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DIETARY PREFERENCES AND ENVIRONMENTAL IMPACT OF THE INDIAN CRESTED PORCUPINE (*HYSTRIX INDICA*) IN PUNJAB, PAKISTAN

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Abstract

Current study aimed to assess the dietary preferences and the extent of plant damage caused by Indian crested porcupines across diverse ecological zones. Field surveys were conducted in 12 locations representing irrigated forest plantations, sub-mountainous tracts, desert ecosystems, and agricultural areas. Vegetation samples, fecal pellets, and live porcupine pairs were collected and analyzed microscopically to identify plant species in their diet from stomach and fecal contents. Damage assessments were carried out using systematic transect and quadrate methods. During Spring season, *Bombix ceiba* (23.34%), *Mangifera indica* (11.33%), *Melia azedarach* (11.67%) and *Triticum aestivum* (7.66%) were the most notably consumed species. Whereas, *Morus alba* (11.59%), *Sorghum vulgaris* (11.18%), *Cucurbita maxima* (9.99%) dominated the dietary regiment during Summers. However, as Fall season arrived, dietary preferences shifted towards *Cucurbita maxima* (21.27%), *Zea mays* (19.78%), and *Cucumis melo* (5.74%). Specific plant parts such as Stems (111, 28.5%) were favored more during Fall, while dietary preference for Pods (18, 4.6%) increased slightly relative to summer. In Faisalabad, wheat was significantly damaged more than onion (0.0427), Barley than Tomato (0.0287), and Sugarcane than Tomato (<0.0001). Whereas in Qadirabad, Percentage damage to Mustard was greatest and significantly different from onion (0.0002). *Bombax ceiba* was found to be most susceptible to porcupine damage in Daphar (33.16%) and Changa Manga (30.69%) Forests. However, other trees like *Albizzia procera* and *Acacia nilotica* exhibited relatively lower damage percentages, indicating a possible resistance or lower preference by the porcupines. Statistical analyses highlighted significant seasonal and ecological variations in dietary preferences and damage patterns. Non-lethal management strategies, increased community awareness, and habitat management were recommended to mitigate the impact of porcupine activity. Future research should focus on long-term monitoring and the development of sustainable pest control methods, including the potential use of natural predators and habitat manipulation to reduce crop and forest damage.

Keywords: Indian Crested Porcupine, Dietary Preferences, Crop Damage, Forest Plantations, Punjab, Pest Management.

INTRODUCTION

The Indian Crested Porcupine (*Hystrix indica*) is a significant herbivorous rodent native to the Indian subcontinent, including the diverse and expansive region of Punjab, Pakistan (Akhtar et al., 2021). Known for its formidable quills and nocturnal activities, this species plays a crucial ecological role while also being recognized as a serious economic pest (Hafeez et al., 2011). Despite its ecological and economic impact, there is a lack of comprehensive research on its dietary preferences and the resulting environmental disturbances in Punjab, Pakistan (Ashraf et al., 2021). This study aimed to bridge this gap by providing an in-depth analysis of the feeding preferences and environmental impact of the Indian Crested Porcupine (Akram et al., 2017). The Indian Crested Porcupine is a highly adaptable species found in a variety of habitats, including canal-side plantations, embankments of drainage channels, irrigated forest plantations, intensively cultivated croplands, graveyards, and mounds of scrapped soil (Fattorini and Pokheral, 2012). The porcupine's ability to thrive in these diverse environments is indicative of its ecological versatility. It has been documented extensively in regions such as the rainfed Pothwar belt, irrigated forest plantations like those in Kundian (Mianwali), Shorkot, Changa Manga, Daphar, and Lal Sohanra, as well as the sandy desert ecosystems of Thal (Hafeez et al., 2015). This adaptability enables the porcupine to exploit a wide range of food resources, which in turn affect indigenous plant community (Corsini et al., 1995). The Indian Crested Porcupine's diet is predominantly herbivorous, encompassing roots, tubers, fruits, and bark. Its feeding habits have significant implications for both natural and agricultural ecosystems (Yuliastuti et al., 2022).

Studies have shown that the porcupine is a major pest of traditional and non-traditional crops, including fruit orchards, vegetables, flowering plants, and forage (Mori et al., 2017). Especially in irrigated plains and mountainous regions, crops of economic importance, such as maize, groundnut, and potato, suffer extensive damage owing to porcupine activity (Inayah et al., 2020). Vegetables like okra, pumpkin, carrot, bitter gourd, and onion are also severely affected.

In desert lands, grasses such as *Cenchrus ciliaris*, *Sorghum halepense*, *Cymbopogon jwarancusa*, and *Elionurus hirsutus* are extensively damaged by porcupines (Taslim et al., 2022). Porcupines exhibit a preference for the bark of certain tree species, roots, bulbs, and succulent tubers, occasionally consuming ripened fruits (Corsini et al., 1995). They also feed on mulberry (*Morus alba*) and mango (*Mangifera indica*) plants (Safeer et al., 2018). Trees with thick and rough bark are generally avoided. The damage inflicted by porcupines on agricultural and forest plantations underscores the need for a detailed understanding of their feeding preferences to develop effective management strategies (Akhtar et al., 2021). In forested areas, porcupines contribute to the natural thinning of vegetation, which can influence forest regeneration and biodiversity (Inayah et al., 2020). In agricultural lands, however, their activities are often viewed as detrimental, causing significant economic losses (Safeer et al., 2018). The extensive burrowing activities of porcupines also have profound effects on soil structure and ecosystem dynamics,

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contributing to soil aeration and nutrient cycling but also leading to soil erosion and instability in agricultural fields (Taslim et al., 2022).

This research has attempted to improve the overall understanding of Indian crested porcupines and their ecological role in Punjab by expounding upon their dietary habits. The findings aim to inform conservation strategies for preservation of biodiversity while concomitantly mitigating human-wildlife conflicts. Furthermore, the study will provide valuable data for sustainable land management practices, promoting coexistence between agricultural activities and wildlife conservation.

MATERIAL AND METHODOLOGY

Ethical Considerations

All research activities were conducted in compliance with ethical standards for wildlife research, ensuring minimal disturbance to the porcupines and their habitats.

Study Area

The research was conducted in various ecological zones of Punjab, Pakistan (Table 1).

Table 1: Study locations and their ecological zones in Punjab, Pakistan

Ecological zones	Site	District	Site Number	GPS Coordinates
Irrigated forest plantations	Changa Manga forest plantation	Kasur, Lahore	1	Latitude: 31.0735° N Longitude: 73.9611° E
	Lal Suhanra National Park	Bahawalpur	2	Latitude: 29.3441° N Longitude: 71.7779° E
	Kundian Forest Plantation	Mianwali	3	Latitude: 32.4523° N Longitude: 71.4767° E
	Daphar and Pakhowal Forest Plantation	Malikwal, Mandi Bahauddin	4	Latitude: 30.9427° N Longitude: 73.5077° E
	Shorkot forest plantation	Jhang	5	Latitude: 30.4985° N Longitude: 72.1272° E
	Cheechawatni forest plantation	Chichawatni, Sahiwal	6	Latitude: 30.5371° N Longitude: 72.6854° E
Sub-Mountainous tract (Rainfed Pothwar Belt)	Kathar	Rawalpindi	7	Latitude: 32.6445° N Longitude: 73.0455° E
	Kheri Murat and Kali Dauli	Attock	8	Latitude: 33.6698° N Longitude: 72.5611° E
Desert Ecosystem	Rakh Goharwala	Bhakkar	9	Latitude: 30.6200° N Longitude: 70.8793° E
	Rakh Choubara	Layyah	10	Latitude: 31.4300° N Longitude: 71.1631° E
Agricultural areas	Peri-urban Faisalabad	Faisalabad	11	Latitude: 31.4504° N Longitude: 73.1350° E
Link canal Ecosystem	Qadirabad	Mandi Bahauddin	12	Latitude: 32.3448° N Longitude: 73.9018° E

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These locations were selected based on their diverse ecosystems, reported porcupine activity, and their economic importance to the region.

Sampling

The observations were conducted from January 2019 to June 2022. The experimental period was segmented into four distinct seasons whereby, Spring (February to April), Summer (May to August), Fall (September to October), and Winter (November to January) were delineated. Vegetation material, fecal pellets and live pairs of Porcupines were collected during surveillance at all the different study locations.

