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Jeffrey J. Jackson
UNDP/SF Regional Project Research into the Control of Grain-eating Birds, Chad

Peter O. Park
UNDP/SF Regional Project Research into the Control of Grain-eating Birds, Chad

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BY AERIAL SPRAYING

Jeffrey J. Jackson[1] and Peter 0. Park
UNDP/SF Regional Project
Research into the Control of Grain-eating Birds (*Quelea quelea*)
P.O.B. 21, N'djamena, Chad

Introduction

Quelea quelea is probably the most important avian pest of cereal crops in the sahelian areas of Africa. Its depredations reduce the cereal production of many African nations that lie within its range. To prevent this damage, bird control organizations carry out campaigns to reduce their numbers. Frequently these efforts have given poor crop protection for the cost of control because of inadequate control technology. Factors contributing to the difficulty of carrying out this kind of control are the migrations of the birds which are still incompletely understood, the inaccessability of many nesting areas, the relatively high reproductive potential of Quelea, and the vastness of the territory involved. (The generic name is used throughout this paper to denote the Red-billed (or Sudan) Dioch, *Quelea quelea.*). In consequence, a general population reduction seems impossible.

However, within a broad program of crop protection there are some places and times when destruction of concentrations of Quelea could be a practical means of control. In particular, this is true in situations where nesting colonies are located near agricultural schemes with high-value cash crops.

Aerial application of avicidal sprays is the principal large-scale method of killing Quelea in control programs. Formerly, parathion in oil solution was used (and still is, to some extent) but increasingly is being replaced by fenthion (sold in a 60% solution as Queletox). Dosages of 3 kg a.i./ha, in 10 or more liters of diesel oil, have been commonly used with spray droplet spectra usually in the range 100-200 microns volume median diameter.

Quelea present themselves as targets to aerial spraying in two seasons when they form large concentrations of perhaps as many as 10 million birds. The first of these periods is during the dry season when dense roosts are formed; the second is the nesting season when, at different stages, either the parent birds or fledglings may be the targets. The research described in this paper was carried out in the course of a program for the development of improved techniques for aerial avicide application, itself a section of the general research program of the UNDP/FAO Regional Project on Research into the Control of Grain-eating birds (*Quelea quelea*).

Previous experience had suggested that direct intoxication of nestlings by airborne avicide was not pronounced. Nevertheless, poisoning of a parent is likely to have an effect on the raising of the nestlings. A detailed

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[1]Present address: FAO Quelea Project, P.O.B. 913, Khartoum (Sudan)

biological program was set up to study these effects.

According to recent findings by Pope and Ward (1972) dosages of fenthion below those acutely toxic apparently lead to death by starvation about 24-36 hours after topical application. They termed this delayed mortality by starvation an “anti-feedant effect.” It is understood (Ward, personal communication) that a number of other organophosphorous insecticides exert a similar effect. The practical application of the laboratory finding was not investigated.

If the reduction in dosage of active ingredient could be associated with a reduction in the volume of spray liquid (in contrast with the published finding that a high volume topical application is most effective), this would represent a significant advance in bird destruction technology. Thus, the two specific objectives of the research reported were:

1. To investigate the use of reduced volumes of spray liquid; and,
2. To assess the usefulness of the reported “anti-feedant” effect of low dosages of fenthion (below those causing a high kill by acute poisoning) in practical bird control.

This investigation attempts to bridge a gap between studies of the effects of avicides on captive birds, and biological research on Quelea in the field. In particular, it seeks to identify indirect toxic effects of low dosages of fenthion on wild birds. The data were obtained by conducting five separate simultaneous biological studies on a nesting colony of Quelea, the dosages of some treatments being designated to insure that a proportion of the birds would survive acute intoxication.

Sources on breeding biology of Quelea include Crook (1956, 1960); Dekeyser (1955); Disney and Haylock (1956); Disney *et al.* (1959); Haylock (1959); Lofts (1962, 1964); Marshall and Disney (1956, 1957); Morel et Bourliére (1955, 1956); Morel *et al.* (1957); Vesey-Fitzgerald (1958); Ward (1965); and Wolfson and Winchester (1959). References on aerial application of avicides to Quelea include Bauer (1966); Gaudchau (1967); Haylock (1960); Laurens (1957, 1960); and Schmutterer (1963).

Methods and Materials

Description of Habitat. The habitat was semi-arid savannah interspersed with ponds and seasonally inundated zones near Lake Chad. Common trees included *Balanites aegyptica, Acacia nilotica andansonii, Acacia nilotica nilotica, Acacia seyal, Ziziphus mauritania* and *Hyphaene thebaica.*

The nesting colony was located in a nearly pure stand of *Acacia nilotica andansonii* with trees relatively uniform in height (about 6m but varying between 4m and 7m). Density of the stand was variable, from isolated trees to sections where passage on foot was difficult, with most of the trees at a medium density. It was possible to drive a Land Rover through the colony in nearly all places, although frequently it was necessary to push down or cut small trees to make a path. Grass cover was primarily *Cenchrus biflorus* which grew densely in the more open areas. Water was not found in the colony itself but was present in ponds to the south and Lake Chad to the north. The closest water source discovered was a pond about 3km south of the colony. The lake margin at the time of the study was about 6km to the north.

