EVIDENCE FOR THE EFFECTIVENESS OF AN OLEO-RESIN CAPSICUM AEROSOL AS A REPELLENT AGAINST WILD ELEPHANTS IN ZIMBABWE

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ABSTRACT

Between July 1993 and May 1994 a series of tests was conducted on free-ranging elephants in Zimbabwe to evaluate the effectiveness of a Capsicum-based aerosol as an elephant repellent. Reactions from the elephants were observed in 80% of three types of tests in Hwange National Park and 89% of two types of tests in the Gokwe Communal Lands. The test results suggest that this Capsicum solution has validity as an elephant repellent over both short (20-30m) and intermediate (50-100m) ranges and that Capsicum is an effective short-term repellent. No data were collected on possible long-term effects. These preliminary results suggest that this chemical may act as a practical elephant deterrent when combined with aversive conditioning of problem elephants. Research is continuing into improving the delivery system and the methodology of application.

INTRODUCTION

Elephants cause considerable damage each year to both subsistence-level agriculture and commercial crops in Africa and Asia. For example, Asian elephants *(Elephas maximus)* in Sumatra annually destroy millions of dollars worth of agricultural crops, including date palms and sugarcane (Sterba, 1989). In India, several hundred people lose their lives to raiding elephants each year (Sukumar, 1989). The African elephant *(Loxodonta africana)* is increasingly in conflict with humans throughout sub-Saharan Africa. Especially vulnerable to elephant depredation are drought-prone areas where crop-raiding elephants threaten food security. Both excessive costs and ambiguous results have hampered the development of effective, non-lethal repellents and deterrents.

There is a pressing economic and social need for a reliable, low cost, easy-to-use elephant repellent. However, elephants are highly intelligent and it is notoriously difficult to modify the behaviour of free-ranging animals. A number of logistical challenges must be accommodated in order to modify effectively the behaviour of a solitary 'problem' elephant or a group of crop-raiding elephants. Crop-raiders quickly habituate to false threats (e.g. drum beating, shouting, etc.), and in some cases persistent bulls have not been deterred by gunfire, including shooting one of the group (R. Martin, pers. comm.). Kangwana (1993) played back tape recordings of Maasai cattle to elephants which have periodically been hunted or injured by the Maasai. She concluded that elephants retreated from the recordings because of an association made between the danger posed by the Maasai and the sounds of their cattle.

A number of studies of elephant communication have demonstrated possibilities for manipulating elephant behaviour with play-backs of vocalisations. Bull elephants were attracted by play-backs of recorded post-copulatory rumbles (Poole *et al.*,1988; Poole & Moss 1989; Langbauer *et al.*, 1991). Play-backs using the musth rumble repel non-musth males, but not musth males or females (Poole, unpublished). There are a number of other calls which could be used to attract or repel elephants which are less well understood, but perhaps could be used in the future. The problem with elephant sounds is that most are of very low frequency and thus require expensive equipment to record and play-back (Anon. reviewer, pers. comm.).

In addition to the need for fast-acting repellents, longer lasting deterrents are needed for application in vulnerable crop-raiding regions. The results of tests in Malawi and South Africa involving a German manufactured deer repellent "HATE-C4" have been equivocal. In Malawi, Bell & Mcshane-Caluzi (1984) reported no significant decrease in crop damage. In South Africa, La Grange (1989) reported positive results with "HATE-C4" but no details were given. This chemical was also tested in Amboseli National Park on refuse dumps in 1981 but the elephants ate the treated material nonetheless (Anon. reviewer, pers. comm.).