Preparation of Reference slides

About 117 unique samples of flora were collected from known porcupine habitats and burrowing sites during surveillance, to prepare reference slides for microscopic comparison.

Reference slides were prepared from the vegetative parts of the sampled plants by firstly desiccating and subsequently hydrating with an equal part concoction made up of distilled water, ethyl alcohol, and glycerin. Subsequent to repeated washings with distilled water, the sludge was passed through a micro sieve (0.05 mm pores) (Hafeez et al., 2011).

The specimens were then soaked in a sodium hypochlorite solution for 20-30 minutes. Basicity was neutralized by addition of diluted acetic acid. After fixation of hematoxylin stain with a mordant solution, a drop of mounting medium, comprised of Arabic gum was added to the stained material and spread over a slide (22x40 mm) (Corsini et al., 1995). Slides were then examined under a light microscope, whereby 54 unique species of plants were identified based upon their microscopic features.

Feeding Preferences

Camera Traps for sampling Porcupine Stomach contents

Camera traps were set up at strategic locations near known foraging sites, burrow entrances, and movement corridors to capture live porcupines. A pair of male and female porcupine were captured from all the study sites during different months of a calendar year. These animals were humanely euthanized and their stomach contents were carefully preserved in 10% Formalin solution.

The guidelines (Sikes and Mammalogists, 2016) and welfare (Soulsbury et al., 2020) of wild rodents were taken into account while performing any euthanizing procedures. The preserved stomach contents were transferred to a petri dish. A white paper with equal-sized squares was placed at the bottom of the petri dish.

This gridded paper helped in organizing and systematically examining the fragments. The fragments of the stomach contents were carefully spread out over the squares in the petri dish and then examined under a microscope (Hafeez et al., 2011).

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Surveillance and collection of Fecal pellets

2 samples of fecal pellets were collected from each of the 12 sites resulting in a total of 24 samples. Dietary composition was inferred through microscopic examination of fecal pellets. The fecal pellets were first washed over a mesh to clean them. They were then immersed in 70% alcohol for 10 minutes. After this, the pellets were stained with a malachite green dye. Plant parts from each species present in the slides were identified at 60X magnification and counted, whereby the total number of fragments was recorded (Hafeez et al., 2011).

Estimation of Dietary Preference

Slides for stomach and pellet samples were microscopically examined. The remnants observed on the slide were identified by comparing them with reference slide library to determine plant species. The overall percent relative frequency of each specie was calculated as:

$$rf(\%) = \{\frac{Total\ number\ of\ fragments\ of\ a\ Species}{Total\ number\ of\ fragments\ analysed}\}\ 100$$

The relative frequency of various food items identified from the stomach contents was analyzed across different seasons to determine the feeding preferences of the species. A similar methodology was employed for the analysis of fecal pellets to ensure consistency and accuracy in the findings.

Damage inflicted to Crops and Forestry

A mixed-methods approach was employed, combining quantitative and qualitative methods to comprehensively assess the damage inflicted by the Indian Crested Porcupine. Field surveys, Camera Traps and Questionnaires were employed to collect information pertaining to Porcupine activities.

Study area for Crop damage

To estimate crop damage, transects were selected in rural union councils of District Faisalabad (Chak 216 RB, Chak 231 RB, Chak 201 RB, Chak 262 RB) and Qadirabad link canal (Chak 351 GB, Chak 322 GB, Chak 389 GB, Chak 375 GB). Abundant crops in these areas included, wheat, sugarcane and maize. Systematic transect lines, covering types of crop fields within each site were traversed on a motor vehicle to identify disturbances associated with porcupine activity. Area was charted at a distance of every 5 kilometers, and surveyed crop fields with porcupine related damages were randomly sampled using a quadrate method. The number of Quadrates (2m x 2m) were placed at regular intervals along transects to quantify the extent of damage.

Study area for Tree damage

Irrigated forest plantations including Changa Manga and Daphar Forest Plantations were surveyed to estimate damage to Tree species namely, *Dalbergia sissoo* (Shisham), *Bombax ceiba* (kapok tree/ moca) and *Eucalyptus camaldulensis* (sufaida). Similarly,

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desert forests such as Rakh Gouharwala and Chaubara Forest Plantations were also surveyed to estimate damage to Tree plants including, *Dalbergia sissoo* (Shisham), *Albizzia procera* (Siris) and *Acacia nilotica* (Kikar). Plantations were categorized by age (very young < 1 year, young > 2 years, and mature > 5 years) and randomly surveyed. Within these compartments, every fifth row was examined, recording both damaged (with characteristic gnawing marks) and undamaged trees (Hafeez et al., 2011). In case of younger trees, uprooted (due to porcupine digging) or chopped stems were considered damaged, while mature trees observed with more than 20% of their stem girth debarked at breast height (1.5 m above ground) were classified as damaged.

Estimation of Plant damage

The percentage damage was calculated using following formula:

$$Percentage\ Damage\ (\%) = \{\frac{Number\ of\ damaged\ plants}{Total\ number\ of\ plants}\}\ 100$$

Statistical Analysis

The Relative frequencies of different Dietary constituents identified from the stomach contents and Fecal pellets of Indian Crested Porcupines during four different seasons were analyzed using a Kruskal-Wallis's test. Plant species were ranked using a Post-hoc Dunn's multiple comparisons test to determine dietary preference. Effect of Seasonal and Ecological variation on the Aggregated Average frequencies (Mean ± SD) of Tree, Shrub and Grass type plant species was determined using a Two-way ANOVA test with Post-hoc Tukey's multiple comparisons test. Percentage damage to crops and trees between different locations were analyzed using Unpaired t-tests while pairwise comparisons amongst species were made using Tukey's multiple comparisons test. All analyses were performed using IBM SPSS Statistics (Version 26.0) and GraphPad Prism (Version 8.4.3) whereby $P<0.05$ was considered statistically significant.

RESULTS

Feeding Preferences

The relative frequencies of different dietary constituents identified from the stomach contents of Indian Crested Porcupines during the four seasons were analyzed using a Kruskal Wallis's test and ranked to determine preference using Dunn's multiple comparisons test (Table 2). P value was observed to be significantly different between relative percentages of dietary constituents for Spring (<0.0001), Summer (<0.0001), Fall (<0.0001) and Winter (<0.0001). During Spring season, *Bombix ceiba* (23.34%), *Mangifera indica* (11.33%), *Melia azedarach* (11.67%) and *Triticum aestivum* (7.66%) were the most notably consumed species. Whereas, *Morus alba* (11.59%), *Sorghum vulgaris* (11.18%), *Cucurbita maxima* (9.99%) dominated the dietary regiment during Summers.

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Table 2: The Relative frequencies of different Dietary constituents identified from the stomach contents of Indian Crested Porcupines during four seasons (Spring, Summer, Fall, Winter) in different ecological zones in Punjab, Pakistan

