Journal of Animal Research: v.8 n.1, p. 137-147. February 2018

DOI: 10.30954/2277-940X.2018.00150.22

Gross Anatomical and Sex wise Biometrical Studies on the Atlas and Axis of Blue bull (*Boselaphus tragocamelus*)

S. Sathapathy[1*], B.S. Dhote[1], D. Mahanta[1], M. Mrigesh[1] and S.K. Joshi[2]

[1]Department of Veterinary Anatomy, C.V.A.Sc., G.B.P.U.A and T, Pantnagar, Uttarakhand, INDIA
[2]Scientist, Jharsuguda, OUAT, Bhubaneswar, Odisha, INDIA

[*]Corresponding Author: S. Sathapathy; Email : srinivas.ouat@gmail.com

Received: 06 Jan., 2018 **Revised:** 19 Jan., 2018 **Accepted:** 22 Jan., 2018

ABSTRACT

The present study was carried out on the atlas and axis of six specimens of adult Blue bull (*Boselaphus tragocamelus*) of either sex. Both the atlas and axis were atypical cervical vertebrae. The atlas presented a large rough tuberosity on its dorsal arch, thick ventral arch and less curved wings those were thick and more horizontal plate bones. They terminated into a rough curved ridge laterally and exceeded behind the articular surface caudally. The cranial articular cavities for the occipital condyles were partially divided into dorsal and ventral parts by a non-articular area and were separated by a narrow interval below. The caudal articular surfaces were flattened behind and were continued to the vertebral canal forming an extensive area known as fovea dentis for articulation with the dens of the axis. There were presences of cranio-internal intervertebral foramen and cranio-external alar foramen connected by a short furrow. A deep atlantal fossa was present in the ventral aspect of wing of atlas. The axis was the longest cervical vertebra that presented a spout like odontoid process projected from the body cranially and an intervertebral foramen at the base of the transverse process. The supraspinous process was blade like cranially that increased in height and thickness backwards and terminated abruptly beyond the level of caudal articular surface of the body. The infraspinous process was in the form of a median ridge. The Biometrical observations on different parameters of atlas and axis reflected significance ($P<0.05$) differences between the sexes of this species.

Keywords*:* Anatomy, atlas, axis, biometry, blue bull, dens

The Blue bull (*Boselaphus tragocamelus*) is known to be one of the biggest antelopes in Asia and is widely found in both the forests and adjoining villages with enough green grass. Blue bull is considered sacred as per Hindu religion since Vedic period (1500-500 BC) and it is considered as religious. The Blue bull belongs to the family Bovidae and comes under the genus *Boselaphus*. The German Zoologist Scientist Peter Simon Pallas explained this species for the first time in 1766. English Zoologist Scientist Philips for the first time in 1833 narrated the binomial combination of the Blue bull. It is quite prevalent in northern and central parts of India especially in the foothills of Himalayas, eastern part of Pakistan and southern part of Nepal, but has vanished from Bangladesh. The adult male appears like ox and so called as Blue bull. They are usually seen in day times in the meadow pasture, timberland areas and agricultural land area. It prefers mostly plain or grassy plain and low hilly areas with shrubs, small bushes, scrub forests with scattered trees and does not usually found in dense forest areas, dense compact wood, etc. The Blue bulls are safeguarded beneath the IUCN since 2003 and also under safeguard of 'Schedule III' of the Indian Wildlife Protection Act, 1972 (Bagchi *et al*., 2004). The Blue bull is safeguarded in various parts of India such as Gir National Park (Gujarat), Kumbhalgarh Santuary (Rajasthan) and Panchamarahi Biosphere Reserve, India. The massive body of the Blue bull can be attributed to the large skeleton of the antelope. Further, the skeleton comprises of large and massive bones of axial and appendicular skeleton that not only protects the viscera, but also provides shape and support to the heavy musculature of the Blue bull. The present osteo-morphological study developed a baseline data on the atlas and axis of adult Blue bull that would immensely help the wild life anatomists and Veterinarians in species identification and solving forensic and vetero-legal cases as no previous work has been done in this field on the Blue bull.

MATERIALS AND METHODS

The present study was carried out on the atlas and axis of six specimens of adult Blue bulls (*Boselaphus tragocamelus*) of either sex. The permission for the collection of bones was acquired from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan. The bones were possessed from the Jodhpur zoo, Rajasthan getting authentic confirmation from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan. The skeletons were taken out from the burial ground that was located in the premises of the office of the Deputy Conservator of Forest Wildlife (WL), Jodhpur. Afterwards, the specimens were processed as per standard technique given by Snedecor and Cochran (1994). The gross study was conducted under the supervision of the Zoo Authority, Jodhpur, India. The different parameters of atlas and axis were measured and subjected to routine statistical analysis [18] and independent samples t-Test with Systat Software Inc, USA and SPSS 16.0 version software.

RESULTS AND DISCUSSION

First cervical vertebra or Atlas

Atlas or C1 was atypical type, which was similar with the findings of Iniyah *et al*. (2015), who reported that the C1 was atypical and in the form of a ring with laterally projected wings and enclosed by large vertebral canal in spotted deer. Pandey *et al*. (2013) found that the atlas of tiger (*Panthera tigris*) was atypical in nature that articulated with the skull cranially and with C2 caudally. The atlas presented a large rough tuberosity on its dorsal arch (Fig. 1), which simulated the findings of Getty *et al.* (1930) and Raghavan (1964) in ox, Konig and Liebich (2005) in ruminants, Goel *et al.* (2011) in deer and contradicted with Getty *et al.* (1930) in horse and in sheep where it was less developed, Miller *et al.* (1964) in dog where the dorsal tubercle was bifid, Smuts and Bezuidenhout (1987) in camel where dorsal tubercle was not prominent and according to Yilmaz *et al.* (2000) in otters, it was uncertain. Choudhary *et al*. (2012) found a prominent prism shaped dorsal tubercle in the atlas of chiru.

