



Original Article

Epidermal properties for taxonomic differentiation of *Phragmanthera austroarabica* Miller & Nyberg: An endemic species to south west of Arabian Peninsula

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Abstract

The epidermal cells are the most numerous, largest, and least specialized as well as, are structurally and functionally variable, which includes several differentiated cell types. The present study aims to investigate the epidermal features of *Phragmanthera austroarabica* leaves and to evaluate its taxonomical significance. Fresh samples of *P. austroarabica* were collected from Heziaz, Sana'a Governorate, Yemen during the period May to September 2017. The epidermal properties of *P. austroarabica* (endemic species to south west of Arabian Peninsula) leaves were investigated; the epidermal cells density; ornamentation surface; stomata density; ratio and type of *Phragmanthera austroarabica* shows a high significant in taxonomical value for the separation between the Arabian *Phragmanthera* (*P. austroarabica*) and Nigerian *Phragmanthera* spp. (*P. capitata*; *P. nigriflora* and *P. talbotiorum*).

1. Introduction

Plants are considered to be anatomically simple and composed of relatively few morphologically distinct cell types (Goldberg, 1988). Cells in the plant body are organized into the ground, vascular, and dermal tissue systems (Brooker et al., 2008). The epidermis is the outermost cell layer of the primary plant body, it is the main component of the dermal tissue system of leaves, epidermal cells have fewer chloroplasts or lack them completely, except for the guard cells (Raven et al., 2005; Evert and Eichhorn, 2006).

The cells of the epidermis are structurally and functionally variable, which includes several differentiated cell types: epidermal cells, guard cells, subsidiary cells, and epidermal hairs (trichomes). The epidermal cells are the most numerous, largest, and least specialized (Hülkamp et al., 1994; Becraft, 1999).

Loranthaceae, one of the mistletoe families of the sandalwood order (Santalales), are a family of flowering

plants. The family is worldwide in distribution and includes about 75 genera and 1,000 species of woody plants, characterized by parasitic nature of its species (Engler, 1897; APG, 2009). The genus *Phragmanthera* Tiegh. (Loranthaceae) is a hemiparasitic shrub (Miller and Cope, 1999), it includes 30 species (Chaudhary, 2001), mainly distributed in Africa and Arabian Peninsula (Burrow & Willis, 2005). According to Miller and Cope (1999) *Phragmanthera austroarabica* is an endemic species to south west of Arabian Peninsula (Saudi Arabia and Yemen), it is intrusive on *Acacia origina*, *Ficus vasta* and *Ziziphus spina-christi* (Ibrahim et al., 2014).

Few studies have been done on morphological and anatomical studies of family Loranthaceae (Barlow and Wiens, 1973; Polhill and Wiens, 1998; Jrais, 2013), as well as on the morphological (Miller and Cope, 1999; Chaudhary, 2000; Waly et al., 2010; Ibrahim et al., 2014) and anatomical (Waly, 2013) features of *Phragmanthera austroarabica*; however, no attempts seem to have been made to study the epidermal features of *P. austroarabica* leaves, therefore the present study aims to investigate the epidermal features of *P. austroarabica* leaves and to evaluate its taxonomical significance in comparing it with epidermal features of the Nigerian *Phragmanthera* spp. recorded by Ibrahim and Ayodele (2013).

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1. Materials and Methods

1.1. Plant samples collection

Fresh samples of *P. austroarabica* (Figure 1) were collected from Heziaz (44°15'39.39"E- 44°15'41.82"E & 15° 7'49.73"N-15° 7'51.85"N) Sana'a Governorate during the

period May to September 2017 and identified according to Miller and Cope (1996), Collenette (1999), Chaudhary (2001) and Ibrahim *et al.* (2014) and compared with Herbarium specimens (SSH. 1278 & SSH. 3478) stored in the Herbarium of the Faculty of Science Sana'a University.



Fig. 1: *Phragmanthera austroarabica*: A: General view of *Phragmanthera austroarabica* intrusive on *Acacia origena* and B: Aerial parts of *Phragmanthera austroarabica* (branches and leaves).

