Testing the efficacy of a chilli–tobacco rope fence as a deterrent against crop-raiding elephants

K. Chelliah[1], G. Kannan[1], S. Kundu[1], N. Abilash[1], A. Madhusudan[1], N. Baskaran[1] and R. Sukumar[1,2,*]

[1]Asian Nature Conservation Foundation, c/o Innovation Centre, and [2]Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India

Chilli-based repellents have shown promise as deterrents against crop-raiding elephants in Africa. We experimented with ropes coated with chilli-based repellent as a cheap alternative to existing elephant crop-raid deterrent methods in India. Three locations (Buxa Tiger Reserve, Wyanad Wildlife Sanctuary and Hosur Forest Division) representing varying rainfall regimes from high to low, and with histories of intense elephant–agriculture conflict, were selected for the experiments that were conducted over 2–3 months during the pre-harvest period of the kharif season in late 2006. Chilli and tobacco powder mixed with waste oil was applied to ropes strung around agricultural fields of 1.4–5.5 km perimeter and elephant approaches were monitored. Elephants breached the rope fences a few times at all three study sites. Female-led herds were far more deterred (practically 100% reduction) than were solitary males (c. 50%) by the chilli–tobacco rope. Efficacy of this method as a deterrent was significantly better in the low-rainfall regime relative to medium and high-rainfall regimes. The initial promising results present a case for more rigorous experimentation; these would help determine if the elephants avoiding the rope are responding physiologically to the chilli–tobacco smell or merely reacting cautiously to a novel substance in their environment.

Keywords: Chilli-tobacco fence, crop raids, deterrents, efficacy, elephant–human conflict.

CROP depredation by elephants is a key conservation issue across their range in Asia and Africa[1–4]. Chronic crop raids foster antipathy among the affected farmers towards the species and negatively impact conservation efforts[3–7]. Effective and economically viable mitigation methods are required to minimize elephant–human conflicts to provide relief to suffering farmers as well as promoting more positive attitudes towards elephant conservation. A range of measures, including simple noise-making devices, trip-wire-activated alarms, thunder flashes, strobe lights, trenches, non-lethal electric fencing[8], playback of infrasonic calls of elephants[9] and pheromone repellents[10] have been tested (Table 1). Results have been mixed, with none of these methods combining low cost with acceptance among people, ease of maintenance and effectiveness beyond the short term.

The elephant has a complex olfactory apparatus capable of an acute sense of smell[11]. Asian elephants have more than 32 highly convoluted olfactory turbinals and a bilobed vomeronasal organ that are used in sophisticated chemical communication involving volatiles such as hormonal metabolites and pheromones in urine, dung, temporal gland secretions, ear and inter-digital gland secretions[12–14]. This has inspired several experiments to discourage crop depredation by targeting the olfactory system of elephants[15,16].

Capsaicin is an active component in *Capsicum* species that stimulates sensory afferent neurons and changes membrane fluidity and lipid composition[17]. Osborn and Rasmussen[15] experimented with chilli essence (10% oleoresin capsicum) sprayed as an aerosol from a can and the elephants retreated during 86% of the trials. Other experiments showed that the elephants were repelled within 2 min by capsicum spray as opposed to 4–14 min by other traditional methods such as flares, noise and fires crackers[18]. The chilli-spray delivery system, however, is effective only when the elephants are downwind to the spray. Capsicum irritant encapsulated in liquid form and hurled at elephants (in the form of a grenade) has also been tried, but often there are problems in the effective delivery of the potential repellent[19,20].

