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SEEDLING MORPHOLOGY OF PARROT TREE [*ALBIZIA LEBBECK* (L.) BENTH. (FAMILY MIMOSACEAE)] FROM OUD METHA PARK, DUBAI, UAE

D. KHAN
Department of Botany, University of Karachi, Karachi 75270, Pakistan.

This paper describes the seedling morphology of *Albizia lebbeck* (L.) Benth. including stomatal characteristics. Seedlings of *A. lebbeck* are epigeal, phanerocotylar type with reserve type cotyledon - exhibiting quite faster growth rate and nyctanastic movement. The cotyledons are opposite ovate, green and thick and food-laden. They are concave inside and convex outside. The area per cotyledon averaged to 162.83 ± 1.47 mm^2 and cotyledonary area per 5-day old seedling averaged to 325.67 ± 4.26 mm^2. They are sessile and provided basally with a groove to accommodate stem with which they form an angle of 45^o. There arise some seven veins from the arch in the basal region of the cotyledons. They traverse lengthwise – apparently brachidodromous.

Primary leaves were unipinnate and subsequent leaves were bipinnate. Primary leaves had no petiolar or acropetiolar glands. Glands associated with bipinnate leaves only – acropetiolar glands were generally more prevalent. In bipinnate leaves, at least one basal leaflet in each rachii was rudimentary. The leaf area per 25-day old seedling averaged to 204.4 ± 8.24 cm^2 varying from 177.9 to 243.4 cm^2. Foliar epidermal cells on dorsal surface are irregular or polygonal in shape and their anticlinal walls were straight in cotyledons and arcuate with some degree of waviness in leaf particularly on the ventral surface. In seedlings the epidermal cells were papillose. In mature tree leaflet the epidermal cells were convex papillose (both flat-topped and conical types with tendency of cuticle deposition on top of cells and then descending along the wall. Delicate non-glandular blunt-apex trichomes were observed on petiole, basal part of rachii and margins of stipules and leaflet. Hypocotylar stomata were of anomocytic type. On cotyledon, paracytic, anisocytic and staurocytic and anomocytic stomata were present. In young leaflet (2.0 x 0.6 cm in size), the stomata were found to be paracytic (c. 85%), anisocytic (c. 14%) and very few tetracytic types on dorsal surface. On ventral surface, paracytic stomata were predominantly abundant with some anisocytic types also. Stomata on dorsal surface of leaflet were quite infrequent and stomatal density averaged to 3.77 ± 0.78 stomata per mm^2 (0-19.96 per mm^2). Stomata on ventral surface of seedling leaflet averaged to 156.96 ± 5.266 stomata per mm^2 varying around 25. 99%. There were no stomata on dorsal surface of leaflet of parent tree and on ventral surface stomatal density averaged to 164.23 ± 9.612 stomata per mm^2. The basic type of stomata in *A. lebbeck* appears to be paracytic ones and other types as secondarily-derived through development of cell wall (s) in subsidiary cell. Stomatal aberrations were observed in *A. lebbeck* generally with respect to the stomatal cell. Stomata without guard cells differentiation (arrested development of guard cells) were observed on both surfaces of cotyledons and leaflets of seedling as well as on mature leaflet from the parent tree presumably as a result of genotoxic effects of very high transport density. Cuticular wax crystalloids were composed of irregular platelets (rosettes of platelets, Faballes type). The number of platelets per rosette varied considerably and appeared to fuse with each other forming lumps.

KEY WORDS: *Albizia lebbeck (*L.) Benth. , seedling morphology, stomatal types and aberration.

INTRODUCTION

Albizia lebbeck (L.) Benth (vernacular: Parrot tree, flea tree, fry wood tree, Siris) is a multipurpose Mimosacean tree widely distributed and cultivated in tropical Asia, N. Australia and tropical Africa (Ali, 1973). It is one of common landscape plants in UAE (Malone (1986).

It is a multipurpose plant. Its wood resembles walnut. It is considered to be a medicinal plant (Jasiem *et al.* (2019). Plant has anti-oxidant potential *in vitro* (Zia-ul-Haq *et al.,* 2013). Mishra *et al.* (2010) have described the plant as analgesic, anxiolytic, anti-inflammatory, anti-diarrheal and nootropic.

This paper describes the seedling morphology of *Albizia lebbeck* obtained from the seeds collected from the tree cultivated in Oud Metha Park, Dubai.

CLIMATIC FEATURES OF DUBAI

UAE is located in Middle East, situated on Arabia Peninsula between Oman and Saudi Arabia bordering the Gulf of Oman and the Persian Gulf. It covers an area of 83,600 Sq. km. Its largest city is Dubai. Dubai landscape is sandy – extreme hot. Days are sunny all the year around. Humidity is discomfortingly high in coastal region. According to Köppen classification (Köppen and Geiger, 1954), its climate is of Bwh type (Tropical desert climate) and bioclimate as given by Holdridge (1947) falls into the category of Tropical Desert Bush formation. Climate of Dubai is described in Table 1. The record high temperature is 52 ^oC and record low 9^oC. Average high temperature is 33.4 and average low 23.5^oC. Rainfall is low – around 103.7 mm which is largely in winter months (December, January – March). Annual seawater temperature averages to 28.3 ^oC –varying 13.69%. UV index is high (11+) in summer. Evapotranspiration for Wadi Ham catchment is presented by Al Mulla (2005) to be ≥ 6 mm per day for March through September and maximum in March and September – around 8.5 mm per day.

Air quality in Dubai is considered primary environmental threat. Air quality index (AQI) ranges in magnitude from 27 to 74. Annual Air Quality index is higher than the maximum limits suggested by World Health Organization (WHO). AQI near Karama is said to be above 60 in winter (www.air.plumelabs.com) – of course

better than Ulaanbaatar (Mangolia, 256), Delhi (160), Karachi (100) but poorer than Oslo (48) (www.Airvisual.com). Fresh air generally has AQI around 20. The particulate matter (PM2.5) amounts to 18 µg/m^3, PM10 around 57 µg /m^3, NO_2 c. 43 µg/m^3 and O_3 c. 52 µg/ m^3. Dubai is among the fifty hotspots for the presence of nitrogen oxides where some 1.5 million cars are the major source of nitrogen oxides (www.thenational.ae/uae...) and some other pollutants. Transport density is high. On an evening of December, 2019, some 5580 vehicles per hour (3720 plying to Deira side and 1860 from Deira side) were recorded by us on the free way near the Oud Metha Park. In addition to it, there is also high traffic density on the traffic artery on the right of the park linking Oud Metha to Karama.

Table 1. Climatic characteristics of Dubai. *

Months	Temperature (^{o}C)				Rain (mm)	Rainy Days	Seawater Temp. (^{o}C)	UV index
	Record High	Average High	Average Low	Record Low				
J	31.8	26.1	17.8	9.0	18.8	4.4	23.4	6
F	37.5	27.4	18.6	10.0	25.0	3.0	21.9	8
M	41.3	31.6	20.9	11.0	32.1	5.8	28.2	10
A	43.5	34.2	23.2	15.4	7.2	2.6	25.5	11 +
M	47.0	38.6	26.1	18.1	0.4	0	29.8	11 +
J	50.9	40.7	28.5	21.2	0.1	0	31.6	11 +
J	52.0	41.2	31.2	23.4	0.1	0	32.7	11 +
A	51.5	41.8	31.5	25.1	0	0	33.5	11 +
S	48.12	39.8	28.7	23.5	0	0.2	33.1	11
O	42.4	35.6	24.3	17.0	1.1	0.5	31.3	8
N	38.0	32.2	21.0	14.8	2.7	1.0	28.6	6
D	33.2	28.3	20.3	12.2	16.2	2.8	25.4	5
Year	52.0	33.4	23.5	9.0	103.7	20.3	28.3	9.1

*, Data source: (*http://en.wikipedia.org/wiki/Climate_of_Dubai#Climate_data)* –date of retrieval – June 29, 2018. (Data being mainly the courtesy of Dubai Meteorological office, Seatemperature.org, Climatebase.ru, Weather Atlas; Gulf News, etc.

