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Acrobasis vaccinii (Lepidoptera: Pyralidae)
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Douglas A. Murray

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THE BIOLOGY, BEHAVIOR, AND CONTROL OF
ACROBASIS VACCINII (LEPIDOPTERA: PYRALIDAE)
IN BLUEBERRIES IN SOUTHWEST MICHIGAN

By

Douglas A. Murray

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

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ABSTRACT

The cranberry fruitworm Acrobasis vaccinii is a serious yet sporadic pest of blueberries but little basic research has been done on it in Michigan.

Through the use of monitoring techniques (emergence traps, virgin female traps, experimental pheromone traps, berry collections, soil sifting, growth chambers) many aspects of the biology, behavior, and biological control agents were documented.

Chemical control testing was carried out over three seasons.

Examining berries for fruitworm eggs during petal fall proved to be the most effective cue to chemical spray controls. The pyrethroids proved to be very effective in controlling the first instar larvae. Timing was critical to control for all chemicals used that were effective.

Success with experimental pheromones was limited but a helpful step in further research.

Several unpublished biological agents were identified including Campoletis patsuiketorum Viereek (Hymenoptera: Ichneumonidae), Villa lateralis (Say) (Diptera: Bombyliidae), Compsilura concinnata (Meigen) (Diptera: Tachinidae), and a fungal pathogen, Paecilomyces spp.

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the knowledge base of mankind and help build a stronger
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beyond my means.

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Douglas A. Murray

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INTRODUCTION

INTRODUCTION

Commercial production of Southwest Michigan's native highbush blueberries started near the turn of the 20th century but did not see a great deal of growth until the late 1960s. By 1975, Michigan had 9,700 acres into blueberry production with a harvest of nearly 25 million pounds of berries (DeVries, 1987). By 1986, acreage had increased to 14,100 acres, while production had increased to over 50 million pounds (DeVries, 1987). Michigan, the number one blueberry producer of all the states, harvests as much tonnage as all of Canada and accounts for 25% of North America's crop (Ricks, 1988).

Growing 50 million pounds of blueberries does not happen without pest problems. More than a dozen diseases and a half dozen insect pests cause direct damage to the blueberry bush and fruit, removing several million pounds of production yearly.

One of the major insect pests which feeds directly on the fruit is the cranberry fruitworm, Acrobasis vaccinii Riley (Lepidoptera: Pyralidae). Although the cranberry fruitworm is a greater pest in cranberry bogs (sometimes removing 80-100% of the crop in untreated plantations), it also does serious damage to blueberries, sometimes removing 50% of a crop (Smith, 1884; Maxwell, 1957). In more recent

years, even with the advancements made in chemical control, blueberry plantations in Southwest Michigan have been known to lose 20% of a crop due to A. vaccinii damage (MBGA, 1986).

Many growers experience a fluctuating rate of damage from year to year and many new plantations can escape cranberry fruitworm damage for 3 or 4 years (MBGA, 1986).

With the increased demand for fresh fruit across the nation, it becomes more important to grow blueberries free of larvae to fill this need.

The investigations reported in this thesis were designed to identify certain aspects of the biology, behavior, and control of A. vaccinii with respect to the production of blueberries in Southwest Michigan. These investigations include studies to (1) develop monitoring techniques, (2) understand the biology of A. vaccinii in Southwest Michigan, (3) develop rearing techniques in a laboratory setting, (4) document behavioral patterns which might help in future control tactics, (5) test the efficacy of present and developmental pesticides, and (6) document biological control agents.

LITERATURE REVIEW

LITERATURE REVIEW

Description

Acrobasis vaccinii was first described by Riley (1884) with specimens sent to him from a Massachusetts cranberry bog by J. B. Smith (1884). There was some disagreement on the genus in which this species belonged but the name remained valid until Hulst (1890) reorganized the family placing the species in a new genus, Mineola. This name remained valid until the early 1950s when it was reorganized back into the Acrobasis genus where it has remained.

Riley's 1884 description of the life stages is acceptable as a general description. Nuenzig's (1979, 1986) descriptions of larvae, pupae, and adults are much better technical descriptions. There have been differences that have shown up among descriptions published between 1884 and 1986. Riley's (1884) use of brown for an older egg color was described by Franklin (1948) and Brodel (1984) as a pale green egg which develops an orange-to-red oval streak as the embryo develops inside the egg. Mature larva length remains quite constant at 10mm through all of the literature dealing with cranberries but is stated as up to 15mm (Nuenzig 1986) in specimens removed from blueberries. Adult wing color varies from Riley's (1884) cold grey and pure white to Franklin's (1948) dark grey-brown with slight pink tinge to Brodel's

(1984) black and white to Nuenzig's (1986) distinct white and reddish-brown to purple. Nuenzig (1986) mentions the presence of light and dark phases.

Acrobasis vaccinii is native in the Eastern United States and Canada, but has been introduced to the West. (Brodel, 1984; Nuenzig, 1986). Older growers in Southwest Michigan say that they never observed A. vaccinii larvae in wild blueberries or cranberries until after commercial fields of blueberries were started and then A. vaccinii populations grew and spread to the native stands. There is no research to substantiate this claim and, therefore, no way to know if A. vaccinii was introduced into Michigan from an outside source.

Biology

Adult A. vaccinii flights start, on calm evenings, during bloom and continues into berry swell (Brodel, 1984). They usually make short flights but have been known to fly 272 feet non-stop (Franklin, 1948).

The variability in adult flight dates seems to be explained by the temperature of the reporting area and the crop on which the A. vaccinii are monitored. Florida blueberries, therefore, have the earliest flight dates recorded in February (Nuenzig, 1986). Flights begin in blueberries in Texas and North Carolina in March (Nuenzig, 1986; Fulton, 1946). Flights begin in blueberries in Massachusetts in late May and continue later on cranberries (Franklin, 1948). Flights begin in Michigan blueberries in

early June (Hutson, 1944) and in New Brunswick cranberries from the middle of June to the end of July (Maxwell, 1957).

The literature states that egg laying starts soon after the end of petal fall, which occurs earlier in the year in the Southern states and later in the Northern states, and earlier for blueberries than for cranberries grown in the same general locations (Franklin, 1948).

Beckwith (1943) describes the biology of egg laying, larval penetration, and feeding habits in detail. Franklin (1948) adds that early instars feed on the seed capsule only; but as larvae mature, they consume more and more of the pulp of the fruit.

Early literature (Beckwith, 1943; Smith, 1884) states that the population of A. vaccinii were not overwintering in the commercial fields, but were flying in from wild cultivars since they did not find evidence of the pupal stage in the fields. Later reports (Hutchinson, 1943; Brodel, 1984) revealed that the larvae do construct hibernacula in the top few inches of soil in commercial fields.

Host Range

Although some authors allude to a wide host range for A. vaccinii (Beckwith, 1943; Hutson, 1944) other authors (Maxwell, 1951, Brodel, 1984; Nuenzig, 1986) list the following hosts:

<u>Common Name</u>	<u>Latin Name</u>
mountain cranberry or foxberry	<u>Vaccinium vitis-idaea</u> L.
huckleberry or dangleberry	<u>Gaylussacia</u> spp.
deerberry	<u>Vaccinium stamineum</u> L.
highbush blueberry	<u>Vaccinium corymbosum</u> L.
cranberry	<u>Vaccinium macrocarpon</u> Ait.

The larvae have also been reared in confinement on apples and beach plum (Franklin, 1948).

Trapping and Collecting

Although incandescent light traps have not been successful in trapping A. vaccinii moths (Maxwell, 1951), fluorescent blacklight trapping has been used successfully (Tomlinson, 1962). Tomlinson (1966, 1970) showed that the trapped population was representative of the general population and more than 50% of the trapped population was caught between 7:30 P.M. and 11:00 P.M.

Maxwell (1951) used emergence cages to successfully trap adults emerging in a cranberry bog.

Hutchinson (1954) mentions the screening of soil by P. E. Marucci as a successful method of collecting A. vaccinii while in their hibernacula.

Chemical Control

Chemical control sprays of earlier eras resulted in sporadic control and unmarketable fruit. Arsenic sprays could not be used due to residue problems; and spray oil

mixes removed the waxy outer layer on the berries, thus making them unmarketable (Beckwith, 1943). Cryolite dust gave good control in some tests, but left spots on the berries which restricted their marketability and may have reduced the size of the berries (Tomlinson, 1951).

In the 1960s, the new organophosphates replaced Ryania pyrethrum, DDT, lead arsenate, methoxychlor, and others, and gave good control without plant damage (Tomlinson, 1960). These included Parathion, Phosphamidon, Malathion, Guthion, and Diazinon. Thiodan and Sevin have been used, where labeling has permitted, up to the present time (Tomlinson, 1960; Koval, 1976). More recent testing has been done with carbofuran chlorpyrifas and Bacillus thurengiensis strains with good control results. However, a lack of EPA labeling for blueberries prevents commercial use (Koval, 1976).

In all cases the timing of the chemical sprays was the most critical factor in the control results (Beckwith, 1943; Koval, 1976; Brodel, 1984).

Biological Control

Insect parasites of A. vaccinii which have been reported in the literature are:

1. Trichogramma minutum Riley (Brodel, 1984) an egg parasitoid reported in Massachusetts,
2. Phanerotoma franklini Gahan (Maxwell, 1951; Franklin, 1948) reported as an egg/larva parasitoid in New Brunswick and Massachusetts,

3. Cryptus albitarsis Cresson (Maxwell, 1951) an Icheumon parasitoid of the larvae in New Brunswick,
4. Pristomerus augtrinus Townes and Townes (Franklin, 1948) an egg/larva parasitoid reported in Massachusetts,
5. Agathis usitata Gahan (Nuenzig, 1979) a branchonid.

There has been very little experimentation done on the possible use of any one or combination of natural control complexes to control A. vaccinii populations in the field. Attempts have been made to use the Trichogramma spp. in Massachusetts (Brodel, 1987), but results have not been published.

IDENTIFICATION

IDENTIFICATION

Adult and larval specimens collected were confirmed as Acrobasis vaccinii, using The Moths of North America (Nuenzig, 1986), and Technical Bulletin 1457, USDA: Taxonomy of Acrobasis Larvae and Pupae (Nuenzig, 1979).

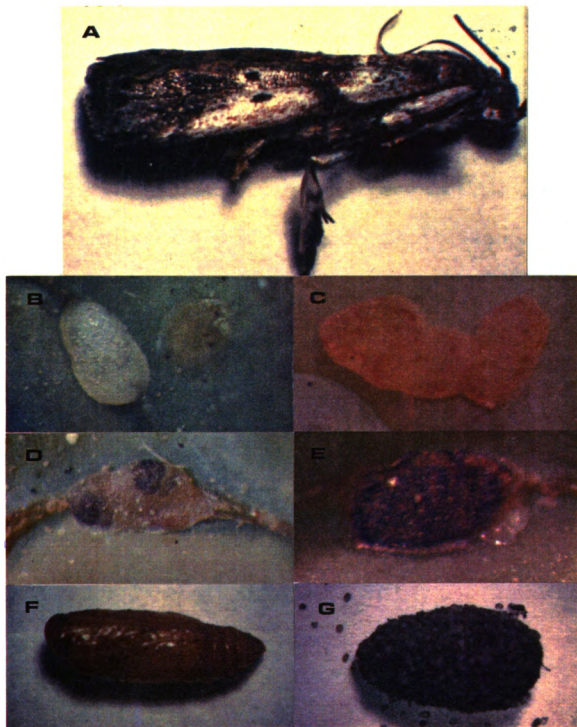


Plate I. The life stages of Acrobasis vaccinii. A, adult, 10X; B, comparison of freshly laid A. vaccinii egg (left) and a Grapholitha packardii Zeller egg (right), 35X; C, one-day-old egg, 35X; D, two-day-old eggs showing head capsule, 35X; E, egg parasitized by a Trichogramma wasp, 50X; F, pupa, 10X; G, hibernaculum, 5X.

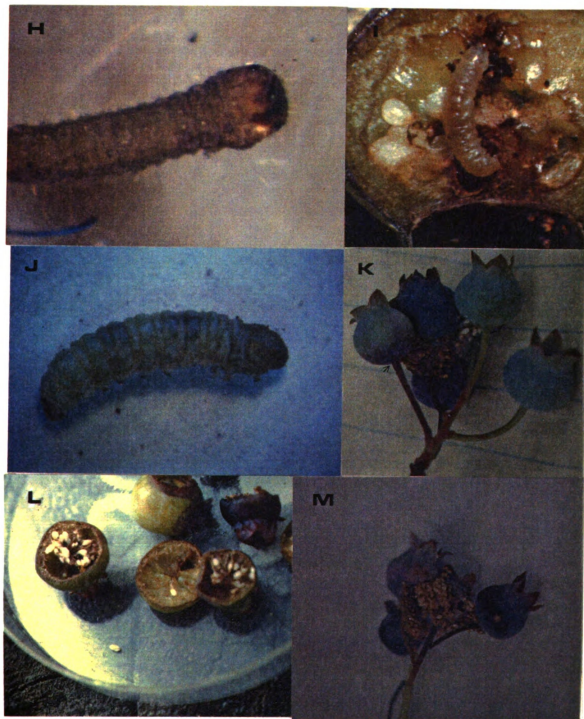


Plate I, continued. H, one-day-old larva, 35X; I, third instar larva, 5X; J, fifth instar larva, 10X; K, damaged berry cluster showing a berry with the first sign of penetration, reddish discoloration (arrow); L, crosssection of damaged berry showing seeds still intact; M, damaged berry cluster after larva has exited.

BIOLOGY

BIOLOGY

MONITORING

Monitoring Adult Flight Activity

Introduction

The activity of the adult A. vaccinii is seldom observed in the field. Knowledge of adult activity has been shown to be useful in planning control strategies for many other lepidopteran.

Several trapping techniques have been developed over the years to alleviate the need for direct observation of the adult moth population.

During the three seasons in which this research was carried out, four trapping techniques were utilized at four locations suspected of having A. vaccinii populations. They were evaluated on their merits of being a useful technique in predicting timing of control sprays.

Methods and Materials

Locations: The four locations selected were (1) the Douglas Research Block, which is a 2-acre blueberry plantation at Michigan State University, Trevor Nichols Experiment Station, Fennville, Michigan, Allegan County;

(2) an abandoned blueberry block 1 mile south of Covert, Michigan, Van Buren County; (3) a poorly managed blueberry block 3 miles north of Grand Junction, Michigan, Allegan County; and (4) a 2-year-old non-sprayed blueberry block 6 miles north of Holland, Michigan, Ottawa County. These sites were chosen because they were evenly spread across much of the commercial blueberry growing area of Southwest Michigan and had a history of A. vaccinii damage (Figure 1).