Plant Nature	Plant Species	Spring		Summer		Fall		Winter	
		rf (%)	Mean Rank	rf (%)	Mean Rank	rf (%)	Mean Rank	rf (%)	Mean Rank
Trees	*Bombix ceiba*	23.34	325.90	8.65	290.40	3.68	273.20	11.09	291.80
	Dalbergia sissoo	7.98	300.40	8.21	296.50	14.00	313.30	6.30	285.80
	Eucalyptus camaldulensis	9.10	302.50	9.36	298.80	3.99	281.80	0.66	237.30
	Mangifera indica	11.33	308.80	11.66	309.50	4.97	291.90	14.36	305.00
	Melia azedarach	11.67	306.40	1.50	251.50	6.40	293.70	1.27	253.90
	Morus alba	8.15	291.20	11.59	304.60	1.23	252.40	11.74	297.50
	Psidium guajava	0.36	209.20	0.02	184.90	0.00	157.30	0.12	214.70
	Acacia jacquemontii	0.33	203.90	0.02	181.30	0.00	154.10	0.00	85.50
	Acacia nilotica	0.44	218.80	0.03	191.50	0.00	163.30	0.00	85.50
	Prosopis cineraria	0.00	79.00	0.03	190.20	0.00	161.80	0.00	85.50
	Tamarix aphylla	0.00	79.00	0.02	181.60	0.00	154.30	0.00	85.50
	Salvadora oleoides	0.00	79.00	0.02	168.50	0.00	143.30	0.00	85.50
	Prosopis juliflora	0.00	79.00	0.54	233.20	0.06	201.20	0.00	85.50
Shrubs	*Calotropis procera*	0.00	79.00	0.00	80.00	1.19	245.80	0.00	85.50
	Calligonum polygonoides	0.00	79.00	0.00	80.00	0.00	156.00	0.00	85.50
	Haloxylon recurvum	0.00	79.00	0.00	80.00	0.00	142.60	0.00	85.50
	Suaeda fruticose	0.00	79.00	0.00	80.00	0.00	120.80	0.00	85.50
	Salsola baryosma	0.00	79.00	0.00	80.00	0.00	82.58	0.00	85.50
	Haloxylon salicornicum	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Capparis spinosa	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Capparis decidua	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Leptadenia pyrotecnica	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Aerva javanica	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Zizyphus nummularia	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Zizyphus mauritiana	0.00	79.00	0.00	80.00	0.00	66.50	1.28	243.50
Grasses	*Cyperus rotundus*	0.00	79.00	0.00	80.00	0.00	66.50	1.28	244.80
	Hordeum vulgare	0.00	79.00	0.00	80.00	0.00	66.50	1.29	245.90

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	Panicum turgidum	0.00	79.00	0.00	80.00	0.00	66.50	0.02	187.50
	Panicum antidotale	0.00	79.00	0.00	80.00	0.00	66.50	0.03	195.00
	Stipagrostis plumosa	0.00	79.00	0.00	80.00	0.00	66.50	0.04	201.50
	Sporobolus iocladus	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Aeluropus lagopoides	0.00	79.00	0.00	80.00	0.00	66.50	0.00	85.50
	Pennisetum divisum	0.36	208.60	0.00	80.00	0.00	66.50	0.00	85.50
	Cymbopogon jwarancusa	0.26	193.80	0.00	80.00	0.00	66.50	0.00	85.50
	Saccharum bengalense	0.29	198.80	0.00	80.00	0.00	66.50	0.00	85.50
	Aristida hystricula	0.45	220.10	0.00	80.00	0.00	66.50	0.00	85.50
	Lasiurus scindicus	0.42	217.30	0.00	80.00	0.00	66.50	0.00	85.50
	Ochthochloa compressa	0.40	206.60	0.00	80.00	0.00	66.50	0.00	85.50
	Cenchrus ciliaris	0.32	203.30	0.00	80.00	2.43	262.70	0.00	85.50
	Sorghum halepense	6.57	297.70	2.11	261.80	3.60	282.80	5.02	287.30
	Sorghum vulgaris	1.37	266.30	11.18	308.40	0.75	242.80	0.01	174.00
	Zea mays	0.35	206.70	4.65	281.80	19.78	318.70	0.02	180.50
	Triticum aestivum	7.66	298.40	0.49	232.30	0.21	219.50	9.39	301.30
	Saccharum officinarum	0.37	210.00	0.02	184.90	0.15	215.30	1.30	247.20
	Allium cepa	0.40	212.90	0.03	187.40	0.01	188.80	1.31	248.30
	Brassica campestris	0.76	235.60	0.05	198.90	0.02	187.10	6.14	284.90
	Brassica oleracea	0.87	244.10	0.06	202.80	0.02	192.10	11.62	315.30
	Cucumis melo	0.33	203.40	2.69	265.30	5.74	288.50	0.02	152.50
	Cucurbita maxima	0.00	79.00	9.99	303.80	21.27	320.00	0.00	85.50
	Lathirus aphaca	0.00	79.00	3.00	270.80	1.28	254.00	0.00	85.50
	Melilotus indica	0.00	79.00	7.60	263.50	3.24	246.90	2.26	256.10
	Solanum lycopersicum	0.42	217.60	0.44	232.20	0.19	218.50	1.40	246.70
	Solanum melongena	0.82	242.00	0.84	239.20	0.36	227.80	1.39	248.40
	Cynodon dactylon	0.61	242.50	1.89	260.70	4.02	286.80	8.76	307.70
Unknown	Unidentified	4.28	255.80	3.30	246.30	1.41	230.90	1.89	254.30
Kruskal-Wallis's statistic		309.3		312.5		309.8		318.5	
P value		<0.0001		<0.0001		<0.0001		<0.0001	

*Statistical Significance was indicated when P<0.05.

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However, as Fall season arrived, dietary preferences shifted towards crop plants namely *Cucurbita maxima* (21.27%), *Zea mays* (19.78%), and *Cucumis melo* (5.74%). These grass species dominated the diet during fall, suggesting a change in feeding behavior to align with seasonal availability (Fig. 1). *Cynodon dactylon* (8.76%), *Triticum aestivum* (9.39%) and *Brassica oleracea* (11.62%) were significantly consumed during Winter, reflecting a seasonal reliance on certain plant species.

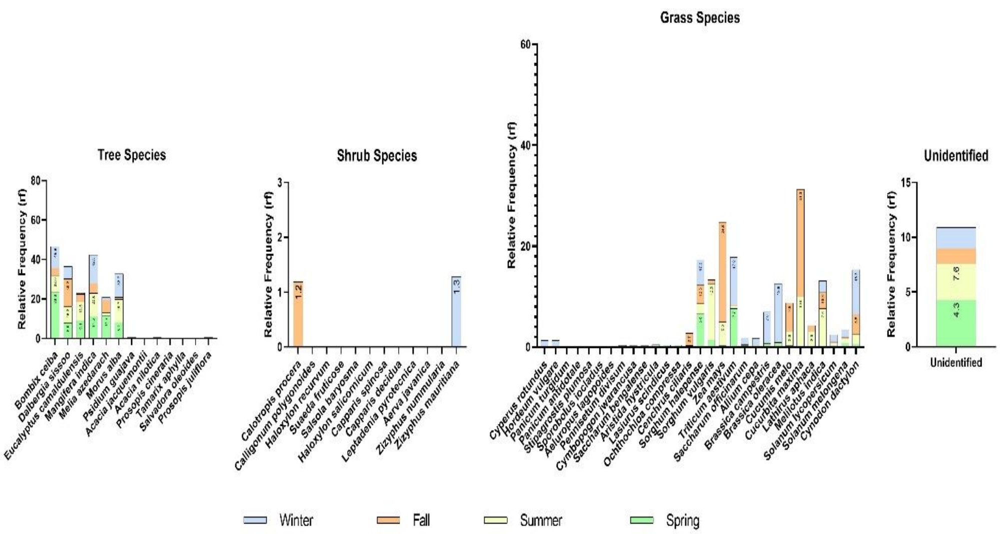

Figure 1: Stacked Bars illustrating the Relative frequency (%) of different dietary constituents identified from the stomach contents of Indian Crested Porcupines during Spring, Summer, Fall and Winter seasons

Fecal pellets were separately examined under a microscope and dietary constituents were identified using reference slides. The Kruskal-Wallis's test results for fecal pellets also indicated significant statistical differences (P<0.0001) in the relative frequencies of dietary constituents across all four seasons, underscoring the seasonal variation in the diet of Indian Crested Porcupines (Table 3). It was observed, that in addition to notable plant species such as *Bombix ceiba* (25.56%, Mean Rank 325.50), *Mangifera indica* (12.79%, Mean Rank 310.80) and *Melia azedarach* (13.16%, Mean Rank 308.60), plant fragments from other trees namely *Dalbergia sissoo* (9.16%, Mean Rank 303.40) and *Eucalyptus camaldulensis* (10.37%, Mean Rank 306.00) were also reported from fecal pellets sampled during spring. While observations for fecal pellets sampled during summer were expectedly similar to the ones reported for stomach contents during the same season. *Sorghum vulgaris* (10.33%, Mean Rank 308.10), *Mangifera indica* (10.76%, Mean Rank 309.30), *Morus alba* (10.70%, Mean Rank 304.80), *Cucurbita maxima* (9.24%, Mean Rank 303.80) and *Bombix ceiba* (8.02%, Mean Rank 290.30) dominated the dietary constitution during summer. Whereas, percentages of dietary constituents in fecal pellets during fall and winter did not vary from the ones identified in the stomach contents.

