

A Delivery System for Carbon Monoxide Fumigation of Indian Crested Porcupine, *Hystrix indica*, Den Using Two-Ingredient Cartridge

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Abstract.- Indian crested porcupine, *Hystrix indica*, in Pakistan, is a pest of economic importance in forestry and agricultural systems. A simple, safe, effective and environment-friendly delivery system for carbon monoxide fumigation of porcupine dens, using two-ingredient cartridge, is described and evaluated. Employing this system, cartridges of various weights were tested in different habitats and soil conditions. The test results indicated 100 percent reduction in active porcupine dens with the usage of 250, 350, 375g cartridges in porous sandy, clay loam and silt loam soils having varied moisture contents. The system is highly suitable for effectively using two-ingredient cartridge for fumigating the dens of foxes, jackals, coyotes, dingoes and denning porcupines.

Key words: carbon monoxide, delivery system, fumigation, gas cartridge, Indian crested porcupine

INTRODUCTION

The Indian crested porcupine, *Hystrix indica*, an Old World porcupine species, is widely distributed in Pakistan. It is commonly found in man-made and natural forest plantations, across the agricultural landscape, sandy deserts, mountainous valleys, and steppe mountain regions (Greaves and Khan, 1978; Roberts, 1997; Khan *et al.*, 2000). It has also been recorded from the moist temperate deciduous forest of Machiara National Park (Azad Jammu & Kashmir) at 3,200 m elevation, the highest point so far recorded of its distribution (Awan *et al.*, 2004). Various studies have identified it as a serious vertebrate detriogen of economic importance in agriculture and forestry systems (Ahmad and Chaudhry, 1977; Greaves and Khan, 1978; Gutterman, 1982; Alkon and Saltz, 1985; Brooks *et al.*, 1988; Sheikher, 1988; Khan *et al.*, 2000). The Indian crested porcupine is a generalist forager and exploits a wide variety of cultivated and wild plants, consuming both hypogeal and epigeal plant tissues (Gutterman, 1982; Alkon and Saltz, 1985; Brooks *et al.*, 1988; Khan *et al.*, 2000). The most important porcupine damage, however, occurs

in man-made irrigated forests and reforested watershed areas of Tarbela and Mangla reservoirs (Nawaz and Ahmad, 1974; Ahmad and Chaudhry, 1977; Greaves and Khan, 1978; Khan *et al.*, 2000). Its importance, as a pest of forest trees, has been recognized in almost all the 'Forest Management Plans' recommending adoption of necessary management measures for its control.

Porcupine populations of the species, *H. indica*, have little been investigated in Pakistan because of their shy nature, being nocturnal, and tendency to live in inaccessible complex burrow system. However, some studies have been carried out on assessment of damage to forest trees, crops, and damage preventative measures (Nawaz and Ahmad, 1974; Ahmad and Chaudhry, 1977; Greaves and Khan, 1978; Ahmed *et al.*, 2003; Khan *et al.*, 1992, 2000, 2006; Khan and Mian, 2008). The most common measures to prevent porcupine damage in Pakistan were the use of the fumigants, such as, aluminium phosphide, sodium cyanide and carbon monoxide (Chaudhry and Ahmad, 1975; Ahmed *et al.*, 2003; Khan *et al.*, 1992, 2006). Among these, carbon monoxide has been extensively investigated in different habitats (Khan *et al.*, 1992, 2006), using a carbon monoxide-generating two-ingredient cartridge containing 65% sodium nitrate and 35% ground charcoal (Savarie *et al.*, 1980). During these trials for efficacy assessment, the two-ingredient cartridge with a small indigenously prepared safety

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fuse (15 cm in length) was used. The ignited cartridge was placed 25 cm deep into the porcupine den, and after making sure that smoke started generating, the den was plugged with dry and green vegetation, and soil dirt as quickly as possible. There were several problems with this technique: leakage of gas during plugging of the den, health hazards to operators and inefficient burning of the fuse. To overcome these problems a new delivery system has been designed and tested for its effectiveness under different soil conditions and habitats, the result of which are being reported in this paper.

