CHARACTERISTICS OF BIRD-RESISTANCE IN AGRICULTURAL CROPS

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ABSTRACT: The use of biochemical or morphological genetic traits in a crop to protect ripening seeds or grain from bird damage remains a promising tool under certain situations. Research on bird-resistance in crops has focused on grain sorghum, corn, sunflower and rice. This crop protection method involves feeding behavior of granivorous birds and its effectiveness depends on the availability of preferred alternate foods. That is, bird-resistant traits provide protection to the crop when other food choices are readily available; however, when alternate food is scarce or high bird populations create serious feeding competition, they are less effective. Several practical factors (i.e., efficacy expectations, agronomic considerations, and cost-effectiveness) were discussed that should be considered in adopting this bird damage control strategy.

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INTRODUCTION

To the novice in vertebrate pest control the term "bird-resistant" seems a panacea; conversely, many workers in the field consider it to be an impractical concept that has not and will not work for the farmer. Neither party is totally correct because the concept is misunderstood. Harris (1969) attempted to establish a common understanding by defining "bird-resistant" as "that mechanism or characteristic of a variety that when given a choice of feeding material, birds will not normally depredate." "Less-susceptible," or "bird-tolerant" are other terms used for clarification. "Bird-resistant" will be used here with the understanding that the concept works best when alternate feeding choices are available.

Bird-resistance can be a useful tool in crop-protection if applied in a well-planned strategy. Typically, the plant breeder segregates genetic traits (chemical and/or morphological) which lower feeding preference for seeds, grains, or fruits at a time when bird damage likely occurs. This makes that cultivar a less desirable feeding choice for birds than other food sources in the vicinity. Doggett (1957), a pioneer of this concept, observed that "varieties may be bred which are unattractive to birds, and which are attacked only as a last resort." Chemical traits generally involve an unpleasant taste, while morphological traits are usually those that impair feeding efficiency. Depending on the crop, morphological or biochemical factors can predominate; in combination they can be synergistic (Harris 1969).

If one were to select a susceptibility attribute most common to ripening crops damaged by birds, it would be the tendency of that crop to accommodate perch-feeding by the depredating species. Grain sorghum, corn, sunflower, and rice, ripening crops heavily involved in bird damage situations around the world, are good examples. Crop-damaging bird species of all sizes can perch on the stalks of grain sorghum, corn and sunflower and in most cases, on lodged rice. Most bird-resistance research has involved these crops, and thus the genetic traits involved (chemical and morphological) are discussed below with this point in mind.

SORGHUM

Most of the early plant genetic work on bird-resistant hybrids involved sorghum (i.e., Doggett 1957, 1970). Worldwide, it is probably the cereal most susceptible to bird damage because of its readily accessible panicle of palatable, nutritious grain on a strong stalk. Fortunately, it has several bird-resistant characteristics (both chemical and morphological) that can be exploited.

Morphological Characteristics

Among the various sizes and shapes of sorghum panicles, the open-head or lax-panicle trait has best inhibited perch-feeding for birds larger than 50 g. In Louisiana, Tipton et al. (1970) observed that open-headed sorghum varieties were damaged less than other types and that these cultivars were damaged mostly by the common sparrow (Passer domesticus). In Botswana, doves (Stretopelia senegalensis and S. capicola) preferred the compact-headed varieties over open-headed ones (Anonymous 1975). Perumal and Subramanian (1973) made similar observations at Tamil Nadu, India, where doves and parakeets (Psittaoula krameri) are a problem. Denver Wildlife Research Center (DWRC) biologists have observed that larger birds such as blackbirds, doves, crows, and larger parakeets do not damage open-headed varieties as much as the smaller weavers, sparrows, and buntings (J. Besser, R. L. Bruggers, and J. W. DeGrazio, personal communication).

In Africa, compact, recurved panicle traits seem to impair feeding activity in birds. Recurving ("goosenecking" or "crooknecking") is favored under rapid growth conditions and results from thick heads being forced out of the side of a very narrow sheath (Martin 1932). The "Korgi" variety has been the source of this trait (Doggett 1957), and the compact heads of some lines also resist damage because birds have mechanical difficulty in penetrating past the outside seeds. Other lines have a peduncle curved in such a way that the panicle is hidden under the foliage, a deterrent for smaller birds which prefer to feed in the open.

Large glumes which envelop the grain apparently make feeding more difficult for birds. Glume length can range from vestigial to being longer than the grain. Perumal and Subramanian (1973), in their study of panicle characters, found that a long-glumed cultivar was damaged less than two others with shorter glumes.

