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Research Article

Antlers Characterization for Identification of Deer Species (Family Cervidae) in Indonesia

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ABSTRACT

There are five species of deer (family Cervidae) living in Indonesia today. Male deer possesses antlers, a unique character of male deer. Antlers have economic values for quite a long time. Antler's growth is influenced by several factors, therefore each species of deer have its own unique antlers' shape and size. Antler's identification usually relies on size measurement and overall shape of complete antlers which still attach to the skull. It is difficult to identify shed, broken or individual antler. The purpose of the research is to understand antlers' morphological characters on each species to become diagnostic characters. Specimens analysed were collections of LIPI and were analysed with Principal Component Analysis (PCA) using PAST3 software. The results showed each species of deer having their own unique antlers' character, and so it can be used to determine the species of Indonesian deer. The important structures for identification are relief, pedicle, brow, *bez*, and main beam.

INTRODUCTION

Deer or cervids (family Cervidae) is one of the families in the Artiodactyl groups which is second most diverse member after bovids (family Bovidae) (Prothero & Foss, 2007). Five valid species of cervids are living and naturally distributed in Indonesia, they are: *Rusa timorensis* (Javan rusa or Sunda sambar), *Rusa unicolor* (Sambar), *Axis kuhlii* (Bawean deer), *Muntiacus muntjak* (Indian muntjac, southern red muntjac, barking deer) and *Muntiacus atherodes* (Bornean yellow muntjac). *Muntiacus montanus* from Sumatra might be another species of deer in Indonesia, but not enough data had been collected to evaluate the validity of this species. Furthermore, there is one introduced species which is *Axis axis* (chital, spotted deer or axis deer) (Goss, 1985; Bubenik & Bubenik, 1990; Stefoff, 2008; Timmins *et al.*, 2016).

One of the characteristics of deer is antlers on individual male. Antlers are frontal bone which grow outwards from frontal skull and usually called *pedicle* (Price *et al.*, 2005). The development of antlers is influenced by several factors, among them are: age, nutrition, and genetics. Consequently, each species of deer forms specific antlers with specific size and shape (Heffelfinger 2006).

Antlers attract human since ancient time. Most of antlers were trade as trophy and displayed on the wall. Some of it was processed into aphrodisiac or as traditional medicine; however the efficacy is not scientifically proven yet (Walrod, 2010). Species identification of deer using antlers commonly based on the size and shape of the complete antlers which still attach to the skull (CITES, 2003). Some antlers were traded separately or individually without its skull, therefore it's difficult to determine the species origin.

Four of the native deer species in Indonesia are an endemic species, i.e. *Rusa timorensis*, *Axis kuhlii*, *Muntiacus atherodes*, and *Muntiacus montanus*. Rusa timorensis and *Rusa unicolor* are considered vulnerable by the IUCN Red list, while *Axis kuhlii* is considered critically endangered. All the native deer species of Indonesia is protected by the Indonesian Government Regulation (2018), except for *Muntiacus montanus* which couldn't be evaluated yet. Even though the deer of Indonesia are protected by the law, some illegal hunting and antlers poaching is still

happening in some places (Hedges *et al.*, 2015; Semiadi *et al.*, 2015; Timmins *et al.*, 2016a, 2016b). An accurate way to identify antlers is needed to help enforcing the law.

The purpose of this research is to identify antlers' morphological characters on each species to be a diagnostic character. These diagnostic characters can be an alternative of species identification. The results were expected to assist the species identification of antlers found without its skull in trade market or fossils.

MATERIALS AND METHODS

Materials

Materials used are deer antlers collection of the Laboratory of Mammals Biosystematics, Museum Zoologicum Bogoriense (MZB), Research Center for Biology–Indonesian Institute of Sciences (LIPI). Data were collected from 88 specimens; 86 of them were antlers that are still intact with the skull. There are 30 antlers of *Muntiacus muntjak* (15 skulls), 2 antlers of *Axis axis* (1 skull), 8 antlers of *Axis kuhlii* (4 skulls), 12 antlers of *Rusa unicolor* (6 skulls), and 36 antlers of *Rusa timorensis* (17 skulls and 2 shed antlers). A complete antler commonly consists of a *pedicle*, *burr*, *base*, *main beam*, *brow* and *bez* (Figure 1).

Methods

The methods used was morphological comparison of antlers characteristics and morphometric analysis based on Boone & Crockett Club (1887) and Semiadi *et al.* (2003). The morphological and morphometric data acquired were then analysed using Principal Component Analysis (PCA) with *software* PAST3. PCA analysis was conducted to exemine characters grouping in order to determine its diagnostic characters. The characters used in this research are shown on Table 1.

Antler's relief is determined from five categories. Smooth for antlers with no relief. Faint for antlers with visible relief striation but couldn't be felt by touch. Weak for antlers with visible striation and could be slightly felt by touch. Strong for antlers with visible thick relief striation and could be felt by touch. Pearled for antlers with strong relief and pearly structure.

