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ECONOMIC INJURY LEVEL AND IMPACT OF THE BANDED SUNFLOWER MOTH (*Lepidoptera: Cochylidae*) POPULATIONS ON SEED PRODUCTION IN SUNFLOWER*

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SUMMARY

Larvae of the banded sunflower moth, *Cochylis hospes,* feed and develop within seeds of cultivated sunflower in the northern Great Plains of the United States and Canada. This research was designed to delineate larval damage to sunflower seeds from known adult populations, and develop an economic injury level (EIL) for *C. hospes* using field and cage studies. Calculations showed that with aerial application costs of $17.30/ha, a sunflower market price of $0.20/kg, and a plant population of 44,600/ha, the EIL was 5.9 larvae per head. A decision of whether economic damage is likely to occur is based on known populations of adult moths. The regression equation ($\overline{Y} = 1.69 + 23.93X$) predicted a final number of mature larvae ($\overline{Y}$) based on the average number of adults per 10 plants during daylight hours in July (X) from 1983-1985 and 1988-1989. A density of 1 adult per 56 plants resulted in an EIL of 5.9 larvae per head. Treatment is directed at larvae and is most effective when applications are made at the R5.1 sunflower growth stage. In 1990, cages infested with one adult per plant resulted in 9.3 larvae per head; cages infested with 10 adults per plant produced 55.2 mature larvae per head. The number of mature seeds damaged by feeding larvae varied from 59.6 seeds per plant in cages with infested with 1 adult per plant to 294.3 damaged seeds per plant in cages infested with 10 adults per plant. Results were similar in 1991. The regression equation to predict mature larvae per head ($\overline{Y}$) was based on adult infestation level (X) was $\overline{Y} = 7.34 + 4.60X$. Thus, each adult results in 11.94 mature larvae per head. Each larva destroyed 6.1 and 4.8 mature seeds in 1990 and 1991, respectively.

Key words: Banded sunflower moth, *Cochylis hospes*, economic injury level, sunflower, *Helianthus*

INTRODUCTION

The banded sunflower moth, *Cochylis hospes* Walsingham (Lepidoptera: Cochylidae), is a pest of cultivated sunflower in the northern Great Plains of the United States and the Canadian prairie provinces of Manitoba and Saskatchewan (Westdal, 1949; Charlet and Busacca, 1986). Beregovoy et al. (1989) reported that moths were caught in pheromone traps from New Jersey to Oregon, and from North Dakota to southern Texas. Beregovoy and Riemann (1987) and Charlet et al. (1992) also reported that banded

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sunflower moth larvae infest heads (capitula) of six species of native sunflower in eastern North Dakota and western Minnesota. Aslam and Wilde (1991) noted that *C. hospes* is a potential pest of cultivated sunflower in Kansas due to its increasing populations.

Female banded sunflower moths deposit eggs on the sunflower bracts and outer surface of the receptacle (Charlet and Gross, 1990). Larvae of *C. hospes* feed and develop within seeds (achenes) in the sunflower head (Beregovoy and Riemann, 1987). Larvae also feed on the involucral bracts, disk flowers and pollen. Immature seeds are completely consumed. Early feeding damage by larvae has a direct impact on the final yield of infested plants (Charlet and Busacca, 1986; Charlet and Miller, 1993). Mature seeds may have their entire contents consumed by 3rd to 5th instars, with 6-7 mature seeds destroyed per larva (Charlet and Gross, 1990).

The biology, seasonal abundance, adult activity, and life tables of the banded sunflower moth have been reported (Beregovoy and Riemann, 1987; Beregovoy et al., 1989; Bergmann and Oseto, 1990; Charlet and Gross, 1990). Charlet and Busacca (1986) demonstrated insecticidal treatment efficacy at different plant growth stages and Oseto et al. (1989) revealed that a delayed planting reduces moth damage without a loss of yield. However, more information is needed on the relationship between adult populations and larval density, and subsequent feeding injury by larvae. The purpose of this research was to determine larval damage to sunflower heads resulting from known populations of adults, and to develop an economic injury level for the banded sunflower moth in cultivated sunflower.

MATERIALS AND METHODS

Field Studies. We conducted studies in 0.5 ha plots from 1983-1985 at Erie, North Dakota and at Prosper, North Dakota from 1988-1989. Plots were seeded with sunflower hybrid '894' on soil that had received a pre-plant application of trifluralin for weed control. No insecticides were applied on the plots in any year. Plots were seeded between 9-13 May in rows with 76.2 cm centers. Plants were spaced 30.5 cm within a row, at a plant population of about 47,000 plants per hectare.