MATERIALS AND METHODS

The seeds of *Albizia lebbeck* were collected from a tree growing in the Oud Metha Park, Dubai, UAE in summer - July 08, 2017. Most of the pods were found infected with fungi and number of seeds eaten by the insects.

The assorted healthy seeds without any dormancy-breaking treatment were sown in August 2017 at 0.75cm depth in soil in pots filled with garden loam soil maintained at 75% water holding capacity. Maximum germination was c. 70% achieved within few days. The seedlings were studied, for their morphological characters including stomatal types. Seedlings type was described according to Garwood (1996) and Vogel (1980). Hickey (1973) and LWG (1999) were followed for description of leaf architecture.

Epidermal impressions from fresh cotyledons, leaflets (c. 2.0 x 0.6 cm in size) of the seedling and the leaflet (c. 4.0 x 2.0 cm in size) of the parent tree were made with clear nail polish (Wang *et al.,* 2006). Stomatal nomenclature suggested by Prabhakar (2004) being simple and based upon structure of stomata and not their ontogenetic pathways was adopted to ascertain stomatal types. For scanning electron microscopy (SEM), air-dried leaflet of 25-day old seedling was mounted on brass stubs and coated with a 250 ^{o}A gold layer with JFC-1500 gold coater. Scanning micrographs were made at 15kV with JEOL JSM-6380A electron microscope at various magnifications. The images were saved digitally on computer. Epicuticular wax crystalloids were identified after Barthlott *et al.* (1998).

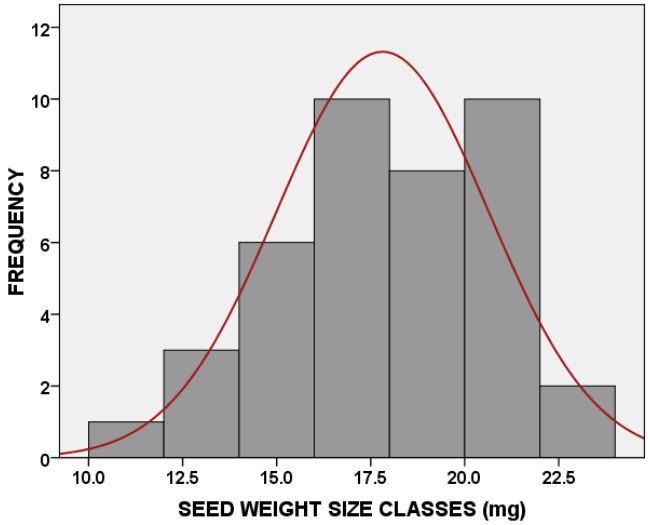
RESULTS AND DISCUSSION

Seeds

The seeds of *A. lebbeck* are pale brown in colour (seed colour darkens on storage), shining, nearly round in outline and compressed disk-like. Both sides of the seeds are faveolate (http://www.efloraa.org/florataxon.aspx?flora_id=5&taxon_id=200011877). The seeds are provided with discrete pleurogram (Fig. 1). The weight of assorted healthy seeds averaged to 17.82 ± 0.4458 mg varying from 10.34 to 23.75 mg, CV = 15.83% (Fig.2). The pods were found to be fungal-infected and eaten by bruchids in substantial number. *Bruchus bilineatopygus* is the key insect pest of *Albizia* causing 80% damage to the seeds besides weevils and other lepidopterous insects (Meshram *et al.,* 2015). Besides, Entomopathogenic fungi (Meshram *et al.,* 2015), Uddin and Khan (2016) reported *Aspergillus niger* and *Paecilomyces varioti* from the pods of *A. lebbeck*. High moisture content (70.63 ± 2.26%) and sugar level (122.45 ± 30.06 mg.g-1 pericarp) in young and maturing pods of *A. lebbeck* was considered to be the reason of large fungal infection of pods of this species in Karachi. The seed

chambers of some fungal-infected pods were also found colonized by *Liposcelis* sp. Seeds of *A. lebbeck* are reported to contain antinutrient principles such as cyanide: 0.21 ± 0.013 mg/kg (mean ± SD), oxalate: 0.04 ± 0.45 mg/kg, saponins: 834.13 ± 1.6 mg/kg and Trypsin inhibitor activity: 16.04 ± 1.31 µg/mg flour (Zia-ul-Haq *et al.*, 2013).

Fig. 1. The sorted healthy seeds of *A. lebbeck* collected from Oud Metha Park, Dubai. Pleurogram is apparent.



N = 40
Mean = 17.82
SE = 0.44583
Median = 17.99
Mode = 15.89
CV = 15.83 %
G1 = - 0.211
Sg1 = 0.374
G2 = 0.126
Sg2 = 0.733
Minimum = 10.34
Maximum = 23.75
KS-z = 0.602
P < 0.602

Fig. 2. Seed weight distribution of healthy assorted seeds of *A. lebbeck* collected from Oud Metha Park, Dubai.

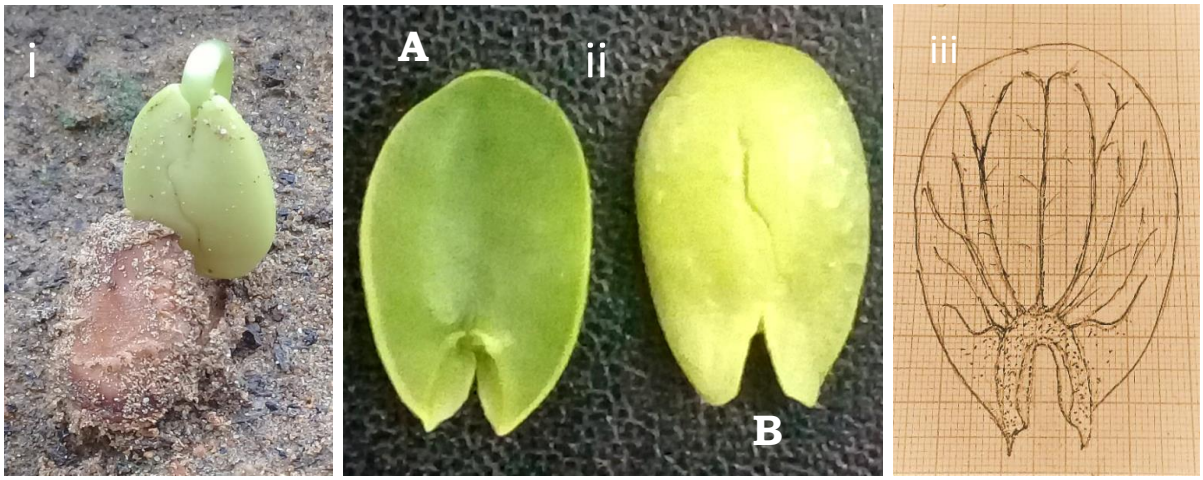


Fig. 3. i) Epigeal germination. ii) Cotyledons are fleshy and thick. A, Upper surface; B, Lower surface. iii) Venation of cotyledon as seen on upper surface in a drying cotyledon.

