for dead larvae, which causes much unproductive searching effort and plot disturbance.

Table 12. Results of the use of baited and unbaited pitfall traps as a white cutworm detection tool.

Pitfall Trap	Plot	NUMBER OF WHITE CUTWORM LARVAE PER PITFALL TRAP						
		9/9	9/10	9/11	9/12	9/13	9/14	TOTAL
Baited	6-1	0	0	0	0	0	0	0
	6-2	0	3	1	0	0	0	4
	6-3	0	0	2	0	0	0	2
	7-1	2	1	3	0	0	0	6
	7-2	0	1	0	1	0	0	2
	7-3	3	1	0	0	0	0	4
	8-1	2	2	2	3	0	0	9
	8-2	0	1	0	0	0	0	1
	8-3	2	2	1	0	0	1	6
	9-1	2	1	1	0	0	1	5
	9-2	0	3	0	0	0	0	3
	9-3	0	0	1	0	0	1	2
	10-1	0	0	1	0	0	0	1
	10-2	2	1	0	0	0	0	3
	10-3	1	0	0	0	0	0	1
	TOTAL	14	16	12	4	0	3	49
Unbaited	6-1	0	0	0	0	0	0	0
	6-2	0	0	0	0	0	0	0
	6-3	0	0	0	0	0	0	0
	7-1	1	0	0	0	0	0	1
	7-2	1	0	1	0	0	0	2
	7-3	0	0	0	0	0	0	0
	8-1	2	1	0	0	0	1	4
	8-2	0	0	0	0	1	0	1
	8-3	0	0	0	0	0	0	0
	9-1	0	0	0	0	0	0	0
	9-2	0	0	0	0	0	1	1
	9-3	0	0	0	0	1	1	2
	10-1	0	0	0	0	0	0	0
	10-2	1	0	0	1	1	0	3
	TOTAL	5	1	1	1	3	3	14

Since white cutworms are distributed within rows rather than between rows (over 90%) and over 80% of the larvae are recovered after one night, a sample taken with a plot of size 2 would estimate approximately 70% of the larval density in asparagus, Thus providing a relatively simple method of obtaining quantitative samples.

For larval detection purposes pitfall traps (both baited and unbaited) and open-baited soil plots were compared. Plots six through ten each consisted of three baited and unbaited pitfall traps, a parallel to row open-baited plot, and a six square foot barrier-baited plot. The estimate of the mean number of larvae per square foot of asparagus row obtained from the barrier-baited plots was 1.73 ± 1.10 (S) for this area. This was not significantly different from the mean obtained from the open-baited plots (1.73 ± .85[S]) (t_9 = .0003, p > .99). From this it appears as though with one night of operation an open-baited plot will estimate the same mean as will a barrier-baited plot over five days. The movement into the open baited plot in one night approximately equals the number of larvae which remain in the soil for more than one night, thus explaining the equalization of these means.

Baited pitfall traps caught an average of .54 ± .89 (S) cutworms per day per trap whereas an unbaited pitfall trap caught an average of .16 ± .39 (S). Since pitfall traps require larval movement before the larvae can be detected, larval detection is dependent upon factors which affect movement. The open-baited plots, on the other hand, indicate the number of larvae present when the plot was initiated as well as those that move into the plot. Taking this into consideration, the open-baited plots were more satisfactory for larval detection than were the pitfall traps (either baited or unbaited).

Probability of Larval Detection

If one assumes the sample means fit a Poisson distribution, then probabilities can be placed on detection of low density white cutworms (less than one per asparagus row foot). This assumption can be made for two reasons: (1) the mean number of larvae recovered per row foot of asparagus in the baited-barrier plots was .74 after one day of operation. This was approximately equal to the variance (.82) which fits the definition of a Poisson distribution given by Ruesink and Haynes (1973) (2). The observed frequency distribution of the number of cutworms collected from the perpendicular to row small plots did not differ significantly from that predicted by a Poisson distribution (Kolmogorov-Smirnov test, $D_{11} = .135$, $p > .20$).

When using the Poisson distribution, the probability of finding r individuals (P_r) per sample can be calculated by (Pielou, 1974):

$$P_r = \frac{\hat{x}^r}{r!} e^{-\hat{x}} \qquad (7)$$

where: $\hat{x}$ is the expected mean density

e is the base of the natural logarithm

However, for detection purposes, one is interested in the probability of finding at least one organism (P). Probabilisticly, this can be expressed as one minus the probability of finding zero organisms and when N samples are taken becomes (Ruesink and Haynes 1973):

$$P = 1-e^{-\hat{x}N} \tag{8}$$

Using this equation, the probability of finding at least one larva, given an expected mean, $(\hat{x})$, was computed for densities from .01 to 1 white cutworm per asparagus row foot and for one to twenty samples (Table 13).

By solving equation 8 for N, the total number of samples (N_p) one would have to take to obtain a given probability of a find for any expected density can be calculated by:

$$N_p = -\ln(1-P_f)/\hat{x} \tag{9}$$

where ln is the natural logarithm of the quantity $(1-P_f)$. These values have been calculated for densities of .01 to 1 larva per asparagus row foot and are also shown in Table 13.

<u>Oceana County White Cutworm Survey</u>

A total of five plots were monitored from which data was obtained for the entire survey. The number of white cutworms caught per day per trap (Figure 16) gradually decreased throughout the season, with a large peak on June 2. On June 1 two of the five fields were chopped to ground level. This was done because

Table 13. Probability of detecting at least one white cutworm larva with one asparagus row foot samples for various larvae densities and sample sizes. N_{95} is the number of samples required to obtain a probability of detection of .950.

	Number of Samples Taken								
$\bar{X}$	1	2	3	4	5	10	15	20	N_{95}
.010	.010	.020	.030	.039	.049	.095	.139	.181	300
.020	.020	.039	.058	.077	.095	.181	.259	.330	150
.030	.030	.058	.086	.113	.139	.259	.362	.451	100
.040	.039	.077	.113	.148	.181	.330	.451	.551	75
.050	.049	.095	.139	.181	.221	.393	.528	.632	60
.060	.058	.113	.165	.213	.259	.451	.593	.699	50
.070	.068	.131	.189	.244	.295	.503	.650	.753	43
.080	.077	.148	.213	.274	.330	.551	.699	.798	37
.090	.086	.165	.237	.302	.362	.593	.741	.835	33
.100	.095	.181	.259	.330	.393	.632	.777	.865	30
.110	.104	.197	.281	.356	.423	.667	.808	.889	27
.120	.113	.213	.302	.381	.451	.699	.835	.909	25
.130	.122	.229	.323	.405	.478	.727	.858	.926	23
.140	.131	.244	.343	.429	.503	.753	.878	.939	21
.150	.139	.259	.362	.451	.528	.777	.895	.950	20
.160	.148	.274	.381	.473	.551	.798	.909	.959	19
.170	.156	.288	.400	.493	.573	.817	.922	.967	18
.180	.165	.302	.417	.513	.593	.835	.933	.973	17
.190	.173	.316	.434	.532	.613	.850	.942	.978	16
.200	.181	.330	.451	.551	.632	.865	.950	.982	15
.250	.221	.393	.528	.632	.713	.918	.976	.993	12
.300	.259	.451	.593	.699	.777	.950	.989	.998	10
.350	.295	.503	.650	.753	.826	.970	.995	.999	9
.400	.330	.551	.699	.798	.865	.982	.998	.999	7
.450	.362	.593	.741	.835	.895	.989	.999	.999	7
.500	.393	.632	.777	.865	.918	.993	.999	.999	6
.550	.423	.667	.808	.889	.936	.996	.999	.999	5
.600	.451	.699	.835	.909	.950	.998	.999	.999	5
.650	.478	.727	.858	.926	.961	.998	.999	.999	5
.700	.503	.753	.878	.939	.970	.999	.999	.999	4
.750	.528	.777	.895	.950	.976	.999	.999	.999	4
.800	.551	.798	.909	.959	.982	.999	.999	.999	4
.850	.573	.817	.922	.967	.986	.999	.999	.999	4
.900	.593	.835	.933	.973	.989	.999	.999	.999	3
.950	.613	.850	.942	.978	.991	.999	.999	.999	3
1.000	.632	.865	.950	.982	.993	.999	.999	.999	3

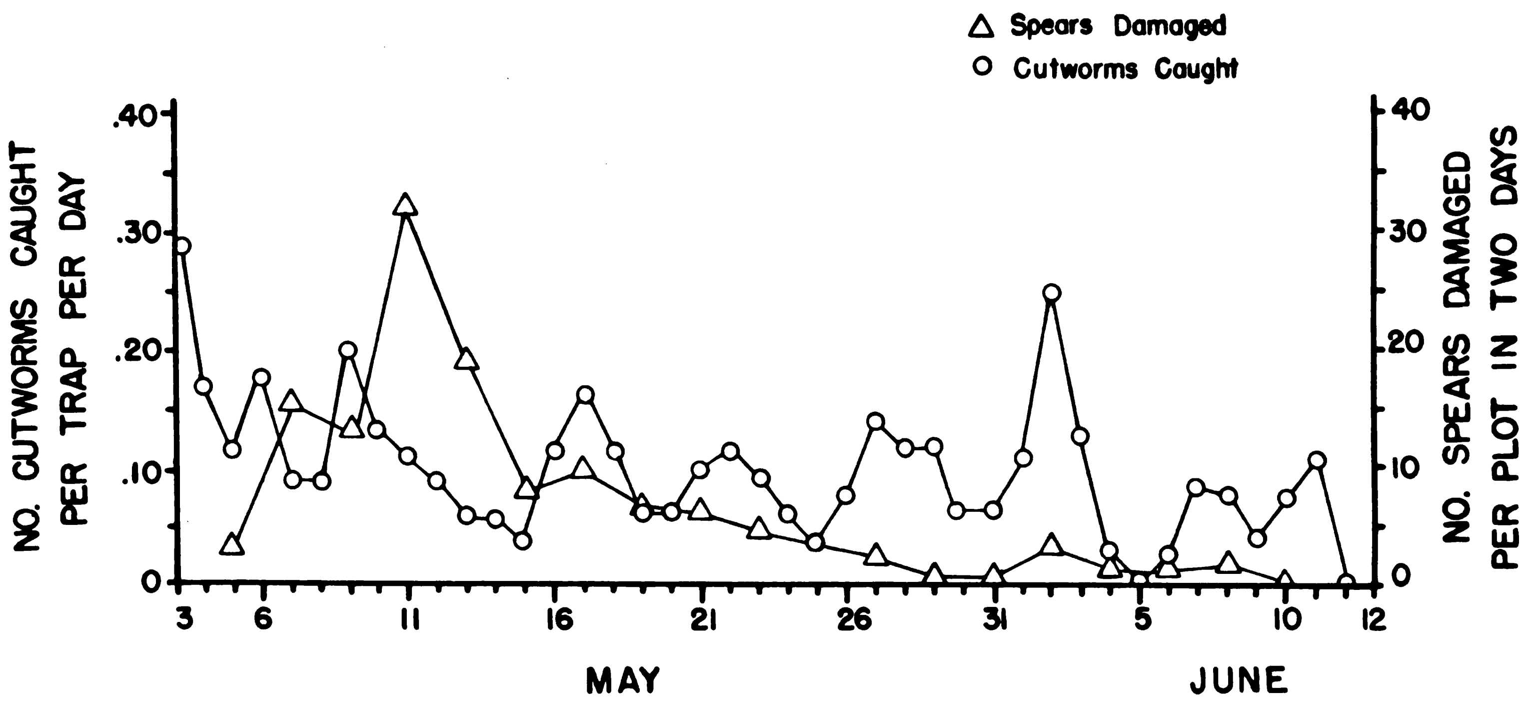

Figure 16. White cutworms caught per trap per day and number of spears damaged per plot for four field plots.

high temperatures had caused the asparagus to grow beyond a marketable length between harvests and the chopping brought the field back under the grower's control. As a result of this chopping, more larvae were collected than was expected. This indicated that larvae were still present in about equal numbers as at the beginning of the survey and the gradual decline was probably not due to mortality but rather to decreased activity. The increased availability of food would be the main reason for this decline in activity since less searching would be required by the larvae in order to find food.

The number of spears damaged per plot increased until May 12, then decreased throughout the season. This increase until May 11 and 12 was due to those days being the first day of harvest for most of the fields. Prior to this date only three fields were monitored daily for damage. Also, spears were constantly emerging throughout this period making more spears available.

There are two main explanations for the decrease in damage after May 12. First, mortality could be reducing the number of cutworms in the area or second, there was a change in feeding behavior of the larvae.

As stated earlier, mortality doesn't seem to be responsible for the reduction in feeding. Therefore, the second hypothesis, a change in feeding behavior, must be explained. In an effort to evaluate feeding damage and feeding behavior, correlations were made between the number of spears damaged per day and the number of white cutworm larvae caught per day with environmental parameters (Table 14).

Table 14. Correlation coefficients between nightly spears damaged and white cutworms caught with environmental parameters (Ray Wybenga Farm).

	SPEARS DAMAGED	CUTWORMS CAUGHT
Cutworms caught	.203	1.000
Number of previous harvests	-.540**	-.495**
Air maximum temperature	.026	-.135
Air minimum temperature	-.235	-.058
Soil maximum temperature	-.205	-.342*
Soil minimum temperature	-.418**	-.329*
Rainfall	-.249	-.182
Percent sky cover (Muskegan)	.001	-.051

*Significant at .05 level.