The control of crop damage by insects, birds and mammals through the use of long-lasting, passive deterrents, is an active area of research in Europe and North America. To control insect predation, attractant pheromones are often combined with lowered amounts of pesticide (Booth, 1988). A variety of non-lethal repellents specific to birds have been used to protect important agricultural crops (Avery, 1989; Mason, 1989; Nolte *et al.*, 1993c). Among mammals, mink and coyote urine deterred mountain beaver damage to Douglas fir trees in the western United States (Nolte *et al.*, 1993a, 1993b). North American deer avoided predator urine (Melchiors & Leslie, 1985; Muller-Schwarze, 1972; Sullivan *et al.*,1985; Swihart *et al.*, 1991). Elk were deterred from feeding on alfalfa by coyote urine (Andelt *et al.*, 1992).

The problem of people-habituated and refuse-raiding black and brown bears prompted a search for deterrents and repellents (Hunt, 1983). Free-ranging and captive bears in a variety of situations have been tested (Hunt, 1984). One of the most promising chemical deterrents has been a Capsicum-resin aerosol. This mixture has been used to repel attacking bears and to condition aversively, habituated, problem bears (Smith 1984; Hunt, 1984, 1985). Because the active principle may affect several sensory systems, the exploration of its possible use as an elephant deterrent was considered. Two unpublished studies in Kenya on the use of Capsicum were known prior to our initial investigation. Capsicum was tested on refuse dumps in Amboseli National Park (Anon. reviewer, pers. comm.) and Capsicum was applied to fence posts in the Laikipia District (V. Booth, pers. comm.). Both tests yielded negative results.

Capsicum, usually derived from the dried, ripe fruits of several species of the family Solanaceae, for example *Capsicum frutescens* (African chillies) or *Capsicum annum* (Tabasco pepper, Louisiana long pepper) are very complex mixtures; over 80 peaks have been detected (using chemical tests) in the head space of Tabasco pepper seeds, including alcohols, aldehydes, ketones, esters, hydrocarbons and furans (Ingham *et al.*, 1993). Capsicum stimulates extrinsic (non-olfactory) innervation in the olfactory mucosa, namely the trigeminal nerve. Capsicum eliminates or severely reduces trigeminal chemosensitivity in the nasal cavity without significantly affecting olfaction or taste (Mason *et al.*, 1987). Trigeminal response to volatile chemical stimuli disappears in human adults chronically tested with large doses of Capsicum (Silver *et al.*, 1985, 1991). Especially relevant to studies involving repellency and deterrence to Capsicum are the relationships between sensitisation and desensitisation and repetitive tests and/or long-term use (Green & Shaffer, 1993; Green, 1991).

In elephants, as in other mammals, the nasal mucosa, both olfactory and respiratory, receive sensory innervation via two branches of the trigeminal (cranial V) nerve. Chemical stimuli, such as the complex Capsicum aerosol used in these tests, may stimulate a variety of sensory receptors including those of olfactory, vomeronasal and trigeminal systems, on entering the nasal cavity (Tucker, 1963, 1971). The elephant, with its long nose, possesses one of the most extensive trigeminal systems known. Its large turbinate areas makes the elephant a highly macrosomatic mammal; its sense of smell is one of the most acute in the animal kingdom. In this nasal region a variety of senses interplay (Rasmussen, 1994).

This report presents the findings of two series of experiments to test the effectiveness of Capsicum spray on wild elephants. The first set was designed to ascertain whether the spray had any effect on the elephants and if so, to establish the range of reaction. The second set was designed to identify potential logistical modifications needed for application of the spray as a deterrent.

MATERIALS AND METHODS

Tests were conducted on wild African elephants at two locations in Zimbabwe: Hwange National Park (22 tests between 16 and 22 July, 1993) and in the Gokwe Communal Lands (GCLs) surrounding the Sengwa Wildlife Research Area (SWRA) (18 tests between February and May 1994).

The chemical tested was OC-10 (made by Bushwacker Backpacking Co.), a 10% oleo-resin Capsicum solution which was propelled from a 15oz aerosol canister. The resin was atomised on firing and had a spray width of approximately one metre and an initial range of four to five metres. The oleo-resin floats in a cloud and can remain effective for up to 75m in a light wind. Partial controls were employed to discount the effect of the investigators presence and/or the discharge of the cans' contents.

