T1992BRE20

DEVELOPMENT OF BIRD-RESISTANT SUNFLOWER

J. J. Hanzel
Dept. of Crop and Weed Sciences,
North Dakota State University, Fargo, ND, USA.

SUMMARY

Bird depredation is a major concern of sunflower producers wherever the crop is grown in the world. Development of bird-resistant varieties would provide an economical, environmentally safe method of contending with the problem. Morphological traits that confer resistance have been identified and include long involucral bracts, horizontally oriented heads, concave heads, and long head-to-stem distances. The objectives of the breeding program are to develop germplasm possessing the bird-resistance traits and superior agronomic qualities, determine the efficacy of each of the traits at preventing bird predation, and determine the mode of inheritance of the resistance traits.

Two germplasm lines, NDBR1 and NDBR2, have been developed and will be released for production of bird-resistant hybrids. Test hybrids produced with the lines possess agronomic and quality traits that are comparable to commonly grown hybrids and suffer little bird damage. Assessments of bird damage in the field have demonstrated that the best protection is provided by concurrent possession of a concave head, horizontally oriented head, and long head-to-stem distance. Expression of the bird-resistance traits appears to be largely determined by nonadditive genetic effects, thus degree of expression varies greatly with choice of parents used to produce hybrids.

INTRODUCTION

Sunflower is a major crop in North Dakota. Annually, 2 to 5% of the crop is lost to depredation by common grackles (*Quiscalus quiscula* L.). yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) L.) and red-winged blackbirds (*Agelaiusphoeniceus* L.). Central North Dakota has more water areas per square mile than anywhere else in the contiguous USA, and, as a result, provides excellent nesting and roosting areas for birds. In addition, this region is located on a main migratory flyway of the birds, with a large concentration of birds present during sunflower seed-filling. Because sunflower has a high oil content, it is an excellent nutritional source for blackbirds preparing for migration south. Birds cause serious problems in sunflower wherever it is grown in the world (1).

Morphological features that protect sunflower from blackbrid depredation have been identified. These include long involucral bracts, horizontally oriented heads, concave heads, and long head-to-stem distance. Fox and Parfitt (3) reported that these traits are moderately heritable and suggested their use in breeding programs to increase tolerance or resistance to bird predation.

Germplasm developed early (circa 1983) in the breeding program at NDSU was bird resistant, however, it did not perform well agronomically (8). In addition, little was known about the efficacy at preventing bird predation and mode of inheritance of each of the individual traits. The objectives of the breeding program have been to develop germplasm possessing the bird-resistance traits and superior agronomic qualities, determine the efficacy of each of the traits at preventing bird predation, and determine the mode of inheritance of the resistance traits.

MATERIALS AND METHODS

Germplasm possessing the morphological traits effecting bird resistance was collected from different sources, i.e., World Collection of Sunflower, United States Department of Agriculture (USDA) Oilseed Breeding Project, etc. Crosses were made to agronomically superior lines to combine bird-resistance traits with agronomic quality traits. A pedigree method of selection was used to develop inbred lines (11). Approximately 400 F_2 plants were grown from each cross. Selection was based upon vigor, maturity, and oil content and selected plants were self-pollinated. In subsequent generations (F_3...,F_n), a single 6.1 m row was grown for each line. Plots were overplanted, then thinned to a final population of 50,000 plants/ha and spacing between rows was 0.76 m. Selection was practiced between and among lines for germination, vigor, uniformity, days to anthesis, height, self-fertility, possession of bird-resistance traits, and oil content. Line selection plots were grown at Fargo, ND.

Beginning in the $F_{3:4}$ generation, each line was crossed to a source of cytoplasmic male- sterility (CMS) to determine sources of fertility restoration among the experimental lines and to begin converting non-restorer lines to CMS germplasm. In addition, seed from these crosses was used to grow preliminary testcross evaluations. Plots of the testcross evaluations consisted of single 6.1 m rows grown in an augmented design with replicated checks. Data was collected for the same traits noted in line selection, as well as, yield and test weight. Advanced testcross evaluations of selected lines consisted of two-row plots grown in a randomized complete block design with two replications when entry numbers were small (<25) or a simple lattice with two replications when entry numbers were larger. Testcross evaluation experiments were grown at Fargo, Casselton, and Prosper, ND.