**Significant at .01 level n = 37

A highly significant inverse correlation was found between the number of spears damaged per day and the number of white cutworm larvae caught. This is due to the increasing amount of food units (spears and butts) being available to the larvae; less movement was required by the larvae to find food and therefore less larvae were collected.

A highly significant inverse correlation was also found between the number of damaged spears and the number of previous harvests. This relationship implies that less damage occurred as the number of butts (unharvested spear portions) remaining in the field increased.

Significant correlations were also found between soil maximum temperature and the highly white cutworm catch and between soil minimum temperature and both spears damaged per night and white cutworms caught per night. These three correlations are merely spurious correlations. Since soil temperatures slowly increase through harvest due to advancement into spring and the number of spears damaged and the number of cutworms caught decrease due to reasons already explained, a non-real negative correlation was observed between these parameters and the survey results.

Asparagus Spear/Butt Ratio

When asparagus spears are harvested, the sections of the asparagus spears below the height at which the spears were harvested (the butts) remain in the field. As the asparagus season proceeds, more butts are added to the field with each successive harvest. White cutworms will also feed on these butts as long as they are palatable, with the length of butt palatability dependent upon temperature and relative humidity. Butts generally become unpalatable due to dessication.

To calculate the percent of spears in the field, the yield information was used to determine spears and butts in the field. Prior to a harvest, the amount of spears in the field is approximately equal to the harvested spear yield. Since spears grow extremely fast, those below harvest height will be ignored for this discussion. Thus prior to the first harvest the only food available for the white cutworms to feed upon were spears.

However, prior to the next harvest, there were the last harvest's butts plus those spears that had emerged which gave the larvae two types of food. The percent of spears (Ps) in the field at harvest T can be calculated by:

$$Ps_T = \frac{S_T}{\sum_{i=H-P}^{H} S_i} \qquad (10)$$

where S_T = number of spears in harvest at harvest T

P = number of days of butt palatability.

H = number of days since first harvest.

There was error involved in this method since new spears are constantly being added to the field due to emergence. However, considering the frequency of harvests (up to thirty per two months), this error was relatively low.

The percent of spears in the field has been calculated for varying days of palatility for a commercial field at Hart, Michigan (Appendix L1) and for a Mary Washington variety at the Horticulture Experimental Farm at Sodus (Appendix L2) and are presented in Figures 17A and 17B, respectively. The difference in the early part of the graph is due to the difference in initial harvest date and the frequency of harvest. The commercial field was harvested more frequently than the experimental field. Ten days was the most realistic average length of butt palatability and will be used from this point in this paper. The percent of

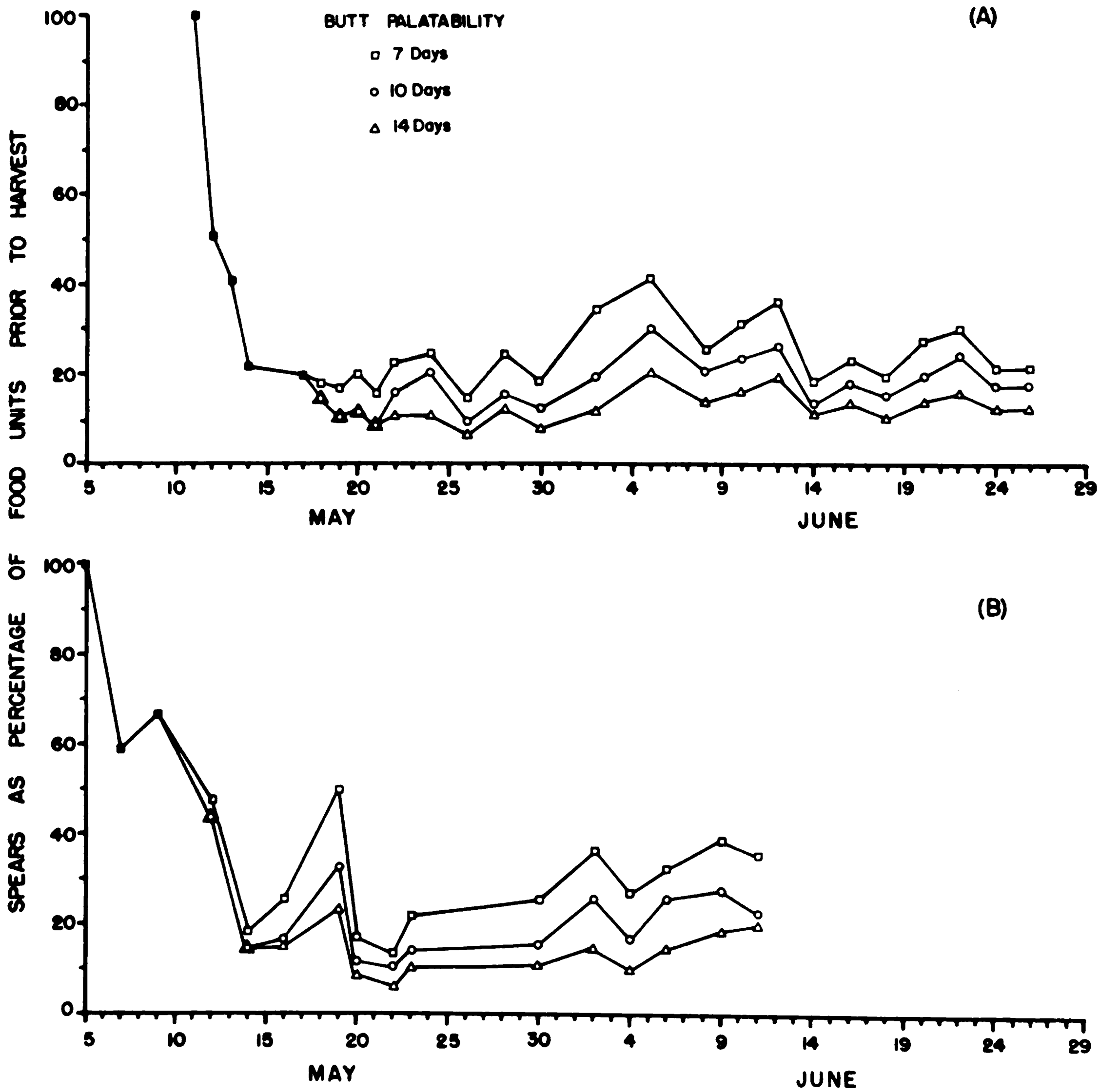

Figure 17. Percentage of food units that are spears for Hart 1975(a) and Sodus farm 1975(b).

spears for the nine Sodus varieties of asparagus (Appendix L3) has been averaged and graphed in Figure 18.

In all these graphs one will notice that with ten days butt palatability, the graphs all tend to plateau off at about 20% of the food units as spears. This is about what was expected if all harvests were of equal size and harvested at two day intervals.

One will notice that the percent spears in Figure 18 and the number of damaged spears per day in Figure 16 both decline similarly through the season. If larval feeding was completely random with respect to spears and butts, then one would expect these two graphs to be similar in form.

Linear regression analysis was performed between the percent spears and the reciprocal of the number of harvests for the mean of the nine varieties of asparagus at the Sodus Experimental Farm and for a commercial field near Hart, Michigan. The following equations were obtained:

$$\text{Sodus} \quad Ps = 12.80 + 92.42\ RH \quad r = .900,\ N = 16 \qquad (11)$$

$$\text{Hart} \quad Ps = 11.54 + 81.37\ RH \quad r = .910,\ N = 26 \qquad (12)$$

where Ps = percent of food units that are spears.

RH = reciprocal of the number of harvests.

The 95% confidence intervals on both the slope and y-intercept of these equations overlapped so they were not significantly different at the .05 significance level.

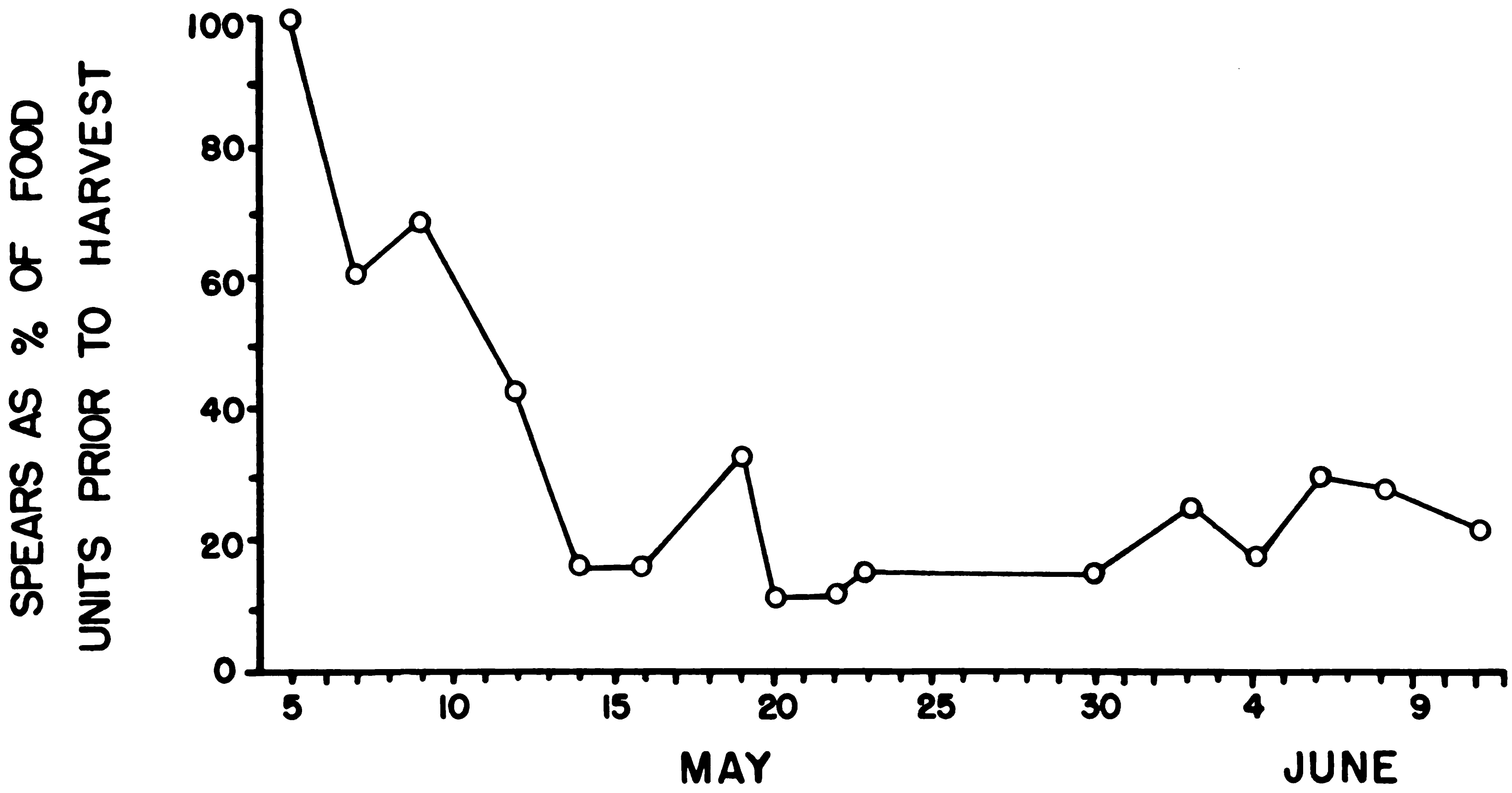

Figure 18. Mean percentage of food units that are spears for the 9 varieties of asparagus grown at the M.S.U. Horticultural Research Farm, Sodus, for 1975. Butts palatable for 10 days.

Larval Feeding Behavior

Field Feeding Behavior

On May 29 and June 11, 20 observations on the location of feeding larvae were recorded. Larvae were recorded as feeding on a spear or butt. The total number of spears and butts within one foot of the larval feeding site were also recorded. In this fashion, 29 larvae were observed with eight feeding on spears and 21 feeding on butts. A total of 73 spears and 210 butts were recorded as present near the larval feeding sites. A chi square test showed no significant difference between the number of larvae feeding on spears or butts and the expected number to be feeding on spears and butts ($\chi_1^2 = .049$, $p = .82$). This implies that larvae feed without preference on spears or butts. It was also observed that several larvae could be found feeding on the same food site when ample food was available. Therefore, it would appear as though there was no intraspecific competition between larvae for food.

Laboratory Feeding Behavior

Results from the laboratory test for randomness of larvae feeding (Table 15), revealed one test of the eight to deviate significantly from random. An overall chi square significance test for a series of individual test significance levels ($\chi^2_{2\,[n-1]} = -2 \ln \sum_{i=1}^{n} \alpha_i$) indicated this series of tests did not deviate

Table 15. Results of the laboratory random feeding tests for white cutworms on asparagus spears or butts.

Trial	# Spears	# Spears Damaged	# Butts	# Butts Damaged	χ^2	α Significance Level
1	8	5	16	3	2.835	.09
2	10	5	20	5	.919	.34
3	14	3	7	4	1.313	.25
4	14	5	7	5	.027	.87
5	6	2	6	4	.333	.56
6	6	4	6	2	.333	.56
7	7	5	7	2	1.143	.29
8	5	5	5	0	6.400	.01*

*Significant at .05, df = 1.

significantly from random (χ^2_{16} = 24.43, p = .081) and no significant preference for feeding sites was observed.

