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Development of Banded Sunflower Moth (Lepidoptera: Cochylidae) and Sunflower Moth (Lepidoptera: Pyralidae) on Three Diets

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ABSTRACT: A comparative study of the effects of sunflower moth diet, banded sunflower moth diet, and a modified sunflower moth diet was conducted on banded sunflower moth, *Cochylis hospes* Walsingham, and sunflower moth, *Homoeosoma electellum* (Hulst). Developmental times and survival to the pupal and adult stages were measured for each diet and pest species. Modified sunflower moth diet with incorporated sunflower leaf tissue gave faster developmental times and a higher percent pupation and adult eclosion for both sunflower moth species than either sunflower moth diet or banded sunflower moth diet. The modified sunflower moth diet that incorporates sunflower leaf tissue provides a single medium which can be used to successfully rear both species of sunflower moth.

Introduction

The banded sunflower moth, *Cochylis hospes* Walsingham, and the sunflower moth, *Homoeosoma electellum* (Hulst), are important economic insect pests of cultivated sunflower, *Helianthus annuus* L., in North America (Schulz, 1978). Early instars of both species feed primarily on sunflower pollen and floral tissues while 3rd and later instars feed on seeds and cause most of the economic damage (Rogers, 1978; Charlet and Gross, 1990).

An early advance in rearing lepidopterous and other phytophagous insects in the laboratory was the use of wheatgerm in the formulation of diets (Bottger, 1942; Beck et al., 1949). These formulations, with some modification, are the basis of diets for many other insects. Both sunflower moth species have been maintained successfully on laboratory diets (Vanderzant et al., 1962; Barker, 1988). However, there is renewed interest in diet components to produce laboratory-reared insect pest species more efficiently. Improvements in artificial diets would be of benefit in laboratory studies. The purpose of this study was to compare three diets and to determine which was the most efficient diet to rear both species.

Materials and Methods

TEST INSECT SPECIES: Banded sunflower moth larvae were from a colony maintained in the Biosciences Research Laboratory, ARS, USDA, Fargo, ND. The rearing procedure used to maintain the parental stock culture was described by Barker (1988). Sunflower moth larvae were from a colony maintained in the Department of Entomology, North Dakota State University, Fargo, ND. The rearing procedure used to maintain the parental stock culture was described by Brewer (1991).

DIET INGREDIENTS: The ingredients of the three diets (A, B, and C) are listed in Table 1. Sunflower moth diet (A) was originally developed by Vanderzant et al. (1962) for rearing of *Heliothis zea*. Banded sunflower moth diet (B) was modified from sunflower moth diet (A) by substituting sunflower meal (ground seed) for casein and

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Table 1. Ingredients of three artificial diets compared for laboratory rearing of the banded sunflower moth and the sunflower moth.

Ingredient	Diet		
	A	B	C
	Mixture (#1)		
Distilled water	200.00 ml	200.00 ml	200.00 ml
Agar	7.90 g	7.90 g	7.90 g
	Mixture (#2)		
Distilled water	77.14 ml	20.00 ml	77.14 ml
Wheat germ	9.38 g	4.72 g	9.38 g
Sunflower meal	—	20.00 g	—
Casein	10.96 g	—	10.96 g
Wesson salt mixture	3.36 g	3.40 g	3.36 g
Sucrose (granular)	10.96 g	11.50 g	10.96 g
	Mixture (#3)		
Vitamin premix	3.16 g	3.15 g	3.16 g
Sorbic acid salt	0.69 g	0.65 g	0.69 g
Methyl paraben	0.69 g	0.65 g	0.69 g
Ascorbic acid	1.68 g	1.25 g	1.68 g
Choline chloride	0.30 g	0.32 g	0.30 g
Benomyl	—	0.05 g	—
Distilled water	—	—	38.40 ml
lyophilized sunflower leaves	—	—	6.78 g

A) sunflower moth diet, B) banded sunflower moth diet, and C) modified sunflower moth diet.

benomyl was added to inhibit fungal growth (Barker 1988). Modified sunflower moth diet (C) ingredients were the same as those of sunflower moth diet (A) except for the addition of lyophilized sunflower (cv: Hybrid 894) leaves and extra water.