RESULTS AND DISCUSSION

Antlers' morphological characters

There are characters which are diagnostic of each taxa. Some characters are qualitative and the rest are binary ("present" or "absent"; value "1" or "0"). Those characters are shown on Table 1. Some characters on Table 1, can only be measured if the antlers are still intact with the skull. Characters which need intact condition are: B (distance between tips of main beams), C (greatest distance between both antlers), and D (greatest distance between both main beam's inner side). Those characters should be considered when identifying antlers, however it couldn't assist to identify shed, broken and individual antlers.

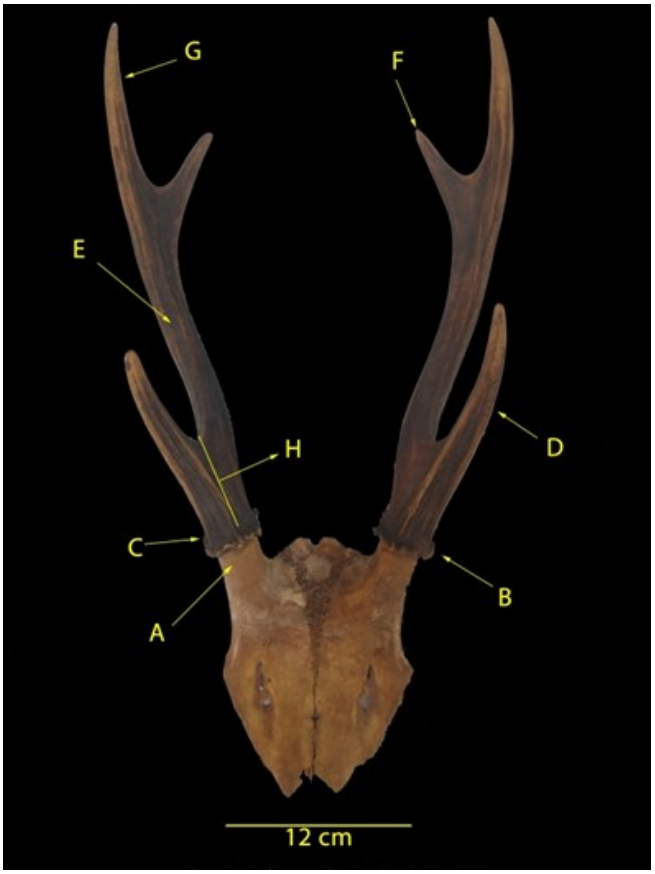

Figure 1. Antlers' main part which are observed: A. Pedicle, B. Burr, C. Base, D. Brow, E. Main beam 2nd segment, F. Bez, G. Main beam 3rd segment, H. BeHt (distance of bez branching to the base), I. BrHt (distance of brow branching to the base).

Accessory on an antler is usually not the main character for identification. Accessories are usually just an abnormal growth of an antler. Therefore, the presence of accessories should not be the main consideration as a diagnostic character.

Diameter, perimeter, and length can be quite significant characters for antler's identification. Nevertheless, along with those characters, other characters should also be considered when identifying antlers. Antler's diameter and perimeter will also increases along with the pedicle growth. Pedicle will grow along with the skull's growth, meaning when an animal age increase, the size will also increases. Each species of deer have their own unique range of size, hence those characters could

Table 1. Variation of antlers characteristics which can be diagnostic characters

No	Code	Characters		Data type
1	Re	Reliefs	Smooth Faint Weak Strong Pearled	Level
2	PDt	Transversal diameter of pedicle		Nominal
3	Pdap	Anteroposterior diameter of pedicle		Nominal
4	PP	Perimeter of pedicle		Nominal
5	BuDt	Transversal diameter of *burr*		Nominal
6	BuDap	Anteroposterior diameter of *burr*		Nominal
7	BuP	Perimeter of *burr*		Nominal
8	BDt	Transversal diameter of base		Nominal
9	Bdap	Anteroposterior diameter of base		Nominal
10	BP	Perimeter of base		Nominal
11	M2P	Perimeter of 2nd beam segment		Nominal
12	M2Dt	Transversal diameter of 2nd beam segment		Nominal
13	M2Dap	Anteroposterior diameter of 2nd beam segment		Nominal
14	M3P	Perimeter of 3rd beam segment		Nominal
15	M3Dt	Transversal diameter of 3rd beam segment		Nominal
16	M3Dap	Anteroposterior diameter of 3rd beam segment		Nominal
17	ML	Main beam length		Nominal
18	BrDt	Transversal diameter of brow		Nominal
19	BrDap	Anteroposterior diameter of brow		Nominal
20	BrP	Perimeter of brow		Nominal
21	BrHt	Brow branching distance to base		Nominal
22	BrAng	Brow branching angle		Nominal
23	BrL	Brow length		Nominal
24	Be	Presencce of *bez*		Binary
25	BeDt	Transversal diameter of *bez*		Nominal
26	BeDap	Anteroposterior diameter of *bez*		Nominal
27	BeP	Perimeter of *bez*		Nominal
28	BeHt	*Bez* branching distance to base		Nominal
29	BeAng	*Bez* branching angle		Nominal
30	BeL	*Bez* length		Nominal
31	B	Distance between the tips of main beams		Nominal
32	C	Greatest distance between both antlers		Nominal
33	D	Greatest distance between both main beam's inner side		Nominal
34	PFl	Flattened pedicle		Binary
35	M2Flb	Laterolaterally flattened 2nd segment of main beam		Binary
36	BrFla	Anteroposteriorly flattened brow		Binary
37	BrFlb	Laterolaterally flattened brow		Binary
38	BrPa	Brow parallels to main beam		Binary
39	BeMed	*Bez* grow inward		Binary
40	BeLat	*Bez* grow outward		Binary
41	AcH1	Accessory on branching of brow		Binary
42	AcBr	Accessory on brow		Binary
43	AcM2	Accessory on 2nd segment of main beam		Binary
44	AcBe	Accessory on *bez*		Binary