Awned lemmas, which protrude beyond the tip of the grain, appear to hinder feeding activity of birds. Studies indicate that varieties with long awns (called "strong-awned") are more resistant to bird attack than awnless (Jowett 1967, Perumal and Subramanian 1973). The same is true for millets; awned Bajra is more bird-resistant than awnless types (Beri et al. 1969).

Chemical Characteristics

Tannins are the best known chemical components associated with bird resistance in agricultural crops. They are found in some sorghums, millets, and fruits. In sorghums, condensed tannins are found in those varieties which produce grain having a testa. The tannin in these varieties exists in the form of polymers, which will bind with protein if of the right size and shape (i.e., active) and cause an astringent taste/tactile response in birds thereby inducing avoidance. In sorghums, this trait is stronger than all of the morphological traits; however, even high-tannin sorghums will be attacked if feeding pressure is severe, (Doggett 1957, 1970).

Thus far, the problem with commercially available tannin-containing hybrids (called "brown sorghums") is that the tannin remains active in the ripened grain causing palatability and nutritional problems. The same tannin polymers that bind with proteins in the mouth causing astringency, will bind with food protein and digestive enzymes. Thus, the ripened grain is both unpalatable and of poor nutritional quality. Because this commonly occurs in brown sorghums, they have a bad reputation and bring substantially lower prices at the market place. Fortunately, there are some tannin-containing sorghum cultivars that may offer at least a partial solution to this dilemma.

Sorghums are classified into three groups (I, II, and III) according to tannin properties. Non-tannin types without a testa are called group I. Testa-containing sorghums are classified as either group II or III based on differences between their performance in two vanillin assays (Price et al. 1978). Group II sorghums have been of interest because in livestock feeding studies group II sorghums were reported to be nutritionally equivalent to group I varieties. (Oswalt 1975, Hartigan 1979).

Tannins in group II sorghums express their protein-binding activity in the immature stages but not the ripened grain. This is advantageous for growers because the immature stages are when birds generally inflict the most damage (Bullard and York 1985).

Inadequate tannin content in the immature stages was a criticism of some of the early group II cultivars (Bullard et al. 1981). The Denver Wildlife Research Center (DWRC) and University of Arkansas, collaborating on group II sorghum research, have since made considerable progress in overcoming that problem. Today, there are several cultivars with tannin activity comparable to group III genotypes in the milk and dough stages. More importantly, recent protein-binding assays indicate that tannin activity disappears at maturity in the same way that it did in the earlier studies (Bullard et al. 1981). Nutritional tests are being conducted to supplement these assays. Other cultivars have bird-resistance not explainable in terms of tannin activity or morphological characteristics. These are being studied further to determine if other chemical components are present which repel birds.

CORN

Ripening corn is subject to bird damage from the milk stage through harvest (Mitchell and Linehan 1967). Most birds peck the center of immature kernels and remove the soft contents. Damage results from kernel loss as well as mold, fungus or insects introduced through the opened husks. Most research on bird-resistance thus far has been on morphological characteristics.

Morphological Characteristics

Research has shown that corn hybrids vary widely in their susceptibility to bird damage (Linehan 1977). Thompson (1963) examined field corn morphological traits such as high ear placement, mature leaves, erect plants, erect ear shanks, husk, and ear characteristics and found husk extension to be most important. Later, Dolbeer et al. (1982, 1984, 1986a) evaluated the importance of 50% silking, husk extension, husk weight, husk extension weight, pericarp strength, cob length and total husk length in field and sweet corn in reducing damage by several species of birds. Bird-resistant varieties generally had longer, heavier husks that were difficult for birds to penetrate.

The size of the damaging bird in relation to husk characteristics is an important consideration. Larger birds are a more serious problem in corn than smaller birds. For example, in Africa the village weaver (Ploceus cucullatus) and chestnut weaver (Ploceus rubiginosus) have heavy, stout bills which can tear the husks and inflict damage (Bruggers 1980). Quelea (Quelea quelea) and golden sparrows (Passer luteus) are smaller and unable to open the husks (Erickson 1979). It is reasonable to assume that analogous situations exist among the granivorous bird species in the United States.

Chemical Characteristics

Thus far, no chemical factors have been identified that would significantly impact the direction of genetic research in corn. Mason et al. (1984) tested dried kernel samples from several varieties and found significant feeding preferences and variation in chemical composition. However, the preference ranking in this study differed from one obtained earlier with husks intact (Dolbeer et al. 1982). The conclusion was that "blackbirds in the field more frequently choose among hybrids on the basis of mechanical factors associated with the husk rather than on the basis of taste."