DIET PREPARATION: The procedure used to prepare all three diets was the same. Ingredients of mixture (#1) were brought to boil and blended for approximately 30 seconds. After a brief cooling period, ingredients of mixture (#2) were added and blended for two minutes. Immediately thereafter, ingredients of mixture (#3) were added and blended for an additional five minutes. The diet was then transferred to a flask and placed in a hot water bath to keep the diet in a liquid state. Each of three diets was apportioned using a Unispense II (Wheaton Instruments, Millville, NJ) dispenser calibrated to deliver 4-ml of diet into a translucent plastic cup (29.6 ml).

After each diet had solidified and cooled, a camel's-hair brush was used to place a single 1-d old larva into each of 30 plastic containers per diet. The containers were-capped and then placed in a growth chamber maintained at 29.5° ± 1° with a light : dark (L:D) cycle of 15:9. Relative humidity was not controlled. Each diet was tested with three replications of 30 first instar larvae for each species.

DATA COLLECTION: For both experiments beginning at 10-days, larvae were examined daily to measure developmental times from first instar to pupa, from pupa to adult, and from first instar to adult. Percent survival to the pupal and adult stages was also measured. The experiments were terminated at six weeks. Individuals that had not reached the adult stage by then were considered dead.

Table 2. Comparison of three diets for development and percent survivorship of the banded sunflower moth.

Diet	Developmental times (±SEM), days			Survivorship (±SEM) (%)	
	1st instar-pupa	Pupa-adult	1st instar-adult	Pupa	Adult
A	29.31 ± 1.02 a	7.85 ± 0.63 b	35.89 ± 0.95 a	9.97 ± 5.58 b	7.76 ± 4.64 c
B	24.33 ± 0.45 c	9.56 ± 0.28 a	33.69 ± 0.48 b	56.90 ± 5.58 a	34.03 ± 4.64 b
C	25.99 ± 0.38 b	8.76 ± 0.21 ab	34.99 ± 0.35 a	71.13 ± 5.58 a	53.37 ± 4.64 a

Means in a column followed by the same letter are not significantly different ($P < 0.05$).
A) sunflower moth diet, B) banded sunflower moth diet, and C) modified sunflower moth diet.

STATISTICAL ANALYSIS: Data were analyzed according to a randomized complete block design using the general linear model procedure of the SAS system (SAS Institute, 1985) for both experiments. When the F tests for treatments were significant ($P < 0.05$), treatments were compared by multiple t-tests obtained by the least squares means statement of general linear model (SAS Institute, 1985).

Results

The developmental times and percent survivorship of the banded sunflower moth on the three diets (A, B and C) are summarized in Table 2. When compared with the banded sunflower moth diet (B), banded sunflower moth larvae fed either sunflower moth diet (A) or modified sunflower moth diet (C) required a significantly longer time to the pupal ($F = 11.06$; d.f. = 2, 114; $P = 0.0001$) and adult ($F = 3.35$; d.f. = 2, 76; $P = 0.0402$) stages. However, developmental times from pupa to adult stage ($F = 4.36$; d.f. = 2, 70; $P = 0.0165$) was significantly slower on the banded sunflower moth diet (B) than the other two diets (Table 2). Percentage of banded sunflower moth larvae surviving to the pupal stage ($F = 28.32$; d.f. = 2, 4; $P = 0.0044$) was highest on the banded sunflower moth diet (B) and the modified sunflower moth diet (C). However, survival to the adult stage ($F = 24.36$; d.f. = 2, 4; $P = 0.0058$) was poor on banded sunflower moth diet (B) compared to the modified sunflower moth diet (C).

The developmental times and percent survivorship of the sunflower moth on the three diets (A, B and C) are summarized in Table 3. Sunflower moth larvae fed modified sunflower moth diet (C) required significantly less time to develop to the pupal stage ($F = 101.70$; d.f. = 2, 191; $P = 0.0001$) and to the adult stage ($F = 75.13$; d.f. = 2, 167; $P = 0.0001$) than larvae fed either sunflower moth diet (A) or banded sunflower moth diet (B). The pupal to adult period ($F = 8.39$; d.f. = 2, 161; $P = 0.0003$) was prolonged by about a day on the modified sunflower moth diet (C). Percent survival of sunflower moth larvae to the pupal ($F = 9.26$; d.f. = 2, 4; $P = 0.0315$) and adult ($F = 52.81$; d.f. = 2, 4; $P = 0.0013$) stages was significantly greater on the modified sunflower moth diet (C) than on the banded sunflower moth diet (B) but equal to the sunflower moth diet (A).