In all tests it was likely that the elephants would have been able to smell the testers. In order to control for the presence of people (i.e. scent and sound), a period of 10 to 20 minutes was allowed to pass before testing. This period increased the probability that the reactions

Two men spraying to demonstrate the initial range of the Capsicum units.

which were recorded were elicited by the spray, rather than the presence of the researchers.

The tests in Hwange were conducted in three types of situations. In seven trials elephants were tested by investigators on foot. The elephants were sighted at random (i.e. the first encounter off the road network) and approached from down-wind so as to determine age and sex. The testers would then move up-wind and spray after a short control period. Seven tests were conducted opportunistically from the vehicle when one or more elephants were within range (between 25-50m) and the wind was favourable. Elephants which appeared to react to the vehicle were not tested. After a pre-test control period the spray was fired in a wide burst towards the selected elephant. The average distance from the vehicle to the elephants in these tests was approximately 40m. In eight tests a radio-controlled remote firing stand was used at waterholes. The stand was located up-wind from a pre-selected water hole, camouflaged with grass and elephant dung and fired from a distance of approximately 250m. The experiments were video-taped from approximately 150m down-wind. After the elephants arrived at a waterhole a pre-test period of 10 minutes was allowed to elapse before the experiment commenced. The test was aborted if the elephants appeared to react to the observers or the sight or smell of the spray stand during this interval.

The 18 tests in the GCLs were conducted in cultivated areas on groups of habituated crop-raiding bulls. In 12 tests the spray was administered while the investigator was on foot and in six tests the remote stand was used. In this series all tests were conducted at night. The sessions were video-taped on nights with moonlight using light-enhancing equipment. The taping began at least 10 minutes prior to the stimulus release. When the elephants entered a selected field, the group was counted, the sexes noted, and individual identification made whenever possible. The owner of the field would then attempt to chase the elephants from the field by traditional means (shouting, throwing burning sticks or shooting sling shots). If after a short period the elephants did not leave the field, the test would begin. The tester moved into position up-wind of the elephants at a distance of 30-50m. When the control period (5-10 minutes) had elapsed, the camera personnel alerted the tester to fire. The firing time was recorded on video tape. An entire can was expelled per trial and the test continued for 30 minutes or until the elephants were out of sight. The area was monitored to ascertain whether elephants returned to the field the same night. However, revisitation rates to fields by tested elephants were not known due to the inability to identify individuals at night.

Observations of the resin cloud indicated that the spray held together for 20 minutes or more in little or no

Photo credit: Ferrel V. Osborn

Test field 4 in GCLs: retarded by drought, then destroyed by elephants.

wind and was still effective after travelling 50-75m in a light wind. Depending on the wind velocity and the distance between the elephants and the testers, a period of 30 seconds to two minutes elapsed before reactions were observed. This period, after the spray was fired and before the elephant reacted, indicated that the animals were not reacting to the sound of the aerosol can, but probably to the components in the spray. When the spray was fired it created a sound similar to that of a high pressure air hose. During the initial spray stand tests, elephants within five metres of the stand seemed frightened by the unusual sound and retreated before inhaling the spray.

RESULTS

The 22 tests conducted at Hwange National Park resulted in 19 (86%) positive responses (Table 1). Of the eight trials with the spray stand, five appeared to cause a repellent reaction. In the other three tests the elephants appeared to react to the sound of the can firing rather than to the spray itself. The nearest animal down-wind of the stand was the first to be affected by the mist from the spray; the animal froze momentarily and audibly expelled air. Affected elephants shook their heads and vocalised, often roaring and trumpeting, before moving off. In four of the tests the elephants stopped, then touched their eyes repeatedly with their trunks, before re-orientating and moving off rapidly.

