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LEVELS OF BIRD DAMAGE TO SORGHUM IN THE AWASH BASIN OF ETHIOPIA AND THE EFFECTS OF THE CONTROL OF QUELEA NESTING COLONIES (1976-1979)

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ABSTRACT: Quantitative assessments of bird damage to lowland sorghum (Sorghum bicolor) were made annually from 1976 through 1979 in the major growing areas associated with the Awash River Basin. Results indicated that the Red-billed Quelea (Quelea quelea) can be an important limiting factor in the overall production of this cereal, and that damage can be locally severe. Lethal control of Quelea breeding colonies found along the Awash River and at Lake Zwai was undertaken in September/October of both 1978 and 1979. Subsequent assessments showed substantially less bird damage in both years and overall losses were minimal.

INTRODUCTION

Sorghum is basic to the lives of people found at lower elevations (below 2,000 meters) of Ethiopia. It is here also that granivorous birds are most numerous. These, particularly Red-billed Quelea, represent the most important of the vertebrate depredators of pre-harvest sorghum.

Lethal control of Queleas is used to reduce the damage in the major sorghum growing areas associated with the Awash River Basin. In general terms the strategy is to destroy only those birds threatening susceptible sorghum. This assumes no overall reduction in the population numbers of Queleas and, therefore, the need for a program of annual control. During 1976 and 1977 this took the form of local control of night roosts when and where damage was occurring. In both 1978 and 1979 Quelea nesting colonies were destroyed prior to dispersal of the birds to the sorghum areas. This dispersal coincides with the time when most of the crop is vulnerable to the birds.

To evaluate the effects of this control, quantitative assessments of bird damage were undertaken when and where possible. What follows is a description of the damage assessment technique, annual estimates of the level of bird damage to sorghum in the system associated with the Awash Basin, and an evaluation of breeding colony control in terms of these damage assessments.

METHODS

Sorghum Areas

The major areas of lowland sorghum associated with the Awash River Basin are listed in Table 1 with the estimate of the year to year range in hectares of sorghum at each. These are mainly subjective estimates based on repeated surveys, both aerial and ground, together with interviews and comparisons with known areas such as on State farms. The resulting estimates are compatible with those from broader, regional surveys (Ethiopian Ministry of Agriculture 1977, Stanford Research Institute 1969). The estimates at Jijiga (International Livestock Centre for Africa 1977) and at Kobo/Alomata (Tamerling, per. com.) are based on actual determinations from land-use studies.

Table 1. Major Areas of Lowland Sorghum Associated with the Awash River Basin of Ethiopia.

Location	Estimated Number of Hectares x 10^3	Harvest Period
Kobo/Alomata[1]	15 - 30	Nov. - Dec.
Waldia	5 - 10	"
Bati	10 - 15	"
Chefa	10 - 15	"
Karakore	1 - 2	"
Robi/Jawa	15 - 20	Oct. - Nov.
Minjar/Welenchiti	5 - 10	Nov. - Dec.
(Malkassa)	(.017)	(Oct.)
Gelemso/Mechara	5 - 10	Dec. - Jan.
Afdem/Miesso/Khora[2]	20 - 30	Oct. - Nov.
Melka Jebdu[3,4]	5 - 10	"
Alemaya[4]	10 - 15	Dec. - Jan.
Erer Valley[4]	10 - 15	Sept. - Oct.
Dakata/Fafam Valleys[4]	1 - 5	"
Jijiga Plain[5]	1 - 35	"
Totals	113 - 222	Sept. - Jan.

1-very dry in 1979
2-very dry in 1979 with an estimated 10 - 15,000 ha
3-very dry in 1979 with an estimated 1 - 5,000 ha
4-little or no production in 1977
5-1976 - 35,000 ha; 1977 - no crop; 1978 - 7,000 ha; 1979 - <1,000 ha

These sorghum areas are situated in the hot-subtropical zone associated with the Awash Basin (FAO 1965), (Fig. 1). This zone lies roughly from 1,000 to 2,000 m in elevation and includes the upper Awash Basin and piedmont areas to the north and east. Annual rainfall varies with location, and generally exceeds 800 mm; it occurs seasonally from March to September, being most intense in the months of July, August, and September. Total rainfall can vary markedly from one year to the next as these areas are drought-prone, particularly to the north and east.