also be considered as diagnostic characters. The length of antlers could vary during growth cycle of antler. Old deer could also have a short antler if that antler had just regrown after being shed at the previous cycle. Besides that, in some cases, antlers could also be broken when two males are fighting each other on mating season or when it's attacked by other animals, including by humans (McPherson & McPherson 2008). Therefore, the full length of the antlers couldn't be measured on some specimens.

Antler specimens of Indonesian deer

Principal Component Analysis was conducted from the data collected. The correlation analysis between group results in eigenvalues and percent variances shown in Table 2, while the scatter plot can be seen in Figure 2 as follows.

The results shown in Figure 2, were the data of antlers analysed in which the antlers were not attached to the skull anymore. Some characters i.e. B (tip to tip distance), C (greatest distance between both antlers), and D (greatest distance between both antlers' inner side) is not included in that PCA due to isolated antlers. The antlers analysed in Figure 2 were only one side and not attached to the skull, therefore it is impossible to measure. Some groups show wide range in the PCA scatter plot, it indicates variance on the characters. This was caused by the difference in condition of the antlers used in analysis. Some specimens was just started its adult stage which was indicated by the size of the skull and mainly its pedicle, meanwhile some specimens have reached its maximal size. Some antlers undergo abnormality in its growth which altered the antler's proportion. Nevertheless, each species group could be shown on the scatter plot and have a quite significant distance between each other. The loading plot of component 1 can be seen as follows on Figure 3, while the loading plot of component 2 can be seen on Figure 4.

Table 2. Eigenvalue and % Variance

PC	Eigenvalue	% Variance
1	24.1244	73.104
2	4.83482	14.651
3	2.55828	7.7524
4	1.48246	4.4923

The *Muntiacus muntjak* group is separated by a great distance from the other groups (Figure 2). This grouping is supported by some characters, namely BrFla (brow flattened anteroposteriorly), PFl (pedicle flattened laterolaterally), and M2Flb (2nd segment of main beam flattened laterolaterally). *Muntiacus muntjak* have a long and flattened pedicle, meanwhile the other species of deer in Indonesia have short and rounded pedicles. The brows are flattened antero-posteriorly. The second segment of main beam is flattened latero-laterally, especially on its tip (Figure 5). Besides that, it is shown in the Figure 2 that bez characters points away from the *Muntiacus muntjak* group.

The antlers of *Muntiacus* doesn't have *bez*, hence the *bez* character in the *Muntiacus muntjak* group will always be 0. The absence of bez is a significant character to differentiate *Muntiacus* with the other groups of deer in Indonesia (Figure 5).

In Indonesia, *Muntiacus* genus is not only represented by *Muntiacus muntjak*, but also *Muntiacus atherodes*. In LIPI, there is no antler collection of *Muntiacus atherodes*, therefore analysis couldn't be done to differentiate between the antlers of *Muntiacus muntjak* and *Muntiacus atherodes*.

The *Axis* group is scattered in the lower quadrant (Figure 2). It is shown that the characters which support this group are BeMed (*bez* grows inward) and BrPa (brow parallel to main beam). All of the species in the *Axis* genus in Indonesia have *bez* that grow inward (Figure 6). This character is also present in *Rusa unicolor*. *Axis* group tend to have brows which grow parallel to the main beam. Re (relief) character on the scatter plot points away from the *Axis* group. Compared to the other deer groups in Indonesia (represented on Figure 2), genus *Axis* have antlers with a relatively weak relief. Genus *Axis* also has cylindrical and slim antlers, meanwhile the *Muntiacus* have a flattened short antlers (shown in Figure 5) and the *Rusa* have a large rugose antlers (see Figure 7 and 8).

