Development of resistance to insect pests attacking the stem and head of cultivated sunflower in the central and northern production areas of North America

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ABSTRACT

There is a need to provide successful and economical management tools for the sunflower producer to reduce losses from the spectrum of insect pests that attack the crop in the major production regions. The use of plant resistance can be a useful strategy in a long-term integrated pest management approach for crop protection. The goal of this project was to investigate host plant resistance as a potentially valuable management resource and screen sunflower accessions, interspecific crosses, and lines for those having reduced seed damage from larval feeding by the sunflower moth, red sunflower seed weevil, and banded sunflower moth and reduced densities of sunflower stem weevil larvae in the stalks. Trials were conducted in the central and northern Plains of the U.S. to screen germplasm in the areas where the different insects have caused economic losses. The discovery of germplasm that has lower insect damage can provide the seed companies with breeding material to be incorporated into hybrids targeted to locations where specific insect problems occur. A long-term goal is to identify germplasm with resistance or tolerance to more than one insect pest. The 2005 and 2006 trials revealed that the most resistant lines had a 70-90% reduction in weevil or moth seed damage or numbers of weevil larvae in stalks compared to the most susceptible lines evaluated. After each year of testing, lines with low damage have been retested to confirm their resistance to attack. Trials were conducted again for all four insect pest species in 2007.

Key words: banded sunflower moth – germplasm – pest management – red sunflower seed weevil – sunflower moth –sunflower stem weevil.

INTRODUCTION

The major insect pests attacking cultivated sunflower include the sunflower stem weevil, *Cylindrocopturus adspersus* (LeConte), the sunflower moth, *Homoeosoma electellum* (Hulst) (Lepidoptera: Pyralidae), the red sunflower seed weevil, *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae), and the banded sunflower moth, *Cochylis hospes* Walsingham (Lepidoptera: Tortricidae). (Charlet et al., 1997; Knodel and Charlet, 2007). Strategies to reduce crop losses for these pests have concentrated on insecticidal control, but host-plant resistance would provide producers with a sustainable integrated pest management approach for crop protection with lower input costs.

The sunflower stem weevil has caused yield losses in North Dakota, Colorado, Kansas, and Texas (Charlet et al., 1997; Armstrong, 1996; Charlet et al., 2002). Mature larvae overwinter in sunflower stalks and adults emerge in early summer. After mating, females deposit eggs in the stem at the base of the plant. Weevil larvae feed inside the stalk, descending to the lower portion of the stalk or root crown by late August. Larvae construct overwintering chambers by chewing cavities into the stem cortex. High larval populations in a plant can weaken the stem through pith destruction, tunneling, or overwintering chambers, causing it to break at soil level resulting in a loss of the sunflower plant prior to harvest. Stalk breakage is most severe during drought stress or when high winds occur as plants are drying prior to harvest (Charlet, 1987; Knodel and Charlet, 2002).

The sunflower moth causes yield losses to cultivated sunflower in the southern and central Plains. Larvae overwinter in the soil in Texas and adults are carried on northerly winds to the central and northern Plains. Female moths deposit eggs in blooming sunflower heads. Larvae feed and develop in the sunflower head, destroying seeds and reducing oil content. Feeding damage in the head may provide an entrance site for the Rhizopus head rot fungal pathogen. Larvae exit the seed when mature and drop into the soil to overwinter (Rogers, 1978, 1992; Charlet et al., 1997).

The banded sunflower moth has been a persistent pest of sunflower in the northern Plains and populations also are present in the central Plains. Adults emerge from the soil in mid-July and are present in the field until mid-August. Adults congregate in field margins on weeds or adjacent crops during the day and then fly into the sunflower field in the evening. Females lay eggs on the outside of the bracts of the sunflower head and larvae feed on the florets, developing seed, and mature seeds. After completing development, larvae drop from the heads and spin cocoons in the soil and overwinter as mature larvae (Charlet and Gross, 1990; Charlet et al., 1997).