Farmers of the Transmara region, Kenya, have traditionally used a burnt mixture of red chilli and elephant dung to repel wild elephants from their crop fields (N. W. Sitati, pers. commun.). Based on this knowledge, Sitati and Walpole[21] experimented with a simple delivery system for the chilli–tobacco essence in this region. A mixture of waste engine oil, chilli and tobacco was applied to a nylon rope (10 mm diameter) fence strung at a height of 1.5 m in two different trials. In the first trial at the village of Nkararu, Kenya, a 1.4 km long chilli–tobacco–essence 'rope fence' was installed along the village–woodland boundary, whereas in the second trial a 4 acre plot at village Lolgorien, Kenya was encircled by a similar rope. Trained farmers were stationed at both sites to observe and record attempts by elephants to raid crops. African elephants learnt to walk along the linear fence at Nkararu and enter the farms at the location where the rope ended. Elephants did not breach the rope even when they were chased away; instead they ran along the rope until its endpoint and then exited the farmlands. At Lolgorien, the chilli rope fence was 100% effective in deterring elephants from the 4 acre plot for a period of 2 years despite nine attempts by elephants to raid the crops here; however, in this case the elephants had alternative unenclosed cultivated plots nearby to raid and did so seven times during the study period[21].

Efficacy of chilli–tobacco–grease rope fence has not been evaluated on a large scale, such as encircling an

*For correspondence. (e-mail: rsuku@ces.iisc.ernet.in)

Table 1. Existing mitigation methods to deter crop-raiding elephants and their limitations

Method	Description	Limitations
Noise and flares	Drums, shouting, firing shots, flares, flashing lights	Short-term effect: elephants learn to recognize them as empty threats
Trenches	Masonry-sided trenches, 2 m deep, 2 m across at the top and 1.5 m wide at the base[3]	Expensive and fill up during rains; completely ineffective in high-rainfall areas
Electric fences	Non-lethal electric pulses of over 5000 V and 1/3000 s in duration[3]	Expensive, regular maintenance needed. Some bulls learn to breach the fence with their non-conducting tusks or through other means
Acoustic deterrents	Playback of musth rumbles[8]	Repels non-musth males, but not musth males and females
	Playback of the buzz of disturbed honey bees: most elephant families fled after approximately 18 s from the onset of the sound[27]	Possible habituation over time
Pheromone repellents	Chemicals secreted by elephants for communication: for example, ketones by musth males could induce behavioural responses[28]	In research phase; delivery system using elaborate mechanical structures prohibitively expensive

Table 2. Description of study sites

Location	Tiamari, Buxa TR	Amavayal, Wyanad WLS	Gulati, Hosur FD
Latitude/longitude of the village centre (decimal degrees)	26.61N/89.77E	11.35N/76.01E	12.39N/77.82E
Area (km^2)	0.25	0.06	1.8
Perimeter (km)	2.20	1.40	5.5
Number of houses	34	3	60
Study period	15 September–30 October 2006	19 September–28 December 2006	9 November–22 December 2006
Land use in the surroundings	Teak (*Tectona grandis*) plantation to the north and east. Mixed degraded forest to the south and paddy fields to the west	Tropical dry and moist deciduous forests	Tropical dry thorn forest on all sides

TR, Tiger Reserve; WLS, Wildlife Sanctuary and FD, Forest Division.

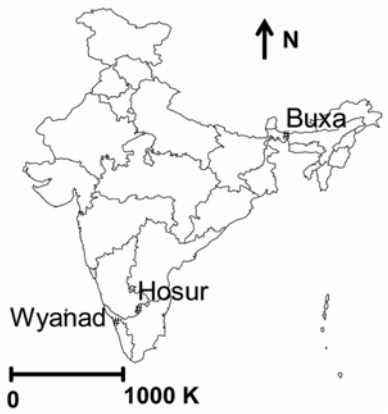

Figure 1. Location of the three experimental sites. High rainfall regime – Tiamari, Buxa Tiger Reserve, West Bengal; Medium rainfall regime – Amavayal, Wyanad Wildlife Sanctuary, Kerala and Low rainfall regime – Gullati, Hosur Forest Division, Tamil Nadu.

