Chapter 10

Porcupine - A Major Vertebrate Pest of Forest Plantations

A.A. Khan and S.H. Khan*

Abstract

In Pakistan, there are many vertebrate pests of forestry plantations, however, Indian crested porcupine, *Hystrix indica*, is abundant and distributed all over the country. It has been identified as a serious pest of traditional as well as non-traditional crops, fruit orchards, vegetables, flowering plants and grasses of forage importance in the rangelands. The most important porcupine damage, however, occurs in forests and reforestation areas. Because of its silvicultural importance it has been included in all the "Forest Management Plans" of the country. In this chapter, its distribution, natural history and habits have been described. Damage and economic impacts of Indian crested porcupine on forest trees, transplants and nursery stocks have been documented. For its management, various tools and technologies have been suggested for adoption.

Keywords: Porcupine; Pest; Tree damage; Economic impacts; Control technologies.

*A.A. Khan
Plant Protection, Pakistan Agricultural Research Council, Islamabad, Pakistan.
*For correspondance: pestwatch360@yahoo.com

S.H. Khan
Department of Forestry and Range Management, University of Agriculture, Faisalabad, Pakistan.

Managing editors: Iqrar Ahmad Khan and Muhammad Farooq
Editors: Muhammad Tahir Siddiqui and Muhammad Farrakh Nawaz
University of Agriculture, Faisalabad, Pakistan.

10.1. Introduction

Vertebrate deteriorations are of great economic concern in the forestry systems of Pakistan. Wild boar, porcupine, flying squirrel, jackal and some species of rats inhabit are widely distributed in forest plantations of Pakistan. Among these wild boars, (*Sus scrofa)* have well adapted to irrigated forest plantations where thick cover is available for shelter. Though omnivorous in feeding habits, they are, to a greater extant, vegetarian in diet. They feed upon a wide variety of seeds, fruits, leaves, tubers, rhizomes, succulent stems, bird's eggs, reptiles, insect larvae and earthworms. They damage water courses through digging, and up-root and trample nursery stock of trees in the nursery plots. They are, also, a potential source of diseases to mammalian wildlife species in the forest plantations. In Pakistan, the jackal (*Canis aureus*) is found in all the irrigated forest plantations, rangelands and plains. Jackals are considered as scavengers and carrion eaters. However, their main diet contents comprise of rodents, reptiles, frogs and supplement this with fruits and beetles. They destroy the nests of ground-nesting birds. They are of no economic importance in forest plantations. However, they have become pests on sugarcane crop, vegetables and sweet melons in the cultivated areas.

Among rodents, Indian giant flying squirrel (*Petaurista petaurista*) and small Kashmir flying squirrel (*Hylopetes fimbriatus*) are arboreal species and mainly confined to Himalayan moist temperate forests. The limited distribution is reported from Murree Hills, Neelum Valley of Azad Kashmir, eastern Swat, lower Chitral, and south of Kaghan Valley from about 1,350 m elevation to the upper limit of the tree line at about 3,050 m (Roberts 1997). They consume and damage acorn of the hill oak (*Quercus dilatata*), Horse Chesnuts (*Aesculus indica*), Walnuts (*Juglans regia*) and immature cones of Blue pine (*Pineus wallichiana*). There are few species of field rats, jirds and voles which are commonly found in forests. They have been observed to damage seedlings, roots of young trees and seeds. In the irrigated forests of Punjab, the short-tailed mole rat (*Nesokia indica*), through burrowing habits, destroy nursery stock of Rose wood or Shisham (*Dalbergia sissoo*) by covering seeds and seedlings with excavated dirt and forming mounds. Mole rats, also, damage water channels and cause loss of water and spreads in areas where it is not required.

Keeping in view of the significant silvicultural importance of Indian crested porcupine, this chapter will mainly focus on the detailed information as forest pest, some aspects of its natural history, economic impacts of damage to trees and nurseries, and damage prevention tools and technologies.

Porcupines belong to the order Rodentia and are represented by two families, i.e. Erethizontidae (New World Porcupines) and Hystricidae (Old World Porcupines). Erethizontidae has four genera (*Erethizon, Coendou, Echinoprocta* and *Chaetomys*) and 23 species, while Hystricidae, also, has four genera (*Thecurus, Hystrix, Atherurus* and *Trichys*) and consists of 20 species (Walker 1999). The genus Hystrix has eight species, i.e. *Hystrix cristata* Linnaeus 1758 (crested porcupine); *H. africaeaustralis* Peters 1852 (Cape porcupine); *H. brachyura brachyura* Linnaeus 1758 (Malayan porcupine); *H. javanica* Cuvier 1823 (Sunda porcupine);

H. crassipinis Gunther 1877 (Bornean porcupine); *H. sumatrae* Lyon 1907 (Sumatran porcupine); *H. pumila,* Gunther 1879 (Indonesia porcupine) (van Weer 1983). *H. indica* Kerr 1792 and *H. hodgsoni* Gray occur within the limits of India and Pakistan, (Agrawal and Chakraborty 1992; Roberts 1997).

Indian crested porcupine (*H. indica*) is the largest rodent species found in Asia and Middle East. It is one of the heaviest rodent with adults weighing within the range of 11-18 kg (Gurung and Singh 1996). It is characterized by a massive body size. Generally, at adult stage, head and body is 640-740 mm in length and short tail which is about 20% of the head and body length, and is covered with short hallow white quills (Prater 1980). The body is covered with quills, banded alternately with dark brown and white. The quills vary in size, measuring 15-35 mm in length. Ventral body surface is scarcely covered with short, black hairs. Among all the quills, there are longer, hallow, rattling quills, which are used by porcupine to alarm the predators (Ellerman 1961).

The broad fore-foot has four well-developed digits, each armed with a thick claw. The hind-foot has five digits. The eyes and external ears are very small, characteristics of burrowing and nocturnal habits. The head terminates in a broad blunt muzzle. Mammae are in 3 pairs situated along the lower flanks. There are five teeth in each jaw-one incisor, one premolar and three molars (Michael et al. 2003). The space between premolar and molars is the diastema. The colour of the incisors is yellowish orange.

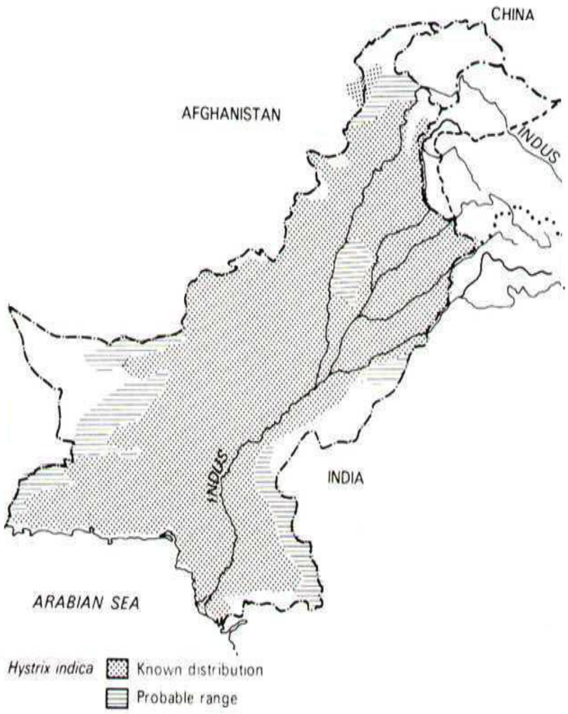
10.2. Distribution

The Indian crested porcupine is widely distributed in different eco-zones of Pakistan (Figure 10.1), and its distribution range extends throughout the southeast, central Asia and parts of the Middle East, including countries, like, India, Nepal, Bhutan, Bangladesh, Sri-Lanka, Israel, Yamen and Saudi Arabia (Corbet 1978; Kingdon 1991; Roberts 1997). The species is well adapted to a variety of environmental conditions and habitats. In Pakistan, it is commonly found in man-made and natural forest plantations, agriculture landscape, sandy deserts of Punjab and Sindh, in the mountainous areas of Khyber PakhtunKhwa (KPK) province, and abundant in steppe mountain regions of Balochistan upto 2,750 m elevation (Greaves and Khan 1978; Geddes and Iles 1991; Roberts 1997; Khan et al. 2000). The species is, also, found in Las belas, Kirthar Range, Kalat, Panjgur and Sibi (Mian et al. 1988; Roberts 1997).