Discussion

The sunflower moth diet (A) was inadequate for the banded sunflower moth. Developmental times were slow and survival was very low. Larvae reared on modified sunflower moth diet (C) were slow developing, reaching the adult stage about 1.3

Table 3. Comparison of three diets for development and percent survivorship of the sunflower moth.

Diet	Developmental times (±SEM), days			Survivorship (±SEM) (%)	
	1st instar-pupa	Pupa-adult	1st instar-adult	Pupa	Adult
A	19.01 ± 0.26 a	7.45 ± 0.15 b	26.18 ± 0.23 a	79.87 ± 4.87 ab	71.10 ± 2.04 ab
B	19.21 ± 0.29 a	6.99 ± 0.18 c	26.33 ± 0.29 a	56.67 ± 4.87 b	46.67 ± 2.04 b
C	14.65 ± 0.24 b	7.90 ± 0.14 a	22.67 ± 0.23 b	84.43 ± 4.87 a	73.33 ± 2.04 a

Means in a column followed by the same letter are not significantly different ($P < 0.05$).
A) sunflower moth diet, B) banded sunflower moth diet, and C) modified sunflower moth diet.

days later than those reared on banded sunflower moth diet (B). However, percent survival to the adult stage was 1.6 times higher on modified sunflower moth diet (C) containing leaf tissue than on banded sunflower moth diet (B) containing sunflower seed meal. Davis (1972) describes a test of several oilseed meals as protein sources for *Tenebrio molitor.* Of the meals tested, sunflower meal was one of the best protein sources. Because the banded sunflower moth does not survive well on diets with casein as the primary protein source, Barker (1988) developed a superior diet which substituted sunflower meal for casein as the main protein source. Our data agree with Barker (1988) in that survival of the banded sunflower moth larvae on banded sunflower moth diet (B) with sunflower meal was almost five times greater than on standard sunflower moth diet (A) with casein. However, survival on modified sunflower moth diet (C) with incorporated leaf tissue and casein was even greater and developmental times were not much different from those on banded sunflower moth diet (B) without casein. Thus, the protein source, casein or sunflower meal, does not seem important. Unidentified components in sunflower may be contributing to the greater survival and faster development of the banded sunflower moth larvae on diets with sunflower tissue. These components are apparently in both sunflower meal and leaf tissue although they may not be present in the same amounts or be equally available.

The sunflower moth (A) and modified sunflower moth (C) diets were adjusted so that both had the same proportion of dry ingredients (0.18). The proportion of dry ingredients for the banded sunflower moth diet was 0.24. Reese and Schmidt (1986) discuss the effects of the percent dry matter in diets on efficiency of conversion of ingested food. In general, efficiency was negatively correlated with percent dry matter of artificial diet. Thus, the greater water availability in the modified sunflower moth diet (C) compared to the banded sunflower moth diet (B) may have increased the diet digestibility and led to a greater survival rate.

Modified sunflower moth diet (C) was also superior for production of the sunflower moth. The average developmental time from neonate to adult was about 3.5 days shorter on the modified sunflower moth diet (C) than either on sunflower moth diet (A) or banded sunflower moth diet (B). Modified sunflower moth diet (C) also produced about 1.6 times more adult moths than the banded sunflower moth diet.

The sunflower moth and the banded sunflower moth larvae both attack and destroy sunflower seeds and coexist in some habitats, thus bioassays may need to be done with both sunflower moth species. The modified sunflower moth diet (C) provides a medium which can be used to successfully rear both sunflower moth species to adulthood. Thus, the use of modified sunflower moth diet (C) with incorporated with leaf tissue and casein as a single medium will reduce the labor, time, and cost of ingredients in diet preparation. The modified sunflower moth diet (C) is an economical and practical diet for rearing both sunflower moth species.

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