The red sunflower seed weevil is a pest of cultivated sunflower in both North and South Dakota, but is also present in the central Plains (Charlet and Glogoza, 2004). Larvae overwinter in the soil, emerge in July, and after mating, females deposit eggs inside the developing sunflower seeds. Larvae feed and develop in the seeds, destroying a portion of the kernel and reducing oil content. When mature, the larvae exit the seeds and drop into the soil in late August or September to overwinter (Brewer, 1991; Rogers, 1992; Charlet et al., 1997).

Plant resistance is an important strategy in a sustainable pest management program for sunflower. Our goal was to evaluate selected sunflower accessions, interspecific crosses, and lines for reduced seed damage from larval feeding by the sunflower moth, red sunflower seed weevil, and banded sunflower moth, and lower populations of stem weevil larvae in stalks. Lines that have less insect damage can provide germplasm for incorporation into hybrids targeted to locations where specific insect problems occur. Our long-term objective is to identify germplasm with resistance or tolerance to more than one insect pest. This will increase grower confidence in the crop and facilitate maintenance and expansion of sunflower acreage in both the central and northern Plains production regions of the United States.

MATERIALS AND METHODS

Sunflower stem weevil

Plots were established at the Northwest Research Extension Center, Kansas State University, Colby, KS. Field trials in 2005 screened 14 selected sunflower hybrids, 8 accessions or Plant Introductions (PIs) obtained from the USDA, ARS, Plant Introduction Station at Ames, Iowa, 12 interspecific crosses, and hybrid ‘894’. In 2006 we screened 9 selected commercial sunflower hybrids, 5 retested accessions, 4 accessions that had previously shown low levels of seed damage from the banded sunflower moth, 4 accessions and an interspecific cross that previously had shown low sunflower moth damage, 5 retested interspecific crosses, 2 susceptible checks, and hybrid ‘894’. The lines were planted each year in single rows 7.6 m long and each was replicated three times in a randomized block design and planted on 9 and 8 May in 2005 and 2006, respectively. As a result of a phenotypic recurrent selection program that genetically combined lines with quantitatively-controlled insect tolerance factors from earlier trials, 60 S_1 line progeny rows also were subjected to insect infestation in 2006 in a separate trial planted on 8 May. The lines were planted in single 7.6 m rows in a block design with checks randomly placed within the trial. Five other hybrids, crosses, or lines (Hir 1734-1, HA 89, Str 1622-2, PI 497939, hybrid ‘894’) were included as checks within the trial. Five stalks (~ 46 cm length plus the root crown) per row were removed in October each year and sent to the USDA, ARS, Northern Crop Science Laboratory, Fargo, ND, for evaluation. Stalks were held in the cold until evaluated. The stalks were then split and the numbers of weevil larvae in each stem determined. Because of time constraints, only one half of each stalk was evaluated and then converted to number per stalk. The degree of resistance or tolerance was measured by comparing the number of weevil larvae per stalk with the germplasm having the lowest number of insects in the trial.

Sunflower moth

Plots were planted at Colby, KS. Sunflower moth feeding damage in the 2004 trials was very low with an average of 0 to 2% in the material evaluated. Because of the reduced amount of damage, the trial was repeated in 2005. Germplasm selected for testing included retested accessions and interspecific crosses with less than 4% feeding damage in 2003, selected susceptible checks and hybrid ‘894’. Other accessions were added because of low damage in sunflower stem weevil, red sunflower seed weevil, and banded sunflower moth screening trials. Seven new accessions also were added. Germplasm selected for evaluation in 2006 included retested accessions and interspecific crosses with less than 4% feeding damage in 2005. The susceptible checks Hir 1734-1 and 01-4094-1 (04-628) were included as was hybrid '894'. All accessions were obtained from the USDA Plant Introduction Station. The entries were replicated three times in a randomized block design and were planted 9 and 8 May in 2005 and 2006, respectively. In a separate trial in 2006, 58 S_1 line progeny rows also were subjected to insect infestation. Five other hybrids or lines (04-628, Cropland 378, HA 89, Str 1622-2, Hybrid '894') were included as checks within the trial. The lines were planted in single 7.6 m long rows on 8 May in a block design with checks randomly placed within the trial. Physiologically mature heads were harvested between 23 August and 12 September each year. Five heads were removed from each row and shipped to Fargo, for evaluation. The heads were dried, threshed, the seed cleaned, and subsamples of 100 seeds per head evaluated for number of seeds damaged by moth larval feeding. The degree of resistance or tolerance to the sunflower moth was measured by comparing the percentage of seeds damaged among those tested.