Many varieties of sorghum are grown in this zone with wide variation in planting and harvesting dates both within and between areas. Bird damage to the maturing panicles occurs primarily in the period of September through November, and can continue for many weeks in any one area.

Quelea quelea

The Red-billed Quelea is the major bird pest of lowland sorghum in the above system. Minor pest species include, in order of importance, *Euplectes franciscanus*, *Ploceus* spp. (Ploceidae) *Streptopelia* spp. (Columbidae), and *Lamprotornis* spp. (Sturnidae). The known distribution of *Q. quelea* in Ethiopia is presented in Fig. 2. This includes two races, *aethiopica* (Sundevall) and *intermedia* (Van Someren). It is the *aethiopica* that is found through the Ethiopian Rift, in the Afar Triangle (Jaeger and Erickson 1979) and, into northern Somalia (Allan, per. com.); and it is therefore the race dealt with in this work.

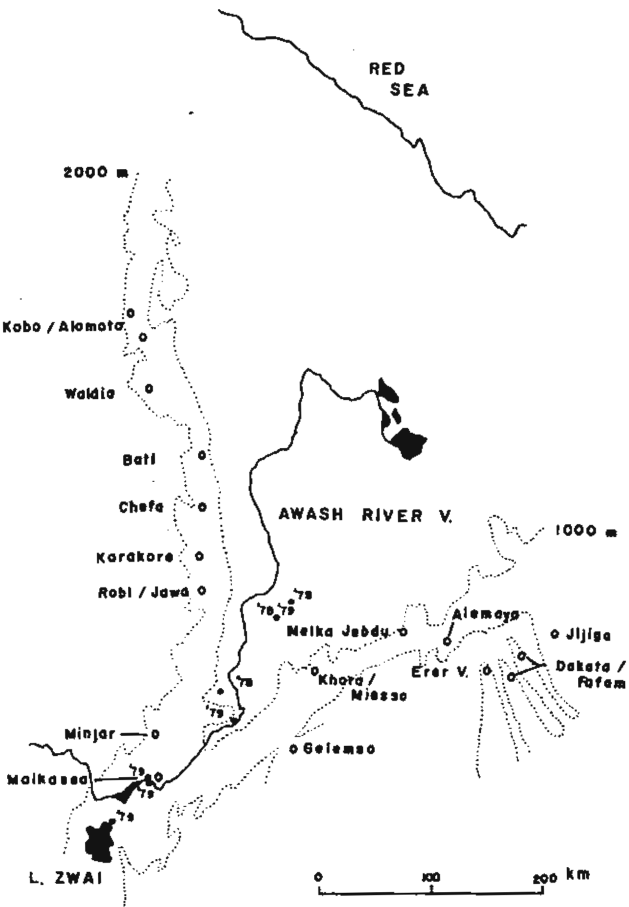

Fig. 1. Major Areas of Lowland Sorghum Associated with the Awash River Basin of Ethiopia Together with the Sites of Quelea Nesting Colonies for the Years 1978 ('78) and 1979 ('79).

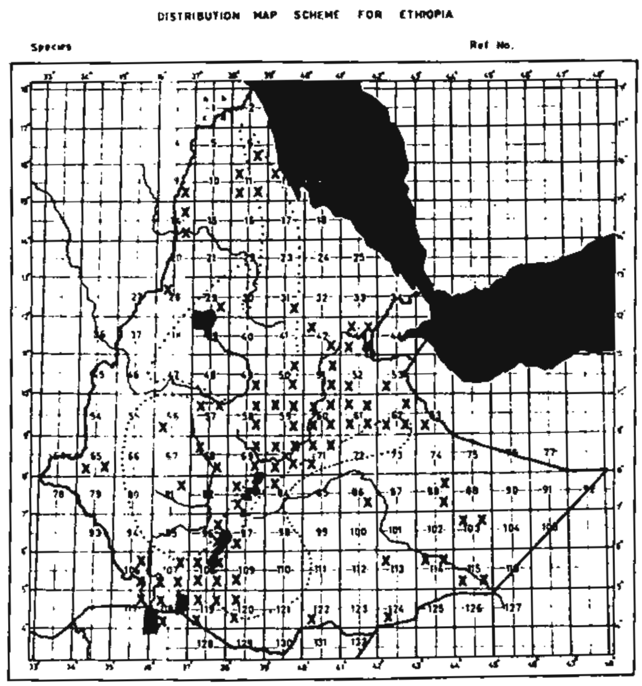

Fig. 2. Distribution Map (Ash 1972) of *Quelea quelea* in Ethiopia. (Records of J.S. Ash, W.A. Erickson, and M.M. Jaeger, Highland area of 2,000 m and above is roughly delineated by dashed boundary line).