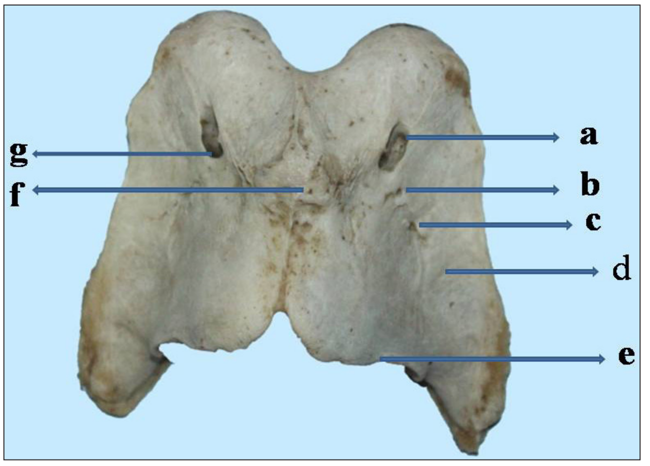

Fig. 1: Dorsal view of Atlas of adult male Blue bull (*Boselaphus tragocamelus*) showing **(a)** Alar foramen, **(b)** Third foramen, **(c)** Fourth foramen, **(d)** Wing, **(e)** Posterior articular surface, **(f)** Dorsal tubercle and **(g)** Intervertebral foramen

The ventral arch was very thick. The wings were less curved than in the horse. The foramen transversarium was absent. The wing was thick and more horizontal plate bone and terminated into a rough, curved ridge laterally and exceeded behind the articular surface caudally (Fig. 2).

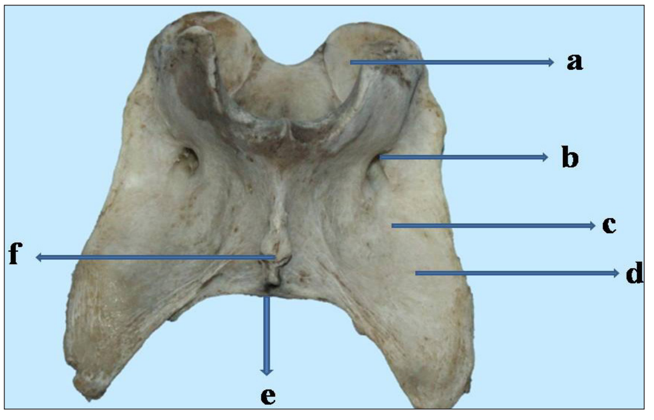

Fig. 2: Ventral view of Atlas of adult male Blue bull (*Boselaphus tragocamelus*) showing **(a)** Anterior articular cavity, **(b)** Foramen in fossa atlantis, **(c)** Fossa atlantis, **(d)** Wing and **(e)** Articular surface of ventral arch and **(f)** Ventral tubercle

This was contrary to the findings of Getty *et al.* (1930) and Raghavan (1964) in ox, where the wing was less horizontal and not exceeded the caudal articular surface;

however these were directed obliquely downwards and backward in horse (Getty *et al.*, 1930); but it was found to be less horizontal and convex dorsally in camel (Smuts and Bezuidenhout, 1987); the shelf-like wings projected from the lateral masses in dog (Miller *et al.,* 1964). The wings of atlas were less developed in Calamian deer (Maala *et al.*, 1992); the wings of C1 were curved upward in buffalo (Shahid and Muhammad, 2001) and the ventral surfaces of the transverse process of the atlas in the horse and deer presented a greater depth than those of a tiger, in which they were shallower, but wider according to Goel *et al.* (2011).

The cranial articular cavities for the occipital condyles were partially divided into dorsal and ventral parts by a non-articular area, and were separated by a narrow interval below (Fig. 3) that agreed to the findings of Getty *et al.* (1930) in horse and ox and Raghavan (1964) in ox; but in dog the anterior articular surface comprised of two cotyloid cavities that sometimes met ventrally according to Miller *et al.* (1964).

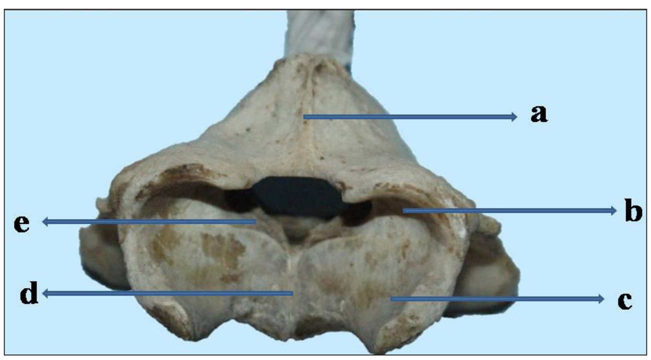

Fig. 3: Cranial view of Atlas of adult male Blue bull (*Boselaphus tragocamelus*) showing **(a)** Dorsal tubercle, **(b)** Dorsal part of cranial articular cavity, **(c)** Ventral part of cranial articular cavity, **(d)** Notch and **(e)** Triangular non-articular depression

The anterior articular surfaces were separated by a deep incisures in camel as the findings of Smuts and Bezuidenhout (1987). The caudal articular surfaces were flattened behind and were continued into the vertebral canal, forming an extensive area known as fovea dentis for the dens or odontoid process of the axis (Fig. 4). There were presence of two foramina on both the sides of dorsum of wing of atlas known as the intervertebral foramen (cranio-internal) and the alar foramen (cranio-external) those were further connected by a short furrow which contradicted with the findings of Raghavan (1964) in ox and Getty *et al.* (1930) in horse where it was connected by a short oval opening. However, in contrast, it was reported by Smuts and Bezuidenhout (1987) that it was connected by a short groove in camel. A notch was found instead of alar foramen in dog according to Miller *et al.* (1964) and in otters according to Yilmaz *et al.* (2000). Dyce *et al.* (2006) found that in some species third (alar) foramina perforated the wing; Ozkan (2007) found in mole-rats that the alar foramen was located, but there was no incisura alaris. These foramina were found to be connected by a short groove in horse and the alar foramen was replaced by a notch in the anterior border of the wing in tigers as reported by Goel *et al.* (2011).