Also, it is found in the upland valleys of Jehlum and Neelum of Azad Jammu and Kashmir (AJ & K) and has been recorded in moist temperate deciduous forests of Machiara National Park at 3,200 m elevation, the highest point so far recorded of its distribution (Awan et al. 2004). The presence of porcupine has been reported from Murree Hills, Kohistan, Shogran, lower Chitral, Swat valley, Bannu, and Kurram valley (Roberts 1997; 2005).

Fig. 10.1 Distribution of Indian Crested Porcupine in Pakistan.

Source: Roberts (1997)



10.3. Natural History

10.3.1. Habitat

The irrigated forest plantations of Punjab and Sindh are major habitats of Indian crested porcupine. Scrub forests and rangelands are also suitable habitats. In addition to these habitats, the high raised, soil dirt built embankments of link and barrage canals of Indus river system have provided most suitable denning sites for porcupines which have helped in their expanded distribution in the crop lands of Punjab, Sindh and KPK provinces. The embankments of drainage canals, old river channels, dried up Kareezes (under-ground water channels) and grave yards have been found infested with porcupines (Khan et al. 1992). Porcupines often make tunnels under walls and hedges to make an entry into a garden or cultivation.

10.3.2. Food and Feeding Habits

The Indian crested porcupine is a generalist forager that exploits a wide variety of cultivated and wild plants, and consumes above ground as well as sub-surface plant material (Gutterman 1982; Alkon and Salts 1985; Ahmad et al. 1987; Brooks et al. 1988; Khan et al. 2000; Pervez 2006; Pervez et al. 2009), including fruits, grains, roots, tubers, and rhizomes (Prater 1980). During one night's foraging, Indian crested porcupine is known to cover considerable distance. Nowak (1991) reported that the porcupines may cover 15 km in one night, but Kingdon (1991) reported that they may cover 30 km before returning to their burrows the next morning. They are also known to chew bones, to meet the requirements of minerals, like calcium, which support the growth of quills (Gurung and Singh 1996), consume insects, small vertebrates and the carrion (Nowak 1991; Michael et al. 2003). The faeces of porcupine contain a large amount of plant fiber, which can be differentiated into identifiable parts of roots, bark, shoots and twigs (Alkon and Saltz 1988), which are characterized elongated and are deposited in clusters on the ground surface .

10.3.3. Reproduction

Indian porcupine breeds in spring (February to April) in the Punjab, Pakistan (Taber et al. 1967; Roberts 1997; Mian et al. 2007). In captivity, they breed all the year around (Prakash 1971). Gestation in the species, on an average, lasts 240 days and the brood size varies, ranging between 2 and 4 offsprings per year (Prater 1980), though 5 foetus were recovered from a porcupine captured from Abbotabad by a hunter (Roberts 1997). Young are born with their eyes open and the body is covered with short soft quills. The female has two pairs of nipples and these are situated along the lower flanks, instead of under the belly, as mostly is the case with other rodents. This allows baby porcupines or porcupids to suckle while the mother is standing or lying on her belly. The Indian crested porcupine is usually monogamous, the parents are found in the den with their offsprings throughout the year. Life expectancy in captivity is around 20 years. In the wild, they do not survive for more than 8-20 years (Roberts 1997).

10.3.4. Behaviour

Indian crested porcupines are shy, nocturnal creatures and avoid even the moonlight nights for foraging (Nowak 1991; Bruno and Riccardi 1995) and tend to live in relatively remote or inaccessible places such as caves, rock crevices and dens, and emerge from such places only well after the dark (Prater 1980; Michael et al. 2003; Agrawal and Chakraborty 1992). The Indian porcupine may travel from the den to the feeding areas, along well-marked and frequently followed tracks (Walker et al. 1999). The species is basically solitary and nocturnal in its foraging activities, though it may be accompanied with young (Kingdon 1974; van Aarde 1987; Roberts 1997). It has a well developed sense of hearing and smell. Food is recognized by the porcupine not only with the help of its strong sense of smell but also with its long vibrissae on the snout (Roberts 1997).

The burrows are usually self constructed and extensive with a long entrance tunnel, single or multiple exists and a large underground chamber (Gurung and Singh 1996), and are used by the same animal for many years (Nowak 1991). One such burrow recorded was 18 m in length, terminating in a chamber 1.5 m below ground level and had three escape holes (Prater 1980). Burrows examined by Greaves and Khan (1978) in the Punjab were found to be up to 20 m in length, often with 2 to 4 side tunnels each ending in an enlarged chamber. It has been reported that pythons and many small mammals occupy porcupine dens, with no living conflicts being together. Mian et al. (2007) recorded small Indian Civet (*Viverricula indica*) and bats escaping from the porcupine den near Chakwal. The first author (KAA) of this chapter observed desert fox (*Vulpes vulpes*) occupying the upper portion of the main tunnel near Bhakkar, Punjab. Different study reports suggest different number of individuals sharing a porcupine burrow. Roberts (1997) reported that the presence of 10 porcupines in a single burrow system, while Arshad (1987) suggested an average of 4 porcupine/burrow.

Indian crested porcupine, when alarmed or irritated, erects quills and rattles the hallow spines present on its tail. If the disturbance continues, it launches backward and sideway attack and strikes near part of its body against the offending animal. This action results in thrusting of the quills deep into the body of the offender, often resulting in serious injuries, which are sometimes fatal (Ellerman 1961). The major part of the injury is caused by the short quills, which are normally present under the longer and thinner quills on the tail. Quite often quills are dislodged from the body of the porcupine and remain in the victim's body. The old belief that a porcupine can shoot out its quills at aggressor is without any scientific evidence. There have been records of lethal attacks by the porcupine on tigers and leopards, while defending itself (Prater 1980; Gurung and Singh 1996). Dogs become excited in the presence of a porcupine, when encounter takes place the dogs receive serious injuries on the throat and chest (Khan et al. 1989).

10.3.5. Digs and Digging Behaviour

Digging by Indian crested porcupine is a unique ecological process in an environment where surface disturbance is made for purpose of exploring subterranean plant organs as its food material (Alkon and Saltz 1985; Alkon 1999; Gutterman 1982;1987; Gutterman et al. 1990; Khan et al. 2000). Khan et al. (2016) studied the digging behavior of *H. indica* in an undulating topography of Islamabad, Pakistan. They recorded that the porcupine excavated and consumed subterranean organs of *Sorghum halpense* and *Cyperus rotundus*. The vegetation, thus, affected, include shrubs, geophytes, hemi-cryptophytes and annuals. As a result of this activity some plant species are totally consumed but later on germinate in the digs, and plant species partially consumed get renewed vegetatively. In areas where drinking water is seasonally scare or not available, exploitation of sub-surface plant biomass by crested porcupine is a key to its welfare and survival. Boekan et al. (1995) observed that *H. indica* foraging and digging generates a network of direct and indirect impacts on ecological systems. Diggings become micro-habitats in which water and organic matter accumulates, resulting into nutrient rich sites, and improving conditions for the germination of trapped seeds, seedling establishment and plant growth (Gutterman and Herr 1981). Garkaklis et al. (2000) and Wilby et al. (2001) suggested that vertebrate diggings in which surface litter and organic debris become trapped can provide a site for the development of sub-surface water repellency and sinks of critical environmental resources at many ecological levels (Alkon 1999). Digs can enhance flow of water, which result in erosion of soil and soil nutrients from hilly and watershed areas. Also, some data suggest that pedturbation by mammals (e.g. Indian porcupine) can be an important force in pedogenesis, in structuring landscape, and in maintaining heterogeneity in ecosystems (Whitford and Kay 1999). Thomson (1974) suggested that the porcupine, H. *africaeaustralis*, is an accelerator factor in the long term successful vegetation change along the Nuanetsi River in south-east Rhodesia.

10.4. Status as a Pest

Indian crested porcupine has been identified as a serious pest of traditional as well as non-traditional crops, fruit orchards, vegetables, flowering plants and grasses of forage importance in rangelands. The most important porcupine damage, however, occurs in forestry and reforestation areas (McDonald 1927; Taber et al. 1967; Pillai 1968; Nawaz and Ahmad 1974; Ahmad and Chaudhry 1977; Greaves and Khan 1978; Sharma and Prasad 1992; Khan et al. 2000; Mian et al. 2007; Khan et al. 2014).