Blacklight Trapping: The first season (1985) a blacklight trap was located in the middle of the 2 acres of blueberries at the Douglas Research Block. The light was an A.C. unit with a 24" vertical mounted fluorescent blacklight bulb that ran through an inverter off a heavy-duty marine battery. It was timed to come on at 7:00 P.M. and turn off at 12:00 P.M. Cyanide crystals were used to kill the insects. The dates that the light was in operation were June 10-11 and 15-16, 1985. Phenologically, this was at petal fall stage when it was anticipated that moths were emerging.

Emergence Trapping: In 1986 and 1987, emergence traps were used at the Douglas Research Block. Each trap had a 1"x6" wood frame base measuring 1 meter on a side, a netted pyramid standing 1 meter tall, and a collection dish at the apex (Figure 2).

In 1986, four traps were randomly placed across the blueberry patch. Each trap was placed over a bush that showed signs of having a blueberry crop the previous year. The bushes were trimmed down to allow the trap to set

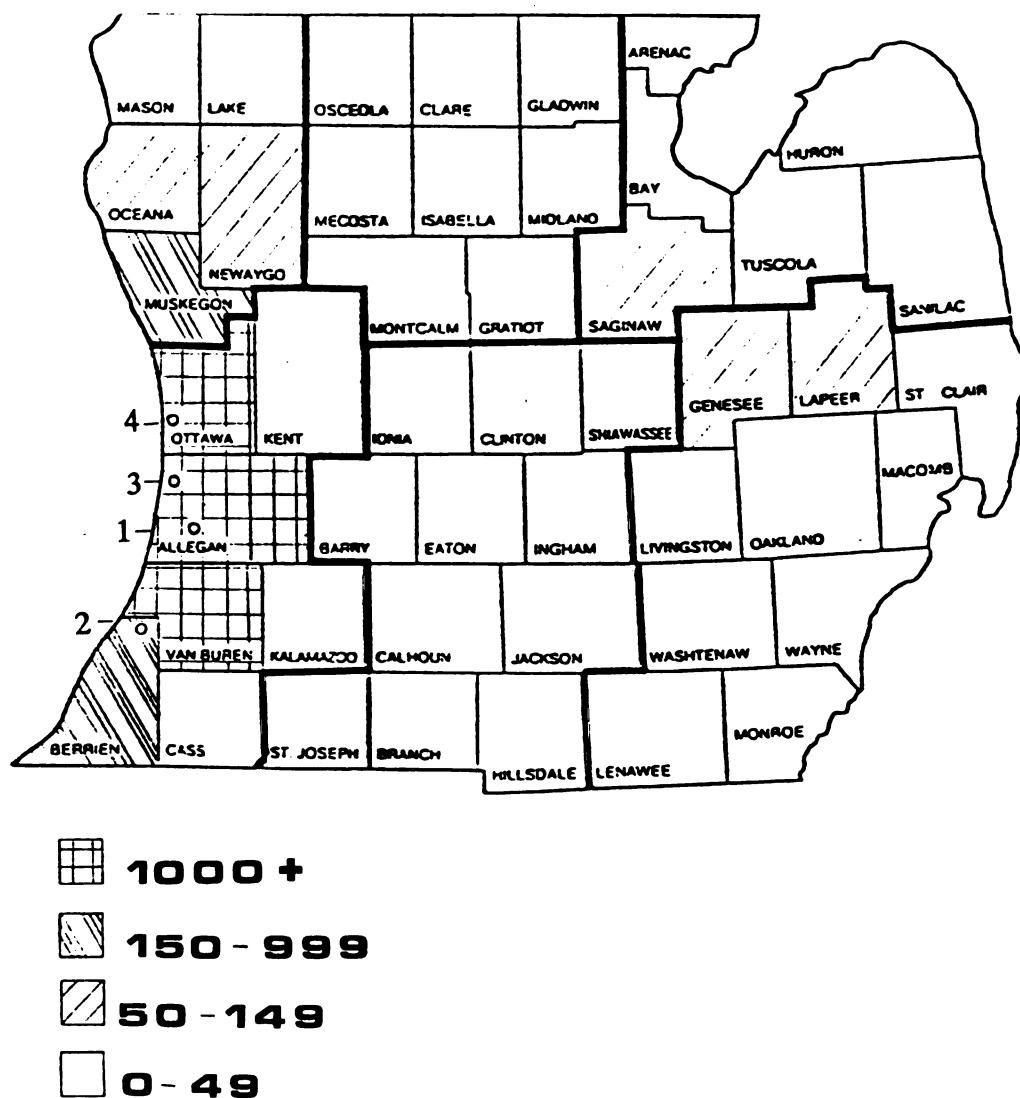


Figure 1. Partial map of Michigan identifying blueberry production by county (DeVries, 1986) and the four experimental *Acrobasis vaccinii* pheromone trapping locations.

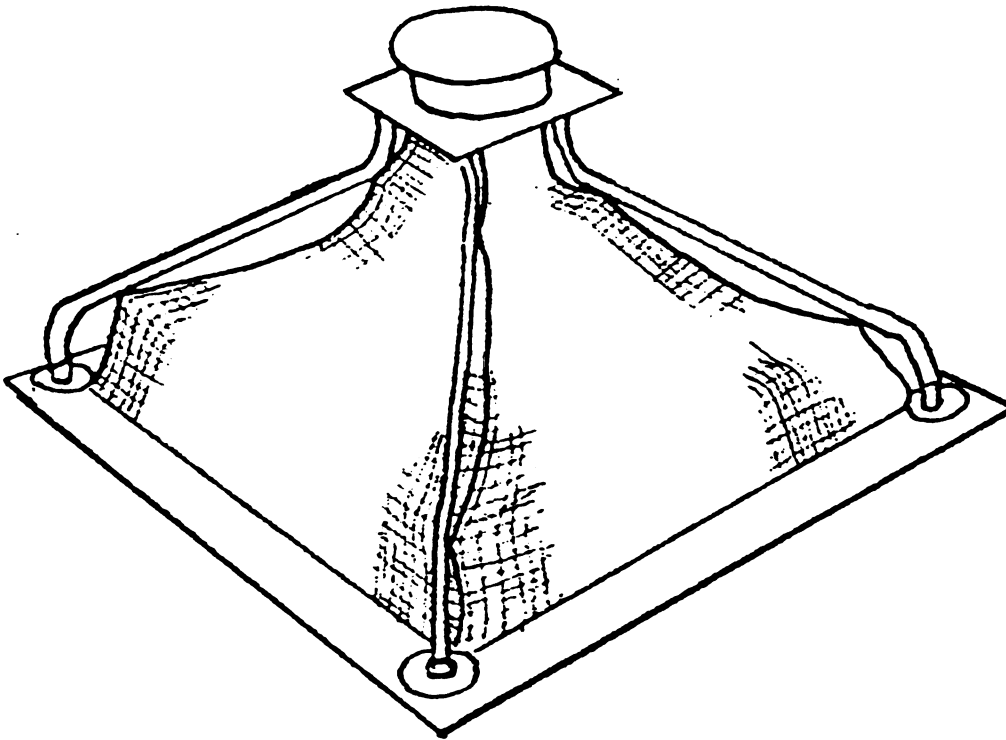


Figure 2. Emergence trap used over top of a blueberry bush.

securely on the ground, and soil was mounded onto the board base to keep it sealed down tightly.

In 1987, three traps were placed in the plantation using the same method. Bushes were selected from those which had had large numbers of infested fruit in 1986.

Virgin Female Trapping: In 1986 and 1987, virgin female traps were used at the Douglas Research Block. These virgin female traps consisted of two basic parts: a cage for live moths, and a trap surrounding the cage to catch moths.

The cage consisted of a 4.5cm diameter acetate tube 15cm long, two discs of aluminum window screening 4.5cm in diameter, and two 1x7.5cm test tubes (Figure 3A). The two discs were heated and melted into the open ends of the acetate tube using a soldering iron. A 1cm hole was snipped out of the screening to allow insertion of a test tube. One test tube was filled with honey-water solution and stoppered with a cotton swab to allow the moths access to a food source. The other test tube was used to place pupae or moths into the acetate tube.

The trap portion consisted of a triangular plastic tent trap 25cm long and 15cm wide, a wire hanger, and a replaceable tangle trap liner. The triangular tent was hung so as to have a flat base in which to lay the tangle trap liner (Figure 3B). The cage was wired to the inner roof of the tent trap.

In 1986, two such traps were hung at random in the non-sprayed section of the block. Adult moths were transported

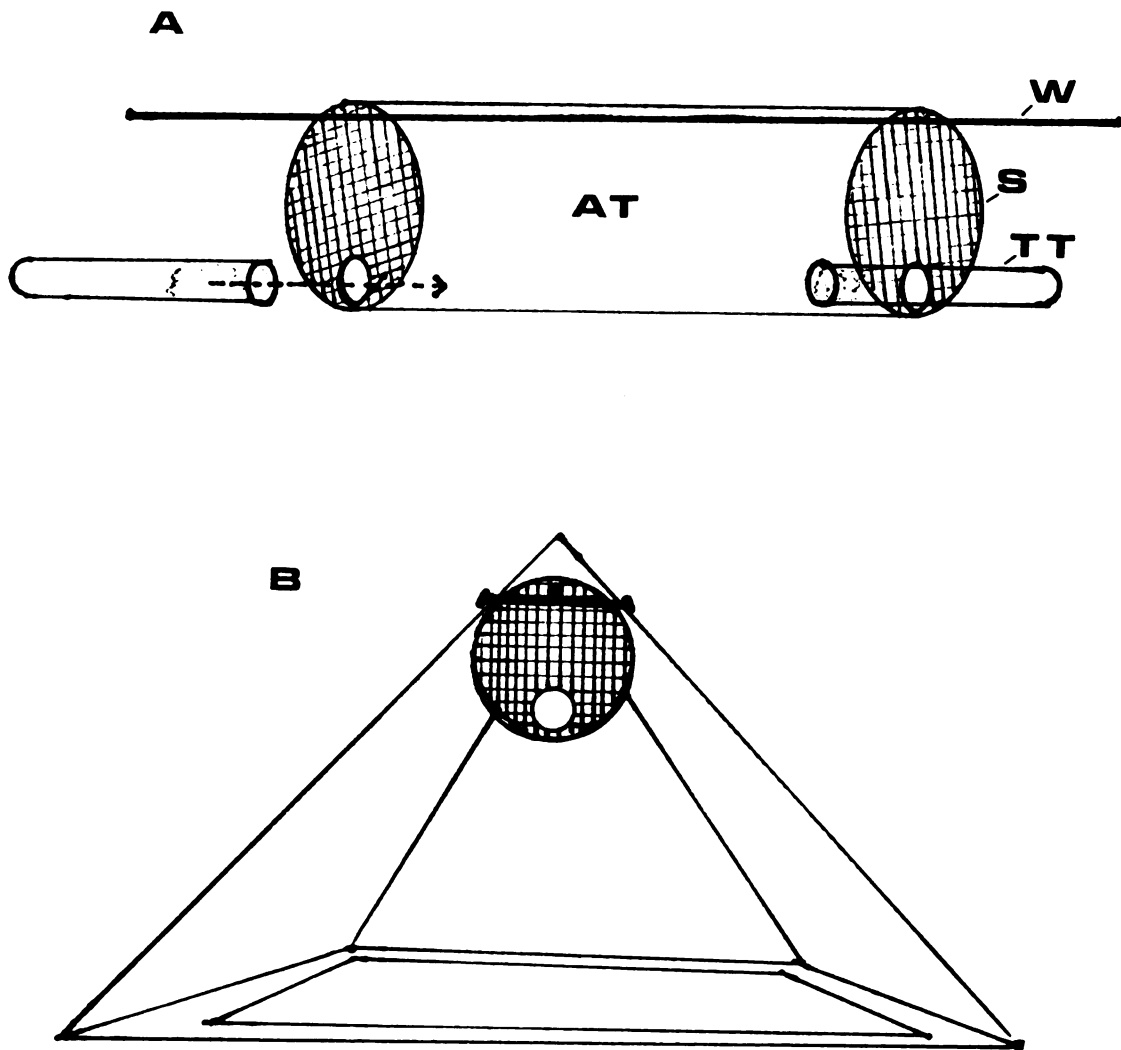


Figure 3. Virgin female trap. A, cage for adult females; AT, acetate tube; S, screening; W, support wire; TT, test tube; B, trap with cage in place.

from the laboratory to the field twice a week so that a female could be no more than 90 hours old before being released into a cage. Fresh females were placed in the cage on every visit when they were available, regardless of the state of the moths already in the cage.

In 1987, the two traps were hung in a row of conifers 3 meters to the west of the block on the north side of a tree. Pre-sexed pupae were placed in each cage on May 15. Data were tabulated for female emergence as well as male catch in the traps.

Pheromone Trapping: In 1987, four locations--Covert, Grand Junction, Douglas, and Holland--were chosen to test synthesized pheromone caps. Each location received one set of 13 pheromone caps on May 18, 1987.

"Pherocon" traps were employed. Each was baited with one experimental pheromone cap shipped from the USDA Experimental Station, Yakima, Washington.

The traps were placed on the west side of the plantation and the west side of the bush, halfway to the top of the bush. At least one row of bushes was left between the traps as a buffer zone. More rows were left if possible. The order of randomization for the traps was re-randomized every week.

Results

Blacklight Trapping: There were many species of insects caught, but no A. vaccinif moths were collected in the blacklight trap.

Emergence Trapping: Even with very low numbers of moths

emerging in 1986, there was a concentrated emergence between May 26 and June 2. The concentration was most evident in 1987 between May 23 and May 30.

The results of A. vaccinii moth counts from the emergence traps set at the Douglas Research Block in 1986 and 1987 are listed in Tables 1 and 2, respectively.

Virgin Female Trapping: The male A. vaccinii catch in the virgin female traps in 1986 was concentrated between May 26 and May 30. In 1987, the male catch was concentrated between May 21 and June 5.

Data on the dates of female moth additions or emergence in a cage as well as male trap catches on a per trap basis for 1986 and 1987 are listed in Tables 3 and 4, respectively.

Pheromone Trapping: Male A. vaccinii catch in pheromone traps was concentrated between June 5 and June 12 of 1987. No A. vaccinii were caught in the test traps before or after these dates.

