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RESISTANCE AMONG CULTIVATED SUNFLOWER GERMPLASM TO THE BANDED SUNFLOWER MOTH (Lepidoptera: Tortricidae) IN THE NORTHERN GREAT PLAINS

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SUMMARY

A five year field trial evaluated 71 oilseed sunflower, *Helianthus annuus* L., accessions, 32 breeding lines, and 25 interspecific crosses for resistance to infestation by naturally occurring populations of the banded sunflower moth, *Cochylis hospes* Walsingham (Lepidoptera: Tortricidae), in North Dakota. Germplasm with resistance to attack by the banded sunflower moth and subsequent larval feeding damage in the seeds was identified. PI 251902 had less than 10% feeding damage per head in all five years of testing and less than 6% in three of the five years. PI 372259 and PI 170401 exhibited 12% or less seed damage in three years of evaluation and PI 253776 had only 3% damage in two of the three years and was the least damaged in 2004. Four other accessions (PI 170385, PI 291403, PI 494859, and PI 505651) revealed resistance in three of five years. A number of the interspecific crosses which were retested based on earlier results showed reduced seed damage in 2003, but subsequently exhibited much greater damage the following year due to higher populations of banded sunflower moth. Hybrid 894 was earlier used by others as a susceptible check; however, in the current investigation, this hybrid consistently had the lowest average seed damage from *C. hospes* feeding among the germplasm evaluated. Results from this investigation indicate that there is potential for developing resistant genotypes with reduced feeding injury that will help sunflower producers reduce yield loss due to the banded sunflower moth. In addition, plant resistance can effectively be combined with delayed planting to decrease densities of *C. hospes*, thus reducing crop losses without disrupting the control of the larvae by parasitoids.

Key words: ***Cochylis hospes*, sunflower, *Helianthus*, host plant resistance**

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INTRODUCTION

During the development of the sunflower (*Helianthus annuus* L.) crop in the Northern Plains in the 1960s and 1970s, the banded sunflower moth, *Cochylis hospes* Walsingham, was reported by Schulz (1978) to be a noneconomic problem requiring no pest management practices. However, since the early 1980s, cultivated sunflower fields in North Dakota, Minnesota, and South Dakota have frequently had economic damage caused by the moth (Charlet and Busacca, 1986; Charlet *et al.,* 1997; Knodel and Charlet, 2007). The banded sunflower moth also occurs on sunflower in the Canadian prairie provinces of Manitoba, Saskatchewan, and Alberta (Westdal, 1975; Arthur and Campbell, 1979) and populations also have been increasing in Kansas (Aslam and Wilde, 1991). Banded sunflower moth larvae have been recovered from nine species of native sunflowers in the United States (Rogers, 1988ab; Beregovoy and Riemann, 1987; Charlet *et al.,* 1992).

Moths spend much of their time in vegetation along field margins during the day. At twilight, females move into the fields to oviposit. Dissections of moths indicated that females mate before entering sunflower fields (Beregovoy and Riemann 1987; Beregovoy *et al.,* 1989). Oviposition begins during early July and continues for approximately 6 weeks. The majority of eggs are oviposited on the outer whorl of the involucral bracts, and some eggs are deposited on the underside of the sunflower head. Newly emerged larvae are found on the involucral bracts and later move to the disk flowers and feed on pollen. Third instars tunnel through disk flowers and feed on immature developing seeds. As the seeds mature and harden, larvae chew into the seeds (Westdal, 1949; Charlet and Busacca, 1986). Consumption of disk flowers may adversely affect yield in sunflower as heads may not compensate for lost disk flowers during seed filling (Charlet and Miller, 1993). After feeding on the kernel of a mature seed, the larva moves to a new seed. Each larva consumes more than six mature seeds (Charlet and Gross, 1990). At maturity, larvae drop from the head and enter the soil to overwinter in silken cocoons (Westdal, 1949; Beregovoy and Riemann, 1987; Charlet and Gross, 1990).