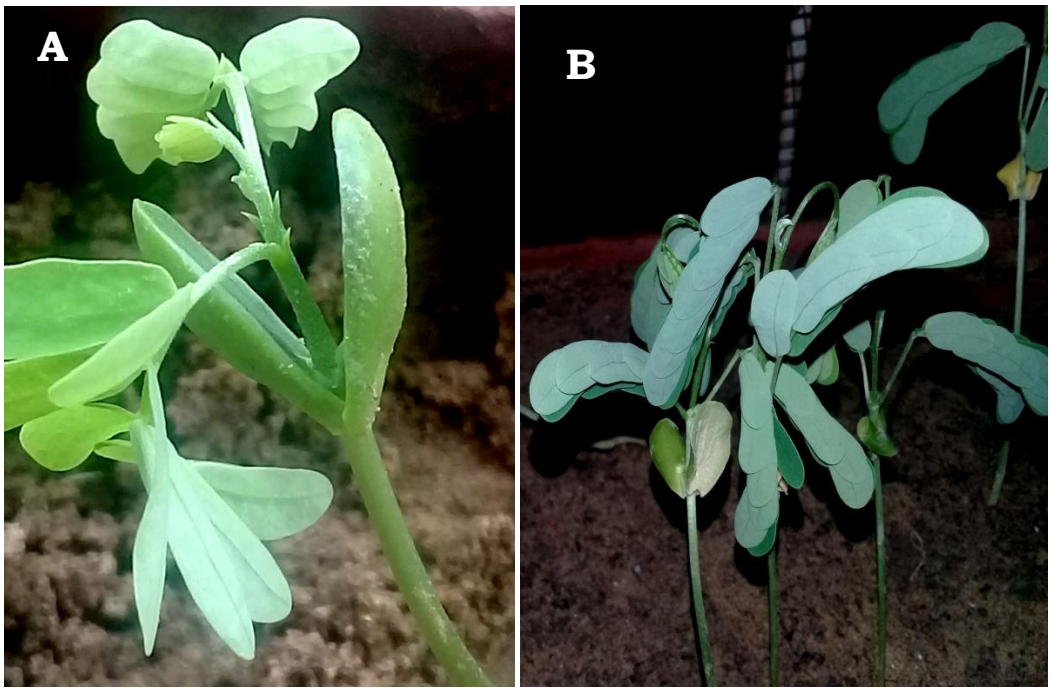


Fig. 4. Five-day old seedling of *Albizia lebbeck* (A) and seedlings showing sleeping movement in night (B).

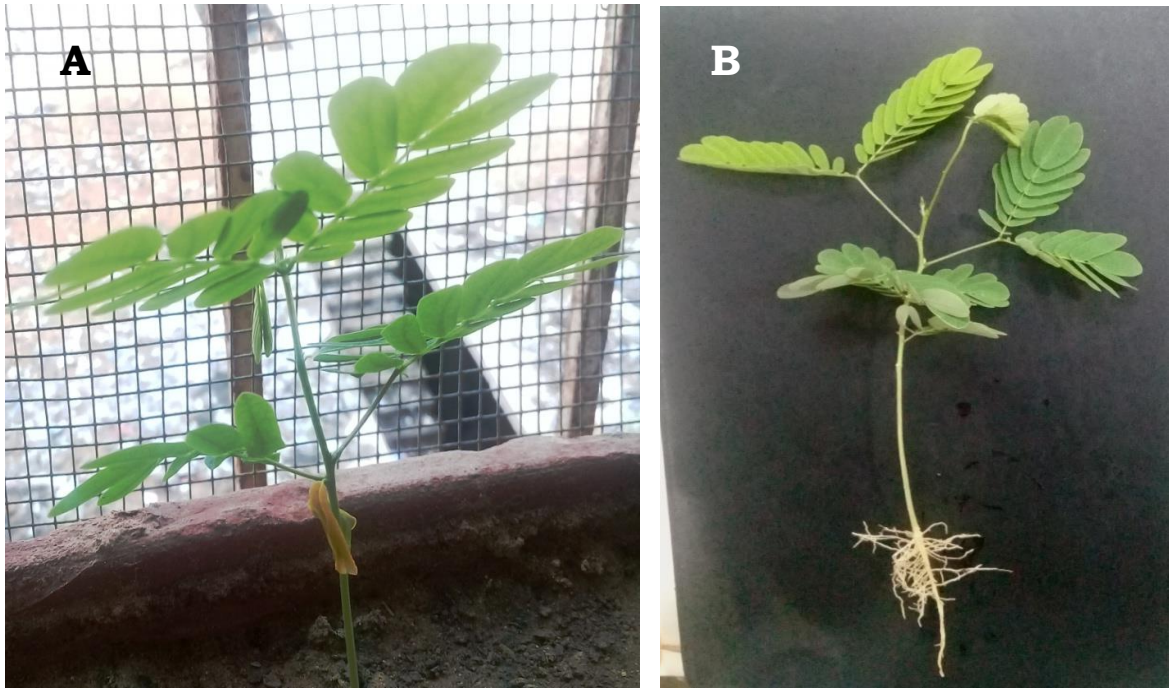


Fig. 5. A, Seedling showing shriveled cotyledons. Cotyledons remain with the seedling for around 20 days. B, A six-leaved, 25 days old seedling bearing tap root with a cluster of secondary roots.

Seedlings

The seedlings emergence from soil was c 70% after 48 h of incubation (Fig. 3i). Lavania and Tiwari (2019) have reported that freshly collected seeds showed 72% germination in *A. lebbeck* which decline with storage. The seedling resembled to that of *Cassia fistula (*Khan and Zaki, 2019*).* Seedling of *A. lebbeck* as per Garwood's (1996) classification appeared as epigeal, phanerocotylar type with reserve cotyledon (Fig. 4). Vogel (1980) put *Albizia* seedlings in "Macaranga type" of seedlings – common (c. 50%) in Malesian woody taxa. Several legumes (*Acacia nilotica, Cassia auriculata, C. occidentalis, Delonix regia, Erythrina suberosa, Leucaena leucocephala, Pelltophorum pterocarpum, Pongamia pinnata, Bauhinia racemosa,* etc.) have been reported to show epigeal

germination (Amritphale and Sharma, 2008; Khan *et al.*, 2014; Khan *et al.,* 2015a and b; Khan and Zaki, 2019, Nakar and Jadeja, 2016). The leaflets of the primary leaf emerge out of the cotyledons even prior to the cotyledonary spreading is complete. The cotyledons are yellowish but soon turn green and become photosynthesizing. They are more or less oval in shape, thick (c 1.0mm) and fleshy (Fig. 3ii). Seedling is quite fast-growing. The five-day old seedlings had root = 5.30 ± 0.20cm long, hypocotyl = 7.77 ± 0.23 cm, epicotyl = 3.67 ± 0.44 and two leaves (tertiary leaf was in offing). Primary unipinnate leaf of 5-day old seedlings had 7.33 ± 0.66 leaflets (6 to 8 in number) and secondary bipinnate leaf had borne 9.76 ± 0.52 (9-10, one of the basal leaflet in a bipinnate leaf was very small in size in comparison to the other leaflets). The morphometry of seven 25-day old seedlings (Fig.5B) is presented in Table 2 to 5. There were up to 7 internodes produced by a seedling – the third one was relatively larger than the other internodes. Hypocotyl in these seedlings averaged 6.50 ± 0.37 cm in length (5-7.8 cm) and total shoot height approximated around 14.20 ± 0.86cm (Table 2). The petiolar length was invariably observed to increase in size with order of the leaves (1-6). The number of leaflets was lower in unipinnate primary leaves than in secondary or higher order bipinnate leaves (Table 3). One seedling showed 4 rachii per leaf instead of two and consequently had much larger number of leaflets (Table 3). Leaf area per individual leaf varied amongst the seedlings and increased in the higher order leaves. There were no missing or rudimentary leaflets in primary leaves but subsequent leaves (bipinnate) had one or two basal leaflets rudimentarily small (Table 4). Similarly primary leaves had no petiolar or acropetiolar glands – such glands associated with bipinnate leaves – acropetiolar glands were generally two-times more frequent than petiolar glands (Table 5) amongst the seedlings studied. The seedlings of *A. lebbeck* appeared to be quite fast growing - faster than *Cassia fistula* and *Dalbergia sissoo* under undisturbed, disturbed or moderately disturbed conditions of the Similipal Biosphere Reserves of India (Banerjee *et al.,* 2004).

