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Pre-monsoon Season Food Plants and Feeding Preference of Blackbuck (*Antilope cervicapra*) in Krishnasaar Conservation Area of Nepal

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KEYWORDS

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ABSTRACT

The Blackbuck *(Antilope cervicapra)*, one of the charismatic grassland animals, is native to the Indian subcontinent. In Nepal, it is confined to the protected areas of the western lowlands, namely the Krishnasaar Conservation Area and Shuklaphanta National Park. The pre-monsoon dietary preferences of blackbucks in enclosed habitats are not well understood. Hence, this study investigated the key grass species, blackbuck's preferences over them, and behavior during feeding in the pre-monsoon season in the Krishnasaar Conservation Area. For this, vegetation data was collected with quadrat sampling (n = 45), and feeding preference was studied using a scan sampling method. A total of 21 species of grasses were recorded from the blackbuck's habitat and grazing sites. Among them, *Imperata cylindrica* and *Cynodon dactylon* were the most dominant species. *Cynodon dactylon* and other species, such as *Eleusine indica*, *Chyrsopogon aciculatus*, *Cyperus rotundus*, and *Hemarthria compressa*, were most preferred by the blackbuck. There was no significant difference in the grazing and resting time (behavior) between males and females. Likewise, the behavior did not differ significantly between morning and evening. This study highlights blackbuck's selective feeding and reliance on specific grass species, emphasizing the need for effective management of high-quality grassland habitats to support their population. The findings of this study could be valuable in removing unpreferred species and promoting selected preferred species to provide enough food for blackbucks in their habitats.

INTRODUCTION

The Blackbuck *Antilope cervicapra* (Linnaeus, 1758) belongs to the Bovidae family and is the only species in its genus. It is also known as the Indian Antelope and Krishnasaar (in Nepal). Male and female blackbucks are morphologically distinct.

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Males are dark brown to blue-black with white undersides and have long twisting horns (35 – 79 cm), while females and young are fawn-coloured with white undersides (Csurhes and Fisher, 2016). The name 'blackbuck' comes from the dark color of the males of the species (Csurhes and Fisher, 2016). Their body length ranges from 100 to 150 cm, with a shoulder height of 60 to 80 cm. The tail length measures between 10 and 17 cm, and the weight varies between 19.5 and 56.7 kg for males and 19 to 33 kg for females (Csurhes and Fisher, 2016). Female blackbucks are sexually mature at the age of 1.5 to 2 years, have a gestation period of five to six months, and give birth to a single baby at a time (Csurhes and Fisher, 2016). Their breeding peaks during pre-monsoon and post-monsoon, although it can occur throughout the year (Priyadarshini et al., 2022). They have a life span of 10-12 years. Male blackbucks' mortality rate peaks during mid-life at six to eight years, a pattern that is clearly absent in females (Jhala and Ishvaran, 2016).

Blackbucks are categorized globally as the least concerned mammal species (IUCN SSC Antelope Specialist Group, 2017). Once abundant across the Indian subcontinent, they are now confined only to Nepal and India, already extinct in the wild in Pakistan and Bangladesh (IUCN SSC Antelope Specialist Group, 2017). They are considered critically endangered in Nepal (Jnawali et al., 2011) and listed as a protected species by the National Parks and Wildlife Conservation Act 1973. They were scattered in the western Terai (Kanchanpur, Bardiya, and the floodplain of the Rapti River) during the late 1960s (KrCA, 2017; Pradhan et al., 1999; Pradhan et al., 2001). However, they are now primarily confined to the Krishnasaar Conservation Area (KrCA) and the Hirapur Phanta of the Shuklaphanta National Park (ShNP).

Blackbucks prefer to live in tropical to subtropical woodland, dry deciduous forest, open short grasslands, scrubland, and lightly wooded forests (Csurhes and Fisher, 2016; Jhala and Isvaran, 2016). They primarily graze in pasturelands and occasionally in croplands, but their population is declining due to habitat modification and hunting (Csurhes and Fisher, 2016). Additionally, other significant threats include overgrazing by livestock in its habitat (Khanal and Chalise, 2011), feral dogs (Meena and Jaipal, 2020), parasites and diseases (Chouhan et al., 2021; KC and Khanal, 2019; Pant and Joshi, 2019), invasive alien plant species (Arandhara et al., 2021; Jadeja et al., 2013), and grassland encroachment (Meena and Chourasia, 2018).