Surveys and Control

Aerial and ground surveys were employed in both 1978 and 1979 to locate Quelea nesting colonies. In 1978 aerial surveys were made in the eastern lowlands associated with Melka Jebdu and Jijiga (Fig. 1) in July and August and in the middle and lower Awash Valley in September. In 1979 aerial surveys were again made in the eastern lowlands in August, in the middle Awash Valley in September, and in the Rift Valley from Lake Zwai south to Lake Awassa in October. These surveys focused on what appeared to be suitably dense vegetation for Quelea breeding: for example, thornbush (*Acacia* spp.) or high marsh grass (*Typha* sp.).

The nesting colonies of Queleas located during 1978 and 1979 are illustrated in Fig. 1. In 1978 three colonies totalling an estimated 7,000,000 birds (Erickson and Jaeger, in prep.) were found in the middle Awash Valley. In 1979 five colonies were discovered between Lake Zwai and the Middle Awash Valley. This followed a late July movement of Queleas north from the lower Omo River Valley and Lake Chew Bahir-(Stephanie) area. (Jaeger and Erickson 1979).

The control operations relevant to this work are listed in Table 2. Control of both night roosts and nesting colonies of Queleas is primarily by aerial spraying of the avicide, fenthion. Dosages range from 5 - 10 l/ha of 24 or 30 percent fenthion with droplet diameters in the range of 80 - 150 microns. Once a target is identified as important the spraying is repeated until a satisfactory result is obtained. Estimates of the numbers of Queleas present at each target and the percent kill are subjective, but based on repeated observations. Breeding colonies, however, in 1978 were measured and the number of active nests in each sampled (Erickson and Jaeger, in prep.).

Table 2. Control Operations on Night Roosts and Breeding Colonies of Quelea quelea (September-December) in Sorghum Growing Areas Associated with the Awash River Basin.

Location of Targets	Grid Square[1]	Date	Area (ha)	Est. Nos. Queleas (x 10^3)	No. of Sorties	Est. Kill (%)
Jigiga[r]	62 - d	9.76	10-15	>100	1	<10
		9.76	30-40	>250	2	>95
		9-10.76	15-20	>100	3	>80
		10.76	15-20	>100	2	>80
Chefa[r]	50 - b	11.76	10-15	>50	29	>50
		11.76	2-3	>10	19	>60
		12.76	10	>20	39	>70
		11.77	10	>75	2	>90
		11.77	20	>100	1	<10
		11.77	10	>100	1	>90
		11.77	25	>150	1	>90
Issa Plain[b]	60 - a	9-10.78	80	1,000	3	>50
Mulu Marsh[b]	60 - b	9.78	15-20	3,300	2	unk.
Awere Melka[b]	59 - d	10.78	10-20	3,100	1	>80
Chefa[r]	50 - b	11.78	10	>50	1	>90
		11.78	15	<50	1	<50
Issa Plain[b]	60 - a	9.79	100	>1,000	2	>70
Malkassa[b]	70 - c	10.79	8-10	unk.	2	>80
		10.79	2-3	"	2	>50
Abidir[b]	70 - b	10.79	2-3	"		untreated
Lake Zwai[b]	69 - d	10.79	40	>3,000	4	>70

1 - Refer to map of Fig. 2. r - Night roost

b - Breeding colony g - Ground spray; all others are aerial sprayings

Method of Damage Assessment

The sorghum growing areas in this system are discrete areas in the lower mountain valleys or plains associated with the two highland systems which define the Ethiopian Rift and Afar Triangle. Each consists of an irregular patchwork of cultivated fields varying in size from small individual holdings to collective farms and much larger State farms. The sorghum cultivation is scattered over a large area, much of which is not readily accessible due to difficult terrain. Each of these areas is traversed by a main road, often with a secondary track(s).