10.4.1. Damage to Trees

Various studies conducted in Pakistan have indicated that the most important porcupine damage is inflicted to the irrigated forest plantations of the Punjab and the Sindh provinces, and the coniferous forests in the northern areas of Pakistan (Nawaz and Ahmad 1974; Ahmed and Chaudhry 1977; Greaves and Khan 1978; Khan et al. 2000; Hussain 2004). In the established stands, the mature and young trees are commonly debarked or completely girdled up to a height of about 20 cm or more, and down to the ground level or even lower, where the spreading roots are damaged and sometimes cut through the bole of young trees. The degree of damage varies from slight to complete girdling, preference for tree species differs in different habitats. The injury may ultimately effect radial growth of the tree (Storm and Halvorson 1967), and sometimes may even result into stunted growth. It has been observed in irrigated plantations that partially or completely debarked *Dalbergia sissoo* and *Morus alba* trees are highly susceptible to parasitic fungi, which is followed by more frequent termite or borer attack, leading to the death of the tree.

The results of available studies on estimates of porcupine damage to irrigated established plantations of the Punjab have been summarized in Table 10.1. Damage to tree stocking of *Pinus roxburghii* and *Robinia pseudoacacia* in Tarbela watershed areas of Abottabad is summarized in Table 10.2.

As early as 1967, a common occurrence of girdling of *M. alba* was reported in the croplands of Punjab (Taber et al. 1967), while Ahmad and Chaudhry (1977) reported damage to same species and serious damage to *Melia azedarach* in irrigated forest plantation of Punjab. Nawaz and Ahmad (1974) estimated tree damage to Changa Manga irrigated plantations through a total census of 10 randomly selected compartments from 5 blocks. The data revealed that about 15% of the trees in the plantations were damaged by porcupine, *M. azedarach* (52.5%) was the most vulnerable tree species, followed by *M. alba* (12.49%) and *D. sissoo* (1.02%). Greaves and Khan (1978) investigated porcupine damage in Chichawatni plantations and quantified damage to different mature tree species. Accordingly, *M. azedarach* and *M. alba* received 72 and 50% porcupine damage, respectively.

Khan et al. (2000) assessed porcupine damage to *D. sissoo* in 1995 at Karluwala irrigated plantation (200 ha) where the density of trees was 477 per ha. Total damage recorded was 3.1% of which 1.4% (170 trees) were completely girdled and 1.0% (121 trees) were severed at the ground level. Bark was removed in patches from 98 trees (0.8%). They also observed damage (complete girdling) to young trees of *Albizia procera* (white variety) but did not quantify the damage as the density of trees was very low and highly scattered in the plantation.

Results of some later studies, conducted in previously un-catered areas, have provided further information on the impact of porcupine on forestry resources of Pakistan. Khan et al. (2000) surveyed Daur, Unhar and Kunhar Divisions of Tarbela Watershed for porcupine damage to chirpine (*Pinus roxburghii*) and robinia (*R. pseudoacacia*) saplings/ transplants. The chir pine and robinia plants were 1-2 years of age and planted at a density of 1,075 trees/ha. The chirpine damage (complete cutting) ranged from 30 to 95% (x = 60%), while damage to robinia ranged between10 to 90% (x = 42%). This substantial mortality of tree stocking was not astonishing,

Table 10.1 Estimates of Indian crested porcupine, *Hystrix indica*, damage to trees in different man-made irrigated forest plantations, Punjab, Pakistan

Tree Species	Location of Plantation	No. of Compartments/ Sampled Area (ha)	Total No. of Trees Examined	No. of Damaged Trees	% Damage
Morus alba	Changa Manga	2 (20.24)	634	90	14.19
″	Gujrat (Daphar)	1 (20.00)	816	37	4.53
Dalbergia sissoo	Mianwali (Kundian)	4 (43.72)	869	154	17.72
″	Bhakhar	4 (25.70)	721	107	14.84
″	Layyah	1 (06.00)	139	17	12.23
″	Muzaffargarh	1 (06.11)	166	25	15.06
″	Chichawanti	1 (16.19)	375	0	0.00
″	Changa Manga	4 (32.18)	1335	31	2.32
″	Lal-Sohanra	3 (30.00)	990	27	2.73
Eucalyptus camaldulensis.	Mianwali (Kundian)	3 (30.36)	851	120	14.01
″	Bhakhar	2 (18.22)	821	133	16.20
″	Layyah	1 (12.15)	79	1	1.26
″	Chichawatni	1 (20.24)	274	0	0.00
″	Changa Manga	3 (42.92)	983	5	0.51

Source: Khan et al. (2014)

Table 10.2 Porcupine, *Hystrix indica*, damage to tree stockings in Tarbela Watershed Management Project Areas, KPK, Pakistan

Watershed division	Trees/ha (No.)	Name of Range	Stocking damage (%)	
			P. roxburghii	*R. pseudoacacia*
Daur	1075	Sherwan	80-85	60-90
		Havelian	90-95	60-70
Unhar	1075	Batagram	35-40	10-15
		Allai	35-40	10-15
Kunhar	1075	Gari Habib- Ullah, Balakot	70-80	70-80
		Balakot/Kunhar	30-40	10-15

Source: Khan et al. (2000)

a similar study in Himachal Pradesh (India) indicated 54.4% mortality of *P. roxburghii* (Sheikher 1998). Hussain (2004) suggested that the chir pine plantation of less than 6 years of age in Sherwan area of Tarbela Watershed was very vulnerable to porcupine attack, resulting in an average estimated damage of 38.1% to ≤ 1 year old trees, and 24% to 1-6 year old plantation. The damage to mature trees, however, was negligible and only partial debarkation of roots and stems was observed. Khan et al. (2014) surveyed eight irrigated forest plantation of the central and southern Punjab to assess the *H. indica* damage to trees. The data collected revealed average damage to *D. sissoo, M. alba* and *Eucalyptus* spp. as 10.45, 9.36 and 7.5%, respectively, and the overall damages were estimated at 9.1%. Tree species having recorded damage by *H. indica* in Pakistan are listed in Table 10.3. Scattered reports of porcupine damage to trees are also available from India and Iran. Up-rooting of young coconut has been reported from different regions of India (Sharma and Prasad 1992; Idris and Rana 2001; Girish et al. 2005). In Iran, *H. indica* is one of the important vertebrate pests on reforestation in western oak forests (Fattahi 1997).

10.4.2. Tree Damage Ranking

Khan et al. (2000) ranked tree damage by porcupine in seven agro-ecological zones of Pakistan. The damage in all these zones was ranked on the basis of distribution and economic value of different plant species, injury levels and whether the damage was localized or widespread. A species of high economic value, with limited or localized distribution in a zone, was ranked at higher level than a species of lower economic value and widespread distribution. Thus, the damage to tree species and its importance was ranked (Table 10.4). The damage profile noted whether a tree was alive or dead and whether it was completely girdled, or merely had patches of bark removed. Cutting, uprooting and pulling out the young plants were also noted. *M. alba* and *M. azedarach* have been ranked in the higher order because these are highly susceptible to porcupine attack and complete girdling is very common. The nursery stocks of *M. alba, M. azedarch, B. ceiba, A. indica and J. regia* have been ranked in the higher order.