The seven trials from the vehicle, conducted exclusively on bulls found singly or in small groups, resulted in the selected animal retreating in all tests. When the spray reached each elephant, it froze, exhaled air and 'periscoped' with its trunk towards the source of the spray. Upon testing the air, the elephants immediately shook their heads vigorously. In all seven tests the bulls turned away from the spray and moved off rapidly. The presence of the vehicle and the testers may have influenced the reaction of these elephants, but the subjects appeared to be unaware of the testers' presence. In each test the "reaction" was recorded after a period of time which corresponded to the rate the Capsicum travels in light wind conditions.

Results from the third type of test, with the investigator on foot, were similar, except that in three of the tests the subjects first 'bluff charged' (moving towards the testers rapidly then stopping and vigorously shaking their heads) before being sprayed. No hesitation was observed after the elephants inhaled the spray, unlike among those observed from the vehicle and during the remote stand tests.

Table 1. Results of tests in Hwange National Park (July 1993).

Test	# Ele	Mode	Location	Reaction	Results
1	FG17	ST	WH	Retreat	After 17 seconds
2	FG9	ST	WH	Unclear	After 31 seconds moved off
3	B4	OF	BSH	Retreat	Closest bull moved first (15 seconds) followed by three (28 seconds)
4	B3	V	BSH	Retreat	All three retreated (21 seconds)
5	FG15	ST	WH	Disorientate & retreat	Group confused for 18 seconds, then moved off rapidly
6	FG12	ST	WH	Retreat	Group moved off after 33 seconds
7	B2	OF	BSH	Retreat & vocalise	Closest bull touched trunk to eyes
8	B1	OF	BSH	Retreat	(27 seconds)
9	FG7	ST	WH	Unclear	FG smelled testers, waited 20 minutes, then reacted to the sound of the stand
10	FG12	V	BSH	Retreat	FG inhaled spray and retreated rapidly
11	FG6	ST	WH	Unclear	FG moved off in panic because of sound of spray stand
12	B1	OF	BSH	Retreat & vocalise	Bull became disorientated and roared, bluff charged
13	B4	V	BSH	Retreat	Closest bull exhaled air, paused, and all moved off together
14	FG9	ST	WH	Retreat	FG retreated when cow closest to stand inhaled spray
15	B2	V	BSH	Retreat	Bull did not react immediately but after 30 seconds
16	B1	OF	BSH	Retreat	Into thick bush
17	FG11	ST	WH	Retreat	FG after two cows inhaled spray
18	B1	V	BSH	Retreat & vocalise	Bull vocalised (roars and rumbles) after inhaling spray
19	B4	V	BSH	Retreat	The first bull's reaction seemed to cause the others to retreat
20	B6	V	BSH	Retreat	First bull to inhale spray charged
21	B1	OF	BSH	Retreat	Thick bush
22	B1	OF	BSH	Charged	Bull charged and when sprayed retreated

FG = family group; B = bull; WH = water hole; BSH = bush; ST = spray stand; V = vehicle; OF = on foot

*Table 2. Results of tests in the Gokwe Communal Lands (February-May 1994)**

Test #	# Ele	Mode	Reaction	Results
Test 1	4	ST	Retreat	Bulls moved off rapidly after inhaling spray
Test 2	2	OF	Retreat	Reaction of the first bull occurred 2:50 seconds after stimulus was released
Test 3	7	ST	Retreat	After 25 seconds, stand approx 30 minutes.
Test 4	UNCL	OF	Retreat & disorientate	Bulls became disorientated; after 28 seconds , moved off; 20 minutes paused, then off in a new direction
Test 5	2	ST	Unclear	Bulls seemed to react to the sound of the spray
Test 6	7	OF	Retreat	Closest group of four retreated rapidly; other three left after 15 minutes
Test 7	14	OF	Retreat & vocalise	Bulls moved from the field slowly
Test 8	2	OF	Retreat	Wind erratic; bulls reacted after 58 seconds
Test 9	9	OF	Retreat	Bulls appeared to panic; moved towards testers then retreated
Test 10	1	ST	Retreat	Bulls moved across field in panic after inhaling spray
Test 11	1	OF	Retreat	Bulls immediately left field after inhaling spray
Test 12	6	OF	Retreat	Two groups of three bulls; only one group retreated
Test 13	3	OF	Retreat	Bulls retreated 2 minutes after first reaction
Test 14	8	OF	Retreat & disorientate	Group became disorientated and moved in a number of directions before retreating
Test 15	4	ST	Retreat & vocalise	First bull vocalised; group moved towards stand, then retreated
Test 16	2	OF	Retreat	Bulls were 20 metres apart; only one bull moved
Test 17	UNCL	OF	Unclear	Sound of the spray
Test 18	4	OF	Retreat	Bulls all moved from the field in different directions