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Table 3: The Relative frequencies of different Dietary constituents identified from the Fecal Pellets of Indian Crested Porcupines during four seasons (Spring, Summer, Fall, Winter) in different ecological zones in Punjab, Pakistan

Plant Nature	Plant Species	Spring		Summer		Fall		Winter	
		rf (%)	Mean Rank	rf (%)	Mean Rank	rf (%)	Mean Rank	rf (%)	Mean Rank
Trees	*Bombix ceiba*	25.56	325.50	8.02	290.30	3.54	273.30	10.40	292.00
	Dalbergia sissoo	9.16	303.40	7.63	296.70	13.04	313.30	5.89	286.30
	Eucalyptus camaldulensis	10.37	306.00	8.68	298.40	3.82	282.80	0.76	239.10
	Mangifera indica	12.79	310.80	10.76	309.30	4.72	291.20	13.20	304.80
	Melia azedarach	13.16	308.60	1.53	251.30	6.04	293.70	1.32	253.80
	Morus alba	9.09	298.70	10.70	304.80	1.28	252.20	10.82	297.30
	Psidium guajava	0.00	120.50	0.19	139.30	0.15	124.40	0.27	167.70
	Acacia jacquemontii	0.00	120.50	0.18	138.80	0.15	124.70	0.16	99.92
	Acacia nilotica	0.00	120.50	0.19	143.70	0.15	128.60	0.16	99.92
	Prosopis cineraria	0.00	120.50	0.19	142.60	0.15	127.70	0.16	99.92
	Tamarix aphylla	0.00	120.50	0.18	138.70	0.15	123.80	0.16	99.92
	Salvadora oleoides	0.00	120.50	0.18	132.10	0.14	118.60	0.16	99.92
	Prosopis juliflora	0.00	120.50	0.66	204.40	0.20	150.70	0.16	99.92
Shrubs	*Calotropis procera*	0.00	120.50	0.17	99.08	1.23	236.20	0.16	99.92
	Calligonum polygonoides	0.00	120.50	0.17	99.08	0.15	124.70	0.16	99.92
	Haloxylon recurvum	0.00	120.50	0.17	99.08	0.14	118.40	0.16	99.92
	Suaeda fruticose	0.00	120.50	0.17	99.08	0.14	114.00	0.16	99.92
	Salsola baryosma	0.00	120.50	0.17	99.08	0.14	98.33	0.16	99.92
	Haloxylon salicornicum	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Capparis spinosa	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Capparis decidua	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Leptadenia pyrotecnica	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Aerva javanica	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Zizyphus nummularia	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Zizyphus mauritiana	0.00	120.50	0.17	99.08	0.14	90.33	1.33	232.20
Grasses	*Cyperus rotundus*	0.00	120.50	0.17	99.08	0.14	90.33	1.33	233.40
	Hordeum vulgare	0.00	120.50	0.17	99.08	0.14	90.33	1.34	234.60

	Panicum turgidum	0.00	120.50	0.17	99.08	0.14	90.33	0.19	139.70
	Panicum antidotale	0.00	120.50	0.17	99.08	0.14	90.33	0.19	142.70
	Stipagrostis plumosa	0.00	120.50	0.17	99.08	0.14	90.33	0.20	145.30
	Sporobolus iocladus	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Aeluropus lagopoides	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Pennisetum divisum	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Cymbopogon jwarancusa	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Saccharum bengalense	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Aristida hystricula	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Lasiurus scindicus	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Ochthochloa compressa	0.00	120.50	0.17	99.08	0.14	90.33	0.16	99.92
	Cenchrus ciliaris	0.00	120.50	0.17	99.08	2.38	262.60	0.16	99.92
	Sorghum halepense	0.00	120.50	2.09	262.30	3.46	283.20	4.72	287.80
	Sorghum vulgaris	0.00	120.50	10.33	308.10	0.83	242.20	0.17	134.30
	Zea mays	0.00	120.50	4.39	281.70	18.37	318.70	0.18	136.80
	Triticum aestivum	8.56	301.80	0.61	231.80	0.34	220.90	8.69	300.80
	Saccharum officinarum	0.66	256.00	0.19	139.60	0.28	191.70	1.35	235.80
	Allium cepa	0.69	257.10	0.19	141.30	0.15	138.30	1.35	237.10
	Brassica campestris	1.08	265.60	0.21	146.30	0.16	139.30	5.74	284.90
	Brassica oleracea	1.20	269.90	0.22	148.30	0.16	139.70	10.72	315.30
	Cucumis melo	0.00	120.50	2.61	267.10	5.43	289.00	0.18	125.50
	Cucurbita maxima	0.00	120.50	9.24	303.80	19.74	319.70	0.16	99.92
	Lathirus aphaca	0.00	120.50	2.90	270.40	1.32	253.20	0.16	99.92
	Melilotus indica	0.00	120.50	7.08	279.70	3.13	262.80	2.21	256.40
	Solanum lycopersicum	0.72	257.60	0.56	218.10	0.31	200.80	1.43	235.20
	Solanum melongena	1.14	269.30	0.93	223.30	0.47	212.00	1.43	237.10
	Cynodon dactylon	0.92	265.60	1.88	260.70	3.85	287.00	8.12	307.80
Unknown	Unidentified	4.90	286.70	3.17	253.80	1.44	238.50	1.88	241.30
Kruskal-Wallis's statistic		326.4		231.2		242.8		232.1	
P value		<0.0001		<0.0001		<0.0001		<0.0001	

*Statistical Significance was indicated when P<0.05.

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Tree species namely, *Bombix ceiba*, *Mangifera indica*, and *Dalbergia sissoo* were observed to be consistently important across all four seasons, with notable variations being identified in their relative frequencies. However, crops (*Sorghum vulgaris, Zea mays*) and grasses (*Cucurbita maxima, Cynodon dactylon*) exhibited significant seasonal variations, illustrating changes in availability and preference. While, shrubs often had lower frequencies throughout the study duration (Fig. 2).

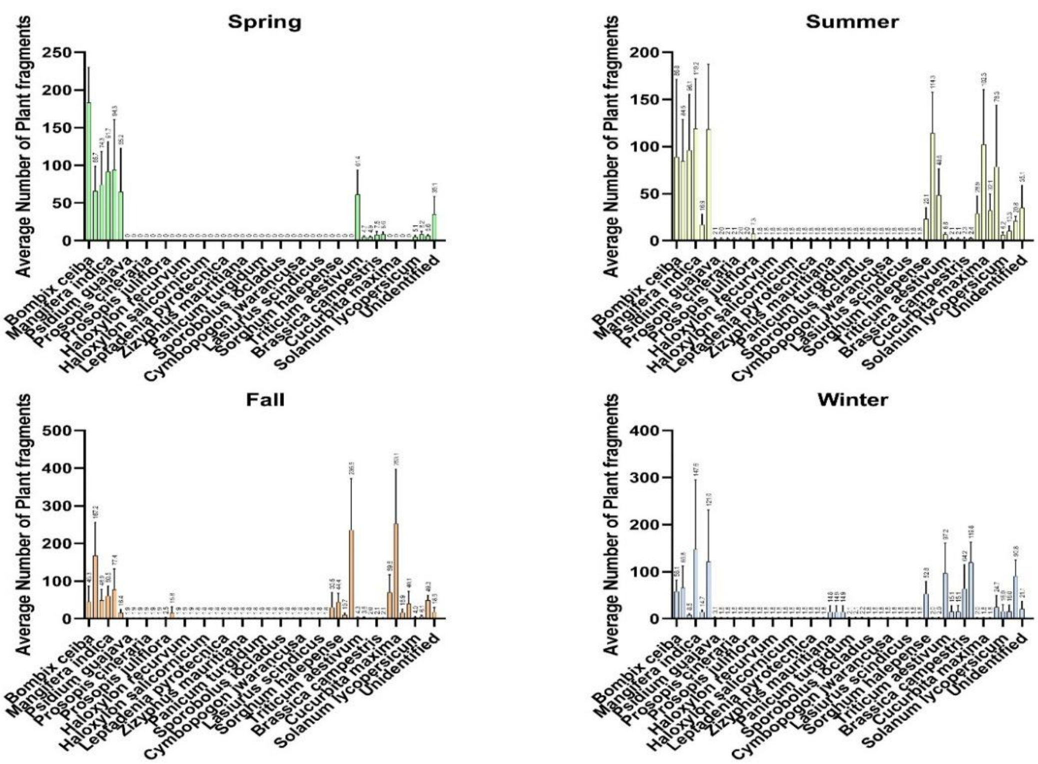

Figure 2: Bars illustrating Mean ± SD values for unique plant fragments identified from fecal pellets Indian Crested Porcupines indigenous to different ecological zones of Punjab, Pakistan (Irrigated Forest, Sub-Mountainous, Agricultural areas, Deserts and Canal Embankments) during Spring, Summer, Fall and Winter seasons