The Krishnasaar Conservation Area (KrCA), also known as the Blackbuck Conservation Area (BCA), is located in the tropical region of Bardiya District, Nepal. Established in 2009, it primarily aims to protect the blackbuck population. The conservation area serves as a habitat for these animals and is overseen by park officials, who also conduct annual blackbuck population counts. According to the 2022 census, the KrCA was home to 234 blackbuck individuals (DNPWC, 2023). The mean herd size was 20.56 ± 1.97 in KrCA (Jha and Isvaran, 2023). The forage and habitat structure determine the group size of blackbucks (Isvaran, 2007). Different scholars have studied the blackbuck from KrCA with various focuses, such as grazing impacts (Khanal and Chalise, 2011), group dynamics (Jha and Isvaran, 2023), and anthropogenic responses (Jha and Isvaran, 2022). Seasons or climatic factors affect the nutritional ecology of the blackbuck (Jhala, 1997). However, information on seasonal food and feeding preferences is limited. Gyawali et al. (2020) documented the late post-monsoon and early winter (November–December) grasses and blackbucks' preference for them in KrCA. The spring/pre-monsoon season (March and April) is the primary breeding season for blackbucks in Nepal (Jnawali et al., 2011); however, information about their food and dietary preferences during this period was lacking.

The optimal foraging theory posits that animals select food sources that maximize their energy intake while minimizing the effort required to acquire them (MacArthur and Pianka, 1966). In comparison, the nutrient balance hypothesis assumes that animal diet selection primarily aims to obtain a nutritionally balanced diet when sufficient food is available (Westoby, 1974; Felton et al., 2016). However, the natural environment's nutrient availability fluctuates for several reasons, including seasonal changes, rainfall, and plant senescence (Himelblau and Amasino, 2001; Lashley and Harper, 2012). It drives herbivores to adopt selective and flexible foraging behavior to navigate nutrient-rich plant communities and seek out limiting nutrients (Dykes et al., 2020). Moreover, the activity budget hypothesis states that females spend more time grazing than males (Michelena et al., 2004). We also assumed that blackbucks prefer certain species over others for their food, and their feeding behavior differs between males and females. In this regard, this study assessed the key grass species, blackbucks' preference for them, and their behavior while feeding during the pre-monsoon (spring) season in KrCA. This study provided valuable information for the management of blackbucks' enclosed habitats as well as their natural habitats.

MATERIALS AND METHODS

Study area

The study was conducted in the Krishnasaar Conservation Area, Bardiya District of western Lowland, Nepal (Figure 1). It is extended between 28°7′ and 28°39′N latitude and 81°3′ and 81°4′E longitude. The elevation ranges from 100 to 250 meters above sea level, encompassing an area of 16.95 km², which includes a core area of 5.27 km² and the surrounding community development zone. The community development zone features built-up areas, croplands, forest patches, and grasslands, supporting approximately 1,669 households and 2,384 livestock. This highlights the region's considerable human and livestock densities (KrCA, 2017). The core area features a diverse landscape comprising grassland, open forest characterized by *Bombax ceiba* trees, croplands, and dense forest with an undergrowth of *Lantana camara*. The Blue Bull (*Boselaphus tragocamelus*) is among its occasional visitors, while buffalo, cattle, and goats commonly graze within this core area (Jha and Isvaran, 2022). However, the grassland in KrCA is currently facing challenges due to the invasion of non-native plants, including *Ageratum conyzoides*, *Cymbopogon jwarankusa*, *Cassia tora*, *Solanum* sp., and *Parthenium hysterophorus* (DNPWC, 2023; KrCA, 2017).