SUNFLOWER

Plant breeders from North Dakota State University (NDSU), funded by and in collaboration with DWRC, and assisted technically by the USDA-Agricultural Research Service and private industry, have made considerable progress in developing sunflower genotypes with improved resistance to red-winged blackbird (Agelaius phoeniceus) feed-

ing. Both chemical and morphological traits have been examined for bird resistance. Lines with resistance potential have been identified and appropriate germplasm tested on red-winged blackbirds.

Morphological Characteristics

Many morphological characteristics have been examined thus far at NDSU. Parfitt (1984) observed that concave heads, medium distances between the heads and stems, and white seed (achenes) discouraged blackbird feeding, while concave and downturned heads were aversive to sparrows. Fox and Linz (1983) later observed that flat or concave heads which are horizontal (facing) to the ground with a head to stem distance greater than 15 cm, long bracts which wrap around the face of the head, and seed held tightly within the developing head, are all features which contribute to bird resistance in sunflower. Their work confirmed earlier reports by Posey et al. (1982) concerning head position and Deodikar et al. (1978) concerning bract length. Recently, Seiler and Rogers (1987) observed that chaff length, head angle, plant height and stem angle were important morphological factors involved in resistance to damage by sparrows, house finches (Carpodacus mexicanus) and red-winged blackbirds.

All of these characteristics either inhibit perch-feeding, seed access, or ease of seed removal from the head. Additional factors possibly contributing to differences in feeding behavior on various cultivars are ease of dehulling by birds and the effect of oil content. Generally, genotypes with heavier hulls also have larger seeds that contain less oil (Robinson 1975, Fick 1978, Fox and Linz 1983). For example, confectionery hybrids in the same area as oilseed varieties suffer less damage comparatively (Besser 1978, Fick 1978). Morphological resistant genotypes tested thus far at NDSU are more like the confectionary (i.e., have greater hull mass and lower oil content) than the oilseed types.

Chemical Characteristics

Purple-hulled genotypes have been reported to suffer less bird damage than oilseed types, possibly through taste aversion to anthocyanin pigment (Fox and Linz 1983, Mason et al. 1986). Recent DWRC studies (Mason, Bullard, Dolbeer and Woronecki, personal communication) indicate that in terms of hull mass and oil content these genotypes are also more like confectionary than oilseed types. Currently, red-winged blackbirds are being evaluated for their feeding response to food containing various levels of oil and anthocyanin. In a one-choice feeding test, the preference for test food (sunflower meal containing various concentrations of sunflower oil) increased as oil content increased, with birds being able to discriminate between differences as small as 15 percent. At this point in testing, the role of anthocyanin in food preference does not appear to be as pronounced.

RICE

All of the bird-resistant rice research reported thus far involves morphological characteristics. Since lodging is the factor that makes this crop more susceptible to bird-damage than the other festucoid cereals (Bullard and Gebrekidan, in press), greater effort should be extended into testing or developing more upright varieties, less prone to lodging.

The flagleaf of rice can obstruct feeding access to the panicle, at least for small birds. In a study of six rice varieties in Malayasian experimental plots where munias (Lonchura striata and L. punctulata) and weavers (Ploceus philippinus) were causing damage, varieties with erect flag leaves had less damage (Avery 1979). In India, Uthamasamy et al. (1982) observed that the cultivars having a narrow angle between the flag leaf and panicle or a long flag leaf were damaged less by rose-winged parakeets (Psittacula krameri), sparrows and weavers.

Rice awns apparently reduced bird damage to ripening rice in at least one study in Liberia, West Africa (Abifarin 1984). Two upland rice varieties with similar height and maturity were compared (bird species not given). The awnless variety had significantly greater damage and lower grain yield.

GENERAL MORPHOLOGICAL TRAITS

In fields where most of the damage is caused by small birds, late in grain development, grain size and hardness may be considered. Doggett (1957) observed that some grains are too large for the beak gape of small birds and they have difficulty in consuming them. Small birds may switch to smaller grass seeds if they are readily available. Results from preference studies indicated that kernel size had little effect on preference for sorghum grain during milk or dough stages, but the smaller grain was highly preferred over the larger in the ripened stage (Bullard and York 1985).

The color, shape or size of seeds can have an effect on food preference behavior in birds. DaCamara-Smeets and Manikowski (1979) observed that if quelea and village weavers (Ploceus cucullatus) are given a choice between differently colored grains, they show a preference for those colored like the grains usually found in their habitat. In taste preference studies of 15 sorghum grains (whole and pelleted), appearance was so important in food selection that birds would often not respond initially to a visually unfamiliar food (Bullard and Shumake 1979). Thus, novelty may be a factor attributing to short-term avoidance of a new bird-resistant cultivar which contrasts in appearance to other hybrids traditionally grown in that locality.