On the scatter plot in Figure 2, *Axis axis* groups located on the outer edge of *Axis kuhlii*'s groups. The fewer numbers of *Axis axis* specimen available for analysis may result in an unfavourable grouping on the scatter plot. *Axis axis* is not a native animal in Indonesia. *Axis axis* in Indonesia was introduced from the middle Asia (Stefoff, 2008). *Axis axis* in Indonesia could only be found in the manmade areas, such as the Bogor Palace (Istana Bogor) and zoos. Therefore, the specimens obtained were in low numbers.

Generally, *Axis axis* antler's is longer than *Axis kuhlii*'s. Furthermore, the antlers of *Axis axis* have *bez* that tends to grow slightly upwards (forming a U-shape), meanwhile in *Axis kuhlii* it tends to grow straight (forming an L-shape) (Figure 7).

The group of genus *Rusa* is scattered on the right side of the quadrant (Figure 2). Characters which support this grouping are diameter and circumference of antlers. Compares to the other groups, genus *Rusa* generally have a bigger antler.

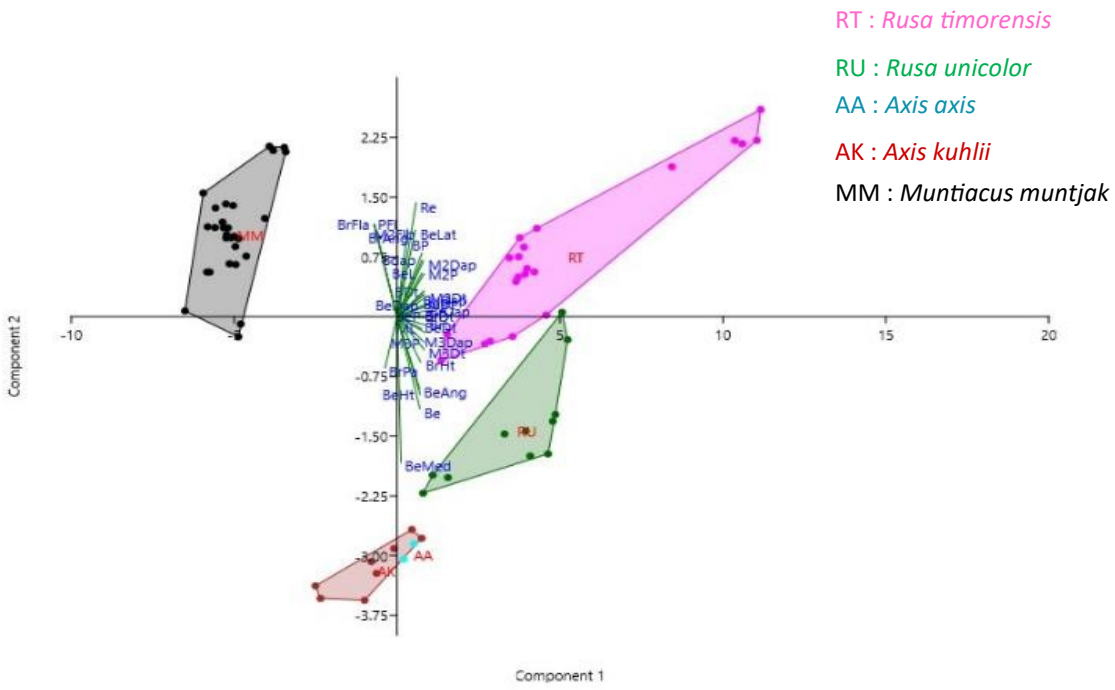

Figure 2. The PCA results of individual antlers.

