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Bird Pests and Crop Protection Strategies for Cereals of the Semi-Arid African Tropics

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Sorghum (*Sorghum bicolor*) and millet (*Pennisetum typhoides*), the staple foods of Africa (Cummings 1976), particularly for the low-income subsistence farmers in Sahelian countries, generally are grown in marginal areas of high climatic risk and account for as much as 97% of the annual cereal production in some of the drought-prone sub-Saharan countries (Table 1). Yields of subsistence crops have stagnated or declined in many of these Sahelian countries (Lele 1981) at a time when increased production is needed. Vertebrate pests are responsible for serious preharvest and postharvest losses to these cereals (Jackson and Jackson 1977).

Historical Overview: Cereal Production and Bird Damage

Among the variety of vertebrate pests, small passerine birds present the greatest threat to increased cereal production in most of the Sahelian countries. The agricultural floodplains in the semi-arid Sahel are within the range of red-billed quelea (*Quelea quelea*), considered as perhaps the most numerous and most serious avian crop pest in the world (Magor 1974). Quelea congregate in wet-season nesting colonies and dry-season roosts in numbers of several hundred thousand to several million birds. Although it has been postulated that they prefer wild grass seeds (Ward 1965), enormous flocks often descend on maturing cereal grains.

Because of their sheer numbers, quelea are particularly destructive pests to the small grains of sorghum and millet. Other ploceid species, including village weavers (*Ploceus cucullatus*), black-headed weavers (*P. melanocephalus*), chestnut weavers (*P. rubigenosus*), sparrows (*Passer* spp.), and bishops (*Euplectes* spp.) also can cause considerable local damage wherever they are abundant. The biology, movements, and crop depredations have been more intensively studied for quelea than for any of these other species. However, village weavers and golden sparrows (*P. luteus*) are now being more completely investi-

Table 1. Sorghum and millet production as percent of total cereal crop production and percent of annual cereal consumption that is imported in 15 Sahelian countries of Africa.

Country	Cereal production % sorghum and millet (Anon. 1980a)	% of cereal consumption imported (Anon. 1980b)
Niger	97	3
Mauritania	93	69
Upper Volta	90	2
Chad	90	3
Sudan	90	2
Uganda	86	1
Senegal	76	28
Somalia	75	34
Mali	73	6
Nigeria	86	10
Gambia	57	23
C.A.R.	50	10
Ethiopia	48	1
Cameroon	46	8
Tanzania	19[a]	13

a Marketed products only. Subsistence production is higher.

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gated (DaCamara-Smeets 1978; Morel and Morel 1978).

Bird damage to cereal production began receiving international attention in the mid-1950s and early 1960s when African nations requested assistance from the United Nations. In the early 1970s, a United Nations Food and Agriculture Organization project was established in about one dozen Sahelian countries to conduct research into the biology, ecology, and control of quelea and other pest birds. Other countries received bilateral assistance from organizations such as Office de la Recherche Scientifique et Technique Outre-mer (ORSTOM), U.S. Agency for International Development (USAID), British Centre for Overseas Pest Research (COPR), and German Technical Assistance (GTZ) to evaluate bird pest problems and strengthen existing plant protection departments. Presently, United Nations-funded regional and national projects and government bird control units exist in both East and West Africa; emergency funds also are regularly allocated for control operations in several other countries.

Although the adverse impact of bird pests on cereals is generally recognized, very little objective information on the actual magnitude of losses was available in any of the affected countries until very recently; these systematic assessments have clarified the seriousness of the bird pest to agriculture (Anon. 1981). Bird damage to cereals is now estimated to annually exceed U.S. $1 million in Somalia (Bruggers 1980), U.S. $3 million in Kenya (Kitonyo and Allan 1979), U.S. $2.4 million in Tanzania (Elliott and Beesley 1979), U.S. $3 million in Ethiopia (Jaeger and Erickson 1980), and U.S. $6.3 million in Sudan (Anon. 1981), or a total of at least U.S. $15 million annually in eastern Africa. Cereal losses to birds in Senegal, the only West African country where reliable data are available, are valued at U.S. $4–5 million; sorghum and millet suffer more than 78% of these losses (Bruggers and Ruelle 1981).