1.2. Anatomical Studies

For leaf epidermal study, at least seven matured and well expanded leaves were cut at the median portion and soaked in concentrated nitric acid for 2 to 10 hrs depending on the texture of the leaf. The appearance of the air bubbles indicated the readiness of epidermises to be separated. The samples were then transferred to Petri dish containing water and with the use of fine forceps and dissecting needle, the upper (adaxial) epidermis and lower (abaxial) epidermis were separated. These were then cleaned with camel hair brush in water (Ibrahim and Ayodele, 2013; Ibrahim *et al.*, 2016). The two epidermal layers (adaxial and abaxial) were stripped and stained with Saffranin, excess stain was rinsed off with clean water and mounted in glycerol on clean slides then covers by cover slide (Sreelakshmi *et al.*, 2014; Ibrahim *et al.*, 2016). The slides were observed by using Leitz (Dialux 20 EB) microscope to determine lamina epidermal (adaxial and abaxial) characters of *P. austroarabica* which were based on the terminology of Dilcher (1974) and Leaf Architecture working group (1999). The characters determined were stomata complex features (stomata type, size and frequency); epidermal cell features (shape, size, cell wall thickness, surface ornamentation and frequency) and trichomes type. Photographs of lamina epidermis (adaxial and abaxial) characters were taken by Canon (IXUS255 HS) digital camera. The stomata frequency, epidermis cell frequency and

trichome frequency were based on average obtained from observation of 10 microscope views at field view 400x (Ibrahim, and Ayodele, 2013), Stomata index (SI) was calculated using the formula of Salisbury (1927);

$$SI = [S / (S + E)] \times 100$$

Where, S = No. of stomata

E = No. of epidermal cells

The stomata ratio (SR) was helpful in defining the type of leaf. It is the ratio of the number of stomata on the abaxial epidermis to the number of stomata on adaxial epidermis, if $SR > 1$ the leaves are classified as amphistomatic, if $0.1 < SR < 1$ as hypoamphistomatic and if $SR < 0.1$ as hypostomatic (Szymura and Wolski, 2011). The stomata size (length × width); epidermal cell size (length × width) and guard cells area (length × width × Franc's constant which is 0.78525) (Ibrahim *et al.*, 2016) were based on average obtained from observation of 60 individual, by the help of ocular micrometer calibrated with stage micrometer (value of 400x 1ocular small division = 2.5µm) and Image j program version 1.51J8.

The taxonomical value of quantitative leaf morphological, epidermal and anatomical features were determined by T. test using Graph Pad Prism 6.01 program, if P- value $P < 0.05$ then the quantitative leaf features is significantly different.

2. Result and Discussion

Plant cells are formed at meristems, and then develop into cell types which are grouped into tissues. Plants have only three tissue types: 1) Dermal tissue is composed of epidermal cells, closely packed cells that secrete a waxy cuticle that aids in the prevention of water loss, 2) The ground tissue comprises the bulk of the primary plant body. Parenchyma, collenchyma, and sclerenchyma cells are common in the ground tissue and 3) Vascular tissue transports food, water, hormones and minerals within the plant. Vascular tissue includes xylem, phloem, parenchyma, and cambium cells (Capellades et al., 1990).

Tables 1 & 2 and Figures 2 & 3 shows the main epidermal characters of the studied *P. austroarabica* leaves as clarified by light microscope. Epidermis cell shape of *P. austroarabica* leaf is polygonal with straight to rounded and rarely undulate cell wall in adaxial surface and straight to rounded cell wall in