Table 10.3 Ranking of trees damaged by porcupine, *Hystrix indica* in various agro-ecological zones of Pakistan

Species	Rank	Agro-ecological zone
Melia azedarach[a]	1	Southern and northern irrigated plains, Barani lands, dry mountains
Morus alba	2	Southern and Northern Irrigated plains, Dry Mountains
Dalbergia sissoo[a]	3	Southern and Northern Irrigated plains
Pinus roxburghii	1	Wet mountains
Robinia pseudoacacia	1	Wet mountains
Acacia modesta	4	Barani lands
Terminalia arjuna	4	Northern irrigated plains
Albizia procera	4	Barani lands
Eucalyptus camaldulensis	4	Barani lands, N. irrigated plains
Broussonetia papyrifera	4	Barani lands
Bombex ceiba[b]	1	Northern irrigated plains
Aesculus indica[b]	1	Wet mountains
Juglans regia[b]	3	Wet mountains

[a]Nursery stocks also receive severe damage, [b]Only nursery stock receive damage
Source: Khan et al. (2000)

10.4.3. Damage to Transplanting

Up-rooting and pulling out of transplants is characteristics behaviour of Indian crested porcupine. Porcupine damages have been reported to young transplants of *D. sissoo, Bombax ceiba, P. roxburghii, R. pseudoacacia* and *Eucalyptus* spp., and in many cases transplants had to be replaced, sometimes twice (Ahmad and Chaudhry 1977; Greaves and Khan 1978; Hussain 2004). Ahmad and Chaudhry (1977) recorded that in scrub forests, *Agave* spp. was completely wiped out several times soon after transplanting but *Acacia modesta* was quite immune to this kind of damage. Nawaz and Ahmad (1974) reported up-rooting of 4700 *B. ceiba* plants from two compartments (31 ha) at Changa Manga plantations. Greaves and Khan (1978) described one record at Chichawatni plantation which indicated that in a 30 ha plot 16% of *B. ceiba* (7420/45,000) transplants had to be replaced at least once owing to porcupine attack. Damage to suckers of date palm (*Phoenix dactylifera*) by up-rooting is also very serious in Punjab and Balochistan. One of the farmers (Dr. Jasra, per comm.) reported the loss of 500 suckers (100% damage) within a month on a farm near Bhakhar. *B. ceiba* transplants are, however, not vulnerable to porcupine attack, when these are 2-3 years old and with the development of thorns on the trunk. In majority of the cases the collar region of transplants attracts porcupines. The first author (KAA) of this article observed complete up-rooting of about 1,000 saplings of *Eucalyptus* spp. within three days of their transplantation at Karluwala forest plantation (District Bhakhar). In Sherwan area of Terbela Watershed as many as 60 pine transplants were damaged by the porcupine on the first night after their transplantation (Hussain 2004).

Table 10.4 Tree species damaged by *Hystrix indica* in Pakistan

Scientific Name	Common/ Local Name
Acacia modesta	Phulai
Aesculus indica	Horse Chestnut
Ailanthus altissima	Asmani
Albizzia procera	Sufed Sirin
Azadirachta indica	Neem
Bombax ceiba	Simal
Broussonetia papyrifera	Chinese Shahtut
Citrus sinensis	Malta
Cocus nucifera	Cocunut
Dalbergia sissoo	Shisham
Eucalyptus camaldulensis	Sufeda
Eugenia jambolana	Jaman
Ficus carica	Anjir
Juglans regia	Walnut
Leucaena leucocephala	Ipil Ipil
Mangifera indica	Aam
Melia azedarach	Bakain
Morus alba	Shahtut
Nannorhops ritchiana	Mazri
Opuntia ficus indica	Thor
Phoenix dactylifera	Date palm
Pinus roxburghii	Chir pine
Pinus wallichiana	Kail
Pistacia khinjuk	Khanjuk
Prosopis juliflora	Mesquite
Prunus arminiaca	Apricot
Prunus ovium	Cherry
Prunus amygdalus	Almonds
Pyrus malus	Apple
Robinia pseudoacacia	Robinia
Terminalia arjuna	Arjun
Zizyphus mauritiana	Ber

Source: Khan et al. (2007)

10.4.4. Damage to Nursery Stocks

Severe damage can occur in nurseries of the irrigated forests in the Punjab, and elsewhere in Sindh. Chaudhry and Ahmad (1975 b) observed devastation of *D. sissoo* seedlings cut off at the collar. Similar kind of damage was seen by Greaves and Khan (1978) to *M. azedarach* in a nursery at Chichawatni with more than 90% of the seedlings destroyed. Khan et al. (2014) examined nurseries of *D. sissoo, B. ceiba* and *M. alba* in five plantations of the Punjab (Table 10.5). Accordingly, a nursery of *B. ceiba* was seriously damaged in Kundian (38.04%), followed by nursery in Changa Manga (16.06%). The highest damage (20.36%) to a nursery of *D. sissoo* was recorded at Kundian whereas the lowest damage (1.01%) was recorded at Muzaffargarh. The percent damage of four nurseries of *D. sissoo* was 9.85 ± 6.66%. Earlier to this, Ahmad and Chaudhry (1977) reported that in a 4 ha plot, six month old *D. sissoo* nursery at Kundian, only 25% of the plants escaped porcupine damage, while the rest were found either clipped or thrown on the ground. They also suggested that porcupine damage has become a limiting factor in raising *D. sissoo* and *B. ceiba* nurseries at Jhang plantation where only 11% living plants were found in a mixed nursery of the two damaged species. Reports from India indicated that 30% of the seedlings of Neem (*Azedarach indica*) and 12% of *Eucalyptus* spp. were damaged by cutting the plants at 5-7 cm above the ground level in Aravelli hills near Jodhpur (Idris and Rana 2001).

Table 10.5 Estimates of Indian crested porcupine, *Hystrix indica*, damage to nursery plants in different man- made irrigated forest plantations, Punjab, Pakistan

Tree species	Location of plantation	No. of quadrates/ sampled area (ha)	Total no. of seedlings examined	damaged seedlings	% damage
Dalbergia sissoo	Mianwali (Kundian)	5 (4.05)	388	79	20.36
"	Bhakhar	9 (3.64)	555	61	10.99
"	Layyah	4 (0.60)	137	5	3.65
"	Muzaffargarh	8 (6.81)	889	9	1.01
Bombax ceiba	Mianwali (Kundian)	7 (2.61)	368	140	38.04
"	Changa Manga	11 (6.10)	2092	336	16.06
Morus alba	Changa Manga	7 (2.41)	882	132	14.97

Source: Khan et al. (2014)

10.4.5. Damage to Rangeland Vegetation

Impacts of porcupine digs and digging on microhabitat vegetative conditions and landscape have not been studied in Pakistan. The role of *H. indica* as a habitat and ecosystem modifier has not been investigated in the subcontinent, except in Israel (Alkon 1999). Studies on Cape porcupine (*H. africaeaustralis*) in southern Africa have indicated significant effects of porcupine foraging on structure of savanna plant communities (de Villers and van Aarde 1994). Geophytes and hemi-cryptophytes are consumed by porcupines through its digging and burrowing activities. Gutterman (1982; 1988) and Guttarman and Herr (1981) studied the impact of *H. indica* on 18 species of geophytes and hemicryptophytes and the influence of digging activity in large areas of the Negev desert highlands of southern Israel. They estimated that for geophytes, 20-30% of the plant population in certain areas was consumed on single occasion. Alkon (1999) studied both microhabitat and landscape impacts of porcupine digs and digging in Negev desert highlands of Israel. The impacts were the trapping of water, organic matter and seeds into the digs which promoted the germination and growth of annual plants including some porcupine forage species.

Nine species of grasses (*Pennisetum spp., Cenchrus ciliaris, Elionurus hirsutus, Cymbopogan jawarancusa, Sorghum helpense, Cynodon dactylon, Cyperus rotundus, Desmostachya bipinnata and Lasiurus sindicus*) were found severely damaged by porcupine diggings at the Karluwala desert range, Bhakhar (Khan et al.

2000; Khan et al. 2007). It has also been observed that porcupine severely damage *Nannorhops ritchiana* and *Lilium spp* through digging. Awan et al. (2004) observed porcupine consuming the tubers of *Arisaema jacquemontii* and roots of *Convolvulus arrinsis*. Further studies may add some more species of rangeland vegetation to this list.

10.5. Economic impact of porcupine damage

Porcupine damage to a tree result into its deformation, development of internal physiological flaws and radial growth retardation. At Changa Managa, based upon the level of (15%) damage and total annual production of 972, 400 cft, the annual losses to plantation run to the tune of 136, 136 cft of wood (Nawaz and Ahmad 1974) with an economic impact of Rs. 894,413 (US$ 25/ha). Economic losses were probably double in the heavily porcupine infested forest at Chichawatni (Greaves and Khan 1978), as compared with that calculated for Changa Manga forest. Hussain (2004) calculated bio-economic impacts of porcupine damage in Tarbela Watershed areas of KPK. He estimated the losses based upon the material cost from nursery raised transplantation of *P. roxburghii* at Rs. 8 per plant, excluding cost of loss of time/season, establishment, transportation and other related resources. Assuming an average of 40% mortality of transplants, based upon two studies (Khan et al. 2000 and Hussain 2004), and plant density of 1,075/ha, the economic losses were Rs. 3,440/ha. If this estimate is amplified to five divisions of Terbala Watershed, the total economic loss may run into millions of rupees. Khan et al. (2000) estimated economic losses suffered by irrigated forest plantations in the central Punjab and natural forests distributed in KPK and suggested an estimated annual economic loss of about US$ 60-70 per hectare. The accuracy of these economic losses could be much improved by more exact studies of the damage and its relation to the actual and potential value of timber extracted at different stages in the forest management cycle.

