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# PROTECTING CORN FIELDS ON THE HOPI INDIAN RESERVATION FROM DEPREDATION BY RAVENS AND RODENTS

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Newly planted kernels of Indian corn (maize), together with the young plants, are palatable food for ravens (*Corvus corax*) and species of rodents which inhabit the Hopi Indian Reservation in northeastern Arizona. During 1980 and 1981, tests were performed on the effectiveness of 4-aminopyridine (4-AP) in limiting damage to corn by these pests. In the 1980 tests, comparison was made of depredation in fields treated with a 1.0% 4-AP bait and in untreated fields. Treated fields were groundbaited with a 1:4 ratio of bait:base which was spread at a rate between 0.8 and 1.0 kg/ha in two applications. Untreated fields were groundbaited with the neutral base at the same total rate. Following groundbaiting, damage to all the fields in the study area dropped from a pretest rate of 11.7 bushels/ha to 3.7 bushels/ha in the untreated fields and to 0.3 bushels/ha in the treated fields. Apparently, ravens no longer attacked corn in any of the fields in the geographical locale. Also, damage attributable to rodents was minimal in the treated fields. In the 1981 test, efficiencies of different 1.0% 4-AP bait:base ratios for protecing growing corn from predators were explored. A bait:base ratio of 1:4 was judged satisfactory by Hopi farmers in protecting corn from rodents, and a ratio no stronger than 1:14 was enough to safeguard the fields from ravens.

## INTRODUCTION

The information presented in this report describes use of 4-aminopyridine (4-AP) in attempts to control depredation by ravens (*Corvus corax*) and various species of rodents in corn fields on the Hopi Indian Reservation in northeastern Arizona. The Hopi Reservation, comprising 631,728 ha, is situated at an elevation of about 1800 meters above sea level in northeastern Arizona. Precipitation is scanty and uncertain (under 30 cm annually). The growing season is short (about 133 days), and tillable soil, limited to 0.4% of the total land, extends along ephemeral washes. Over 90% of the arable soil is devoted to cultivation of Indian corn (maize) which has been the diet crop of the Hopis from the time they assumed sedentary life in the 11th century A.D.

From the time early varieties are planted in late April until the stalks of later varieties are about 18 cm high, usually in early July, the kernels and corn sprouts are a preferred food for ravens and rodents. Over the years, the Hopi tribe has used, or has sponsored use of, diverse attempts at controlling these predators. These attempts have included frightening devices (both visual and acoustical), trapping and shooting, poisons, and biological control (burrow and roost destruction). None of the techniques has proved satisfactory. For this reason, the effectiveness of 4-AP, a chemical which holds promise for control of pests, was investigated. Under some circumstances, baits containing 4-AP have evoked distress behavior in affected birds and, as a result, have triggered enduring avoidance (location aversion) of the baited area by both the survivors and other members of the flock (Goodhue and Baumgartner, 1965; Stickley et al., 1976). Also, 4-AP has toxic effects on rodents at dosage rates similar to those found effective with small birds (Goodhue and Baumgartner, 1965). No previous work, however, has explored the possibility that 4-AP may equally well protect crops from depredation by birds and by rodents. Tests on the protective value of 4-AP bait against depredation of corn were undertaken in an environment favorable to the work. 4-AP leaches from bait in a rainfall of no more than 0.7 cm, but rainfall on the Hopi Reservation is normally zero from late May through early July.

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Materials and Methods. The 1.0% 4-AP bait used in the work was prepared in 10-kg batches on an as-needed basis as follows: To 1.5 liters of tap water were added 100 g of hydrochloric acid and then 100 g of 4-AP (Sigma Chemical Company, St. Louis, Missouri). After the 4-AP had dissolved, 9.9 kg of Indian corn kernels were slowly added to the liquid as it was steadily stirred. Thereafter, the kernels were sun-dried. During preparation of the bait, and at all stages of use later, precautions, which included use of disposable plastic gloves, were taken to safeguard the user from direct skin contact with the bait.

Testing of the 1.0% 4-AP bait was conducted in a centrally located section, measuring 45 × 10 km, of the Hopi Reservation which included parts of three intensively farmed washes. Immediately prior to the test, estimates were made of the numbers of ravens and rodents in the area, and the extent of devastation to growing corn was tabulated. During the first week of June, between 75 and 78 different ravens were sighted in various flocks within the area. Also, live traps laid in six planted fields snared seven species of rats and mice. The mean number was 63 trapped rodents/ha, and the range was 30 to 99 rodents/ha. The two most commonly encountered species, deer mice (*Peromyscus maniculatus*) and Ord kangaroo rats (*Dipodomys ordii*), comprised 31.1% and 25.1%, respectively, of all captures. These two species are recognized by Hopi farmers as the primary threats to corn among all mammals inhabiting the Reservation. Inspection of the same six corn fields which had been planted from two to three weeks earlier showed that the mean destruction came to 33.8% of planted corn. Because Hopi corn fields yield a mean of 34.7 bushels/ha (Curtis, 1970), this destruction represented a loss of about 11.7 bushels/ha (U.S. $31.90/ha).