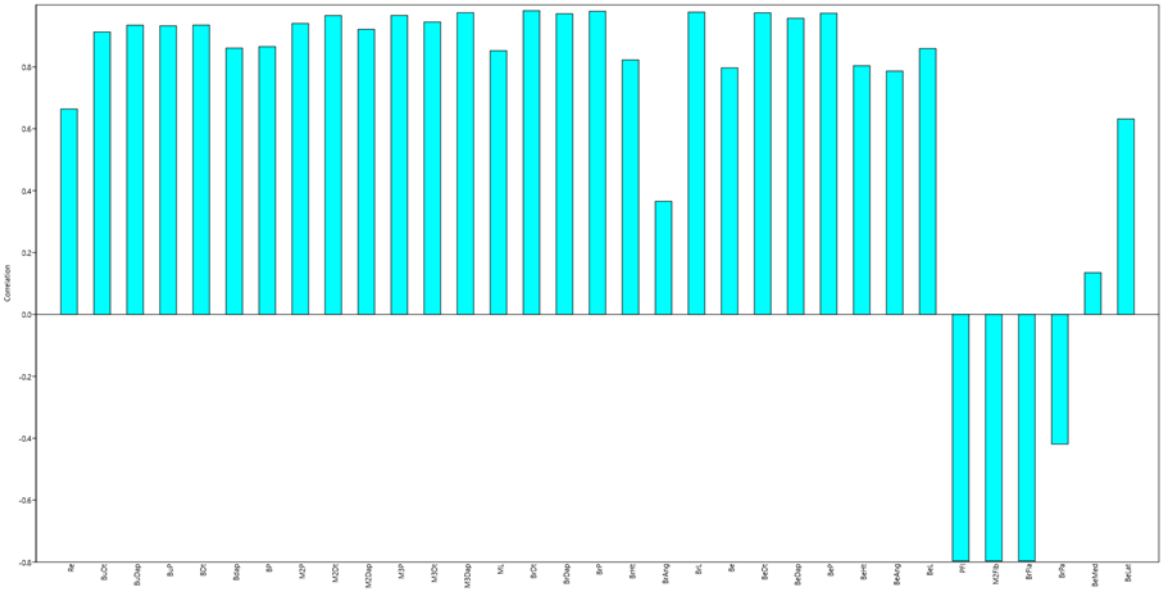

Figure 3. The loading plot of component 1

Rusa unicolor's group is supported by some characters, which are: the combination of BeAng (*bez* branching angle), BeHt (distance of *bez* branching to base), BrHt (distance of *bez* branching to base), also characters of the diameter and circumference which generally support the *Rusa* group. *Rusa unicolor* can be differentiated from *Rusa timorensis* by some characters, especially BeMed (*bez* grows inward), where *Rusa unicolor* have *bez* that grow inward just like those in *Axis kuhlii*. *Bez* of *Rusa unicolor*'s antlers also tend to grow straight just like *Axis kuhlii*'s, but they can be differentiated by some characters. *Rusa unicolor* have higher BrHt value, while *Axis kuhlii* have lower BrHt value. *Rusa unicolor*'s antlers also have stronger relief than *Axis kuhlii*'s, *Rusa unicolor* also have larger *bez* while *Axis kuhlii*'s are relatively slender (Figure 8).

Rusa timorensis group is supported by some characters, namely Re (relief), BeLat (*bez* grows outward), M2Dap (anteroposterior diameter of main beam's 2nd segment), BP (perimeter of base), and M2P (perimeter of main beam's 2nd segment). *Rusa timorensis*'s antlers tend to have pearled relief. Among

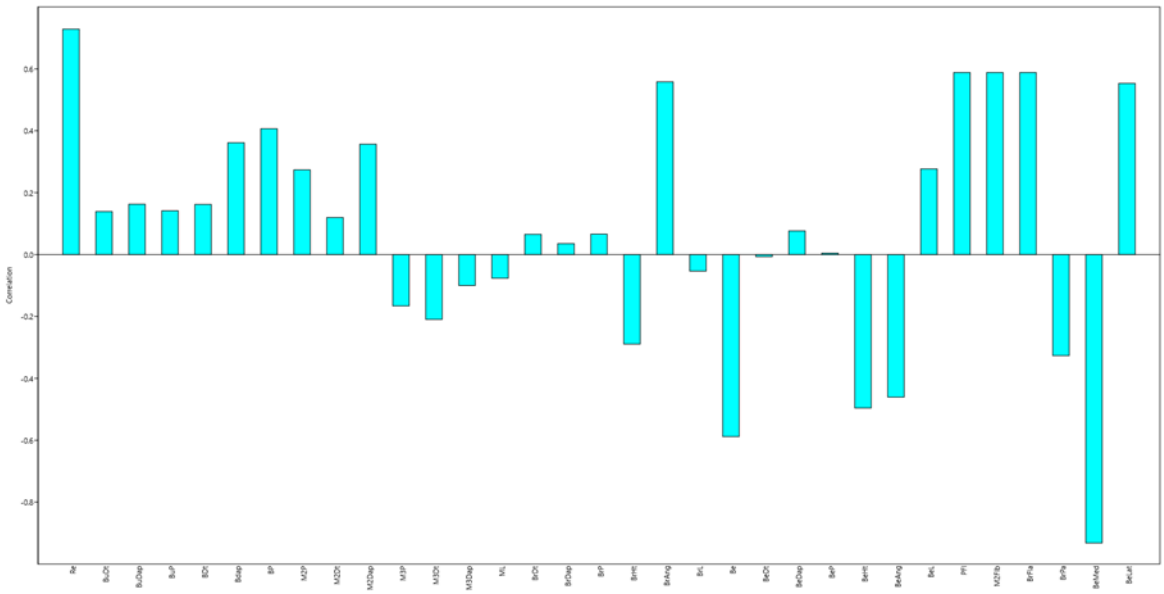

Figure 4. The loading plot of component 2

Indonesian deer, *Rusa timorensis* is the only one whose *bez* grows outward (represented on Figure 2).

Figure 5. *Muntiacus muntjak* specimen, left: dorsal view and right: lateral view, with description: A. Pedicle, B. Burr, C. Brow, D. 2nd segment of main beam.