Fig .6. A) Round discoidal glands of *A. lebbeck* seedlings. A, petiolar gland - located on the mid region of young petiole and several trichomes. B, Acropetiolar gland (near the base of the rachii) and trichomes on the rachis. Both petiole and the rachii are trichomatous. Trichomes are non-glandular, unicellular and straight or curved. C, A trichome from near margin of dry leaflet (Mag. 45 x 10X).

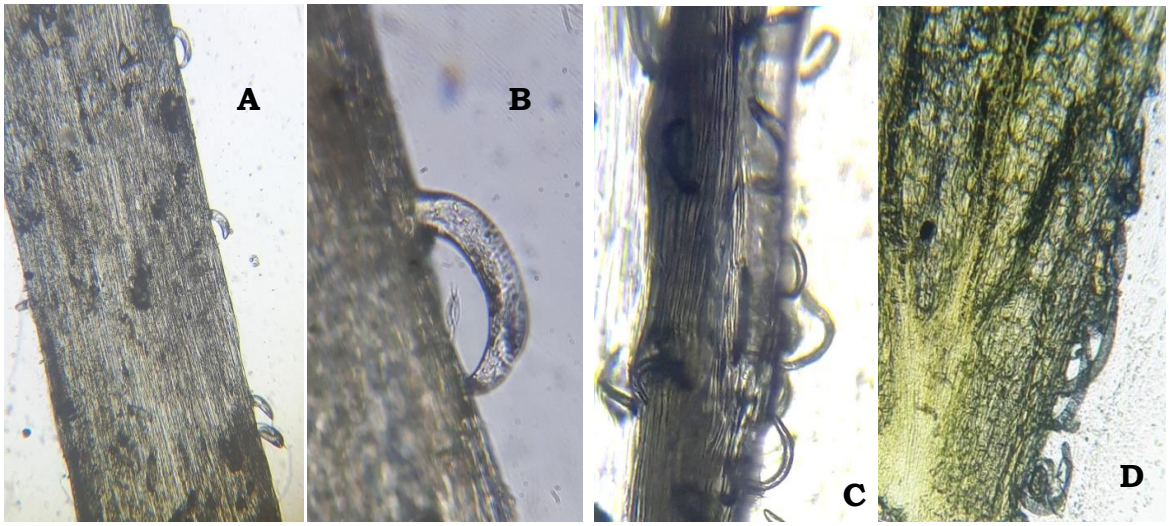


Fig. 7. Trichomes on hypocotyl (A and B), epicotylar stem (C) and margins of young stipule (D).

Hypocotyl: Hypocotyl green and rapidly elongating. The basal part of the hypocotyl in some seedlings became brown purple in colour with time.

Cotyledons: The cotyledons are opposite ovate, green and thick and food-laden. They are concave inside and convex outside. They are sessile and provided basally with a groove to accommodate stem with which they form an angle of 45^{o} on either side (Fig. 4A). The area per cotyledon averaged to 162.83 ± 1.47 mm^2 and cotyledonary area per 5-day old seedling averaged to 325.67 ± 4.26 mm^2. Cotyledons stay with the seedlings is short-lived due to rapid growth of seedlings. They began yellowing and shriveling by the 10^{th} day of growth and get abscised by 15-20 days of emergence. In some 25-day-old seedlings, however, the yellow brown shriveled cotyledons may still be seen attached to the seedling. Venation in fresh cotyledon is not discretely visible. However, on drying vasculature became somewhat clear on upper surface of the cotyledon. There arise some seven veins from the arch in the basal region of the cotyledons. They traverse lengthwise – apparently brachidodromous (Fig. 3iii).

Leaves: The primary and secondary leaves are formed quite earlier even when the cotyledons are partially open and the leaves peep out from between the cotyledons. The primary leaf is unipinnate paripinnate and the subsequent leaves are bipinnate paripinnate in form. Leaves are petiolate, stipulate and stipellate. The basal leaflets were generally very small (Fig. 8). The leaves are sensitive to dark and light. They show nyctanastic movement (Fig. 4B). The petioles are provided with discoidal green gland at the mid-point of the petiole and / or at the bifurcation point of rachii (acropetiolar) (Fig. 6A and B). The leaflets are oblong in shape, marginally entire and dorsiventral in texture. Higher is the order of the leaf; larger is the average length of petiole of the leaf, average number of leaflets per leaf and larger the leaf area per leaf (Table 3). The leaf area per seedling averaged to 204.4 ± 8.24 cm^2 varying from 177.9 to 243.4 cm^2 (N = 7, CV = 10.67%) (Table 3). There were two rachii per leaf in bipinnate leaves but one seedling had sixth leaf with four rachii bearing 68 leaflets *in toto*. In bipinnate leaves, at least one basal leaflet in each rachii was rudimentary (Fig. 8; Table 4). Seedlings had the tendency of producing more acropetiolar glands than petiolar ones (Table 5).

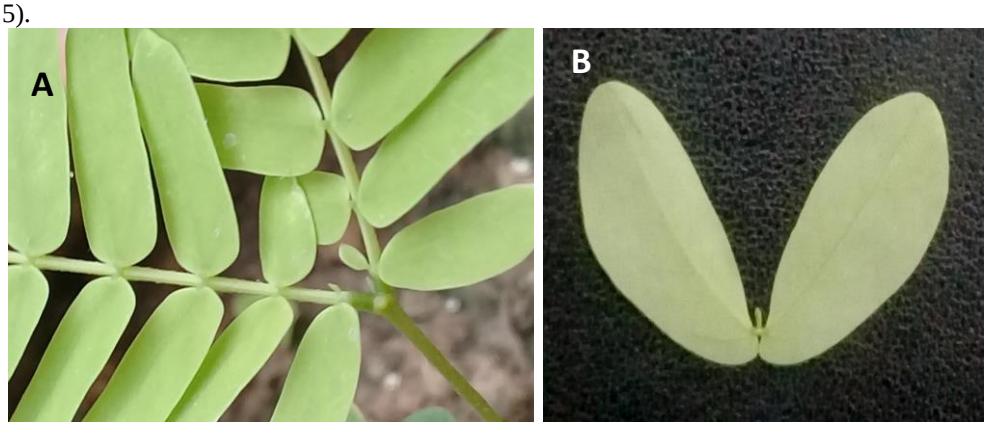


Fig. 8. Secondary leaf of *Albizia lebbeck* seedling. Leaves are bipinnate and paripinnate in nature bearing leaflets varying somewhat in shape and size. One of the basal leaflets in both rachii is much reduced in size. Midrib extension at the apex between the terminal leaflets is clearly visible.

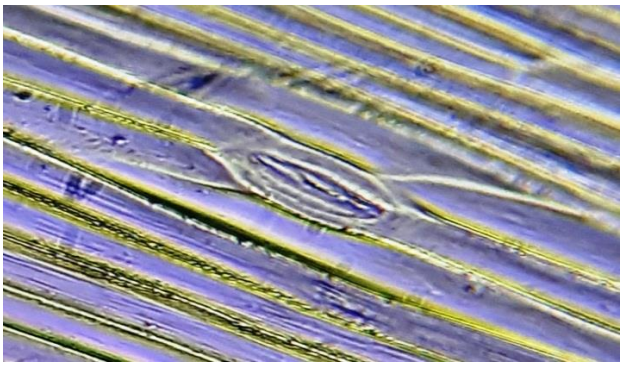


Fig. 9. Anomocytic elliptic stoma (surrounded by six subsidiaries) on the surface of hypocotyl of five-day old seedling.