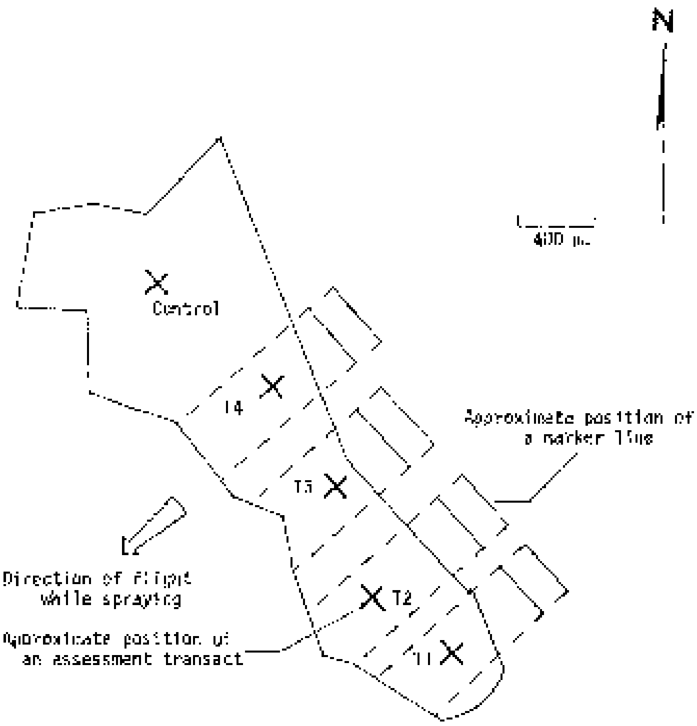

Figure 1. Hadjee el Hamis nesting colony

Operational Methods

a) Survey and Site Preparations. Survey work was begun in late August 1972, when large numbers of Quelea began arriving from the south in the area of N'Djamena, Chad, prior to nesting. An intensive search was made to locate nesting colonies between the 11° and 13° parallels in Cameroon and western Chad. The choice of the research area was based on its proximity to an air-strip, ease of vehicle travel, and stage of the colonies. A suitable site was discovered near Hadjer el Hamis, Chad (Lat. 12°51'N, Long. 14°51'E), on which four treatments could be applied to parallel bands across the site of some 150ha, together with an untreated control area at one end (See Table 1 and Figure 1).

All applications were in parallel swathes at 20m intervals. The directions of flight were designed to be (at least partly) transverse to the predominant wind direction (See Table 3); the precise orientation of the aircraft tracks (bearing 235°) and their spacing was fixed by reference to two parallel marker tracks outside the sites. Twenty meter marks along both lines were measured off, and as spraying proceeded, marked landrovers traveled from mark to mark in such a way that the aircraft could use the two vehicles to fix the alignment of the spray flight tracks. After the position of the spray bands had been selected, cruciform evaluation transects were marked within the colony for each band, 200 m across the line of flight, and 200 m along the line of flight. Sampling sites for the nest observations were marked at 20 m intervals with numbered, colored plastic flagging.

b) Treatments.

(i) Spray Equipment

A Piper PA18 aircraft was fitted in the outboard positions with two AU2000 Micronair rotary atomizers to which Variable Restrictor Units had been fitted in the spray-liquid line directly before the atomizer. These atomizers were driven by 6-bladed windmills (12½" total diam.). Spray liquid was fed from the Sorensen belly-tank through a filter unit by means of a standard windmill-driven gear pump, via an on-off-return three-way valve which allowed for the control of the spray liquid pressure (which was recorded by a manometer mounted on the outside of the windscreen).

(ii) Spray Liquids and Methods of Application

Solutions of fenthion of 6, 12, 24, and 60 percent a.i. were prepared by diluting Queletox 60% with dieseline in the ratios of 10:90; 20:80; 60:90; and 60:0 respectively. Volumes of liquid prepared were related to the area to be treated and volume application desired (See Table 2).

The aircraft flew between 3 and 7 meters above the tree tops and spray liquid was only emitted when the aircraft was passing over the flagged area. In order to maintain maximum accuracy of application, spraying was only carried out while flying one direction over the site and not on the return.

Selection of the periods for spraying was closely related to the behavior of the birds. There was a massive return of feeding flocks at or a little before sunset, with the majority of the birds in the colony before 10 minutes after sunset. However, operational restrictions on the aircraft prevented the onset of spraying from being delayed until this late and the actual periods of spraying resulted from a compromise between the two conflicting requirements.

Ground observers noted the times of passage for individual spray runs. The extent of the sprayed areas in each band was computed from the total spraying times, the air speed, and the swath width. From these, the actual dosage rates were calculated, using known volumes and concentrations of the spray liquids.

Meteorological Records. While spraying was in progress the following meteorological records were taken at a mobile weather station set up at the one end of the marker lines: temperature at 2m and 5m above the ground, the wet-bulb temperature (2m), and the wind direction and velocity at 2m. (In early evening the variations in wind velocity between 2m and 5m were not great. See Table 3.)

Spray droplet spectrum Assessment. Arrays of cards bearing sensitive papers were placed on the ground along the transverse arm of the transects, such that the equivalent of 3 swatch widths were sampled by 13 cards at 5m intervals. The diameters of samples of the droplet-stains were measured visually, using a low power microscope fitted with an eyepiece micrometer. After allowance for the appropriate spread factor, the volume medium diameter of the sample and the 25% - 75% range were determined graphically (Table 4).

Biological Methods

a) Immediate Assessments of Kills. In addition to the detailed biological assessments which follow, a crude measurement of the acute kill, as a proportion of the numbers of adult birds present before spraying, was conducted. A body count of corpses (15-18 hours after spraying) under trees selected at random was compared with the numbers of nests in the same trees. A kill percentage was obtained, assuming two adults per nest and also assuming that the chances of affected birds moving from their home tree equal those of strangers coming to die under the selected tree. The numbers of male and female birds were noted. This method is considered to be the sort of measurement a national bird control team might be expected to carry out on a routine basis.

b) Cage Studies. Four wire mesh cages were installed near the center of each study transect. Two of these cages, measuring lm x lm x lm were placed on the ground, one in the open and the other under medium dense Acacia cover. Ten birds taken from holding cages at the camp were placed in each ground cage. The other two cages, measuring 40cm x 50cm x 60cm were suspended from Acacia branches at nest level. Each tree cage contained 5 birds. All cages were supplied with perches and with ample food (millet) and water as long as the birds remained alive. The general condition of captive birds was observed and recorded daily.

c) Non-target Species. Following each spray, a search was made along the study transect for non-target species killed.

d) Nest observations. Every morning for the duration of the study, five nests were taken from each of the 20 marked sampling sites, giving a total of 100 nests observed per day per study area. The easiest method for collecting the nests proved to be working from a Land Rover. The following data were recorded for each nest: (1) total number of eggs; (2) number of eggs infertile or with dead embryos; (3) number and (4) weight of living nestlings; (5) number of dead nestlings; (6) presence of a dead adult in the nest; and (7) the number of vacant nests. Nestlings were weighed using a Pesola 30 gram spcing balance.

e) Collection of Fledglings. At least 50 fledglings were collected by shooting from each of the five study areas on October 13 and weights of the individuals were recorded.