The primary management strategy for control of banded sunflower moth has been the use of insecticides, although research has also shown that delayed planting can reduce feeding damage (Charlet and Busacca, 1986; Oseto *et al.,* 1989). In addition, crop management programs relying primarily on insecticide usage can be detrimental to both parasitoid diversity and activity. There are a number of predators and several parasitoid species attacking the banded sunflower moth. However, in most years the control exerted by these natural enemies is inadequate to maintain banded sunflower moth populations below economic injury levels (Bergmann and Oseto, 1990; Charlet, 2001). Genetic resistance offers an alternative management strategy that would decrease economic losses from seed-infesting sunflower pests while reducing input costs. Resistance to the banded sunflower moth was reported in some sunflower germplasm (Brewer and Charlet, 1989; Jyoti and

Brewer, 1999) and in some native sunflower species (Charlet and Brewer, 1995). Studies were initiated in 2002 in North Dakota to evaluate sunflower germplasm for potential resistance to banded sunflower moth. Diverse sunflower germplasm was exposed to naturally occurring moth infestations to evaluate differences in seed damage caused by this insect pest.

MATERIALS AND METHODS

During the 2002 to 2006 growing seasons 71 oilseed sunflower accessions, 32 breeding lines in early generation selection, and 25 interspecific crosses were evaluated for resistance to infestation by naturally occurring populations of the banded sunflower moth. Each year, USDA sunflower hybrid 894 was included in the trials. The sunflower accessions were obtained from the USDA Plant Introduction Station, Ames, IA. Interspecific crosses were provided by one of the authors (G.J.S.). Trials were conducted at the North Dakota State University Prosper Research Site in Cass County in eastern North Dakota. Twenty-three to 98 entries were evaluated annually in single-row plots 8 m long, with rows 76 cm apart, and plants spaced 30.5 cm apart within rows; ~54,000 plants/ha. Entries with relatively low levels of seed damage per head were selected for retesting in subsequent years along with some susceptible lines. Plots were planted between 18 and 27 May each year in a randomized complete block design with four replicates, except for 2005 and 2006 when only three replicates were examined. Plots received a preplant application of fertilizer and herbicide, but no other chemical treatments were used. Plants were examined prior to flowering to minimize any affect that plant maturity would have on severity of attack by *C. hospes*; lines that were deemed to be late enough to escape attack were excluded from the evaluation.

The degree of infestation was the percentage of seed with *C. hospes* feeding injury per head. Five heads per row (total of 15-20 heads per treatment) were removed after plants had senesced. Sunflower heads were harvested from September to October and sent to Fargo, ND. Heads were dried, threshed, and the seed cleaned prior to evaluation. The GLM analysis of variance option (SAS 2001) was used to compare percentage of seed damaged per head among the different treatments for each study year. Percentages were transformed to the square root of the arcsine prior to analysis. Means were separated using the Fisher protected least significant difference (LSD) test (Carmer and Walker, 1985) at $P<0.05$.

RESULTS

There were significant differences in percentage of seed damaged per head by *C. hospes* larvae among the germplasm tested from 2002 to 2006, with over 29% damaged seed per head in the most susceptible lines in four of the five years (Table 1). In 2002, the first year of the trial, the mean damage ranged from one to 42% *C. hos-*

pes seed damage per head among the 98 lines and interspecific crosses evaluated. Lines or crosses exhibiting 4% or less average feeding damage per head were tested again in 2003. Potential susceptible checks, including an interspecific cross averaging 42.1% and the line 01-4095-1 averaging 31.2% seed damage per head, also were selected.

Table 1: Percentage of seeds damaged by *C. hospes* larvae per head in selected sunflower accessions evaluated at Prosper, ND, 2003 to 2006