ECONOMIC CONSIDERATIONS

The use of bird-resistant hybrid technology in farming can be effective for fields that consistently receive heavy damage, if other factors such as relative yield, market price, ease of harvesting, and added farming expenses cost less than expected damage losses. Dolbeer et al. (1986b) illustrated the need for farmers to be knowledgeable about yield and damage potential. They tested a bird resistant corn cultivar (Gries 622A) against other hybrids commonly grown and found that while it received less redwinged blackbird damage, it did not produce more grain because of being a low-

yielding cultivar. Also, most of the test fields received less damage than expected. They concluded that damage often does not reach projected levels even in areas considered to have high bird damage, and the bird-resistant cultivar must be competitive with high-yielding varieties grown locally. Another consideration is compensatory growth.

If damage tends to be early, low to moderate, and spread throughout the field, increased growth in undamaged seeds may compensate for some or all of the loss in yield. Thus, even though birds and some damage have been observed in the field, there may be little or no actual loss in yield and consequently justification for utilizing management strategies such as hybrid resistance. Compensatory growth has been observed in corn (Linehan 1967, Dyer 1976, Woronecki et al. 1976, 1980), sorghum (Beesley 1978) and sunflower (Sedgwick et al. 1986). Estimates of damage that can be replaced are variable and at least for sorghum, depend on variety (Beesley 1978).

DISCUSSION/RECOMMENDATIONS

Dolbeer et al. (1986b) reasoned that since the number of farmers affected by economically significant bird damage in corn is small, there is little incentive for seed companies to develop new lines solely for bird resistance. They suggested that an alternative would be to develop a bird-resistance rating system for commercially marketed seed corn hybrids. Farmers in high damage areas would have the option of considering bird resistance along with other characteristics (e.g., yield, percent water) in selecting a hybrid to plant. This concept should be explored to see if significant variations in husk characteristics exist among the commercial hybrids.

Sorghum is the most drought-resistant cereal grain available, and for that reason is the only choice available for many semi-arid farms around the world. Unfortunately, birds are often a problem in these areas, there are no reliable morphological-resistant types, and farmers receive lower prices for group III sorghums. Since group II hybrids are the most reasonable solution, research is being focused on nutritional studies to see if in-vitro tannin effects parallel our protein-binding assays. If results are satisfactory, some new group II lines with excellent agronomic qualities are ready for release. Since any testa-containing sorghum is now considered a "brown sorghum," it will take advertising and extension training efforts to convince the farmers and buyers that these lines are economically viable.

With sunflower, bird problems reside primarily among the oilseed varieties which are priced according to oil content. Thus far, candidate bird resistant hybrids have unacceptable oil content. There is a move in the sunflower industry to develop an anthocyanin market as a natural replacement for FD&C Red Number 40 synthetic food color. If the price for marketed anthocyanin could replace the price differential paid for seeds with low oil content, morphological resistant types carrying this gene could profitably be grown in fields where bird damage is traditionally high. Unless the oil content is increased significantly in the candidate morphological-resistant genotypes, it is doubtful that growers will gamble with a product having low market value since even these will be heavily damaged if bird pressure is intense. The most promising goal would be to develop a purple-hulled cultivar, having the best morphological characteristics for bird-resistance and increased oil content.

The suggestion that farmers should plant alternate crops not susceptible to bird damage is often not justified. Many farmers feel that their survival is contingent upon fully utilizing the programs of the Agricultural Stabilization and Conservation Service of the U. S. Department of Agriculture (ASCS). If they stay current with the program crops (wheat, corn, grain sorghum, barley and oats), then there are limitations (history, etc.) on their acreage. Planting choices on the residual acres are often few if they consider market outlets, transportation costs, seasonal or climatic factors, and soil type.

The concept of utilizing bird-resistant traits in agricultural crops to avoid or minimize damage has now been sufficiently tested to warrant consideration as an alternative method for crop protection. Seed companies should explore the opportunities in sorghum and corn immediately, and watch plant breeding developments in sunflower. Extension agents and animal damage control specialists should become aware of the intricacies of the concept, the situations under which it can be used successfully, and be prepared to inform and instruct the public. The approach to crop protection should be from a managed integrated crop protection strategy, and this is one of several tools that can play an important role in such a management system.

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