RESULTS AND DISCUSSION

Assessment of Spray and Meteorological Conditions. Estimates of droplet size from the analysis of the droplet spectra as recorded on sensitive papers are given in Table 2. All treatments showed a reasonably narrow range of droplet sizes with the two higher active ingredient dosage, T1 and T2, having very similar spectra. The higher volume, low dosage treatment T3 had a droplet spectra with a vmd twice that of the corresponding lower volume application T4. Malfunctioning of one of the Micronairs apparently accounted for this.

Meteorological conditions for treatments T1, T2 and T4 were similar, though the first application followed soon after a rain storm and residual turbulence may have affected the spray behavior. T3 was carried out in a slight cross-wing. Dosages of active ingredient were reasonable close to target.

Estimates of immediate Kill. The series of treatments showed wide differences in acute kill. Mean percent kill is summarized as follows: T1, 39%; T2, 62%; T3, 4%; T4, 10%; Control, 0%. There seemed to be some interaction between sex and treatment in two cases, with a higher percentage of females found dead after T1 and a higher percentage of males dead after T2. However, there was no consistent sex effect in the kill inflicted upon adult birds in these trials and others not reported herein, and it did not appear that there was any intrinsic difference in susceptibility of the sexes to poisoning by fenthion. Differences in behavior such as time of return to the colony or uneven distribution of the sexes as to where they perch may explain the differential kills observed.

In the comparison of the pairs of treatments of higher and lower volume dosages, for both the higher active ingredient pair (T1 and T2) and for the lower pair (T3 and T4), the lower volume treatment was the more effective. However it is not certain that these differences can be ascribed solely, or even in part, to the volume of application for other slight variations, inevitable in carrying out operations on successive days, may also exert an influence; slightly higher active ingredient dosages, slightly later period of application whereby a higher proportion of birds had returned to the roost, variations in droplet size distribution, and variations in meteorological conditions. Nevertheless, the significantly greater kill from the lower volume application T2 suggests that such ULV spraying can be useful in practical bird control.

Cage Studies. All 20 of the adult birds placed in cages in the T1 and T2 areas died within 24 hours after the spray. In areas T3 and T4, some birds showed signs of distress the morning after the spray, but all recovered and lived longer than three days after the spray. At this time all appeared in good condition. These results show some important differences, as compared with spray effects observed on wild birds where the degree of acute kill was related approximately to the dosage.

It seems likely that all birds in the T1 and T2 areas received a lethal dose and that the incomplete kill of wild birds was related to behavioral factors, for example, a proportion of the birds being outside the sprayed area, either because they had not returned to the colony or had fled from it, scared by the noise of the aircraft. The recovery of affected birds in the T3 and T4 areas after an apparently insufficient dosage for acute intoxication was unexpected in the light of the observations of Pope and Ward (1972). These recoveries may have been made possibly by the proximity of food and water, not immediately accessible to the wild birds.

Non-target Species Killed. A combined total of approximately 20 Golden Sparrows *(Passer luteus)* and 5 Glossy Starlings (*Lamprocolius chalybaeus)* were found dead in the treatment areas. Helmet Guinea Fowl (*Numida meleagris)* were commonly seen in the vicinity of the colony, but none were found dead.

Nesting Success and Natural Mortality in the Control Area. The purpose of conducting a study in the untreated Control area was to determine the natural calendar of events, including hatching, nestling development and fledging, and mortality of young and nesting success. This information is used in the following sections as a base from which to determine the effects of the avicide.

a. Calendar of Events. Hatching was first observed on September 25, marked by the appearance of a few broken shells of hatched eggs on the ground. The percentage of hatching was still quite low, as a check of several nests revealed no nestlings. The majority of the eggs hatched between September 26 and 29, with the peak of hatching occurring between September 26 and 27.

b. Mortality. The total number of nestlings in the 100 nests examined each day showed four major trends (fig. 2). First, there was a sharp increase in numbers, peaking on September 29; second, a period of gradual decline in numbers between September 29 and October 2; third, a period of stability between October 2 and 6; and fourth, a rapid decline evident after October 6. The initial increase was a result of hatching; the period of decline reflected nestling mortality, and fledging resulted in the final sharp decline.

Nesting mortality can be better understood by examining Figure 3. The upper line (b) represents the total number of living nestlings, as in Fig. 2. This trend is compared with the lower line (a) which represents the mean number of living nestlings per nest each day. The mean number of young decreased rapidly from 2.7 per nest to about 2.0, followed by relative stability until the young began leaving the nest on October 7. Field observations showed that in almost every case where one nestling of a clutch died, it was the smallest one. In broods of three, the two larger nestlings were generally similar in weight and the third much smaller (See Fig. 4). During the period of stability (October 2-6) only 14 nests per 100, on the average, still contained three living young. This represents a decrease from 49 nests with broods of three at the peak of hatching on September 29. Apparently there was a shortage of food in the vicinity of the colony; and two nestlings were, on the average, the maximum number that the parent could raise.

c. Nesting Success and Number of Young Produced. A nest was defined as successful if it fledged one or more young during the normal fledging period. Ten percent of the nests had failed (were empty) just prior to fledging, therefore, 90% of the nests were successful. With a mean brood size of 2.0 prior to fledging (Fig. 3) the Control area produced about 180 young birds per 100 nests. Of the fledglings collected on October 13, 10% were probably seriously underweight (less than 15.0 grams)(See Fig. 10). These underweight birds probably stand a poor chance of survival. By subtracting 10% of 180 (= 18 birds) from 180, it is estimated that 100 nests produced 162 birds, or about 1.6 young per pair. There were 274 individuals (eggs + nestlings) per 100 nests on September 26. Natural mortality had accounted for about 41% loss in production between September 26 and October 13.