Trap catches are listed in Table 5 as totals per date for the three locations that caught moths.

Discussion

Blacklight Trapping: Data collected later during this research showed that the actual flight dates of A. vaccinii in Michigan were earlier in the season than anticipated. This would account for the lack of A. vaccinii moths caught in the blacklight traps.

The lack of AC power in the Douglas Research Block and the need for daily recharging of the DC power system to keep

Table 1. Emergence trap catches at the Douglas Research Block, 1986

=====

Date	Trap No. 1	Trap No. 2	Trap No. 3	Trap No. 4
5-12	-	-	-	1
5-16	-	-	-	1
5-26	-	1	-	2
6-02	1	-	1	-

Table 2. Emergence trap catches at the Douglas Research Block, 1987

=====

Date	Trap No. 1	Trap No. 2	Trap No. 3
5-23	10	-	-
5-30	4	9	-
6-03	1	1	-

Table 3. Virgin female trap catches at the Douglas Research Block, 1986

Date	Trap No. 1		Trap No. 2	
	No. females added	No. males caught	No. females added	No. males caught
5-16	5	-	2	-
5-22	2	-	2	-
5-26	-	-	1	4
5-30	-	-	-	3

Table 4. Virgin female trap catches at the Douglas Research Block, 1987

Date	Trap No. 1		Trap No. 2	
	No. females emerged	No. males trapped	No. females emerged	No. males caught
5-19	2	-	-	-
5-21	1	6	-	-
5-28	-	4	-	-
6-05	-	-	1	4

Table 5. Experimental pheromone trap catches
for three locations in Southwest Michigan, 1987

=====

Date	Location		
	Douglas	Covert	Grand Junction
6-05	2	-	-
6-09	3	1	-
6-12	6	-	1

the light and timer running was very time consuming and therefore blacklight trapping was not continued in subsequent years of this research.

The blacklight trap could not be evaluated as a control spray cue in this research; and because the data was incomplete, its value for studies concerning A. vaccinii is not known.

Emergence Trapping: Bushes selected in 1986 were chosen because of their large size. It was anticipated that they would have had a large amount of berries in 1985 and, therefore, a higher A. vaccinii population. Bushes in 1987 were chosen after being monitored and found to have a 70% infestation rate of A. vaccinii in 1986. The latter method of selection netted many more adults than the 1986 method, but success was not assured.

It is doubtful that this design of emergence trap could be used as a control spray cue on a commercial basis. Because damage of the magnitude experienced in the Douglas Research Block seldom occurs in commercial blocks, the chances of catching any moths is slight.

All of the adults caught in these emergence traps were trapped between the time of pupation and egg laying. This suggests that the moths trapped are a true representation of the native population at the Douglas Research Block.

Virgin Female Trapping: Several factors involving the virgin female trapping research study were given special attention.

1. Hibernacula collections coincided closely with the normal time of adult emergence. This was done in order to minimize the effects of the environmental changes the pupa would go through in the laboratory and cage before emergence of the adult. Observations of A. vaccinii in the field by soil sampling prior to this time helped in this area, as did rearing A. vaccinii from pupa to adult in the laboratory.
2. The pupae were carefully removed from the hibernacula to prevent mortality. To accomplish this, two fine-point forceps were used to tease one end of the hibernacula open enough to slide the pupae out.
3. An error in sexing the pupae could result in a male adult in the virgin female cage. This could seriously affect pheromone production.
4. It was important to place the traps in a location where they would be accessible to males in flight, but not where the sun would cause mortality of the pupae in the cage. In 1987, several of the pupae dehydrated before adults emerged.

For these reasons and others, the virgin female trap system is not a viable system for commercial growers to use for timing control sprays.

The virgin female traps used did catch adults between the time of pupation and egg laying. This suggests that the moths trapped are a true representation of the native population at the Douglas Research Block.

With more research into trap design and field location and an abundance of pupae available for the cages, virgin female traps could be a reliable monitoring tool for further research on A. vaccinii.

Pheromone Trapping: The testing of experimental pheromone isomers did not result in a single isomer being outstanding as an attractant, but a few of the isomers did attract A. vaccinii. These preliminary results have helped to determine the direction of future pheromone research.

Most of the adults caught in the pheromone traps were caught after egg laying had started. This may reflect the fact that the isomers tested were not selective enough to compete with the natural A. vaccinii pheromone; but after most of the mating was over and the natural pheromone quantity was lower in the area, the isomers were able to attract a few males.

Monitoring Egg Laying Activity

Introduction

Chemical control sprays were targeted at controlling A. vaccinii larvae before they entered the berry. To insure control, sprays were scheduled to be applied at the commencement of egg laying and 10 days later.

Two sampling methods were carried out in 1986 and 1987 to determine if the egg stage could be reliably monitored.

Methods and Materials

In 1986, 100 individual berries were selected at random (one per cluster, two per row) from 50 rows of 12 bushes each in a non-sprayed section of the Douglas Research Block.

These berries were examined in the field for A. vaccinii eggs, using a 10x hand lens to help in identification.

In 1987, 50 clusters of berries were sampled at random, one from each of 50 rows of a non-sprayed section. Each row consisted of 12 bushes. Every berry of each cluster sampled was examined as before. After the first eggs were detected, samples collected on Mondays and Wednesdays were refrigerated at 3oC in bags and egg counts on these were done the following Friday.

Results

The data show peak egg laying about June 6 in 1986 and May 29 in 1987.

The results of monitoring A. vaccinii eggs by sampling blueberries at the Douglas Research Block in 1986 and 1987 are listed in Tables 6 and 7, respectively,

Discussion

Both techniques were adequate at detecting egg laying at low levels of infestation. The data show that at the Douglas Research Block viable eggs were present for a very short time, i.e., approximately 2 weeks.

This differs from research done in other areas of the country.

Table 6. A. vaccinii egg counts on 100 berry samples from the Douglas Research Block, 1986

=====	
Date	No. of <u>A. vaccinii</u> eggs

5-30	-
6-03	8
6-06	11
6-13	5
6-16	-

Table 7. A. vaccinii egg counts on 50 berry cluster samples from the Douglas Research Block, 1987

=====			
Date	Total No. of berries	No. of eggs	% of berries w/eggs

5-24	523	-	-
5-28	549	26	5
5-29	541	38	7
6-01	564	20	3.5
6-03	992	32	3
6-05	651	31	4.7
6-08	557	23	4
6-10	691	3	.4
6-12	596	1	.2
6-15	602	2	.3
6-17	526	-	-

As a control strategy, monitoring the egg stage of A. vaccinii proved to be the most reliable, convenient, and cost-effective monitoring technique.

Unlike a pheromone trap, which can attract moths from long distances, sampling berries for eggs results in information about the population of A. vaccinii inside the monitored area only.

Little training would be necessary for a grower or field scout to conduct sampling and egg counts. Counting can be done in the field, or samples can be collected and stored in a refrigerator for counting at a later time.

Although sampling needs to be done fairly frequently before eggs are first laid, it does not need to be continued throughout the season.

Supplies and equipment are limited to a hand lens and bags if samples are collected and stored.

With the large populations of A. vaccinii at the Douglas Research Block, a relatively small sample size of berries would be expected to detect egg laying activity. Presently it is not known what sample size is necessary to detect egg laying at an economic threshold in a commercial block of blueberries in Michigan.

Monitoring of the Larvae

Introduction

The A. vaccinii larva spends very little time exposed. In its feeding stage it is almost exclusively inside berries.

When it is done feeding it moves into the ground and remains in its hibernacula until pupation occurs the following spring.

Two berry sampling methods were employed to monitor the larva stage in an attempt to pinpoint timing of initial damage and migration to the soil.

Methods and Materials

Initial Appearance: The same berry samples used to monitor for egg laying were used to collect data on egg hatch in 1986 and initial larvae damage in 1987.

In 1986, the 100 berry samples were examined and the number of hatched A. vaccinii eggs recorded.

In 1987, berries from the 50 cluster samples were examined for signs of penetration. These signs included definite entry holes and discoloration of the berry around the stem end.

Migration out of the Berries: Later in the season as the larvae matured, a random sample of 20 damaged berry clusters were removed from a 50-row non-sprayed section of the Douglas Research Block and examined for the presence or lack of A. vaccinii larvae.

Results

Initial Appearance: The data show that egg hatch in 1986 occurred over a 10-day period. The greatest incidence of larval penetration occurred between May 27 and June 8,

1987. After this date the percentage of initial penetration remained constant.

Results of egg hatch data are shown in Table 8. Results of initial larvae damage are shown in Table 9.

Migration out of the Berries: The results of the data collected on the presence of mature larvae migrating out of berry clusters indicate that most larvae have exited before July 4 in both 1986 and 1987 (Table 10).

Discussion

Initial Appearance: Egg hatch at the Douglas Research Block covered a very short time (10 days to 2 weeks in 1986 and 1987). If this is an accurate representation of the native population, it leaves a small window for applying chemical control sprays. This small window also means that an effective chemical applied at the proper time could be expected to give control of A. vaccinii over the entire period of time the larvae are active on the exterior of the berries.

Migration out of the Berries: An examination of damaged clusters for mature A. vaccinii larvae did not prove to be an effective monitoring method for determining timing for spray applications. Searching damaged clusters often resulted in destruction of the larva present, which made positive identification of the specimen very time-consuming and often impossible. Parts of the damaged cluster entanglement would usually fall to the ground when the

Table 8. Egg hatch of A. vaccinii from 100 berry samples taken from the Douglas Research Block, 1986

=====

Date	No. of eggs hatched	% of total eggs found that were hatched	% of berries w/hatched eggs
6-05	-	-	-
6-06	2	18	2
6-13	12	70	12
6-16	24	100	24

Table 9. Initial A. vaccinii larval damage to berries from 50 cluster samples taken from the Douglas Research Block, 1987

=====

Date	No. of berries w/signs of entry	No. of berries sampled	% damaged berries
5-28	-	549	-
5-29	6	541	1
6-01	1	564	-
6-03	13	992	1.3
6-05	46	651	7
6-08	92	557	16.5
6-10	71	691	10.3
6-12	45	596	7.6
6-15	62	602	10.3

Table 10. Migration of A. vaccinii larvae out of damaged berry Clusters at the Douglas Research Block, 1987

=====

Date	No. of damaged clusters with larva present	Date	No. of damaged clusters with larva present
6-20	10	7-03	1
6-25	3	7-07	1
6-30	7	7-14	-
6-30	-	7-14	-

cluster was picked or when a damaged cluster nearby on the bush was picked. After losing part of the cluster, it was difficult to determine if the larva had been lost in the droppings.

Empty damaged clusters were present on the first sampling date, which indicate that larvae were already leaving clusters before June 20, 1987. Yet 5% of the berry clusters were still infested on July 7, 1987. This would indicate that chemical control sprays would have to be used in the field for a considerable length of time to obtain control of A. vaccinii at this stage.

Monitoring of the Pupae

Introduction

One objective of this research was to develop a method of monitoring A. vaccinii populations in a blueberry field that might be used as a cue for the timing of control sprays.

Experimentation was undertaken to develop a technique for collecting A. vaccinii pupae from the field, pinpoint the time of year the pupal stage is present, and evaluate the monitoring of the pupal stage as a cue for the timing of control sprays.

Methods and Materials

Soil samples were collected with a shovel from around the base of blueberry bushes to a depth of 5cm. The soil was shoveled onto the top of a series of screens made from 3/8", 1/4", 1/5", and 1/8" wire mesh attached to the bottom of 1"x2"

wood frame measuring 60cm long and 45cm wide. These four screens were stacked on a shaking rack (Figure 4). After the soil was sieved, the "catch" on the 1/5" screen was bagged and transported to the laboratory. The 1/4" and 1/8" catches were examined quickly for any hibernacula that might have ended up in them before they were emptied back under the bushes.

The catch of the 1/5" screen was placed, a handful at a time, on a white sorting tray. To avoid injury to the insect hibernacula were removed and opened with two pair of fine-point forceps.

The stage of the A. vaccinii was determined and recorded.

Results

Data gathered on the pupal stage of A. vaccinii at the Douglas Research Block from soil samples taken between March 16 and April 25, 1986 indicate that pupae formation started the first week of April and was completed by the end of the month (Table 11).

Discussion

The collection technique developed was satisfactory for collecting hibernacula when the conditions were suitable and the population was high. The soil needed to be dry enough to sift through the screens without clogging them. The roots and weeds around the base of the bush made it more difficult to remove the soil sample from that area for sifting. Some damage to the blueberry root system did occur. A white

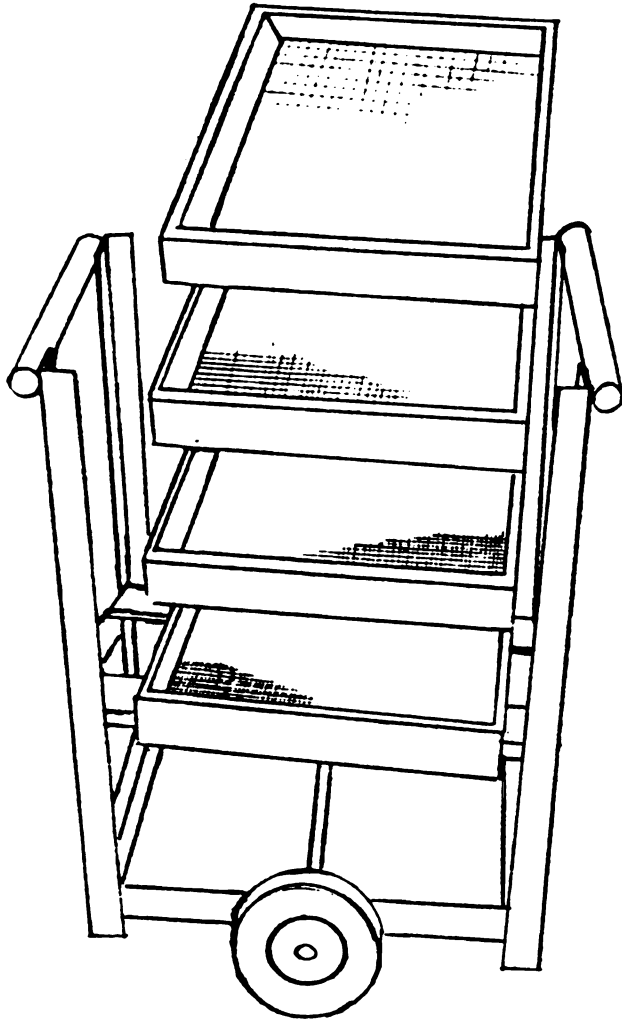


Figure 4. Shaking rack and siftly screens used to sort hibernacula from the soil.