abaxial surface (Figure 2). The mean of epidermal cells length (24.1 μm), width (18.5 μm) and size (462.9 μm^2) in the adaxial epidermis is smaller than the mean of epidermal cell length (31.8 μm), width (21.7 μm) and size (707 μm^2) in the abaxial epidermis (Table 1); furthermore, the mean of epidermal cells density/ field of view 400x in the adaxial epidermis (281 epidermal cell/ field of view 400 x) is higher than the mean of epidermal cell density / field of view 400x (250 epidermal cell /field of view) in the abaxial epidermis (table 1); moreover, the mean of epidermis cell wall thickness at the adaxial epidermis (1.4 μm) is smaller than the mean of epidermis cell wall thickness (1.7 μm) at the abaxial epidermis (Table 1). On the other hand; the degrees of surface orientation varies from thin to thick area at the surface of the adaxial epidermis cells to striation at the surface of abaxial epidermis cells; while, the surface orientation is only presented on the Subsidiary cell at the adaxial epidermis in the form of a thin to thick area (Figure 2).

Table 1. Quantitative epidermal characters comparison between adaxial and abaxial surface of *Pragmenthera austroarabica* leaves

Epidermal Characters	Adaxial			Abaxial			P-Value	
	Min	Max	Mean \pm SD	Min	Max	Mean \pm SD		
Epidermis cells	Frequency of Epidermis cells per field of view (400x)	261	292	281 \pm 11	207	275	250 \pm 21	0.0010***
	Epidermis cell Length μm	15.2	35.2	24.1 \pm 5	18	46.2	31.8 \pm 7	< 0.0001****
	Epidermis cell Width widest point μm	10.9	30.3	18.5 \pm 4.6	12.3	34.5	21.7 \pm 5.4	0.0011**
	Epidermis cell Size μm^2	177	1068.5	462.9 \pm 189.2	231.1	1471.4	707 \pm 272.1	< 0.0001****
	Epidermis cell wall thickness μm	0.93	1.9	1.4 \pm 0.22	1.1	2.4	1.7 \pm 0.29	< 0.0001****
Stomata	Frequency of Stomata per field of view (400x)	12	18	16 \pm 1.9	18	22	19 \pm 1.5	0.0002***
	Stomata ratio			0.843				0< SR<1
	Stomata index % per field of view (400x)	4.4	6.3	5.3 \pm 0.6	6.3	8.4	7.2 \pm 0.7	< 0.0001****
	Stomata Length μm Min	26.8	41	32.6 \pm 3.3	25.4	43.1	32.6 \pm 3.3	0.9985
	Stomata Width μm Min	11.7	18.9	14.5 \pm 1.4	11.7	17.5	14.3 \pm 1.2	0.4126
	Stomata complex size μm^2	369	718.9	473 \pm 73.1	356.6	587.4	466 \pm 60	0.5717
	Guard cells Length μm	26.8	41	32.6 \pm 3.3	25.4	43.1	32.6 \pm 3.3	0.9985
	Guard cells Width μm Min	5.3	7.2	6.4 \pm 0.5	5	7.1	6.2 \pm 0.5	0.0511
	Guard cells cell Area μm^2	125.6	213.8	163.2 \pm 21.2	103.1	216.4	158.8 \pm 21.8	0.2662
	Trichome	Frequency of Trichomes per field of view (400x)	1	7	3 \pm 2	3	8	5 \pm 1.6
Trichome index% per field of view (400x)		0.3	2.5	1.1 \pm 0.7	1.1	3.3	2.1 \pm 0.7	0.0058**

Table 2. Qualitative and quantitative epidermal characters comparison between *Pragmenthera astroarabica* and the Nigerian *Pragmenthera* spp.*