PCA results on Figure 10 was an analysis of paired antlers. In this analysis, character B (tip to tip distance), C (greatest distance between antler), and D (greatest distance of main beam's inner side) was included in the analysis. By including B, C, and D characters, some changes can be seen on the scatter plot shown on figure 10. The eigenvalue and % variance is shown on Table 3.

On the *Axis* group (Figure 10), changes can be seen that the *Axis axis's* and *Axis kuhlii*'s group become distinctly separated. *Axis axis's* antlers tend to spread widely, where *Axis kuhlii*'s tend to grow upward. This causes the distance between antlers in *Axis axis* to be wider than those of *Axis kuhlii*'s, hence *Axis axis* have greater value of B, C, and D. On larger specimens (which couldn't be found in LIPI's collection), *Axis axis*'s antlers grows significantly wider than shown in the PCA result (see Figure 11).

Table 3. Eigenvalue and % Variance of paired antler specimens' PCA

PC	Eigenvalue	% variance
1	28.3827	72.776
2	5.29825	13.585
3	3.10356	7.9579
4	2.21546	5.6807

On the *Rusa* group (Figure 10), changes occur by which the groups become more clumped together. The changes happen because in the *Rusa* group, the specimens used were highly varied in terms of their ages and phases in the growth cycle; hence the variance of size is high. While the sizes vary highly between age groups, the distance between antlers tend to be the same, hence the low variance of distance between antlers' characters makes the scatter plot become more clumped. The distance between *Rusa timorensis's* and *Rusa unicolor*'s group also decreases. This was caused by the relatively equal antlers' average circumference and diameters of both species.

It should also be noted that in its growth,

Figure 6. Comparison of *Muntiacus muntjak* and *Rusa unicolor* antlers. *Muntiacus muntjak* antlers don't have *bez*.

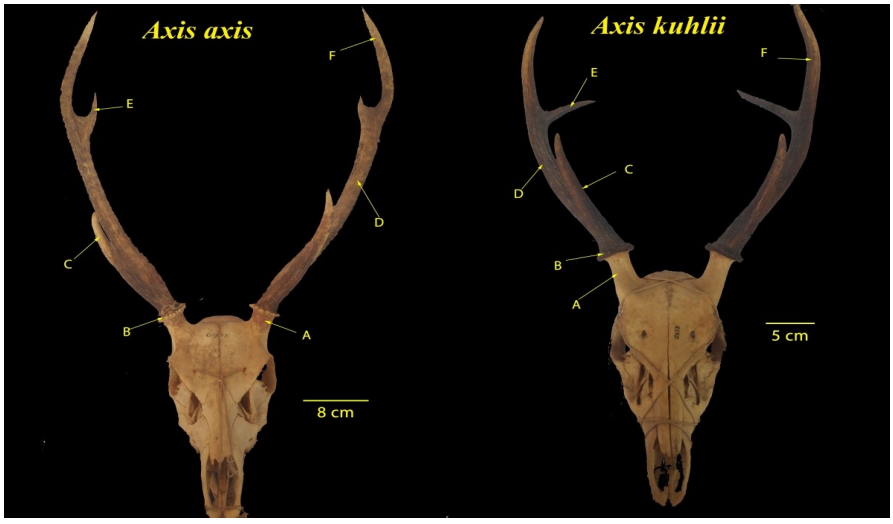

Figure 7. Specimens of *Axis* group: *Axis axis* (left) and *Axis kuhlii* (right), with description: A. Pedicle, B. Burr, C. Brow, D. 2nd segment of main beam, E. Bez, F. 3rd segment of main beam.

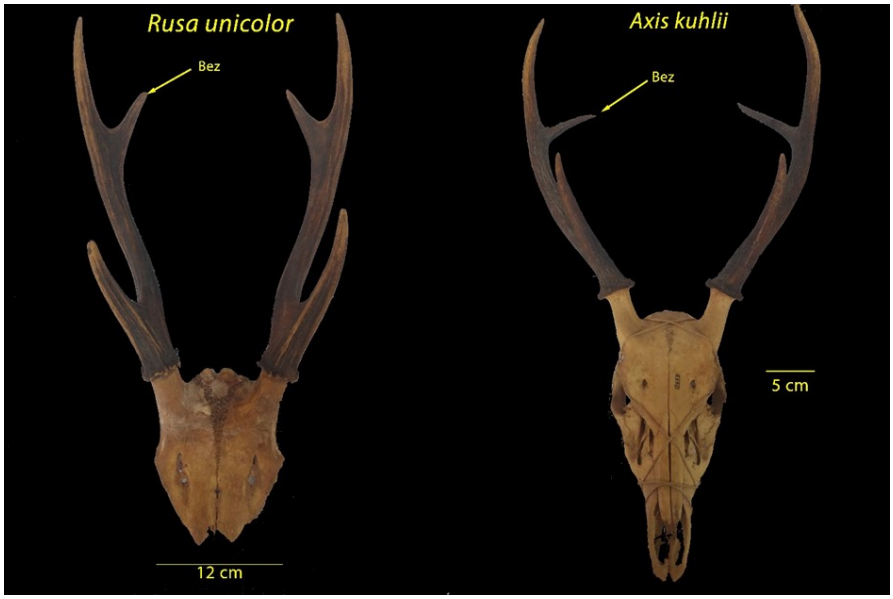

Figure 8. Antler comparison of *Rusa unicolor* (left) and *Axis kuhlii* (right).