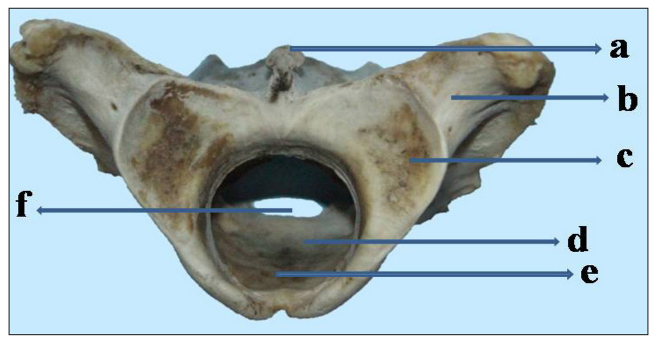

Fig. 4: Caudal view of Atlas of adult male Blue bull (*Boselaphus tragocamelus*) showing **(a)** Ventral tubercle, **(b)** Wing, **(c)** Caudal articular surface, **(d)** Floor of neural canal, **(e)** Fovea dentis and **(f)** Cervical vertebral foramen

There were presences of two external openings of the third and fourth foramen on both the sides of dorsum of wing of atlas in Blue bull, just behind the alar foramen and intervertebral foramen that simulated to the reports of Raghavan (1964) in ox, but was in disagreement with Getty *et al.* (1930) in horse, Miller *et al.* (1964) and Dyce *et al.* (2006) in dog, where it was not present, Smuts and Bezuidenhout (1987) in camel where an accessory alar foramen was present instead of these foramina and Yilmaz *et al.* (2000) in otters.

A deep atlantal fossa or fossa atlantis was present in the ventral aspect of atlas or C1 in Blue bull which was in agreement with Raghavan (1964) in ox, whereas it was in form of depressions in dog (Miller *et al.,* 1964) and in horse (Getty *et al.*, 1930a). The atlantal fossa was significant in mole-rats (Ozkan, 2007). It was also in disagreement with Goel *et al.* (2011) who reported that the ventral surfaces of the transverse process of the atlas in the horse and deer presented a greater depth than those of a tiger, in which they were shallower, but wider. The foramen alare penetrated the wing of atlas to open in the fossa atlantis in Blue bull. A single ventral opening was present in the atlas, which simulated the findings of Getty *et al.* (1930) in horse, Miller *et al.* (1964) and Dyce *et al.* (2006) in dog, Raghavan (1964) in ox, Konig and Liebich (2005) in ruminants and carnivores, Levine *et al.* (2007) in horse and dog and Goel *et al.* (2011) in horse and tiger. However, it contradicted the reports of Smuts and Bezuidenhout (1987) in camel and Meena (2012) in chital, where they found double ventral openings in C1.

The transverse foramen was absent in the atlas of Blue bull which was concurrent to the finding of Getty *et al.* (1930), Raghavan (1964) and Frandson and Spurgeon (1992) in ox, Konig and Liebich (2005) in ruminants and Meena (2012) in chital, but it was present in horse by Getty *et al.* (1930a), in dog by Miller *et al.* (1964) and Dyce *et al.* (2006), in camel by Smuts and Bezuidenhout (1987), in porcupine by Yilmaz (1998), in otters by Yilmaz *et al.* (2000), in buffalo by Shahid and Muhammad (2001), in horse and dog by Levine *et al.* (2007), in mole-rats by Ozkan (2007) and in tiger according to Goel *et al.* (2011).

Biometrical observation

The biometrical observations revealed that the average weight of C1 was found to be 279.16±1.80 gm in adult Blue bull. Further, it was measured to be 276.83±2.88 gm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 281.5±1.58 gm.

The average length of wing was found to be 13.82±0.61cm in adult Blue bull. Further, it was measured to be 13.53±0.90 cm and 14.10±0.88 cm in females and males respectively. The average width of the wing at the cranial aspect was found to be 3.24±0.04 cm in adult Blue bull. Further, it was measured to be 3.15±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 3.33±0.03 cm. Similarly, the average width of the wing at the middle was found to be 2.71±0.06 cm in adult Blue bull. Further, it was measured to be 2.58±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.84±0.07 cm. The average width of the wing at the caudal aspect was found to be 1.83±0.04 cm in adult Blue bull. Further, it was measured to be 1.72±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.95±0.03 cm. The average cranial distance between the wings at the dorsal aspect was found to be 2.38±0.10 cm in adult Blue bull. Further, it was measured to be 2.20±0.06cm and 2.20±0.06 cm in females and males respectively. The average cranial distance between the wings at the ventral aspect was found to be 4.23±0.10 cm in adult Blue bull. Further, it was measured to be 4.03±0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 4.43±0.03 cm. The average caudal distance between the wings was found to be 9.68±0.14 cm in adult Blue bull. Further, it was measured to be 9.40±0.06 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be9.97±0.09 cm. The average distance between the caudal most point of the wing and midpoint of neural ring was found to be 1.41±0.05 cm in adult Blue bull.

Further, it was measured to be 1.31±0.04 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.51±0.07 cm. The average vertical diameter of vertebral canal at the cranial aspect was found to be 2.26±0.07cm in adult Blue bull. Further, it was measured to be 2.13±0.03 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.40±0.07 cm. The average vertical diameter of vertebral canal at the caudal aspect was found to be 3.77±0.05 cm in adult Blue bull.

Further, it was measured to be 3.68±0.04 cm and 3.86±0.06 cm in females and males respectively. The average transverse diameter of vertebral canal at the cranial aspect was found to be 3.58±0.09 cm in adult Blue bull. Further, it was measured to be 3.43±0.08cm and 3.72±0.10 cm in females and males respectively. Similarly, the average transverse diameter of vertebral canal at the caudal aspect was found to be 3.72±0.05 cm in adult Blue bull. Further, it was measured to be 3.64±0.04 cm and 3.80±0.06 cm in females and males respectively.