Epidermal characters and Leaf surface		<i>P. astroarabica</i>	Nigerian <i>Pragmenthera</i> spp.			
			<i>P. capitata</i>	<i>P. nigrimana</i>	<i>P. talbotiorum</i>	
Qualitative Characters	Cell shape	Adaxial	Polygonal/ Isodiametric	Polygonal/ tetragonal	Polygonal	Polygonal
		Abaxial	Polygonal/ Isodiametric	Polygonal	Polygonal	Polygonal
	Anticlinal Wall Pattern	Adaxial	Straight / Rounded and rarely Undulate	Straight / Rounded	Straight / Rounded	Straight
		Abaxial	Straight / Rounded	Straight / Rounded	Straight / Rounded	Straight
	Stomata type	Adaxial	3 types: Brachypharacytic, Hemiparacytic & Pericytic	2 types: Pericytic/ paracytic	1 type: Pericytic	1 type: Pericytic
		Abaxial	3 types: Brachypharacytic, Hemiparacytic & Pericytic	1 type: Pericytic	1 type: Pericytic	1 type: Pericytic
	Presence of Trichomes (Trichome base or scar) / Type of Trichomes	Adaxial	Trichome bases/ Candelabra	Absent	Trichome base/ Trichomemany armed, unicellular	Trichome bases
		Abaxial	Trichome bases/ Candelabra	Trichome bases abundant	Abundant trichomes & Trichome base / Trichomemany armed, unicellular	Trichome bases
	Surface ornamentation of epidermal cells	Adaxial	Thin to thick area & striation absent	Scarcely striated	Absent	Absent
		Abaxial	Highly striated	Highly striated	Absent	Slightly striated or thinly striated

* Qualitative and quantitative epidermal characters of Nigerian *Pragmenthera* spp. (*Phragmanthera capitata*, *Phragmanthera nigrimana* & *Phragmanthera talbotiorum*) recorded by Ibrahim & Ayodele (2013).

Table 2. Continued.

Qualitative Characters	Subsidiary cell striation	Adaxial	Thin to thick area & striation absent	Some striated	Absent	Absent
		Abaxial	Absent	All highly striated	Highly striated	Highly striated
Other characters observed	-	-	Epidermal cells around the Trichome base are normal Epidermal cells	-	Epidermal cells around the trichome base different from surrounding cells by being smaller in size and took up more stain	Epidermal cells around the trichome base different from surrounding cells by being smaller in size and took up more stain
	No. of Epidermal Cell per field of view (x400)	Adaxial	261 (281±11) 292	132 (201±7) 256	72 (122±8) 182	156 (202±7) 256
Quantitative Characters	Cell width at the widest point (µm)	Adaxial	10.9 (18.5±4.6) 30.3	22.5 (37.75±1.91) 57.5	32.5 (45.25±2.00) 67.5	30.0 (43.38±1.57) 55.0
		Abaxial	12.3 (21.7±5.4) 34.5	22.5 (34.25±1.85) 57.5	27.0 (46.25±2.75) 70.0	30.0 (38.88±1.45) 50.0
	Cell wall thickness (µm)	Adaxial	0.93 (1.4±0.22) 1.9	2.5 (3.83±0.20) 5.0	3.75 (4.58±0.11) 5.0	2.25 (2.50±0.04) 3.00
		Abaxial	1.1 (1.7±0.29) 2.4	2.5 (2.7±0.06) 3.0	3.75 (4.44±0.10) 5.0	3.0 (4.36±0.14) 5.0
	No. of stomata per field of view (x400)	Adaxial	12 (16±1.9) 18	7 (8±0.33) 12	1 (4±0.33) 7	1 (3±0.26) 5
		Abaxial	18 (19±1.5) 22	11 (17±0.57) 21	14 (22±0.63) 25	21 (24±0.35) 26
	Length of stomata (µm)	Adaxial	26.8 (32.6±3.3) 41	27.5 (34.13±0.73) 40.0	32.5 (40.0±0.60) 45.0	32.5 (39.75±0.77) 45.0
		Abaxial	25.4 (32.6±3.3) 43.1	27.5 (36.25±0.86) 40.0	32.5 (37.5±0.63) 42.5	32.5 (37.75±0.87) 45.0
	Width of stomata (µm)	Adaxial	11.7(14.5±1.4) 18.9	10.0 (16.75±0.48) 20.0	17.5 (21.75±0.48) 27.5	15.0 (18.5±0.56) 22.5
		Abaxial	11.7 (14.3±1.2) 17.5	15.0 (18.25±0.37) 20.0	17.5 (20.75±0.63) 25.0	20.0 (22.25±0.36) 25.0
	Stomata index	Adaxial	5.3	3.8	3.2	1.5
		Abaxial	7.2	9.71	18.8	19.2
Stomata ration	-	0.84	0.47	0.18	0.13	

* Qualitative and quantitative epidermal characters of Nigerian *Pragmenthera* spp. (*Phragmanthera capitata*, *Phragmanthera nigrimana* & *Phragmanthera talbotiorum*) recorded by Ibrahim & Ayodele (2013).