Data collection

The data were collected during the Spring (March–April) of 2024. A reconnaissance survey was carried out before detailed fieldwork. For vegetation sampling, quadrats (wooden frame) measuring 1 m × 1 m were utilized, which are typically used for sampling grasses and herbs (Gyawali et al., 2020; Habiba et al., 2021; Tewari and Rawat, 2013). A total of 45 quadrats were randomly placed in rows of four to seven across the grasslands and *Bombax ceiba* trees, covering the core area with fresh pellets and signs of grazing. They were spaced approximately 200 to 250 meters apart (Figure 2). The grass species, their count, and coverage percentage were recorded at each quadrat. The coverage percentage was visually estimated based on the ground covered by grass within the quadrat. The grass species were identified by their local names with the help of park officials.

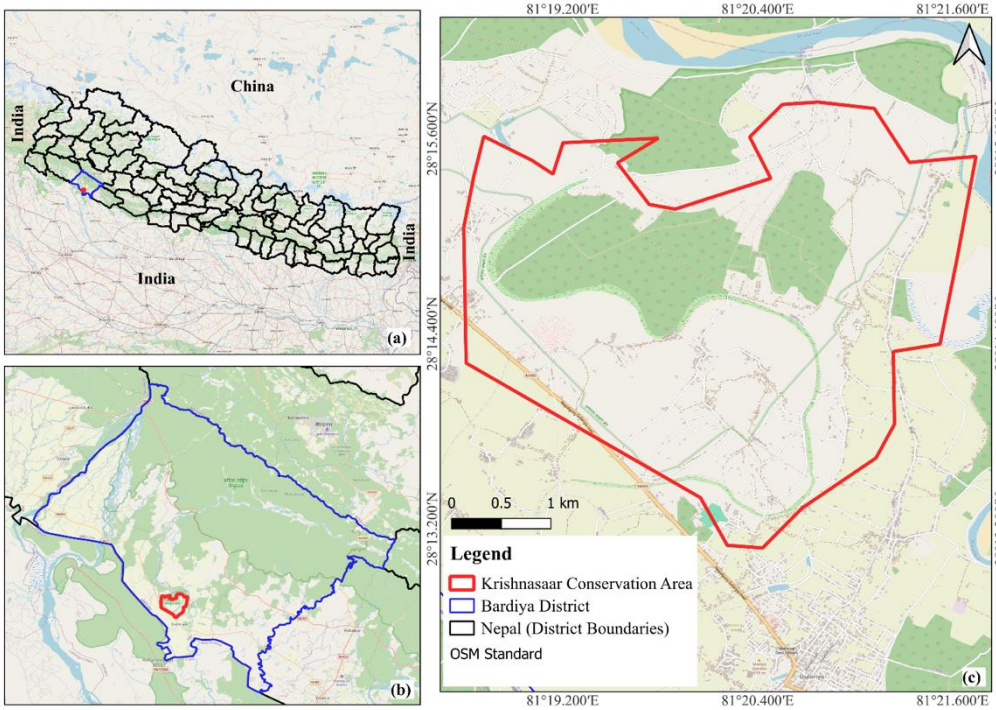

Figure 1: Study area map showing the district boundaries of Nepal (a), Bardiya District (b), and the Krishnasaar Conservation Area (c). The map was prepared in QGIS version 3.36.2-Maidenhead

After that, blackbuck's feeding behavior and preferred plants were investigated using the scan sampling approach (Altmann, 1974). Scan sampling is a method in which a group of animals is chosen to study their behavior. All visible group members are observed within a short period, resulting in a record that closely resembles a simultaneous sample of all individuals (Altmann, 1974). A group was defined as all individuals located within 50 meters of at least one other individual (Isvaran, 2005; Jha and Isvaran, 2022). The scan points were determined near the road trail for easy walking and visibility, and they were approximately 50–60 m apart from the grazing groups (Figure 2). Blackbucks were scanned using a pair of binoculars by two observers, with each group scan lasting 15 minutes. Once we identified a group, we counted the males (distinguished by color and horn), females (larger than fawns but without horns), and fawns. One observer then focused on the males and recorded the proportion of time spent grazing and resting during each minute over the 15-minute period. Simultaneously, another observer recorded the same behavioral measures for the females. Based on these observations, we estimated the total time spent resting and grazing by males and females. We also noted the grass species that the blackbucks predominantly grazed or avoided during the observation period. The procedure was conducted over 15 consecutive days, with four-hour sessions each day, totaling 60 hours of observation. Observations were conducted in the early morning from 6:00 to 8:00 h and in the evenings from 16:00 to 18:00 h. This timing was selected because foraging behavior generally peaks from morning to midday and again just before dusk (Latif et al., 2024). The preferences for noted grass species were categorized with the assistance of park officials into highly

preferred, medium preferred, low preferred, and very low preferred.