Red sunflower seed weevil

Plots in 2005 were established at two locations: Highmore, SD, and Prosper, ND. Field trials at each site screened the same germplasm: 2 interspecific crosses, 17 accessions obtained from the USDA Plant Introduction Station and hybrid '894'. Plots in 2006 were planted at the same locations. Field trials at each site screened the same germplasm: 2 interspecific crosses, 4 retested accessions, 5 accessions with low banded sunflower moth damage, 2 interspecific crosses and 5 accessions with low sunflower moth damage from previous trials, and hybrid '894'. The entries were planted in a randomized block design with three replications on 16 June at Highmore and on 20 May at Prosper in 2005 and 7 and 9 June at Highmore and on 18 May at Prosper in 2006. In a separate trial in 2006, 60 S_1 line progeny rows also were subjected to insect infestation at the same two locations. Four other hybrids, crosses or lines (PI 431542, Hir 828-3, HA 89, and hybrid '894') were included as checks within the trial. The lines were planted in single 7.6 m long rows on 7 and 9 June (Highmore) and on 18 May (Prosper) in a block design with checks randomly placed within the trial. At Highmore because of very dry conditions in 2005, up to ten heads from each row were harvested in October and shipped to Fargo for evaluation. At Prosper, five heads were randomly removed from each row from mid-September to early October each year and taken to Fargo for evaluation. Harvest occurred in early November at Highmore and heads were sent to Fargo for evaluation. The heads from both locations were dried, threshed, and the seed cleaned. Subsamples of 100 seeds per head from each nursery were evaluated for number of seeds damaged by seed weevil larval feeding and the percentage of damaged seeds determined. Resistance or tolerance to the banded sunflower moth was measured by comparing the percentage of damaged seeds among the germplasm evaluated in the trials.

Banded sunflower moth

In 2005, plots were established at Prosper, ND. Five interspecific crosses, one new line, 17 accessions obtained from the USDA Plant Introduction Station and hybrid '894' were screened. The entries were planted in a randomized block design with three replications on 20 May. Plots in 2006 also were planted at Prosper, ND. Field trials screened 2 interspecific crosses, a new line, 11 retested accessions, 6 new accessions, an accession with low sunflower moth damage and two accessions with low seed weevil damage from previous trials, and hybrid '894'. The treatments were planted in a randomized block design with three replications on 18 May. In a separate trial, 60 S_1 line progeny rows also were subjected to insect infestation. Five other hybrids or lines (PI 251902, Par 1673-2, HA 89, P21VRI, and hybrid '894') were included as checks within the trial. The lines were planted in single 7.6 m long rows on 18 May in a block design with checks randomly placed within the trial. Five heads were randomly removed from each row when plants were physiologically mature in mid-September both years and taken to Fargo for evaluation. The heads were dried, threshed, the seed cleaned, and subsamples of 100 seeds per head evaluated for number of seeds damaged by moth larval feeding. The degree of resistance or tolerance to the banded sunflower moth was measured by comparing the percentage of seeds damaged among those tested.

RESULTS AND DISCUSSION

Sunflower stem weevil

In the 2005 trial, the mean number of sunflower stem weevil larvae occurring in the germplasm tested ranged from 7 to 70 larvae per stalk. Among all the individual stalks evaluated, numbers ranged from 0 to a high of 166 per stalk. Among the 35 lines or hybrids tested, 13 were below 25 and five below ten weevil larvae per stalk. The line with the best performance in the trial was accession PI 431516 with a mean of only 6.6 larvae per stalk. This was the first year in which this line was tested. Three interspecific crosses Str 1622-2, Hir 828-2 and Hir 828-3 had less than 20 weevil larvae per stalk. Accession PI 497939 only had 9 larvae in 2005, 12 in 2004, and only six in 2003. The accession PI 386230 had only 9 larvae per stalk and was among the ten lowest in 2004. Hybrid '894', which had only an average of 16 larvae per stalk in 2004, had over 30 larvae per stalk in 2005. The commercial hybrid with the lowest density among those tested was Fontanelle 902NS with 21 larvae per stalk.