Two-way ANOVA test was employed to determine the relationship between seasons and different plant types which are consumed by Indian crested porcupines. To that end, effect of seasonal variation was determined on aggregated average values of trees, shrubs and grasses. Highest average frequency of tree consumption occurred during spring (428.36 ± 274.54) season. Whereas, Tree consumption slightly decreased during Summer (401.81 ± 291.93), and continued a downward trend during Fall (316.12 ± 228.64) and Winter (316.44 ± 287.04) (Table 4). Authors did not identify any shrub remnants in

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stomach or pellet samples during Spring (0 ± 0). Nevertheless, it peaked by Fall (21.56 ± 25.83).

Table 4: Effect of Seasonal variation on the Aggregated Average frequencies (Mean ± SD) of Tree, Shrub and Grass type plant species identified under a microscope from stomach contents and fecal pellets of Indian crested Porcupines

Plant Type	Spring		Summer		Fall		Winter	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Trees	428.36 ^{Aa}	274.54	401.81 ^{Aa}	291.93	316.12 ^{Bb}	228.64	316.44 ^{Bb}	287.04
Shrubs	0 ^{Ac}	0	11 ^{Ab}	13.97	21.56 ^{Ac}	25.83	20.74 ^{Ac}	23.45
Grasses	98.34 ^{Db}	78.71	366.48 ^{Ca}	257.01	585.31 ^{Aa}	424.33	417.31 ^{Ba}	307.87
Unidentified	25.85 ^{Ab}	20.29	25.85 ^{Ab}	20.29	13.39 ^{Ac}	10.27	15.34 ^{Ac}	13.59

*Statistical Significance was indicated with different superscripts within Columns $^{(a, b, c)}$ and Rows $^{(A, B, C, D)}$ when P<0.05.

From a relatively lower preference for grasses during Spring (98.34 ± 78.71), its consumption significantly increased during Summer (366.48 ± 257.01) and subsequently peaked during Fall (585.31 ± 424.33) (Fig. 3). Frequencies for Unidentified plant fragments remained steady during spring and summer, while significant reductions were reported in fall. When pairwise analyses were performed within the seasonal groups, dietary preference was significantly higher for trees as opposed to grasses (P<0.0001) and shrubs (P<0.0001). Whereas, consumption of grasses was significantly greater than tress during fall (P<0.0001) and winter (P=0.0002) seasons.

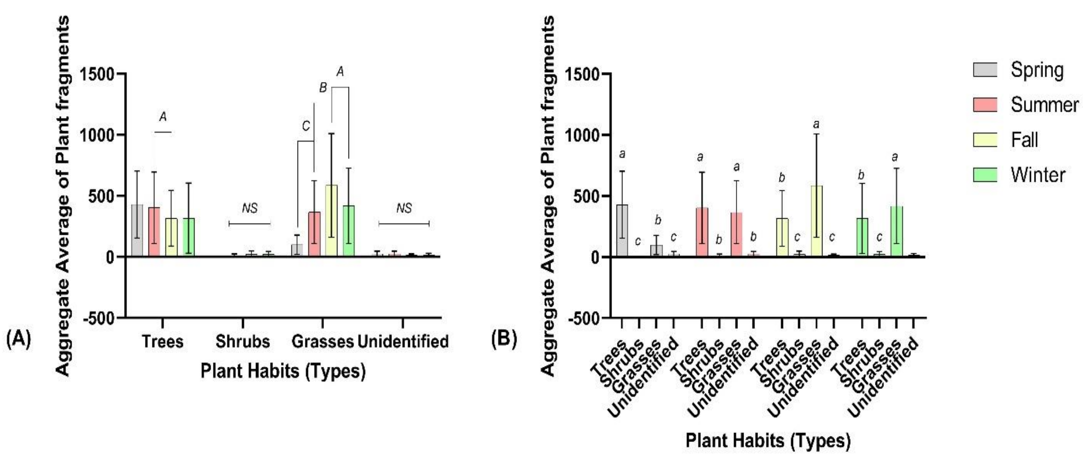

Figure 3: (A) Interleaved bars illustrating the aggregate average of plant fragments (Mean ± SD) for Trees, Shrubs, Grasses, and Unidentified categories across four seasons (Spring, Summer, Fall, Winter), whereby significant

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differences between seasons were indicated by different letters (A, B, C) within each plant habit, while (NS) denoted no significant difference; (B) Separated bars illustrating aggregate average of plant fragments (Mean ± SD) for different plant habits within each season, whereby significant differences between plant habits (Trees, Shrubs and Grasses) were indicated by different letters (a, b, c) when P<0.05

Two-way ANOVA test was also employed to determine the relationship between ecological zones and relative preference for different plant types. Tree consumption was significantly higher in Sub-Mountainous Tract (Rainfed Pothwar Belt) (415.48 ± 312.63) as opposed to Link Canal Embankment (244.56 ± 191.55) (P= 0.0309) (Table 5). Whereas, there was not any statistical difference of shrub consumption between any of the surveyed ecological zones.

However, consumption of grasses was significantly higher in. Link canal embankments as opposed to any of the other ecological zones namely Irrigated Forest plantations (<0.0001), Sub-Mountainous tract (Rainfed Pothwar Belt) (<0.0001), Desert Ecosystem (<0.0001), and Agricultural areas (<0.0001).

Table 5: Effect of Ecological variation on the Aggregated Average frequencies (Mean ± SD) of Tree, Shrub and Grass type plant species identified under a microscope from stomach contents and fecal pellets of Indian Crested Porcupines

Seasons	Irrigated forest plantations		Sub-Mountainous tract (Rainfed Pothwar Belt)		Desert Ecosystem		Agricultural areas		Link canal Embankment	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Trees	325.09 Aa	286.28	415.48 Aa	312.63	402.19 Aa	192.36	423.76 Aa	383.64	244.56 Bb	191.55
Shrubs	14.32 Ab	23.88	6 Ac	12.83	0 Ac	0	18.18 Ab	25.14	15.07 Ac	18.03
Grasses	346.43 Ca	452.86	241.28 Db	305.41	86.73 Eb	60.36	457.74 Ba	591.47	710.03 Aa	369.71
Unidentified	17.87 Ab	18.66	29.13 Ac	19.27	17.31 Ac	11.44	21.71 Ab	9.74	9.16 Ac	6.67

*Statistical Significance was indicated with different superscripts within Columns (a, b, c) and Rows (A, B, C, D, E) when P<0.05.

Highest consumption of shrubs was observed around agricultural areas while most Unidentified plant fragments were indicated in samples obtained from sub-mountainous tracts. Pairwise comparisons within the ecological groups, reveled that dietary preference for trees was significantly higher than grasses in Sub-Mountainous (P=0.0001) and Desert ecosystems (P=0.0001). But significantly lower in case of Link canal embankments (P=0.0001) (Fig. 4).