Effects of the Treatment on Nesting Success and Nesting Mortality

a) Weight gain. In every instance there was a noticeable divergence in the rate of weight gain between survivors in the Treatment areas and the Control area. This divergence was first apparent ½ to 1½ days after the spray (indicated by an S in Fig. 5), with the heavier dosages (T1 and T2) showing the greater effect. Nestlings in these two areas averaged smaller than in the two lighter dosage areas (T3 and T4). The average weights at the south east end of the colony were a bit less than in the control area prior to the spray. This may indicate that the birds began nesting slightly later than the birds at the other end.

b) Nesting Mortality. Figure 6 shows the total number of live nestlings per 100 nests in the Control and Treatment areas. The time of spray is indicated by an S following the spray. The number of live nestlings per 100 nests was depressed relative to the numbers in control nests with the effect evident for all treatments 1½ days after spraying. The higher dosage treatments (T1 and T2) apparently had the greatest effect on nestling mortality. Figure 7 expresses the results more clearly, as the dates of the spray in T1, T2, and T3 are plotted to coincide with T4 and the Control. The two lower lines represent the greater mortality in T1 and T2, Prior to the sprays, numbers of live nestlings per 100 nests were higher in the control area than in the treatment sites at the south east of the colony.

The effects on nestling mortality are also illustrated by the numbers of empty or dead nests discovered in each area (“dead” nests containing only dead nestlings). Figure 8 shows the data for the four treatment areas compared with the control. The number of empty nests in the control area remained below 10% until fledging began and then rose to 100%. The treated areas showed increases in the proportion of empty nests in the 3-4 days after the respective spray applications and then showed increases in the proportion of empty nests due to fledging on the same dates as the control.

On October 8, 13% of the nests were empty or dead in the control area and 59%, 75%, 40% and 21% in T1, T2, T3 and T4, respectively. Presumably these higher numbers of abandoned nests in the treatment areas represent the death of one or both parents due to the sprays.

Unfortunately some of the sprays (T2 and T3) were so close in time to fledging that the effect of nest loss is partly hidden by normal fledging (Fig. 8). In areas T1, T2, and T4, the effects of the spray on nest abandonment were complete before fledging began and in T3, nearly so. The separation of nest abandonment due to the spray and due to fledging is shown in Figure 9. This is done by plotting the variation in the rate of increase in the number of nests empty or dead each day following a treatment. The difference in the number of nests empty or dead on successive days, instead of the absolute number, is plotted on the vertical axis. For example, on October 8, there were 13 empty dead nests in the Control; on October 9 the number was 56 nests dead or empty. There was an increase of 43, that is a change of +43 to +23. Figure 9 shows two peaks in nest abandonment for all the treatments. The first of these is the result of the spray, and the second is the result of the fledging of the survivors; a high mortality peak due to a treatment results in a small fledging peak as in T1, and a low mortality peak is paired with a high fledging peak as in T4. The control fledging peak is the highest of all and is included for comparison.

c) *Fledgling Weights.* There were differences in the weights of fledglings shot in the treatment areas as compared with the control area, shown in Figure 10. Fledglings in the control area showed an approximately normal distribution around a mean weight of 17.26 g. Mean weights of the fledglings in the treatment areas were considerably lower, with the heavier treatments (T1 and T2) showing the greatest differences (mean weights of 13.75 g and 13.88 g, respectively).

Quelea fledglings normally equal or surpass the weight of their parents during the first week after leaving the nest, being extremely fat. Presumably this fat helps them make the transition from being fed to finding their own food, and it is likely that birds which are very underweight at this time stand a much poorer chance of survival during the first several weeks after leaving the nest. No data are presently available to support this idea. For the sake of comparison of the effect of the treatments on nesting success, we have arbitrarily assumed that fledglings weighing 14 g or less four days after the end of the main fledging period stand a poor chance of survival.

d) *Nesting Success and Number of Young Produced.* A nest was defined as being successful if it fledged one or more young during the normal fledging period. Comparative nesting success was: Control, 90%, T1, 37%, T2, 25%, T3, 67%; and T4, 82%. Data for the treatment areas are based on the number of nests with live young on October 8 (See Figure 8). These data are acknowledged to contain a small error because some fledging had already occurred. This is unavoidable, however, as effects of the last two sprays (T3 on October 3, and T2 on October 4) were not fully apparent until after fledging had begun. Overlap of spray effects and fledging also adds an error to the estimates of mortality and number of young produced per 100 nests.

The number of healthy young produced per 100 nests in the treatment areas is estimated by taking the number of living young per 100 nests at the low point between the mortality peak and the fledging peak in Figure 9 and multiplying that number by the percentage of nestlings estimated to be healthy. The data are summarized in Table 2. There were 63, 40, 104, and 143 nestlings in T1 through T4 respectively at this point. From Figure 10, the percentage of healthy fledglings (i.e., not seriously underweight) collected October 13 was 52%, 38%, 70%, and 62% in T1 through T4 respectively. These figures are taken to approximate the percentage of healthy nestlings at the time of fledging. Multiplying the estimated percentage of healthy nestlings by the total number of nestlings per 100 nests in each of the treatment areas gives an estimated 33, 15, 73, and 89 healthy young produced per 100 nests in T1 through T4 respectively, as summarized in Table 5.

From the estimate of the number of healthy young produced per 100 nests, mortality between hatching and fledging can be estimated. There were 274 individuals (eggs and young) at the beginning of hatching. Mortality was 88%, 95%, 73%, and 67% in T1 through T4, respectively. Comparative figures of estimated percent acute post-spray mortality of adults were 39%, 62%, 40%, and 10%.

This considerable reduction in nesting success is perhaps the biological observation of most interest to pest control operators. This has practical application because, in some cases, it might allow the use of reduced amounts of chemical in areas where young birds are the principal crop pest. This situation frequently occurs when young birds remaining in the area cause damage. In such situations a high kill of adults apparently is not necessary.

The factors that contribute to decreased nesting success and low weight of nestlings and fledglings are of particular interest. Among the possible causes of the low weight is a sublethal effect of fenthion that results in retarded growth of the nestlings or perhaps reduced efficiency of feeding on the part of surviving parents. Such an effect on the parents seems unlikely in view of the recovery from the effects of the spray by the caged birds. A second possibility is that one of the parents was killed, and the remaining parent was unable to give sufficient food to the young. Normally both parents feed the young (Ward, 1965; Morel and Bourliere, 1955). If the low weights are due to this cause, there remains the question of whether the effect on the young is the same when only the male or only the female is feeding the young. If one parent is much more important than the other in providing food, the determination of which parent is the more important to the young and the best time to spray in order to get this parent would probably improve the efficiency of this kind of control operation.