In 2006, the mean number of larvae occurring in the material tested ranged from 5 to 51 larvae per stalk. Among the 31 lines or hybrids tested, 21 were below 25 and three below ten weevil larvae per stalk. One of the two accessions with the best performance in the trial was accession PI 431516 with a mean of only 6.5 larvae per stalk. This was the second year in which this line was tested, and in 2005 it had the lowest number of larvae in the trial. The line with the lowest number of larvae in the trial was PI 386230 with a mean of 5 larvae per stalk; in 2005 it was among those with the lowest larval density per stalk and was among the ten lowest in 2004. The accession Ames 3454 had 9 larvae per stalk, the same as in 2005. The results from the trial evaluating the S1 lines showed high numbers of larvae occurring in some of the stalks with means from 0 to140 larvae per stalk among those tested. However, a total of 22 showed average larval densities of less than 25 per stalk. Thirty-two were selected for reevaluation in 2007.

Sunflower moth

Other than two lines which showed over 30% damage, the remaining 34 tested showed an average of less than 10% seed damage per head in the 2005 trial. Although some inconsistencies in the results were evident compared to those in previous years, a number of lines that have repeatedly had low damage also were among those tested with reduced percent seed damage again in 2005. The susceptible line 01-4094-1 was again the most damaged of those evaluated. Eleven lines with low damage in 2003 sustained an average of 2% or less damage per head in 2005. This group included hybrid '894'. Others with less than 2% damage included four that had previously shown reduced seed damage in trials for banded sunflower moth (PI 505651, PI 291403, PI 494861 and PI 494859), one in trials for sunflower stem weevil (Ames 3391), and one in trials for red sunflower seed weevil (Ames 3269). Two of the accessions that were new in the 2005 trial also had less than 2% seed damage from sunflower moth feeding (PI 170405 and PI 193775).

Insect pressure from the sunflower moth was very heavy in 2006 as shown by the amount of seed damage in the trial; the damage ranged from 1 to 81% seed damage among the selected accessions and lines evaluated. The amount of damage sustained by the accessions tested was surprising because, other than the susceptible checks, those included in the 2006 trial only had shown 4% or less damage in 2005. However, hybrid '894', which had the lowest amount of damage in the trial, also was among the lowest in 2005 with only 0.3% damage. Others in the 2006 trial with lower damage levels included PI 170385 (9.6%) and Ames 3269 (11.6%) which averaged 2.5% and 1.1% damage, respectively, in 2005. PI 170414 averaged only 10.6% damage in 2006 and had averaged 0% damage in 2005, although only 3 heads were evaluated. The results from the trial evaluating the S1 lines showed feeding damage levels from 0.2 to 70% among those tested. A total of 36 showed average percentage damage of less than 10%. The check, hybrid '894' again showed lower damage from moth feeding in this trial. The best of these lines were retested in 2007 to confirm their resistance to damage by the sunflower moth.

Red sunflower seed weevil

The damage at Highmore in 2005 indicated high levels of weevil infestation, with a range of 2 to 59% seed damage among the germplasm tested at this location. Those showing damage levels of 18% or less included the three accessions PI 431545, Ames 3269, and PI 431542; however, the results were from only a limited number of heads evaluated. Ames 3269 had been tested in both 2003 and 2004 and showed only 13% damage each year. PI 431542 had the least damage of all germplasm in 2005 as well as in 2004. Hybrid '894' averaged 43% seed damage which was higher than the 2004 trial in which it averaged 24% damage. The density of red sunflower seed weevil at the Prosper trial was much lower than the Highmore location, based on the amount of seed damage. Percentage damage ranged from a high of 4% in accession PI 431569 to 0.7% in Ames 3269. Hybrid '894', which scored near the middle of the selected germplasm evaluated at Highmore, was near the bottom in level of seed damage at Prosper at 1.5%. The accessions 431542 and Ames 3269 scored near the bottom in percentage of damage at both locations. Some others showed inconsistent results, but the differences were likely because of the lower levels of damage that occurred at Prosper.