Most of the Sahelian countries must import cereals to meet their annual consumption requirements. Some countries such as Gambia, Senegal, Somalia, and Mauritania import as much as [illegible]9% of the cereals consumed annually (Table 1). With an estimated food deficit for developing countries of the world by 1990, projected to be 120 million tonnes, food production must be increased wherever feasible and appropriate, particularly in low-income agrarian countries (Wortman 1980). There is a great potential for increasing sorghum and millet production (Cummings 1976), and yields can be protected if bird depredations are reduced. The expenses for research and bird control operations will be returned manyfold by the employment of appropriate crop protection techniques.

Crop Protection, Control Operations, and Research of Bird Pests

Traditional Crop Protection

Bird scaring in traditional African agricultures is an important part of a family's farming activity (Doggett 1957). Farmers presently are protecting their crops from birds with the same traditional techniques used since crop cultivation began, including trying to frighten birds by shouting; using noise making devices such as gourds, cans, drums, or cracking whips; throwing [illegible] stones; and protecting the [illegible] heads with coverings of grass or cloth. Many farmers, in their frustration, resort to hiring shamen and to using fetishes in attempts to alleviate damage. Some of these frightening methods can provide some protection when bird numbers are low and when farmers are protecting their own small fields (Pepper 1973; Ruelle and Bruggers, in press). However, these methods are effective only on those areas that a family can manage and protect. Still, damage is seldom prevented but instead redistributed more evenly than would naturally occur (Flegg 1980). As agricultural practices are upgraded and fields are enlarged, the scale of farming makes these methods impractical (Park 1974) and they disappear (Doggett 1957). Furthermore, traditional methods are ineffective in most quelea damage situations and can constitute as much as 15–80% of the production cost on large government agricultural production schemes (Bruggers 1980). New, innovative, more effective approaches to crop protection are needed that could free farmers from the task of scaring birds and allow them to devote more time to improving cultural practices. Proper cultural practices have the potential of minimizing or even alleviating bird damage.

National Control Operations

Because of the failure of traditional methods to

cope with pest birds, national and regional bird control organizations were formed in the 1950s and 1960s. These organizations now operate in some 16 countries (Ward 1979), employing lethal techniques that annually destroy up to 1 billion birds in a strategy apparently aimed at overall population reduction.

Ndiaye (1979) reported that in the Senegal River Valley the use of flame throwers killed 150 million fledglings in 1953, explosives killed 20-60 million adults between 1953 and 1966, and parathion sprays killed 200 million fledglings and adults in 1964. Mallamaire (1959) stated that in the Senegal River Valley over 500 million quelea were killed by flame throwers and explosives in control operations between 1954 and 1956. In the Republic of South Africa, over 100 million quelea were destroyed by aerial spraying of avicides in 1 year. Yet damage continued (Flegg 1980) and many farmers have been compelled to forego sorghum production (D. Lourens, personal communication to J. De Grazio). During 1980 in Tanzania, the avicide fenthion was applied to 29 breeding colonies totaling 944 ha, with varying degrees of success (Elliott and Beesley 1979). Likewise, an average of 77 colonies and 35 roosts reportedly are annually located in Sudan, and 75% of them treated with avicides (Anon. 1981). These massive annual control campaigns (in conjunction with a variety of causes of desertification) apparently can reduce the quelea population in local areas such as the Senegal River Valley. A strategy of total population reduction is doomed to fail in most situations because of the high reproductive potential of quelea, the vast inaccessible areas in which they are distributed (Ward 1979), and because all the major bird pests in the African savanna are highly mobile migrants (Jones 1975) and opportunistic feeders. More than 50-60% of the total population would need to be located and killed in control operations just to remove the expected annual recruitment; it is likely that most of the adults killed each year are the "doomed excess" (Ward 1979) and may not even be responsible for damage. Likewise, the many inaccessible "reservoirs" existing in the vast range of quelea preclude a strategy of permanent reduction in numbers (Ward 1965; Ward 1979).