Since feeding damage was random, the amount of resulting damage was then a function of the percent of spears present in the field.

Larval Movement Rates

Casagrande (1976) developed an insecticide strip spray model for the cereal leaf beetle. Casagrande's model was modified with the necessary assumptions to make it appropriate for evaluating white cutworm movement (Appendix D). These assumptions were: (1) A bait insecticide would be used (Sevin[R]) and its band of application could be controlled; (2) Any larvae that came within this baited band would stop and feed resulting in 100% mortality; (3) The toxicity of the bait would last for three days. This was chosen because this is the mean time interval between rains for Hart, Michigan (Climatological Data); (4) The cutworms were actively moving about the fields for five hours per night. This value was obtained from field observations and movies of larvae; most activity takes place from about 10:30 p.m. to 3:30 a.m. during the spring months.

Diffusion Coefficients Obtained from Pitfall Traps

Diffusion coefficients (D) from the M.S.U. Botany Farm experiments are presented in Table 16. In these experiments the only variable that had to be measured was time (T) since the distance (r) was fixed at four feet. D could then be calculated for each larvae by the simplified equation:

$$D = \frac{4.0}{T} \qquad (13)$$

The nightly diffusion coefficients for the two nights were found to be significantly different ($t_{36} = 3.16$, $p = .003$). This difference in movement rates was probably the result of the differences in air temperature and relative humidity for the two nights. On June 19, D was higher than on June 18 as were both temperature and relative humidity.

Table 16. Observations on white cutworm movement in 1974 at the M.S.U. Botany Farm.

	JUNE 18			JUNE 19		
Time Released	10 p.m.			10 p.m.		
No. Released	75			26		
Temperature	56°F			62°F		
	Hours to Move 4' (t)	No. Caught	D	Hours to Move 4' (t)	No. Caught	D
	.58	4	6.90	.20	3	20.0
	.80	6	5.00	.32	1	12.62
	1.00	4	4.00	.40	1	10.00
	1.23	1	3.25	.47	2	8.57
	1.42	1	2.82	.60	2	6.67
	1.53	2	2.61	.70	1	5.71
	1.97	3	2.03	.83	1	4.80
	2.30	1	1.74	.92	1	4.36
				1.00	1	4.00
				1.42	1	2.82
				1.93	1	2.07
				2.25	1	1.78
$\bar{D}$			4.215			8.665
S			1.707			6.324
$S_{\bar{x}}$			.364			1.581
n			22			16
95% Confidence Interval	$3.502 \leq \bar{D} \leq 4.928$			$5.566 \leq \bar{D} \leq 11.764$		

Diffusion Coefficients Obtained from Movies

From the movies taken of larvae in a commercial asparagus field on May 19, 1975, estimates of D were obtained for each of the larvae observed (Table 17). Since the time between frames was fixed at eight seconds (.0022 hours), the equation for diffusion coefficients simplifies to:

$$D = \frac{r^2}{.0088} \tag{14}$$

where r equals the mean distance the larvae moved per frame.

The mean value of D obtained from the movie (1.629 square feet per hour) was significantly different from the lowest mean D estimated from the pitfall traps (4.215 square feet per hour) ($t_{31} = 4.51$, $p < .0001$). This is probably due to two main factors. (1) The larvae in the movies were in a natural field condition and no pre-experimental handling or stresses were present. (2) The soil in Oceana County is sandier than the soil at the Botany Farm. Therefore the Botany Farm soil may have been artificial to the larvae and the higher D values probably reflect the larvae searching for a more familiar soil texture--sandy.

Evaluation of Larval Movement

Once D had been calculated, the model could then be implemented and treatment strategies simulated. In Figure 19, the effect of treatment spacing and diffusion coefficients on expected percent

Table 17. Movement observations of white cutworms based on movie on May 19, 1975. 1 Frame = 8 sec. (.0022 hr.).

Cutworm	Mean Distance Moved in .0022 hr (r)	D
1	.1978	4.45
2	.0616	.43
3	.1166	1.54
4	.0958	1.04
5	.1239	1.74
6	.0375	.16
7	.1372	2.14
8	.1154	1.51
9	.1506	2.58
10	.1083	1.33
11	.0930	.98

$\bar{D} = 1.629$

$S = 1.166$

$S_{\bar{x}}$ .352

n 11

95% Confidence Intervals

$.940 \leq \bar{D} \leq 2.318$

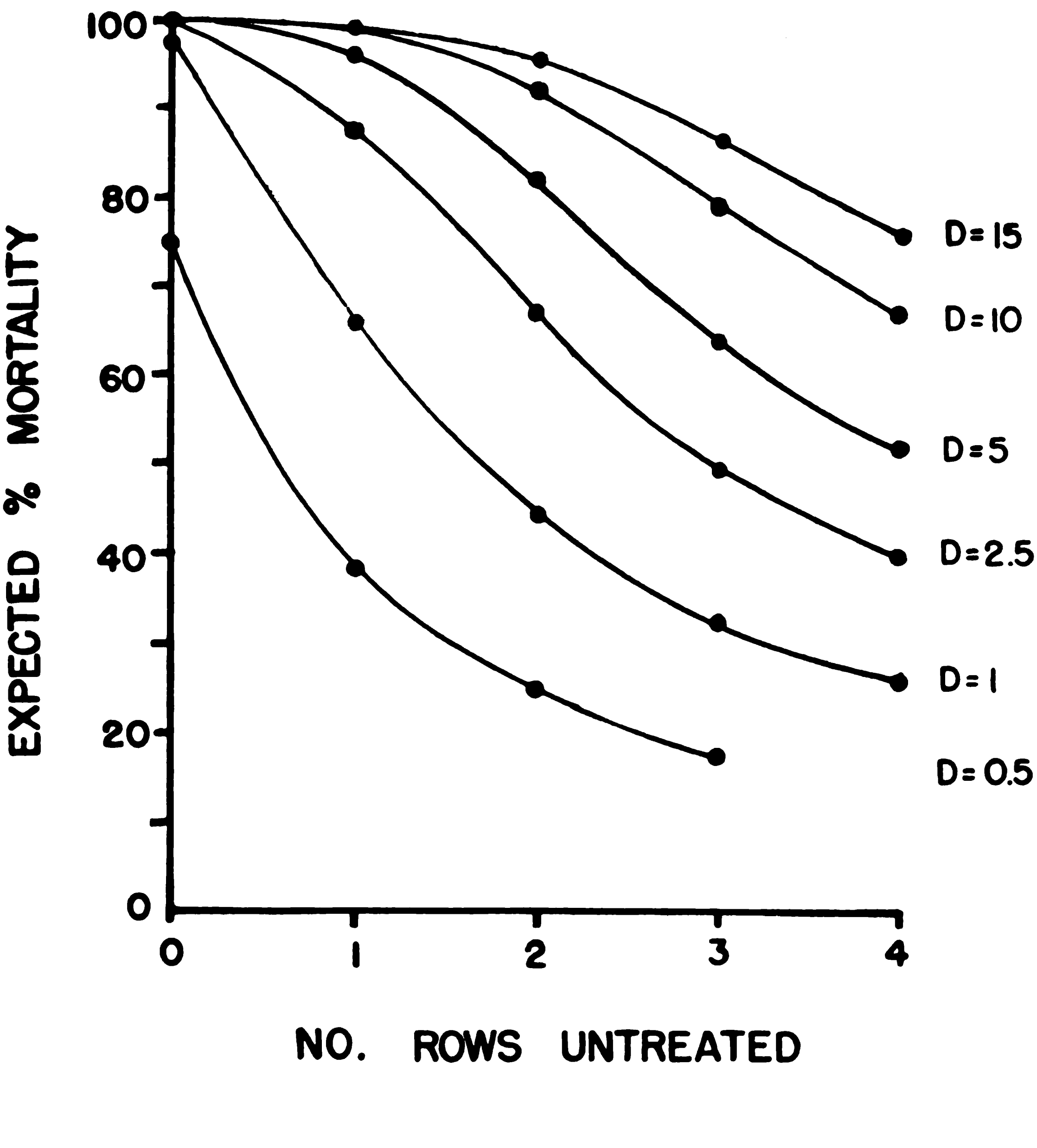

Figure 19. Effects of treatment spacing and diffusion coefficients on expected mortality for 15 hours simulation. Rows are 5 feet apart.

mortality is shown. The range of D values simulated is about equal to the range obtained from the movement experiments.

One can readily see that through manipulation of the treatment spacing a desired mortality can be selected for which is very useful in a pest management framework where a certain number of white cutworms present may be desirable.

Probably the most realistic D value to use is the value obtained from the field observations since the larvae were under a natural condition and no prior handling was necessary. This D value (approximately 1.6 square feet per hour) was used in a simulation to show the effects of duration of insecticide efficacy on expected percent mortality (Figure 20).

Over 60% of the expected mortality occurred within three days (15 hours) of bait application. Since the average frequency of rainfall was equal to three or four days for Oceana county in May, this was desirable because the bait's efficacy decreases once it has been exposed to water. A solution to this would be the development of an insecticide bait that is more moisture-resistant.

Estimation of Field Degree-Day Accumulation

A three sensor Wilk-Lambrecht thermograph was operated in a commercial asparagus field on the farm of Mr. Lyle Sheldon from October 1974 through November 1975 (Appendix M1). The sensors were placed at three strata, ten inches above, one inch below, and six inches below the soil surface. These were the strata where the larvae spent most of their time. This field was a typical asparagus

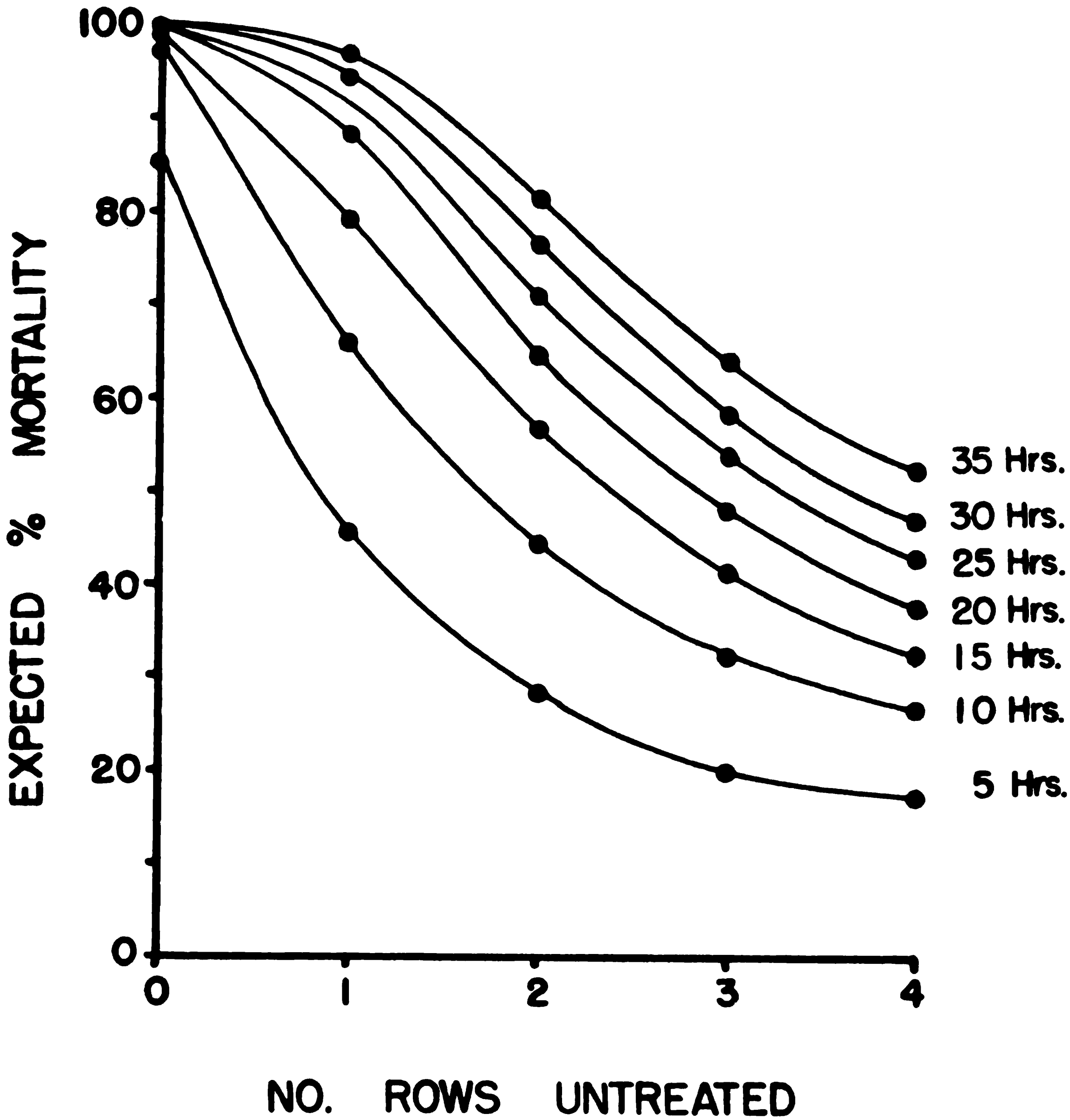

Figure 20. Effect of simulation time on expected mortality with a constant diffusion coefficient (D = 1.6). Rows are 5 feet apart.

field in Oceana county with respect to soil type and drainage. It was located 7 1/4 miles southwest of the Hart weather station.