The damage survey technique employed was devised to allow for annual assessment of bird damage in most, if not all, of the major sorghum areas considered here, and to do so in the time immediately prior to the onset of harvest. To accomplish this a series of transects is used within any area whereby a visual estimation of the percent bird damage is made on a regular random sample of each of 1,000 panicles. Two hundred panicles are examined at each of five sites. An attempt is made to select evenly spaced sites over as much of the area that is accessible by road or track. This is usually at 5 to 10 km intervals. At each site four separate straight-line transects examining 50 panicles each are followed. These follow one another sequentially and do not all originate from the same starting point- and each is in a randomly selected direction as the pattern of sorghum allows. On individual transects two sorghum stalks are blindly chosen at each of 25 stops separated by intervals of 20 paces. This particular formula for sampling was designed to cover a wide area, and to minimize bias where possible. Because the sorghum is usually irregularly distributed the use of shorter transects with only two estimates per stop facilitates sampling in a straight line while examining panicles over a relatively large area. Transects of longer length necessitate more adjustments in and individual decisions about direction changes.

One of three principal observers conducted each assessment. Individual correction factors were determined for the observers for their estimates at two levels of damage: 1 - 20 and 81 - 100 percent loss and 21 - 80 percent loss. This was done by each observer making 94 test estimates, two independent estimates for each of 47 test panicles; each estimate was separated into one of the two above categories, the difference was determined between each estimate and the actual damage, and the differences were then averaged for each category. The resulting correction factors are listed in Table 3. As can be seen the test estimates were consistently low, and more so in the middle range of 21 - 80 percent damage. Actual damage was determined by counting the damaged and undamaged kernels on all 47 test panicles.

Table 3. Individual Correction Factors for Estimates of Percent Bird Damage to Sorghum Panicles

Observer	Percent Bird Damage	
	1 - 20; 81 - 100	21 - 80
# 1	+6	+9
# 2	+2	+10
# 3	+8	+11

The original estimates were then corrected so as to test for difference among observers and to determine the repeatability or intraclass correlation (Sokal and Rohlf 1969). All damage assessments were corrected according to correction factor of the principal observer. Zeros were not adjusted nor were estimates which would result in corrections equal to or greater than 100 percent. In a two-way ANOVA with replication (mixed model) (Sokal and Rohlf 1969) no significant difference existed between the observers ($.50 > F_{.05\ (2,92)} > .75$). In addition, the intra-observer correlation was high (R=0.97). Test panicles used here included representatives of a minimum of 20 varieties, all collected from areas where damage assessments were made. Furthermore, the 47 test panicles represented a wide range of percentage of bird damage ($\bar{x}$ = 40.4$\pm$ 32.75, 1 S.D.).

RESULTS

Damage Levels

The pre-harvest damage assessments for the years 1976 through 1979 are presented in Table 4 as percent loss to birds in the separate growing areas. The estimated sorghum production for this system as a whole and the overall losses due to birds are given in Table 5. In general the loss estimates may be low due to assessments often being made 2-3 weeks prior to harvest. Nevertheless, these determinations indicate that bird damage can be locally severe such as at Jijiga in 1976 where damage to 35,000 hectares was an estimated 51.4 percent. At an average country-wide yield of 10 quintals per hectare (Ethiopian Ministry of Agriculture 1977), this is a loss of 17,990 metric tons. Local control of Quelea roosts (Table 2), although late, did prevent damage from becoming even greater. As shown in Table 5 losses in the four major growing areas where damage assessments were made in 1976 were estimated to be from 24,100 to 26,800 metric tons, or 12 to 16 percent of the total annual production for this system. Damage assessments could be made in only two major growing areas in 1977, but the levels were similar to those of the year before. Very serious damage would have occurred at Chefa in 1977 had it not been for timely and effective local control (Table 2). In general, there is no reason to believe that Quelea damage in either 1976 or 1977 was unusually high or low. Rainfall throughout the area was average to good.