Between the start of the second week in June and the summer solstice which marks the end of the planting season among the Hopis, 32 fields were groundbaited on the same day each was planted in corn. Half of the fields were treated with 4-AP, and the other half of the fields were left untreated. The mean size of the treated fields was 1.3 ha and that of the untreated fields was 1.1 ha. The treated fields were groundbaited with the 1.0% 4-AP bait (1 part) combined with a base of neutral corn (4 parts). The untreated fields were groundbaited with the base alone. Then, 10 days later, each field was groundbaited for a second time. On each occasion, the bait mixture was deposited in a grid-like fashion over every field. From 10 to 12 kernels of the mixture were dropped at 10-footstep (8.6 m) intervals in straight rows across the fields, and the same intervals were maintained between rows. In this way, about 135 bait sites/ha were established. The total amount of mixture laid down in both the treated and the untreated fields in the two applications was between 0.8 kg and 1.0 kg/ha. Thus, the 4-AP bait in the mixture was deposited at an estimated mean rate of around 590 kernels/ha in the treated fields.

Results and Discussion. From mid-July until the end of the month, checks were made on the number of ravens still in the 45 × 10 km area and on the extent of rodent activity in the treated and untreated fields. Also, the 32 corn fields were examined for degree of depredation in each. No rain fell in the region between early June and mid-July. Consequently, 4-AP was not leached from the bait, and the efficiency of the chemical in protecting corn from predators during the period of vulnerable growth could be ascertained.

The second series of counts showed only 11 ravens in the area, and no raven was found in the vicinity of Hopi corn fields. At the same time, there was decreased activity by rodents in the treated corn fields. In early June, signs of rodent activity were evident in all 32 fields. By mid-July, however, no new trails or fresh excavations could be found in any of the treated fields, but these signs were abundant in the untreated fields.

In 13 of the 16 fields treated with 4-AP bait, no shoots or planted kernels were destroyed. In the other three treated fields, damage ranged from 1.1% to 11.0% of the planted corn. Mean damage for all treated fields was 1.0%. In contrast, all 16 of the untreated fields were damaged, and the mean destruction amounted to 10.7%. These percentages may be translated into estimated losses of corn. On the basis of a normal yield of 34.7 bushels/ha, the estimated mean loss of corn was 3.4 bushels/ha greater on the untreated fields than on the treated fields (U.S. $9.25/ha).

Between the data of planting and mid-July, the different rates of destruction for the treated and the untreated fields was probably due to reduction of rodents in the treated fields. The effect of the 4-AP bait on the ravens probably occurred immediately after groundbaiting and caused the ravens to abandon all corn fields in the 45 × 10 km area. This inter-

pretation is supported by comparing damage occurring prior to groundbaiting with damage to the 16 untreated corn fields. Comparison shows that the mean rate of destruction (11.7 bushels/ha) in the six corn fields examined before groundbaiting began was 8.0 bushels/ha greater than the rate of destruction (3.7 bushels/ha) visited on the fields groundbaited with the base alone. These figures indicate that ravens may be charged with more than twice the damage to Hopi corn fields than can be attributed to rodents. This conclusion is upheld by Hopi farmers who contend that ravens do more damage to corn than do all other predators on the Reservation combined.

## 1981 TEST

A second test of how well 4-AP bait protected Hopi corn fields from depredation was conducted in the summer of 1981. The work performed in 1980 had shown that a 1:4 ratio of 4-AP bait:base significantly reduced predation on corn, but the 1:4 ratio had been selected on intuitive grounds. Whether similar protective effects could be gained from using weaker 4-AP bait ratios was not known. The purpose of the 1981 work was to find the protective values of systematically varied bait mixtures containing different ratios of 4-AP bait:base.

Materials and Methods. The 1.0% 4-AP bait used in this test was prepared in the same way that has been described for the 1980 work. After drying, the 4-AP bait was mixed with different amounts of a neutral corn base. The strongest ratio was 1.0% 4-AP bait (1 part) to base (4 parts). Successively weaker ratios were as follows: 1:6.5, 1:9, 1:11.5, and 1:14.