Table 11. Timing of the pupae stage of A. vaccinii at the Douglas Research Block, 1986

=====

Date	No. of viable hibernacula collected	No. of pupae	% pupation
3-16	36	-	-
3-30	29	-	-
4-12	43	3	7
4-19	37	20	54
4-25	94	90	96

sorting tray was found to work best because the high contrast helped distinguish the oblong hibernacula from the debris.

It took approximately 8 hours to sample, sift, and sort out the hibernacula from under 60 bushes. This would net between 150 and 250 viable A. vaccinii depending on the density of the population in the 60 bushes chosen and the amount of weeds present under those bushes.

In most old-growth blueberry fields in Michigan, digging up soil samples at the base of the bushes is difficult because of the entanglement of roots that exist there. If a section was removed it would not pass through the sieves.

The amount of labor involved in the sampling of pupae using a shovel and screens precludes this method for use in predicting emergence of adults for timing of sprays.

Monitoring Adult Emergence

Introduction

Predicting the time of emergence of the adult A. vaccinii in Michigan was important, not only to gain information but also to develop trapping systems based on adult emergence. Research was undertaken to determine the time of adult A. vaccinii emergence at the Douglas Research Block in the spring of 1986.

Methods and Materials

Hibernacula were sorted from the Douglas Research Block on March 24, 1986 and April 7, 1986 (as detailed in "Monitoring of the Pupae: Methods and Materials"). Ten

hibernacula per sorting were placed in a 1-pint plastic container that was half full of moist silica sand. A tight sealing lid was placed on the container. Containers were held at $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

Results

Emergence of adult A. vaccinii was mainly from April 28, 1986 to May 1, 1986 for pupae collected March 24, 1986, and from May 1, 1986 to May 8, 1986 for pupae collected April 7, 1986.

Data collected from the two containers of hibernacula sorted from the soil at the Douglas Research Block are listed in Table 12.

Discussion

Collecting hibernacula from the field and storing them in a controlled setting can result in emergence information.

Soil temperature recorded at the Douglas Research Block during the spring of 1986 showed an average temperature $5\text{--}10^{\circ}\text{C}$ below the controlled container temperature. This may explain why the emergence in the container occurred before any recorded emergence in the field.

This controlled setting emergence served as a cue for placing adult traps in the field prior to emergence.

Table 12. Adult A. vaccinii emergence from hibernacula collected from the Douglas Research Block on March 24 and April 7, 1986

Date of emergence	No. of adults emerged from container	
	March 24 collection	April 7 collection
3-31	-	-
4-07	-	-
4-14	-	-
4-21	-	-
4-28	1	-
5-01	2	1
5-04	-	4

LABORATORY STUDIES

LABORATORY STUDIES

Development from Egg to Larvae

Introduction

Experimentation was undertaken to rear a full generation of A. vaccinii in a controlled setting. Eggs were hatched and the larvae reared on two food sources.

Methods and Materials

Blueberries containing A. vaccinii eggs were collected in the spring of 1987 at the Douglas Research Block and were used as an egg source. Berries containing A. vaccinii eggs were separated into two groups: (1) those with young, pale green eggs, and (2) those with mature, orange eggs with head capsules visible. The young eggs were placed together in a 1-pint plastic container with a tight-fitting lid. They were examined every 2 days until they reached maturity. Mature eggs were placed in one of the two following environments:

Artificial Medium: Mature eggs were removed from the green blueberry with a scalpel and placed in a small cup that contained artificial codling moth food medium (Appendix A). Each cup was capped with a clear plastic lid. Larvae were monitored daily.

Green Berry: Mature eggs were placed, with the berry they were attached to, in a 100x15mm petri dish. The dish

contained four green berries on one side and one tablespoon of moist, sterile silica sand on the other. A petri dish was opened when any berry started to mold, when the larva had eaten all the berries, or when the larva formed a hibernaculum. When a berry was removed, the larva was located. If it was inside the removed berry, it was teased out with a probe and placed on the remaining berries. Removed berries were replaced with green berries so that a continuous source of green berries was available.

The soil was moistened with 3-5 drops of water if it dried out.

Green berries collected from the field, when found free of disease, eggs, and larva, were stored in zip-lock bags in the refrigerator and used as replacement green berries.

Results

Artificial Medium: The longest that any larva lived on the artificial medium was 8 days. Many became lethargic after 4 days and showed no further sign of eating. Several fed for the first 5 days but then started looking for another source of food.

Green Berry: The green berry rearing technique proved to be very successful. Twenty-seven of the 30 eggs placed in petri dishes hatched and 25 of the those larvae grew to maturity and spun hibernacula in the moist sand.

Discussion

Artificial Medium: The formula used contained formaldehyde, and it has been shown that some lepidopteran larvae do not survive well on this formulation. Further testing needs to be done to find a suitable artificial medium.

Green Berry: The green berries are the limiting factor in this rearing technique. They kept their quality when stored in sealed containers in the refrigerator for 2 months. With advanced planning and lower refrigeration temperatures it might be possible to collect green berries in the spring and store them for a full year.

Development from Larvae to Pupae

Introduction

Many more pupae than the 25 collected from the egg/larvae rearing experiment were needed for the pheromone research being carried out in Yakima, Washington. Sorting pupae from the Douglas Research Block soil samples was time consuming and damaging to the root system of the blueberry bushes.

Experimentation was done to develop a collecting and rearing technique that would produce large numbers of pupae, reduce labor, and lessen the damage to the bushes.

Methods and Materials

Infested berry clusters were monitored during June and July of 1987 at the Douglas Research Block until evidence was found of larvae leaving the clusters. At this time hundreds

of infested clusters were collected in 1-gallon poly zip-lock bags and taken to the laboratory.

A 2-part rearing chamber was designed and built to house the infested clusters with their larvae.

The chamber consisted of a lower tray measuring 18"x24"x2-1/2" with a plywood bottom, plus an upper tray measuring 18"x24"x2-1/2", with 1/8" wire mesh for a bottom, and an 18"x24" fine-screened top that could be sealed to the top of the upper tray (Figure 5). The lower tray was filled halfway with moist, sterile silica sand and fastened securely to the bottom of the upper tray. The infested berry clusters were placed on the wire mesh in the upper tray until they were level with the top. The top was then secured. The union between the trays and the lid was secured tightly to keep any small larvae from crawling through them. The chambers were stored at $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for 1 month before the top tray was removed and the sand sifted through window screening to collect the hibernacula. Hibernacula attached to the sides of the tray were removed with a scalpel. Hibernacula were placed 10 at a time into 1-pint plastic containers filled half full with moist, sterile silica sand, sealed closed with a plastic lid, and stored at $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for 2 months. The containers were then refrigerated at 3°C for 4 months, returned to $10^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for 2 weeks, and then returned to the laboratory at temperatures of $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

Two hibernacula from each container were teased open at one end and the state of the A. vaccinii was observed

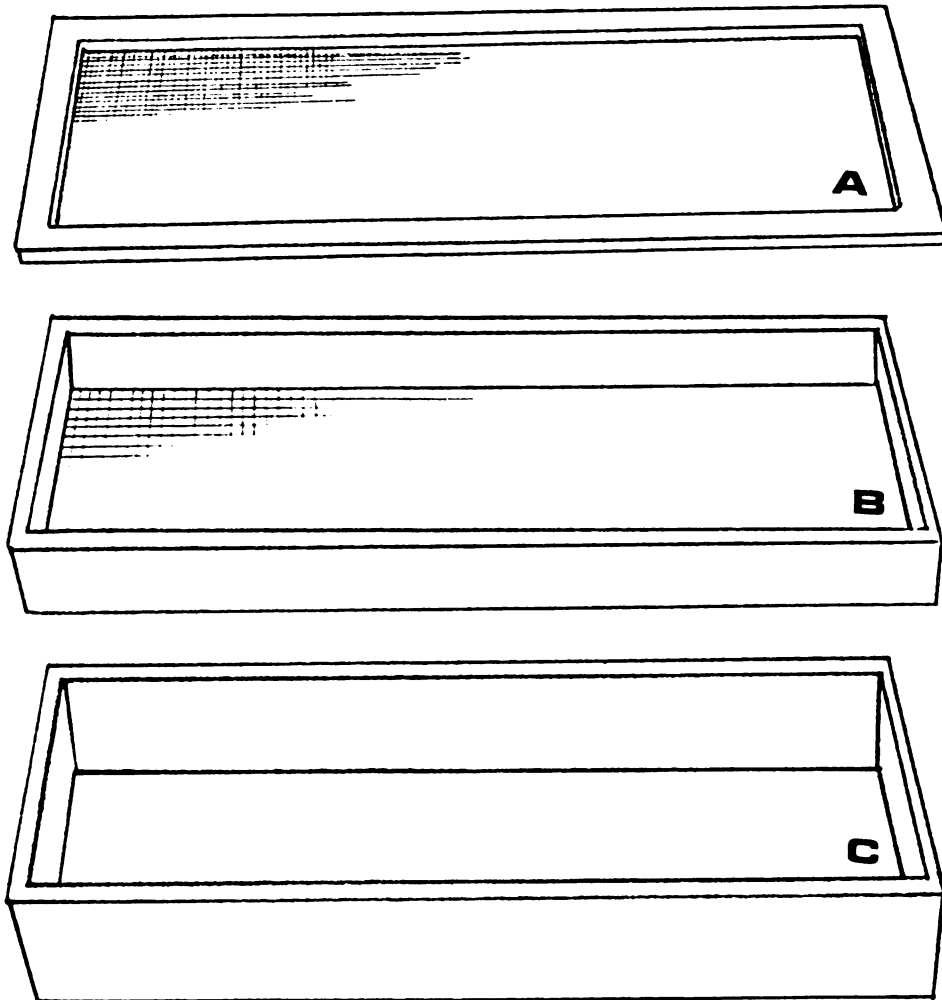


Figure 5. Two-tray chamber. A, fine screened top; B, infested berry chamber; C, sand chamber.

weekly. The hibernacula that contained larvae were placed back into their containers and the hibernacula with pupae were removed. After the third week all of the remaining hibernacula were checked twice a week until no further pupation occurred.

Results

On an average, a chamber filled with damaged clusters yielded 300 hibernaculum.

Discussion

This method of rearing A. vaccinii pupae took much less field labor than the soil sampling/sifting method described previously. Most of the time was spent in examining hibernacula for pupae. The limiting factor was no longer the weather and manpower required, but the quantity of infested clusters that could be collected, and the storage space needed for chambers and containers.

Many of the hibernacula that did not produce pupae were found to be infested with fungal pathogens or parasites. In a few containers the high humidity resulted in a total loss of A. vaccinii to mycosis.

One container that had a cracked lid dried up during the refrigeration time and all the larvae dehydrated.

Hibernacula stored individually in sealed test tubes could eliminate the spread of fungus, and the dehydration of the larvae.

The 4-month refrigeration period reflects a similar time

of cold in the field in Michigan. A shorter time would probably suffice, but research has not shown a length of time or need of diapause by A. vaccinii.

Development from Pupae to Adult

Introduction

Few problems are involved in rearing adult A. vaccinii from pupae other than avoiding extremes in temperature and moisture. One of the techniques employed during this research follows.

Methods and Materials

Pupae were removed from hibernaculum and placed in test tubes. Each test tube was capped with a cotton ball and stored horizontally in a test tube rack at $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

Results

The success rate of getting the pupae to the adult stage was over 95%.

Discussion

Removing the pupa from the hibernaculum allowed the pupa to be closely examined before it was placed into a test tube. Any pupa that was found to be malformed, parasitized, or infected with a fungal pathogen was removed from the healthy population.

The test tube was large enough to house an individual pupa and gave the adult room to crawl after emergence.

Observation of the formation of the moth in which the

pupa turned from a green-brown liquid to a gray-black powder was possible while the pupa remained inside the clear test tube.

Development from Adult to Egg

Introduction

Several combinations of adults and cages were used to facilitate the production of viable eggs in captivity.

Methods and Materials

Pupae were sexed and monitored daily until the color change occurred, thus indicating the formation of the moth. They were then placed in one of four cages.

Cages consisted of acetate cylinders 10cm in diameter and 30cm tall. The ends were covered with tops from 10cm petri dishes. Each cylinder contained a 25ml cup filled with 1ml of honey, 9ml of water, and a cotton ball (Figure 6). Each cylinder was lined with a different material: (1) brown paper, (2) light green paper, (3) waxed paper, or (4) no liner at all. Pupae were placed in the cylinders in three different arrangements: (1) one female, one male, (2) one female, five males, and (3) five females, five males.

For one set of experiments, using five pupae of each sex, the pupae were arranged so they all emerged within 24 hours of each other. Another set were arranged so the males were 4-5 days old when the females emerged.

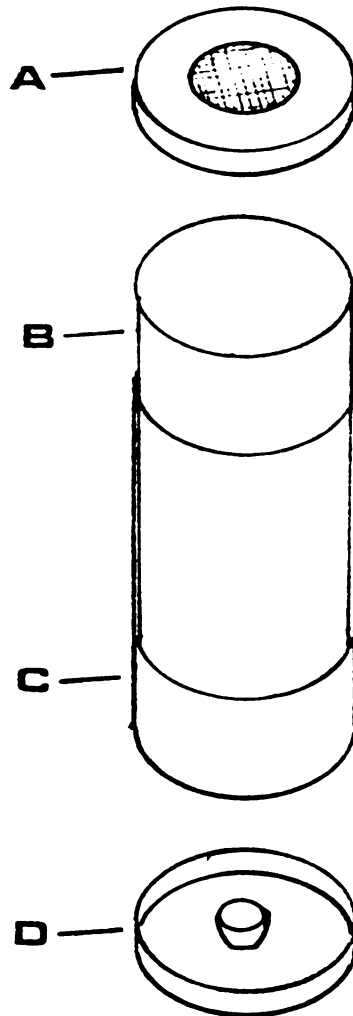


Figure 6. Acetate chamber used for mating and egg laying. A, screened top; B, paper liner; C, acetate tube; D, bottom with container of honey water.

Results

The moths all lived between 9 and 14 days in the cylinders and no eggs were found in any of the cylinders.

Discussion

This is an indication that the environmental conditions inside the cylinder were not proper and more research in this area needs to be conducted.