entire village by a fence instead of just small isolated plots; neither has it been tested in India as a deterrent for crop-raiding Asian elephants. We tested the efficacy of the chilli–tobacco–grease method in three forest villages in different Indian states (Tiamari in Buxa Tiger Reserve, West Bengal; Amavayal in Wyanad Wildlife Sanctuary, Kerala; Gullati in Hosur Forest Division, Tamil Nadu; Table 2 and Figure 1). These villages are located in regions with a history of chronic elephant–human conflicts[22–24] and represent high, medium and low rainfall regimes respectively (Figure 2). The entire forest village in each trial was encircled with a single strand of jute or cotton rope at an average height of 2 m. The rope was coated with oil–chilli–tobacco mixture (1 kg each of chilli powder and tobacco mixed in 10 litre of waste oil from vehicle engines). The farmers and/or researchers reapplied the mixture on the rope every third day.

Elephant approaches were monitored through direct and indirect signs in all the three villages. One or two informants were appointed in each village to talk to the farmers and note down elephants visually sighted by them during the night vigils. Village informants, whenever visibility permitted, recorded the approximate age-group, gender, solitary tusked male or tuskless male (locally known as 'makhna'), time of visit and duration of crop-raids or attempted crop-raids. Qualitative description

Table 3. Proportion of elephant approaches that resulted in a breach of the chilli–tobacco–rope fence

Location	Total rainfall during the study period (mm)	Duration (days)	Number of approaches (between 0 and 25 m from the fence)		Number of breaches		Proportion of elephant approaches that resulted in a breach of the fence		
			Male	Female-led herd	Male	Female-led herd	Male	Female-led herd	All elephants
Tiamari, Buxa TR	226	46	12	3	11	0	0.92	0.0	0.73
Amavayal, Wyanad WLS	203	72	10	0	5	0	0.50	0.0	0.50
Gulatti, Hosur FD	28	44	16	18	6	1	0.38	0.06	0.21

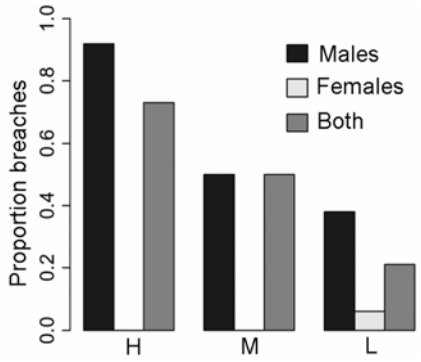

Figure 2. Chilli–tobacco–essence rope fence efficacy versus rainfall regimes. Proportion of breaches is the proportion of elephant approaches within 25 m of the chilli–rope fence that resulted in a breach. Females refer to female led herds. H, High rainfall (Buxa); M, Medium rainfall (Wyanad); L, Low rainfall (Hosur). The proportion of breaches by female-led herds in the high and medium rainfall regimes is zero.

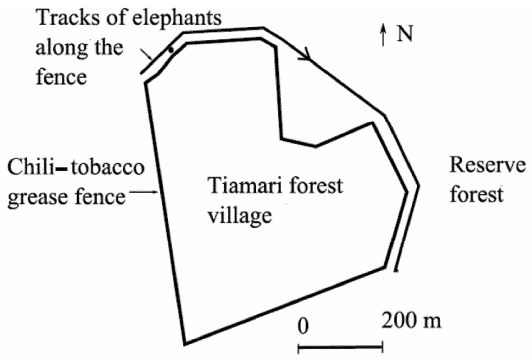

Figure 3. An example of avoidance behaviour by a female-led herd in Tiamari, Buxa, inferred from track evidence. The polygon with solid black line is the chilli–tobacco–grease fence along the boundary of Tiamari forest village. The outer solid black line along the periphery shows the path which the herd of elephants took. The black dot on the northwest corner of the village indicates the place where a single set of adult tracks leads towards the rope, stops short and then retraces and rejoins the tracks of the herd.

of the responses of elephants to the chilli–tobacco rope was also recorded.