**All test were conducted on bulls at night on agricultural land.*
ST = spray stand; OF = on foot

Results from the 18 tests in the GCLs, as recorded on video tape, revealed a similar pattern of response throughout (Table 2). In two tests it appeared that although the conditions seemed satisfactory, the elephants did not inhale the spray. In the other 16 remaining tests, the elephants seemed to ignore the sound of the spray being fired and continued to feed. The elephant in contact with the spray immediately stopped feeding and raised its head in alarm. This action was followed by an audible exhalation of air, then a rumble or roar. The rest of the group froze until the next animal in line inhaled the spray. The elephants then emitted a series of excited trumpets, rumbles and roars, followed by a hurried and disorientated exit from the field in the opposite direction from which the spray came.

DISCUSSION

The data presented in this study suggest that Capsicum oleo-resin spray possesses short-term repellency towards African elephants. Affected elephants retreated and did not continue their normal routine (i.e. drinking at a waterhole or continuing to feed). However, in these field tests we could not eliminate completely the variables of human scent and the sound of the firing can. It is impossible to quantify precisely the reaction of a wild elephant to a specific stimulus in a situation with numerous confounding factors. This difficulty has been pointed out in the study by Langbauer *et al.* (1989, 1991) on the reactions of elephants to play-backs of infrasonic calls. These investigators recognised that actions as subtle as lifting the head or increased ear fanning could be considered responses. They usually had no way of asserting whether the responses they recorded were a response to the play-back or to infrasonic calls from distant elephants. With regard to these Capsicum tests, it is similarly difficult to ascertain the details of how the elephants were affected. Tests on captive elephants would be more conclusive, but ethical considerations of tests with irritants pose a constraint.

Can elephants be aversively conditioned?

Information from wildlife managers and recent field observations during this study suggest that crop-raiding may be taught by example from a small number of older bulls to younger ones. We suggest that elephants which are "initiators" of destructive behaviour should be targeted for behaviour modification. If a relatively small number of bulls are inciting others to engage in destructive behaviour, problem populations could be controlled by altering the actions of a few individuals. If the elephants which initiate crop-raiding could be taught to avoid agricultural areas a serious economic problem could be ameliorated. Conditioning through the use of aversive stimuli (ie. pepper spray) when the elephant is engaged in an undesired behaviour, may be sufficiently disturbing to cause the raider to associate adversity (i.e. itching skin, watering eyes, burning sensation in the trunk mucosa, trigeminal pain reception) with the particular behaviour (i.e. crop destruction). Theoretically, elephants could be discouraged from foraging in agricultural areas. In this experiment the repellent, but not the deterrent properties of this spray have been demonstrated.

In 1982, Hunt (1984) offered two definitions in the context of Capsicum spray research on bears: "Repellents are activated by humans and should immediately turn an animal away in a close approach or attack. A deterrent should prevent undesirable behaviours by turning an animal away before a conflict occurs. Deterrents need not be monitored or manually activated by humans ". Our current studies are aimed at increasing the effectiveness of Capsicum as a deterrent now that we believe we have demonstrated its repellent properties. The possibility that an elephant may associate a sound (whistles or horns) with the adverse reactions (pain) to the Capsicum is currently being evaluated. Periodic reinforcement of a sound with Capsicum spray may be necessary, if an elephant learns that the single stimulus of sound is a false threat.