This step in the rearing process was the only condition that prevented rearing A. vaccini through a full generation.

BEHAVIORAL STUDIES

BEHAVIORAL STUDIES

Egg Laying

Introduction

Experimentation was done in an attempt to substantiate the statement in the literature that A. vaccinii eggs are laid on the calyx end of the blueberry.

Methods and Materials

Berries sampled from the Douglas Research Block in the spring of 1987 were examined for A. vaccinii eggs and the location was noted.

Results

Out of 159 eggs examined, 156 were placed on the inside rim of the calyx cup and 3 were on the exterior of the calyx cup. These three eggs were collected on the first day eggs were found, May 24, 1987, and were all located in the same berry cluster on berries that had not yet dropped their petals.

Discussion

The data clearly show that A. vaccinii at the Douglas Research Block prefers to lay eggs inside the calyx cup. The only evidence that did not agree with this could be explained by a mechanical obstruction by the petal.

Larvae Penetration

Introduction

Conventional chemical control methods are aimed at the first instar larvae of A. vaccinii because (1) less chemical is needed to kill a young larva than a mature larva, (2) once inside the berry the larva is nearly free from chemical contact, and (3) the first instar larva is supposed to crawl from the calyx cup to the stem end before entering the berry, which exposes it to chemical residue on the berry. Since the first instar larva crawling to the stem end of the berry is an important step in the chemical control strategy experimentation was done to substantiate this belief.

Methods and Materials

Blubberies collected from the Douglas Research Block between May 28, 1987 and June 15, 1987 were examined for any evidence of larval penetration. This evidence included a visible entry hole, red-blue discoloration of the berry, and any empty A. vaccinii egg shell on the berry cup.

Berries with such evidence were examined and dissected under a dissecting microscope to substantiate that the damage was caused by A. vaccinii. Larval entry holes were catagorized as being located at the (1) stem bundle, (2) shoulder, (3) side, or (4) calyx cup (Figure 7).

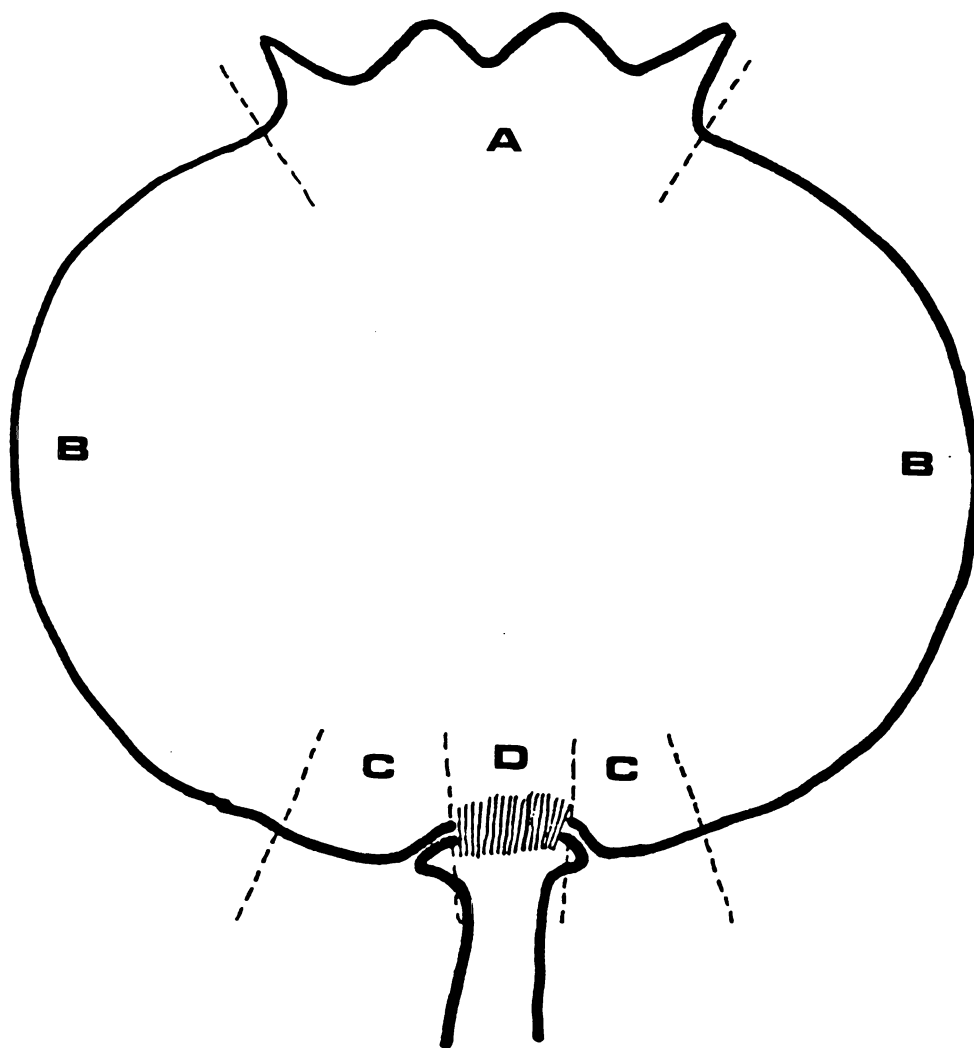


Figure 7. Designated areas of initial penetration into a blueberry by the larva. A, calyx cup; B, side; C, shoulder; D, stem bundle.

Results

Of the 67 berries examined by eye, 16 of them were not dissected because the microscope revealed that they were discolored due to something other than the penetration of a lepidopteran larva; 5 had hatched eggs but no evidence of larval penetration outside or inside; and 46 had larval entry holes.

Of the 46 berries that had larval entry holes, 37 were located at the stem bundle, 4 at the shoulder, 3 at the side, and 2 at the calyx cup (Table 13). This translates into 80% of the entry holes being located in approximately 5% of the total berry surface area.

Discussion

The claim that A. vaccinii larvae crawl to the stem end of the berry is definitely supported by the data gathered during this research. The five berries that had empty A. vaccinii eggs but no larval penetration could be due to the larva crawling off of the initial berry and on to another. If this is the case, these larvae would be exposed to chemicals for a longer period of time.

It was interesting that within the group of 37 stem entries, 36 of them were located in such a way that the fiber bundle connecting berry to stem was damaged (Figure 7). To accomplish entry at this location the larva must crawl under the shoulder of the stem and chew through the tough bundle fiber of the berry. This damage at entry, unlike the other

Table 13. Location of initial penetration of A. vaccinii larvae at the Douglas Research Block on blueberries collected between May 28 and June 15, 1987

=====

Entry location	No. of <u>A. vaccinii</u> larvae	No. of non- identified larvae*	% of total
1. Stem bundle	36	1	80
2. Shoulder	4	-	9
3. Side	1	2	7
4. Calyx cup	1	1	4

*Non-identified refers to larvae that could not be found or if found had been mutilated during dissection beyond identification.

entry positions, causes the berry to discolor within 24 hours of entry.

It is believed that this location is not a selection of the easiest entry location, but results in a change in the berry which the A. vaccinii larva can utilize.

Hibernacula Location

Introduction

Collecting A. vaccinii hibernacula from the Douglas Research Block for research purposes involved time consuming, labor-intensive soil sampling. Knowledge of any location where hibernacula formation was concentrated could significantly decrease the time and labor involved in collecting large quantities.

Experimentation was undertaken to identify preferred hibernacula formation locations so that locations of concentration could be utilized for collection purposes.

Two techniques were used to collect data. One consisted of removal of the soil around a blueberry bush in the field. The other consisted of removal of the sand from a two-tray sand chamber.

Methods and Materials

Field Observation: On September 3, 4, and 5, 1985, 10 blueberry bushes at the Douglas Research Block were selected on the basis of having a 50% infestation rate during the 1985 season and having very few weeds around the base of the bush. The soil in a 50cm radius circle was removed down to a 5cm

depth. A 5cm-wide putty knife and a 1cm-wide spatula were used to scrape the soil away approximately 1cm at a time. Uncovered hibernacula were examined to determine if they were viable (larva present) or non-viable (empty cases from past years). The depth and distance from the center point were determined and recorded for the viable hibernacula.

Laboratory Observation: A two-tray sand chamber (as detailed in "Development from Larvae to Pupae: Methods and Materials") was modified by placing 10cm lengths of blueberry branches in the sand tray that protruded up into the infested blueberry clusters. Six branches were placed in the sand on a 15cm grid. The sand was removed 1cm at a time from the tray after hibernacula were formed. The depth and horizontal location of the hibernacula were determined and recorded.

Results

Field Observation: Field observations showed that 62% of all hibernacula uncovered at the Douglas Research Block were within 1cm of the surface. The remaining 38% were within 2cm of the surface. Fifty-six percent of the hibernacula were located within 10cm of the bush center. Another 30% were located within 15cm of the bush center (Table 14).

Laboratory Observation: In the two-tray sand chamber 58% of the hibernacula were within 1cm of the top of the sand. Another 40% were between 1-2cm deep. Nearly 90% of the hibernacula were located within 2cm of the tray side or a branch (Table 15).

Table 14. Location of hibernacula under 10 blueberry bushes at the Douglas Research Block from collection taken on September 3, 4, and 5, 1985

Depth in cm	No. of Hibernacula at a given distance from the bush center, in cm			
	0-10	10-15	15-25	25-50
0-1	12	6	2	1
1-2	7	4	2	-
2-3	-	-	-	-
3-4	-	-	-	-
4-5	-	-	-	-

Table 15. Location of hibernacula in a two-tray sand chamber

Depth in cm	Horizontal Location		
	No. of Hibernacula within 2cm of the tray side	No. of Hibernacula within 2cm of a branch	No. of Hibernacula any other location
0-1	104	41	16
1-2	72	29	12
2-3	-	1	-
3-4	2	1	-

Discussion

Soil sampling was generally concentrated in the area immediately outside the bush crown (10cm from center point) at a horizontal distance of one shovel blade length (25cm) and a depth of 3-5cm. Results of the field observation experiment showed that over 40% of the hibernacula occurred in this area.

The data indicates that the highest density of hibernacula was located near the junction of the bush or tray and the soil.

This would appear to support the theory that the A. vaccinii larvae usually crawl down the blueberry bush from the infested fruit clusters and form hibernacula soon after contacting the soil.

A high percentage of the hibernacula were formed at very shallow depths. Some of the hibernacula in the field observation experiment could be observed among the stems before any soil was removed. The hibernacula that were found below 2cm in the sand tray were located in the tray corners or along one of the blueberry branches where the moist sand had not been packed tightly. Hence, they could crawl into those locations with little difficulty. This may suggest that the depth at which A. vaccinii hibernacula are found depends a great deal on the density of the soil they come in contact with at the base of the bush. In the sandy soil at the Douglas Research Block they did not bury themselves very deep. In the bog sod conditions in some blueberry blocks

they might easily crawl down into the tangled root systems 10cm or more.

When there was no sand available in petri dishes containing infested fruit, the formation of the hibernacula was in the damaged berry and frass that the larva occupied at maturity. Very often the larva migrated to the bottom of the infested berry cluster and the hibernaculum was webbed to the bottom of the petri dish.

CHEMICAL CONTROL

CHEMICAL CONTROL

Introduction

Research on the efficacy of pesticides is necessary to keep commercial growers aware of resistance problems and insure that new pesticides are made available. In Michigan, growers were experiencing sporadic control of A. vaccinii without the knowledge of why chemical controls were failing.

Chemical control of A. vaccinii on blueberries in Michigan is governed by one or more of the following factors:

I. Field Conditions

- A. Many blueberry blocks are grown with rows overlapping so that driving between rows with ground spray rigs is not possible.
- B. In wet springs equipment often can not be driven down the boggy rows.
- C. The alternative to ground spraying is aerial application, which does not give the dilute coverage needed for A. vaccinii control, and is limited to fair weather.

II. Timing

- A. Adult moths emerge, mate, and start laying eggs during bloom.

- B. Eggs start hatching and larvae penetrate into berries before bloom is finished.
- C. The number of pesticides registered for blueberries is limited. Experimental pesticides that are non-toxic to pollinators when applied during bloom time and that will control A. vaccinii are not labeled for use on blueberries.

III. Biology of A. Vaccinii

- A. The larva does not feed until it enters the berry in the protected area of the stem.
- B. Once the larva enters a berry it can live unexposed to surface pesticides for the remainder of its feeding life.
- C. Acrobasis vaccinii is a sporadic pest appearing and disappearing from commercial blocks for several years at a time. This makes it difficult to determine whether a spray program or natural causes is responsible for keeping this pest under control.

Pesticide research studies were carried out at the Douglas Research Block in 1985, 1986, and 1987 to determine an effective chemical control program.

Methods and Materials

A randomized complete block design was employed in a 3-year study. Each block consisted of 20 rows of 12 bushes.

Each treatment was randomly assigned to one row in each block. The number of treatments varied from year to year. At least one row was left between treatments as a buffer zone.

Materials were applied dilute with a handgun sprayer.

The timing of the first spray was targeted for the beginning of egg laying. This was accomplished by examining 500 berries from a random sample of 40 berry clusters for A. vaccinii eggs every other day after moth emergence was detected. Spray application was delayed past first egg laying only long enough to prevent injury to pollinators in the area.

In 1985, there was a 2-week interval between spray applications. In 1986 and 1987, there was a 10-day interval between the first and second spray application and a 2-week interval between the second and third application.

Evaluation in 1985 consisted of 10 berries harvested from 5 berry clusters in each of the 4 treatment rows, for a total of 200 berries per treatment. Each berry was examined for A. vaccinii damage and the results tabulated.

In 1986 and 1987, a total of 400 clusters per treatment were examined. These clusters consisted of 10 clusters selected from each of 10 bushes from each of the 4 treated rows. The cluster was evaluated as a whole unit. Any chewing, webbing, or frass from A. vaccinii on any berry constituted a damaged cluster. A cluster was defined as a grouping of berries that were in contact with one another.

Chemical control was rated as excellent (damaged of 1% or less of the clusters), good (damage of 1-2% of the clusters), fair (damage of 2-5% of the clusters) or poor (damage of more than 5% of the clusters).

Results

In 1985, the pyrethroid "Pydrin 2.4EC" resulted in the best control of A. vaccinii, keeping damaged clusters below 1.5%. Two other chemicals "Sevin XLR" and "Guthion 25" kept damage at the 4% level. "Orthene 75sp" did not control A. vaccinii well in the 1985 trials (Table 16).