Regression analysis between the degree-day accumulations at the Sheldon thermograph (S) and the Hart weather station (H) produced the regression equations in Table 18. The equations for each month proved to be significantly different from one another at .05 significance level; therefore, a more accurate prediction can be made through the use of individual monthly regression equations rather than the yearly regression equations.

These regression equations enable estimations of degree-day accumulations in the field based on readily accessible weather information from the Hart weather station.

Table 18. Regression equations for estimation of field degree-day accumulations at the lyle Sheldon farm (S) from degree-day accumulation from the Hart, Michigan, weather station (H) for 1975.

Month	+10		-1		-6	
April	S = 6.123 + 2.061 H	r^2 = .981	S = -1.576 + 1.741 H	r^2 = .969	S = -.677 + .820 H	r^2 = .971
May	S = 38.035 + 1.489 H	r^2 = .994	S = 3.883 + 1.556 H	r^2 = .993	S = -38.451 + 1.428 H	r^2 = .994
June	S = 119.563 + 1.243 H	r^2 = .999	S = 105.417 + 1.353 H	r^2 = .999	S = 46.437 + 1.255 H	r^2 = .999
July	S = 183.491 + 1.163 H	r^2 = .999	S = 66.906 + 1.402 H	r^2 = .999	S = -32.653 + 1.367 H	r^2 = .998
August	S = 12.728 + 1.268 H	r^2 = .999	S = 107.993 + 1.385 H	r^2 = .996	S = 15.408 + 1.346 H	r^2 = .997
September	S = -764.369 + 1.626 H	r^2 = .994	S = 26.605 + 1.443 H	r^2 = .997	S = 74.776 + 1.317 H	r^2 = .988
October	S = -642.527 + 1.574 H	r^2 = .996	S = 805.358 + 1.102 H	r^2 = .991	S = 1062.16 + .905 H	r^2 = .982
November	S = 542.617 + 1.122 H	r^2 = .891	S = 2062.580 + .615 H	r^2 = .864	S = 2140.584 + .486 H	r^2 = .874
Yearly	S = 46.016 + 1.289 H	r^2 = .999	S = 42.478 + 1.404 H	r^2 = .999	S = 1.295 + 1.328 H	r^2 = .999

S = Sheldon thermograph
H = Hart Weather Station

CONCLUSION

This study has been an effort to design a larval sampling method for white cutworms and to describe their biology and behavior.

Early in this study it became apparent that standard destructive soil samples were not applicable to asparagus. Therefore a non-destructive sampling technique was developed which incorporated Sevin^{R} bait in the sampling. Barrier-baited six square feet plots were the most desirable for quantitative samples and small open-baited plots were most effective for larval detection.

Treatments for control of larvae should be applied in the fall when the larvae are small and soil temperatures are still high. Harris (1968, 1971a, 1975) has shown in laboratory experiments with *Euxoa messoria* (Harris), *Agrotis ipsilon* (Hufnagel), *Pseudaletia unipuncta* (Hawthorn) that larger instars are more tolerant to an insecticide than are smaller instars.

If one assumes this to be true for white cutworms, then treating when the weighted mean instar is between 2.0 and 4.0 good control could be expected. This range of WMI was selected because smaller instars tend to be skeletonizers of asparagus seedlings and are less affected by the baits. Soil temperatures are also higher in late August or September than in May and O'Brien (1967) and Harris (1971b) have shown that many organochlorines and other insecticides' toxicities are directly related to temperature. Therefore, an insecticide applied in May would be less toxic than if it were applied in early September, thus making late August or early September the ideal time for larval control.

A simulation of the effects of treatment spacing on expected mortality has shown that by varying the treatment spacing a specific mortality can be selected. This is instrumental in a pest management system where the pest population must be kept at a desired level rather than be eliminated. More work should be done on validation of the assumptions of the model, especially on the efficacy of the insecticide and its length of toxicity.

Research should be continued in locating the diurnal resting sites for the moths, since no significant numbers of adults were ever found during the day. This would be instrumental in understanding the biology and could aid in control.

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APPENDIX A

HOST RANGE OF THE WHITE CUTWORM

Table A1. Host range of the white cutworm as reported in published literature.

COMMON NAME	SCIENTIFIC NAME	REFERENCES
A. Forage Crops		
Sweet Clover	Trifolium sp.	Hudson & Wood (1930), Walkden (1950), Beirne (1971).
B. Fruits		
Apples	Malus pumila	Riley (1869), Beutenmuller (1901), Gibson (1912, 1915), Middleton (1913), Crumb (1932), Tietz (1951), Forbes (1954).
Cherries	Prunus cerasus	Riley (1869), Beutenmuller (1901), Crumb (1932).
Grapes	Vitis vinifera L.	Riley (1869), Slingerland (1895), Beutenmuller (1901), Crumb (1932), Tietz (1951).
Peaches	Prunus persica	Riley (1969), Slingerland (1895), Beutenmuller (1901), Gibson (1912, 1915), Crumb (1932), Tietz (1951).
Pears	Pyrus communis	Riley (1869), Tietz (1901), Gibson (1912, 1915), Hudson & Wood (1930), Crumb (1932).
Raspberries (Young leaves)	Rubus sp.	Hudson & Wood (1930).
Rhubarb	Rheum rhaponticum	Beirne (1971).
C. Stimulants		
Tobacco	Nicotiana tabacum L.	McLeod, Svec*.

Table A1. (cont'd)

COMMON NAME	SCIENTIFIC NAME	REFERENCES
D. Trees and Scrubs		
Elm	Ulmus americana	Crumb (1932).
Evergreens	Gymnosperm	Hudson & Wood (1930).
Honeysuckle	Lonicera sp.	Crumb (1932).
Oak	Quercus sp.	Crumb (1932), Tietz (1951).
Over-cup Oak	Quercus sp.	Knutson (1944).
White Oak	Quercus alba	Knutson (1944), Teitz (1951).
Willow sprouts	Salix sp.	Salkden (1950).
E. Vegetables		
Asparagus	Asparagus officinalis	M.S.U. (1971)•.
Beans	Phaseolus sp.	Hudson & Wood (1930), Beirne (1971).
Beets	Beta vulgaris	Hudson & Wood (1930), Beirne (1971)
Cabbage	Brassica oleracea	Hudson & Wood (1930), Tietz (1951).
Carrots	Daucus carota	Hudson & Wood (1930), Beirne (1971).
Corn	Zea mays L.	Hudson & Wood (1930), Beirne (1971).
Onion	Allium cepa	Beirne (1971).
Peas	Pisum sativum	Hudson & Wood (1930), Beirne (1971).
Potatoes	Solanum tuberosum	Hudson & Wood (1930), Beirne (1971).
Radishes	Raphanus sativa	Gibson (1912, 1915), Hudson & Wood (1930), Tietz (1951), Beirne (1971).

Table A1. (cont'd)

COMMON NAME	SCIENTIFIC NAME	REFERENCES
F. Weeds		
Canada Thistle	Cirsium arvense (L). Beauv.	Hudson & Wood (1930).
Couch Grass	Agropyron repens (L) Beauv.	Hudson & Wood (1930).
Evening Primrose	Oenothera biennis (L)	Hudson & Wood (1930).
Green Fox Tail	Setaria viridis (L) Beauv.	Hudson & Wood (1930).
Horsetail	Equisetum sp.	Hudson & Wood (1930).
Large Flowered Dock	Rumex venosus Pursh	Walkden (1950).
Milkweed	Asclepias syriaca L.	Hudson & Wood (1930).
Pigeon Grass	Setaria glauca (L) Beauv.	Hudson & Wood (1930).
Russian Thistle	Salsola kali var. Tragus	Hudson & Wood (1930).
Miscellaneous		
Bush Fruits		Crumb (1932), Tietz (1951).
Fruit Buds & Leaves		Saunders (1883), Slingerland (1895), Gibson (1912, 1915), Knutson (1944), Tietz (1951), Frost (1955), Hardwick (1970).
Nursery Stock		Hardwick (1970).
Shade Trees		Slingerland (1895).
Shrubbery		Riley (1869).
Garden Vegetables & Plants		Hague (1898), Gibson (1912, 1915), Middleton (1913), Knutson (1944), Frost (1955), Beirne (1971).

Table A1. (cont'd)

COMMON NAME	SCIENTIFIC NAME	REFERENCES
Miscellaneous (cont'd)		
Low Plants		Tietz (1951).
Roadside & Irrigation Ditch Wasteland		Crumb (1932).
Succulent Plants		Crumb (1932).

*Unpublished Agriculture Canada Data

•Unpublished M.S.U. data

APPENDIX B

ASPARAGUS GROWER QUESTIONNAIRE PACKET

February 18, 1976

Dear Asparagus Grower:

The enclosed questionnaire is designed to aid in cutworm research and act as a preliminary damage survey. It is being sent to all the asparagus growers in Oceana County and should give us an estimate of acreages, location and damage.

The first question is very important in that we will be able to locate the asparagus fields and plot them on a soil type map. We can then study the relationship between each fields soil type and the other information found in the following questions. Please draw in the location, as close as possible, of your fields in the model sections, number them, and give township. All this is very important in locating that field on the soil map. Please do this for each of your asparagus fields. If you have more than one field on a section, please draw them on separate model sections. Also if you have more than five fields, we would appreciate including them and answers on another sheet of paper.

The additional enclosure "Asparagus Insect Identification and Control 1975" is intended for your personal reference. Be sure to take note of the changes in recommended chemicals from 1974.

Oceana County is presently the only county that has reported problems with white cutworms. They have been collected in 10 of the 22 asparagus growing counties but are not problems there. We are, therefore, trying to learn what is the unique factor or factors in Oceana County which has allowed this buildup.

The white cutworms overwinter a few inches below the soil surface and wait there for the first asparagus spears to emerge in the spring. There is evidence of a preference for sandy soil. The cutworms feed until mid June when they pupate--go underground and change to a moth. This takes about 2 weeks and the male moths begin flying about the end of June, with female emergence about 1 week after males. The adults feed on milkweed, this is the basis for the question on herbicides and uncontrolled weeds. The females lay up to 600 eggs which hatch in about two weeks. The young cutworms begin feeding about the middle of July or early August on the ferns and on November 1st were observed feeding on ferns at a height of about 2 feet. This may be an important factor in fall treatment. A parasite has also been reared from larvae and more research needs to be conducted on it.

February 18, 1976
Page 2

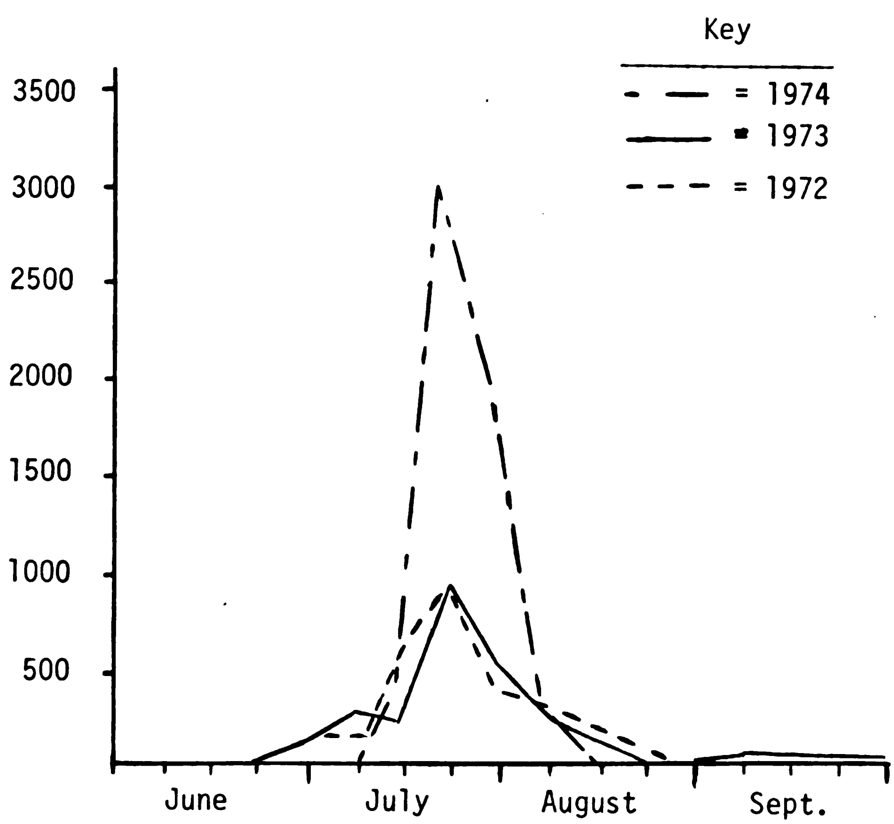
Your cooperation in filling out this questionnaire has been greatly appreciated and will be very valuable in our research. All responses will be confidential and used only for cutworm research.

The figure below gives an indication of the number of moths caught in the past three years and indicates the coming year may be much worse. There were about three times more moths collected than in the two previous years.