The average cranio-caudal diameter of intervertebral foramen was found to be 0.65±0.02cm in adult Blue bull. Further, it was measured to be 0.45±0.03 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 0.65±0.03 cm. Similarly, the average latero-medial diameter of intervertebral foramen was found to be 1.18±0.03 cm in adult Blue bull. Further, it was measured to be 1.11±0.04 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.25±0.03 cm. The average distance of the intervertebral foramen from cranial aspect of wing was found to be 2.98±0.10 cm in adult Blue bull. Further, it was measured to be 2.75±0.12 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 3.20±0.09cm. The average diameter of alar foramen was found to be 0.17±0.02cm in adult Blue bull. Further, it was measured to be 0.15±0.03 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 0.20±0.02 cm. Similarly, the average distance between the alar and intervertebral foramen was found to be 0.93±0.13 cm in adult Blue bull. Further, it was measured to be 0.75±0.14cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.10±0.20 cm. The average diameter of dorsal tubercle was found to be 2.02±0.04 cm in adult Blue bull.

Further, it was measured to be 1.95±0.05 cm and 2.10±0.03 cm in females and males respectively. The average diameter of the ventral tubercle was found to be 0.81±0.07 cm in adult Blue bull. Further, it was measured to be 0.66±0.04 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 0.97±0.04 cm. The average distance between intervertebral foramen and dorsal tubercle at the cranial aspect was found to be 3.13±0.05 mm in adult Blue bull. Further, it was measured to be 2.98±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 3.27±0.05 cm.

Similarly, the average distance between intervertebral foramen and dorsal tubercle at the middle was found to be 2.15±0.07 cm in adult Blue bull. Further, it was measured to be 2.00±0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.30±0.06 cm. The average distance between intervertebral foramen and dorsal tubercle at the caudal aspect was found to be 2.03±0.08 cm in adult Blue bull. Further, it was measured to be 1.85±0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.20±0.09 cm. The average distance between the alar foramen and dorsal tubercle was found to be 2.99±0.08 cm in adult Blue bull. Further, it was measured to be 2.80±0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 3.18±0.06 cm.

The average length of cranial articular surface was found to be 2.74±0.09 cm in adult Blue bull. Further, it was measured to be 2.64±0.15 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.85±0.10 cm. Similarly, the average length of caudal articular surface was found to be4.14±0.15 cm in adult Blue bull. Further, it was measured to be 4.02±0.23 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 4.26±0.20 cm. The average width of cranial articular surface at the dorsal aspect was found to be 2.43±0.08 cm in adult Blue bull. Further, it was measured to be 2.29±0.08 cm and 2.56±0.11 cm in females and males respectively. The average width of cranial articular surface at the middle was found to be 2.69±0.05 cm in adult Blue bull.

Further, it was measured to be 2.59±0.07 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.80±0.02 cm. Similarly, the average width of the cranial articular surface at the ventral aspect was found to be 2.75±0.04 cm in adult Blue bull. Further, it was measured to be 2.64±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.86±0.04 cm. The average width of the caudal articular surface at the dorsal aspect was found to be 0.63±0.04 cm in adult Blue bull. Further, it was measured to be 0.56±0.06 cm and 0.70±0.05 cm in females and males respectively. The average width of the caudal articular surface at the middle was found to be 1.65±0.06 cm in adult Blue bull.

Further, it was measured to be 1.50±0.07 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.80±0.04 cm. The average width of the caudal articular surface at the ventral aspect was found to be 1.75±0.08 cm in adult Blue bull. Further, it was measured to be 1.68±0.13 cm and 1.81±0.11 cm in females and males respectively. The average distance between two caudal articular facets at the cranial aspect was found to be 2.34±0.07 cm in adult Blue bull. Further, it was measured to be 2.21±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.47±0.06 cm. The average distance between two caudal articular facets at the middle was found to be 2.20±0.04 cm in adult Blue bull. Further, it was measured to be 2.13±0.06 cm and 2.27±0.03 cm in females and males respectively. The average distance between two caudal articular facets at the caudal aspect was found to be 1.92±0.07 cm in adult Blue bull. Further, it was measured to be 1.78±0.03 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.05±0.07 cm. Choudhary *et al*. (2012) recorded that the maximum width at the cranial and caudal articular cavities was 5.7 and 5.3 cm in chiru respectively, whereas it was 4.77±0.32 and 4.25±0.20 cm respectively in sheep. The maximum width at the cranial and caudal ends and at the middle point of the wings in chiru was 6.5 cm, 7.3 cm, 7.55 cm respectively while similar observations for the sheep were recorded as 5.36±0.14 cm, 4.97±0.22 cm and 6.01±0.32 cm respectively. The dorso-ventral diameters of neural canal at the cranial and caudal ends were found to be 1.9 cm and 2.2 cm in chiru, while they were 1.36±0.10 cm and 2.17±0.05 cm in sheep. The transverse diameter for the cranial and caudal ends were recorded as 2.6 cm and 2.25 cm respectively in chiru, while they were found to be 2.28±0.04 cm and 2.11±0.07 cm in sheep. The cranio-caudal length of the dorsal surface of the dorsal arch at the middle axis was found to be 3.0 cm and 2.21±0.07 cm in chiru and sheep respectively. The maximum height, width and length of the dorsal tubercle were recorded as 1.0 cm, 1.4 cm and 2.1 cm respectively. The length of the ventral surface of the ventral arch at the middle axis of chiru was found as 3.2 cm and 2.45±0.16 cm in sheep. Further, the maximum height, width and length of ventral tubercle of chiru were recorded as 0.3 cm, 0.85 cm and 1.4 cm respectively and 0.48±0.06 cm, 0.73±0.06 cm and 1.36±0.22 cm in sheep. The diameters for the right and left intervertebral foramina were observed as 0.35 cm and 0.5 cm, right and left alar foramina were found as 0.4 cm and 0.55 cm, respectively in chiru. Similar observations were recorded as 0.29±0.02 cm and 0.30±0.02cm and 0.36±0.02cm and 0.36±0.03 cm respectively in sheep. Pandey *et al*. (2013a) reported that the weight of C1 was 65.67±1.48 g in tiger (*Panthera tigris*). The vertical and transverse diameters of vertebral canal were 3.80±0.10 cm and 3.40±0.30 cm respectively. The anterior articular area was found to be comma shaped and deeply concave. It articulated with the occipital condyle of the skull. The length and width of body were recorded to be 2.58±0.09 cm and 2.57±0.07 cm respectively. Further, the length of the wings or alae of atlas was 5.92±0.06 cm and the width at anterior, middle and posterior region of the alae was 3.34±0.05 cm, 2.83±0.04 cm and 2.26±0.05 cm respectively. The ventral notch was semi-lunar in shape and reported to be wider (4.40±0.06 cm). The dorsal notch was found to be shorter (2.97±0.07 cm) and consisted of two small tubercles in the center of the notch. This feature was also found in sloth bear (Kalita and Kalita, 2004). Further, the length of transverse canal was reported to be 2.03±0.07 cm. Its anterior opening was measuring 0.60±0.00 cm in diameter and present at the root of alae behind the alar notch. The posterior opening was reported to be 0.60±0.00 cm in diameter. These findings simulated with the observations on atlas given by Pandit (1994) in tiger, Taluja *et al*. (2002) in tiger and Kumar (2008) in leopard. The alar foramen was represented by alar notch. This notch was deep that measured 1.33±0.03 cm. The present finding was in agreement with the reports of Evans and Christensen (1964) in dog.