The importance of wild seeds versus cultivated cereals in the diet of quelea needs further investigation. Ward (1965) found that quelea in Nigeria ate predominately wild seeds and postulated that they actually prefer them to cultivated seeds. From food habit studies in Somalia, only 15% of 3282 quelea collected between 1975 and 1979 had eaten cereal crops (the rest ate wild seeds or insects); about half of those eating cereals had eaten sorghum. Erickson (in press) found wild and cultivated seeds to be the main diet of quelea in agricultural zones of Ethiopia. Forty-six percent of the adult quelea sampled in the Upper Awash Valley during 1977/1978 had eaten cultivated grain; the concentration and availability of seed was more important than its size and type. Sorghum was, however, an important cereal grain in the diet of over 2000 village weavers and chestnut weavers collected in Somalia (Bruggers 1980). These species may even prefer cultivated grain to wild seed, a belief also shared by Erickson (in press) for village weavers in Ethiopia. For these reasons, and because only a small proportion of birds in a population may actually be causing damage, more sophisticated and specific approaches to control of bird damage are needed.

Many improvements have been made in the actual control practices of national crop protection organizations (Anon. 1980c). Parathion has been replaced with 60% fenthion and spray quantities of this avicide have been reduced from more than 30 l/ha to 10–15 l/ha when applied by fixed-wing aircraft and 1–2 l when applied by helicopter equipped with ULV spraying equipment. Chemicals such as cyanophos, which are potentially safer and less persistent, are being evaluated (Jaeger and Erickson 1981; P. Ruelle, personal communication). Spray operation procedures, improved with an increased understanding of spray formulations and dynamics and the behavior of the target species, have resulted in fewer and more efficient applications to colonies in some countries. However, spray application improvements are still needed. In addition, techniques such as firebombs have been recognized as obsolete (Mallamaire 1959) and have been eliminated in most countries; they are still used in Kenya. Others, such as poisoning waterholes and using explosives, are still used but only in a few countries. Overall, there has been a slow but perceptible change to the more careful use of methods that are more effective and environmentally safe.

Crop Protection Research—Chemical Repellents

The past decade has also seen the experimental

introduction of methods to directly protect cereals from birds. In the laboratory, the insecticide-molluscicide methiocarb [3,5-Dimethyl-4-(methylthio) phenol methylcarbamate] is repellent at the level of 0.015% to red-billed quelea (Shumake et al. 1976) and to some other bird pests (Shefte et al., in press). Its application to ripening cereals has given increasingly positive results as the behavior of the species has become better understood; the application techniques have been refined; and specific, appropriate pest situations for its use were identified. Methiocarb has effectively protected sorghum and millet in Senegal (Bruggers, in press) and Ethiopia (Bruggers et al. 1981b, Erickson et al., in press) (Table 2). It has a half-life of 6–7 days on ripening sorghum in Senegal and residues on the seed and glumes at 20–25 days after application of 24 ppm (3.0–3.5 ppm on the seed itself) indicating that it can be safely applied at normal repellent use levels (Gras et al. 1981). It is registered as a bird repellent in the United States, both as a seed treatment and on several fruit crops (DeHaven et al. 1979; Schafer 1979).

Barriers

The use of physical barriers such as nylon or plastic nets with characteristics to withstand ultraviolet radiation is another method used to protect ripening cereals. Nets were not regularly used in Africa before the mid-1970s, but are now being increasingly employed at research centers and production schemes. When properly installed and maintained they can provide nearly complete protection from birds. Their expense, however, limits their use to high-value crops. In Kenya (F. Pinto, personal communication), Senegal (J. Denis, personal communication), and Ethiopia (B. Gebrekidan, personal communication) permanent netting enclosures, costing as much as U.S. $1 000/ha are being used to protect valuable seeds in variety trials from birds. Nonetheless, the cost compares favorably with that of hiring bird scarers for the entire maturation period of a crop (Bruggers, in press).