Sincerely,

Donald C. Cress
Extension Specialist
In Entomology

Emmett P. Lampert
Graduate Student



Asparagus Insect Identification and Control for 1975

Prepared by:
Edgar L. Strong
Donald C. Cress
Emmett P. Lampert

There are three insects that cause economic damage to asparagus in Michigan. These are the common asparagus beetle, the twelve-spotted asparagus beetle, and cutworms.

Common Asparagus Beetle

Description: The adults are about 1/4 inch in length, with a bluish black head, a red thorax (back), and dark blue wing covers marked with lemon yellow and margined with red. The larvae (immature beetles) are olive gray with black heads, and the brownish eggs are elongate and attached by one end to the foliage. There are several generations per year.

Damage: Both adults and larvae of these beetles cause feeding damage. The adults congregate in early spring and feed upon the tender new spears. They eat out and cause a brownish discoloration of the tissue. The larvae feed on both tender young spears and foliage.

Twelve-spotted Asparagus Beetle

Description: This beetle is slightly larger than the common asparagus beetle. The adults are red orange in color with black antennae and six black spots on each wing cover. They lay their eggs with a side attached to the plant rather than on end.

Damage: The adults of this beetle cause some damage in early spring by eating the buds of the new tender spears and some foliage. The larvae cause little damage because they feed on the insecide of the berries.

Cutworms

Description: There are several types of cutworms that cause damage to asparagus. The white cutworm is most important in Oceana County. Cutworms are the immature stages of moths and can be identified by being soft bodied worm-like insects. They have three pairs of front legs and four or five pair of hind legs. They have a dark, distinct head and their body color can vary considerably.

Damage: Damage by cutworms can be caused by either climbing the spear and feeding on the tip and sides, cutting the spears at the ground level and feeding on it, or feeding below the soil on the spears.

Insect Control on Asparagus for 1975

When to Apply	Amount of Active Chemical per acre and formulation	Warning
Pre-emergence:	For cutworms only: dieldrin, 1 pound WP.	Apply in spring before the first spears emerge. Avoid drift. Follow all label directions.
Soil and Spears: (During harvest)	For Asparagus beetles: Sevin, 1 pound WP or SC.	1 day. Space treatment 3 days apart.
	or	
	Methoxychlor, 1 pound WP or D.	3 days. Unless washed and blanched.
	or	
	Malathion, 1 1/4 pound EC.	1 day.
	For Cutworms only:* Sevin, 2 pounds B	1 day. Repeat treatment as needed.
Fall treatment:	Sevin 2 pounds B	Consult County Extension Service for timing.

WP=wettable powder; SC=suspension concentrate; D=dust; B=bait; EC=emulsifiable concentrate

*Please note changes from 1974 recommendations.

COOPERATIVE EXTENSION SERVICE

Michigan State University
U. S. Department of Agriculture
Cooperating

Cooperative Extension Service
Entomology Department

East Lansing, Michigan 48824

NAME ____________________

PHONE NO. ____________________

1. If you are renting out your land, please indicate the renter and return.

   Renter ____________________

2. In the model sections below please draw in your asparagus fields, list the section number, and the township name.

Field 1	Field 2	Field 3	Field 4	Field 5
Sec# ______	Sec# ______	Sec# ______	Sec# ______	Sec# ______
Township ______	Township ______	Township ______	Township ______	Township ______
Acreage ______	Acreage ______	Acreage ______	Acreage ______	Acreage ______
Age ______	Age ______	Age ______	Age ______	Age ______

3. Cutworm damage present in field.

Field 1	Field 2	Field 3	Field 4	Field 5
yes ______	yes ______	yes ______	yes ______	yes ______
no ______	no ______	no ______	no ______	no ______

4. Chemicals used for cutworm control and active ingredient per acre used.

   A) Sevin Dust
   B) Sevin Bait
   C) Devin Spray (WP)
   D) Dieldrin (WP)
   E) Methoxychlor (WP)
   F) Methoxychlor Dust
   G) Chlordane (WP)
   H) Chlordane (EC)
   I) Chlordane Granule
   J) Other ____________________

Field 1		Field 2		Field 3		Field 4		Field 5	
Chem.	A.I./acre	Chem.	A.I./acre	Chem.	A.I./acre	Chem.	A.I./acre	Chem.	A.I./acre
___	______	___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______	___	______

5. Time control measures taken. A = Fall B = Spring

   Field 1 ______ Field 2 ______ Field 3 ______ Field 4 ______ Field 5 ______

6. Other insecticides used for other insects and the active ingredient per acre used.

   A) Sevin Dust
   B) Sevin WP
   C) Chlordane WP
   D) Chlordane Dust
   E) Dieldrin
   F) Methoxychlor WP
   G) Malathion D
   H) Malathion WP
   I) Malathion EC
   J) Other ____________________

Field 1		Field 2		Field 3		Field 4		Field 5	
Chem.	A.I./acre	Chem.	A.I./acre	Chem.	A.I./acre	Chem.	A.I./acre	Chem.	A.I./acre
___	______	___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______	___	______
___	______	___	______	___	______	___	______	___	______

7. Are your fields on a till or no-till cultivation system? A = till B = no-till

Field 1 ________ Field 2 ________ Field 3 ________ Field 4 ________ Field 5 ________

8. Herbicides and fungicides used and active ingredient/acre used.

A) Zineb
B) Polygram
C) Maneb
D) Manzate 200
E) Dithane M-45
F) Princep (Simazine)
G) Karmex
H) Dowpon
I) 2,4-D
J) Other ____________________________

Field 1		Field 2		Field 3		Field 4		Field 5	
Pesticide	A.I./acre	Pesticide	A.I./acre	Pesticide	A.I./acre	Pesticide	A.I./acre	Pesticide	A.I./acre
________	________	________	________	________	________	________	________	________	________
________	________	________	________	________	________	________	________	________	________
________	________	________	________	________	________	________	________	________	________

9. Weed problems not controlled

A) Milkweed
B) Sandbur
C) Other (please list)

Field 1	Field 2	Field 3	Field 4	Field 5
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________

10. Field irrigated or not irrigated. A = Irrigated B = Not irrigated

Field 1 ________ Field 2 ________ Field 3 ________ Field 4 ________ Field 5 ________

11. Field well drained. A = yes B = no

Field 1 ________ Field 2 ________ Field 3 ________ Field 4 ________ Field 5 ________

12. Fertilizers used.

A) Nitrogen
B) Phosphorus
C) Magnesium
D) Pot Ash
E) Lime

Field 1	Field 2	Field 3	Field 4	Field 5
________	________	________	________	________

13. Crops adjacent to your field.

A) grassland
B) woods or shrubs
C) fence rows
D) corn
E) neighbor's asparagus field
F) apples
G) peaches
H) pears
I) other

Field 1 ________ Field 2 ________ Field 3 ________ Field 4 ________ Field 5 ________

14. Type of harvest procedure. A) handpicked B) sled harvested

Field 1 ________ Field 2 ________ Field 3 ________ Field 4 ________ Field 5 ________

15. Time of year when you chop old fern. A) Fall B) Winter C) Spring

Field 1 ________ Field 2 ________ Field 3 ________ Field 4 ________ Field 5 ________

16. Could I contact you for further information? Please check: yes ____ no ____

17. Comments, if any.

Thank you for your cooperation in completing this questionnaire. Please return to D.C. Cress in the envelope provided.

Sincerely yours,

Donald C. Cress
Extension Specialist
In Entomology

APPENDIX C

ASPARAGUS CUTWORMS SURVEY DATA SHEET

CUTWORM PITFALL SURVEY

Field Number:____________ Grower:____________________

Date	Number Collected	TODAY'S FIELD INFORMATION			PREVIOUS NIGHT'S INFORMATION					
					SKY				WIND SPEED	
		Harvest	Control		Clear	Partly Cloudy	Cloudy	Rained	0-10	10+

BETWEEN HARVEST INFORMATION

Number of spears per crown: 1.______ 2.______ 3.______

Number of spears damaged by cutworms per crown: 1.______ 2.______ 3.______

APPENDIX D

COMPUTER LISTINGS OF STRIP BAIT MODEL

```
      PROGRAM STRIP (INPUT=128,OUTPUT=128)
*****  THIS PROGRAM IS A MODIFICATION OF DR. DICK
*****  CASAGRANDE"S CEREAL LEAF BEETLE  STRIP SPRAY
*****  MODEL.  IT HAS BEEN MODIFIED WITH HIS HELP
*****  TO EVALUATE WHITE CUTWORM MOVEMENT.
      DIMENSION X(96),Z(160),Y(160)
20    NHOURS=15
      PRINT*,"ENTER THE DIFFUSION COEFFICIENT.  "
      READ *,D
      DENS=100.
*****  DEN=INITIAL LARVAL DENSITY PER FOOT OF STRIP
      TDEAD=0.
*****  TDEAD=NUMBER OF DEAD LARVAE
      T=0.
      DT=10.
      MT=60/DT+.001*DT
      NS=1
*****  NS=WIDTH OF BAITED STRIP
      PRINT*,"ENTER THE NUMBER OF UNSPRAYED FEET, I2."
      READ 15,NU
*****  NU=WIDTH OF UNTREATED STRIP
15    FORMAT(I2)
      NT=NS+NU
      NT2=NT/2
      TD=DENS*NU
*****  ZEROES OUT BAITED STRIP (IN FEET)
      DO 2 J=1,NT
      Y(J)=0.
2     CONTINUE
*****  INITIALIZES DENSITY IN UNBAITED STRIP (IN FEET)
      DO 3 J=1,NU
      Y(J)=DENS
3     CONTINUE
10    FORMAT(1X,5F10.3)
      CALL DIFFUSE (D,DT,NT2,X)
      TM=0.
      DO 5 I=1,NHOURS
      DO 4 II=1,MT
      TM=TM+DT
      T=TM/60.
      CALL LOCATE(NT2,NT,NS,X,Y,Z,TDEAD,T1)
      PER=TDEAD/T1
4     CONTINUE
      PRINT 10,T,TDEAD,PER,T1
5     CONTINUE
      PRINT*,"ARE YOU DONE WITH THIS PROGRAM?  "
      READ 16,ANS
16    FORMAT(A1)
      IF(ANS.EQ.1HN) GO TO 20
      END
      SUBROUTINE DIFFUSE(D,DT,NT2,X)
*****  THIS SUBROUTINE COMPUTES THE NUMBER OF CUTWORMS
*****  WHICH MOVE 1 TO NT2 FEET.
      DIMENSION X(96)
```

```
      TOT=0.
      S=SQRT(2*D*DT)
      M=NT2*12
***** CALCULATES THE NUMBER MOVING R INCHES
***** IN THE BAITED STRIP
      DO 1 I=1,M
      Y=I-1
      X(I)=(1/(S*2.506627))*2.71828**(-(Y*Y)/(S*S*2))
      TOT=TOT+2*X(I)
1     CONTINUE
      TOT=TOT-X(1)
      TOT=0.
      R=0.
***** CALCULATES THE NUMBER MOVING R INCHES IN THE
***** UNBAITED STRIP
      DO 2 I=1,6
      R=R+X(I)
2     CONTINUE
      R=R-(X(1)/2.)
      X(1)=R*2
      TOT=X(1)
      M=7
      DO 3 I=2,NT2
      R=0.
      DO 4 J=1,12
      R=R+X(M)
      M=M+1
4     CONTINUE
      X(I)=R
      TOT=TOT+2*X(I)
3     CONTINUE
      PRINT 10,(X(I),I=1,NT2)
      DO 5 I=1,NT2
      X(I)=X(I)*(1./TOT)
5     CONTINUE
10    FORMAT(1X,10F7.2)
      RETURN
      END
      SUBROUTINE LOCATE(NT2,NT,NS,X,Y,Z,TDEAD,T1)
***** THIS SUBROUTINE CALCULATES THE NUMBER CUTWORMS IN
***** EACH FOOT OF THE BAITED AND UNBAITED STRIPS
      DIMENSION Z(160),Y(160),X(96)
      T1=0.
      NU=NT-NS
***** CALCULATES THE NUMBER OF CUTWORMS IN EACH FOOT
***** OF STRIP FROM 1 TO NU+NS
      DO 4 I=1,NT
      Z(I)=Y(I)*X(1)
      M=I+1
      IF(M.GT.NT)M=1
      DO 5 J=2,NT2
      Z(I)=Z(I)+X(J)*Y(M)
      M=M+1
      IF(M.GT.NT)M=1
5     CONTINUE
      M=I-1
      IF(M.LT.1)M=NT
      DO 6 J=2,NT2
      Z(I)=Z(I)+X(J)*Y(M)
      M=M-1
      IF(M.LT.1) M=NT
6     CONTINUE
4     CONTINUE
***** CALCULATES THE NUMBER OF CUTWORMS MOVING INTO THE
***** BAITED STRIP AND THE NUMBER DYING
      DO 8 J=1,NT
      Y(J)=Z(J)
      IF(J.GT.NU)TDEAD=TDEAD+Y(J)
      IF(J.GT.NU)Y(J)=0.
      T1=T1+Y(J)
8     CONTINUE
      T1=T1+TDEAD
      RETURN
      END
```

APPENDIX E

QUESTIONNAIRE RESULTS

Appendix E1. Fertilizers used and acreage and number of asparagus fields for the cutworm damage conditions as reported from questionnaires. (A zero entry indicates no response for that category.)