Second cervical vertebra or Axis

The axis or C2 of the Blue bull was the longest of the cervical vertebrae and atypical type. The present findings were in accordance with the findings of Getty *et al.* (1930) in horse and ox, Hughes and Dransfield (1953) in horse, Raghavan (1964) in ox, Smuts and Bezuidenhout (1987) in camel, Konig and Liebich (2005) in ruminants, Dyce *et al.* (2006) in dog, Levine *et al.* (2007) in horse, dog and ox and Goel *et al.* (2011) in horse, deer and tiger. A spout-like process was projected from the body cranially known as the dens or odontoid process (Fig. 5 and Fig. 6), which simulated the findings in ox (Getty *et al.,* 1930 and Raghavan, 1964), but it was peg like eminence in dog (Miller *et al.*, 1964), blade-like anteriorly and expanded posteriorly in otters (Yilmaz *et al.*, 2000), rod-like in carnivores and more spout-like in other species (Konig and Liebich, 2005 and Dyce *et al.*, 2006), while the odontoid process of ox was wider than horse and in dog it was relatively narrower and longer than that of large domestic species (Levine *et al.*, 2007). The odontoid process was reported to be 'C' shaped in the deer, horse and was 'denslike' in the tiger (Goel *et al.,* 2011).

The dorsal surface of the dens was deeply concave and had a wide groove with rough pits and the ventral surface was articular, smooth and convex in this study which is in accordance with the findings of Getty *et al.* (1930) in ox, horse and sheep, Raghavan (1964) in ox and Dyce *et* *al.* (2006) in dog. Goel *et al.* (2011) found that the dorsal surface of the dens presented two deep impressions on either side of the midline in horse and deer that were not prominent in the tiger.

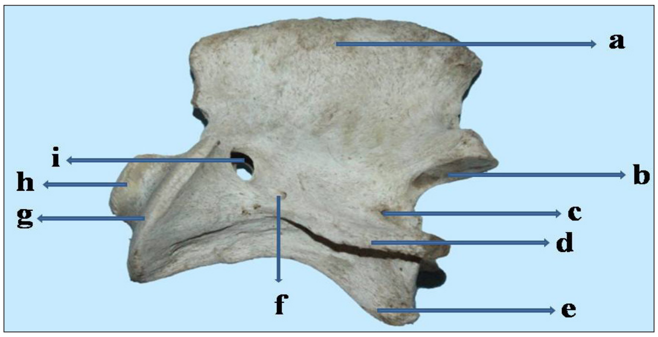

Fig. 5: Lateral view of Axis of adult female Blue bull (*Boselaphus tragocamelus*) showing **(a)** Dorsal supraspinous process, **(b)** Caudal articular process, **(c)** Caudal opening of transverse foramen, **(d)** Transverse process, **(e)** Ventral spine, **(f)** Cranial opening of transverse foramen, **(g)** Flat articular surface of cranial end of body, **(h)** Dens or odontoid process and **(i)** Intervertebral foramen

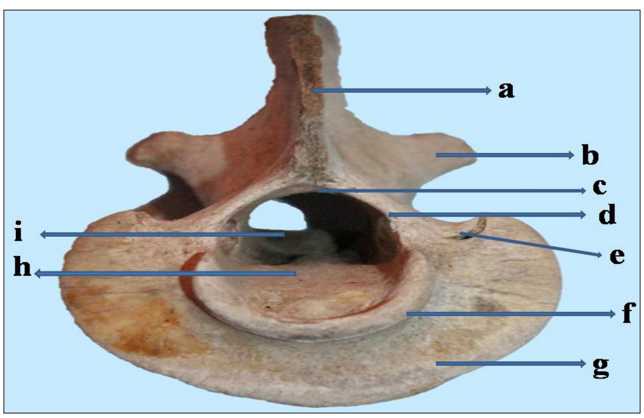

Fig. 6: Cranial view of Axis of adult female Blue bull (*Boselaphus tragocamelus*) showing **(a)** Dorsal supraspinous process, **(b)** Transverse process, **(c)** Laminaee, **(d)** Pedicle, **(e)** Intervertebral foramen, **(f)** Dens or odontoid process, **(g)** Flat articular surface of cranial end of body, **(h)** Cranial aspect of floor of neural canal and **(i)** Caudal aspect of floor of neural canal

The supraspinous process was projected a little in front over the canal. It was blade like cranially and increased in height and thickness backwards that terminated abruptly beyond the level of caudal articular surface of the body (Fig. 7 and Fig. 8), which was more or less similar in ox but the spine thickness was more (Getty *et al.*, 1930 and Raghavan, 1964), while in horse the spinous process was found to be very large and strong. Its free border was thickened posteriorly and continued to the posterior articular processes by two ridges (Getty *et al.*, 1930).