Control of Breeding Colonies

Damage assessments and production figures (Tables 4 and 5) for the years 1978 and 1979 correspond to the two years where the control of Quelea breeding colonies was undertaken in the upper and middle Awash Valley. Here bird damage is very low with a sharp reduction in estimated losses when compared with the previous two year period. This is most clearly seen when comparing the three large sorghum areas adjacent to the middle Awash Valley: Chefa, Robi and Miesso (Fig. 2). The indications are that Queleas are an annual problem in these areas (Table 4). In 1976 the combined estimated losses were 6,065 to 8,840 tons ($909,750 - $1,326,000), while from Chefa and Robi in 1977 losses were 3,335 to 4,600 metric tons ($500,250 - $690,000) with damage reported from Miesso. This compares with combined losses in 1978 and 1979 of 645 to 890 ($96,750 - $133,500) and 955 to 1,345 ($143,250 - $201,750) tons, respectively; although the estimated area at Miesso in 1979 is less than in the previous three years (Table 1). The dollar - value estimates are based on an average market value of $150 (US dollars) per metric ton.

The overall estimated losses in 1978 and 1979 are one and two percent ($225,000 - $330,000 and $345,000 - $525,000), respectively. This compares with 12 to 16 percent ($3,615,000 - $4,020,000) in 1976, where less of the total area was assessed, 45 - 54 percent, than compared with 63 - 69 and 81 - 87 percent, respectively, for 1978 and 1979 (Table 5).

Damage to 17 hectares of experimental sorghum at Malkassa (Table 4) was reduced in 1978, primarily due to relatively few Queleas moving into this area following control of breeding colonies in the middle Awash Valley. In 1979, however, two breeding colonies were situated very near this sorghum plot (Fig. 1) and the pressure from Queleas was heavy. Damage was minimized, however, primarily through the use of the chemical repellent methiocarb (Erickson and Jaeger 1979). Aerial control of the nearby breeding colonies was late. Sorghum is well suited to the semi-arid conditions in this area; but it is not grown due to the presence of Queleas (Brhane, per. com.). The situation was similar at nearby Lake Zwai where in 1979 a 66 hectare sorghum field, immediately adjacent to a large Quelea colony, was reported to be completely destroyed despite a significant reduction in the numbers of birds with aerial control (Table 2). Again, however, the control was late relative to this sorghum plot.

Table 4. Pre-harvest Assessments of Bird Damage to Sorghum in the Major Growing Areas Associated with the Awash River Basin (1976 - 79).

Location	Bird Damage (Percent Loss ± 1 S.E.)				
	No Control			Control	
	1975	1976	1977	1978	1979
Kobo/Alomata			(-)	(-)	1.2±0.14 (n=600)
Waldia					2.3±0.23 (n=800)
Bati			(-)	1.5±0.20 (n=1,000)	1.0±0.25 (n=1,000)
Chefa		18.6±0.79* (n=1,000)	9.2±0.66* (n=1,000)	0.6±0.06* (n=1,000)	1.9±0.23 (n=1,000)
Karakore Robi/Jawa		10.3±0.51 (n=1,000)	16.1±0.62 (n=1,000)	3.1±0.36 (n=1,000)	3.5±0.32 (n=1,000)
Minjar/Welenchiti			(-)	2.8±0.27 (n=1,000)	(-)
(Malkassa)		41.8±2.83 (n=200)	40.3±2.83** (n=200)	5.7±1.26** (n=200)	22.1±1.91** (n=304)
Gelemso/Mechara	(+)	(+)		(-)	
Afdem/Miesso	(++)	13.3±0.56 (n=1,000)	(++)	0.6±0.10 (n=1,000)	2.4±0.22 (n=1,000)
Melka Jebdu				3.0±0.26 (n=1,000)	(-)
Alemaya				(+)	0.4±0.10 (n=1,000)
Erer Valley	(++)			1.7±0.14 (n=1,000)	9.3±0.61 (n=1,000)
Dakata/Fafam Jijiga Plain		51.4±1.11* (n=1,000)		3.2±0.22 (n=1,000)	(-)

*Local Control of Quelea roosts
**Methiocarb treatment
(-)Qualitative assessment, no significant bird damage apparent
(+)Significant bird damage apparent
(++)Serious bird damage apparent

The absence of Queleas from certain areas in 1978 and 1979 affords an opportunity to appraise damage levels from the other pest species taken collectively. Few or no Queleas were seen at Kobo/Alomata ('79), Waldia ('79), Bati ('78, '79), Chefa ('79), Robi ('78, '79), Minjar ('78), and Alemaya ('79). Damage ranged from 0.4 to 3.5 percent (Table 4), being the most serious at Robi where *E. franciscanus*, *P. rubiginosus*, *P. galbula*, and *P. cucullatus* were all locally abundant. Damage at this level is not considered serious enough to warrant control.