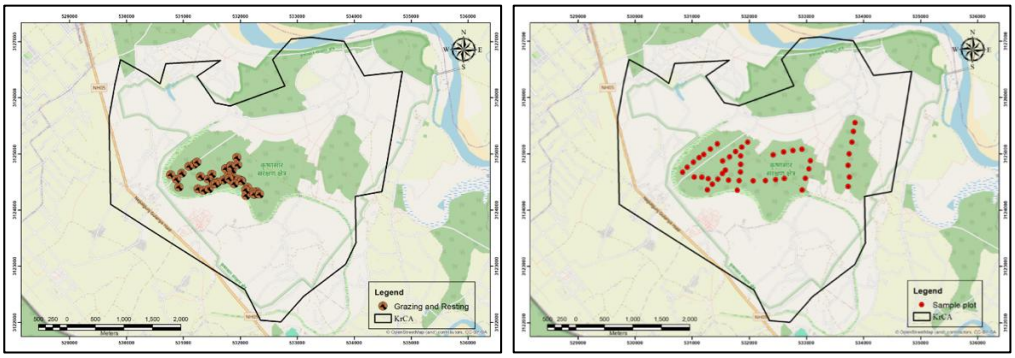

Figure 1: Map showing the scan points for feeding behavior (left) and quadrats for vegetation sampling (right) within the study area.

Data analysis

Data were analyzed using MS Excel and RStudio Version 4.4.2. The relative density (RD), relative frequency (RF), relative coverage (RC), and importance value index (IVI) were calculated for the sampled grasses (Aryal et al., 2014). These parameters provided a comparison among the grass species

$$\text{Density} = \frac{\text{Total number of individual of a species}}{\text{Total number of quadrates sampled} * \text{size of a quadrate}} * 100 \ldots\ldots\ldots\ldots (i)$$

$$\text{RD} = \frac{\text{Density of a species}}{\text{Total density of all species}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

$$\text{Frequency} = \frac{\text{Total number of quadrates in which a species occurs}}{\text{Total number of quadrates sampled}} * 100 \ldots\ldots\ldots\ldots (iii)$$

$$\text{RF} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all species}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

$$\text{Coverage} = \frac{\text{Approximate area covered by an individual}}{\text{Total number of plots sampled}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots (v)$$

$$\text{RC} = \frac{\text{Cover of individual species}}{\text{Total cover of all species}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (vi)$$

$$\text{IVI} = \text{RD} + \text{RF} + \text{RC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (vii)$$

The average time males and females spent grazing and resting was estimated, along with the time of day. Additionally, a non-parametric statistical test was conducted to analyze differences in grazing and resting behavior between males and females and across different times of the day (morning and evening). The Wilcoxon rank-sum test was applied at a significant level of 0.05 in RStudio.

RESULTS

Relative density, frequency, coverage, and importance value index of grasses

A total of 21 species of grasses and shrubs were documented in the study area. Among them, *Imperata cylindrica* was the most dominant species, exhibiting the highest relative density (41.68%), frequency (29%), coverage (42.98%), and importance value index (IVI) of 113.66, followed by *Cynodon dactylon*, *Desmodium* sp., and *Saccharum spontaneum* (Table 1).

Table 1: Relative density (RD), relative frequency (RF), relative coverage (RC), Importance Value Index (IVI), and preference of grasses in the study area.