Fig. 7: Ventral view of Axis of adult female Blue bull (*Boselaphus tragocamelus*) showing **(a)** Dens or odontoid process, **(b)** Ventral spine, **(c)** Transverse process, **(d)** Flat articular surface of cranial end of body, **(b)** Intervertebral foramen, **(c)** Transverse foramen and **(d)** Caudal articular process

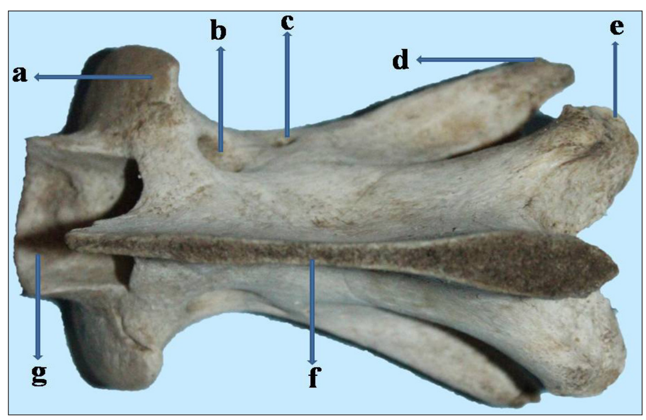

Fig. 8: Dorsal view of Axis of adult female Blue bull (*Boselaphus tragocamelus*) showing **(a)** Flat articular surface of cranial end of body, **(b)** Intervertebral foramen, **(c)** Transverse foramen, **(d)** Transverse process, **(e)** Caudal articular process, **(f)** Dorsal supraspinous process and **(g)** Dens or odontoid process

The dorsal spine over hanged the cranial and caudal aspect of neural canal in cat (Brelend, 1943) and in dog (Miller *et al.*, 1964 and Bhattacharyya *et al.,* 2005), whereas the spine was in the form of bifid tuberosity before sloping ventralwards towards the posterior articular processes in camel (Smuts and Bezuidenhout, 1987), wedge-like in Calamian deer (Maala *et al.*, 1992), broad but not high in ox (Frandson and Spurgeon, 1992) and blade-like anteriorly and expanded posteriorly in otters (Yilmaz *et al.,* 2000). The spinous process over hanged the anterior and posterior end of the body in carnivores, but only the posterior end in the pig; it was found to be rectangular bony plate in ruminants and bifurcated posteriorly in the horse (Konig and Liebich, 2005). The spinous process was reported to be directed caudo-dorsally, thicker and higher than the other cervical vertebrae and there was a deep groove on the caudal face in mole-rat (Ozkan, 2007) that could not be found in the Blue bull. It was found to be large, strong and bifid in horse, deer, whereas it over hanged both the dorsal arch of C1 and the laminae of C3 in tiger (Goel *et al.,* 2011).

A circular foramen was present a little behind the cranial notch of C2 of Blue bull at the cranial base of the transverse process that represented the intervertebral foramen. It was more or less similar in ox and horse (Getty *et al.*, 1930) and in ox (Raghavan, 1964), but anterior vertebral notch was present instead of intervertebral foramen in dog (Miller *et al.*, 1964), carnivores (Konig and Liebich, 2005) and in tiger (Goel *et al.,* 2011). The transverse processes were stouter and the transverse foramen was small. Further, the transverse process was single, i.e. not bifid and directed backwards. The present observation agreed with the reports given by Raghavan (1964) in ox, Getty *et al.* (1930) in horse, Smuts and Bezuidenhout (1987) in camel, Yilmaz *et al.* (2000) in otters, and Girgin *et al.* (1988) in fox and dog. The transverse foramen perforated the transverse process and opened at the middle of the body of C2 in the Blue bull that simulated the findings of Meena (2012) in chital. But the transverse foramen was small and sometimes not found in ox (Getty *et al.*, 1930), Raghavan (1964), but passed through the pedicles in dog (Miller *et al.,* 1964). The transverse foramen did not cross the transverse process and lied within the anterior half of the pedicle and opened in to the vertebral canal in camel (Smuts and Bezuidenhout, 1987).

The infraspinous process was in the form of a median ridge in the axis of Blue bull that became increasingly prominent behind and terminated into a tubercle projecting beyond the level of the caudal concave articular surface of the centrum of C2 that was found to be similar as in ox (Raghavan, 1964), in Calamian deer (Maala *et al.*, 1992) and in chital (Meena, 2012), but the ventral crest was present only in two-thirds part of centrum in camel (Smuts and Bezuidenhout, 1987); while the ventral crest was not found in C2 of sloth bear (Bhattacharyya *et al.,* 2005).

Biometrical observation

The biometrical observations revealed that the average weight of C2 was found to be 288.44±2.08 gm in adult Blue bull. Further, it was measured to be 284.68±2.05 gm and 292.2±1.85 gm in females and males respectively. The average length of the body was found to be 14.05±0.01 cm in adult Blue bull. Further, it was measured to be 13.87±0.09 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 14.23±0.09 cm. Similarly, the average width of the body at the middle was found to be 2.93±0.08 cm in adult Blue bull. Further, it was measured to be 2.77±0.07 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 3.10±0.06 cm. The average length of the odontoid process was found to be 1.13±0.07cm in adult Blue bull.

Further, it was measured to be 1.00±0.06 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.27±0.07 cm. Similarly, the average circumference of the odontoid process was found to be 7.20±0.11 cm in adult Blue bull. Further, it was measured to be 7.00±0.12 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 7.40±0.06 cm. The average distance between the odontoid process and intervertebral foramen was found to be 1.55±0.06 cm in adult Blue bull.

Further, it was measured to be 1.38±0.05 cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 1.72±0.05 cm. The average vertical diameter of vertebral canal at the cranial aspect was found to be 2.12±0.05 cm in adult Blue bull. Further, it was measured to be 2.03±0.07cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.20±0.06 cm. Similarly, the average vertical diameter of vertebral canal at the caudal aspect was found to be 2.39±0.04 cm in adult Blue bull. Further, it was measured to be 2.31±0.04cm in females that was significantly lesser ($P<0.05$) than that of males, where it was found to be 2.47±0.03 cm. The average transverse diameter of vertebral canal at the cranial aspect was found to be 2.42±0.02cm in adult Blue bull. Further, it was measured to be 2.32±0.07cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.52±0.02 cm. Similarly, the average transverse diameter of vertebral canal at the caudal aspect was found to be 2.40±0.02 cm in adult Blue bull.