MATERIALS AND METHODS

Study sites

The experimental sites were located in different ecological zones of Punjab, Pakistan, having different soil types and rainfall status. Three sites, namely Dagar Kotli, Goharwala and Karluwala desert rangelands, 20-30 km apart, were located in Bhakhar District in Thal - name derived from the Sanskrit words "Marus Thal" meaning "Sea of Sand". At these ranges, Indian crested porcupine utilizes "open or shrubby", level or undulating more or less arid porous sandy plains. The rainfall of the area is erratic, varying from 100 to 200 mm annually. Average winter temperature ranges between 14 and 16°C, December and January being the coldest months when the temperature frequently drops below zero. Mean summer temperature ranges between 34 and 37°C, with maximum temperature in May and June when it rises upto 50°C or even more. The area consisted of abundant sand dunes which were barren and were used for cultivating chick pea, sweet melon, onion, pearl millet, sorghum and guar gum (*Cyamopsis tetragonoloba*). There were some patches of thick vegetation between dunes and low-laying areas offering perfect den sites for porcupines. The vegetation mostly consists of trees which are usually thorny, stunted, and dominated by *Acacia* spp. The other common species are: *A. modesta*, *A. nilotica*, *Salvadora oleoides*, *Prosopis cineraria*, *Tamarix aphylla*, *Zizyphus* spp. *Commiphora mukul* and *Cappari decidua*, alongwith some species of grasses (*Cenchrus ciliaris*, *Pennisetum villosum* and

Lasirus hirsute), and are common in the study area.

Three experimental sites were in Daphar plantation, located in district Gujarat. It is a man-made irrigated forest, established in 1918 and covered an area of 2919 ha of clay loam soil. Primarily, the plantation is being raised for the supplies of *Dalbergia sissoo* wood for manufacturing quality furniture. Less than 5 % of the plantation area is covered with *Morus alba* and *Euclyptus* spp. Porcupine dens were located in the soil of raised embankments of abandoned irrigation channels. The climate of the area is continental subtropical, with high summer temperature and cold nights in winter, torrential and erratic monsoon rains. The mean maximum temperature of the hottest month (June) is 48.88 °C and mean minimum temperature of the coldest month (January) is 18.33 °C. Three sites were located in a green belt of H-10 Sector, Islamabad, the capital city of Pakistan. These sites, 2 km apart, were located in linear plantation of mixed tree species (*A. modesta*, *D. sissoo* and *Broussonetia papyrifera*), 0.5 km wide, with a rolling topography providing very suitable denning sites for porcupines. The climate of this location is tropical, where the annual average rainfall is 855 mm, monsoon rains (July-August) average 514 mm. The maximum temperature in the hottest month (June) is 45°C and minimum temperature in the coldest month (January) is -2°C.

Delivery system

The delivery system provided a means of inserting a carbon monoxide fumigant cartridge safely into deep porcupine den; it entailed modification of a 140 cm steel pipe with a 3 cm inside diameter. A 0.5 cm hole was drilled 25 cm from one end of the pipe. A plastic cap was fixed at the other end to stop any exhaust of smoke containing carbon monoxide. Commercial safety fuse material for use in the system was obtained from Nobel Industries (Pvt.), Wah Cantt, Pakistan. It consisted of a central core of specially formulated black gunpowder with jute and cotton countering, waterproofed by a mixture of bitumen, wax, and polyvinyl chloride. It was specified to burn at a rate of 100-120 sec/m in damp and dry conditions. A length of 125 cm of the fuse was inserted into the exterior hole of the pipe and pulled at the distal end.

At this end the cartridge was fixed along the pipe with masking tape and coupled with the fuse (Fig.1). The pipe was then lowered down into the porcupine den, at least 100-110 cm deep and the den was then plugged firmly with vegetation and soil, keeping the fuse end of the pipe exposed. At this stage the system was ready to operate and the fuse was then ignited at the exterior hole. It took about 8.5 minutes for the complete burning of the fuse and the cartridge. After 10 min, the pipe was withdrawn from the den.

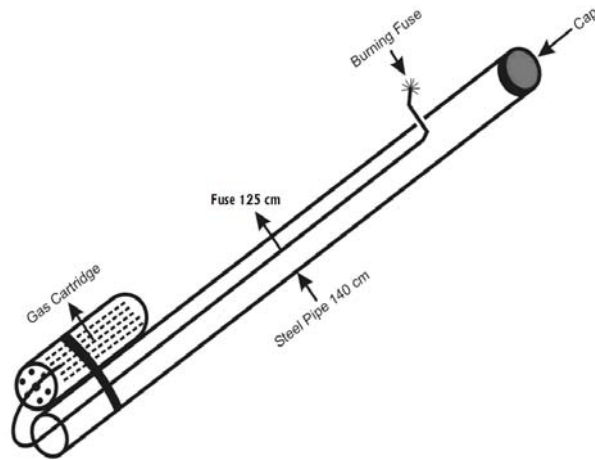


Fig. 1. Schematic diagram of fumigation system using a two-ingredient carbon monoxide cartridge for the control of Indian crested porcupine damage.