Genetic and Phenologic Characteristics

Plant breeders presently are directing much effort into breeding varieties of sorghum that are "bird resistant" or that mature when birds are not present. However, Doggett (1957) stated that "bird resistance" is a relative term and noted the improbability of developing strains of sorghum that would be immune to attack by hungry birds in the absence of alternate food. Even so, certain plant characteristics, such as loose and pendant heads, large glumes, awns, and bitter taste or astringency, have at times been associated with reduced damage. Sorghum varieties with these characteristics might be more appropriately termed "less susceptible."

The most promising deterrent of these characteristics seems to be a high content of astringent tannins. Certain varieties have the tannins present at repellent levels during the milk and early dough stages (usually the most susceptible period to bird attack) before losing their astringency at harvest, and are thus nutritionally acceptable to farmers (Bullard and Elias 1979; Bullard et al. 1981). These varietal characteristics are difficult to evaluate, because when they are screened and grown in proximity, birds avoid the less acceptable ones, giving a false estimate of "resistance" (Beesley and Lee 1979). When they are planted in areas with high bird pressure and little alternate food, they are usually heavily damaged, as in Puerto Rico (Roger R. Bullard, personal communication) and Botswana (Beesley and Lee 1979). Plant breeders are continuing to actively pursue the development of improved varieties. In Kenya the variety "mombassa" is planted over a wide area by farmers and incurs less damage than other varieties (F. Pinto, personal communication).

Because pest birds of Africa are migratory (Jones 1975), a potentially promising approach might be the development of cereal varieties that mature while birds are absent. Although this approach is complicated by inconsistencies in periods and amounts of rainfall and the traditional sowing practices of farmers (Doggett 1957), it is becoming more attractive as agriculture is upgraded by development schemes. From observations in Chad and Cameroon during several years, Elliott (1979) documented that the planting time of irrigated rice could be regulated so that harvest occurred before the birds arrived in the area, and damage could be greatly reduced. In one season damage was less than 1%. He also noted the practical difficulties of timing crops to such a precise schedule, but believed it would be worthwhile as damage increased to 13–26% when the timing of harvest and the arrival of the birds overlapped.

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Table 2. Results from selected field and cage trials with methiocarb applied to ripening heads of sorghum and millet in Africa. All data are available in manuscripts cited in references.

Location	Year	Area (ha)	No. replicates	Avg % damage and/or yield	
METHIOCARB FIELD STUDIES					
Sorghum					
Darou, Senegal,	1975				
—treated		0.22	1	4%	49.4 g/head
—untreated		0.17	1	67%	15.8 g/head
Melkassa, Ethiopia					
—treated	1980	12.00	1	14.2%	
	1979	12.00	1	22.1%	
	1978	12.00	1	5.7%	
	1977	12.00	1	<2–3% after application, 23% before application	
—untreated	1976	12.00	1	42%	
Millet					
Bambey, Senegal,	1975				
—treated		0.04	1		4.6 g/head
—untreated		0.04	1		2.2 g/head
METHIOCARB CAGE STUDY					
Sorghum					
Jodah, Sudan,	1978				
—treated		8 m^3	3	0.9–2.6%	
—untreated		8 m^3	1	42.6%	
NETTING ENCLOSURE STUDIES					
Sorghum					
Machachos, Kenya,	1979				
—treated		0.02–0.06	3	0–4%	
—untreated		3.00	1	9.8%	
Millet					
Bambey, Senegal,	1976				
—treated		0.10	1	15.5%	
—untreated		0.04	3	93–100%	

Future Advances and Crop Protection Implications

The need to increase cereal production in tropical Africa, where "...food consumption will actually decline below present inadequate levels" (Barney 1980), is particularly acute. Reducing cereal losses caused by birds is one of the most difficult and challenging of all vertebrate pest problems, yet it is one important way of helping to achieve this goal. The past two decades have been characte-

rized by a growing awareness of the extent and cost of bird damage to crops and the formulation of a scientific approach to understanding and solving the problems. During the coming years, research will play an important role in describing the behavior and movements of bird pests relative to crop damage, and in defining particular approaches to effective crop protection efforts based on this knowledge.