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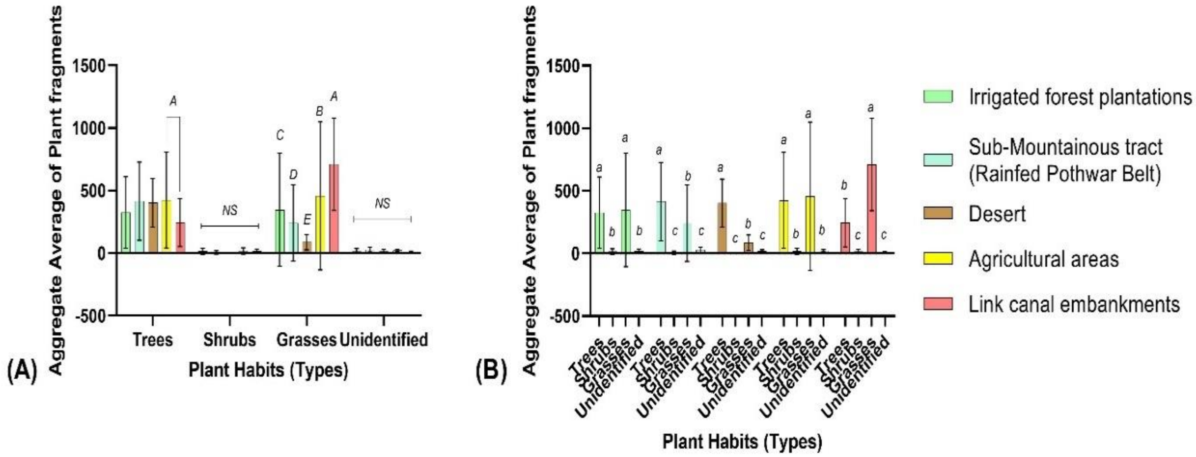

Figure 4: (A) Interleaved bars illustrating the aggregate average of plant fragments (Mean ± SD) for Trees, Shrubs, Grasses, and Unidentified categories across five ecological zones, whereby significant differences between different habitats were indicated by different letters (A, B, C, D, E) within each plant habit, while (NS) denoted no significant difference; (B) Separated bars illustrating aggregate average of plant fragments (Mean ± SD) for different plant habits within each habitat type, whereby significant differences between plant habits (Trees, Shrubs and Grasses) were indicated by letters (a, b, c) when P<0.05

The data for frequency of plant parts has been expressed as counts and percentages of total frequency (Table 6). During spring, spikes (95, 24.4%) and seeds (90, 23.1%) constituted some of the most consumed parts of the plant by porcupines. Whereas, authors observed that Pods (0, 0%) were rarely consumed. Contrarily in summer, Stems (86, 22.1%), Leaves (96, 24.7%) and Seeds (118, 30.3%) constituted most of the porcupine diet.

Table 6: Seasonal variation in Average frequencies (Mean ± SD) of plant parts (Stem, Leaf, Seed, Root, Spike, Tuber, Flower and Pod) identified under microscope from stomach contents of Indian crested Porcupines in different ecological zones of Punjab

Seasons	Stem	Leaf	Seed	Root	Spike	Tuber	Flower	Pod	Total Frequency
Spring	63 (16.2%)	70 (17.9%)	90 (23.1%)	60 (15.4%)	95 (24.4%)	4 (1.0%)	7 (1.8%)	0(0%)	389
Summer	86 (22.1%)	96 (24.7%)	118 (30.3%)	81 (20.8%)	71 (18.3%)	41 (10.5%)	0 (0%)	11 (2.8%)	504
Fall	111 (28.5%)	119 (30.6%)	125 (32.1%)	93 (23.9%)	82 (21.1%)	43 (11.1%)	0 (0%)	18 (4.6%)	591
Winter	127 (32.6%)	56 (14.4%)	88 (22.6%)	63 (16.2%)	72 (18.5%)	22 (5.7%)	47 (12.1%)	33 (8.5%)	508

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However, Stem (111, 28.5%) consumption was the higher during Fall, while dietary preference for Pods (18, 4.6%) increased slightly relative to summer. Subsequently, during winter Leaf (56, 14.4%) consumption significantly decreased from the fall season and Pods (33, 8.5%) constituted higher dietary percentage than any other season (Fig.5).

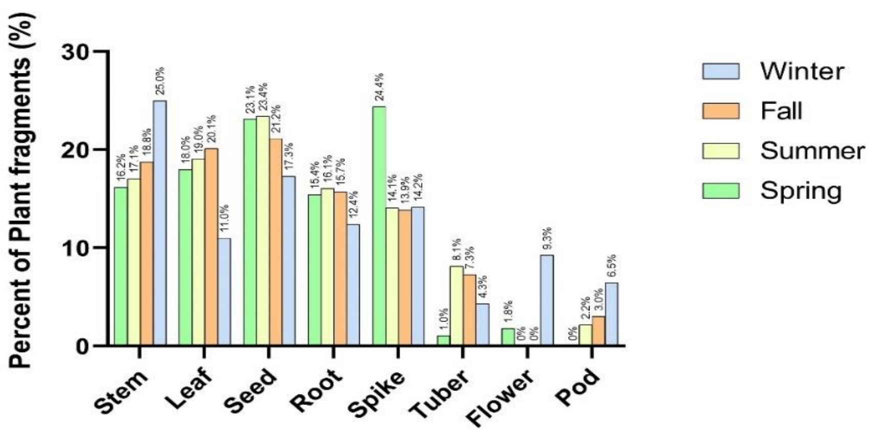

Figure 5: Bars illustrating Seasonal variation in the Percent frequencies (%) of plant parts identified from stomach contents of Porcupines indigenous to different ecological zones of Punjab, Pakistan (Irrigated Forest, Sub-Mountainous, Agricultural areas, Deserts and Canal Embankments)

Crop and Tree damage

In Faisalabad, the average damage to wheat crop was around 6.29% with a standard deviation of 1.05, whereas it was slightly lower in Qadirabad (5.79±1.56). 19 fields of Barley were surveyed in Faisalabad and 17 fields in Qadirabad. The damage percentage for mustard and Tomato were higher at 8.74% and 5.60%, respectively. Of 10 Sugar fields examined in Faisalabad, 6 were damaged, affecting 5 out of 56 plants (Table 7).

Table 7: Damage to crops caused by Indian Crested Porcupines estimated as Average Percentages in different Union Councils of Faisalabad and Qadirabad

Crop Specie	Location	Number of fields examined	Number of damaged fields	Quadrates Surveyed	Total Number of plants	Damaged Plants	Extent of Damage (%)	
							Mean	SD
Wheat	Faisalabad	22	7	28	11796	776	6.29	1.05
	Qadirabad	18	9	36	13972	860	5.79	1.56
Barley	Faisalabad	19	7	28	12548	806	6.95	1.44
	Qadirabad	17	6	24	13045	924	7.19	1.06
Mustard	Faisalabad	32	12	48	5208	393	5.76	3.96
	Qadirabad	32	14	56	5240	449	8.74	1.45
Sugarcane	Faisalabad	10	6	24	56	5	9.38	2.08
	Qadirabad	18	10	40	100	7	7.29	3.99

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Maize	**Faisalabad**	10	6	24	220	14	6.64	1.81
	Qadirabad	22	8	32	317	19	5.36	1.78
Onion	**Faisalabad**	14	3	12	892	19	1.60	1.15
	Qadirabad	13	2	8	572	22	1.87	2.84
Tomato	**Faisalabad**	13	1	4	36	3	2.08	4.17
	Qadirabad	16	3	12	116	9	5.60	5.94
Melon	**Faisalabad**	7	4	16	84	6	5.22	3.52
	Qadirabad	9	6	24	148	8	5.88	2.86

Unpaired t tests for each of the crop varieties surveyed for crop damage between Faisalabad and Qadirabad districts revealed that there were no significant differences between the percentage damage to any of the crops namely, Wheat (*Triticum aestivum*) (>0.9999), Barley (*Hordeum vulgare*) (>0.9999), Mustard (*Brassica campestris*) (0.2885), Sugarcane (*Saccharum officinarum*) (0.7305), Maize (*Zea mays*) (0.9776), Onion (*Allium cepa*) (>0.9999), tomato (*Solanum lycopersicum*) (0.1247), Melon (*Cucumis melo*) (0.9998) at either of the districts. However, when Tukey's multiple comparisons test was performed between different crop species damaged within the same locality certain crops demonstrated a greater tendency towards being damaged by porcupines. In Faisalabad, wheat was significantly damaged more than onion (0.0427), Barley than Tomato (0.0287), and Sugarcane than Tomato (<0.0001). Whereas in Qadirabad, Percentage damage to Mustard was greatest and significantly different from onion (0.0002) (Fig. 6).