Both "Sevin 80s" and "Lorsban 50wp" used in 1986 resulted in excellent control of A. vaccinii (Table 17).

Most of the chemicals used in 1987 resulted in commercially acceptable control. "Sevin 80s", "Asana 1.9ec", and "Lorsban 50wp" resulted in excellent control. The only poor control resulted from the use of an experimental product, "CME-13406 15%sc", in a test plot where the results showed 23% damaged clusters, almost half of the control plot (Table 18).

Discussion

Evaluation of Damage: In 1985, the individual berry as a sample unit was chosen to simulate A. vaccinii damage on a grading belt. After using this method several problems were recognized.

1. The larva always damaged more than one berry in a cluster while feeding.

Table 16. Chemical control of A. vaccinii at the Douglas Research Block, 1985

Application dates: 6-16, 6-19

Evaluation date: 7-2

=====

Chemical formulation	Rate of product /acre	No. of damaged berries	% of <u>A.</u> <u>vaccinii</u> damaged clusters	Control rating
Sevin XLR	1892ml	8	4.0	F
Orthene 75sp	605g	27	13.4	P
Pydrin 2.4EC	315ml	3	1.5	G
Guthion 2S	946ml	8	4.0	F
Control	-	58	27.1	-

Table 17. Chemical control of A. vaccinii at the Douglas Research Block, 1986

Application dates: 6-6, 6-17, 6-30, 7-12

Evaluation date: 7-17

=====

Chemical formulation	Rate of product /acre	% of <u>A.</u> <u>vaccinii</u> damaged clusters	Control rating
Sevin 80s	1135g	.5	E
Lorsban 50wp	1362g	.5	E
Control	-	26	-

Table 18. Chemical control of A. vaccinii at the Douglas Research Block, 1987

Application dates: 6-2, 6-12, 6-25

Evaluation date: 7-7

=====

Chemical formulation	Rate of product /acre	% of <u>A.</u> <u>vaccinii</u> damaged clusters	Control rating
Sevin 80s	1134g	0.5	E
Asana 1.9ec	100ml	0.75	E
Imidan 50wp	907g	4.75	F
Spur 22ew	284g	2.0	G
Danitol 2.4ec	316ml	1.5	G
Lorsban 50wp	1361g	0.5	E
Lorsban 50wp+	269g	-	-
Imidan 50wp	448g	2.25	F
Orthene 75wp	595g	4.0	F
CME-13406 15%sc	296ml	23.0	P
TD-2242 3ec	2.52l	1.25	G
Control	-	55.0	-

2. Feeding damage on one berry removed from its cluster could not reliably be linked to A. vaccinii, whereas, observing feeding damage on a berry in a cluster that had frass and/or webbing and/or an active larva facilitated definite identification.
3. The fungus that grew on the A. vaccinii frass, which was held in the cluster by the webbing, usually rotted a portion of the healthy berries in the cluster.
4. Picking one berry out of a cluster often dislodged the damaged berries, causing them to drop to the ground and thus removing them from the sample population.

All of these factors favored the whole cluster as a unit to be evaluated for damage in the field rather than an individual berry.

Spray Method: It should be noted that the spray method used in this research (dilute to drip with a handgun) is not used commercially on blueberries in Michigan but was chosen because it removes the possibility of failure of a chemical spray due to poor coverage, and lends itself to small plot coverage.

Spray Timing: In 1985, the timing of the first spray was scheduled for first cover (approximately June 20, 1985) because of existing research and knowledge. But on June 4, 1985, while evaluating a berry sampling technique, both A. vaccinii eggs and larval entries were observed. The

first spray was then rescheduled for the next possible spray date, June 6.

In 1986 and 1987, sprays were applied as soon as possible after egg laying was detected. In both years sprays were delayed long enough to remove the bee hives from the area. This delay allowed 2% or less injury to the berries from larvae before sprays were applied. This may have had a slight negative effect on the efficacy of some of the treatments.

It should be noted here that all commercial growers contacted did not apply their spray until 7 days or more later because of their concern for pollination and the pollinators.

With increased availability of Bacillus thurengiensis (Bt) strains active against lepidopteran, and the safeness of Bt toward pollinators and the environment, Bt testing would seem a good direction to go with future research.

The advancements made in incorporating Bt strains into plant cell structure, combined with A. vaccinii's behavior of entering the blueberry at the stem bundle (as detailed in "Behavior: Larvae Penetration"), could someday prove a useful avenue of control.

BIOLOGICAL CONTROL

BIOLOGICAL CONTROL

Mycotic Control

Introduction

During the study of the life cycle of A. vaccinii in Southwestern Michigan, mycotic larvae were found in hibernacula removed from the soil at the Douglas Research Block. A Paecilomyces spp. (Brown and Smith, 1957) was consistently isolated from mycotic larvae.

Many Paecilomyces species have been cultured from many economic pest insects but none have been previously reported as a pathogen of A. vaccinii.

The purpose of this study was to describe the fungus isolated from A. vaccinii larvae, determine its pathogenicity to A. vaccinii, and report the incidence of infected larvae in the field.

Methods and Materials

Pathogen Identification

In June of 1986, mycotic A. vaccinii larvae collected from the Douglas Research Block were placed individually in petri dishes half filled with moist, sterile silica sand to allow fungal sporulation. Each dish was placed in a sealed plastic bag containing 1ml of deionized water and stored at 26oC for at least 48 hours. Samples of sporulating fungi

from each hibernaculum were mounted in lactophenol for identification, and streaked onto sabouraud maltose agar (SMA) plates. Isolates from individual colonies were then transferred to clean SMA plates and the fungus allowed to develop for 6 weeks. Morphological features of isolated fungi were studied and photographed on SMA plates, using a phase contrast compound light microscope and a scanning electron microscope. Fungal samples for the compound light microscope were mounted in lactophenol. Fungal samples for scanning electron microscope were cut into 3mm squares of SMA culture which were prepared using the osmium tetroxide procedure (Klomprens, 1986).

Pathogenicity to A. Vaccinii

Hibernacula removed from the Douglas Research Block in September of 1986 were teased open. Any active larva was removed from its hibernaculum, placed in a petri dish with moist, sterile silica sand, and allowed to rebuild its hibernaculum. The dishes were kept moist and observed for signs of mycosis for 30 days before non-mycotic hibernacula were selected for inoculation.

Conidia used for inoculation were removed from two sources: (1) synnemata grown on A. vaccinii inside hibernacula which had been sporulated (as described in "Pathogen Identification"), and (2) SMA plate cultures which had been sporulated from field synnemata on one SMA plate, transferred to a second and then a third SMA plate.

Conidia from these synnemata and SMA plates were removed by stroking a fine probe through them. The probe was then inserted inside each hibernaculum through a previously made pin hole and the larva was contacted to facilitate inoculation.

Control hibernacula were pierced with the pin and the larvae were contacted with a sterile probe.

Each hibernaculum was sporulated (as described in the section titled "Pathogen Identification"). After 20 days the larvae were classified as dead (no visible signs of causal agent), mycotic (fungal growth present), or healthy. Fungi growing on the mycotic larvae were identified under the compound microscope.

Pathogenicity to A. Vaccinii Parasitoids

During the selection of non-mycotic larvae for inoculation tests, two larvae were inadvertently selected that contained two different parasitoids. They were Cryptus albitarsis (Cresson), a hymenopteran, and Villa lateralis (Say), a dipteran (Appendices B and C). They were inoculated, as described above, as healthy A. vaccinii larvae and allowed to sporulate (as described in the section titled "Pathogen Identification").

On February 1, 1987, inoculation of two C. albitarsis and two V. lateralis hibernacula was completed using the methods described above and sporulated (as described in the section titled "Pathogen Identification").

Incidence of Infected Larvae in the Field

Five collections from the Douglas Research Block taken on April 28, May 21, June 2, June 9, and October 10, 1986 were used to show incidence of mycotic A. vaccinii in the field. Hibernacula were sorted out of the soil samples removed from around the base of 5 randomly selected rows of 12 bushes each, for a total of 60 bushes. Each hibernaculum was opened and classified as empty, containing insect parasitoid, containing mycotic A. vaccinii, or containing healthy A. vaccinii.

Field Mortality

Two collections taken from the Douglas Research Block on April 28, 1986 and October 10, 1986 were used to evaluate natural mortality of A. vaccinii due to Paecilomyces spp. Hibernacula were sorted out of soil samples removed from 5 randomly selected rows of 12 bushes each, for a total of 60 bushes. Each hibernaculum was opened and classified as empty, containing an insect parasitoid, or containing mycotic A. vaccinii.

Mortality of Larvae Removed from Hibernacula

Eighteen active larvae that were removed from hibernacula collected from the Douglas Research Block on October 29, 1986 were placed individually into petri dishes with moist, sterile silica sand. These were held at $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for 120 days, then at 3°C for 36 days, and then returned to $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for 60 days. The hibernacula were then examined and

classified as (1) healthy (adult moth present in the dish), (2) Paecilomyces spp. infected, (3) non-Paecilomyces spp. fungi present, or (4) insect parasitoid present.

Mortality of Larvae Removed from Green Berries

Six hundred and seventy-eight mature larvae removed from infested fruit from the Douglas Research Block on July 3, 1987 were placed in three 18"x24"x3" pans with 1" of moist silica sand covering the bottom and a fine mesh sealed over the top. The pans were then held at 26°C for 30 days. The sand was sifted and the hibernacula removed. They were placed, 10 at a time, in 1-pint plastic containers filled half full with moist silica sand and sealed with plastic lids. These were housed in a growth chamber for 60 days at 26°C after which the temperature was slowly reduced to 3°C over a 14-day period and held there for 120 days. The temperature was slowly raised back to 26°C over a 14-day period and held there for another 30 days. The hibernacula were then opened and classified as parasitized (insect parasitoid pupal case present), healthy (A. vaccinii pupal case present), Paecilomyces spp. infected, or cause of mortality unknown.

Results

Identification

Colonies on SMA plates started out as white tufts, but with age formed a matted basal felt of yellow-orange which was covered with a fine, cottony, white overgrowth

(Plate II A). Synnemata started developing on 21-day-old SMA plates. They had a yellow-orange color but a non-uniform globular, spatula-shaped head.

Acrobasis vaccinii became covered with a white mycelial growth while in the hibernaculum but more often the fungus was first observed as a fine, white hyphal brush emerging through the hibernaculum wall. As this brush lengthened the hyphae fused and became the yellow-orange, sterile stipes of the synnemata. The dusty-white sporulating head that eventually forms on the stipes was observed as either club shaped, 7-12mm long and 2-4mm wide (Plate II C); or dagger shaped, 0-30mm long and 1-2mm wide (Plate II B).

Hyphae were smooth, hyaline, and 0.5 to 2.7 μ wide (Plate II F,G). Conidiophores were septate, smooth, hyaline, 1-2 μ in diameter and from 20-200 μ long (Plate II F,G). Phialids were flask shaped, 6.0-9.0 μ long and 1.0-4.5 μ wide, with the slender neck portion 0.7 μ or less in diameter (Plate II F,G). They were born individually or in whorls (Plate II F,G). Conidia were smooth, lemon-shaped, 2.7-3.2 μ long, 1.6-2.5 μ wide and occurred in chains of 20 or more (Plate II F,H).

Pathogenicity to A. Vaccinii

Thirty days after inoculation with conidia from larval coremium, 78% of the larvae inoculated died of mycosis (Table 19). Paecilomyces spp. was isolated from all these mycotic larvae after a 20-day sporulation period. One of the control

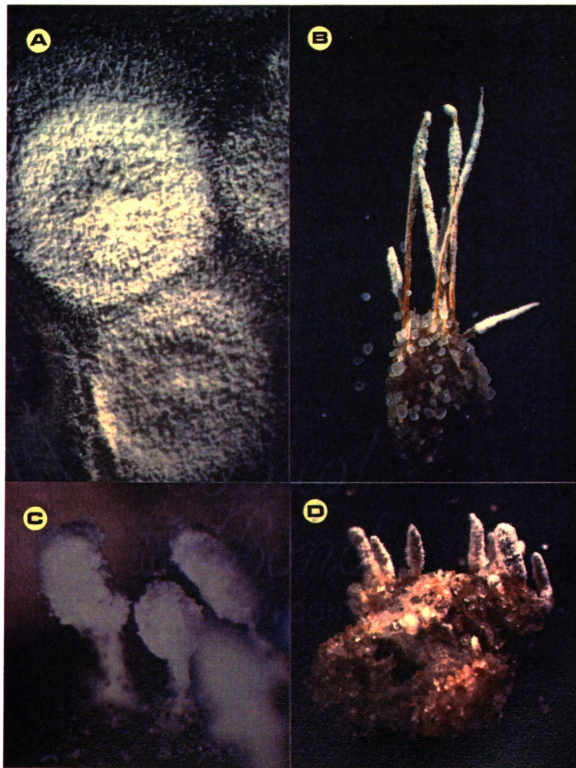


Plate II. Paecilomyces spp. found to be a pathogen to Acrobasis vaccinii. A, SMA culture; B, spear shaped synnemata, 10X; C, club shaped synnemata, 10X; D, hibernaculum torn open to expose hyphal mass, 10X.

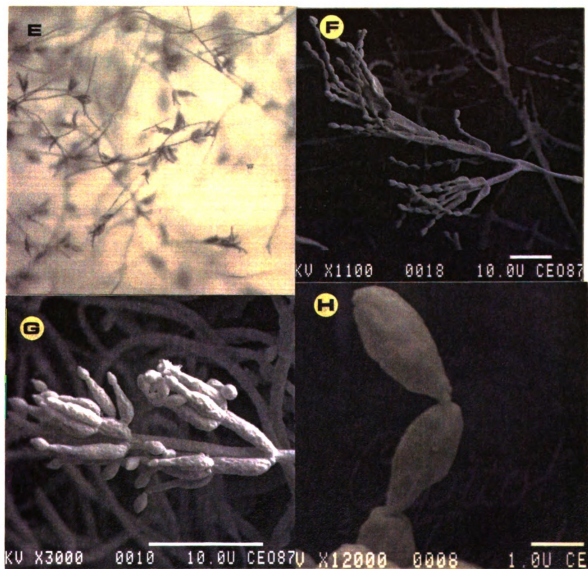


Plate II, continued. E, compound light microscope, 100X; F, scanning electron microscope (SEM), 1100X; G, SEM, 3000X; H, SEM, 12000X.

Table 19. Inoculation of A. vaccinii with Paecilomyces spp.