Near the end of May, announcements were posted throughout the Hopi Reservation in which the Hopi farmers were invited to accept, free of charge, a bait for the control of ravens and rodents in newly planted corn fields. In the announcement, the farmers were asked to bring with them a sturdy container with a lid to hold the bait to be provided. When the farmers arrived at the distribution point, use of the bait was discussed on an individual basis with each farmer. The farmer was then given disposable plastic gloves (1 pair for each corn field to be groundbaited) and enough bait mixture to groundbait at the rate of 0.5 kg/ha. In no case was the farmer told what 4-AP bait:base ratio he had been given.

During the individual conversation, the farmer was told not to handle the bait unless gloves were worn and to keep the bait away from livestock. Also, so that groundbaiting practices could be kept consistently the same among farmers, two precautions were taken. First, the farmer was carefully instructed through use of diagrams on the procedure of dropping about 12 kernels of the bait mixture at intervals of 10 footsteps along straight rows of a corn field and to keep the rows 10 footsteps apart. Second, the 4-AP bait:base mixture given to each farmer was enough to groundbait the corn fields cultivated by him at the rate of 0.5 kg/ha. The acreage in corn claimed by each farmer was checked against an annual survey (Bureau of Indian Affairs) on land allocations by the Hopi clans to tribal members.

Results and Discussion. Between the beginning of June and the summer solstice, 4-AP baits were given to 136 Hopi farmers. These farmers accounted for 34.5% of active farmers on the Reservation, and they farmed a total of 241 ha in diverse parts of their tribal lands. The 1:4 ratio was given to 28 farmers, and the other four ratios were given, in each instance, to 27 farmers.

Effectiveness of the different baits were determined by the "double blind" procedure. Neither the Hopi farmers nor the persons who questioned the farmers on the matter of bait effectiveness knew the amount 4-AP bait in the mixture each farmer had been given. The questioning was done by Hopi Indians employed by the Bureau of Indian Affairs. In the interviews, the farmers were asked to rate the baits as either satisfactory or unsatisfactory in protecting the corn fields against (1) rodents and (2) ravens.

Results from the interviews are summarized in Table 1. Inspection of Table 1 shows that there was an inverse relation between strength of the 4-AP bait:base ratio and the percentage of farmers expressing satisfaction with the mixture as a deterrent to depradation by rodents. Where rodents were, presumably, less abundant, weaker concentrations of 4-AP proved satisfactory. A 1:4 ratio of bait:base was needed, however, to deter predation by rodents on all Hopi corn fields. In contrast, even the weakest of the 4-AP bait:base ratios (1:14) was sufficient to prevent damage by ravens. Furthermore, the protection was gained at a cost of approximately $0.75 per hectare against rodents and at a cost of no more than $0.25 per hectare against ravens. Explanation for the difference in the concentration ratios needed to defend

TABLE 1. Summary of Judged Success Rates from Using Different Ratios of 1.0% 4-AP Bait to Neutral Base against Pests in Hopi Corn Fields

| Judged success | Ratios of 4-AP bait to base | | | | |
|---|---|---|---|---|---|
| % (against) | 1.4 | 1:6.5 | 1:9 | 1:11.5 | 1:14 |
| Rodents | 100% | 88.2% | 80.0% | 77.8% | 16.7% |
| Ravens | 100% | 100% | 100% | 100% | 100% |

corn fields from ravens and from rodents, respectively, may lie in the physiological characteristics and behavioral patterns of the two animal forms. The rodents encountered on the Hopi Reservation tend to hoard foodstuffs in their burrows. Consequently, even though a single kernel of 4-AP bait is lethal to a 70-g kangaroo rat, many such kernels may be removed from a treated field by a particular kangaroo rat or other, small, rodent before a lethal kernel is eaten. The ravens, which weigh about 1150 to 1450 g, can become ill before a lethal amount of 4-AP bait in a bait mixture has been eaten. Presumably, the resulting distress behavior in the affected ravens, as has been demonstrated for other species of flock birds (Goodhue and Baumgartner, 1965), induces a prolonged avoidance reaction with respect to the given area on the part of all members of the flock.

## CONCLUSIONS

1. For complete protection of Hopi corn fields from rodents, it is necessary to apply a mixture containing 1 part bait treated with 1.0% 4-AP and 4 parts neutral base calculated on 0.5 kg/ha applied once.

2. For protection of corn fields from ravens, a mixture containing bait treated with 4-AP and neutral base in a 1:14 ratio is no less effective than a mixture in a 1:4 ratio.

3. In regions with a high concentration of pest birds and rodents and a low level of precipitation, losses after introducing bait with 1.0% 4-AP were economically justifiable.

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