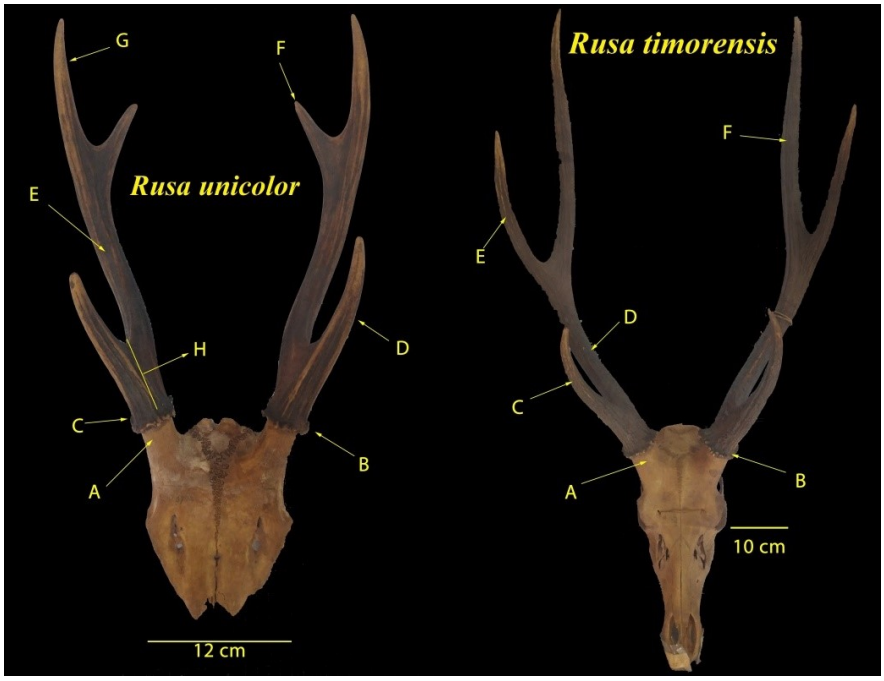

Figure 9. Specimens of *Rusa unicolor* (left) and *Rusa timorensis* (right), with description: A. Pedicle, B. Burr, C. Brow, D. 2nd segment of main beam, E. Bez, F. 3rd segment of main beam.

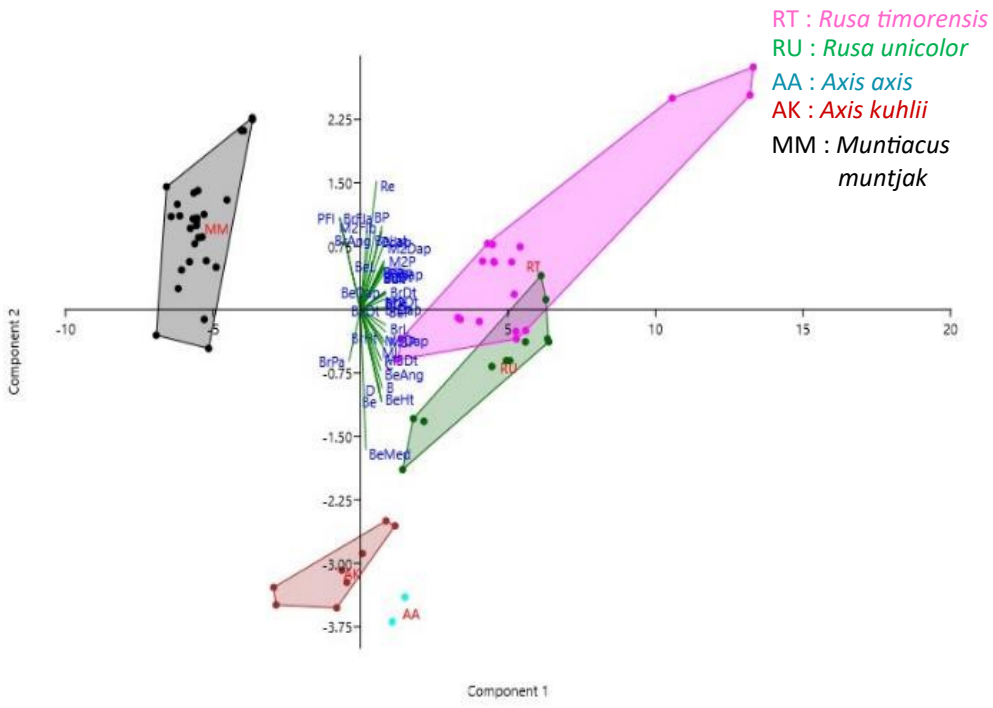

Figure 10. PCA result of paired antler specimens.