Treatment	No. of treated larvae	30-day post treatment		
		Dead larvae	Mummified larvae	Healthy larvae
Inoculated with Conidia from Larval Coremium	14	-	11	3
Control	13	1	-	1
Inoculated with Conidia from SMA Culture	11	-	11	-
Control	10	2	-	8

larva died but sporulation by Paecilomyces spp. did not appear on it after 20 days.

All of the larvae inoculated with conidia from SMA plate cultures died of fungal mycosis during the 30-day test period. Paecilomyces spp. was isolated from all of these mycotic larvae after a 20-day sporulation period. Only two of the control larvae died and sporulation by Paecilomyces spp. did not appear on them after 20 days.

Pathogenicity to A. Vaccinii Parasitoids

The inadvertent inoculation of one V. lateralis and one C. albitarsis resulted in death of the V. lateralis but had no effect on the C. albitarsis. The inoculation of two V. lateralis pupae and two C. albitarsis pupae on February 1, 1987 resulted in the death of the V. lateralis but had no effect on the C. albitarsis. Paecilomyces spp. sporulation was present and was isolated from all V. lateralis specimens after a 20-day sporulation period.

Incidence of Infection in the Field

Data collected from five collections from the Douglas Research Block indicated that more than 5% of all hibernacula collected on any date were mycotic (Table 20).

Field Mortality

Results of the two collections, taken from the Douglas Research Block on April 28, 1986 and October 10, 1986

Table 20. Incidence of infection and field mortality of A. vaccini due to Paecilomyces spp. collected at the Douglas Research Block, 1986

Date	No. of hibernacula collected	% empty hibernacula	% hibernacula % hibernacula		proportion of mycotic A. <u>vaccini</u> that <u>Paecilomyces</u> spp. was sporulated from
			containing insect parasites	containing mycotic A. <u>vaccini</u>	
4-28	544 est	75	2	6	5-15 (33%)
5-21	127	67	20	21	ND
6-02	311	85	-	14	ND
6-09	471	75	10	15	ND
10-10	146	81	1	8	6-09 (66%)

indicated that 24% and 39%, respectively, of the A. vaccinii population were mycotic (Table 20).

Five of the 15 mycotic hibernacula that showed sporulation from the April date and 6 of the 9 from the October date produced Paecilomyces spp.

Mortality of Larvae Removed from Hibernacula

Of the October 29, 1986 collection of larvae removed from their hibernacula and allowed to remake hibernacula in silica sand, 6 sporulated with Paecilomyces spp. 8 emerged as adults, 2 were mycotic and showed non-Paecilomyces spp. fungal growth after sporulation, and 2 were parasitized by an Ichneumonid parasitoid.

Mortality of Larvae Removed from Green Berries

Of the 678 hibernacula formed by the fully grown larvae collected from the Douglas Research Block, 140 were healthy, 178 were parasitized, and none were Paecilomyces spp. infected. The cause of mortality for the remaining 360 was undetermined.

Discussion

The fungus consistently isolated from infected A. vaccinii is similar to previous descriptions of Paecilomyces facinosus (Brown & Smith, 1957) (Onions, 1975) varying slightly in the length of conidiophores, phialids, and conidia.

The procedure used in preparing SMA cultured Paecilomyces

spp. for SEM photomicroscopy did affect the fine structure of the fungi. It is likely that the wrinkling and collapsing of conidia, phallids, conidiophore, and hyphae are a result of the preparation technique and not a "true" characteristic of the fungus. Due to the methods of fixation it was difficult to find long chains of conidia (20 or more) for SEM photomicroscopy but was easy to find long chains for photomicroscopy under the compound light microscope.

The data collected from the green berry larvae collection supports the theory that this Paecilomyces spp. is soilborne and the larvae are infected when they build their hibernacula.

Estimating the incidence of infected larvae in the field was complicated by three factors: (1) after the adult A. vaccinii had emerged the empty hibernacula remained intact in the ground for several years, (2) it is not possible to distinguish between the current year's empty hibernacula and previous year's empties, and (3) empty hibernacula tend to collapse and sift through the 5-square-per-inch mesh used for sorting A. vaccinii from the soil.

The result of these three factors is that some of the hibernacula counted as empty are from previous years and some of the current year's empties were not counted. Therefore, the "number of hibernacula collected" in Table 20 is not an exact representation of the current year's A. vaccinii population. This inaccuracy is passed along in the remaining data of the table.

It may be shown with further research that this Paecilomyces spp. in a sprayable form, directed at the crown of the blueberry bush just prior to hibernacula formation, could be a viable control tactic.

Egg Parasites

Introduction

During the spring berry sampling in 1987 at the Douglas Research Block, A. vaccinii eggs could be found that were black instead of the typical yellow-orange (Plate I E). Attempts were made to identify the reason for the color change.

Methods and Materials

Seventeen black eggs collected between June 1, 1987 and June 10, 1987 were held on the original berry in small petri dishes and monitored daily over a 3-week period. After emergence the adults were placed into a vial of KAAD for later identification.

Results

Six of the eggs were opened and the adult emerged without being observed. A very small hymenopteran emerged out of seven eggs, but the vial they were stored in was misplaced so they were not identified. The remaining four eggs did not have anything emerge from them. These seventeen eggs represent 9.7% of all eggs collected that spring.

Discussion

It is believed that the small hymenopteran is Trichogramma minutum (Riley), which has been reported as an egg parasitoid of A. vaccinii in the Eastern United States (Brodel, 1984; Nuenzig, 1979). The six adults that were never seen were presumably small enough to escape from the petri dish before being found.

Use of the Trichogramma spp. for control purposes shows merit in that they are already mass reared. They would be safe to release during bloom time, and they might control other lepidopteran that are present in the blueberry field at the same time.

Other Parasitoids

On several occasions A. vaccinii collected from the field as mature larvae or in hibernacula and reared in the laboratory have yielded parasitoids instead of A. vaccinii adults.

One such collection of mature larvae collected from the Holland, Michigan site in June of 1986 contained 78 hymenopteran parasitoids from a total of 278 larvae. This hymenopteran complex consisted of 2 Ichneumonidae--Cryptus albitarsis (Cresson), and Campoletis patsuiketorum (Viereek) (Appendix D).

One other collection of hibernacula obtained from the Douglas Research Block in the spring of 1986 contained 9 Villa lateralis (Say) out of 136 pupae reared to adults.

Another collection that same spring contained 17 V. *lateralis* and 2 *Compsilura concinnata* (Meigen) (Appendix C) out of 213 hibernacula.

Other parasitoids reared from hibernacula collected from the Douglas Research Block are *Diadegma compressum* (Cresson), *Bassus usitatus* Gahan, *Microtypus* n.sp., and *Memorilla pyste* (Walker) (Appendix C).

Very little is known about any of these parasitoids. Several of them are quite general in their host range which could limit their abilities as a *A. vaccinii* control. More research in this area needs to be done.

PHENOLOGY

PHENOLOGY

Monitoring Plant Growth Stage

Introduction

It was envisioned that by monitoring the blueberry bushes as well as A. vaccinii, a phenological relationship could be determined for timing chemical sprays.

In 1986 and 1987, monitoring of the "Jersey" blueberry bushes from budbreak to berry swell was done at the Douglas Research Block.

Methods and Materials

Fifty flower clusters were examined at random, 2 per row across 25 rows at the Douglas Research Block in 1986 and 1987. Flower clusters were catagorized by the most dominant stage existing in a cluster: pre-bloom (flower closed showing no color); pink (flower closed, showing change in color); bloom (flower open with color); or petal fall (petal detached from berry). The percentage of clusters in each catagory was tabulated.

Results

The "Jersey" blueberry at the Douglas Research Block in 1986 and 1987 reached 20% pink by the first week of May, 50% bloom before the middle of May, and over 90% petal fall by the first week of June.

The results of the flower cluster monitoring at the Douglas Research Block in 1986 and 1987 are tabulated in Tables 21 and 22, respectively.

Discussion

In comparing the phenological data with the biological data (Figure 8) moth activity and egg laying began at about 50% bloom and lasted a few days after 100% petal fall.

Michigan blueberry growers, following the Michigan State University Spray Calendar guidelines previous to 1985, were scheduling A. vaccinii control sprays for first cover approximately two weeks after petal fall. Chemical control sprays applied at this time, during the 1986 and 1987 seasons, would not be effective.

The ideal time for control of adults in 1986 and 1987 was during full bloom. A spray at early petal fall would be ideal for controlling larvae at egg hatch.

The lack of a pesticide registered for use during bloom rules out adult control sprays. An early petal fall spray would require removal of pollinators in the area or registration of a pesticide that would not affect the pollinators.

Sandoz Incorporated does have a pyrethroid (Spur 22ew) that has proven to be non toxic to honey bees and was shown to give good control of A. vaccinii even at late petal fall (see Chemical Control, 1987).

Table 21. Plant growth stage of "Jersey" blueberry at the Douglas Research Block, 1986

=====				
Plant Stage				
Date	% prebloom	% pink	% bloom	% petal fall
5-05	74	20	6	-
5-12	-	48	50	2
5-16	-	14	80	6
5-19	-	10	60	30
5-23	-	2	14	84
6-01	-	-	8	92
6-09	-	-	-	100

Table 22. Plant growth stage of "Jersey" blueberry at the Douglas Research Block, 1987

=====				
Plant Stage				
Date	% prebloom	% pink	% bloom	% petal fall
5-06	80	20	-	-
5-13	-	38	58	4
5-20	-	8	80	12
5-28	-	2	48	50
6-02	-	-	20	80
6-07	-	-	6	94
6-10	-	-	-	100

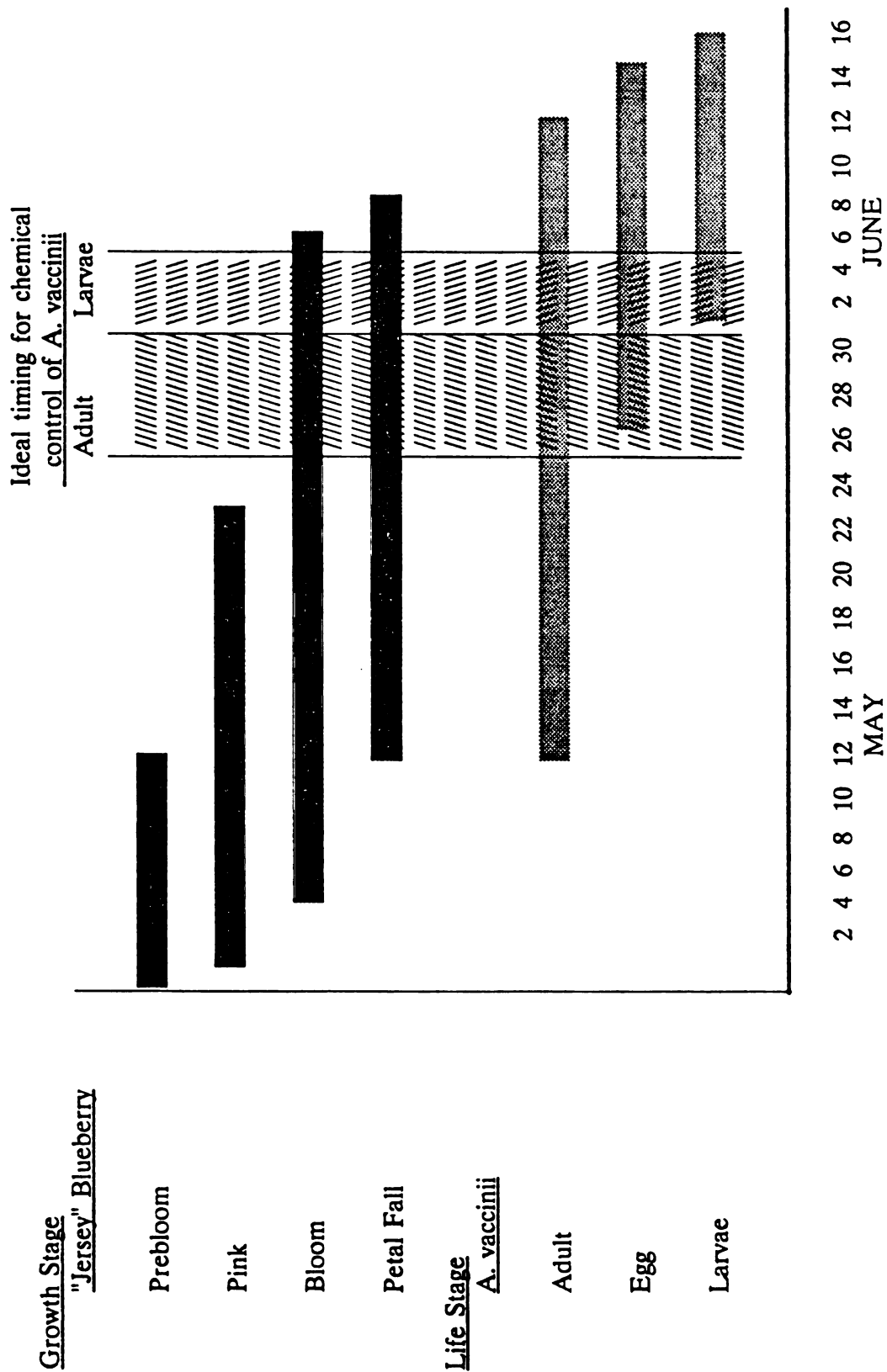


Figure 8. Growth stage of "Jersey" blueberry bushes and life stage of Acrobasis vaccinii monitored at the Douglas Research Block, date averaged for 1986 and 1987

SUMMARY

SUMMARY

Investigations carried out for this thesis resulted in new data concerning the biology, behavior, and control of A. vaccinii, with respect to the production of blueberries in Southwest Michigan that have not been reported previously.

Adult activity is during the bloom period for "Jersey" variety blueberries, generally from mid-May until mid-June. Monitoring for adults was most successful at the Douglas Research Block using emergence traps placed over blueberry bushes that had a 50% or greater fruit loss the previous year. Testing of developmental pheromone caps showed some success and should prove to be the most effective way of monitoring adults in the future.

Eggs were laid in the calyx cup of the berry during the first two weeks of June. During those two weeks "Jersey" blueberries went from 50% petal fall to 100% petal fall. Examining the calyx cup of the blueberry starting at full bloom proved to be a very effective method of determining when there was a population of A. vaccinii present. The first chemical control spray should be applied within the week following the first sign of egg laying. This should correspond to peak egg laying and the hatch of the first eggs.