Sampling for banded sunflower moth began when plants were in the vegetative (V2) growth stage (appearance of the first pair of true leaves) (Schneiter and Miller, 1981). Sampling continued 1 or 2 times per week until larvae were no longer detected in sunflower seeds. Adults were visually counted on 10 plants at five randomly selected sites in each of four blocks per plot (200 plants total). A total of 2-5 randomly selected sunflower heads per block (8-20 heads per plot) were removed from the field and held in the laboratory at 4-5^{o}C for subsequent examination. The number of larvae infesting seeds of a head was determined by dissecting the head to expose damaged seeds. The mean number of adults observed in the field and laboratory counts of the mean number and larvae per head were determined. The average developmental growth stage of sunflower plant also was determined for each sampling date.

After physiological maturity of the plants (R9, September-October), 5-15 randomly selected heads per block (20-56 per plot) were removed and taken to the laboratory to determine seed weight per head, number of seeds per head and percent of damaged seeds.

Regression analysis was used to relate populations of mature larvae with average adult populations in the field (SAS Institute, 1990).

Cage Studies. Experiments were conducted in 1990 and 1991 at Fargo, North Dakota, in Lumite saran screened cages (1.8 X 1.8 X 1.8 m) supported internally with four square aluminum conduit frames. Metal rods were pounded into the ground and attached to the frames at each inside corner. Cages were secured to the soil with cables. The 5 treatments (0, 1, 2, 4, 10 adults per plant) were replicated 3 times in a randomized block design. Cages were seeded with oilseed sunflower hybrid '894' on land previously treated with trifluralin for weed control on 15 and 21 May, in 1990 and 1991, respectively. Plants within cages were thinned to a final population of 15 plants per cage. No insecticides were applied to the plants.

Adult banded sunflower moths were reared in the laboratory using procedures of Barker (1988). Adult moths (1:1 sex ratio) were added to cages when plants were at the R3 (bud) growth stage. The 1:1 sex ratio used in the study was based on field observations reported by Beregovoy and Riemann (1987) that showed an equal male to female ratio. Soil was banked against the base of the cages to prevent insect entry or exit. Heads were bagged prior to maturity to collect larvae as they exited the sunflower heads. At physiological maturity of plants, heads (5-10 per cage) were harvested (21-26 September), the larvae were removed and the heads were dried and seeds removed. The number of seeds and their weight per head were determined. Seeds were visually evaluated for feeding damage by larvae based on the presence of exit holes, or larvae remaining in the seed. The number of larvae per head and number of damaged seed per head were determined. The number of seeds damaged per larva was also calculated. Data were subjected to analysis of variance and significantly different means were separated using LSD. Data from the two years were compared (GLM) for significant interactions and a regression analysis was used to predict larval density based on adult infestation levels (SAS Institute, 1990).

RESULTS AND DISCUSSION

Field Studies. There have been many definitions of the economic injury level since the concept was first discussed by Stern et al. (1959); but most definitions consider it to be the point where management costs and the benefit from control are equal. The economic injury level is not a static value, because individual components such as market price for products and costs of control frequently change. Oseto and Braness (1980) developed an economic injury level for the red sunflower seed weevil, *Smicronyx fulvus* LeConte, and McBride et al. (1992) recently updated it. To determine an economic injury level, one must calculate a gain threshold or minimum economic damage which is:

(1) Gain threshold = Chemical application costs ($/ha) / Market price of the crop($/ha)

At a market price of $0.20/kg, which was the average sunflower price for the period 1977-1978 to 1990-1991 (Flaskerud, 1994), and an aerial application cost of $17.30/ha, the gain threshold is 86.5 kg/ha. Approximately 6-7 seeds are destroyed by each *C. hospes* larva (Charlet and Gross, 1990). Therefore, based on an average weight of 0.05 g per sunflower seed (n=100), each banded sunflower moth larva destroys 0.33 g (0.00033 kg) of seed. Dividing the gain threshold by 0.00033 kg, which is the amount of seed destroyed by each larva, results in an estimate of the number of *C. hospes* larvae per ha required to produce the minimum economic damage (86.5 kg/ha):

(2) No. larvae/ha = Gain threshold (kg/ha) / Weight loss caused by a single larva (kg)

The number of larvae per ha required to reach the gain threshold is thus 262,122 larvae per ha. The number of larvae per head needed to reach the gain threshold is based on the plant population in the field.

(3) No. larvae/head = No. larvae per ha / Plants (heads) per ha

Therefore, with a plant population of 44,600 heads per ha, a total of 5.9 larvae per head would equal the economic injury level for our assumed parameters (treatment costs, sunflower market price, and plant population).