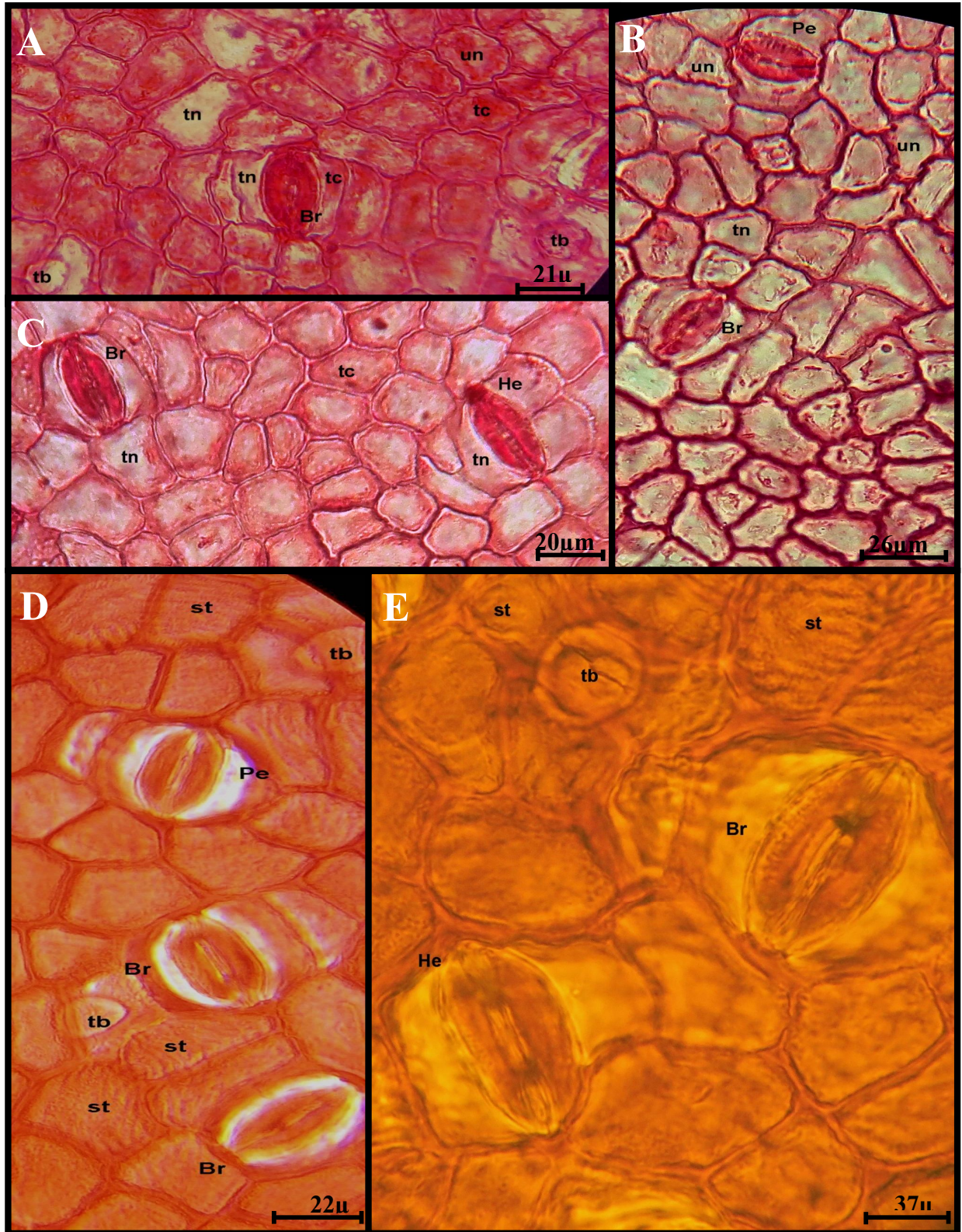


Fig. 2. Epidermal Characters of *Phragmanthera austroarabica* leaf, A-C: Adaxial surface (400x); D-E: Abaxial surface (400x); Br: Brachypharacytic stomata; He: Hemiparacytic stomata; Pe: Peralytic stomata; tb: Trichome base; tn: Thin area of surface ornamentation; tc: thick area of surface ornamentation; st: Striated surface ornamentation; un: Undulate epidermal cell wall pattern.

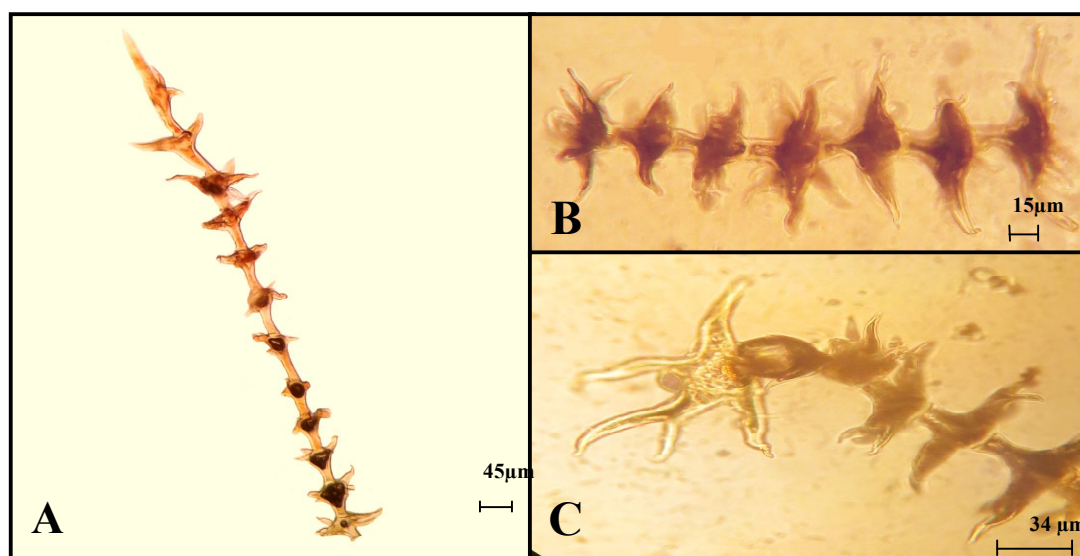


Fig. 3. *Candelabra* trichome, A: General view (100x); B: uniseriate axis and unicellular branches of hairs (400x) and C: Apex of the uniseriate axis (400x)

Candelabra trichome (trichomes having uniseriate axis from which arise unicellular branches of hairs) and their bases were recorded in this study and this agreed with Solereder (1908) where the presence of *Candelabra* trichome is a characteristic of Loranthaceae epidermis (Figure 3).

Brachypharacytic (2 cells flanking the sides of the guard cells but not completely enclosing them, parallel to the long axis of the guard cells and may or may not be elongate), Hemiparacytic (1 of the cells adjacent to one guard cell enclosing it and parallel to its long axis, the other guard cell having 3 or more normal epidermal cells surrounding it) and pericytic type (1 cell enclosing both guard cells) stomata complex types were occurred in the adaxial and abaxial epidermis of the *P. austroarabica* leaves (Figure 2). The mean of stomata density (19 stomata complex / field of view 400x) and mean of stomata index (7.2%) on the abaxial were higher than the mean of stomata density (16 stomata complex / field of view 400x) and the mean of stomata index (5.3%) on adaxial surface; moreover, stomata ratio shows that leaves of the studied *P. austroarabica* are hypoamphistomatic (leaves that have stomata on both surface, with more on the abaxial surface than the adaxial surface). On the other hand, the adaxial epidermis and abaxial surface had almost equal stomata size and guard cell area (Table 1).