FERTILIZER	CUTWORM DAMAGE: Reported		None Reported		Not Given		Total	
	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields
Nitrogen	1832	128	924	64	79	5	2835	197
Phosphorous	799	59	526	34	75	4	1400	97
Magnesium	216	11	120	8	69	3	405	22
Potash	1297	86	683	47	6	1	1986	134
Lime	1157	73	684	48	14	2	1855	123
Manure	49	3	23	3	0	0	72	6
All but Manure	170	9	0	0	13	2	183	11
Not Given	132	12	126	11	N/A*	2	258	25

* acreage for these fields not reported

Appendix E2. Insecticides used for other insect control and acres and number of fields for each insecticide as reported from questionnaires. (A zero entry indicates no response for that category.)

INSECTICIDE	CUTWORM DAMAGE: Reported		None Reported		Not Given		Total Per Insecticide	
	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields
Sevin Dust	426	28	199	15	0	0	625	43
Sevin WP	1292	100	629	39	86	6	2007	145
Chlordane WP	138	6	42	4	6	1	186	11
Dieldrin Sp	215	11	99	4	0	0	314	15
Methoxychlor	23	2	0	0	0	0	23	2
Malathion D	0	0	0	0	0	0	0	0
Not Given	299	22	264	22	8	3	571	47

Appendix E3. Herbicides and fungicides used and acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response for that category.)

HERBICIDE	CUTWORM DAMAGE: Reported		None Reported		Not Given		Total	
	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields
Zineb	171	7	35	1	0	0	206	8
Polygram	305	18	43	4	0	0	348	22
Maneb	278	15	0	0	0	0	278	15
Manzate 200	14	1	0	0	0	0	14	1
Dithane M-45	222	10	159	7	0	0	381	17
Princep	1589	123	849	60	100	9	2538	192
Karmex	396	16	139	10	0	0	535	26
Dowpon	890	65	86	11	23	4	999	80
2, 4-D	124	7	0	0	0	0	124	7
Sodium Salt	65	5	0	0	0	0	65	5
Other	9	2	50	3	0	0	59	5
None	162	10	108	10	N/A*	1	270	21

* Acreage for this field not given

Appendix E4. Tillage and cutworm damage with acres and number of fields for each as reported from the questionnaires. (A zero entry indicates no response for that category.)

TILLAGE	CUTWORM DAMAGE							
	Reported		None Reported		Not Given		Total	
	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields
Tilled	899	73	699	56	56	6	1654	135
Zero-Till	1145	73	324	23	44	4	1513	100
Not Given	116	6	51	2	0	0	167	8
TOTALS	2160	152	1074	81	100	10	3334	243

Appendix E5. Tillage and weeds with acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response for that category.)

WEEDS	TILLAGE							
	Tilled		Zero Tilled		Not Given		Total	
	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields
Milkweed	859	69	736	53	34	2	1629	124
Sandbur	845	53	657	47	59	4	1561	104
Ragweed	47	2	149	11	0	0	196	13
Horsenettle	5	3	0	0	0	0	5	3
Ground Cherry	5	3	0	0	0	0	5	3
Pigweed	4	2	28	2	0	0	32	4
Poplar Seedlings	10	1	0	0	0	0	10	1
Grass (crab,quack)	277	12	283	20	0	0	560	32
Thistles	71	2	0	0	0	0	71	2
Other	52	4	87	6	0	0	139	10
Not Given	356	36	337	21	108	4	801	61

Appendix E6. Cutworm damage and weeds with acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response for that category.)

WEEDS	CUTWORM DAMAGE							
	Reported		None Reported		Not Given		Total	
	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields	No. of Acres	No. of Fields
Milkweed	1089	84	510	37	30	3	1629	124
Sandbur	972	65	507	33	82	6	1561	104
Ragweed	70	4	82	7	44	2	196	13
Horsenettle	4	2	1	1	0	0	5	3
Ground cherry	4	2	1	1	0	0	5	3
Pigweed	0	0	32	4	0	0	32	4
Poplar seedlings	10	1	0	0	0	0	10	1
Grass (crab,quack)	439	23	121	9	0	0	560	32
Thistles	71	2	0	0	0	0	71	2
Other	38	2	101	8	0	0	139	10
Not Given	497	33	292	25	12	3	801	61

Appendix E7. Cutworm damage and adjacent crops with acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response for that category.)

ADJACENT CROPS	CUTWORM DAMAGE Reported No. of Acres	Reported No. of Fields	None Reported No. of Acres	None Reported No. of Fields	Not Given No. of Acres	Not Given No. of Fields	Total No. of Acres	Total No. of Fields
Grassland	853	55	473	41	35	3	1361	99
Woods & Shrubs	1353	83	384	24	29	3	1766	110
Fence Rows	562	35	290	15	37	4	889	54
Corn	184	9	231	13	20	1	435	23
Neighbor's Asparagus	584	37	242	14	13	2	839	53
Apples	306	27	140	10	29	3	475	40
Peaches	238	12	23	4	24	2	285	18
Pears	62	12	80	3	0	0	142	15
Cherries	303	21	160	9	0	0	463	30
Pickles	56	7	19	2	0	0	75	9
Plums	25	3	0	0	0	0	25	3
Hay	56	2	0	0	0	0	56	2
Road Ditches	140	8	0	0	0	0	140	8
Pasture	13	1	0	0	0	0	13	1
Potatoes	0	0	11	2	0	0	11	2
Other	0	0	25	2	0	0	25	2
Not Given	87	9	94	6	8	1	189	16

Appendix E8. Method of harvest and cutworm damage with acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response for that category.)

METHOD OF HARVEST	CUTWORM DAMAGE Reported No. of Acres	Reported No. of Fields	None Reported No. of Acres	None Reported No. of Fields	Not Given No. of Acres	Not Given No. of Fields	Total No. of Acres	Total No. of Fields
Hand	1769	123	949	72	96	8	2814	203
Sled	196	10	0	0	0	0	196	10
Hand and Sled	12	1	35	1	0	0	47	2
Fox Harvester	48	3	0	0	0	0	48	3
Not Harvested	22	2	31	3	4	1	57	6
Not Given	113	13	59	5	N/A*	1	172	19

* acreage for this field not reported

Appendix E9. Drainage and cutworm damage with acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response to that category.)

DRAINAGE	CUTWORM DAMAGE									
	Reported		None Reported		Not Given		Total		Percentage	
	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields
Well drained	1904	132	921	66	100	8	2925	206	88.03	84.77
Poorly drained	128	7	48	5	0	0	176	12	5.28	4.94
Not Given	128	13	105	10	N/A*	2	233	25	6.99	10.29
TOTALS	2160	152	1074	81	100	10	3334	243		

* acreage for these fields not reported

Appendix E10. Irrigation and cutworm damage with acres and number of fields for each as reported from questionnaires. (A zero entry indicates no response for that category.)

IRRIGATION	CUTWORM DAMAGE							
	Reported		None Reported		Not Given		Total	
	No.of Acres	No. of Fields	No. of Acres	No. of Fields	No.of Acres	No. of Fields	No.of Acres	No. of Fields
Irrigated	67	4	51	1	0	0	118	5
Not Irrigated	1972	137	964	75	100	8	3036	220
Not Given	121	11	59	5	N/A*	2	180	18
TOTALS	2160	152	1074	81	100	10	3334	243

* acreage for these fields not reported

APPENDIX F

YEARLY BLACKLIGHT TRAP CATCHES

FOR OCEANA COUNTY

Table F1. Yearly blacklight trap catches of white cutworms from Oceana.

	1973		1974				1975[Δ]						
	SHELBY		SHELDON				SHELDON			HAWLEY			
Date	Total	^{o}D >50	♀	♂	Total	^{o}D >50	♀	♂	Total	♀	♂	Total	^{o}D >50
6/14-23	50	750	0	0	0	616	6	88	94	2	9	12	751
6/24-7/1	350	885	2	16	18	729	169	819	988	4	34	47	934
7/2-8	146*	1044	48	504	522	883	371	1167	1559	42	97	147	1094
7/9-15	898	1189	266	1595	1861	1042	194	322	531	18	58	119	1187
7/16-22	507	1333	464	792	1256	1187	66	129	207	20	23	64	1354
7/23-29	194	1484	79	107	186	1322	10	24	38			81	1498
7/30-8/5	102	1626	17	16	33	1436	1	1	8	1	1	15	1681
8/6-12	12	1804	*	*	*	1574	0	0	0	0	0	0	1805

*Samples not received properly for these sample intervals

[Δ]Differences between total column and sum of males and females due to moths received without abdomens.

APPENDIX G

DEGREE-DAY ACCUMULATION FOR HART, MICHIGAN

Table G1. Degree-day accumulations for Hart, Michigan.

1973

°D > 50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1	1	42	135	334	885	1549	2256	2635	2884	2892
2	1	1	42	142	354	907	1566	2287	2650	2884	2892
3	1	1	42	142	372	929	1582	2315	2664	2884	2892
4	1	1	42	144	390	950	1598	2341	2675	2884	2892
5	1	1	42	146	408	968	1626	2363	2683	2884	2892
6	1	5	43	154	426	987	1654	2381	2689	2884	2892
7	1	10	43	161	442	1015	1682	2392	2697	2884	2892
8	1	10	43	169	460	1044	1712	2401	2707	2884	2892
9	1	10	43	176	480	1068	1740	2415	2725	2884	2892
10	1	10	43	184	502	1092	1762	2425	2745	2884	2892
11	1	17	43	189	529	1107	1784	2441	2767	2884	2892
12	1	17	43	194	551	1123	1804	2450	2785	2884	2892
13	1	17	43	194	563	1151	1821	2458	2798	2885	2892
14	1	24	43	194	579	1174	1843	2472	2808	2888	2892
15	1	30	49	196	598	1189	1861	2482	2820	2889	2892
16	1	30	54	198	622	1202	1881	2487	2824	2889	2892
17	1	30	55	200	641	1218	1902	2490	2824	2889	2892
18	1	30	62	204	661	1240	1924	2495	2825	2889	2892
19	1	30	77	212	684	1266	1948	2500	2829	2889	2892
20	1	30	92	219	702	1289	1971	2503	2834	2889	2892
21	1	30	108	228	719	1310	1985	2505	2837	2891	2892
22	1	30	117	236	734	1333	1995	2514	2843	2892	2892
23	1	31	119	247	750	1355	2007	2524	2851	2892	2892
24	1	32	119	257	766	1379	2023	2533	2861	2892	2892
25	1	32	122	270	780	1405	2043	2549	2877	2892	2892
26	1	35	125	280	804	1429	2073	2571	2882	2892	2892
27	1	36	126	288	826	1452	2105	2593	2883	2892	2892
28	1	38	127	298	842	1470	2137	2604	2883	2892	2892
29	1	40	127	305	851	1484	2169	2617	2883	2892	2892
30	1	41	128	310	866	1508	2199	2625	2884	2892	2892
31	1	41	128	318	866	1528	2228	2625	2884	2892	2892

Table G1. Continued.

1974

°D > 50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	5	125	323	729	1374	1943	2224	2352	2376
2	0	0	7	133	333	751	1392	1949	2224	2361	2376
3	0	4	13	141	341	779	1410	1954	2224	2368	2376
4	0	4	17	143	359	803	1423	1960	2230	2368	2376
5	0	4	17	144	381	817	1436	1968	2240	2368	2376
6	0	4	17	144	403	833	1454	1978	2248	2368	2376
7	0	5	17	144	424	856	1474	1990	2248	2368	2376
8	0	5	17	144	438	883	1493	2006	2249	2371	2376
9	0	5	17	146	458	913	1513	2026	2250	2373	2376
10	0	5	18	149	472	941	1533	2046	2255	2374	2376
11	0	5	19	153	477	958	1556	2070	2261	2374	2376
12	0	5	27	157	484	974	1574	2092	2268	2374	2376
13	0	5	34	157	494	1002	1595	2104	2270	2374	2376
14	0	5	36	162	508	1032	1610	2110	2273	2374	2376
15	0	5	36	165	522	1042	1628	2122	2273	2374	2376
16	0	5	36	167	529	1058	1650	2129	2275	2374	2376
17	0	5	40	175	531	1079	1668	2141	2276	2374	2376
18	0	5	43	182	540	1107	1687	2145	2276	2374	2376
19	0	5	43	193	557	1133	1709	2156	2276	2375	2376
20	0	5	51	205	575	1153	1735	2163	2276	2375	2376
21	0	5	65	223	597	1169	1763	2167	2276	2375	2376
22	0	5	70	239	609	1187	1789	2167	2279	2375	2376
23	0	5	70	251	616	1203	1809	2168	2284	2376	2376
24	0	5	70	258	625	1221	1823	2172	2287	2376	2376
25	0	5	70	262	634	1241	1836	2178	2291	2376	2376
26	0	5	78	266	645	1263	1858	2188	2293	2376	2376
27	0	5	90	271	659	1283	1882	2204	2298	2376	2376
28	0	5	108	279	674	1302	1896	2217	2308	2376	2376
29	0	5	117	293	689	1322	1908	2224	2318	2376	2376
30	0	5	123	304	709	1338	1919	2224	2328	2376	2376
31	0	5	123	314	709	1354	1933	2224	2340	2376	2376

Table G1. Continued.