Epidermis

Foliar epidermal cells on dorsal surface are irregular or polygonal in shape and their anticlinal walls were straight in cotyledons and arcuate with some degree of waviness in leaf particularly on the ventral surface. In

seedlings the epidermal cells were papillose. In mature tree leaflet the epidermal cells were convex papillose (both flat-topped and conical types with tendency of cuticle deposition on top of cells and then descending along the walls (Fig. 14-18).

Trichomes

Several delicate non-glandular trichomes were observed on petiole, basal part of rachii and margins of stipules and leaflet (Fig. 6C and 7). Banerjee *et al.* (2004) have reported two types of trichomes in *A. lebbeck* – non-glandular trichomes dispersing all over the leaf surface and glandular trichomes restricted to the surrounding of the midrib. We couldn't find glandular trichomes in the early seedlings of this species. Jasiem *et al.* (2019) have reported multicellular non-glandular trichome in *A. lebbeck* collected from College of Pharmacy of Mustansiriyah, University of Baghdad, Iraq.

Table 2. Morphometric data of 25-day old seedlings (N =7).

Organ	Seedlings							MEAN ± SE
	I	II	III	IV	V	VI	VII	
Root (cm)	8.0	9.0	9.5	5.8	10.6	14.0	11.0	9.70 ± 0.9713
Hypocotyl (cm)	7.2	6.0	6.0	5.0	7.8	7.3	6.0	6.50 ± 0.3720
Shoot length (cm)	14.2	17.23	16.5	11.0	12.2	14.0	14.0	14.20± 0.8576
Number of Leaves	6	6	6	6	6	6	6	6.0 ± 0.0
Internode I (cm)	1	1	0.8	0.6	0.6	0.7	0.9	0.80 ± 0.065
Internode ii (cm)	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.13 ±0.029
Internode iii (cm)	1.5	1.4	0.9	1.0	1.3	1.2	1.6	1.26 ±0.092
Internode iv (cm)	1.2	1.3	1.2	0.8	0.8	1.0	1.0	1.04 ± 0.075
Internode v (cm)	0.9	1.2	1.4	1.0	0.5	1.1	1.0	1.014 ±0.106
Internode vi (cm)	1.0	1.0	1.3	1.2	0.6	1.0	0.7	0.84 ±0.143
Internode vii (cm)	-	-	-	-	-	0.5	0.3	0.40 ±0.10

Table 3. Petiolar length, Number of leaflets and area of leaves (from base to apex) in 25-day old seedlings.

Organ	Seedlings							MEAN ± SE
	I	II	III	IV	V	VI	VII	
Petiolar length (cm)								
First leaf	1.8	1.2	1.4	1.0	0.6	0.7	1.0	1.10 ± 0.16
Second leaf	1.5	2.5	2.4	1.6	1.0	1.3	1.2	1.64 ± 0.22
Third leaf	2.0	1.6	1.9	3.0	2.2	1.6	2.2	2.07 ± 0.18
Fourth leaf	2.5	4.0	4.1	3.2	2.5	3.0	3.8	3.30 ± 0.26
Fifth leaf	3.4	4.3	4.0	4.7	3.2	3.2	3.5	3.76 ± 0.22
Sixth leaf	4.0	5.5	5.0	5.5	3.6	4.7	4.7	4.71 ± 0.27
Seventh leaf	-	-	-	-	4.2	-		0.60 ± 0.60
Number of leaflets *								
First leaf	8	10	8	10	8	10	10	9.14 ±0.40
Second leaf	22	22	18	20	18	22	22	20.60 ± 0.72
Third leaf	16	22	18	22	18	20	18	19.14 ± 0.86
Fourth leaf	25	26	16	34	26	22	22	24.43 ± 2.07
Fifth leaf	36	36	30	36	26	30	33	32.29 ± 1.48
Sixth leaf	32	68 ♦	26	26	26	38	32	35.43 ± 5.68
Leaf area (cm^2) per leaf *								
First leaf	11.6	13.8	13.0	11.5	7.36	9.2	9.3	10.8 ± 0.87
Second leaf	28.5	25.9	18.6	26.0	25.4	31.0	31.1	26.6 ± 4.01
Third leaf	27.7	29.5	26.3	30.8	39.5	30.4	27.4	30.2 ± 1.67
Fourth leaf	43.3	33.8	23.7	51.7	42.4	35.86	35.6	38.0 ± 3.33
Fifth leaf	54.7	54.0	48.0	32.5	41.1	47.4	50.9	47.8 ± 3.3
Sixth leaf	17.4	88.4♦	48.4	52.9	40.8	59.7	50.2	51.1 ± 8.0
Leaf area per seedling (cm^2)								
Seedling leaf area	183	243	178	205	197	214	210	204.4 ± 8.24

*, Rudimentary leaflets not included. ♦, a leaf with four rachii instead of two.

Table 4. The number of rudimentary or missing leaflets in leaves.

Leaves *	Seedlings						
	I	II	III	IV	V	VI	VII
First leaf ○	-	-	-	-	-	-	-
Second leaf	1, 1	-	-	2	-	-	1, 1
Third leaf	1, 1	1	-	1, 1	-	2	-
Fourth leaf	1, 1	1,1	1,1	-	-	-	-
Fifth leaf	-	1, 1	1, 1	2	-	-	1
Sixth leaf	-	1, 1	-	-	-	-	1, 1

*, From base to apex

Table 5. Petiolar and Acropetiolar glands on leaves of *A. lebbeck* seedlings.

Leaves *	Petiolar glands							Acropetiolar glands						
	Seedlings							Seedlings						
	I	II	III	IV	V	VI	VII	I	II	III	IV	V	VI	VII
First ○	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Second	-	-	-	-	-	-	+	-	-	-	-	+	-	-
Third	-	-	-	+	-	-	-	-	-	-	-	+	+	+
Fourth	-	-	-	+	-	-	-	-	-	-	-	+	+	+
Fifth	+	-	-	+	-	-	-	-	-	-	-	+	+	+
Sixth	+	-	-	+	-	+	-	-	+, +	+	-	+	+	+
Seventh	Very young leaves – no gland could be seen									+	Very young leaves			

*, From base to apex. Petiolar gland = 9; Acropetiolar glands = 17.