Selection and fumigation of dens

At all the study sites, we had no difficulty in locating individual porcupine dens. Only porcupine-occupied dens and in current use were fumigated. As emphasized by Dolbeer *et al.* (1991) the treated dens were determined as of target animal species harbouring by examination of signs. This was ensured by tracking on powdery soil patches (1m^2) in front of the main openings of the dens for foot prints for three consecutive nights. Only in two instances did we observe foot prints of the desert fox (*Vulpes vulpes*) at Karluwala study site. The cartridge was made from cardboard cylinder and its length was adjusted in accordance to the quantity of active ingredients. On both ends of it caps made up from cardboard paper were fixed. On the end where

the fuse was coupled seven holes (0.5 cm each) were made. The hole in the middle of the cap was used for the insertion of the fuse. The laboratory prototypes gas cartridges containing 250, 350 and 375g of active ingredients were used for fumigating the dens. Altogether one hundred and ninety dens were fumigated in different soil conditions encompassing different porosity and moisture content. The efficacy of carbon monoxide fumigation of porcupine dens was assessed by examining closed/open holes for three successive nights after treatment.

RESULTS

One hundred and ninety dens were treated at nine sites with gas cartridges (375g = 66, 350g = 55, and 250g = 69) employing our newly designed cartridge delivery system and were subsequently observed for three nights. One cartridge was used for each active den. Based on the number of dens closed at the time of reinspection, percent reduction in live dens was 100 percent at all sites where cartridges of varied weights were used (Table I). Soil types with varying degree of moisture content noted only visually had, apparently, no affect on the success of den treatment. The treatments were equally effective in porous sandy, clay loam and silty loam soils, and similarly in arid plains, irrigated plantations and moderate to high rainfall areas. The estimated quantity of carbon monoxide produced into a porcupine den by using 250, 350 and 375g of active-ingredients was 87, 122 and 131g, respectively (Savarie *et al.*, 1980). After fumigating a den, the pipe was cleared off burned fuse; we did not record any fuse failure.

In two instances, dens had secondary exists that we took to be separate dens; these were plugged when we saw smoke escaping. It was latter fumigated as it was a separate independent den. Results of this study indicated that carbon monoxide, at the rates applied by cartridge fumigation was highly efficacious against porcupines. Therefore, this new delivery system shows considerable promise as an effective, safe, easy to operate, environment-friendly, humane method for the control of Indian crested porcupine damage.

Table I.- Carbon monoxide fumigation against *Hystrix indica* using a two-ingredient cartridge in different soil and vegetation conditions.

Geographic location	Site	Soil type	Cartridge weight (g)	No. dens treated	No. dens reopened	Reduction (%)
Bhakhir	Dagar Kotli	Porous sandy	375	25	0	100
	Karluwala		350	18	0	100
	Goharwala		250	23	0	100
Gujrat	Daphar	Clay loam	375	23	0	100
	Daphar		350	20	0	100
	Daphar		250	25	0	100
Pothwar	Islamabad	Silt loam	375	18	0	100
	Islamabad		350	17	0	100
	Islamabad		250	21	0	100

DISCUSSION

Carbon monoxide producing two-ingredient gas cartridge (Savarie *et al.*, 1980) has been extensively evaluated and tested against many burrowing mammals in different under-ground habitats (Matschke and Fagerstone, 1984; Zhi and Chang, 1986; Khan *et al.*, 1991; Dolbeer *et al.*, 1991; Khan *et al.*, 1992; Ramey, 1995; Hart *et al.*, 1996; Ross *et al.*, 1998; Khan *et al.*, 2006). Among these studies, only Khan *et al.* (1992, 2006) tested this cartridge of various weights against Indian crested porcupine with varied degree of success (72-100%). In these studies, the cartridge, using locally prepared safety fuse, after ignition, was placed into the porcupine den (25 cm deep), making sure that smoke was generating, the den opening was plugged with vegetation and soil as quickly as possible. There were several problems noticed with this delivery technique: leakage of gas during the plugging process, potential health hazards to operators and inefficient burning of the fuse. To overcome these difficulties and to enhance the efficacy as minimum standards for registration, various workers have used different delivery systems. Savarie *et al.* (1980) attached the cartridge to a 6-foot metal rod, ignited, inserted it as far as possible into the coyote (*Canis latrans*) den, and plugged the hole. Animal Control Technologies of Australia, Somerton, Victoria, developed Den-Co-Fume[®] fumigator, a portable system with flexible steel pipe for fumigating the dens of foxes which

were inaccessible or in those locations having a high risk of fire (Ross *et al.*, 1998). Except for these two examples, ignited cartridges, were either placed or thrown into the burrows that were then plugged.