10.6. Control Tools and Technologies

Before taking up any operational control measures against porcupines, particularly in irrigated forest plantations, it is highly desirable that surveys be carried out to map out exact location of active/live porcupine dens. This will help in planning and selecting correct type of materials and methods and in the monitoring and evaluation of any control programme.

10.6.1. Non-Chemical Methods

10.6.1.1. Trapping and Snaring

The use of live cage traps against *Hystrix* spp., apparently without any notable success, has been reported by Chuan (1969) in oil palm plantations in Malaysia and by Thomson (1974) in riverine forest in Rhodesia, using fresh baits of sweet potato and pineapple. At Changa Manga, trapping by forest officials was carried out by means of "Duplex trap" but caught only one porcupine in four traps baited with sweet potato and meat set in heavily infested areas for a period of several days. At Chichawatni, Greaves and Khan (1978) caught only two porcupines by using five cage traps baited with potato, carrot and cucumber. It would seem from these experiences that cage trapping is of limited value as a control measure, except perhaps carried out intensively. The capital cost of the traps and their transportation, added to their management, are also some other limiting factors in using them on a large scale. Keeping these factors in view, this method cannot be recommended. Vertebrate Pest Control Institute at Karachi evaluated the effectiveness of "Leg-hold" steel traps, near Nooriabad, Karachi. Five such traps were set along the porcupine trails. Not a single animal was caught during three nights of trapping. Farmers in Attock, Abbotabad, Mansera and some areas of Balochistan commonly use snares, made up of clutch wires of motor cycles. The snare is set in front of the main and active opening of the porcupine den. According to farmers this method is highly successful in preventing porcupine damage to crops.

10.6.1.2. Hunting and Shooting

In majority of cases, hunting using dogs and shooting is conducted as an individual effort to control porcupines. Expert hunters (shikaris) are attracted when reasonable bounty rates are offered. In 1970's at Changa Manga reasonable bounty system greatly reduced the population of porcupine in the plantation. Dogs become wildly excited on seeing a porcupine or its presence in the hunting area. On encounter hunting dogs (bullterriers) in most cases, receive lethal injuries and also fatal ones (Khan et al. 1989). These practices need to be ignored as being ineffective in controlling porcupines.

10.6.2. Chemical Control

10.6.2.1. Acute Poison Baiting

Indian crested porcupine and other species of the Hystrix genus are omnivores in captivity, readily eating grain, meat and vegetables (Crandall 1964) and there are general evidences and statements in the literature to the effect that porcupines can be controlled with poison baits, including figs treated with thallium sulphate, strychnine or phosphorus (Kumerloeve 1967) and vegetable bait containing zinc phosphide (Lesnyak and Kasymov 1969; Pillai 1968). In the Punjab, irrigated forests, however, Chaudhry and Ahmad (1975a and 1975b) reported that porcupines ignore potato and cucumber, though they readily take guava and, more especially apples. A bait prepared by applying 1.0 to 1.5 g of potassium cyanide to cut pieces of apples was apparently highly successful in small scale trial, but apples similarly treated with zinc phosphide or carbaryl were not taken by porcupine. Mushtaq et al. (2009) conducted a very comprehensive study in Balakot – Abbottabad forests tract to evaluate preference of grain bait bases. Accordingly, groundnut was the most preferred food item, followed by maize, wheat, millet, rice, gram and oats. The results of this study indicated that significantly higher quantities of all the grains were consumed in cracked form than in the whole form. They also suggested that groundnut and maize if offered in 1:1 ratio combination can be a useful and cost effective bait base. Faulkner and Dodge (1962) suggested the use of granulated sugar as additive to increase the consumption of acute poison baits. To enhance palatability and consumption of grain bait bases, Mushtaq et al. (2013) evaluated 10 additives (saccharin, common salt, bone meal, fish meal, peanut butter, egg yolk, egg shell powder, mineral and coconut oils) at 2 and 5% using groundnut – maize (1:1) as basic bait. Saccharin at 5% concentration significantly enhanced the consumption of bait over the basic bait. The results of this study suggested that groundnut – maize (1:1) supplemented with 5% saccharin was the preferred bait combination, and can be used with different rodenticides for the management of Indian crested porcupine.

With the establishment of FAO/UNDP Vertebrate Pest Control Center at Karachi and availability of funds under Agricultural Linkages Programme, research on porcupine accelerated more on scientific lines in all the agro-ecological zones of the country. Khan et al. (1992) conducted field trials to determine the efficacy of two acute poisons against *H. indica* in Changa Manga forest plantations and vegetable farms near Quetta. The results of baiting treatments with sodium fluoroacetate (1080) and strychnine indicated a significant efficacy difference between 1080 and strychnine baiting. Baiting with 1080 was highly effective and caused an average 88% reduction in animal activity (range 70-100%). Strychnine was less effective and reduced animal activity by 40% (range 20-40%). Also, there was no difference between potato and squash as bait base when used with 1080. Arshad et al. (1988) tested the efficacy of Temik (10 G), 1080 and Endrin (19.5%) with ripened bitter gourd, chopped mango stones and boiled maize. The results of this study indicated 100% mortality with 1080, 85.7% with Temik and 36.4% with Endrin. However, the baiting technique, ground surface exposure, is highly hazardous that can cause primary poisoning to livestock and non-target wildlife. Ahmad et al. (2003) obtained 86.7% reduction in porcupine activity with 1080. Khan et al. (2006) evaluated 2% zinc phosphide, made up of whole maize grain, 2% cooking oil and 2% molasses, and packed as 100 g plastic sachet. The field trials were conducted in hilly/stoney areas of Fateh Jhang. One plastic sachet, slit open in the middle, was placed deep in the den. Altogether, 36 dens were treated and evaluated 7 days after treatment, which indicated only 27.78% reduction in the activity of porcupine. This small scale reduction in the porcupine activity may be attributed to a garlic like smell, bitter taste and development of bait- shyness to zinc phosphide (Rozoska, 1953). Khan et al. (2010) evaluated the effectiveness of arsenic trioxide, using cut pieces of apple, and obtained 89% reduction in the porcupine activity in a forest plantation near Faisalabad.

10.6.2.2. Chronic or Anticoagulant Baiting

Results of some studies conducted in Pakistan indicate that anticoagulants have potential promise against porcupine in various eco-habitats. These toxicants are highly effective, eco-friendly and contain very low level of hazards to livestock and non-target wildlife species, unlike acute poisons (Townsend et al. 1983; Hegdal and Blaskiewicz 1984). Some preliminary studies have been conducted in Punjab and Sindh, using compounds like coumatetralyl and brodifacoum. Ahmad et al. (2003) tested brodifacoum (0.005%) and achieved 72% reduction in animal activity.

However, the authors did not mention the quantity of bait applied per den of porcupine. Khan et al. (2006) evaluated coumatetralyl (0.0375%) bait made up of whole maize grain, 2% cooking oil and 2% molasses, and one kg of the bait was packed in plastic bags. Seventy four porcupine dens were treated by placing one bag, slit open in the middle, deep in each den. After the first baiting, the porcupine activity was reduced by 66.67 and 71.43% at two sites, respectively. The second supplement baiting gave 100% reduction at the two sites. Khan and Mian (2008) studied the field efficacy of coumatetralyl (0.0375%) maize grain bait against *H. indica* in a floriculture farm, where Dutch Iris and gladiolus were being severely damaged. The bait was placed underneath a bait station, in an earthen container. The bait stations were established either near an active den or at entry points along the fence line of the farm. Bait consumption increased up to 7th day, thereafter, it steadily decreased by the 14th day, reaching zero level on the 15th day. As a result of baiting, dead porcupine showed symptoms of anticoagulant poisoning. Analysis of post-treatment porcupine activity showed no signs of activity on the farm, indicating 100% reduction of porcupine population.