S.N.	Local Name	Scientific Name	RD	RF	RC	IVI	Preference
1	Baxa ghas	*?*	1.76	3	2.12	6.88	++
2	Bayer	*Ziziphus jujuba*	0.74	3	3.42	7.17	-
3	Chhammarbhadi	*Cyperus* sp.	0.21	1	0.35	1.56	-
4	Dubo	*Cynodon dactylon*	17.78	14	15.2	46.98	+++
5	Dudhe ghas	*Euphorbia hitra*	0.19	1	0.23	1.43	++
6	Gadra Khar	*?*	0.19	1	0.07	1.25	+
7	Ghode dubo	*Hemarthria compressa*	1.98	1	1.28	4.26	+++
8	Godammey	*?*	0.08	1	0.26	1.33	++
9	Janewa	*Bothriochloa bladhii*	5.3	8	6.11	19.41	++
10	Jarakush	*Cymbopogan jwarankusa*	1.88	4	6.39	12.27	-
11	Jhusi	*?*	0.04	1	0.12	1.15	++
12	Kash	*Saccharum spontaneum*	5.79	6	7.38	19.18	+
13	Khadedaar	*?*	1.27	3	1.19	5.45	-
14	Kodo ghas	*Eleusine indica*	0.09	1	0.35	1.44	+++
15	Kuro	*Chyrsopogon aciculatus*	2.99	2	1.63	6.62	+++
16	Mothe	*Cyperus rotundus*	0.27	1	0.58	1.85	+++
17	Panchuniya	*?*	0.12	1	0.23	1.35	++
18	Rato phul	*Sporobolus* sp.	0.04	1	0.05	1.09	+
19	Siru	*Imperata cylindrica*	41.68	29	42.98	113.66	+
20	Dhursuli	*Colebrookea oppositifolia*	1.9	2	0.81	4.71	++
21	Tinpate	*Desmodium* sp.	15.7	16	9.25	40.95	++

Note: +++ = high preference, ++ = medium preference, + = low preference, and - = very low preference

Preference of Blackbuck over grass species

Blackbucks consumed *C. dactylon, E. indica, C. aciculatus, C. rotundus,* and *H. compressa* more frequently and preferably. In contrast, they consumed *Z. jujuba, A. hymenoids, Cyperus* sp., and Khadedaar the least (Table 1). They primarily fed on new grass shoots. They rarely fed on the young shoots of *B. ceiba* (Simal) and *Senegalia catechu* (Khayer); only when they could not find grass to eat. Browsing was almost negligible.

Behaviors of the Blackbuck during feeding

Females were found grazing more in the evening (average = 11.9 min) than in the morning (average = 8.65 min). At the same time, males grazed slightly more in the

morning (average = 10.3 min) than in the evening (average = 9.38 min). Likewise, females rested somewhat more in the morning (average = 2.88 min) than in the evening (average = 1.25 min). In comparison, males rested almost equally in the morning (average = 2.85 min) and evening (average = 2.5 min) (Table 2). Overall, the grazing (average = 10.5 minutes) was dominant over resting (average = 2.5 minutes). The Wilcoxon rank-sum test showed no significant difference in resting and grazing time/behavior between male and female blackbucks (p-values > 0.05). Likewise, there was no significant difference in grazing or resting between the times of the day tested (p-values > 0.05) (Table 3). Figure 3 shows the density of resting and grazing by males and females at different times of the day. The images taken during the behavior study are presented in Figure 4.

Table 2: Average grazing and resting times of Blackbuck across sex and time of day.

Sex	Time of the day	Average grazing (min)	Average resting (min)
Female	Morning	8.65	2.88
Female	Evening	11.9	1.25
Male	Morning	9.38	2.85
Male	Evening	10.3	2.5

Table 3: Summary statistics of Wilcoxon rank-sum test.