Every evening before sunset the one or two informants walked the entire periphery of the village and erased old elephant footprints where it was possible, or marked them where it was not possible to easily erase the footprints. Every morning the same two informants walked the entire periphery and made a note of new elephant footprints and the distance from the rope. Every third day a researcher visited the village and collected information from the informants, then walked around the village periphery and marked all elephant approaches, the distance from the fence and breach points, if any, using a hand-held GPS unit.

Elephants breached the rope at all three study sites (Table 3); however, there was a clear gender bias in the efficacy of the fence at all the three sites (Figure 2). Female-led herds were 100% repelled at Tiamari and Amavayal (at Gullati only one female-led herd entered the paddy fields through a 3 m gap in the fence meant for vehicle entry). Gulatti, the driest of the three sites, showed the smallest proportion (0.21) of elephant approaches that resulted in a rope breach, with Amavayal (medium-rainfall regime) at 0.50 and Tiamari (high-rainfall regime) at 0.73 with progressively more breaches (Figure 2). Differences in the observed proportion of breaches across rainfall regimes are statistically significant ($G = 13.1$, $df = 2$, $P < 0.05$). The experiment was not rigorously designed to compare relative efficacies of the fence across rainfall regimes, as there were no controls for confounding factors such as differences in guarding efficacy, elephant density, monitoring methods and the presence of one or two regular crop-raiding elephants.

Avoidance behaviour was observed on several occasions at all three sites by some female-led herds as well as bulls. Avoidance behaviour was characterized by sniffing with the trunk pointed towards the fence (as observed by farmers on night guard) and walking along the fence at a distance that varied between 2 and 10 m (Figure 3). Based on avoidance behaviour elicited in female-led herds and some bulls, we propose that chilli fences have the potential to reduce crop raids by elephants, especially in low-rainfall regimes. However, it is likely that the rope at current concentrations of chilli and tobacco (about 1 g/m of rope) acted as a psychological barrier owing to its novelty, rather than as a physiological deterrent (through olfactory irritation) because of the following observations.

(i) On several occasions elephants hunched under the rope where the terrain was uneven, causing the rope to be

at a height of c. 2.33 m instead of 2 m. A difference of 0.33 m is not sufficient to cause a huge difference in smell potency.

(ii) On several occasions elephants walked along the fence at a fairly close range and entered the fields through a narrow gap no wider than 3 m. If smell were such a major olfactory irritant and caused unbearable discomfort, the elephants would not have entered through such a narrow gap.

(iii) A marked gender bias in repelling efficacy was observed. Had the chilli–tobacco essence been a major olfactory deterrent, it should be equally uncomfortable to both male and female elephants. However, what we observed was a clear difference in the behavioural responses of female-led herds and some bulls. Female-led herds in general are more conservative in terms of risk-taking behaviour owing to the presence of calves and juveniles[25]. The chilli–tobacco fence is a novel element encountered in an already risky scenario of crop-raiding and therefore, it may have been effective in arresting raids by female-led herds.

(iv) The behavioural responses of elephants to the chilli–tobacco fence, based on limited night-time observations, do not seem to be as sharp as those (viz. alarm, head shake, exhalation and hasty retreats) observed in African elephants exposed to oleo-resin capsicum spray in the 1993 and 2002 trials[15,18].

Responses to a novel substance diminish with time, whereas true biological responses do not[14]. Therefore, repeated exposure of elephants to the chilli–tobacco fence is required to determine the nature of the response observed in such experiments.

The chilli–tobacco–grease rope fence can be easily rendered ineffective by rain and even dew, but the low-cost relative to other barriers makes it an attractive option, especially in low-rainfall areas. At the time of our experiment, the cost of chilli–tobacco essence was around Rs 500/km/application. At an application frequency of once in three days, the cost of maintenance of a single-strand fence for 3 months in a year leading up to harvest is estimated to be around Rs 12,000/km. A second strand at a height of 1.5 m to prevent smaller elephants from entering the fields may further improve the efficacy of the fence, but at an increased cost of fence installation. In comparison[26,27], elephant-proof trenches cost approximately Rs 100,000/km and non-lethal electric fences cost approximately Rs 150,000/km. Materials used in the chilli–tobacco grease fence are locally available at affordable prices and there are no labour charges when the community participates in fence installation and maintenance.