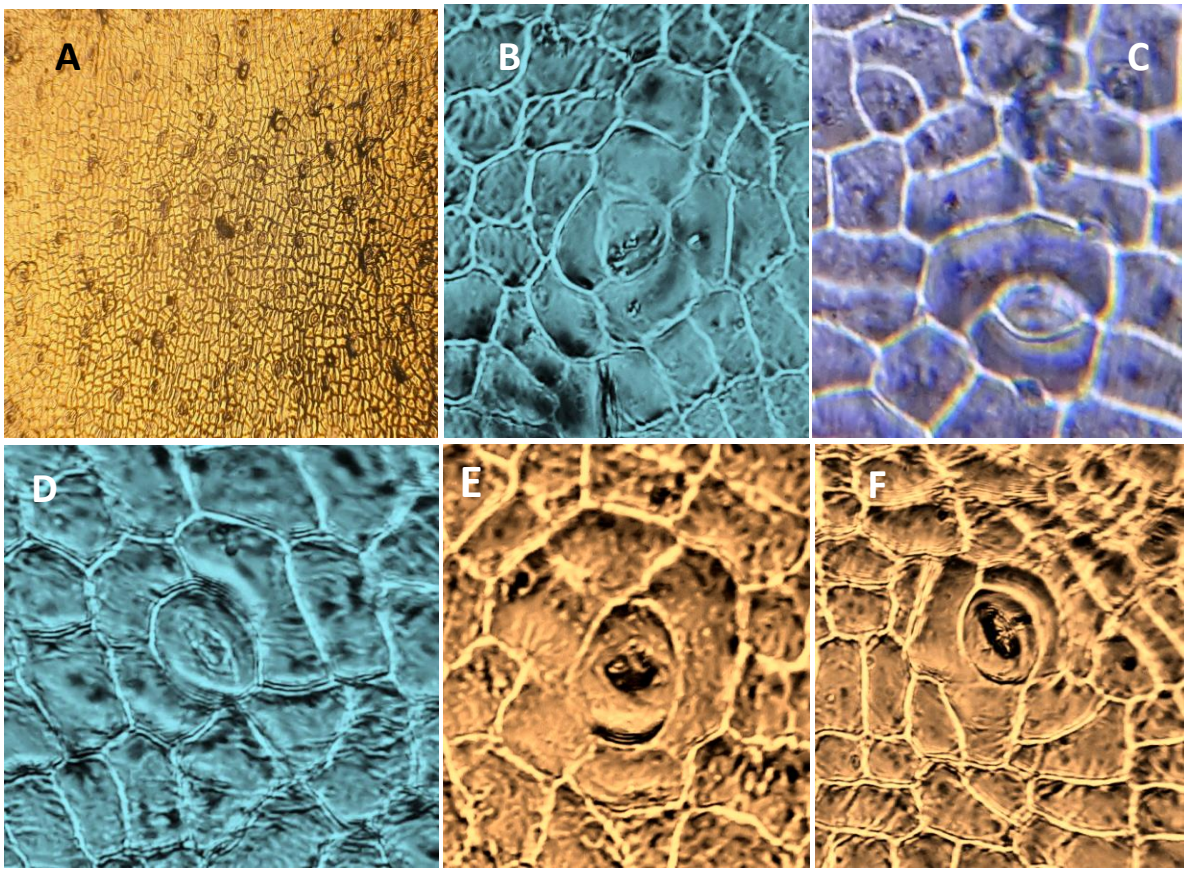


Fig.10. Nail polish imprint of stomata on lower surface of cotyledon of 5-day old seedling showing stomata of varied types; A, General view; B, staurocytic; C, Paracytic; D and E, Anomocytic and F, anisocytic (note that one subsidiary is distinct and others indistinct).

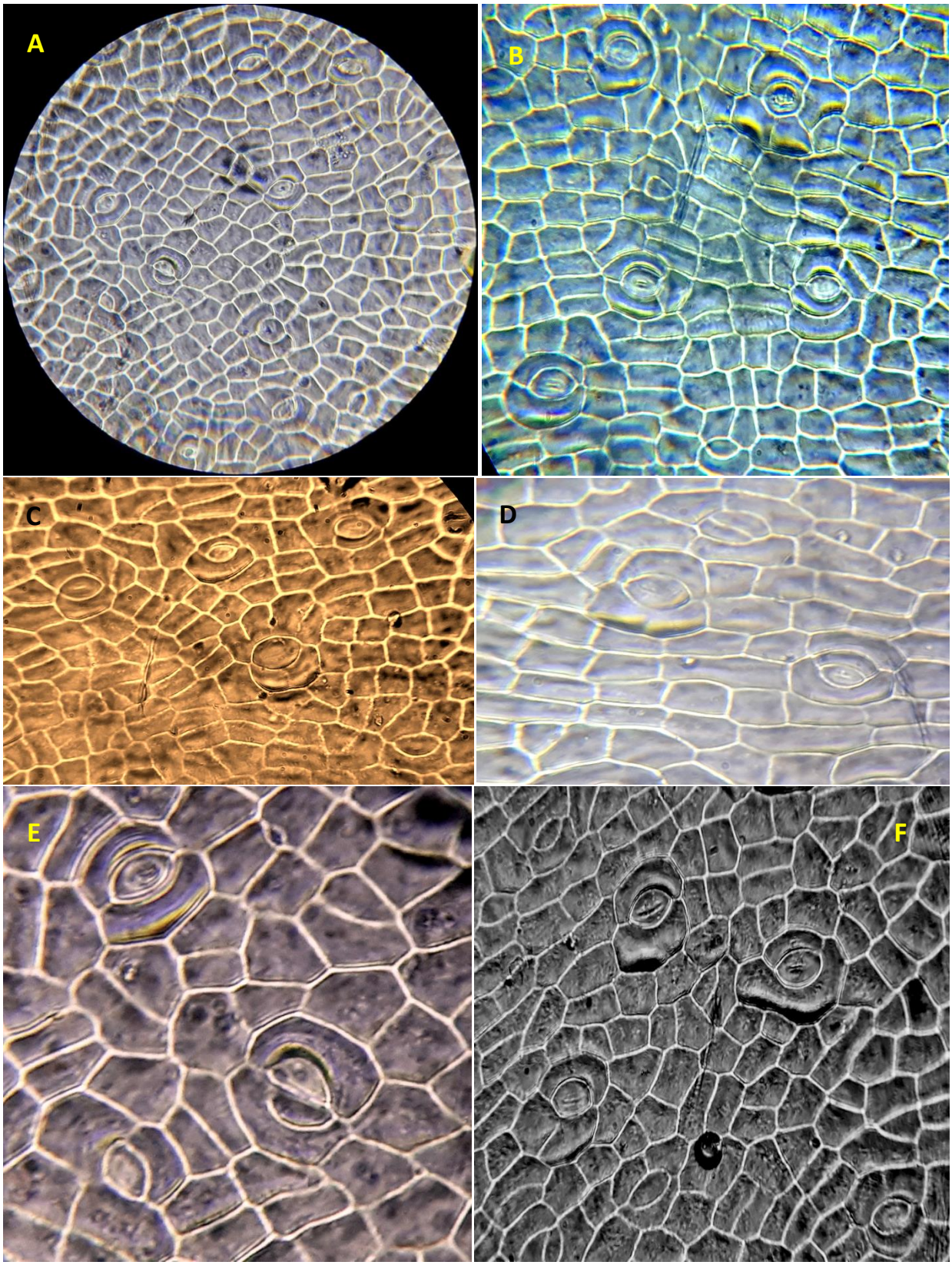


Fig.11. Nail polish imprint of upper surface of cotyledon of a 5-day old seedling showing varied types of stomata. Note unequal subsidiaries and obliquely paced guard cells (E).

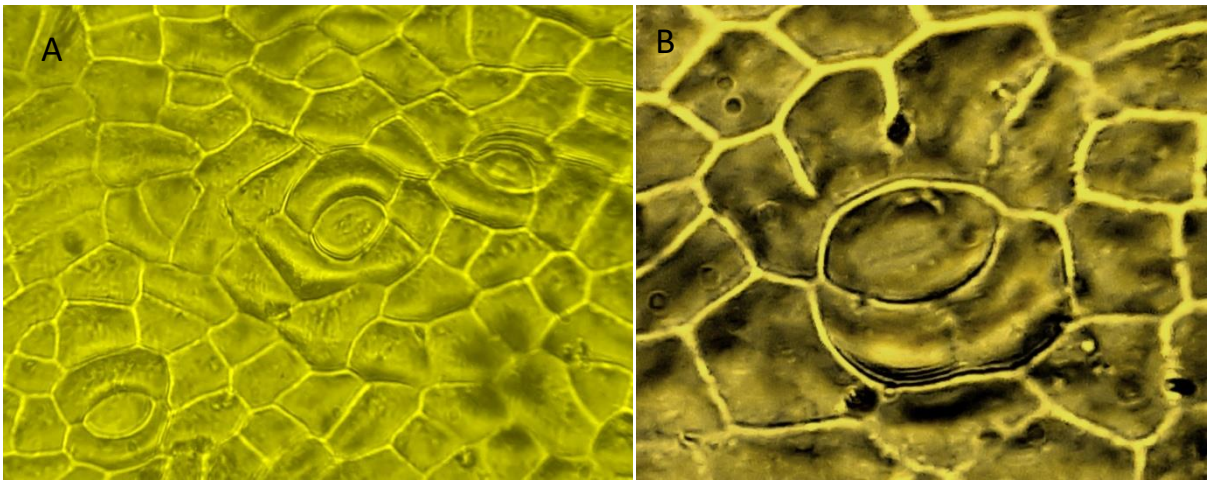


Fig. 12. A pair of stomata (one paracytic and other anisocytic) in close neighborhood besides a paracytic stoma – without guard cells (A). The development of new multiple cell walls in a subsidiary cell (B) seen on upper surface of a 5-day old cotyledon.