10.6.2.3. Fumigation

Fumigation is a technique that must be considered for the control of any burrowing rodent, and was suggested long ago by Fletcher (1914) using the materials available at that time such as carbon bisulphide or pyrotechnic mixtures containing sulphur. McDonald (1927) found that a cyanide gassing powder (Cyanogas) pumped into porcupine den at an average dosage of 80 g per den was effective in the Kanpur district in India. In Pakistan, Chaudhry and Ahmad (1975a and 1975b) reported the same fumigant as giving a 50% kill when applied at a dosage of 225 g per burrow in stony soil or 450 g in the longer burrows in loamy soils, the powder was packed in plastic bag attached to a long stick and deposited deep in the burrow, the borrow entrance was then firmly blocked with soil dirt. A large scale porcupine eradication programme in 1973-1975 was carried out in Changa Manga forest plantation in which cyanide gassing powder was used. The dosage applied per burrow was 225 to 900 g by means of a hand pump. Altogether, 887 active porcupine burrows were treated. As a result of this 83% success was obtained in the prevention of porcupine damage to trees. They calculated that as a result of this eradication programme, the damage of 14.5% in the entire plantations was reduced to 0.026%.

Khan et al. (1992) described a new method of gassing porcupine burrows in which cyanide powder was pumped into the active burrow using a “Dust-R” pump (B&G Equipment Company, Plumstead ville, PA, USA). The procedure adopted was to block the emergency exists to the burrow and plugged the mouth of one or two of the major active openings with brushwood and soil dirt. Before doing this, plastic hose pipe measuring 1.5 m length and 1.5 cm in diameter was inserted deep into the burrow and then covered up firmly with soil dirt, leaving about 25 cm of hose pipe outside the burrow. After fumigation, the hose pipe is withdrawn from the burrow and blocked. Khan et al. (1992) treated 65 burrows by adopting this procedure in Changa Manga plantation. They pumped the cyanide gas into the burrow at the rate of 15 strokes (9.45 g), 25 strokes (15.75 g) and 35 strokes (22.05 g), and obtained 70, 80 and 100% control of porcupines. This method is much superior, effective and economical compared to practices already described. By this method cyanide powder is evenly distributed inside the burrow and reacts quickly with the moist air inside the burrow to produce sufficient quantity of hydrogen cyanide gas to the porcupine and pose no threat to the operator.

Aluminium phosphide is another potential fumigant which has not been studied in detail except in few cases. Chaudhry and Ahmad (1975a and 1975b) reported that aluminium phosphide tablets, each containing 1.0 g of phosphine gas, gave 100% mortality when applied at the rate of two or more tablets per burrow in stony soil or more tablets per burrow in loamy soil. Khan et al. (1992) tested the efficacy of aluminium phosphide (Phostoxin) in the arid areas near Quetta and irrigated plantations of Changa Manga. They obtained 43-83% reduction in animal activity near Quetta and 50-87% in Changa Manga, apparently showed no significant difference between the two locations. Ahmad et al. (2003) attempted further studies in the dry lands of Malir district of Karachi Division. They applied 4, 6 and 10 tablets per burrow and obtained 100, 95.6 and 96% reduction in activity, respectively. Mushtaq et al. (2008) evaluated aluminium phosphide fumigation in a more scientifically designed field experiment near Haripur-Havelian, KPK. In randomly selected burrows, they obtained 100% reduction in burrow activity with the application of eight tablets per burrow, 85% with six tablets/burrow and 75% with four tablets/burrow. In categorized burrows, 100% reduction in burrow activity was recorded when four tablets/burrow were used in small (circumference, 100.2± 2.75 cm), six tablets in medium (127.7 ±0.93 cm) and eight tablets in large (157.4 ±2.44 cm) sized burrows. Khan et al. (2010) observed that four tablets/burrow were ineffective, five and six tablets/burrow provided partial control, while seven, tablets provided complete control of porcupine in an irrigated forest plantation in the district of Faisalabad.

Presently, carbon monoxide gas has been advocated as fumigation gas for control of burrowing mammals. The gas is generated with the ignition of various types of pyrotechnic devices containing mixture of various materials. Charcoal and sodium nitrate, commonly used in such devices, are relatively innocuous agents and have a low toxicity profile. However, the ignition product, carbon monoxide, is highly toxic to mammals. Savarie et al. (1980) developed a two ingredient pyrotechnic fumigant containing (w/w) 65% sodium nitrate and 35% charcoal powder. They obtained a mortality rate of 96% in coyote pups with the usage of 240 g cartridge. Ramey (1995) and Ross et al. (1998) tested successfully two-ingredient cartridge against badgers and rabbits. Khan et al. (1992) evaluated a prototype cartridge of various weights in Changa Manga and in dried up riverine channels near Quetta. The cartridge, after ignition, is placed 25 cm deep into the porcupine burrow and, after making certain that smoke is being generated smoothly, the burrow is plugged with brush wood and soil dirt. Post-treatment observations are taken 48 h after treatment. They obtained 72 and 87% success on using 100 and 150 g cartridges, respectively, and 100 % reduction in porcupine activity by using 250 g cartridge. Again, Khan et al. (2006) using 250 g cartridge obtained 95.9% reduction at Changa Manga, while 100% reduction was achieved at Dogar Kotli and Piranwala. At Karluwala and Hassan Abdal, the reduction achieved was 89.29 and 94%, respectively. Overall, average reduction in the porcupine activity at five locations was 95.89%.

During the studies with two- ingredient cartridge a small indigenously prepared safety fuse (1.5 cm in length) was used, and the cartridge after ignition was placed deep into the porcupine burrow with the help of a shovel. There were some problems with this technique; some cartridges did not burn, leakage of gas during plugging of the burrow, and health hazards to operators. To overcome these problems a new delivery system was designed by Khan et al. (2011) for carbon monoxide fumigation of Indian crested porcupine burrow using two-ingredient cartridge. The delivery system consists of a 140 cm long steel pipe with a 3 cm inside diameter. A 0.5 cm hole is drilled 25 cm from one end of the pipe. A plastic cape is fixed at the other end to stop any exhaust of smoke containing carbon monoxide. Commercial safety fuse is used for ignition of the cartridge (Nobel Industries (Pvt) Wah Cantt, Pakistan. The fuse consists 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 is specified to burn at a rate of 100-120 sec/m in damp and dry conditions. A length of 125 cm of the fuse is inserted into exterior hole of the pipe and pulled at the distal end. At this end the cartridge is fixed along the pipe with masking tape and coupled with the fuse. The cartridge fixed pipe is lowered down into the porcupine burrow at least 100-110 cm deep and the burrow is then plugged firmly with vegetation and soil dirt, keeping the fuse end of the pipe exposed. At this stage the system is ready to operate and the fuse is then ignited (Figure 10.2). It takes about 8.5 minutes for the complete burning of the fuse and the cartridge. After 10 minutes the pipe is withdrawn from the burrow. Khan et al. (2011) tested this new delivery method by treating 190 burrows in Bhakkar, Gujrat and Islamabad, using cartridges of 250, 350 and 375 g. In all cases 100% reduction in porcupine activity was obtained. The Detailed results of these trials are summarized in Table. 10.6.

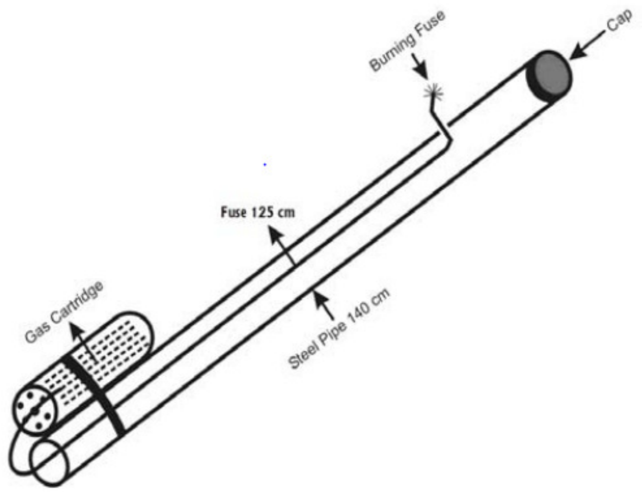


Fig. 10.2 Schematic diagram of fumigation system using a two-ingredient carbon monoxide cartridge for the control of Indian crested porcupine. *Source: Khan et al. (2011)*

Table 10.6. 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 (%)
Bhakhar	Dagar Kotli	Porous	375	25	0	100
	Karluwala	sandy	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

10.6.2.4. Repellents

A number of toxicants has been suggested for application to trees as porcupine repellents (Witmer and Pipas 1988) including a mixture of whitewash and lead arsenate (Fletcher 1914) and zinc phosphide in starch paste, acid free coal tar or other sticker (Chuan 1969). Endrin is said to have been tried in this way in Pakistan, but was considered to be too costly and hazardous, and of limited effectiveness. It may be assumed that rodent repellents could find a use against *Hystrix* where a limited number of trees require protection for a short period of time. It is reported that the use of zinc phosphide/coal tar mixture is standard practice in large-scale oil palm plantations in Malaysia (Chuan 1969). According to the same author of the paper application of sodium arsenite and sulphur gave complete protection of young oil palms.