Bird damage was assessed at locations in Nelson and Stutsman counties in North Dakota where bird populations are high. Each line in the pedigree selection program was grown at two sites. Plots consisted of single rows spaced in the same manner as those at Fargo. Bird damage was quantified by using a template-type scale based on the formula:

$$\% \text{ bird damage} = 1-(1\text{-fraction of total radius removed})^2 \times 100$$

When seed was available, testcross hybrids were grown at these locations and assessed for bird damage. Bird damage was collated to possession of bird-resistance traits in each line and hybrid to investigate the efficacy of each of the traits at preventing depredation.

The mode of inheritance of the bird-resistance traits was evaluated in two studies using progeny of crosses between lines possessing the traits and HA 89, a USDA line that is susceptible to bird predation. In the first study, the parents of four crosses, along with F_1, F_2, F_3, and backcross F_1 generations were grown at Fargo in 1986. In the second study, HA89 was crossed to near-isogenic sunflower lines possessing individual bird-resistance traits in a genetic background of HA89. The parents, F_1, F_2, and backcross F_1 progeny of 10 crosses were grown at Fargo in 1991. In both studies, the four traits were measured at the R7 stage of growth (12). Bract length was measured in mm using a metric ruler. Head shape was measured as a dioptre valve with 0 being a flat head, positive values being increasing convexity, and negative valves indicating increasing concavity (9). Head angle was measured in degrees with a protractor, with 0° being a head that faced upward, 90° being a head that was perpendicular to the ground, and 180° indicating a head that faced the ground. Head-to-stem distance was measured in mm with a metric ruler as the distance from the stalk to the closest point of the head. Data was submitted to various statistical analyses. Broad-sense heritabilities were computed for each trait (6) and F_2 distributions were subjected to chi-square analysis (13). The importance of different genetic effects on expression of each trait was evaluated by using a generation means analysis (10).

The stability of the morphological traits affecting bird resistance was investigated by growing breeding lines with resistant and susceptible expressions of the traits at three locations in North Dakota in 1988 and 1989. Plot dimensions and measurement details are as discussed above. The design was a randomized complete block with three replications. The data was analyzed using standard analysis of variance procedures (13).

RESULTS

An average of 500 lines and populations, ranging from the F_1 to F_7 generations, were grown each year for evaluation. In 1987, 14 lines were selected for increase and elaborate testing for bird resistance and agronomic quality. The agronomic performance of the lines was comparable to or better than that of lines used to produce widely grown hybrids (8). In addition, these lines suffered little bird damage, whereas standard inbred lines were heavily damaged.

Testcross hybrids produced by crossing the selected bird-resistant lines to various standard inbred lines performed well agronomically with most traits comparable or better than those of widely grown hybrids (8).

However, the bird-resistance traits were not expressed in all hybrids, and most of the testcross hybrids were susceptible to bird depredation.

The data obtained through bird damage assessments was collated to possession of the bird-resistance traits. It appeared that bract length was not as effective at preventing depredation as originally thought. The bracts may cause reluctance by birds to feed on the seed at first, but under most circumstances, the birds were able to eventually eat them. The other three traits were effective at deterring predation, but none seemed to offer an efficient protection when present alone.

The results from the two inheritance studies were mixed for some of the traits. The early study indicated that additive effects were prominent for bract length and head angle in some crosses and that long head-to-stem distances showed at least partial dominance to shorter ones (2). The later study indicated that for all traits, heritability was low and that nonadditive effects, i.e., dominance and epistatic effects, were more important than additive ones (5).

The study to investigate stability of genotypes when grown in diverse environments indicated that significant genotype x environment effects were not the result of changes in rank between resistant and susceptible genotypes, but represented differences in magnitude of response in the genotypes (4).

DISCUSSION

After testing for bird resistance and agronomic quality, a decision was made to release two germplasm lines, NDBR1 and NDBR2 (7). Hybrids produced with these lines perform well agronomically but mature seven to 10 days later than most widely grown hybrids. However, the extended 'green' period allows maintenance of expression of the bird-resistance traits and reduces bird depredation. Bird damage in hybrids produced with the two lines averaged less than 10% when hybrid checks suffered 70 to 100% damage.