Further, it was measured to be 2.29±0.05 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.51±0.04 cm. The average length of the dorsal supraspinous process was found to be 9.00±0.11 cm in adult Blue bull. Further, it was measured to be 8.80±0.12 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 9.20±0.06 cm. The average height of the dorsal supraspinous process at the cranial aspect was found to be 0.31±0.01 cm in adult Blue bull. Further, it was measured to be 0.09±0.01 cm and 0.32±0.01 cm in females and males respectively. The average height of the dorsal supraspinous process at the middle was found to be 0.31±0.01 cm in adult Blue bull.

Further, it was measured to be 0.29±0.01 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 0.34±0.01 cm. The average height of the dorsal supraspinous process at the caudal aspect was found to be 1.10±0.02 cm in adult Blue bull. Further, it was measured to be 1.07±0.03 cm and 1.13±0.01 cm in females and males respectively.

The average thickness of dorsal supraspinous process at the cranial aspect was found to be 0.32±0.02 cm in adult Blue bull. Further, it was measured to be 0.29±0.01 cm and 0.35±0.02 cm in females and males respectively. The average thickness of dorsal supraspinous process at the middle was found to be 0.32±0.01 cm in adult Blue bull. Further, it was measured to be 0.29±0.01 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 0.35±0.01 cm. Similarly, the average thickness of dorsal supraspinous process at the caudal aspect was found to be 1.13±0.03 cm in adult Blue bull. Further, it was measured to be 1.07±0.02 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be1.18±0.02 cm. The average length of transverse canal was found to be 2.89±0.04 cm in adult Blue bull. Further, it was measured to be 2.83±0.06 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 2.96±0.04 cm. The average diameter of transverse canal at the cranial aspect was found to be 0.33±0.02 cm in adult Blue bull. Further, it was measured to be 0.29±0.02 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 0.37±0.01 cm.

Similarly, the average diameter of transverse canal at the caudal aspect was found to be 0.23±0.02 cm in adult Blue bull. Further, it was measured to be 0.18±0.01 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 0.28±0.01 cm. The average length of transverse process was found to be 5.78±0.16 cm in adult Blue bull. Further, it was measured to be 5.65±0.25 cm and 5.90±0.20 cm in females and males respectively. The average distance between the transverse processes at the caudal aspect was found to be 7.12±0.10 cm in adult Blue bull. Further, it was measured to be 6.97±0.09 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 7.27±0.15 cm. The average length of the caudal articular process was found to be 2.43±0.05 cm in adult Blue bull. Further, it was measured to be 2.34±0.05 cm and 2.52±0.06 cm in females and males respectively. The average width of the caudal articular process at the dorsal aspect was found to be 0.53±0.02 cm in adult Blue bull. Further, it was measured to be 0.47±0.01 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 0.58±0.02 cm.

Similarly, the average width of the caudal articular process at the middle was found to be 1.12±0.03 cm in adult Blue bull. Further, it was measured to be 1.06±0.03 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 1.18±0.03 cm. The average width of the caudal articular process at the ventral aspect was found to be 1.70±0.04cm in adult Blue bull. Further, it was measured to be 1.61±0.03 cm in females that was significantly lesser (P<0.05) than that of males, where it was found to be 1.79±0.05 cm. Kumar (2008) described that the odontoid process of C2 was conical in shape and was 1.47±0.02 cm in length in leopard. Further, he stated that the length and width of dorsal supraspinous process were 8.22±0.06 cm and 2.26±0.09 cm respectively. The length of transverse process was recorded as 3.22±0.03 cm. The alar notch was deep and measured 1.33±0.03 cm. Pandey *et al.* (2013) reported that the length and width of the centrum of axis were 5.44±0.04 cm and 3.66±0.00 cm respectively in the tiger (*Panthera tigris*). The weight of C2 was found to be 58.03±0.66 g. The odontoid process was cylindrical in shape and 2.40±0.06 cm long. Its circumference was recorded as 1.23±0.03 cm.

CONCLUSION

The atlas and axis of Blue bull were atypical cervical vertebrae. It was revealed that the various parameters of atlas such as the average weight of the vertebra, average width of the wing, the average cranial distance between the wings at the ventral aspect, the average caudal distance between the wings, the average cranial vertical diameter of vertebral canal, the average cranio-caudal and latero-medial diameters of intervertebral foramen, the average diameter of alar foramen, the average distance between the alar and intervertebral foramen, the average diameter of ventral tubercle, the average distance between intervertebral foramen and dorsal tubercle, the average distance between alar foramen and dorsal tubercle, the average length and width of cranial and caudal articular surfaces and the average distance between the two caudal articular facets at the cranial and caudal aspects were significantly more ($P<0.05$) in adult males than females. Similarly, the various parameters of axis such as the average length and width of the body, the average length and circumference of the odontoid process, the average distance between the odontoid process and intervertebral foramen, the average vertical and transverse diameter of the vertebral canal, the average length, height and thickness of the dorsal supraspinous process, the average length and diameter of the transverse canal, the average distance between the transverse process at the caudal aspect and the average width of the caudal articular process were significantly more ($P<0.05$) in adult males than females. There is no previous information on these parameters in the atlas and axis of Blue bull, nor in any other domestic animals with which comparisons could be made. We therefore believe that the data presented above would form a baseline for further work especially comparability and compatibility are now desirable traits as efforts are geared up towards massive improvement in the livestock sector of the international economy.

ACKNOWLEDGEMENTS

The authors are grateful to the Ministry of Environment of Forests (MoEF), New Delhi and Jodhpur Zoo, Rajasthan, India for providing facilities and support for carrying out research on the bones of Blue bull. Funding was provided by Department of Science and Technology, New Delhi and Indian Council of Agricultural research, New Delhi, India as Ph.D. grant (DST-INSPIRE Fellowship and ICAR-SRF (PGS)) to the first author.