The economic injury level is based on the number of larvae per head. However, a decision on whether economic damage is likely to occur is based on the number of adult moths in the field. Therefore, a way is needed to translate adult populations to the number of larvae that will result from their eggs.

Adults of the banded sunflower moth are active in sunflower fields during July in North Dakota. Although peak populations occur during the second half of July, adults are present in fields until mid-August (Beregovoy and Riemann, 1987; Charlet and Gross, 1990). Although some moths are active in sunflower fields during the day, most remain in vegetation along field margins. At twilight, females move into a field to oviposit. Dissection of adult females indicated that mating occurs before moths enter a sunflower field. The average adult life span for moths is 7 to 10 days. The sex ratio of moths in fields indicate an equal number of males and females (Beregovoy and Riemann, 1987; Bergmann and Oseto, 1990). Within a week after their emergence, moths begin laying eggs on bracts when sunflower is in the late bud stage. Females lay more eggs on pre-bloom to bloom stage sunflower (R4-5) than on early bud (R2-3) or post-bloom (R6) sunflower. The majority of eggs are deposited on the outer whorl of bracts, but some eggs also are laid on the underside of sunflower heads (Beregovoy and Riemann, 1987; Charlet and Gross, 1990).

Moth density was much lower in July 1988 and 1989 than in 1983-1985 (Table 1). We used a regression equation ($P<0.003$, $R^2 = 0.96$) to predict the final number of mature larvae (*Y*) resulting from an average adult populations (number per 10 plants) made during daylight hours in the field during mid to late July (X), when plants are in the late bud stage. The equation was: $\overline{Y} = 1.69 + 23.93X$ (SE a = 2.75, SE b = 1.96). A density of 0.18 adults per 10 plants (1 adult per 56 plants) in the field in late July will result in a larval population of 5.9 per head.

A sunflower field must be monitored to determine if adult populations exist that will result in an economic injury level (larvae per head). The scouting should be conducted prior to anthesis (R5) of plants. Since adults congregate along field margins, shelterbelts, and other areas outside of sunflower fields during the day and move into fields at night, treatment is directed at larvae feeding in the sunflower head. Control is most effective when application is made at the R5.1 growth stage, or when plants have just begun to shed pollen. At this plant stage, banded sunflower moth larvae are present but sunflower heads have not begun forming seeds (Charlet and Busacca, 1986). Charlet and Gross (1990) reported that the peak density of first instars occurs between 28 July and 6 August when plants are in the R4-5 growth stage. When plants are in the R4-5 stage, larvae begin feeding on disk flowers, may be exposed on the head, and are most susceptible to the insecticidal treatment. On older plants where seeds have started maturing, most larvae will be feeding within the seeds and will be protected from insecticides. Also, on older plants, much of the feeding damage has already occurred.

Table 1. Adult banded sunflower moth populations per 10 plants during July, and resulting mature larvae per sunflower head, North Dakota, 1983-1985, 1988-1989.

	Mean number [a]	
Year	Moths / 10 plants during July	Mature larvae / head
1983	0.52	16.9
1984	1.40	34.4
1985	0.47	14.5
1988	0.01	2.1
1989	0.29	4.9
Mean	0.54	14.6

[a] Regression between adult population and larval density significant at $P<0.003$ ($R^2 = 0.96$)

Table 2. Number of damaged seeds, seeds per head, yield and larvae per head at different adult banded sunflower moth infestation levels at Fargo, ND, 1990-1991.

	Mean ± SE [a]			
Adults per plant	No. damaged seeds/plant	No. seeds per head	Seed wt (g) per head	No. larvae per head
1990				
0	0a	1387.8±83.2ab	56.8±4.5ab	0a
1	59.6±8.4b	1421.8±70.9a	63.3±5.1b	9.3±1.2a
2	125.8±12.2c	1216.4±94.0ab	50.7±4.7ab	22.8±2.5b
4	169.1±14.5d	1339.0±78.1ab	59.2±4.8b	36.5±3.4c
10	294.3±27.2e	1167.8±107.1b	45.0±6.1a	55.2±6.1d
1991				
0	0a	1539.1±64.2a	69.6±4.2a	0a
1	54.4±5.0b	1288.8±45.5b	68.4±4.0a	11.9±1.2b
2	84.2±9.3b	1324.4±57.6b	61.9±4.0a	18.1±1.9b
4	136.4±15.5c	1223.8±50.1b	50.6±3.6b	32.8±3.7c
10	203.1±20.3d	1268.6±47.1b	60.7±3.3ab	44.3±4.2d