Accession	*C. hospes* % damaged seeds per head (mean±SE)			
	2003	2004	2005	2006
01-4027-2	11.3±2.2 ab	---	---	---
01-4056-2	9.4±2.6 bcde	---	---	---
01-4061-2	5.9±1.5 defgh	---	---	---
01-4078-2	6.8±1.5 bcdefg	---	---	---
01-4080-1	8.1±2.1 bcde	---	---	---
01-4090-1	7.8±1.4 bcde	---	---	---
01-4095-1	9.4±1.5 bcd	---	---	---
Arg 1575-2	11.9±2.9 abc	---	---	---
Deb Cuc 1810	5.6±0.7 cdefg	19.2±4.5 ghi	29.7±3.9 de	---
Des 1474-2	14.7±1.6 a	---	---	---
Gig 1616-2	6.6±1.4 bcdefg	24.9±4.9 defg	---	---
Hybrid 894 (standard check)	4.1±0.5 efghijk	8.9±0.9 jklmn	7.5±0.8 i	5.7±0.8 d
P21-VRI	---	---	32.9±7.6 cd	11.4±2.1 bc
Par 1673-2	20.3±5.7 a	39.4±5.0 c	46.5±6.9 ab	29.4±5.6 a
Pra Pra 1142	7.6±1.7 bcde	20.5±3.5 fgh	20.6±3.8 ef	---
Pra Run 1329	12.0±2.8 ab	---	---	---
Res 834-1	17.4±4.0 a	33.2±5.7 cd	17.9±3.9 fgh	24.7±3.7 a
Res 834-3	7.5±1.3 bcde	18.2±3.4 gh	---	---
Rf Ann 19	7.0±1.6 bcdef	16.6±2.7 ghij	35.3±4.5 cd	---
PI 162453	---	---	---	5.8±0.7 cd
PI 170385	1.8±0.6 k	6.3±2.3 lmnop	13.0±2.7 fghi	5.3±3.9 defg
PI 170391	4.0±1.1 fghijk	8.2±2.4 klmnop	11.2±2.4 fghi	lodged
PI 170401	---	3.4±0.8 op	12.3±2.1 fghi	1.5±0.5 efg
PI 170414	---	23.4±5.6 efg	---	---
PI 170415	-	8.2±1.5 klmno	18.9±2.8 fg	---
PI 175728	---	5.5±1.9 mnop	13.7±1.8 fghi	7.3±1.9 cd
PI 181994	---	---	---	3.3±0.7 def
PI 195573	---	---	---	1.4±0.4 efg
PI 219649	---	---	---	1.0±0.3 fg
PI 250085	---	---	---	5.5±1.9 de
PI 250855	---	---	---	4.6±2.0 de
PI 251902	5.1±1.0 efghi	8.2±1.6 klmno	9.3±1.6 hi	5.8±1.6 d
PI 253776	2.8±0.8 ijk	3.3±1.2 p	12.8±2.8 fghi	---
PI 265503	6.5±2.5 efghi	12.0±1.6 hijk	10.7±1.9 ghi	3.3±0.9 defg

Table 1: Percentage of seeds damaged by *C. hospes* larvae per head in selected sunflower accessions evaluated at Prosper, ND, 2003 to 2006

PI 267665	3.4±0.9 hijk	6.9±1.9 lmnop	19.7±3.8 fg	---
PI 291403	2.2±0.7 k	5.3±2.6 nop	16.5±3.1 fgh	2.9±0.8 def
PI 307946	---	11.6±1.6 hijk	---	---
PI 372259	---	9.0±2.2 ijkl	11.4±2.5 ghi	5.2±3.0 de
PI 386230	---	29.2±5.1 cdef	---	---
PI 431513	---	79.1±4.6 a	---	---
PI 431542	-	32.1±6.7 cde	57.5±6.8 a	---
PI 431545	---	---	---	13.8±4.6 b
PI 432516	---	---	---	0.5±0.3 g
PI 494859	2.9±0.8 ghijk	4.4±1.2 mnop	18.6±3.7 fg	5.9±2.3 d
PI 494861	2.5±0.8 jk	---	---	---
PI 497939	---	38.9±4.6 c	44.2±5.4 bc	10.9±1.7 bc
PI 505651	3.4±1.3 ijk	12.1±2.5 hijkl	13.1±2.0 fghi	1.3±0.3 efg
PI 505652	5.1±1.2 efghij	10.0±2.1 klmn	15.2±4.6 fghi	---
PI 650421	---	6.3±1.6 klmnop	15.3±2.0 fgh	---
PI 650497	---	57.4±5.7 b	---	---
PI 650558	---	39.2±6.8 c	---	---
Mean	7.1	18.6	19.8	6.5

Means followed by the same letter in a column are not significantly different ($P<0.05$; LSD); Percentages transformed to square root of the arcsine before analysis and untransformed means are presented; 7-46 heads were examined per accession each year

In 2003, the percentage of banded sunflower moth feeding damage ranged from 1.8% in accession PI 170385 to 20.3% in the interspecific cross Par 1673-2 (Table 1). PI 505651, PI 494859, PI 494861, PI 291403, and PI 170385 had less than 4% damage in both 2002 and 2003. Hybrid 894 also showed reduced feeding with average seed damage per head of 4.1%. All of the interspecific crosses and lines evaluated had greater than 5% *C. hospes* feeding damage, although two (Deb Cuc 1810 and Gig 1616-2) were lower than the trial average in the amount of seed damage per head. Crosses that sustained seed damage greater than 6% were not included in further trials.