The qualitative and quantitative micro characters presented in table 2 shows the strong affinity of the species in the genus level, the epidermal cell shape, anticlinal wall and stomata type were more or less the same in *P. austroarabica* (Arabian *Phragmanthera*) and the three Nigerian *Phragmanthera* species (*P. capitata*, *P. nigritana* and *P. talbotiorum*) recorded by Ibrahim and Ayodele (2013); some of those characters might show an important taxonomic significant within the species level. The mean density of epidermal cells (per field view 400x) on the adaxial surface (281cell) and abaxial surface (250 cell) of *P. austroarabica* (Table 1 & 2) is higher than the mean density of epidermal

cells on the adaxial surface (122, 201 and 202 cell) and abaxial surface (95,158 and 101 cell) of *P. nigeritana*, *P. capitata* and *P. talbotiorum* respectively (Ibrahim and Ayodele, 2013).

Contrary to Solereder (1908) who noted larger epidermal cells on the adaxial surface than the abaxial cells; while, the present study recorded that the mean width of abaxial epidermal cells (21.7µm) is larger than the mean width of adaxial epidermal cells (18.5µm) in *P. austroarabica* (Table 1 & 2); on the other hand Ibrahim and Ayodele (2013) recorded that the mean width of epidermal cells on both adaxial and abaxial surface of *P. capitata* (37.8 µm, 34.3 µm) and *P. nigeritana* (45.3 µm, 46.3 µm) correspondingly, have almost the same mean width; while the mean width of adaxial epidermal cells (48.4 µm) is larger than the mean width of abaxial epidermal cells (38.9 µm) in *P. talbotiorum*.

Generally the mean width of adaxial and abaxial epidermal cells in *P. austroarabica* is smaller than the mean width of adaxial and abaxial epidermal cells in the three Nigerian *Phragmanthera* species (Table 2) that recorded by Ibrahim and Ayodele (2013). The mean wall thickness of adaxial (3.83 µm, 4.58 µm and 2.5 µm) and abaxial (2.7µm, 4.44µm and 4.36µm) epidermal cells in *P. capitata*, *P. nigritana* and *P. talbotiorum* respectively, is higher than the mean wall thickness of *P. austroarabica* adaxial (1.4 µm) and abaxial (1.7 µm,) epidermal cells (Table 2).

According to Table 2 the anticlinal wall pattern of all comparison species were straight to curved with the exception of undulate wall pattern presents in the adaxial epidermal cells of *P. austroarabica* (Figure 2); such anticlinal wall has also been recorded for parasitic plants especially in the family Loranthaceae and Viscaceae (Bako *et al.*, 2003; Varela *et al.*, 2004 and Ibrahim *et al.*, 2009); on the other hand Stace (1965) stated that the environmental condition of a place such as humidity plays a significant role in determining the anticlinal wall pattern.

Straight to curved cell wall pattern is distinctive to species growing in drier or arid environment (Ibrahim and Ayodele, 2013); all *Phragmanthera* species found on aerial parts of the host (Miller and Cope, 1996; Chaudhary, 2001; Waly *et al.*, 2012; Ibrahim and Ayodele, 2013 and Ibrahim *et al.*, 2014) and thus exposed to high light intensity, temperature and less humidity than their host (Ibrahim and Ayodele, 2013).

The presence of thin to thick area ornamentation surface at the adaxial epidermal and subsidiary cells in *P. austroarabica* (Figure 2 and Table 2) shows a taxonomical significant value in distinguishing *P. austroarabica* (Arabian *Phragmanthera*) from the three Nigerian *Phragmanthera* species (*P. capitata*; *P. nigritana* and *P. talbotiorum*) recorded by Ibrahim and Ayodele (2013).