[a] Means in a column followed by the same letter in a column are not significantly different (p=0.05; LSD)

Cage Studies. In 1990, cages infested with one *C. hospes* moth per plant resulted in 9.3 larvae per head and plants infested with 10 adults per plant had produced 55.2 mature larvae per head at the end of the season. There was a significant difference between each moth infestation level tested (F=42.07, df=4, P=0.0001) (Table 2). The number of mature seeds damaged by larval feeding varied from 59.6 in the cages with 1 adult per plant to 294.3 damaged seeds in the cages with 10 adults per plant (F=55.68, df=4, P=0.0001). A significant difference was detected between each moth infestation level. Results were similar in 1991, although there was no difference in either the number of larvae per head or number of damaged seed in the cages infested with one or two adults per plant (Table 2). There were less larvae per head in the cages at most of the moth infestation levels and correspondingly fewer damaged seeds per plant than in 1990.

There was no significant difference between g of seed produced per head in 1990 and 1991 between the control and the cages infested with ten adults per plant. This was surprising considering the large number of seeds damaged and the fact that there was a significant reduction in the number of seeds per head between the control and the cages infested with ten adults per plant (Table 2). A possible reason for the lack of a yield difference could be that both damaged and undamaged seeds were included in determining the gm of seed produced per head. Under normal field conditions, the combining process would not retain damaged seeds and they would be lost, thus resulting in a lower seed weight in the hopper. The reduced number of mature seeds per head likely is due to feeding by the early instars on disk flowers and immature seeds (Charlet and Busacca, 1986). Destruction of disk flowers may adversely affect yield in sunflower since plants do not compensate for lost disk flowers during seed filling (Charlet and Miller, 1993).

Data for number of larvae per head in 1990 and 1991 were combined and subjected to GLM to determine if there was a year by treatment interaction. A t-test showed that there was no significant interaction in the number of larvae per head between the 2 years and the different moth infestation levels (t=1.97, df=319, P=0.22), so the data were combined for a regression analysis. The regression equation used to predict the number of mature larvae per head based on adult populations was $\overline{Y}=7.34+4.60X$ (SE a=0.28, SE b=1.40). Thus, each adult results in 11.94 mature larvae per plant. The r^2 of only 0.44 showed that there are other variables unaccounted for that also influence the density of larvae that successfully develop to maturity on the sunflower head. The higher number of larvae produced per adult in the cages compared with the field data reported earlier in this paper is probably because in the cage studies adults were confined and in the field studies adult population estimates were made during the day when fewer adults are present in the fields.

The number of seeds damaged per larva was calculated for 1990 and 1991 for each of the adult infestation levels based on number of larvae per head and number of damaged seed per head. A comparison among adult infestation levels showed no significant difference among any of the four treatments at the 5% level in either year. In 1990, larvae destroyed a mean of 6.1±0.3SE mature seeds. The number of seeds destroyed by each larva was slightly lower in 1990 than in 1991, with a mean of 4.8±0.2SE seeds per larva. These results are similar to the 6.0 to 6.9 mature seeds consumed per larva reported by Charlet and Gross (1990) from field data.

CONCLUSIONS

The economic injury level for the banded sunflower moth was determined to be 5.9 larvae per head, when the chemical application costs were $17.30 per ha, the market price for sunflower seed was $0.20 per kg, and the plant population was 44,600 per ha. The EIL is dynamic, so it will vary depending on fluctuating prices received for sunflower seed, application costs, and plant density. For example, when higher prices for sunflower seed are expected, the EIL for the banded sunflower moth would be lower. The decision on whether larval populations will reach the EIL is based on adult *C. hospes* populations in the fields during mid to late July. The regression equation to predict the adult density which will result om the EIL is: $\overline{Y}=1.69+23.93X$. An adult population of 1 adult per 56 plants will result in an EIL of 5.9 larvae per head. An assessment of adult populations needs to be made prior to anthesis since treatment is most effective at the R5.1 sunflower growth stage. Results from cage studies infested with 1 to 10 adult banded sunflower moths per plant showed that each moth resulted in 11.94 mature larvae per plant ($\overline{Y}$=7.34 +4.60X). The higher number of larvae produced per adult in the cages compared with the field data reported earlier in this paper is probably because in the cage studies adults were confined and in the field studies adult population estimates were made during the day when fewer adults are present in the fields. The cage studies also revealed that an average of 5 to 6 seeds are consumed by each larvae, which is similar to the number of seeds destroyed per larva in the field.