Population densities of banded sunflower moth were much higher in the 2004 trial than in 2003, and ranged from 3% *C. hospes* damaged seed per head in accession PI 253776 to 79% in accession PI 431513 (Table 1). Hybrid 894 had a relative low percent of damaged seed per head (8.9%) compared to the trial average of 18.6%. Accessions PI 505651, PI 494859, PI 291403, and PI 170385, which had less than 4% damage in both 2002 and 2003, had only 4 to 8% *C. hospes* seed damage in 2004. PI 253776, which sustained the least amount of damage in the trial, had less than 3% seed damage in 2003. All of the interspecific crosses had moth feeding seed damage greater than 18% per head.

The percentage of banded sunflower moth feeding damage in the 2005 trial ranged from 8% seed damage per head in hybrid 894 to 58% in accession PI

431542 (Table 1). PI 251902 and PI 170391 had less than 11% *C. hospes* seed damage in 2005, compared with only 8% damage in 2004 and less than 5% in 2003. PI 265503 sustained only 11% damage in 2005 trial, showed 12% damage in 2004, and less than 7% in 2003. Hybrid 894 sustained the least amount of damage in 2005, less than 9% seed damage in 2004, and only 4% in 2003. All of the interspecific crosses had greater than 18% feeding damage, which was similar to results from 2004.

In 2006, the percentage of banded sunflower moth feeding damage was lower than observed in 2005 and ranged from 0.5% in accession PI 432516 to 29% in interspecific cross Par 1673-2 (Table 1). One of the evaluated accessions (PI 170391), which had shown reduced levels of damage to *C. hospes* in previous years, was susceptible to lodging and was lost to wind damage. The majority of the tested germplasm sustained less than 10% damage from moth larval feeding. Three of the accessions tested for the first time in 2006 were the lowest in the trial, showing less than 2% seed damage per head from banded sunflower moth feeding.

DISCUSSION

Results from this five year study revealed germplasm with resistance to attack and damage from larval feeding by the banded sunflower moth. PI 251902 showed less than 10% feeding damage per head in all five years and less than 6% in three of those years. PI 372259 exhibited 12% or less seed damage in three years of evaluation, as did PI 170401; and PI 253776 showed 3% seed damage in two of the three years of trials and was the least damaged in the 2004 trial. Four accessions (PI 170385, PI 291403, PI 494859, and PI 505651) that appeared resistant to damage from *C. hospes* in three of the five years of testing also were among the least damaged in 2005, the year with the highest trial mean.

A number of the interspecific crosses which were retested based on results of the 2002 trial and showed reduced seed damage in 2003, subsequently exhibited much greater damage in 2004. The crosses Gig 1616-2, Pra Pra 1142, and Res 834-3 had shown less than 8% *C. hospes* seed damage per head in 2003, but in the subsequent year sustained 18 to 24% damage. The interspecific cross Par 1673-2 was selected as a susceptible check and showed consistently high seed damage and in two of the four years was the most severely damaged of all the germplasm tested.

Hybrid 894 is a public domain hybrid that previously has been produced by a number of commercial sources and was included in these trials as a standard check. In the past, it was used by others as a susceptible check in banded sunflower moth studies (Brewer and Charlet, 1989; Jyoti and Brewer, 1999). However, in the current investigation this hybrid consistently had the lowest average seed damage from *C. hospes* feeding among the germplasm evaluated. In the 5 years of testing, it was under 9% seed damage each year and sustained only 4% seed damage per head in both 2002 and 2003. The reasons for the disparity in earlier results are uncertain, but some differences could have been in plant phenology. As noted by Brewer and Charlet (1989), some of the PIs with lower damage in that trial were later maturing than hybrid 894.

Results from this investigation show there is promise in developing resistant genotypes for the banded sunflower moth to reduce feeding injury and assist producers in preventing yield loss. The ability to utilize host plant resistance for controlling this insect pest would add another option for inclusion in an integrated pest management approach. Although shown to be valuable, chemical control is expensive and relies on field scouting and sampling based on counts of either adult moths or eggs on the sunflower head (Mundal *et al.,* 2006; Mundal and Brewer, 2008). In addition, plant resistance can be effectively combined with delayed planting, which has been shown to reduce densities of *C. hospes* and reduce crop loss without disrupting the biological control of the larvae by parasitoids in the field (Charlet and Busacca, 1986; Oseto *et al.,* 1989; Charlet, 2001). The nature of the resistance mechanisms resulting in the reduced seed damage in the germplasm is currently being investigated. In addition, further effort is under way to use the identified lines to introgress resistance genes into cultivated sunflower through conventional breeding facilitated by the use of marker-assisted selection.