Stomata

Stomatal types in *A. lebbeck* seedling and tree are described in Table 6. Hypocotylar stomata were anomocytic type (Fig. 9). On cotyledons, paracytic, anisocytic and few staurocytic stomata were present (Fig. 10, 11). In young leaflet (2.0 x 0.6 cm in size), the stomata were found to be paracytic (c. 85%), anisocytic (c. 14%) and very few tetracytic types on dorsal surface. On ventral surface, paracytic stomata were predominantly abundant with some anisocytic types also (Fig. 15 and 16). On very young leaflets some meristemoids were seen near veins. Ogundipe and Akirinlade (1998) reported two types of stomata in genus *Albizia* – paracytic and anomocytic. Stomata in *A. lebbeck* were described to be of anomocytic type by Banerjee *et al.* (2004).

Stomata on dorsal surface of leaflet were paracytic, anisocytic and staurocytic types but quite infrequent. They were comparatively much larger in number on ventral surface. Some meristemoids were also observed. Ogundipe and Akirinlade (1998) described leaves in genus *Albizia* to be hypostomatous. In *A. lebbeck* seedlings raised from the seeds of a Dubai tree, the dorsal surface of leaflet was devoid of stomata in 65% of the frames of vision and varying from 1 to 2 stomata in 35 % of the frames of vision at magnification of 45 x 10 X. Overall stomatal density averaged to 3.77 ± 0.78 stomata per mm^2 (0-19.96 per mm^2). The leaves of *A. lebbeck* seedling appeared to be amphistomtatous type but predominantly hypostomatous. On ventral surface of leaflet, paracytic stomata were abundant.

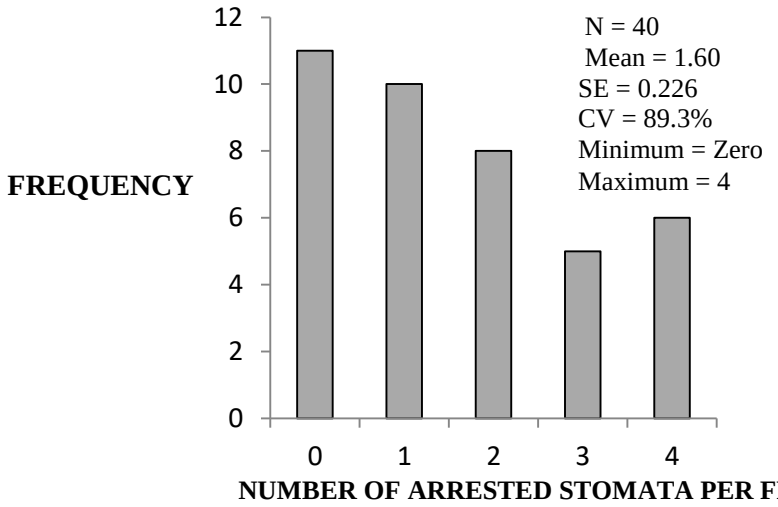


Fig.13. Frequency distribution of number of arrested stomata (stomatal cell not developing into guard cells) occurring in frames of vision (N = 40, magnification: 40 x 10 X) in an epidermal imprint of upper surface of young cotyledon (5-day old) of *A. lebbeck*. Around 27.5 % of frames showed no arrested stomata.

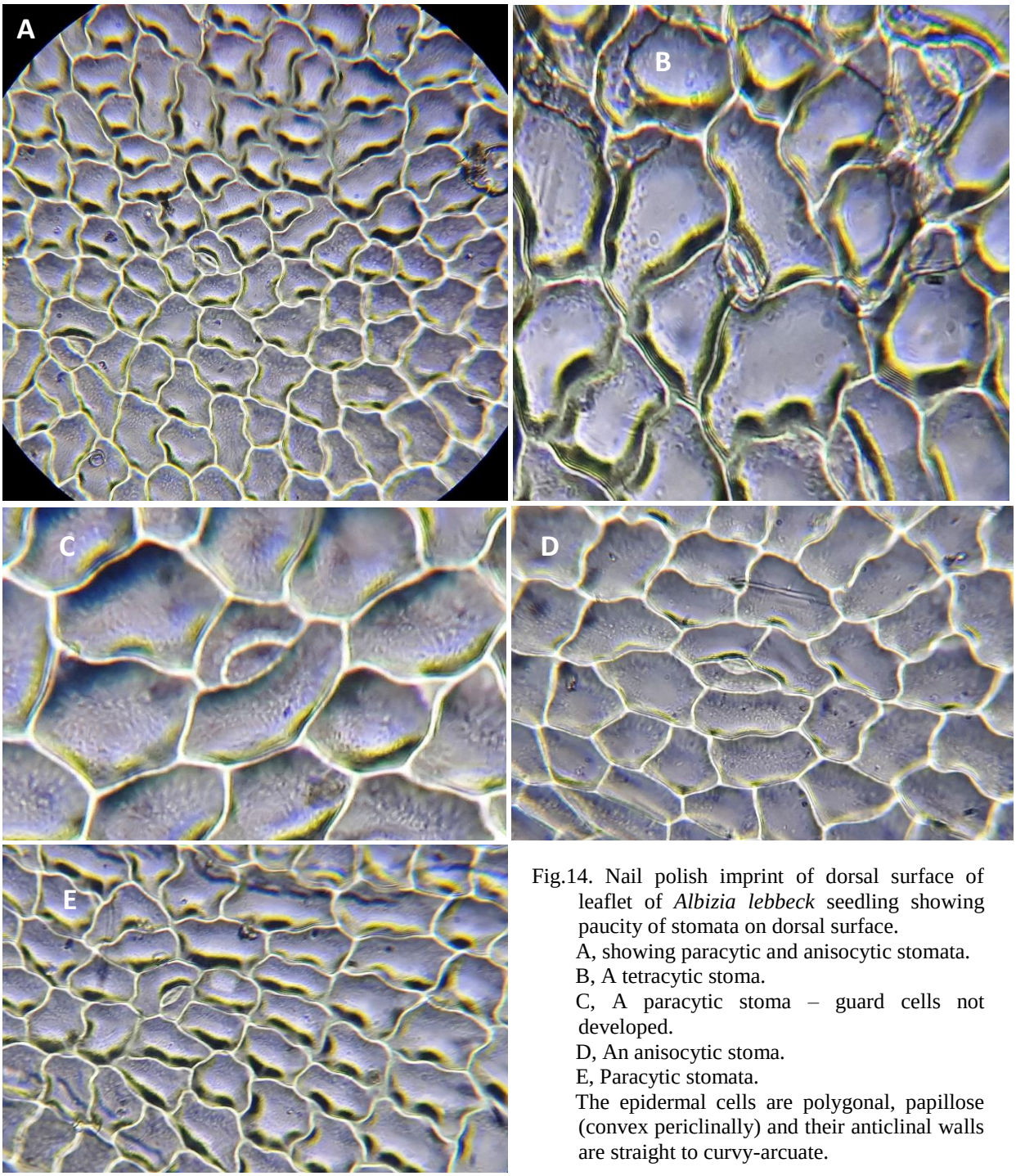


Fig.14. Nail polish imprint of dorsal surface of leaflet of *Albizia lebbeck* seedling showing paucity of stomata on dorsal surface.
A, showing paracytic and anisocytic stomata.
B, A tetracytic stoma.
C, A paracytic stoma – guard cells not developed.
D, An anisocytic stoma.
E, Paracytic stomata.
The epidermal cells are polygonal, papillose (convex periclinally) and their anticlinal walls are straight to curvy-arcuate.