Development of an effective control strategy requires survey information on the seasonal distribution of susceptible crops and of the bird pests. During the 1970s, survey work was first accomplished using solely Landrovers, then Landrovers in conjunction with fixed wing aircraft, and later helicopters. This work is extremely time-consuming, logistically difficult, and expensive. Some new and interesting techniques to facilitate gathering this kind of information recently have been investigated. Miniature radio transmitters weighing 1.8 g have been developed (Bruggers et al. 1981a) and successfully used to locate nesting colonies of quelea and follow their movements and those of village weavers in remote parts of Ethiopia (Bruggers et al., in press). The transmitters provide an economically efficient tool for locating and subsequently controlling nesting colonies during their early development. Likewise, aerially applied fluorescent particles used to mass-mark birds in the Ethiopian Rift Valley during 1981 also have control implications (Jaeger et al., in press). A number of marked birds already have been recovered in roosts and breeding colonies in the northern Rift Valley, as far as 750 km from the nesting colonies in which they were sprayed in mid-June. This preliminary finding suggests a fragmented and probably multidirectional dispersal from breeding colonies in southern Ethiopia. These findings demonstrate that quelea breed twice in the Rift Valley and imply that there is little justification for their control in the south (Jaeger, unpublished data). The feasibility of detecting trace element patterns in feathers to identify populations is also being investigated. These techniques can provide information that will allow for early detection of colonies and permit control operations to be directed at those colonies actually causing damage even though they may be temporally and spatially separated from cropping areas.

Such a strategy, but based on morphological criteria of the birds and breeding phenology, was successfully employed in Ethiopia between 1978 and 1980 (Jaeger and Erickson 1980). Bird damage to sorghum was much lower between these years as compared with the previous 2 years when control was not attempted. Without lethal control of breeding colonies during 1976 and 1977, the combined estimated losses of sorghum to birds in certain critical cropping areas were 27 to 30% in 1976 and 13% in 1977 representing U.S. $4.0 and 0.7 million, respectively. Average overall losses for this area are projected at 40 000 metric tons annually (16%), valued at U.S. $6.0 million. This compares with overall losses of 2, 3, and 4% during 1978, 1979, and 1980, respectively (representing between U.S. $0.3 and 0.9 million each year), when selected breeding colonies were destroyed (Table 3). During 1980, avicidal sprays were directed at quelea concentrations of more than 8 million birds occupying more than 90 ha in 7 locations of Ethiopia with 50–90% success (Table 4). The success of these control operations is being systematically evaluated on the basis of preharvest damage assessments and increased yields, not solely the percent kill of birds, as is commonly practiced in Africa.

Ways of using the chemical repellent methiocarb more effectively also are being explored. Practices are changing from those of applying the chemical to an entire field to spraying only the edges or spots in the field that are being damaged (Bruggers et al. 1981b). Similarly, laboratory and preliminary field trials have shown that combining a sensory cue (like wattle tannin) with reduced quantities of methiocarb can provide protection that is comparable, but less expensive, than that obtained when methiocarb was used alone (Bullard, Bruggers, and Kilburn, Denver Wildlife Research Center, unpublished data).

Woronecki and Dolbeer (1980) pointed out that the control of bird damage usually is directed at the pest bird with little consideration given to understanding its relationship to the control of other pests in the field. They show that the presence or absence of insects may greatly influence bird damage control programs, particularly when chemical repellents are used. Similarly, the presence of weeds in a field can completely negate any repellent effects of a chemical (Bruggers, unpublished data). Management techniques will be more consistently effective if bird damage control is approached from an integrated, not isolated viewpoint (Woronecki and Dolbeer 1980) and cultural practices are considered. An important outgrowth of the interest in bird pest prob-

Table 3. Sorghum production estimate ranges for the major growing areas associated with the Awash River Basin in Ethiopia as related to preharvest losses to birds (1976–1980).[a]