Behavior	Variables	W	p-value
Grazing	Sex	1286.5	0.7721
Resting	Sex	1198	0.595
Grazing	Time of the day	1404	0.2106
Resting	Time of the day	1128	0.217
Significance level: 0.05			

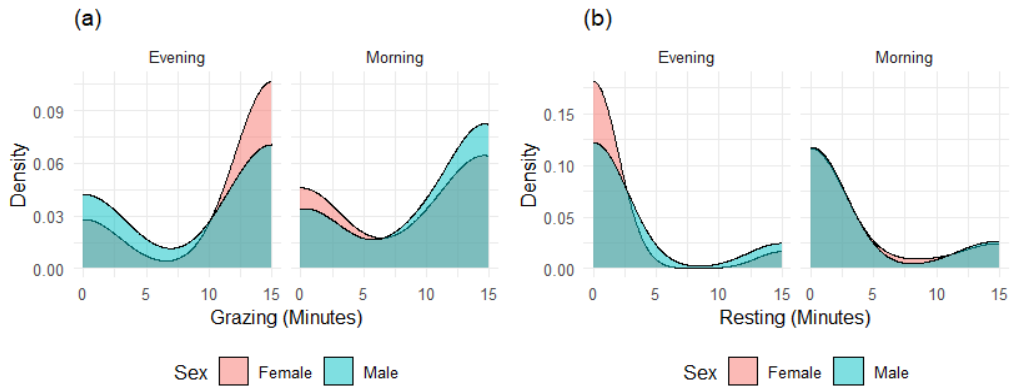

Figure 2: Density plot showing the grazing (a) and resting behaviors (b) of Blackbucks by sex and time of the day.

Figure 3: Grazing and resting female (left) and male (right) in the study area.

DISCUSSION

The present study provides insight into pre-monsoon season foods and the feeding preferences of the blackbucks in KrCA. This information is crucial for vegetation management in the area to provide sufficient food for them. Altogether, 21 grass species were recorded from the study area during the survey. *Imperata cylindrica* was the most abundant and dominant grass species, followed by *C. dactylon*, *Desmodium* sp., and *S. spontaneum*. Khanal (2002) documented 32 species of plants (12 forbs, nine grasses, four shrubs, and seven trees) during the proposal phase of KrCA, with *C. dactylon* and *I. cylindrica* being dominant in the grassland area. This is similar to our current observation indicating the region's protected native vegetation. Likewise, another study in Hirapur Phanta of ShNP reported the dominant *I. cylindrica* and *C. dactylon* in the blackbuck habitat (Pant and Joshi, 2019). Livestock grazing (cow and buffalo) was a major problem in previous years in KrCA, removing grass biomass from the blackbuck habitat (Khanal and Chalise, 2011). Overgrazing alters the seasonal diversity of palatable grasses in the blackbuck habitat (Kumar et al., 2024). Moreover, blackbucks avoid areas of human interference even though these areas have high-quality forage (Jha and Isvaran, 2022; Krishna et al., 2016). The Krishnasaar Conservation Area is a popular tourist destination that permits visitor access, making it essential that human impact is minimized in the regions with preferred grass species. The pre-monsoon serves as the primary breeding season for blackbucks in Nepal (Jnawali et al., 2011). Therefore, it is crucial to manage forage to ensure an adequate food supply during this period.

Blackbucks preferred consuming plant species like *C. dactylon, E. indica, C. aciculatus, C. rotundus,* and *H. compressa* to consuming species like *Z. jujuba, A. hymenoids, Cyperus* sp., and Khadedaar. While they occasionally fed on the young shoots of *B. ceiba* and *S. catechu*, they rarely browsed on these species. The findings of this study could inform management strategies aimed at removing less preferred grass species from the KrCA, thereby promoting the growth of preferred species. Due to the limited availability and poor quality of grass, the KrCA office has resorted to cultivating crops such as paddy and lentils to supplement forage resources. Blackbucks, in particular, favour tender young leaves and pods. A total of 30 grass species were documented in KrCA during November and December (Gyawali et al., 2020). Among these, Blackbucks highly preferred *C. dactylon*, which aligns with our findings. They also preferred *Bothriochloa bladhii, Youngia japonica,* and *Echinochloa colona* (Gyawali et al., 2020). Conversely, they least favored species like *Brachiaria* sp., *Setaria*