References

Agrawal, V.C. and S. Chakraborty (1992). The Indian crested porcupine, *Hystrix indica*, (Kerr). In: Prakash, I. and P.K. Ghosh (ed). Rodents in Indian Agriculture, Vol. 1, Scientific Publishers, Jodhpur, India, pp.2-30.

Ahmad, A. and M.I. Chaudhry (1977). Studies on habits, habitat and damage of porcupine, *Hystrix indica*, Rodentia: Mammalia. Pak. J. For. 27: 147-150.

Ahmad, S.M., A. Pervez and A.A. Khan (2003). Deterioration impact and evaluation of control methods of Indian crested porcupines (*Hystrix indica*) on rangelands in Sindh, Pakistan. J. Nat. Hist. Wildl. 2:19-23.

Ahmed, E., I. Hussain, M.H. Khan and J.E. Brooks (1987). Vertebrate pest damage to maize in Faisalabad district, Pakistan. Tech. Rep., 10, Government of Pakistan /USAID Project on Vertebrate Pest Control, NARC, Islamabad, Pakistan.

Alkon, P.U. and D. Saltz (1988). Influence of season and moonlight on temporal activity patterns of Indian crested porcupine, *Hystrix indica*. J. Mammal. 69(1): 71-80.

Alkon, P.U. and D. Saltz (1985). Potatoes and the nutritional ecology of crested porcupine in a desert biome. J. Appl. Ecol. 22:727-737.

Alkon, P.U. (1999). Microhabitat to landscape impacts: crested porcupine digs in the Negev desert highlands. J. Arid Environ. 41:183-202.

Arshad, M.I. (1987). Studies on habitat pattern, feeding preferences, reproductive biology and strategy for control of Indian crested porcupine (*Hystrix indica* Linn.) around Faisalabad agriculture biome. M.Sc. Thesis, University of Agriculture, Faisalabad, 77 pp.

Arshad, M.I., R.A. Khan and A. Khaliq (1988). Strategies for the control of Indian crested porcupine, *Hystrix indica.* Pak. J. Sci. Indus. Res. 31(1): 784-785.

Awan, M.S., R.A. Minhas, K.B. Ahmed and N.I. Dar (2004). Distribution, food and habitat preferences of small mammals in Machiara National Park, District Mazaffarabad, Kashmir, Pakistan. Punjab Univ. J. Zool. 19:17-31.

Boeken B., M. Shachak, Y. Gutterman, S. Brand (1995). Patchiness and disturbance: plant community responses to porcupine diggings in the central Negev. Ecolography, 18: 410-422.

Brooks, J.E., E. Ahmad and I. Hussain (1988). Characteristics of damage by vertebrate pests to groundnut in Pakistan. In: Crabb, A. and R.E. Marsh (ed). Proceedings of Vertebrate Pest Confernce, Univ. Calif. Davis, C.A. USA. pp. 129-133.

Bruno, E. and C. Riccardi (1995). The diet of the crested porcupine, *Hystrix cristata* L. 1758 in a Mediterranean rural area. Zeitschrift fr Sugetierkunde. 60: 226-236.

Chaudhry, M.I. and A. Ahmad (1975a). Porcupines-how to control them? Leaflet, 8 pp, Pakistan Forest Institute, Peshawar, Pakistan.

Chaudhry, M.I. and A. Ahmad (1975b). Trials of poisonous gases and baits against porcupines. Pak. J. For. 25: 46-50.

Chuan, C.R (1969). Porcupines and grasshoppers as pests of the oil palm. Progress in oil palm, 155-161. Incorporated Society of Planters, Kuala Lumpur.

Crandall, L.S. (1964). Management of Wild mammals in Captivity. University Chicago Press, USA.

Corbet, G.B. (1978). The Mammals of the Palearctic Region: a taxonomy review. London and Ithaca, British Museum and Cornel University Press, NY. 314p.

Ellerman, J.R. (1961). The fauna of India including Pakistan, Burma and Ceylon, Mammalia, Vol.3 (Rodentia) Part I. Delhi, Govt. of India, 482 pp.

Fattahi, M. (1997). Effect of *Hystrix indica* on reforestation of western oak forests of Iran. In: XI World Forestry Congress, Antalya, Turkey, 13-22 October, 1997. Vol. 1.

Fletcher, T.B. (1914). Some South Indian insects and other animals of importance, Govt. Press, Madras, India.

Faulkner, C.E. and W.E. Dodge (1962). Control of the porcupine in New England. J. For. 60:36-37.

Garkaklis, M.J., J.S. Bradley, R.D. Woollwer (2000). Digging by vertebrates as an activity promoting the development of water repellent patches in sub- surface soil. J. Arid Environ. 45:35-42.

Geddes, A.M.W. and M. Iles (1991). The relative importance of crop pest in south Asia. Natural Resources Institute, London, Bull. No. 39, 102 pp.

Girish, C., B.B. Hosetti and A.K. Chakravarthy (2005). Porcupine menace in coconut palm ecosystem of Dakshina Kannada region of Karanataka. Tigerpaper. 32: 28-32.

Greaves, J. H. and A.A. Khan (1978). The status and control of porcupines, genus *Hystrix*, as forest pests. Common For. Rev. 57: 25-31.

Gurung, K.K. and R. Singh (1996). Field guide to the mammals of Indian subcontinent, Academic Press, San Diego, USA.

Gutterman, Y. and N. Herr (1981). Influence of porcupine (*Hystrix indica*) activity on the slopes of the northern Negev mountains: germination and vegetation renewal in different geo-morphological types and slopes directions. Oecologia. 51: 332-334.

Gutterman, Y. (1982). Observation on the feeding habits of the Indian crested porcupine (*Hystrix indica*) and the distribution of hemicryptophytes and geophytes in the Negev desert highlands. J. Arid Environ. 5: 261-268.

Gutterman, Y. (1987). Dynamics of porcupine (*Hystrix indica* Kerr) diggings: their role in the survival and renewal of geophytes and hemicryptophytes in the Negev desert highlands. Israel J. Bot.35:133-143.

Gutterman, Y. (1988). An ecological assessment of porcupine activity in a desert biome. In: Ghosh, P.K. and I. Prakash (ed). Ecophysiology of Desert Vertebrates. Scientific Publishers, Jodhpur, India, pp. 289-372.

Gutterman, Y., T. Golan, M. Garsani (1990). Porcupine diggings as a unique ecological system in a desert environment. Oecologia 85:122-127.

Hegdal, R.I. and R.W Blaskiewicz (1984). Evaluation of the potential hazard to barn owls of TALON (brodifacoum bait) used to control rats and house mice. Environ. Toxicol. Chem. 3: 167-179.

Hussain, I. (2004). Investigation on Indian crested porcupine *Hystrix indica*, damage to forest flora and development of prevention practices in Terbela-Mangla Watershed areas. 1st Annual Progress Report (2003-2004), ALP Project, IPEP, NARC, Islamabad, 21 pp.

Idris, M. and B.D. Rana (2001). Some observations on infestation of porcupine, *Hystrix indica* Kerr in the forest nursery of arid region. Rodent Newsl. 25(1-2): 5.

Khan, M.A., N.I. Chaudry, W. Akhtar (1989). Porcupine quill: A cause of cutaneous sinus tracts in dogs. Pakistan Vet. J. 9(3):148-149.

Khan A.A., M. Ahmed, S. Ahmed and S.W.A. Rizvi (1992). Evaluation of the comparative efficacy of fumigants and acute poison baits against *Hystrix indica*. For Ecol. Managt. 48: 295-303.

Khan A.A., A. Mian, R. Hussain (2007). Pictorial guide of porcupine (*Hystrix indica*) damage to trees and crops in Pakistan. Pakistan Agricultural Research Council, Islamabad/ University of Arid Agriculture, Rawalpindi, Pakistan.