High levels of red sunflower seed weevil occurred in the 2006 trial with a range of 7 to 52% seed damage among the germplasm tested at Highmore. Eight lines showed damage levels of 15% or less. Ames 3269 had the lowest amount of damage in both 2003 and 2004, was one of the lowest in 2005, and showed only 13% damage in 2006. Three of the least damaged accessions had shown low damage from sunflower moth in earlier trials (PI 175728, PI 162453, and PI 193775). The results from the trial evaluating the S1 lines showed feeding damage levels from 0.3 to 40% among those tested. Of the 59 evaluated, 25 showed average percentage damage of less than 13%. The best of the lines were retested in 2007 to confirm their resistance to red sunflower seed weevil damage. The density of red sunflower seed weevil at the Prosper trial was lower compared to the Highmore location based on the amount of seed damage from the germplasm evaluated. Percentage damage ranged from a high of 0.9% to 24%. There were a number of inconsistencies at the two sites. Hybrid '894', which scored near the middle of the selected germplasm evaluated at Highmore (34%), was at the bottom in the level of seed damage at Prosper with 0.9%. The accession Ames 3269 scored at the bottom in percentage of damage at Highmore, but was the most damaged of those tested at Prosper. Some others, however, were similar in amount of damage between the two locations likely because of the lower levels of damage at Prosper. Only 47 of the S1 lines were evaluated for damage due to lodging from a wind storm. The results from the trial showed feeding damage levels from 20 to 0.6% among those tested. Of those evaluated, 31 showed average percentage damage of less than 4%. The best of the lines were retested in 2007.

Banded sunflower moth

The percentage of banded sunflower moth feeding damage ranged from 8% in hybrid '894' to 58% in accession PI 431542 in 2005. The accessions PI 251902 and PI 170391, which had less than 11% damage in 2005, had only 8% damage in 2004 and less than 5% in the previous year. PI 265503 which sustained only 11% in the 2005 trial incurred 12% damage in 2004 and less than 7% in the 2003 trial. Hybrid '894', which sustained the least amount of damage in the trial, had less than 9% damage in the 2004 trial and only 4% in the 2003 trial. All of the interspecific crosses had greater than 18% feeding damage.

In the 2006 trial, the percentage of banded sunflower moth feeding damage ranged from a low of 0.5% in accession PI 432516 to 29% in interspecific cross Par 1673-2. The majority of the tested germplasm sustained less than 10% damage from moth larval feeding. PI 162453 which had shown reduced sunflower moth damage in previous trials sustained less than 6% feeding damage from banded sunflower moth. The accessions PI 170401 and PI 505651 had less than 2% damage and were also low in 2005. Three of the new PIs tested in 2006 (PI 195573, PI 219649, PI 432516) were the lowest in the trial, showing less than 2% feeding damage. The results from the trial evaluating the S1 lines showed feeding damage levels from 0.4 to 14% among those tested. A total of 19 were lost to lodging from wind. Of the remaining 41 S1 lines, 17 showed average percentage damage of less than 3%. The best of these lines were retested in 2007 to confirm their resistance to banded sunflower moth damage.

CONCLUSIONS

Evaluation of sunflower germplasm for resistance to important sunflower seed-feeding and stem-infesting pests has been conducted in regions where these insects have caused economic losses. Nurseries for the sunflower moth and sunflower stem weevil were located in KS, for the banded sunflower moth in ND, and nurseries for the red sunflower seed weevil were placed in ND and SD. Results from both 2005 and 2006 identified promising resistance in germplasm against the four insects studied. There was a reduction in seed damage of 90% and 80% between the most susceptible and the most resistant line in the sunflower moth and banded sunflower moth trials, respectively. The red sunflower seed weevil trials in both locations had genotypes with a 70% to 80% reduction in seed damage and 90% fewer larvae per stalk in the stem weevil trials. After each year of testing, lines, accessions, or interspecific crosses with low damage are retested to confirm their resistance to attack. Trials were again conducted for all four insect pest species in 2007 and the results are currently being evaluated. The lines that are determined to be the most resistant in the 2007 trials will be random-mated to begin development of the next cycle of S_1 progeny lines.

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