Indian crested porcupine dens may be classified as open refugia as these are passed on to succeeding generations and other animals may use them. Small Indian Civets or Rasse (*Vivericula indica*) have been observed coming from porcupine dens in early evening (Mian *et al.*, 2007). Multiple occupancy of dens is common in *H. indica*; Nawaz and Ahmed 1974 recorded an average of 2.4 porcupines per den. Observations made by foresters are on the higher side of 4-6 porcupines per den. The *H. indica* den may vary in diameter, depth and angle of descent and complexity. Prater (1980) described porcupine burrow which extended more than 18.5 m. With all this information in view, this new delivery system was evaluated in different eco-zones, having different soil types.

In Pakistan, forest officers managing irrigated plantations typically use four 3 g tablets of aluminium phosphide per den. This dose produces 4 g of phosphine gas that is sufficient to kill porcupines dwelling in small sized burrow systems (Mushtaq *et al.*, 2008). According to foresters achieving more than 50 % kill with this recommended dose is difficult. In addition, there are some technical problems with the use of phosphine fumigation for Indian porcupine. Most important is that the release of phosphine within the period porcupines are in dens is likely insufficient to kill

them. Total phosphine is produced within 72 hrs, 40 % within the first day of its application. However, in such practical applications, the porcupines are exposed to phosphine fumigation for only 6-12 hrs before leaving dens in early evening, thus animals are exposed to 20% or less of the gas produced. In such cases majority of the animals reopen the plugged den openings. Secondly, the leakage of phosphine gas from crevices or tunnels of rodents or lizards in the soil that are linked internally with the porcupine burrow system. This leakage is difficult to detect at the time of treatment or even after few hours of it. Our solution to these problems related to making den fumigation an effective technique for porcupine damage management required both a different treatment system and adaptations to the unique characteristics of porcupine dens. Our results indicated that the use of a two-ingredient cartridge for releasing carbon monoxide into the dens of porcupines was effective and could be used safely by foresters with minimal training. This system could also be adapted to treating dens or burrow systems of other mammals with little or no modification. Other advantages of this system were that it could be used in dry, hot, windy weather and would have no significant impact on non-target species if used correctly as emphasized by Dolbeer *et al.* (1991). Fumigation of Indian crested porcupine dens with carbon monoxide using this delivery system can be an effective means of damage prevention in irrigated forests, desert lands, and agricultural plains.

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REFERENCES

- AHMAD, A. AND CHAUDHRY, M.I., 1977. Studies on habits, habitat and damage of porcupines, *Hystrix indica*, Rodentia: Mammalia. *Pakistan J. For.*, **27**: 147-150.
- AHMAD, S.M., PARVEZ, A. AND KHAN, A.A., 2003. Deterioration impact and evaluation of control methods of Indian crested porcupine (*Hystrix indica*) on rangelands in Sindh, Pakistan. *J. nat. Hist. Wildl.*, **2**: 19-23.
- ALKON, P.U. AND SALTZ, D., 1985. Potatoes and the nutritional ecology of crested porcupines in a desert biome. *J. appl. Ecol.*, **22**: 727-737.
- AWAN, M.S., MINHAS, R.A., AHMED, K.B. AND DAR, N.I., 2004. Distribution, food and habitat preferences of small mammals in Machiara National Park, District Muzaffarabad, Kashmir, Pakistan. *Punjab Univ. J. Zool.*, **19**: 17-31.
- BROOKS, J.E., AHMAD, E. AND HUSSAIN, I., 1988. Characteristics of damage by vertebrate pests to groundnut in Pakistan. *13th Vertebrate Pest Conference* (eds. A. Crabb and R.E. Marsh) University of California, Davis, C.A. USA, pp. 129-133.
- CHAUDHRY, M.I. AND AHMAD, A., 1975. Trials of poisonous gases and baits against porcupines. *Pakistan J. For.*, **23**: 46-50.
- DOLBEER, R.A., BERNHARDT, G.E., SEAMANS, T.W. AND WORONECKI, P.P., 1991. Efficacy of two gas cartridge formulations in killing woodchucks in burrows. *Wildl. Soc. Bull.*, **19**: 200-204.
- GREAVES, J.H. AND KHAN, A.A., 1978. The status and control of porcupines, genus *Hystrix*, as forest pests. *Common. For. Rev.*, **57**: 25-31.
- GUTTERMAN, Y., 1982. Observation on the feeding habits of the Indian crested porcupine (*Hystrix indica*) and the distribution of some hemicyptophytes and geophytes in the Negev desert highlands. *J. Arid Environ.*, **5**: 261-268.
- HART, S., MARKS, C.A. AND STAPLES, L., 1996. Den-Co-Fume-Humane control of foxes (*Vulpes vulpes*) in natal dens. In: *Humaneness and vertebrate pest control* (eds. P.M. Fisher and C.A. Marks). Popet Printing, Tynong Norh., pp. 58-61.
- KHAN, A.A., AHMAD, M. AND HUSSAIN, I., 1991. Evaluation of four fumigants against the short-tailed mole rat, *Nesokia indica* Gray and Hardwicke, 1932. *Trop. Pest Managt.*, **37**: 96-99.
- KHAN, A.A., AHMED, M., AHMED, S. AND RIZVI, S.W.A., 1992. Evaluation of the comparative efficacy of fumigants and acute poison baits against Indian crested