1975

°D > 50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	2	53	418	934	1581	2165	2403	2590	2661
2	0	0	2	58	427	958	1611	2181	2403	2593	2661
3	0	0	2	66	435	986	1635	2193	2407	2599	2661
4	0	0	2	67	444	1008	1657	2204	2415	2603	2661
5	0	0	2	69	458	1030	1681	2212	2423	2610	2661
6	0	0	2	74	468	1054	1695	2220	2431	2618	2662
7	0	0	2	81	474	1074	1706	2227	2437	2629	2662
8	0	0	2	90	480	1094	1719	2237	2446	2635	2662
9	0	0	2	99	491	1108	1741	2242	2456	2639	2662
10	0	0	2	108	507	1124	1763	2253	2462	2640	2662
11	0	0	2	120	524	1134	1787	2267	2464	2640	2662
12	0	0	2	130	536	1143	1805	2271	2469	2640	2662
13	0	0	2	136	552	1156	1829	2273	2487	2640	2663
14	0	0	2	146	568	1167	1845	2278	2503	2640	2665
15	0	0	2	152	583	1187	1864	2286	2515	2640	2665
16	0	0	3	157	593	1211	1884	2296	2516	2642	2665
17	0	0	8	166	609	1238	1906	2304	2517	2647	2665
18	0	0	17	178	628	1262	1920	2320	2518	2653	2665
19	0	0	20	194	649	1288	1930	2336	2519	2656	2665
20	0	1	20	216	675	1310	1944	2341	2522	2659	2665
21	0	2	20	240	699	1330	1962	2349	2531	2659	2665
22	0	2	22	263	725	1354	1980	2353	2537	2659	2665
23	0	2	24	285	751	1377	2000	2357	2550	2659	2665
24	0	2	25	302	773	1401	2024	2361	2566	2659	2665
25	0	2	26	322	795	1417	2048	2364	2574	2659	2665
26	0	2	28	342	815	1431	2068	2368	2575	2659	2665
27	0	2	29	360	837	1455	2083	2373	2578	2659	2665
28	0	2	29	373	861	1476	2099	2380	2584	2659	2665
29	0	2	38	386	888	1498	2119	2387	2585	2659	2665
30	0	2	47	403	912	1524	2137	2396	2585	2661	2665
31	0	2	47	411	912	1552	2149	2396	2586	2661	2665

APPENDIX H

DIET USED FOR REARING WHITE CUTWORMS

Table H1. Diet used for rearing white cutworms. Diet obtained from Drs. Dupre and McLeod, Agriculture Canada.

	Ingredients	Quantity
A.	Soaked white beans	854 gm
	Distilled H_2O	1000 ml
	Formaldehyde	8 ml
B.	Ascorbic Acid	13 gm
	Brewers Yeast	128 gm
	Methyl-P-hydroxy benzoate	8 gm
	Sorbic Acid	4 gm
	Wheat Germ	200 gm
	Mositol	4 gm
C.	Distilled H_2O	2000 ml
	Agar	100 gm

1. Blend A in a blender until smooth.
2. B is mixed dry then added to A and blend again until smooth (B1).
3. C is brought to 188°-190°F to insure that agar is dissolved.
4. Let C cool to about 70°F then mix with B1 in a large container.
5. Pour into containers and refrigerate--do not freeze.

APPENDIX I

WHITE CUTWORM DEVELOPMENTAL TIMES

Table 11. Developmental times for white cutworms at different temperature. Larval development obtained from Dupré and McLeod unpublished. Photoperiod = 16 hours light, 8 hours dark.

	Rearing Temperature °F				
Stage	40°	50°	60°	70°	80°
Egg	*	*	20	9	6
	59°Δ	68°	77°Δ	77°	86°
1	18.3	6.3	4.4	4.6	3.4
2	14.3	5.5	3.7	4.1	3.4
3	14.6	5.9	4.7	4.5	3.7
4	19.8	7.3	5.9	5.8	4.8
5	24.8	9.0	8.5	8.7	6.7
6	21.2	8.6	12.1	9.4	8.1
7 & D	45.4	49.7	44.9	34.0	30.4
TOTAL	204.75	92.3	84.2	71.1	60.5

*No eggs hatched after five months.
Photoperiod = 0 hours light, 24 hours dark.

Δ59° Photoperiod = 0 hours light, 24 hours dark.
77° Photoperiod = 12 hours light, 12 hours dark.

APPENDIX J

INSTARS AND WEIGHTED MEAN INSTAR OF FIELD COLLECTED LARVAE

Table J1. Total number of instars collected by date.

Date	Instar 2	3	4	5	6	7	WMI
5/ 6/74				1	68	24	6.42
10/ 5/74				10	2		5.18
11/ 1/74					35	23	6.58
5/ 3/75					6	2	6.41
5/ 4/75					3	1	6.41
5/ 5/75				6	70	3	6.01
5/ 6/75				2	21	15	6.55
5/ 7/75				1	21	2	6.13
5/ 8/75				1	6	1	6.13
5/ 9/75				1	12	2	6.19
5/10/75					7	3	6.48
5/11/75					9	2	6.32
5/12/75			1	1	6	1	5.99
5/13/75					5	4	6.63
5/14/75					18	11	6.56
5/15/75					2		6.00
5/16/75					4	4	6.68
5/17/75					6	3	6.52
5/18/75					3	6	6.81
5/19/75					9	83	6.95
5/20/75					3	3	6.68
5/21/75						5	7.00
5/22/75					3	4	6.74
5/23/75					1	4	6.89
5/24/75						3	7.00
5/25/75						1	7.00
5/26/75						4	7.00
5/27/75					1	4	6.89
5/28/75						4	7.00
5/29/75					3	3	6.68
5/30/75						1	7.00
6/ 1/75						4	7.00
6/ 2/75						8	7.00
6/ 3/75						5	7.00
6/ 6/75						1	7.00
6/ 7/75						3	7.00
6/ 8/75						2	7.00
6/ 9/75						1	7.00
6/10/75						2	7.00
6/11/75				1		2	6.64
6/21/75					4		6.00
6/22/75					3		6.00
6/23/75					2		6.00
6/24/75					2	3	6.76

Table J1, continued.

Date	Instar 2	3	4	5	6	7	WMI
7/ 1/75						1	7.00
7/ 2/75					1	1	6.68
7/ 4/75						1	7.00
8/26/75	1	2	17	1			4.10
9/ 7/75			6	47			4.92
9/ 8/75			10	73	1		4.92
9/ 9/75			14	116	1		4.93
9/10/75			4	24	1		4.94
9/12/75				28	2		5.07
11/15/75				4	11		5.75

APPENDIX K

SMALL OPEN-BAITED PLOT RESULTS

Table K1. Results of the small open-baited plots for white cutworm detection.

Plot-Row Relationship	LARVAE COLLECTED PER DATE				
	9/6	9/7	9/8	9/9	9/10
Between two**					
Plot 1			*	0	2
2			*	1	0
3			*	3	3
4			*	0	2
5			*	1	0
6		*	8	2	0
7		*	9	11	5
8		*	16	9	2
9		*	8	8	1
10		*	22	6	2
Perpendicular					
Plot 11	*	4	2	1	0
12	*	2	1	2	0
13	*	0	1	0	2
14	*	4	3	3	4
15	*	1	0	0	0
16	*	0	1	4	2
17	*	3	5	1	2
18	*	1	0	1	0
19	*	4	0	5	0
20	*	3	0	3	2
21	*	0	0	1	0
Parallel					
Plot 22			*	1	1
23			*	1	0
24			*	1	0
25			*	0	1
26			*	1	1

* day plot initialized

** plot 1 to 5 were low density
plot 6 - 10 were high density

APPENDIX L

PERCENT OF FOOD UNITS THAT ARE SPEARS

Table L1. Percent of food units that are spears under varying lengths of butt palatability for a commercial field in 1975.

		Days Butts Palatable							
Harvest	Date	5	7	9	10	12	14	18	21
1	5/11	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	5/12	51.86	51.86	51.86	51.86	51.86	51.86	51.86	51.86
3	5/13	41.33	41.33	41.33	41.33	41.33	41.33	41.33	41.33
4	5/14	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66
5	5/17	31.62	20.00	20.00	20.00	20.00	20.00	20.00	20.00
6	5/18	31.50	17.26	14.65	14.65	14.65	14.65	14.65	14.65
7	5/19	27.33	14.81	10.66	10.66	10.66	10.66	10.66	10.66
8	5/20	26.77	21.45	14.15	12.48	12.48	12.48	12.48	12.48
9	5/21	16.31	16.71	11.03	9.59	8.55	8.55	8.55	8.55
10	5/22	28.71	23.12	19.95	16.56	13.34	13.34	13.34	13.34
11	5/24	33.48	24.66	21.09	21.09	16.07	13.36	13.36	13.36
12	5/26	21.96	14.95	11.46	9.97	9.97	7.78	6.55	6.55
13	5/28	33.76	24.54	18.11	16.30	12.86	12.86	8.84	8.84
14	5/30	29.56	19.18	14.71	13.03	10.28	8.29	6.77	5.85
15	6/2	56.08	34.52	27.40	19.67	15.82	12.61	9.57	7.96
16	6/5	57.03	42.67	31.42	31.42	26.67	20.71	13.35	11.27
17	6/8	38.63	26.41	26.41	21.17	16.51	14.37	9.84	7.75
18	6/10	55.01	32.08	24.41	24.41	20.56	16.80	12.36	10.02
19	6/12	38.98	38.98	27.14	27.14	22.08	19.27	14.79	12.54
20	6/14	24.74	19.26	19.26	14.24	14.24	11.91	9.08	8.30
21	6/16	31.17	22.79	18.68	18.68	14.52	14.52	11.18	9.77
22	6/18	30.60	20.17	15.59	15.59	13.15	10.53	9.16	8.31
23	6/20	36.34	28.06	20.45	20.45	16.58	14.36	11.84	10.45
24	6/22	40.66	30.76	25.55	25.55	20.01	16.86	12.64	11.33
25	6/24	28.48	22.74	18.22	18.22	15.61	12.65	9.76	8.39
26	6/26	29.63	22.21	18.57	18.57	15.44	13.53	9.83	8.91

Table L2. Percent of food units that are spears under varying lengths of butt palatability for the Sodus farm in 1975.

		Days Butts Palatable							
Harvest	Date	5	7	9	10	12	14	18	21
1	5/5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	5/7	59.16	59.16	59.16	59.16	59.16	59.16	59.16	59.16
3	5/9	67.83	67.83	67.83	67.83	67.83	67.83	67.83	67.83
4	5/12	54.00	47.83	44.33	44.33	44.33	44.33	44.33	44.33
5	5/14	29.95	18.76	16.98	15.93	15.93	14.93	15.93	15.93
6	5/16	25.87	25.87	17.94	16.52	15.66	15.66	12.66	15.66
7	5/19	65.18	50.18	32.63	32.63	25.14	23.61	22.67	22.67
8	5/20	21.73	17.61	12.20	12.20	9.67	9.14	8.80	8.80
9	5/22	17.54	13.40	11.14	11.14	7.99	6.44	5.90	5.90
10	5/23	22.62	22.62	18.25	15.66	11.76	11.76	9.24	8.95
11	5/30	33.92	25.16	15.67	15.67	13.04	11.40	7.38	7.05
12	6/2	57.09	37.50	31.10	25.08	17.25	14.78	10.49	8.94
13	6/4	40.23	27.76	20.16	17.31	14.45	10.40	8.14	6.60
14	6/6	33.68	33.68	25.95	25.95	17.93	15.42	10.25	9.32
15	6/9	53.41	39.01	27.85	27.85	22.92	18.86	11.74	10.52
16	6/11	51.78	36.45	29.52	23.02	23.02	19.75	15.47	11.20

Table L3. Percent of food units that are spears for the nine varieties of asparagus grown at the Sodus farm, 1975. Butts palatable for ten days.

Cultivar	HARVEST 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MSU 1	100	68.2	69.9	45.8	18.1	14.1	34.3	10.2	14.3	14.7	15.6	26.2	16.2	29.1	31.1	23.0
Mary Washington	100	59.2	67.8	44.3	15.9	16.5	32.6	12.2	11.1	15.7	15.7	25.1	17.3	26.0	27.9	23.0
UC 66	100	44.2	62.6	40.7	16.1	19.5	35.2	12.3	10.5	16.5	14.7	26.9	19.8	33.7	26.5	23.6
UC 72	100	66.7	71.0	47.1	22.3	16.9	31.5	12.4	12.6	13.9	17.1	26.7	15.2	28.0	24.6	26.6
UC 309	100	60.9	69.7	42.4	12.5	17.3	30.6	12.4	10.3	15.7	15.2	25.5	20.9	28.1	26.8	23.6
UC 711	100	67.5	79.5	49.0	19.2	16.7	35.4	10.8	10.3	18.1	12.1	28.4	20.0	28.9	27.6	22.6
NJ 44x22	100	61.1	58.0	32.7	10.3	12.0	34.0	13.0	12.5	18.6	15.7	25.1	15.6	31.5	27.1	27.5
NJ Improved	100	58.1	68.5	43.5	14.7	15.4	31.8	11.7	10.9	14.3	14.3	22.2	15.6	37.4	35.5	21.2
NJ 51x22	100	62.2	73.2	47.4	17.3	19.1	33.8	12.0	12.5	15.8	15.1	24.2	19.6	29.6	23.8	6.8
MEAN	100.	60.92	68.91	43.64	16.27	16.37	33.24	11.88	11.66	15.90	15.05	25.56	17.78	30.24	27.85	21.98
S	0.	7.26	6.08	4.86	3.55	2.35	1.69	.87	1.37	1.62	1.36	1.77	2.27	3.47	3.53	6.03
$S_{\bar{x}}$	0.	2.42	2.03	1.62	1.18	.78	.56	.29	.46	.54	.45	.59	.76	1.16	1.18	2.01

APPENDIX M

DEGREE-DAY ACCUMULATION FOR THE THERMOGRAPH OPERATED

AT THE FARM OF MR. LYLE SHELDON,

SHELBY, MICHIGAN

Table M1. Degree-Day Accumulations for Sheldon.