Production estimates for sorghum	Without quelea concentration control		Witn quelea concentration control		
	1976	1977	1978	1979	1980
(1) Total area (ha × 10^3)	147–220	86–142	119–194	98–167	98–169
(2) Total yield[b] (mt × 10^3)	147–220	86–142	119–194	98–167	98–169
(3) Area assessed (ha × 10^3)	80–100	25–35	82–122	85–135	85–140
(4) (3)/(1) (%)	54–45	29–25	69–63	87–81	87–83
(5) Loss to birds (mt × 10^3)	24.1–26.8	3.3–4.6	1.5–2.2	2.3–3.5	3.8–6.1
(6) (5)/(3) (%)	30–27	13–13	2–2	3–3	4–4
(7) (5)/(1) (%)	16–12	4–3	1–1	2–2	4–4
(8) Actual loss ($ × 10^6) (5) × $150/mt[c]	3.6–4.0	0.5–0.7	0.2–0.3	0.3–0.5	0.6–0.9

a. 1976–1979 data from Jaeger and Erickson (1980).
b. Based on an average yield of 1 metric ton (mt) or 10 quintals/ha.
c. Average market value.

Table 4. Control operations on night roosts and breeding colonies of *Quelea quelea* (September–December 1980) threatening sorghum-growing areas associated with the Awash river basin in Ethiopia.

Target location	Bird concentration	Date	Area (ha)	Est. no. quelea (× 10^3)	No. of spray sortie	Est. kill (%)
Melkassa	nesting	18–19 Sept	15–20	Unknown	2	>90
Abadir	nesting	23–25 Sept	10	2 600	2	>80
Nura hera	nesting	24–25 Sept	11–13	300–350	2	<50
Lake Zwai	nesting	4 and 21 Oct	30–40	≥5 000	2	>80
Melkassa	roosting	13–14 Oct	10	100–200	2	>80
Bisidimo	roosting	4 Oct	2–3	40–50	1	>80
Kemisse	roosting	4–5 Dec	2–3	40–50	2	>90

lems is the growing awareness and concern shown by individuals planning agricultural developments. With increasing regularity, the potential damage by bird pests to these projects is being considered. On some occasions, the crops are changed to those less susceptible to bird damage; on others, plant protection specialists or consultants are hired and money is budgeted for crop protection operations (Anon. 1980d; D. Gowing, personal communication). Although seemingly obvious concerns, these are recent developments.

The transfer of appropriate scientific and technological advances through assistance programs to government control organizations and agricultural institutions will become easier in the future as more trained individuals become incorporated into plant protection departments. At the University of Gezira, Sudan, formal undergraduate training in vertebrate pest problems already has begun, and a M.S. degree program in crop protection is proposed for ratification. The University of Nairobi also is considering including a course on vertebrate pest management in its M.S. program.

Several American universities, including the University of California at Davis and Bowling Green State University, Bowling Green, Ohio, are involved in training international students in vertebrate pest management. Bowling Green State University has provided degree and nondegree training in crop protection techniques to over 40 international students during the past 20 years.

Many of the students presently in the program are from Tanzania, Somalia, Kenya, Ethiopia, and Sudan. An experimental vertebrate pest management course aimed at the needs of international students is being taught at Colorado State University, Fort Collins, Colorado, and plans are being made to establish a degree program in that specialty. African plant protection personnel have recently completed extended training courses in pesticide application methods, finished pilot training projects, and participated in field techniques workshops on quelea control. Most of the individuals involved in these kinds of training return and continue working in their country.

In conclusion, considerable progress has been made in the last 10 years in understanding the biology and behavior of pest birds particularly quelea and in developing control techniques and strategies of crop protection by a relatively few number of individuals. Many crop protection choices presently exist and more will become available in the future. With more trained individuals evaluating the pest species and its habitat related to agricultural practices, then selecting appropriate methods to alleviate damage, with the emphasis on effectiveness, safety, cost, and minimal environmental contamination, integrated crop protection programs can be expected to be more frequently implemented in the future.

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