antler could experience abnormality or damage. The abnormality in antler's growth and damage can alter the shape and size of the antler. The branch which is not normally present in the antler is called "abnormal" or "accessory". Antlers growth can also be faster or slower in some individuals. The alteration of growth speed can also alter the maximum size of antlers. Therefore, some individuals of the species can have a different antler's characteristic from the one described in this article.

Diagnostic characters of antlers for each species

Based on the analysis, it can be seen that each group is separated from the others. That grouping is supported by some characters. The characters which

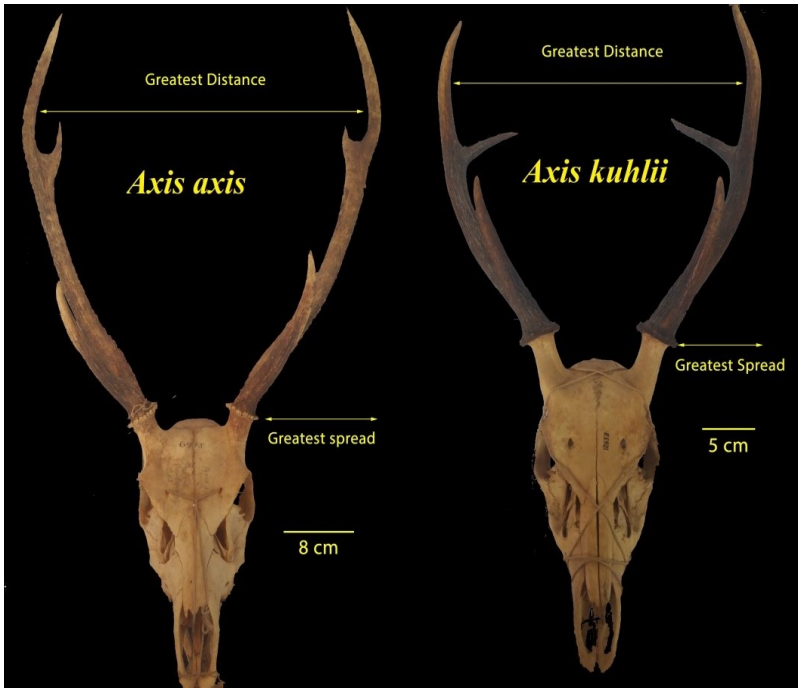

Figure 11. Comparison of antler's distance in *Axis axis* (left) and *Axis kuhlii* (right)

Table 4. Diagnostic characters of the antlers.

No	Species	Characters	Remarks
1	*Muntiacus muntjak*	Brow as the only branch	
		Pedicle long and flattened	
		Main beam flattened laterolaterally	Especially on the tip
		Brow flattened anteroposteriorly	Does not flattened on some individuals
		Low BrHt	0.7–2 cm
		Relief weak to strong	
2	*Axis axis*	Relatively widely curved	Not significant in some individuals, especially young ones
		BrHt intermediate	3–4 cm
		Brow angle intermediate	Approximately 50°
		Bez grows inward	
		Low *bez* angle	Around 35–40°, forms U-shape
		Weak relief	
3	*Axis kuhlii*	Relatively upright	
		BrHt intermediate	3–4 cm
		Brow angle intermediate	Approximately 50°
		Bez grows inward	
		Relatively high *bez* angle	Around 60–70°, forms L-shape
		Weak relief	
4	*Rusa unicolor*	Large diameter	Usually > 2cm
		Bez grows inward	
		Bez angle intermediate	Around 45–65°
		Brow angle intermediate	Around 40–55°
		High BrHt	Around 5–8 cm
		Extensions on branching	Especially on brow, forms area connecting brow and main beam
		Strong relief	Pearled in some individuals
5	*Rusa timorensis*	Large diameter	Usually > 2cm
		Bez grows outward	
		Bez angle intermediate	Around 50–70°
		Brow angle intermediate	Around 35–60°
		Extensions on branching	Especially on *bez*, forms area connecting *bez* and main beam
		Relief mostly pearled	No pearl but have strong relief in some individuals

supported a certain group become that group's diagnostic characters shown on Table 4.

CONCLUSION

Based on the research, it can be concluded that antler's characters could become diagnostic characters to identify cervids species. The diagnostic characters are pedicle, main beam, relief, brow, bez, and diameter of the antlers. *Muntiacus atherodes*'s and *Muntiacus montanus*'s antlers need to be analysed to distinguish it from *Muntiacus muntjak*.

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