Khan, A.A. and A. Mian (2008). Field evaluation of coumatetralyl bait (0.0375%) against Indian crested porcupine *Hystrix indica* Kerr. Pak. J. Zool. 40:63-64.

Khan, A.A., A. Mian and R. Hussain (2006). Investigations on the use of poison baits and fumigants against Indian crested porcupine (*Hystrix indica*) Pak. J. Sci. Ind. Res. 49: 418-422.

Khan, A.A., A. Mian and R. Hussain (2011). A delivery system for carbon monoxide fumigation of Indian crested porcupine, *Hystrix indica*, den using two-ingredient cartridge. Pak. J. Zool. 43: 727-732.

Khan, A.A., S. Ahmad, I. Hussain and S. Munir. (2000). Deterioration impact of Indian crested porcupine, *Hystrix indica*, on forestry and agricultural systems in Pakistan, Intl. Biodet. Biodeg. 45:143-149.

Khan, A.A., S. Hafeez, M. Abbas and W. Mehmood (2010). Assessing the efficiency of aluminium phosphide and arsenic trioxide in controlling the Indian crested porcupine (*Hystrix indica*) in an irrigated forest plantation of Punjab, Pakistan. Pak. J. Agric. Sci. 47: 99-103.

Khan, A.A., A. Mian and R. Hussain, (2014). Deterioration impact of Indian crested porcupine, Hystrix indica Kerr in irrigated forest plantations in Punjab, Pakistan. Pakistan J. Zool. 46:1691-1696.

Khan, A.A., M. Mushtaq and A.M. Ghumman. (2016). Digging and clipping behavior of Indian crested porcupine, *Hystrix indica* Kerr, in a green belt of Islamabad. Pak. J. Zool. 48:817-820.

Kingdon, J. (1974). East African Mammals in Evaluationary Atlas. Academic Press, London. Pp. 204.

Kingdon, J. (1991). Arabian Mammals – A Natural Histry. Academic Press, London, 279 pp.

Kumerloeve, H. (1967). Zur Verbreitung des Stachelschweines *Hystrix leucura* (Sykes, 1831) in Kleinasien. Saugertierliche Mitteilungen. 15: 242-249.

Lesnyak, L.P. and T.A. Kasymov (1968). The diet of the porcupine in the Chatal'skie mountains. Referativnyi Zhurnal Biologiya. No. 51555.

McDonald, M.J. (1927). Destruction of rats and porcupines. Indian For. 53: 444-445.

Mian, A., A.A. Khan and R. Hussain (2007). Biology and management of porcupine, *Hystrix indica*, in central Punjab, Pakistan. ALP Project, Final Progress Report (2003-2007). Department of Zoology, PMAS Arid Agriculture Universirt, Rawalpindi, Pakistan.

Mian, A., M. Ali, R. Ali and S.B. Tousif (1988). Distribution of some mammalian pests of orchards in Balochistan. Pak. J. Agric. Res. 9:125-128.

Michael.H., G. Devra, G. Kleiman, C.M Volerius, Mellisa (eds.) (2003). Grzimek's Animal life Encyclopedia, 2nd edition, V-12-16, Mammals I-IV.Farmington Hills,ME: Gale Group.

Mushtaq, M., A. Mian, I. Hussain, S. Munir, I. Ahmed and A.A. Khan. (2009). Field evaluation of different grain baits bases against Indian crested porcupine, *Hystrix indica*, Pak. J. Zool. 41(1): 7-15.

Mushtaq, M., A. Mian, I. Hussain, S. Munir, I. Ahmed and A.A. Khan (2013). Field evaluation of some bait additives against Indian crested porcupine (*Hystrix indica*) (Rodentia: Hystricidae). Integrative Zool. 8: 285-292.

Mushtaq, M., A.A. Khan and A. Mian (2008). Evaluation of aluminium phosphide fumigation for the control of Indian crested porcupine (*H. indica*) in scrubland. Pak. J. Zool. 40:179-183.

Nawaz, A. and F. Ahmad (1974). Control of porcupines in Changa Manga irrigated plantation. Tech. Rep., Forest Deptt. Punjab, Pakistan, 14 pp.

Nowak, R.M. (1991). Walker's Mammals of the World. 5th Edition, Vol. 1. Johns Hopkins Univ. Press, Baltimore, U.S.A.

Pervez, A. (2006). Developmental biology, feeding patterns and management strategy against Indian crested porcupine (*Hystrix indica*) in Sindh and Balochistan. 3rd Annual Report (2005-2007) ALP/SARC/PARC Karachi,56 pp.

Pervez, A., S.M Ahmad, S.B. Lathiya, E. Khadijah (2009). Food habits of the Indian crested porcupine, *Hystrix indica,* in Sindh, Pakistan. Pak. J. Zool. 41(4):319-322.

Pillai, P.N.R . (1968). Pests of rubber in India. Pesticides Annual, Bombay, India, 97: 89-91.

Prakash, I. (1971). Breeding season and litter size of the Indian desert rodents. Z. Angew Zool. 58(4): 441-454.

Prater, S.H. (1980). The book of Indian Animals. 3rd Edition, Bomboy Nat. Hist. Soc., Bombay, India. 324 pp.

Ramey, C.A. (1995). Evaluation the gas cartridge for coyotes in controlling badgers. 6th Eastern Wildl., Damage Control Conf., pp. 79-84.

Roberts, T.J. (1997). The Mammals of Pakistan. Oxford Univ. Press, Karachi, Pakistan. pp. 525.

Roberts, T.J. (2005). Field Guide to the Sall Mammals of Pakistan. Oxford University Press, Karachi. pp 280.

Ross, J., R.J.C. Page, A.K. Nadian and S.D. Langton (1998). The development of a carbon monoxide producing cartridge for rabbit control. Wild. Res. 25:305-314.

Rozoska, J. (1953). Bait shyness – a study in rat behavior. Brit. J. Anim. Behav. 1: 128-135.

Savarie, P.J., J.R. Tigner, D.J. Elias and D.J. Hayes (1980). Development of simple two-ingredient pyrotechnic fumigant. In: Clark, J.P. (ed). 9th Vertebrate Pest Conference, Univ. Calif. Davis C.A., USA. pp. 215-221.

Sharma, D. and S.N. Prasad (1992). Tree debarking and habitat use by porcupine (*Hystrix inidica* Kerr) in Sariska National Park in Western India. Mammalia. 56(3): 351-361.

Sheikher, C. (1998). Porcupine damage in agroforestry system in Himachal Pradesh. Rodent Newsl. 22: 12-13.

Storm, G.L. and C.H. Halvorson (1967). Effect of injury by porcupines on radial growth of Ponderosa pine. J. For. 740-743.

Taber, R.D., A.N. Sheri and M.S. Ahmad (1967). Mammals of the Lyallpur region, West Pakistan. J. Mammal. 48: 392-407.

Thomson, W.R. (1974). Tree damage by porcupine in southeast Rhodesia. J. South Agr. Wildl. Managt. Assoc. 4: 123-127.

Townsend, M.G., E.M. Odam, P.I. Stanley and H.P. Wardail (1983). Assessment of the secondary poisoning hazard of warfarin to weasels. J. Wildl. Managt. 48: 628-632.

van Aarde, R.J. (1987). Demography of Cape porcupine (*Hystrix africaeaustralis*) population. J. Zool. London. 213: 205-213.

van Weer, D.J. (1983). Specific distinction in Old world porcupines. Zool. Garten NF., Jena. 53(1983), 3/5.S:226-232.

de Villers M.S. and R.J. van Aarde (1994). Aspects of habitat disturbance by Cape porcupines in a savanna ecosystem. South Agr. J. Sci. 29: 217-220.

Walker, E.P. (1999). Mammals of the World Vol. III. Johns Hopkins University Press, Baltimore, USA.

Witmer, G.W. and M.J. Pipas (1988). Porcupine damage and repellent research in the interior Pacific northwest. In: Baker, R.O. and A.C. Crabb (ed). Proc. 18th Vertebr. Pest Conf. univ. Calif. Davis. pp. 203-207.

Whitford W.G., F.R Kay (1999). Biopedturbation by mammals in deserts: a review. J. Arid Environ. 41:203-230.

Wilby A., M. Shachak, B. Boeken (2001). Integration of ecosystem engineering and tropic effects of herbivores. Oikos 92: 436-444.