The economic considerations of the application of these chemicals are very important. It is recognised that the logistical hurdles regarding the cost and effective application are formidable. The Capsicum aerosol which was tested is relatively expensive (US$18 per unit) and has to be imported. However, electric fencing schemes in Zimbabwe are funded by foreign donors at an installation cost of US$500 to $1500 per km (Hoare, 1992). Most crop damage in Zimbabwe occurs between February and May (Taylor, 1993; Hoare & Mackie, 1993), followed by eight months of relatively low levels of conflict. Considering these factors, non-permanent deterrents may become more economically viable over time. In addition, the value of subsistence agriculture cannot be measured in purely economic terms. Often the affected crop is the only source of food for rural families. The time spent defending crops and sourcing the availability of alternative food must be considered. If the chemical experiments described above are successful in deterring elephants, these technologies could be simplified and administered by local wildlife authorities during the crop-raiding season.

Photo credit: Ferrel V. Osborn

Bulls crossing through an electric fence.

Future areas of research

The responses of an animal are dictated by genetic selection pressures, learning experiences and instinctive propensities of particular species (Bullard, 1985). Protecting crops from animal consumption with a chemical compound with which the animal is unacquainted, may be less effective than a biological product which has been repeatedly encountered by the animal in its environment. The understanding of the repellent and attractive properties of natural scents and their components is only in the initial stages of development. Tests to assess the effectiveness of chemical repellents that include natural products such as elephant pheromones or other semio-chemicals, are being planned. Such chemical communicators could prove to have long-term biological effectiveness and, similar to insect pheromones, could be synthesised and used in economically viable pest control programmes.

Chemical compounds with potential species-specific deterrent capabilities may prove an effective way to deter elephants. Gorman (1986) tested African elephant temporal gland secretion as an elephant repellent with somewhat ambiguous results. However, areas of potential research include studies similar to the recent study of the chemical senses of Asian elephants which specifically examined how female elephants communicate sexual receptivity (Rasmussen *et al.*, 1993). The ongoing studies of musth awareness chemosignals emitted by musth Asian bulls and perceived by females (Perrin *et al.*,1994, Perrin *et al.*, submitted) also offer possibilities for future elephant attraction, repulsion and containment. The avoidance reactions exhibited by female elephants to specific light volatile fraction from musth bulls when expelled from air canisters (Perrin *et al.*, submitted) are also potentially useful. It has been suggested that elephants secrete different chemical components through the temporal glands depending on differing situations (Anon. reviewer, pers. comm.). Synthesised temporal gland secretions from periods of intense fear (i.e. culling) could be used as a repellent.

Ongoing and future work in this project

Ten crop-raiding bull elephants were radio-collared in the SWRA of Zimbabwe and their movements monitored during the 1994/5 wet season. Fields adjacent to SWRA were defended with Capsicum in an effort to determine the validity of this method which will be tried again during the 1995/6 growing season. Improvements aimed at the design of the Capsicum delivery system and reduction in the cost per unit are ongoing (e.g. an inexpensive Capsicum powder grenade). Field testing of semio-chemicals and identified elephant pheromones is planned for early 1996.

Farmers, researchers and wildlife managers in Africa and Asia are exploring techniques for repelling elephants. However, very few of these data are published. For example, farmers in Kenya burn chili peppers claiming the smoke keeps elephants away. It has been suggested that a slowly burning Capsicum device, made by a farmer and placed around his fields, might keep elephants away (Anon. reviewer, pers comm). We are very interested in any ideas or suggestions regarding the control of elephants by chemical means and we invite correspondence to the first author's Zimbabwe address.

To conclude, with proper design, a Capsicum or chemical-based technique could be a cost effective supplement, or even an alternative to electric fencing or the shooting of problem elephants. The results of our first experiments offer hope that chemical repellents such as Capsicum may provide affordable, non-lethal tools for managing elephants in areas of conflict with humans.

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