Based on our preliminary experiments with chilli–tobacco essence, we propose that it is a potential cost-effective elephant crop-raid mitigation method in dry regions. However, long-term experiments with varying concentrations and compositions of chilli–tobacco essence with controls for confounding factors are required to test the efficacy of the chilli–tobacco–grease fence against elephants. Other promising, harmless, volatile chemicals or objects that have been tested on captive elephants and found effective should also be tested for comparison against chilli–tobacco essence. Repeated exposure of elephants to the chilli–tobacco fence is essential to determine if the elephants that avoided the fence were responding physiologically to the chilli–tobacco smell, or merely reacting cautiously to a novel substance in their environment. In such case, the use of different substances during successive seasons or years to prevent conditioning and installing the rope just after the crop flowering stage, coinciding with the withdrawal of rainfall, would be a more effective mitigation strategy. The cost of installing and maintaining a chilli–tobacco fence is considerably less than that of trenches and high-voltage electric fences. Alternate delivery mechanisms that can reduce labour involved in reapplying the chilli–tobacco–grease will enhance the acceptance of this mitigation measure among farmers. Research to produce a long-lasting chemical base for gradual delivery of the deterrent would be one step in this direction.

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Suppression of ACC oxidase expression in tomato using heterologous gene from banana prolongs shelf-life both on vine and post-harvest

Atul Batra, Vidhu A. Sane, Prabodh K. Trivedi, Aniruddha P. Sane and Pravendra Nath*

Plant Gene Expression Laboratory, National Botanical Research Institute (CSIR), Rana Pratap Marg, Lucknow 226 001, India

1-Aminocyclopropane-1-carboxylate (ACC) oxidase is the final enzyme in the biosynthesis of plant hormone ethylene which has been identified as a key player in controlling ripening and softening of fleshy fruit. We have used banana ACC oxidase gene in antisense orientation in order to suppress ethylene biosynthesis in transgenic tomato. There was a significant increment by more than 10 days in the shelf-life of the transgenic fruit post red ripe stage. There were no differences in total soluble sugar content and pH. The amount of ethylene produced by transgenic fruit was always lower at every stage of ripening compared to wild type. The activities of cell-wall hydrolases and ACC oxidase were reduced by 40–60% and 30–40% respectively, in the turning and red ripe stages of transgenic fruits. It is concluded that antisense suppression of ACC oxidase in tomato using heterologous gene provides a suitable system for prolonging on-vine and off-vine shelf-life of tomato after red ripe stage of maturity.

Keywords: ACC oxidase, cell-wall hydrolases, ethylene, fruit ripening, transgenic fruit.

FRUITS form a major part of human and animal diet and are an important source of vitamins, minerals and antioxidants. The quality of a fruit is determined by a wide range of desirable characters such as nutrition, flavour, taste, processing qualities and shelf-life. The world total fruit production is a few hundred million tonnes annually, out of which 40% of all tropical fruits is contributed by India[1]. Though India leads the world in the production of banana (16 million tonnes equivalent to 20% of the world produce) and mango (11 million tonnes equivalent to 65% of the world produce), it lags behind in export due to less-than-satisfactory quality of the produce largely due to poor post-harvest practices. It is estimated that up to 30–50% of the fruit may be lost due to inadequate post-harvest management, including less-than-efficient means to check over-ripening, causing an estimated loss of a few billion dollars per year[1]. Improved post-harvest management, including development of varieties which have

*For correspondence. (e-mail: pravendranath@hotmail.com)