Trichomes and trichome base were found on the adaxial and abaxial surface of *P. austroarabica* (Figure 2 & 3 and Table 1 & 2), although Ibrahim and Ayodele, (2013) noted that trichomes and trichome base were observed on the adaxial and abaxial surface of *P. nigritana* and *P. talbotiorum*; while the trichome base were observed only on the abaxial surface of *P. capitata* and absent from the adaxial surface. More over the epidermal cells around the trichome base in *P. austroarabica* are similar in size to the normal surrounding epidermal cells (Figure 2); while in *P. nigritana* & *P. talbotiorum* the epidermal cells around the trichome base are different from the normal epidermal cells by being smaller in size and took up more stain (Ibrahim and Ayodele, 2013).

The mean stomatal density on the adaxial (16 stomata/field view x 400) and abaxial (19 stomata/field view x 400) surface of *P. austroarabica* is higher than the mean stomatal density on the adaxial & abaxial surface of *P. capitata*; *P. nigritana* & *P. talbotiorum* (Table 2). Furthermore the mean of stomatal complex length on the adaxial and abaxial surface in *P. capitata*; *P. nigritana* and *P. talbotiorum* is longer than the mean stomatal complex length on the adaxial and abaxial surface in *P. austroarabica* (Table 2). On the other hand; the stomata ratio of *P. austroarabica* leaves (0.84) is higher than the stomata ratio of *P. capitata* (0.47); *P. nigritana* (0.18) and *P. talbotiorum* (0.13) leaves (Table 2).

Brachypharacytic, Hemiparacytic and Peralytic stomatal type occurs together on the adaxial and abaxial surface of *P. austroarabica* (Figure 2); on the other hand Pericytic and Paralytic stomatal type occurs on the adaxial surface of *P. capitata* and only Pericytic stomatal type was occurred on the abaxial surface of *P. capitata*, adaxial and abaxial surface of *P. nigritana* & *P. talbotiorum* (Ibrahim and Ayodele, 2013).

3. Conclusion

The information was obtained from the present study that it didn't only add a new knowledge about the genus *Phragmanthera* Tiegh. (Loranthaceae), but it was the first study that described in details the epidermal and stomatal characters of *Phragmanthera austroarabica* (endemic species to south west of Arabian Peninsula) which shows a high significant in taxonomical value for the separation between *P. austroarabica* and Nigerian *Phragmanthera* spp. (*P. capitata*; *P. nigritana* and *P. talbotiorum*).

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المخلص العربي

خصائص بشرة نبات الـ *Phragmanthera austroarabica* Miller & Nyberg (المتوطن في جنوب غرب الجزيرة العربية) و قيمتها التصنيفية

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تتميز البشرة بان خلاياها هي الاكثر و الاكبر عددا و الاقل تخصصاً حيث ان البشرة تتضمن العديد من الخلايا المتباينة في التركيب و الوظيفة . تهدف هذه الدراسة الى التعرف على خصائص بشرة اوراق نبات الـ *Phragmanthera austroarabica* Miller & Nyberg (المتوطن في جنوب غرب الجزيرة العربية) و تقييم اهميتها من الناحية التصنيفية. حيث تم فحص و دراسة بشرة اوراق طرية لنبات الـ *P. austroarabica* Miller & Nyberg التي تم جمعها من منطقة حزيز – محافظة صنعاء خلال الفترة من مايو الى سبتمبر ٢٠١٧ و قد اظهرت بعض خصائص البشرة (كثافة خلايا البشرة، الزوائد على سطح خلايا البشرة، كثافة، معدل و نوع الثغور) قيمه تصنيفية في التفريق بين الـ *Phragmanthera* (المتوطن في جنوب غرب الجزيرة العربية) و انواع الـ *Phragmanther* المتواجدة في نيجيريا (*P. capitata*; *P. nigritana* and *P. talbotiorum*)



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Epidermal properties for taxonomic differentiation of *Phragmanthera austroarabica* Miller & Nyberg: An endemic species to south west of Arabian Peninsula

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