REFERENCES

Bagchi, S., Goyal, S.P. and Shankar, K. 2004. Herbivore density and biomass in a semi-arid tropical dry deciduous forest of western India". *J. Trop. Eco*., **20**(4): 475-478.

Bhattacharyya, R., Kalita, P.C. and Kalita, H.C. 2005. Anatomical comparison of the axis of sloth bear and domestic dog. *Indian Vet. J*., **82** (12): 1297-1300.

Breland, O.P. 1943. Manual of comparative anatomy, Mcgraw-Hill Book Company.Inc, New York and London, pp 146-151.

Choudhury, A.R., Baba1, M.A., Khan, M., Ganai, T.A.S. and Sheikh, F.D. 2012. Comparative Gross Anatomical Studies on the Atlas of Chiru (*Pantholops hodgsoni*) and Sheep (*Ovis aries*). *Indian J. Vet. Anat.,* 24(2): 76-77.

Dyce, K.M., Sack, W.O. and Wensing C.J.G. 2006. Text Book of Veterinary Anatomy, Saunders Elsevier, 4th ed., pp 35 – 41.

Evans, H.E. and Christensen G.C. 1964. Anatomy of the Dog. W.B. Saunders, Philadelphia, pp. 941.

Frandson, B.S. and Spurgeon, T.L. 1992. Anatomy and physiology of farm animals. Lea and Febiger, Philadelphia. 5th ed. pp 64-68.

Getty, R., Sisson, S. and Grossman, J.D. 1930. The Anatomy of the Domestic Animals. W.B. Saunders Comp., Philadelphia. 2nd ed. (Vol. 1), pp 25-27, 33-45,125-130.

Girgin, A., Karadag, H., Bilgiç, S. and Temizer, A. 1988. A study on the macro-anatomical differences of the skeletons of wolf and fox as compared with the skeleton of dog. *Selçuk U. Vet. Fak. Der.,* **4**: 169-182.

Goel, A., Shah, A., Gaikwad, S., Dhande, P. and Kothari, M. 2011. Comparative quantitative analysis of osseous anatomy of the cranio-vertebral junction of the tiger, horse and deer. Stuttgart, Germany: Thieme, 1st ed. pp 2:32–37.

Hughes, H.V. and Dransfield, J.W. 1953. Osteology and Arthrology of Domesticated Animals, 4th ed., BTC London. pp 25-51.

Iniyah, K., Jayachitra, S., Balasundaram, K. and Sivagnanam, S. 2015. Gross anatomical studies on vertebral column in white spotted deer (*Axis axis*). *Asian J. of Sci. and Tech.,* **6**(2): 1083-1085.

Konig, H.E. and Liebich, H.G. 2005. Veterinary Anatomy of Domestic Animals, 3rd Edn, Schattauer, Stuttgart, Germany. pp 49-104, 145-160, 215-236.

Kalita H.C. and Kalita P.C. 2004. Comparative anatomy of the atlas of sloth bear (*Melursus ursinus*) and dog (*Canis familaris*). *Ind. J. Vet. Anat*., **16**: 61-63.

Kumar, R. 2008. Studies on characteristic features of axial skeleton of leopard as an aid in wildlife forensic. M.V.Sc. Thesis, JNKVV, Jabalpur (MP), India. pp 59.

Levine, J.M., Levine, G.J., Hoffman, A.G., Mez, J. and Bratton, G.R. 2007. Comparative Anatomy of the Horse, Ox and Dog: The Vertebral Column and Peripheral Nerves. CE article-1, pp 279-281.

Maala, C.P., Arca, R.R., Bravo, M.V.A., Villamor, C. and Marte, R.G. 1992. Vertebral column of the Calamian deer *Cervus (Axis) calamianensis*. *Philippine J. Vet. Anim. Sci*., **18**(3): 229-238.

Meena, V. K. 2012. Gross studies on the bones of vertebral column in chital (*Axis axis*). Masters' thesis submitted to the Rajasthan University of Veterinary and Animal Sciences, Bikaner.

Miller, M.E., Christensen, G.C. and Evans, H.E. 1964. Anatomy of the Dog. WB Saunders Company, Philadelphia, USA, pp 51- 61.

Ozkan, Z.E. 2007. Macro-anatomical investigations on the skeletons of Mole-rat (*Spalax leucodon nordmann*) III. Skeleton axiale. *Vet. Archiv*., **77**: 281-289.

Pandey, Y., Pandey, A., Taluja, J.S., Shrivastav, A.B. and Rakhi, V. 2013. Morphometry of cervical vertebrae in tiger (*Panthera tigris*). *Ind. J. Vet. Surg*., **34**(2): 127-132.

Pandit, R.V. 1994. Osteology of Indian tiger (*Panthera tigris)*. Tech. Bull. No. VI, Conservator of Forest and Director, Project Tiger, Melghat, Amravati (India), pp 1-27.

Raghavan, D. 1964. Anatomy of Ox. Indian Council of Agricultural Research, New Delhi, pp 17-38.

Shahid, R.U. and Muhammad, F. 2001. Comparative gross anatomical study of the axial skeletons of buffaloes and cows. *Pak. Vet. J*., **21**(1): 55-56.

Smuts, M.S. and Bezuidenhout, A.J. 1987. Anatomy of Dromedary, Oxford Science Publications, pp 9-20.

Snedecor, G.W. and Cochran, W.G. 1994. Statistical Methods. 8th edn. lowa State University Press, Ames, lowa, USA.

Taluja, J.S., Vaish R. and Parmar M.L. 2002. Morphometry of atlas in tiger (*Abstract). In:* XVII Indian Association of Veterinary Anatomist Convention, Mumbai, 14-16 Nov., pp 66.

Yilmaz, S. 1998. Macro-Anatomical investigations on the skeletons of porcupine (*Hystrix cristita*). *Anatomia Histologia Embryoligia.,* **27**: 293-296.

Yilmaz, S., Dinç, G. and Toprak, B. 2000. Macro-anatomical investigations on skeletons of otter (*Lutra lutra*) III. Skeleton axiale. *Vet. Arhiv*., 70: 191-198.