Another question that, if answered, could lead to increased effectiveness of chemical control of nesting colonies is: When are nesting Quelea most vulnerable to poisoning? It is possible that the birds were not equally vulnerable on the different days when the sprays took place. A study of change in susceptibility to fenthion during the nesting cycle might be valuable. If susceptibility of the birds varies widely during the nesting cycle, selection of the most sensitive period should be beneficial.

Conclusions

Aerial applications of fenthion in diesel oil solution to nesting Quelea at a dosage of 2.9 kg active ingredient/ha produce high immediate kills of parent birds, providing that the behavior of the birds is fully taken into consideration. The effects on caged birds demonstrate that there was sufficient poison to give a miximum kill; yet in practical situations, when Quelea colonies are treated after hatching, the conflict between the limitations in suitable spray time imposed by bird behavior and the availability of sufficient daylight for the spraying operations means that less than 100% kill must be considered satisfactory. Dosages of around 0.5 kq active ingredient per ha produce only low immediate mortality.

In these series of trials, lower volume applications of around 4 liters/hectare were more effective than the corresponding active ingredient dosages of around 10 liters/hectare. At 2.9 kg/ha this difference was marked; but other slight variations between the nominal pairs of treatments mean that reservations must be made to any conclusion that ULV treatment is preferable.

The differences observed in the proportions of males and females suffering acute kill varied; but as those differences were of doubtful significance and may have been due to undetermined behavior factors, there was no evidence of differences in sex susceptibility to fenthion.

Natural mortality of 41% of young birds was observed in the unsprayed area between hatching and fledging. During this time the mean clutch size declined from approximately 2.75 individuals per nest to about 2.0. This appeared to be due to food shortage, as in most cases the decrease in numbers was the result of the smallest young being outcompeted by larger siblings.

All treatments caused increased nestling mortality in the period between 1 and 4 days after spraying, as compared with the untreated control area. In addition, all spray treatments resulted in debilitation of surviving young, expressed by a lower rate of weight gain and by stunted fledglings. These results may be explained either by the effects of the chemical on growth of the young, by a shortage of food resulting from the loss of a parent, or both.

Calculations of reproductive efficiency for the control and treatment areas indicate that there were reductions in the numbers of successful fledglings of 88% and 95%, respectively, for the two high dosage treatments and 73% and 67%, respectively, for the two lower dosage treatments. These compare with immediate kills of 39% and 61% and 14% and 10%, respectively. Since young birds are often responsible for severe damage to cereal crops in their early months, even relatively poor kill of parent birds in control operations may exert a disproportionately beneficial effect in reducing crop losses.

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Table 1. Outline details of sites

Site	Approximate date of initiation	Approximate number nests/tree	Area treated (a) Flight line	x Width of band	- ha.	Stage in breeding cycle on date of Treatment Day(b)	Description
T1	11/9	45	520m	280m	14.5	20	Nestlings: 4-5 days old
T2	"	30	570m	240m	13.6	23	7-8 " "
T3	"	35	540m	320m	17.4	22	6-7 " "
T4	"	50	810m	240m	19.5	21	5-6 " "

Notes: (a) The treated areas are expressed as the mean length of the flight path X width of the sprayed area as derived from the number of passages completed over the area.
(b) The day numbering is from initiation (commencement of nest building) with egg-laying occurring about day 3-4, hatching day 14-15, and fledging around day 26-28.

Table 3. Meteorological conditions at the time of spraying.

Site	Mean Temp[a] 1.7m	Mean Temp[a] 4.9m	Rel. Humidity[b] 1.7m	Wind[c] Direc.	Wind[c] Vel.	Remarks
T1	25.7°	26.2°	90%	315°	0.8 kph	Sky partly overcast following rainstorm 30 minutes before treatment
T2	30.9	31.3	55-65%	315°	0.5 kph	
T3	32.3	32.3	60-75%	315°	2.9	Sky clear
T4	30.7	32.6	50-70%	315°	0	Sky clear

[a]The temperature and wind velocity figures are the means of the values determined during the period of spray application.

[b]The relative humidity rose during the period of spraying and the range of values tabulated are those during this period.

[c]During the treatment T1, the pilot reported that the spray cloud could be seen hanging in the trees for 15-20 seconds after the passage of the aircraft.

Table 2. Details of treatments

Site	Treated on: Date	Treated on: Time[a]	Setting of regulator	Micronairs blade angle	Spray liquid Press.	Spray liquid Conc.	Emission l/min.	Dosage l/ha.	Dosage kg.ha	Flight Alt.[b]	Droplet diam.[c] vmd (25%-75%)
T1	10/1	1745 1801	13	40°	45psi	24%	21.5	9.7	2.3	4m	130 (90-175)
T4	10/2	1747 1805	11	30°	40psi	12%	11.0	5.7	0.67	4m	100 (80-130)
T3	10/3	1745 1805	13	40°	45psi	6%	16.0	8.6	0.52	3-4m	220 (175-275)
T2	10/4	1754 1809	11	30°	40psi	60%	9.3	4.8	2.9	4m	130 (105-180)

[a]Sunset occured approximately 17.50.

[b]The flight altitude is in meters above the treetops.

[c]In the description of the spray droplet characteristics, the volume median diameter (vmd) in microns is tabulated together with the range of droplet sizes covering 25% to 75% volume diameters, the latter range giving an indication of the homogeneity of the spray. All droplets are those received on the ground.

Table 4. Relation of the details of the spray applications to the mean immediate mortality of adult birds.

Site	Dosage l/ha	Dosage kg/ha	Mean Mortality Males	Mean Mortality Females	Mean Mortality Total
T1	9.7	2.3	29%	53%	39%
T2	8.0	2.0	72%	52%	62%
T3	8.6	0.52	2%	7%	4%
T4	5.0	0.67	9%	11%	10%

Table 5. Summary of nesting success, number of healthy young produced per 100 nests, and mortality after 20 days following egg hatching.