1974 at -6 inches.

°D>50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0	34	41
2	0	0	0	0	0	0	0	0	0	38	41
3	0	0	0	0	0	0	0	0	0	38	41
4	0	0	0	0	0	0	0	0	0	38	41
5	0	0	0	0	0	0	0	0	0	41	41
6	0	0	0	0	0	0	0	0	0	41	41
7	0	0	0	0	0	0	0	0	0	41	41
8	0	0	0	0	0	0	0	0	0	41	41
9	0	0	0	0	0	0	0	0	0	41	41
10	0	0	0	0	0	0	0	0	2	41	41
11	0	0	0	0	0	0	0	0	4	41	41
12	0	0	0	0	0	0	0	0	10	41	41
13	0	0	0	0	0	0	0	0	12	41	41
14	0	0	0	0	0	0	0	0	12	41	41
15	0	0	0	0	0	0	0	0	12	41	41
16	0	0	0	0	0	0	0	0	12	41	41
17	0	0	0	0	0	0	0	0	12	41	41
18	0	0	0	0	0	0	0	0	12	41	41
19	0	0	0	0	0	0	0	0	12	41	41
20	0	0	0	0	0	0	0	0	12	41	41
21	0	0	0	0	0	0	0	0	12	41	41
22	0	0	0	0	0	0	0	0	12	41	41
23	0	0	0	0	0	0	0	0	12	41	41
24	0	0	0	0	0	0	0	0	12	41	41
25	0	0	0	0	0	0	0	0	12	41	41
26	0	0	0	0	0	0	0	0	12	41	41
27	0	0	0	0	0	0	0	0	12	41	41
28	0	0	0	0	0	0	0	0	14	41	41
29	0	0	0	0	0	0	0	0	16	41	41
30	0	0	0	0	0	0	0	0	22	41	41
31	0	0	0	0	0	0	0	0	28	41	41

Table M1. Continued.

1975 at -6 inches.

°D>50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	40	562	1234	2133	2913	3215	3396	0
2	0	0	0	47	576	1268	2165	2937	3225	3398	0
3	0	0	0	51	590	1304	2193	2955	3235	3402	0
4	0	0	0	53	600	1338	2229	2973	3245	3404	0
5	0	0	0	54	616	1372	2261	2987	3255	3407	0
6	0	0	0	60	628	1404	2291	3003	3264	3413	0
7	0	0	0	71	638	1434	2319	3015	3271	3419	0
8	0	0	0	83	651	1462	2346	3015	3280	3425	0
9	0	0	0	91	670	1487	2372	3027	3290	3429	0
10	0	0	0	100	694	1512	2398	3041	3298	3431	0
11	0	0	0	114	713	1530	2425	3058	3302	3431	0
12	0	0	0	130	727	1548	2451	3068	3305	3431	0
13	0	0	0	150	745	1568	2478	3076	3317	3431	0
14	0	0	0	169	767	1586	2502	3088	3331	3431	0
15	0	0	1	188	785	1608	2529	3098	3340	3431	0
16	0	0	4	207	799	1634	2557	3110	3346	3431	0
17	0	0	10	226	815	1663	2586	3122	3348	3431	0
18	0	0	14	245	835	1689	2610	3136	3350	3431	0
19	0	0	14	269	859	1718	2634	3152	3351	3431	0
20	0	0	15	291	887	1746	2654	3162	3353	3431	0
21	0	0	17	313	917	1776	2673	3169	3359	3431	0
22	0	0	21	337	949	1808	2693	3178	3363	3431	0
23	0	0	22	362	981	1840	2711	3184	3373	3431	0
24	0	0	22	389	1007	1870	2735	3193	3385	3431	0
25	0	0	23	416	1037	1898	2757	3197	3389	3431	0
26	0	0	25	444	1066	1922	2783	3205	3390	3431	0
27	0	0	25	469	1096	1954	2810	3205	3392	3431	0
28	0	0	25	487	1128	1988	2834	3205	3393	3431	0
29	0	0	28	511	1163	2022	2856	3205	3393	3431	0
30	0	0	34	529	1199	2058	2876	3205	3393	3431	0
31	0	0	34	547	1199	2095	2893	3205	3393	3431	0

Table Ml. Continued.

1974 at -1 inch.

°D>50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0	62	68
2	0	0	0	0	0	0	0	0	0	67	68
3	0	0	0	0	0	0	0	0	0	67	68
4	0	0	0	0	0	0	0	0	0	67	68
5	0	0	0	0	0	0	0	0	0	67	68
6	0	0	0	0	0	0	0	0	0	68	68
7	0	0	0	0	0	0	0	0	2	68	68
8	0	0	0	0	0	0	0	0	2	68	68
9	0	0	0	0	0	0	0	0	3	68	68
10	0	0	0	0	0	0	0	0	8	68	68
11	0	0	0	0	0	0	0	0	11	68	68
12	0	0	0	0	0	0	0	0	20	68	68
13	0	0	0	0	0	0	0	0	22	68	68
14	0	0	0	0	0	0	0	0	23	68	68
15	0	0	0	0	0	0	0	0	25	68	68
16	0	0	0	0	0	0	0	0	27	68	68
17	0	0	0	0	0	0	0	0	27	68	68
18	0	0	0	0	0	0	0	0	27	68	68
19	0	0	0	0	0	0	0	0	27	68	68
20	0	0	0	0	0	0	0	0	27	68	68
21	0	0	0	0	0	0	0	0	27	68	68
22	0	0	0	0	0	0	0	0	27	68	68
23	0	0	0	0	0	0	0	0	30	68	68
24	0	0	0	0	0	0	0	0	30	68	68
25	0	0	0	0	0	0	0	0	31	68	68
26	0	0	0	0	0	0	0	0	32	68	68
27	0	0	0	0	0	0	0	0	33	68	68
28	0	0	0	0	0	0	0	0	39	68	68
29	0	0	0	0	0	0	0	0	41	68	68
30	0	0	0	0	0	0	0	0	47	68	68
31	0	0	0	0	0	0	0	0	55	68	68

Table M1. Continued.
1975 at -1 inch.

°D>50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	81	655	1378	2289	3093	3435	3649	0
2	0	0	0	93	676	1408	2320	3119	3445	3651	0
3	0	0	0	99	690	1442	2352	3137	3455	3655	0
4	0	0	0	102	700	1477	2384	3151	3465	3658	0
5	0	0	0	105	717	1512	2420	3160	3475	3668	0
6	0	0	0	112	731	1544	2450	3176	3486	3676	0
7	0	0	0	126	743	1571	2478	3188	3495	3680	0
8	0	0	0	137	757	1599	2504	3202	3506	3688	0
9	0	0	0	143	779	1623	2531	3214	3517	3692	0
10	0	0	0	155	807	1647	2559	3229	3524	3694	0
11	0	0	0	171	825	1665	2588	3241	3528	3694	0
12	0	0	0	190	839	1682	2614	3253	3533	3694	0
13	0	0	1	214	861	1701	2643	3257	3551	3694	0
14	0	0	1	234	885	1718	2669	3270	3568	3694	0
15	0	0	5	254	899	1742	2699	3280	3577	3694	0
16	0	0	11	274	914	1770	2729	3292	3583	3694	0
17	0	0	17	294	932	1802	2759	3305	3586	3694	0
18	0	0	25	314	954	1828	2783	3326	3590	3694	0
19	0	0	25	342	982	1858	2807	3336	3591	3694	0
20	0	0	30	360	1014	1888	2827	3344	3594	3694	0
21	0	0	35	382	1046	1922	2845	3352	3601	3694	0
22	0	0	43	410	1082	1956	2865	3363	3606	3694	0
23	0	0	45	438	1116	1989	2882	3369	3618	3694	0
24	0	0	45	468	1143	2021	2907	3380	3632	3694	0
25	0	0	50	498	1175	2050	2927	3384	3637	3694	0
26	0	0	55	530	1205	2076	2955	3394	3643	3694	0
27	0	0	55	557	1237	2108	2983	3405	3646	3694	0
28	0	0	55	581	1271	2142	3008	3417	3647	3694	0
29	0	0	63	607	1307	2178	3032	3425	3648	3694	0
30	0	0	72	619	1342	2214	3052	3425	3648	3694	0
31	0	0	72	637	1342	2251	3070	3425	3648	3694	0

Table M1. Continued.
1974 at +10 inches.

°D>50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0	140	184
2	0	0	0	0	0	0	0	0	0	153	184
3	0	0	0	0	0	0	0	0	0	153	184
4	0	0	0	0	0	0	0	0	0	155	184
5	0	0	0	0	0	0	0	0	0	155	184
6	0	0	0	0	0	0	0	0	0	161	184
7	0	0	0	0	0	0	0	0	3	164	184
8	0	0	0	0	0	0	0	0	8	173	184
9	0	0	0	0	0	0	0	0	10	177	184
10	0	0	0	0	0	0	0	0	20	177	184
11	0	0	0	0	0	0	0	0	28	177	184
12	0	0	0	0	0	0	0	0	41	177	184
13	0	0	0	0	0	0	0	0	43	177	184
14	0	0	0	0	0	0	0	0	46	177	184
15	0	0	0	0	0	0	0	0	53	177	184
16	0	0	0	0	0	0	0	0	57	177	184
17	0	0	0	0	0	0	0	0	59	177	184
18	0	0	0	0	0	0	0	0	59	177	184
19	0	0	0	0	0	0	0	0	59	180	184
20	0	0	0	0	0	0	0	0	60	180	184
21	0	0	0	0	0	0	0	0	61	180	184
22	0	0	0	0	0	0	0	0	66	180	184
23	0	0	0	0	0	0	0	0	80	182	184
24	0	0	0	0	0	0	0	0	82	182	184
25	0	0	0	0	0	0	0	0	85	182	184
26	0	0	0	0	0	0	0	0	95	182	184
27	0	0	0	0	0	0	0	0	101	182	184
28	0	0	0	0	0	0	0	0	107	182	184
29	0	0	0	0	0	0	0	0	113	184	184
30	0	0	0	0	0	0	0	0	118	184	184
31	0	0	0	0	0	0	0	0	130	184	184

Table M1. Continued.

1975 at +10 inches.

°D>50°F

DAY	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2	2	6	108	642	1269	2025	2762	3125	3443	0
2	2	2	6	121	654	1297	2049	2782	3137	3445	0
3	2	2	6	130	662	1329	2079	2799	3149	3451	0
4	2	2	6	131	672	1357	2107	2819	3161	3455	0
5	2	2	6	137	686	1384	2137	2826	3173	3465	0
6	2	2	6	145	698	1411	2159	2841	3182	3479	0
7	2	2	7	158	703	1435	2177	2855	3190	3489	0
8	2	2	8	172	711	1459	2195	2864	3207	3503	0
9	2	2	8	175	731	1477	2224	2880	3219	3510	0
10	2	2	9	184	756	1495	2253	2894	3231	3514	0
11	2	2	10	197	770	1505	2277	2914	3243	3519	0
12	2	2	11	215	783	1514	2301	2929	3251	3519	0
13	2	2	12	231	805	1526	2325	2934	3271	3519	0
14	2	2	14	250	825	1540	2349	2949	3289	3519	0
15	2	2	19	269	839	1564	2376	2962	3302	3520	0
16	2	2	23	288	859	1590	2402	2982	3313	3520	0
17	2	2	28	307	877	1620	2429	2996	3321	3520	0
18	2	2	43	326	901	1644	2448	3018	3327	3520	0
19	2	2	44	360	932	1674	2467	3030	3328	3520	0
20	2	2	48	384	963	1699	2489	3036	3335	3520	0
21	2	2	49	414	991	1726	2510	3044	3347	3520	0
22	2	2	52	443	1023	1752	2528	3058	3359	3520	0
23	2	2	54	469	1052	1780	2550	3068	3376	3520	0
24	2	3	54	496	1080	1810	2580	3079	3393	3520	0
25	2	3	60	522	1108	1827	2598	3087	3401	3520	0
26	2	5	70	546	1138	1844	2628	3099	3406	3520	0
27	2	5	70	563	1166	1878	2652	3113	3412	3520	0
28	2	5	70	582	1195	1906	2675	3113	3419	3520	0
29	2	5	85	609	1229	1933	2697	3113	3424	3520	0
30	2	5	99	619	1243	1963	2716	3113	3425	3520	0
31	2	6	99	633	1243	1993	2735	3113	3428	3520	0