- porcupine, *Hystrix indica*. *For. Ecol. Managt.*, **48**: 295-303.
- KHAN, A.A., AHMAD, S., HUSSAIN, I. AND MUNIR, S., 2000. Deterioration impact of Indian crested porcupine, *Hystrix indica*, on forestry and agricultural systems in Pakistan. *Int. Biodet. Biodeg.*, **45**: 143-149.
- KHAN, A.A., MIAN, A. AND HUSSAIN, R., 2006. Investigations on the use of poison baits and fumigants against Indian crested porcupine (*Hystrix indica*). *Pakistan J. sci. indust. Res.*, **49**: 418-422.
- KHAN, A.A. AND MIAN, A., 2008. Field evaluation of coumatetralyl bait. (0.0375%) against Indian crested porcupine, *Hystrix indica* Kerr. *Pakistan J. Zool.*, **40**: 63-64.
- MATSCHKE, G.H. AND FAGERSTONE, K.A., 1984. Efficacy of a two- ingredient fumigant on Richardson's ground squirrels. *11th Vertebrate Pest Conference* (eds D.O. Clark), University of California, Davis, C.A. USA, pp. 17-19.
- MIAN, A., KHAN, A.A. AND HUSSAIN, R., 2007. *Biology and management of porcupine, Hystrix indica, in central Punjab, Pakistan*. ALP Project. Final Progress Report (2003-2007). Dept Zool. P.M.A.S. Arid Agric. Univ. Rawalpindi, 129 pp.
- MUSHTAQ, M., KHAN, A.A. AND MIAN A., 2008. Evaluation of aluminum phosphide fumigation for the control of Indian crested porcupine (*H. indica*) in scrublands. *Pakistan J. Zool.*, **40**: 179-183.
- NAWAZ, A. AND AHMAD, F., 1974. *Control of porcupines in Changa Manga irrigated plantation*. Tech. Rep., Forest Department, Punjab, Pakistan, 14 pp.
- PRATER, SH. (Ed.) 1980. *The book of Indian animals*. 3rd ed. Bombay Natural History Society, Bombay, India.
- RAMEY, C.A., 1995. Evaluating the gas cartridge for coyotes in controlling badgers. *6th Eastern Wildlife Damage Control Conference*. pp. 79-84.
- ROBERTS, T.J., 1997. *The Mammals of Pakistan* (revised edition). Oxford University Press, Karachi, Pakistan.
- ROSS, J., PAGE, R.J.C., NADIAN, A.K. AND LANGTON, S.D., 1998. The development of a carbon monoxide producing cartridge for rabbit control. *Wildl. Res.*, **25**: 305-314.
- SAVARIE, P.J., TIGNER, J.R., ELIAS, D.J. AND HAYES, D.J., 1980. Development of simple two-ingredient pyrotechnic fumigant. *9th Vertebrate Pest Conference* (ed. J.P. Clark), University of California, Davis, C.A. USA, pp. 215 -221.
- SHEIKHER, C., 1998. Porcupine damage in agroforestry system in Himachal Pradesh. *Rodent Newsl.*, **22**: 12-13.
- ZHI, D. AND CHANG, Z.W., 1986. Efficiency of a carbon monoxide gas cartridge against field rodents. *12th Vertebrate Pest Conference* (ed. T.P. Salmon), University of California, Davis, C.A. USA., pp. 163-165.

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