	T1	T2	T3	T4	Control
No. successful nests/100	37	25	67	82	90
Nesting success	37%	25%	67%	82%	90%
No. living young/100 nests at beginning of fledging	63	40	104	143	180
Percent of fledglings healthy	52%	38%	70%	62%	90%
Estimated no. healthy young produced/100 nests	33	15	73	89	162
Estimated percent mortality after 20 days following 90% egg hatching	68%	95%	73%	67%	41%
Estimated percent acute post-spray mortality of adults	29%	62%	4%	10%	--

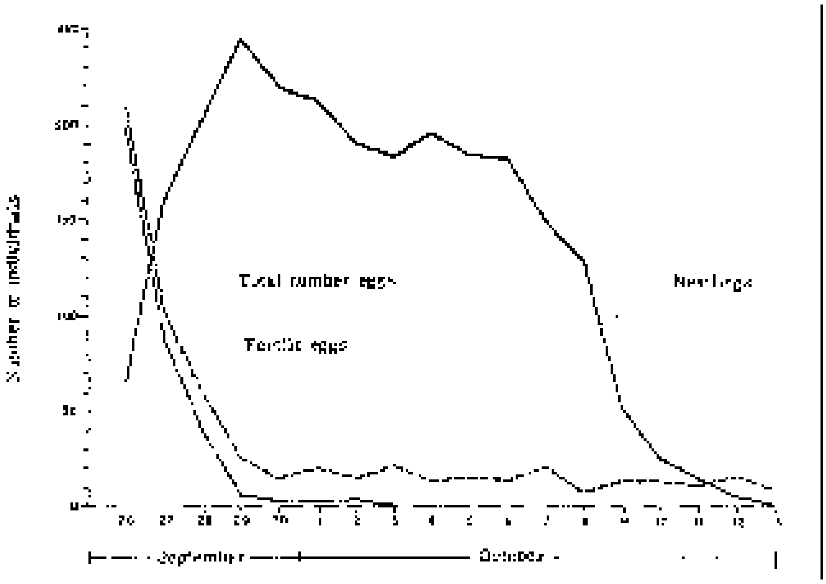

Figure 2. Total number of living nestlings, total number of eggs, and total number of fertile eggs in the Control Area.

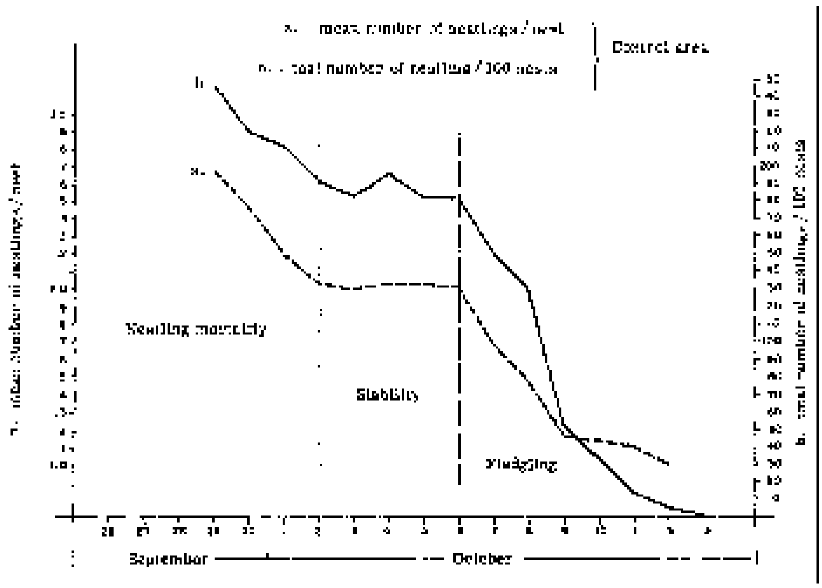

Figure 3. Numbers of nestlings in control area and clutch size.

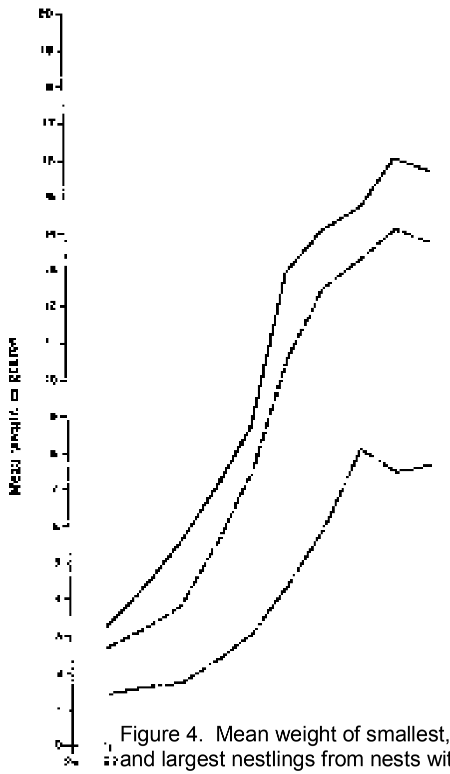

Figure 4. Mean weight of smallest, medium, and largest nestlings from nests with 3 nestlings in Control Area.

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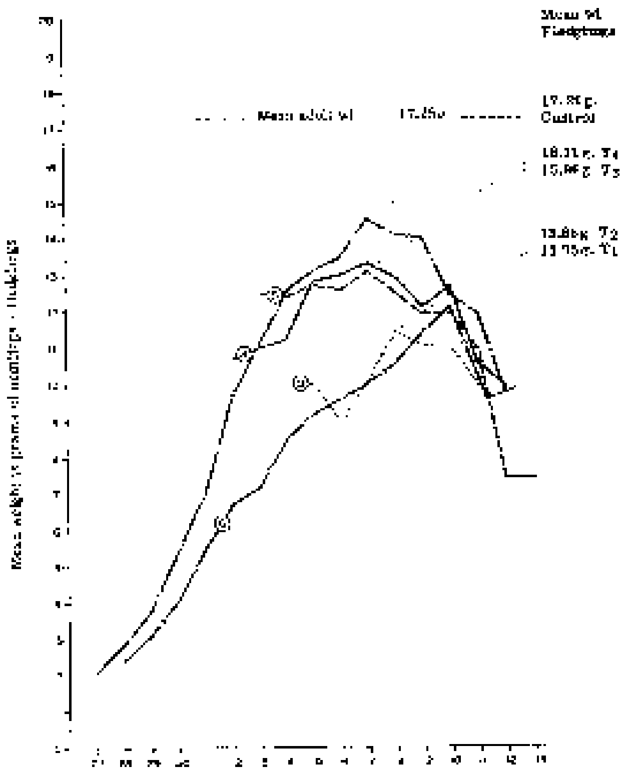

Figure 5. Weight gain of nestlings.