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RESISTENCIA DE GERMOPLASMA DE GIRASOL CULTIVADO A LOS ATAQUES DE POLILLA (Lepidoptera: Tortricidae) EN LAS GRANDES PLANICIES DEL NORTE

RESUMEN

Durante 5 años, se realizó un ensayo a campo en Dakota del Norte donde se evaluaron 71 introducciones de girasol (*Helianthus annuus*) 32 líneas puras y 25 cruzamientos interespecíficos respecto a la resistencia a la infestación natural de la polilla de girasol, *Cochylis hospes* Walsingham (Lepidoptera: Tortricidae). Se identificó germoplasma con resistencia al ataque de la polilla así como a los daños posteriores de las larvas en las semillas. La introducción PI 251902 tuvo menos del 10% de daños por capítulo en los 5 años y menos del 6% en 3 de los 5 años. Las introducciones PI 372259 y PI 170401 exhibieron 12% o menos de daño en semillas en 3 años de evaluación, mientras que PI 253776 tuvo 3% de daños en 2 de los 3 años y fue la menos dañada en 2004. Otras 4 introducciones (PI 170385, PI 291403, PI 494859 y

PI 505651) revelan resistencia en 3 de los 5 años. Un número de cruzas interespecíficas que fueron reevaluados según resultados previos, mostraron daños reducidos en 2003, pero posteriormente mostraron daños muchos mayores al año siguiente debido a poblaciones más numerosas de polillas. El híbrido 894 era utilizado por otros investigadores como testigo susceptible; sin embargo, según este trabajo, este híbrido tuvo mostró el daño promedio más bajo de semillas por *C. hospes* entre el germoplasma evaluado. Los resultados de esta investigación indican que hay potencial para el desarrollo de genotipos resistentes que ayudará a los productores de girasol reducir la pérdida de rendimiento debido a la polilla de girasol. Además, la resistencia de la planta puede combinarse con un atraso en la fecha de siembra a fin de para disminuir la densidad de *C. hospes*, reduciendo las pérdidas sin por ello interrumpir el control de las larvas por los parasitoides.

RÉSISTANCE DE SOUCHES DE TOURNESOL CULTIVÉES À LA COCHYLIS RAYÉE (Lepidoptera : Tortricidae) DANS LES GRANDES PLAINES NORDIQUES

RÉSUMÉ

Un essai en champ durant cinq ans a permis d'évaluer 71 variétés de tournesol huile (*Helianthus annuus* L.), 32 lignes de sélection et 25 croisements interspécifiques pour la résistance à l'infestation naturelle par les populations de cochylis rayée du tournesol, (*Cochylis hospes)* Walsingham (lépidoptère, Tortricidae) dans le Nord Dakota.

Suite à l'attaque par la cochylis rayée, son développement et l'alimentation des larves, des génotypes résistants ont été identifiés. Le génotype PI 251902 a subi moins de 10% d'attaques par plante pour chacune des cinq années de l'essai et moins de 6% trois années sur cinq. PI 372259 et PI 170401 ont eu 12% ou moins de dégâts sur les graines en trois ans d'évaluation, PI 253776 seulement 3% deux ans sur trois et était le moins touché en 2004. Quatre autres accessions (PI 170385, PI 291403, PI 494859 et PI 505651) ont révélé une résistance trois années sur cinq.

Dans un certain nombre de croisements interspécifiques, retestés sur la base de résultats précédents, les dommages sur les graines ont été limités en 2003 mais beaucoup plus importants l'année suivante en raison d'une forte présence de populations de cochylis rayée du tournesol. L'hybride 894 avait été utilisé dans des études antérieures comme témoin de sensibilité ; cependant, dans la présente expérimentation, cet hybride a été l'un des moins endommagés parmi le matériel génétique évalué.

Les résultats indiquent qu'il y a des possibilités pour développer des génotypes résistants avec de faibles blessures consécutives à l'alimentation du parasite, ce qui aidera les producteurs de tournesol à réduire la perte de rendement due à la cochylis rayée. En outre, la tolérance des plantes peut efficacement être combinée avec un semis décalé afin de diminuer la densité de population de *Cochylis hospes*, réduisant de ce fait les pertes de récolte sans perturber le contrôle des larves par les pesticides.