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NIVEL ECONOMICO DE DAÑOS E IMPACTO SOBRE LA PRODUCCION DE SEMILLAS DE LA POLILLA DE BANDAS DEL GIRASOL (*Lepidoptera: cochylidee*).

RESUMEN

Las larvas de la polilla de bandas de girasol, *Cochylis hospes*, se alimentan y desarrollan dentro de las semillas del girasol cultivado en el norte de la Gran Llanura de los Estados Unidos y Canadá. Esta investigación se diseño para definir el daño de larvas en las semillas de girasol de poblaciones conocidas del adulto y desarrollar un nivel económico de daños (EIL) para *C. hospes* utilizando estudios en campo y cajas. Los cálculos mostraron que con la aplicación aerea de 17-30 $/ha, un precio de mercado de 0.20 $/kg, y una población de 44600 pl/ha, el EIL fué de 5-9 larvas por capítulo. La decision de si el daño económico se produce se basó en poblaciones conocidas de adultos de polillas. La ecuación de regresión ($\overline{Y}$= 1.69 + 23.93 X) predijo un número final de larvas adultos ($\overline{Y}$) en 10 plantas durante las horas del dia en Junio (X) desde 1983-1985 y 1988-1989. Una densidad de una dulto por 56 plantas resultó un EIL de 5.9 larvas por capítulo. El tratamiento es dirigido a las larvas y es mas efectivo cuando las aplicaciones son realizadas en el estado de crecimiento R. 5.1. En 1990 las cajas infectadas con un adulto por planta resultaron un 9.3 larvas por capitulo. El número de semillas maduras dañadas por las larvas varió desde 59.6 semillas por planta en las cajas infectadas con 1 adulto por planta a 294.3 semillas por planta en cajas infectadas con 10 adultos por planta. Los resultados fueron similares en 1991. La ecuación de regresión para predecir las larvas maduras por capítulo ($\overline{Y}$) basada en el nivel de infectación de adultos (X) fué $\overline{Y}$= 7.34 + 4.60 X. Por tanto, cada adulto resultó en 11.04 semillas maduras por capítulo. Cada larva destruyó 6.1 y 48 semillas maduras en 1990 y 1991 respectivamente.

IMPORTANCE DES DÉGÂTS ÉCONOMIQUES ET IMPACT SUR LA PRODUCTION DE GRAINES DE TOURNESOL DES POPULATIONS DE MOUCHE RAYÉE DU TOURNESOL (*Lepidoptera Cochylidae*).

RÉSUMÉ

Les larves de la mouche rayée du tournesol, *Cochylis haspes*, se nourrissent et se développent à l'intérieur des graines due tournesol cultivé dans les grandes plaines du Nord des Etats Unis et du Canada. Cette recherche a été entreprise pour définir les dégâts occasionnés aux graines de tournesol par les larves des populations adultes connues, et pour estimer l'incidence économiques des dommages (EIL) causés par à *C. hospes,* en réalisant des études au champ et sous cage. Des calculs montrent qu'avec des coûts d'application aériens de $ 17.30/ha, un prix du marché du tournesol à $ 0.20/kg, et un peuplement de 44600/ha, l'EIL était de 5.9 larves par capitule. La prévision de l'importance des dommages économiques est basée sur la connaissance des populations de mouches adultes. L'équation de régression ($\overline{Y}$=1.69 + 23.93X) prédit un nombre final de larves matures ($\overline{Y}$) basée sur le nombre moyen d'adultes pour 10 plantes durant les heures de jour en Juillet (X) de 1983 à 1985 et de 1988 à 1989. Une densité de 1 adulte pour 56 plantes conduit à un EIL de 5.9 larves par capitule. Le traitement est dirigé sur les larves et est plus efficace lorsque les applications sont faites au stade végétatif repère du tournesol R5.1. En 1990, des cages infestées avec 1 adulte par plante produisirent 9.3 larves par capitule; des cages infectées par 10 adultes par plante produisirent 55.2 larves matures par capitule. Le nombre de graines mûres endommagées par les larves a varié entre 59.6 graines par plante dans les cages infestées par 1 adulte par plante jusqu'à 294.3 graines endommagées par plante dans cages infestées par 10 adultes par plante. Les résultates de 1991 étalient similaires. L'équation de régression pour prédire le nombre de larves matures par capitule ($\overline{Y}$) basé sur le degré d'infestation par les adultes (X) était $\overline{Y}$=7.34 + 4.60 X. Ainsi, chaque adulte a prodult 11.94 larves matures par capitule. Chacune des larves a détruit 6.1 et 4.8 graines matures, respectivement en 1990 et 1991.