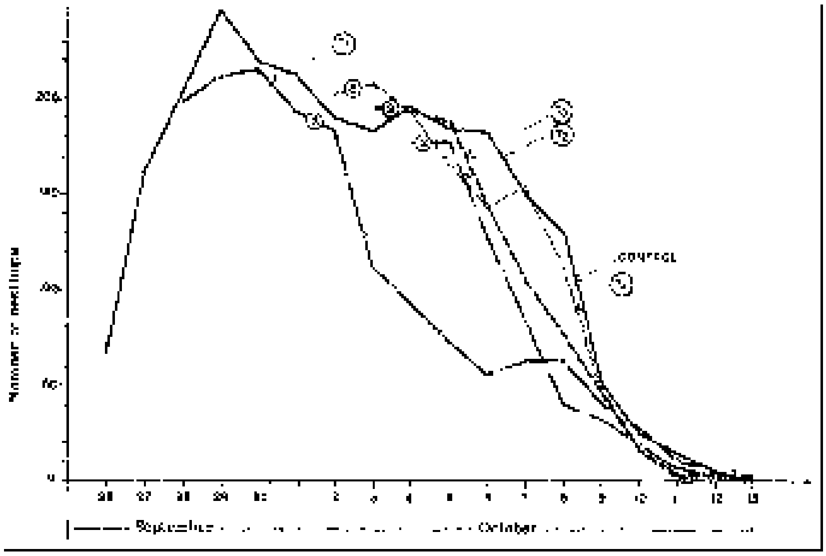

Figure 6. Total number of live nestlings in control and treatment areas. S = evening of spray

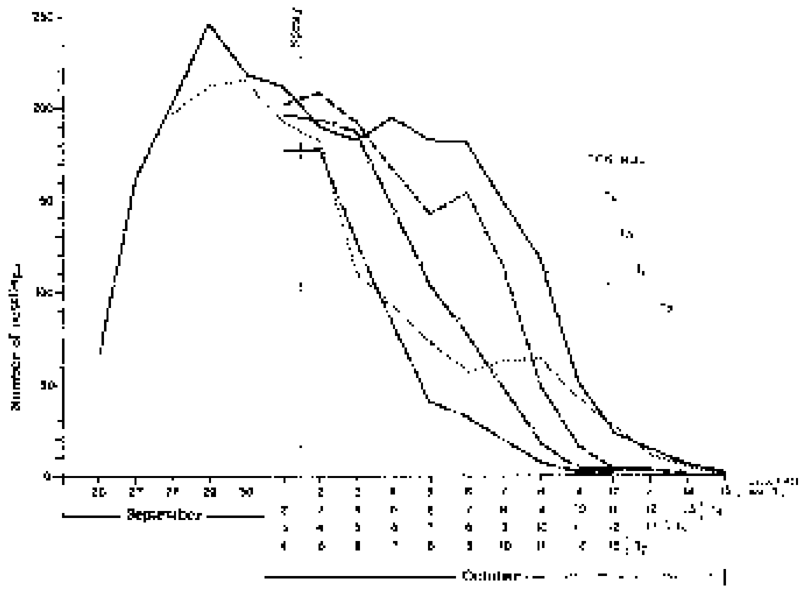

Figure 7. Total number of live nestlings in control and treatment areas. Dates of treatments 2, 3, and 4 adjusted to coincide with spray.

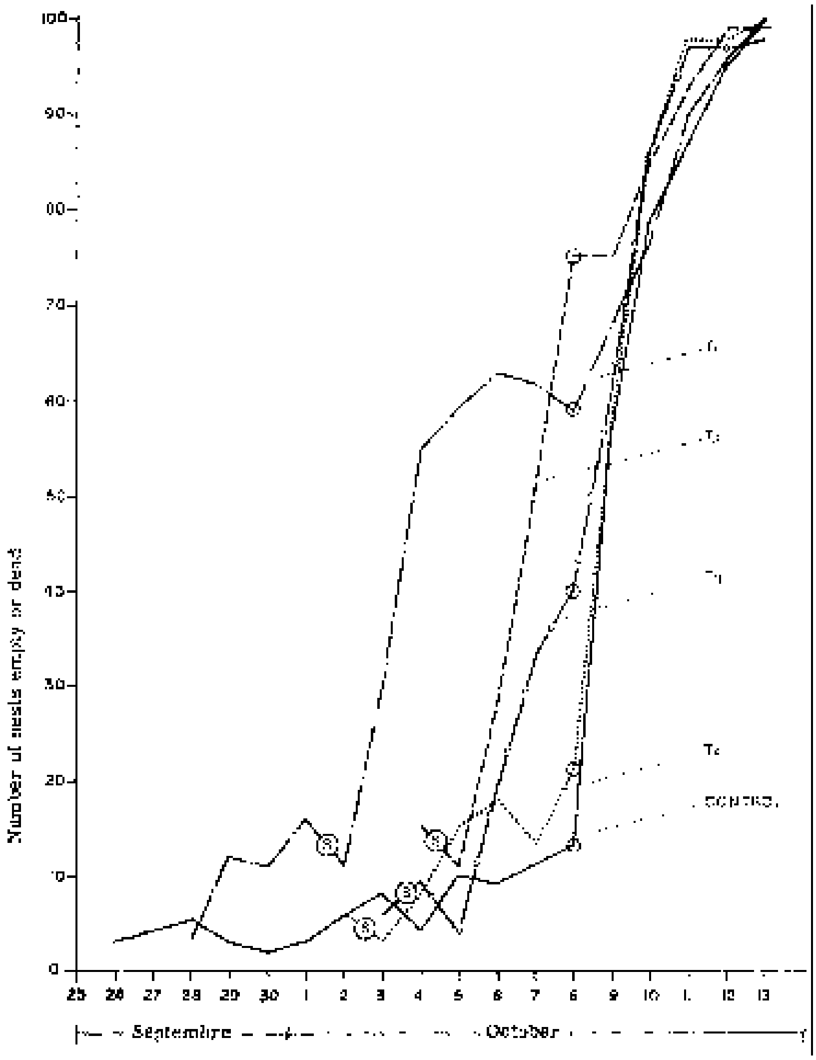

Figure 8. Number of empty or dead nests in each area each day.