glauca, Hedyotis sp., and *Echinochloa* sp. At the same time, they tended to avoid species such as *Cyperus* sp., *Ageratum conyzoides*, and *Cassia tora* (Gyawali et al., 2020). A study revealed that Blackbucks highly prefer various plant species, including *Evolvulus nummularius, Fimbristylis bisumbella, C. dactylon, Hemarthria compressa, Morus alba, Zea mays*, and *Cyperus niveus*, in ShNP (Pant and Joshi, 2019). Additionally, another investigation conducted in ShNP found that during the winter season, the diet of Blackbucks comprised eight species, with *I. cylindrica* being the most prominent, followed by *C. dactylon* and *Arundinella* sp. In the monsoon season, their diet included 13 plant species, again highlighting *I. cylindrica* as the primary choice, followed by *Arundinella* sp., *C. dactylon*, and others (BK and Awasthi, 2018). In the semi-arid region of western Haryana, India, blackbucks were observed to consume *Artemisia scoparia*, *Cucumis callosus*, *Ziziphus jujuba*, and *Ziziphus nummularia* more frequently (Delu et al., 2021). The variation in dietary preferences may be attributed to the availability of different grasses across seasons and habitats. In southern India, this seasonal food preference was also apparent, with the wet season diet being less diverse, indicating a higher reliance on a primary food source. Conversely, during the dry season, their diet was more varied, showing less dependence on a single type of food (Sathishkumar et al., 2023). Additionally, Blackbucks have been reported to cause damage to agricultural fields by consuming crops such as sugarcane, pigeon peas, vegetables, and others in India (Asif and Modse, 2016; Das et al., 2018).

Females were observed to graze more frequently in the evening, whereas males showed a smaller difference in grazing activity between morning and evening. It was found that females change their resting pattern between morning and evening more than males. Overall, there was no significant difference between the sexes in terms of grazing or resting time. The finding suggests synchronized behavior of feeding in Blackbucks. Synchronized behavior is when multiple individuals perform identical behaviors simultaneously (Duranton and Gaunet, 2016; Maeda et al., 2021). However, further study is recommended to validate this conclusion. Our finding contrasts with the activity budget hypothesis, which assumes that females spend more time grazing than males (Michelena et al., 2004). Likewise, the time of the day tested (morning and evening) did not impact grazing and resting behavior, indicating that morning and evening are equally crucial for Blackbucks in acquiring nutrition. Grazing was a dominant activity over resting. It is in line with the evidence that the morning and evening times are peak times for Blackbuck foraging (Latif et al., 2024). In the behavioral study of the Blackbuck in KrCA, Jha and Isvaran (2022) also reported that foraging was the primary activity observed during the total scan period. Similarly, KC and Khanal (2019) found that feeding was the most prevalent activity, followed by resting, among Blackbucks in captivity in the Pashupatinath area of Kathmandu. Farooq et al. (2022) observed that in a study on captive Blackbucks in Pakistan, the time spent resting was lower during the spring and monsoon seasons compared to the summer, with adult blackbucks dedicating more time to feeding than fawns. Additionally, Latif et al. (2024) noted that adult blackbucks engaged in longer durations of foraging in the Cholistan Desert, Pakistan. Furthermore, Ayyub (2024) found that captive Blackbucks spent more time resting, feeding, ruminating, sitting, and foraging during spring. Variations in feeding ratios to resting time have also been observed in western Haryana, India, where both male and female Blackbucks exhibited increased feeding durations (Delu et al., 2021; Delu and Singh, 2023). It is important to note that resting time is associated with rumination. Our study was conducted during morning and evening, suggesting that the observed durations may align more with the

Blackbuck's feeding behavior rather than resting during that time in the study area.

CONCLUSION

The present study provided crucial information on Blackbuck's preference for spring/pre-monsoon season forage. A total of 21 grass species were recorded, of which *Imperata cylindrica* and *Cynodon dactylon* were the most dominant species. Besides *C. dactylon*, the Blackbuck preferred other species such as *E. indica*, *C. aciculatus*, *C. rotundus*, and *H. compressa*. For Blackbuck's long-term diet supply, the preferred species should be promoted for growth. There was no significant difference in the grazing and resting time (behavior) between the sexes and the time of the day (morning and evening). A diet analysis study based on blackbuck fecal samples could provide robust insights into their dietary preferences. Additionally, we also recommend further studies that assess seasonal variation in diet and compare preferences between enclosed and natural habitats.

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