A continuation of berry monitoring, looking at the stem

end, will reveal the first larval penetration which will be 3-4 days after the first eggs are laid. The newly-hatched larva crawls around the berry until it locates the stem, then chews its way through the stem fiber bundle into the berry interior. This short exposure time is the best time for controlling the larval stage of A. vaccinii with chemical sprays. Many chemicals tested showed good commercial level control, the best being "Asana 1.9ec", "Sevin 80s", and "Lorsban 50wp". But the closer to first egg hatch that the sprays were applied, the better were the results.

Larvae that mature in the berry clusters usually feed on 4-10 berries and web several more together with the eaten ones. By mid-July most larvae have left the berries, crawled to the ground, and formed hibernacula near the crown of the bush in the top few centimeters of soil. They remain there until the next spring.

Pupation occurs in the hibernacula from mid-April to the beginning of May. Monitoring of the pupae can be accomplished by sifting the soil and debris from around the plant crown. Five-square-per-inch wire mesh proved to be ideal for removing the hibernacula from the rest of the sample. Collecting berry clusters while larva were still present and placing them in two-tray sand chambers, where the berries can be suspended over sand, proved to be an effective method of collecting large numbers of hibernacula. After the larvae have left the berries and built hibernacula in the sand, they can be easily sifted out. Acrobasis vaccinii

remained in the pupae stage for about a month before emerging as adults.

By collecting A. vaccinii eggs on green berries in the plantation at the Douglas Research Block, it was possible to rear them through to adults in a petri dish. After the larva had penetrated the initial berry, several more green berries were added. A small amount of sand was made available for hibernaculum formation, and a diapause period of 4 months at 30C resulted in pupa formation and, finally, adult emergence. No successful egg laying was accomplished with these adult moths.

A significant biological control agent was discovered, identified, and proven to be virulent to A. vaccinii larvae in their hibernacula. Paecilomyces spp. was found on A. vaccinii hibernacula removed from the Douglas Research Block and proved to be over 75% effective at controlling A. vaccinii in laboratory tests. It is believed the Paecilomyces spp. is most like P. farinosus and is soil-borne.

Seven A. vaccinii insect parasitoids, previously unreported, were reared from collections taken from the Douglas Research Block and the Holland, Michigan block.

APPENDICES

APPENDIX A
ARTIFICIAL DIET

APPENDIX A

ARTIFICIAL DIET

Ingredients	Quantity
A. Pinto beans (dry)	427 gm
Brewers yeast	64 gm
Ascorbic acid	6 gm
Methyl-P-hydroxybenzoate	4 gm
Sorbic acid	2 gm
Distilled water	615 ml
B. Agar	26 gm
Distilled water	615 ml
C. Vitamin solution	50 ml
Formaldehyde	4 ml
Aureomycin (18% soluble)	3.5 gm
<u>Vitamin solution</u>	
Inositol	2.0 gm
Niacin	.1 gm
Riboflavin	.05 gm
Pyridoxine HCl	.025 gm
Calcium pantothenate	.1 gm
Thiamine HCl	.025 gm
Folic acid	.025 gm
Biotin	.002 gm
B ₁₂	.002 gm
Distilled water	100 ml

1. Blend A in a blender until smooth.
2. Heat B until all of the agar is dissolved and allow to cool.
3. Mix A, B and C together into a large container.
4. Pour into containers and cover.

APPENDIX B

LETTER OF CONFIRMATION OF IDENTIFICATION
OF A PARASITE OF ACROBASIS VACCINII

APPENDIX B

LETTER OF CONFIRMATION OF IDENTIFICATION
OF A PARASITE OF ACROBASIS VICCINII



United States
Department of
Agriculture

Agricultural
Research
Service

Beltsville Area
Beltsville Agricultural
Research Center

Beltsville, Maryland
20705

March 9, 1987
(Ref.: Lot 87-01663)

Dr. Fred Stehr
Department of Entomology
Michigan State University
East Lansing, MI 48824-1115

Dear Fred:

The following identification is a complete report on the specimens submitted with your request of February 18, 1987.

DIPTERA

Bombyliidae

Villa lateralis (Say) [2 adults, 1 pupa] 3

This is also a confirmation of my telephone report of March 6, 1987.

Determined March 6, 1987 by L. V. Knutson
Research Entomologist, Systematic Entomology Laboratory, BBII, USDA

The specimens will be returned under separate cover.

We request that the enclosed form be used in any future submittals. This ensures entry of the request into our computerized tracking/inventory system, and saves the taxonomist and the requestor time.

We would like to suggest that you include duplicate data labels when submitting specimens in alcohol, in the event that the identifier wishes to keep part of the material. As there is an insufficient amount of technical assistance available to the Research Entomologists in the Systematic Entomology Laboratory your assistance in this regard would be very much appreciated.

Sincerely,

LLOYD KNUTSON, Director
Biosystematics and Beneficial
Insects Institute

Enclosures

Separate cover: Specimens

APPENDIX C

LETTER OF CONFIRMATION OF IDENTIFICATION
OF SEVERAL ACROBASIS VACCINII LARVAL PARASITES

APPENDIX C

LETTER OF CONFIRMATION OF IDENTIFICATION OF SEVERAL ACROBASIS VACCINII LARVAL PARASITES

Dave Biddinger
Department of Entomology
Michigan State University
243 Natural Sciences Bldg.
East Lansing, MI 48824



Dear Dave,

March 27, 1989

Thank you very much for your recent submission of specimens for identification to The Center for Insect Identification, Inc. on February 27, 1988. The specimens represent 2 species of Tachinidae (Diptera), 2 species of Braconidae (Hymenoptera) and 1 species of Ichneumonidae (Hymenoptera). All of these specimens were submitted as larval parasites of the cranberry fruitworm, *Acrobasis vaccinii* Riley.

<u>Identification #</u>	<u>Identification</u>
00023	<i>Bassus usitatus</i> Gahan (Hymenoptera: Braconidae: Agathidinae)
00024	<i>Microtypus</i> n.sp. (Hymenoptera: Braconidae: Orgilinae)
00025	<i>Diadegma concoloratus</i> (Cresson) (Hymenoptera: Ichneumonidae)
00026	<i>Compsilura concinnata</i> (Meigen) (Diptera: Tachinidae)
00027	<i>Nemorilla pyste</i> (Walker) (Diptera: Tachinidae)

One specimen of *B. usitatus* was retained by the identifier. The new species of *Microtypus* has been seen prior to this occasion, but this represents the first host association. If you would like to get the species described, let us know and we will try to work something out. We would probably need additional reared specimens to try to do this. For more information on the tachinid parasites, consult Arnaud's host-parasite catalog for the Tachinidae.

Please acknowledge "The Center for Insect Identification" as the source of identifications of these specimens in any future publication. The individual identifiers to cite are: Dr. Monty Wood (Tachinidae); Dr. Scott R. Shaw (Braconidae); and Dr. Henry Townes (Ichneumonidae).

Thank you, once again, for using the services of The Center for Insect Identification. We look forward to serving you again in the not-too-distant future.

Sincerely yours,

P.O. Box 26245 • Lansing, MI 48909 • (517) 887-7310
Gregory H. Dahlem
Director

APPENDIX D

CONFIRMATION OF IDENTIFICATION OF TWO ACROBASIS VACCINII LARVAL PARASITES

APPENDIX D

CONFIRMATION OF IDENTIFICATION OF TWO ACROBASIS VACCINII LARVAL PARASITES

Two other parasites of Acrobasis vaccinii were submitted to The Center for Insect Identification, Inc. during the fall of 1987. The specimens were identified as: Cryptus albitarsis (Cresson), and Campoletis patsuiketorum (Viereek). These specimens are both Hymenoptera in the Ichneumonidae family. The individual identifier was Dr. Henry Townes.

APPENDIX E
VOUCHER SPECIMEN DATA

APPENDIX E

Record of Deposition of Voucher Specimens*

The specimens listed on the following sheet(s) have been deposited in the named museum(s) as samples of those species or other taxa which were used in this research. Voucher recognition labels bearing the Voucher No. have been attached or included in fluid-preserved specimens.

Voucher No.: 1989-03

Title of thesis or dissertation (or other research projects):

THE BIOLOGY, BEHAVIOR, AND CONTROL OF
ACROBASIS VACCINII (LEPIDOPTERA: PYRALIDAE)
IN BLUEBERRIES IN SOUTHWEST MICHIGAN

Museum(s) where deposited and abbreviations for table on following sheets:

Entomology Museum, Michigan State University (MSU)

Other Museums:

Investigator's Name (s) (typed)
DOUGLAS A. MURRAY

Date DEC. 1, 1990

*Reference: Yoshimoto, C. M. 1978. Voucher Specimens for Entomology in North America. Bull. Entomol. Soc. Amer. 24:141-42.

Deposit as follows:

Original: Include as Appendix E in ribbon copy of thesis or dissertation.

Copies: Included as Appendix E in copies of thesis or dissertation.
Museum(s) files.
Research project files.

This form is available from and the Voucher No. is assigned by the Curator, Michigan State University Entomology Museum.

APPENDIX E ..

Voucher Specimen Data

Page 1 of 1 Pages

Species or other taxon	Label data for specimens collected or used and deposited	Number of:							Museum where deposited
		Eggs	Larvae	Nymphs	Pupae	Adults ♂	Adults ♀	Other	
<i>Acrobasis vaccinii</i>	MSU Exp. Sta., Douglas, MI. June 12, 1986 D. Murray					2	5		MSU
<i>Diadegma compressum</i>	MSU Exp. Sta., Douglas, MI June 12, 1986 D. Murray					4	5		MSU
<i>Cryptus albitarsis</i>	MSU Exp. Sta., Douglas, MI June 12, 1986 D. Murray					1	2		MSU
<i>Microtypus</i> n. sp.	MSU Exp. Sta., Douglas, MI June 12, 1986 D. Murray						1		MSU
<i>Campoletis patsuiketorum</i>	MSU Exp. Sta., Douglas, MI June 12, 1986 D. Murray						1		MSU
<i>Bassus usitatus</i>	MSU Exp. Sta., Douglas, MI June 12, 1986 D. Murray						2		MSU
<i>Villa laterallis</i>	MSU Exp. Sta., Douglas, MI June 12, 1986 D. Murray				12	1	2		MSU
All specimens reared from All specimens reared from collected out of soil samples	<i>A. vaccinii hibernacula</i> from Douglas, MI.								

(Use additional sheets if necessary)

Investigator's Name(s) (typed)

Douglas A. MurrayVoucher No. 1989-03

Received the above listed specimens for deposit in the Michigan State University Entomology Museum.

Richard L. SmithDate 7 February 1991

Curator

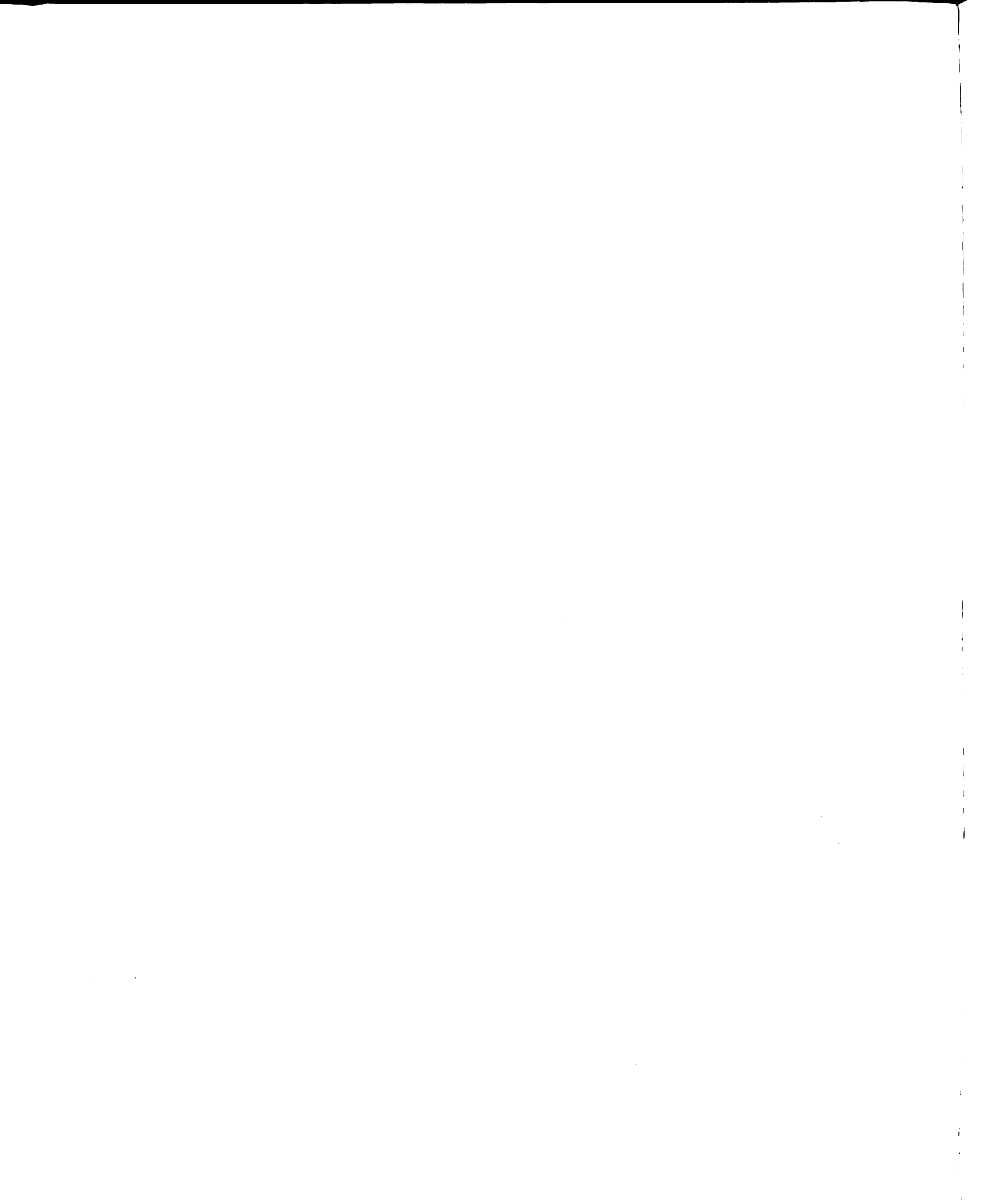
Date Dec. 1, 1990

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