As the result of numerous bird damage assessments, it appears that the best protection is afforded by the concurrent possession of a concave-shaped head, a horizontally-oriented head, and long head-to-stem distance (7). Bract length appeared to be less effective.

Expression of the bird-resistance traits appeared to be largely determined by nonadditive genetic effects, as the degree of the expression varies greatly in relation to the choice of parent used in hybrid combination with NDBR1 and NDBR2. This is supported by the inheritance studies (2, 5). This preponderance of nonadditive effects indicates that plant breeders may experience difficulties when attempting to derive inbred lines or produce sunflower hybrids possessing the bird-resistance traits.

Results of the stability study indicated that performance of genotypes with bird-resistance traits was stable across environments and that transfer of morphological traits that confer bird resistance to hybrids for use across a wide geographical area may be possible (4).

CONCLUSIONS

Sunflower lines and hybrids were produced that suffered significantly less bird damage than widely-grown genotypes. This reduced amount of damage was attributed to the possession of certain morphological traits by the resistant genotypes. Development of bird-resistant genotypes adds another tool to an integrated management system that sunflower producers must employ to lessen losses to bird predation.

The mode of inheritance of the bird-resistance traits seemed to involve largely nonadditive genetic effects. Selection for the traits may have to be delayed until later generations in line development and hybrid production may involve testing many lines in specific combinations.

Contrasting results were obtained in several inheritance studies. Additional studies are planned at several locations over years to attempt to understand the mode of inheritance of the bird-resistance traits more clearly.

ACKNOWLEDGEMENTS

The research was funded by a cooperative agreement with USDA-APHIS-ADC. The author would like to thank the researchers of that agency and the technical and graduate student personnel of NDSU for their invaluable assistance.

REFERENCES

1. Besser, J. F. 1978. Birds and sunflower. *In* J. F. Carter (ed.) Sunflower science and technology. Agronomy 19:263-278.
2. Foley, B. J., and J. J. Hanzel. 1987. Inheritance of morphological traits conferring bird resistance/tolerance to sunflower. p. 2. Proc. Sunflower Research Workshop, Aberdeen, SD. 10 Dec. 86. National Sunflower Assoc., Bismarck, ND.
3. Fox, G. J., and D. E. Parfitt. 1982. Genetic sources of resistance/tolerance to bird predation of sunflower. p. 66-67. *In* Agronomy abstracts. ASA, Madison, WI.
4. Gross, P. L., and J. J. Hanzel. 1991. Stability of morphological traits conferring bird resistance to sunflower. Crop Sci. 31:997-1000.
5. Hagen, M. M. 1992. Inheritance of four bird-resistance traits in sunflower (*Helianthus annuus L.*). MS thesis. North Dakota State Univ., Fargo.

6. Hallauer, A. R., and J. B. Miranda, Fo. 1981. Quantitative genetics in maize breeding. Iowa State University Press, Ames.

7. Hanzel, J. J., and M. M. Hagen. 1992. Development of bird resistant sunflower-update of NDSU research. p. 2-3. Proc. Sunflower Research Workshop, Fargo, ND. 16-17 Jan. National Sunflower Assoc., Bismarck, ND.

8. Hanzel, J. J. 1989. Bird resistant sunflower. p. 23-25. Proc. Sunflower Research Workshop, Fargo, ND. 9-10 Jan. National Sunflower Assoc., Bismarck, ND.

9. Mah, J., G. M. Linz, and J. J. Hanzel. 1990. Relative effectiveness of individual sunflower traits for reducing red-winged blackbird depredation. Crop Protection 9(5):359-362.

10. Mather, K., and J. L. Jinks. 1971. Biometrical genetics. The study of continuous variation. Cornell University Press, Ithaca, NY.

11. Miller, J. F. 1987. Sunflower. p. 626-668. *In* W. R. Fehr (ed.) Principles of cultivar development, v. 2. Crop species. MacMillan, New York.

12. Schneiter, A. A., and J. F. Miller. 1981. Description of sunflower growth stages. Crop Sci. 21:901-903.

13. Steele, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics. 2nd ed. McGraw-Hill, New York.