DISCUSSION

Damage Levels

Results obtained here indicate that Queleas can be an important limiting factor in the overall production of lowland sorghum in areas associated with the Awash River Basin, and that damage can be locally severe. This situation probably applies to much of the remainder of approximately 500,000 hectares of lowland sorghum grown annually in Ethiopia (Brhane, per. com.) and to its potential for expanded production.

Table 5. Sorghum Production Estimates for the Major Growing Areas Associated with the Awash River Basin as Related to Pre-Harvest Losses to Birds (1976 - 79).

Production Estimates for Sorghum	No Control[1]		Control	
	1976	1977	1978	1979
1 Total Area (ha x 10^3)	147-220	86-142	119-194	98-167
2 Total Yield[2] (mT x 10^3)	147-220	86-142	119-194	98-167
3 Area Assessed (ha x 10^3)	80-100	25-35	82-122	85-135
4 3/1 (%)	54-45	29-25	69-63	87-81
5 Loss to Birds (mT x 10^3)	24.1-26.8	3.3-4.6	1.5-2.2	2.3-3.5
6 5/3 (%)	30-27	13-13	2-2	3-3
7 5/1 (%)	16-12	4-3	1-1	2-2
8 Loss to Birds[3] (\$ x 10^6)	3.6-4.0	0.5-0.7	0.2-0.3	0.3-0.5

[1]Refers to control of Quelea breeding colonies

[2]Based on an average yield of 1 metric ton (mT) or 10 quintals/ha

[3]Average market value of $150/metric ton

Currently there appears to be no good, alternative to sorghum for the low semi-arid areas other than through the use of irrigation. Fewer, faster maturing varieties and closer synchrony in planting dates might prove beneficial in reducing bird damage. There is no commercial interest in the birds as a food supplement, a prejudice based on religious custom. Other potential uses exist but remain to be explored. Chemical repellents and frightening agents have little applicability over the large areas considered here. In addition, bird scaring by traditional means is very time-consuming and ineffective. One alternative presently available and commonly used in eastern Africa is the lethal control of Quelea roosts and nesting colonies. The annual program of damage assessments presented here is an attempt to systematically monitor this control in terms of cost/benefit, and thereby enabling periodic re-assessment and refinement of the control strategy (Dyer and Ward 1977).

The extreme damage at Jijiga in 1976 (Table 4) prompts a question as to the credibility of this particular estimate in terms of the numbers of Queleas and the daily damage caused by individuals. For example, it would take 4,000,000 birds each destroying 50 g/day, 90 days to account for 18,000 metric tons. Are these reasonable figures? Damage assessments were conducted at Jijiga at the end of September. Severe local damage, however, was observed by late August. By this time some areas of dry sorghum had been completely destroyed, while in other parts flowering was only then occurring. Damage was being done almost exclusively by young juveniles. Breeding occurred in this area during July coincident with damage to the early maturing sorghum by adults. Queleas in the wild eat roughly 1-3 g/day (dry weight) of seed (Jaeger, per. obs., Moseman 1966 from Jackson and Jackson 1977). They can, however, destroy much more; and there are differing opinions as to how much this might be. In many of the sorghum fields visited at Jijiga broken fragments of the grain covered the ground, apparently the result of Queleas. Where the grains were attacked when yet "milky" or "doughy" they had been simply punctured, possibly for the moisture; and they subsequently dried and shriveled. This is to suggest that Queleas destroy considerably more grain than they actually ingest. Obtaining sufficient food in sorghum must take relatively little time; but the intention movements of feeding may continue. Queleas have, for instance, been found stripping the tassels of maize (i.e. male inflorescence) where no evidence of ingestion was found upon dissection (Jaeger, per obs.). Queleas can potentially handle thousands of wild grass seeds per day. In excess of 3,000 have been counted in the crop-sac and proventriculus of a single bird (Jaeger, per. obs.), suggesting that two or three times that number might have been taken over a 12 hour period. The sorghum panicles used for the tests described earlier (See METHODS) had an average of 3242 seeds/head with a range of 497 to 6479. The average dry weights of these seeds/head were not taken; but based on those from other similar panicles can range from less than 100 to over 300 g. It is conceivable then that an individual Quelea might destroy several thousand sorghum seeds in a single day, totalling 100 or more g. In the case of Jijiga it appeared more likely that fewer than 4,000,000 birds were destroying sorghum at any one time; but that those present accounted for an average daily loss of greater than 50 g/bird. This estimate, however, is considerably higher than the 17 - 18 g destroyed/Quelea/day given by Moseman (1966, in Jackson and Jackson 1977).