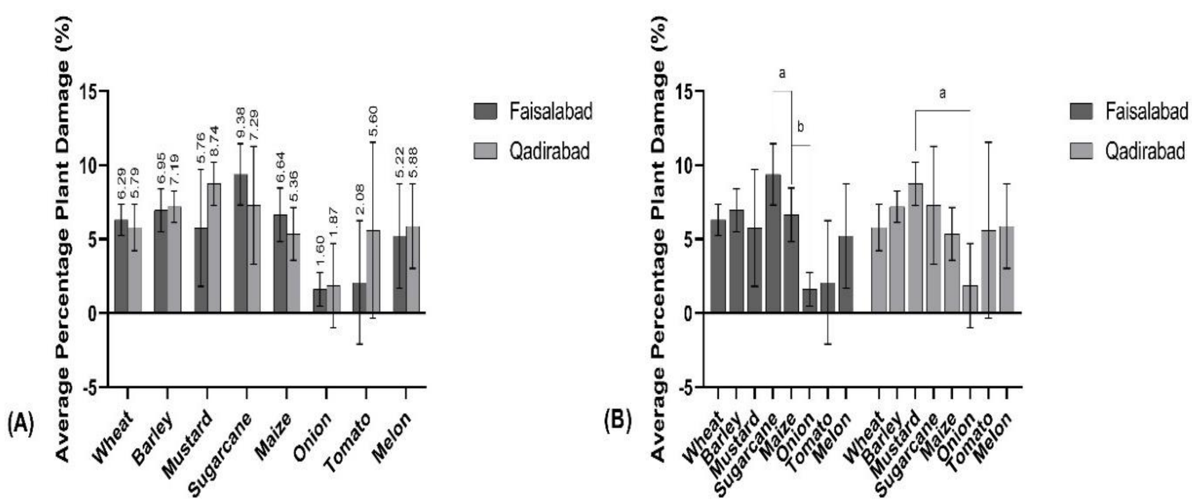

Figure 6: (A) Interleaved bars illustrating the average percentage of plant damage to common crops across different union councils in Faisalabad and Qadirabad; (B) Separated bars illustrating statistical comparison between damage to different crop plants within a particular locality. Significant differences between Crops were indicated by letters [(a, b, c)] when P<0.05

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Dalbergia sissoo (Shisham) was surveyed at both the irrigated plantations and desert forests for Porcupine associated damage. 4 compartments with 1,123 plants at Changa Manga, 6 compartments with 1,530 plants at Daphar, 2 compartments with 510 plants at Gouharwala and 2 compartments with 611 plants at Chaubara forest were surveyed for damage to *Dalbergia sissoo* (Shisham) trees. However, P=0.9865, indicated no significant difference in damage across these locations to Shisham trees. Similarly, damage to *Bombax ceiba* (Kapok Tree/Moca) was marginally different between Changa Manga (30.69±1.41) and Daphar (33.16±1.6) forests. Percentage damage to *Albizzia procera* (Siris) (0.3262) and *Acacia nilotica* (Kikar) (0.4904) were surveyed at desert forests (Gouharwala and Chaubara) with their values being non-significantly different at either location (Table 8).

Table 8: Damage to Trees caused by Indian Crested Porcupines estimated as Average Percentages in different Man-made Plantations (Changa Manga, Daphar, Gouharwala and Chaubara Forests) across Punjab, Pakistan

Tree Specie	Location	Compartments	Total Number of plants	Damaged Plants	Extent of Damage (%)		P Value
					Mean	SD	
Dalbergia sissoo (Shisham)	Changa Manga Forest	4	1123	169	15.05	1.71	0.9865
	Daphar Forest	6	1530	230	15.03	2.04	
	Gouharwala Forest	2	510	74	14.51	1.81	
	Chaubara Forest	2	611	91	14.89	1.61	
Bombax ceiba (kapok tree/ moca)	Changa Manga Forest	4	720	221	30.69	1.41	0.0825
	Daphar Forest	3	570	189	33.16	1.6	
Eucalyptus camaldulensis (sufaida)	Changa Manga Forest	4	1036	167	16.12	1.53	0.1757
	Daphar Forest	3	778	109	14.01	2.04	
Albizzia procera (Siris)	Gouharwala Forest	2	520	27	5.19	1.4	0.3262
	Chaubara Forest	2	589	19	3.23	1.64	
Acacia nilotica (Kikar)	Gouharwala Forest	3	1563	88	5.63	1.83	0.4904
	Chaubara Forest	1	544	21	3.86	1.54	

Current findings suggested that several variations were observed in damage percentages for different tree species across different locations. However, most differences were not statistically significant. *Bombax ceiba* (Kapok Tree/Moca) exhibited the highest damage percentages, at Changa Manga (30.69±1.41) and Daphar (33.16±1.6) indicating a greater preference or vulnerability to porcupine damage (Fig. 7). Whereas, the damage percentages for *Albizzia procera* (Siris) were much lower at both Gouharwala (5.19±1.4) and Chaubara (3.23±1.64) Forests. Tukey's multiple comparisons test was used to rank the average damage to a particular tree species. It was observed that with a mean rank of 31.93, *Bombax ceiba* (Kapok Tree/Moca) incurred significantly greater damage than *Albizzia procera* (Siris) ($P < 0.0001$) and *Acacia nilotica* (Kikar) ($P < 0.0001$)

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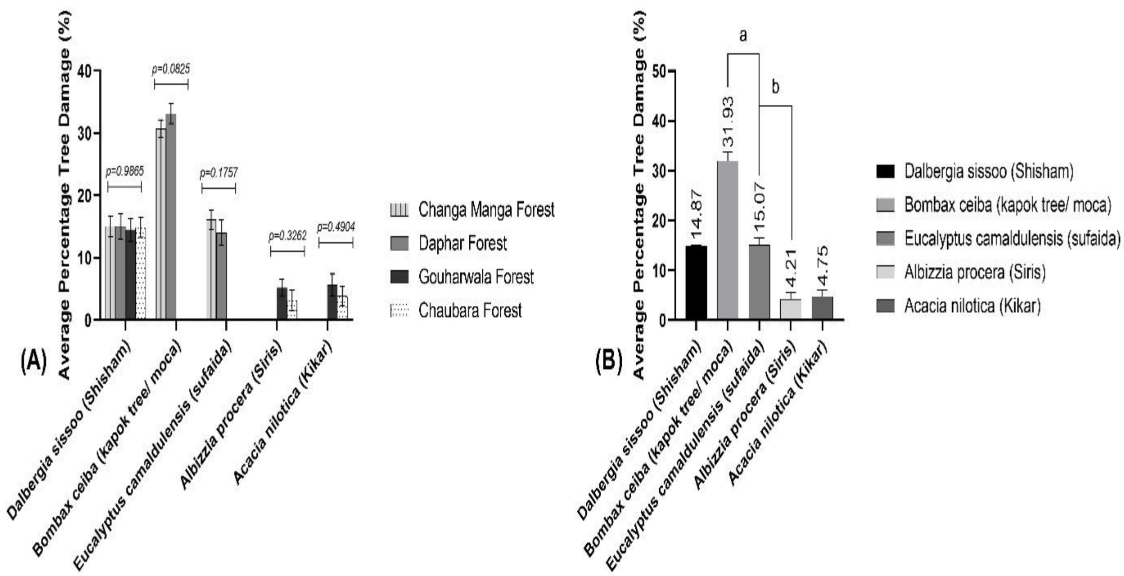

Figure 7: (A) Interleaved bars illustrating the average percentage of Tree damage to different species within Changa Manga, Daphar, Gouharwala and Chaubara Forests; (B) Mean bars with ±SD illustrating statistical comparison between damage to different types of Tree species within all localities. Significant differences between Tree damage (%) were indicated by letters (a, b, c) when P<0.05.

DISCUSSION

Dietary preferences and the environmental impact of the Indian Crested Porcupine (*Hystrix indica*) indigenous to Punjab, Pakistan, were studied in present circumstances. The analyses were undertaken by sampling across different ecological zones and seasons.