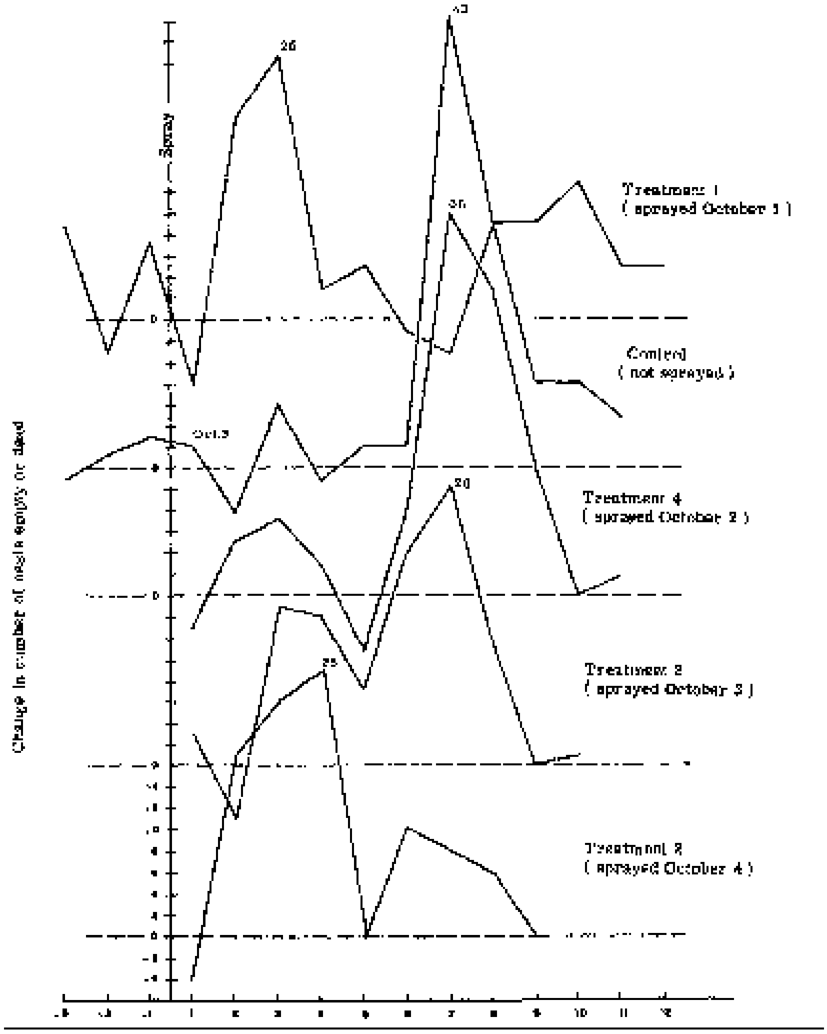

Figure 9. Number of new nests abandoned each day following spray. Data plotted individually. Spray dates coincide; unsprayed control is included.

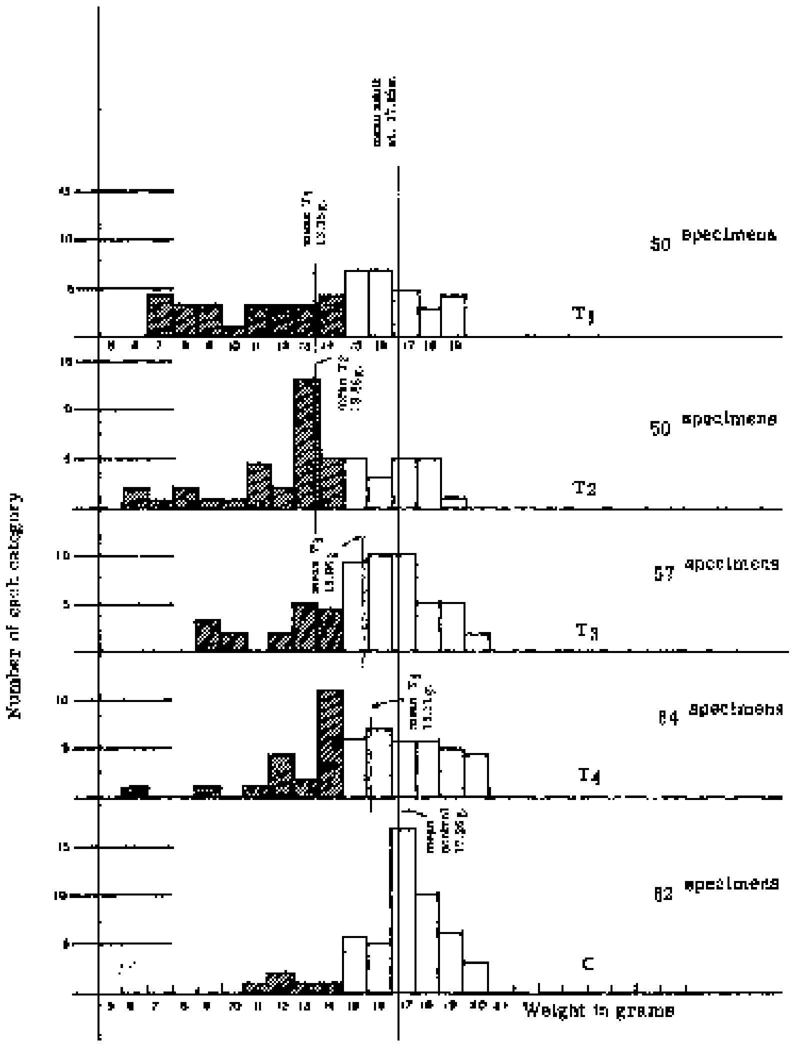

Figure 10. Fledgling weights on October 13.