Control of Breeding Colonies

These results show substantially less bird damage in both 1978 and 1979 where the overall damage is minimal as compared with losses the previous two years; and there is no reason to believe this to be the result of year-to-year differences in the numbers of Queleas. Rather the indications are that this is the result of an effective control of Quelea breeding colonies along the Awash River and at Lake Zwai during the period of September/October.

There is, however, evidence for additional untreated breeding colonies within this system. This is based on samples of juveniles where there are two distinct peaks in the progress of the primary feather moult (Ward, unpub. tech.) suggesting that an earlier July breeding had occurred in all four years (Jaeger and Erickson, unpub.). The colonies themselves have not been located; but are most likely to the east of the Awash Basin, somewhere in the general area of Jijiga. The location probably changes from year to year. The juveniles produced here appear to remain in the general vicinity of where breeding occurred, thereby affecting only local sorghum (e.g. Jijiga 1976 and Erer Valley 1979) in August and September. Quelea damage at this time has not been found elsewhere within this system. These same adults are believed to breed a second time along the middle Awash River. This coincides with the breeding of those Queleas who have moved into the Awash Valley from the Ethiopian Rift, to the south. It is the general dispersal from this September/October breeding which appears to have the more widespread effect on lowland sorghum. Queleas, for example, from those breeding colonies in the semi-arid, grassland savanna along the middle Awash River appear to disperse to both of the highland boundaries of the basin following river tributaries to the sorghum growing areas such as Afdem/Miesso/Assobot, Minjar, Robi/Jawa, and Chefa/Kemisse.

Favorable results in 1979 might have been due in part to the unusual distribution of breeding colonies, specifically those in the upper Awash Valley and at Lake Zwai. The probable pattern of dispersal from these areas is unknown; it is possible that these birds would have remained in this general area of the upper Awash Valley during October/November where little sorghum is grown other than that at Minjar, but where wild seeds and cultivated seeds other than sorghum are abundant (Erickson 1979). No quantitative assessment of damage was made at Minjar in 1979; but surveys indicated that there were neither Queleas nor bird damage.

Of the two breeding colonies found in the middle Awash Valley in 1979 (Table 2, Fig. 1) only the larger colony on the Issa Plain was destroyed. That at Abidir had dispersed before control could be carried out. There is irrigated agriculture at Abidir providing abundant wild grass seeds; and cereals agriculture is a short distance away, up the Awash River. Possibly then the Queleas from Abidir remained in this general area, or otherwise dispersed so as not to have an appreciable effect on the sorghum.

CONCLUSIONS

1 - Quelea damage to lowland sorghum in areas associated with the Awash River Basin is serious enough to warrant control.

2 - Aerial control of Quelea breeding colonies during September/October appears to reduce effectively this damage within acceptable levels. (Total costs of this control are approximately $45,000/year).

3 - The benefits of control of breeding colonies over the local control of roosts are obvious in terms of the greater requirements in man-power, aircraft, avicide, vehicles, and other logistical support needed to protect individual sorghum areas. In addition, the extent of environmental damage is minimized in terms of the amount of chemical used, the area over which it is sprayed, and the numbers of non-target birds affected.

4 - Quantitative damage assessments undertaken annually are an integral part of the control program. The method of damage assessment used here requires verification from more rigorous measurements and from replications within the same area. In addition there is a need for verification of the estimates of the hectares of sorghum within each of these growing areas. The suitability of satellite imagery for these determinations is now being explored.

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