Dietary Preferences

Presently, authors noted that there was a distinct seasonal pattern in the dietary preferences of Indian Crested Porcupines. Whereby, during spring season, Porcupines mainly consumed plant parts from various tree species namely *Bombax ceiba* (23.34%), *Mangifera indica* (11.33%), and *Melia azedarach* (11.67%). Moreover, crops such as *Triticum aestivum* (7.66%) were also consumed to a significant degree. Previously, *Triticum aestivum* (21.62±1.45%) was reported to be most intensively consumed plant during spring while other notable dietary constituents included *Bombax ceiba*, *Brassica campestris*, and *Sorghum halepense* (Hafeez et al., 2011). Additionally, both studies noted the presence of plant fragments from *Eucalyptus camaldulensis* and *Dalbergia sissoo* in the diet during spring (Hafeez et al., 2011). Authors have hypothesized that

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relative preferences for these species aligned with their availability and nutritional value during different seasons. Prior observations have noted that *Zea mays* and *Sorghum vulgaris* were predominantly consumed during summer by Indian crested porcupines sampled nearby agricultural zones (Hafeez et al., 2015, 2014; Khan et al., 2021).

Relative frequencies for *Prosopis juliflora*, *Morus alba*, and *Melia azedarach* were also observed to a considerable degree (Khan et al., 2021). Current study, corroborated previous findings, confirming the dominance of *Morus alba* (11.59%) and *Sorghum vulgaris* (11.18%) in the diet during summer. As fall approached, the dietary preferences shifted towards crop plants from natural vegetation, whereby *Cucurbita maxima* (21.27%), *Zea mays* (19.78%), and *Cucumis melo* (5.74%) became principal contributors to the porcupine diet. A similar phenomenon was reported by previous experimentation as well (Hafeez et al., 2015). Nevertheless, other than *Triticum aestivum,* most stalwarts such as *Sorghum halepense*, *Hordeum vulgare*, and *Bombax ceiba* were not observed to be substantial dietary components in current settings during winter. Whereas, *Cynodon dactylon* (8.76%) and *Brassica oleracea* (11.62%) were significantly consumed. Authors have justified this difference by highlighting the fact that unlike prior investigations several ecological zones were sampled during present study (Safeer et al., 2018; Ashraf et al., 2021). For the most part, relative dietary frequencies in current outcomes and prior publications did not differ between stomach contents and fecal pellets (Hafeez et al., 2011). However, considerable seasonal change in dietary fragments was apparent in fecal pellets as well. The analysis of plant parts consumed by porcupines revealed interesting seasonal variations in their dietary preferences. Prior investigations have exhibited a relatively higher rate of consumption for leaves, stems, seeds, and spikes (Hafeez et al., 2011). Our study corroborated these prior findings and elaborated the seasonal variation in consumption patterns, particularly noting a significant increase in grass consumption during the summer and fall.

Crop and Tree damage

The impact of dietary preferences on the environment was evident from the damage to crops and trees across different ecological zones. In agricultural areas, the damage to crops varied but was significant, with wheat and barley being some of the most affected. The damage percentage for wheat was slightly higher in Faisalabad (6.29%) compared to Qadirabad (5.79%), while barley exhibited higher damage percentages in Qadirabad (7.19%). Although, certain prior investigators have attributed 0.88% (Akhtar et al., 2021) and 0.96% (Hafeez et al., 2012) of damage to wheat crops due to porcupine activity in Sub-mountainous regions of Pakistan, current findings were more comparable with prior reporting which observed crop damage of around 4.58 ± 1.14% in Faisalabad, 6.82 ± 2.03% in Quaidabad, and 5.88 ± 1.53% in Sheikhupura. Authors observed that Sugarcane, Mustard and tomato crops also showed notable damage. Particularly in Qadirabad, mustard damage reached 8.74% while damage to sugarcane fields was around 9.38% in Faisalabad. However prior investigations have observed greater damages for vegetable fields rather than sugarcane or mustard (Akhtar et al., 2021;

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Hafeez et al., 2012). Authors believe that this difference could be justified by the sheer size and coverage of these crops in the current study area. Researchers have noted that, despite smaller percentage of vegetation coverage for vegetable crops, plants namely tomatoes and potatoes have been previously reported to be extensively damaged by porcupine activities (Akhtar et al., 2021; Hafeez et al., 2012, 2011; Gutterman, 1982; Akram et al., 2017; Mori et al., 2017). One such publication has associated 17.56% of crop damage to porcupine activity in Attock Punjab (Khan et al., 2000). Another researcher has posited that despite vegetables being harvested at relatively smaller acreage, instance of plant disturbances owing to Indian crested porcupines were much higher in pea, cauliflower, tomato, chili pepper, potato, radish, and turnip fields according to the anecdotal experiences of farmers. Similar outcomes and vegetable crop damages have been suggested in an inquiry undertaken at Baluchistan as well (Hafeez et al., 2012).

Author of the current manuscript has observed that, tree damage in man-made plantations varied across locations but *Dalbergia sissoo* was found to experience relatively consistent damage across different forests, with no significant differences. *Bombax ceiba* was found to be most susceptible to porcupine damage, particularly in Daphar Forest (33.16%) and Changa Manga Forest (30.69%). However, other trees like *Albizzia procera* and *Acacia nilotica* exhibited relatively lower damage percentages, indicating a possible resistance or lower preference by the porcupines. Interestingly, *Eucalyptus camaldulensis* (sufaida) which once was thought to resist damage from porcupine species was found to be heavily affected (Hafeez et al., 2011, 2012) during current observations whereby 16.12% and 14.01% damage was reported for Changa Manga and Daphar forests respectively.

Observations have revealed that porcupine species peel off dead tree bark to access the inner cortex of the tree thereby exposing, xylem, and phloem (Polotzek et al., 2023). During current inquiry, author observed distinctive scratch marks and engravings from the porcupines' incisors on the inner bark, which had previously been evidenced. However, prior investigations have also reported complete transection of tree trunks for younger *Dalbergia sissoo* plants, at an angle of 45º (Hafeez et al., 2011).

Similarly, North American porcupines have been known to damage Sitka spruce (33% damage) more often than western hemlock (15%) (Woods and Zeglen, 2003), establishing a certain preference for particular tree trunks similar to other types of vegetation. Previously, damage to *Eucalyptus camaldulensis* was observed to be greater than *Dalbergia sissoo* at a plantation in Bhakhar (Hafeez et al., 2012). Whereas, a completely contradictory situation was reported in Kundian (Khan et al., 2014). In current finding, author observed no significant difference in damage to either of the aforementioned tree species indicating a myriad of underlying causes governing damage by porcupines. Thereby suggesting a multidimensional behavioral modification as opposed to a simple straightforward preference.

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CONCLUSION

The current study reinforced prior findings regarding the dietary preferences and environmental impact of the Indian Crested Porcupine in Punjab, Pakistan. The porcupine's diet varied significantly with seasonal changes, with a notable preference for certain crops and plant species. This seasonal adaptability underscores the need for targeted management strategies to mitigate the impact on agriculture and natural vegetation. Measures such as burrow fumigation and sustained pest vigilance are recommended to control the porcupine population and protect valuable crops and plant species. In conclusion, the dietary preferences and environmental impact of the Indian Crested Porcupine in Punjab, Pakistan, exhibit significant seasonal and ecological variations. These findings underscore the need for targeted management and conservation strategies to balance the ecological role of porcupines with the protection of valuable crops and tree species.

Recommendations and Future Perspectives

Following recommendations could be implemented to develop a comprehensive and sustainable strategy for managing the impact of the Indian crested porcupine on agriculture while preserving ecological balance. Future research should continue exploring innovative solutions and enhancing our understanding of porcupine ecology to support effective management practices.

1) Farmers should employ effective crop protection strategies involving physical barriers like electric fences or corrugated mesh to prevent porcupines from accessing crop fields. Additionally, using natural repellents and integrated pest management practices can help mitigate crop losses.
2) Since porcupine damage is more common in areas with limited natural vegetation, habitat management practices that increase the availability of natural food sources in non-cultivated areas could reduce their dependence on crops.
3) Modern technologies, such as motion-activated lighting, ultrasonic repellents, and remote monitoring systems, can enhance porcupine management effectiveness. Research into the development and application of these technologies should be encouraged.
4) Policies that support farmers in implementing porcupine control measures are essential. Subsidies or financial assistance for installing protective barriers and compensation schemes for crop losses due to wildlife can significantly relieve affected farmers.
5) Encouraging the use of non-lethal control methods, such as live trapping and relocation, can help manage porcupine populations without resorting to killing the animals. Research into humane trapping and relocation techniques should be prioritized.

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