Several species of family Mimosaceae are reported to bear paracytic stomata (Table 7) except *Mimosa invisa, M. pigra and M. pudica* which have been reported to have diacytic stomata (Edeoga *et al.*, 2008*)*. This appears to be a case of misidentification as a number of paracytic stomata may clearly be seen in Fig.1 and Fig. 2 in Edeoga *et al.* (2008) paper. Other Mimosa species such as *M. diplotricha*, *M. himalayana* and *M. pudica* from India have been reported to have paracytic stomata (Begum and Borthakur, 2013), besides few anomocytic stomata in *M. himalayana*. Some species of genus Acacia have paracytic stomata (*A. senegal* and *A. macrostachya*) and others anomocytic and anisocytic stomata (*A. albida*) and only anisocytic stomata (*A. sieberiana* var. *sieberiana*) (Abubakar and Yunusa, 1998). *Prosopis juliflora* and *P. cineraria* (family Mimosaceae) are reported to bear paracytic stomata and polyhedral epidermal cells with straight anticlinal walls in their leaves. The two stomatal

subsidiaries in *P. juliflora* are reported to be unequal (Robertson *et al.*, 2010). *Parkia clappertoniana* - Stomatal complex was predominantly paracytic with occasional occurrence of anomocytic stomata near the midrib. The oval stomata have conspicuous stomatal ledges (Partha and Rahaman, 1985). It appears that in *A. lebback* the basic primary stomatal type is paracytic type which in later course of time may change to anisocytic or anomocytic types due to the development of wall (s) within a subsidiary cell (Fig. 12B).

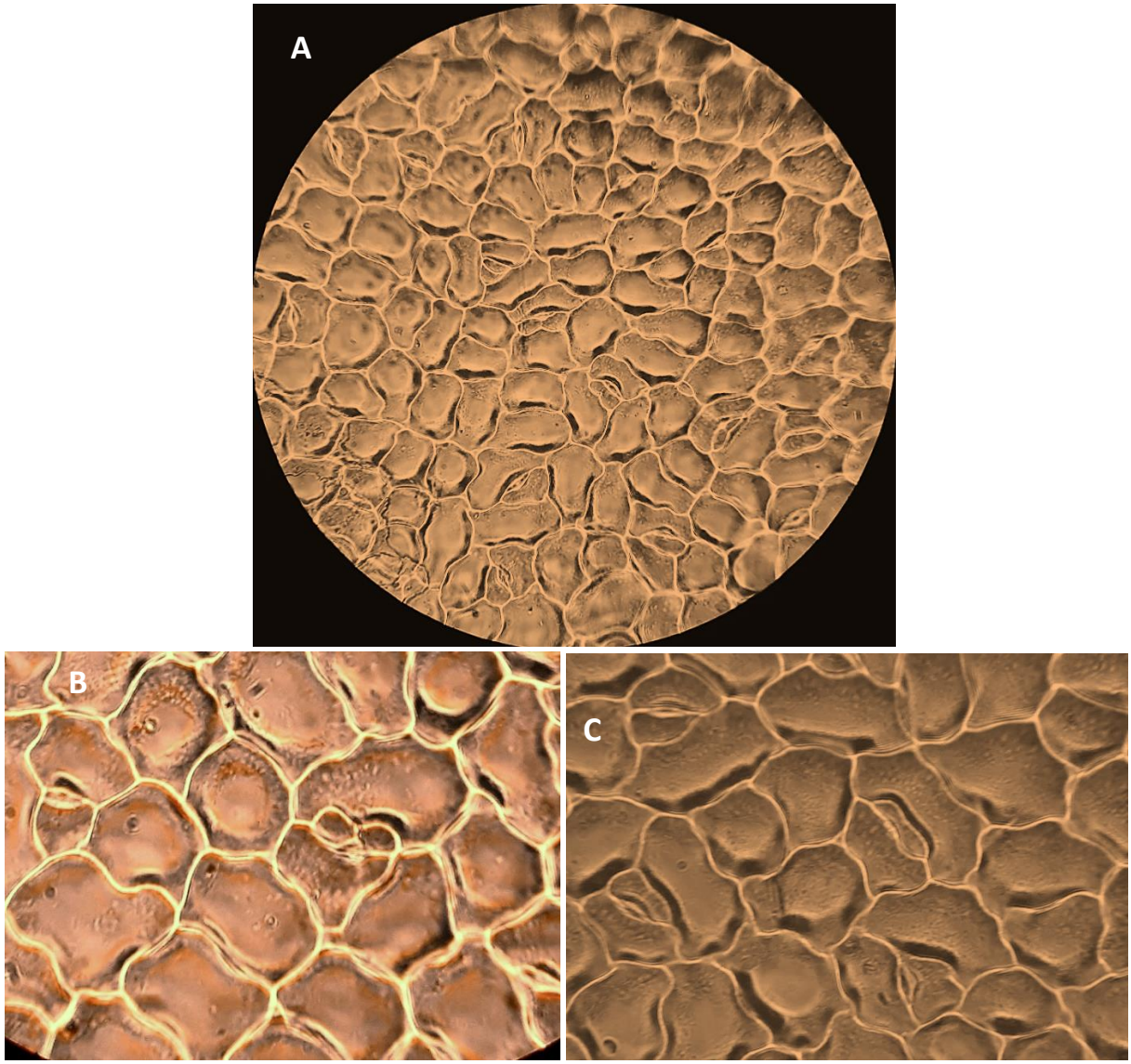


Fig. 15. Nail polish imprint of ventral surface of leaflet. Note, comparatively larger number of paracytic stomata (A). An abnormal paracytic stoma with two superposed stomatal cells (no guard cells) (B). A paracytic stoma bearing more or less dumb-bell shaped stomatal cell not developed in guard cells (C). The epidermal anticlinal walls are curvy with faint undulations.

The structure of stomata and trichomes on leaflets of 21 species of the Mimosaceae were described by Shah *et al.*, 1972). Non-glandular trichomes in *Mimosa pudica* were of three types: unicellular, with a rounded thick-walled base and a terminal unicellular body, and multicellular. Capitate, clavate, or cylindrical, 3–6-celled glandular hairs were observed on leaflets of *Mimosa pudica* only. Leaflets were amphistomatic in all species except *Adenanthera pavonia*, *Calliandra* sp., *Parkia biglandulosa*, *Pithecellobium dulce*, and *Samanea saman* in which they are hypostomatic. Only paracytic stomata are found in Leucaena leucocephala and Mimosa pudica. In the rest of the species stomata were of more than one type. In spite of the diversity, the most frequent type in these species is paracytic. Anisocytic stomata, in all cases, were described by Shah *et al.* (1972) to be secondarily-derived from paracytic ones by transverse or oblique wall formation in a subsidiary cell. This is explicit in *A. lebbeck* as well.

The studies in *C. fistula* seedlings (Khan and Zaki, 2019) also indicated that the basic type of stomata in this species appeared to be the one with paracytic arrangement of subsidiaries which may in later course of time turn into anisocytic type as a result of the development of a wall within a subsidiary. Such a structure by further development of cell walls may change to anomocytic type. Our results are in confirmation to the speculation made by Stace (1966). He wrote, *"It seems that many of the genera may have basically paracytic subsidiary cells but that extra walls have usually developed, thus giving the appearance of an anomocytic state. The reported occurrence of anomocytic, anisocytic and paracytic stomata on one leaf of Anopyxis (Boodle and Fritsch in Metcalfe and Chalk, 1950) is probably explicable in this way."*

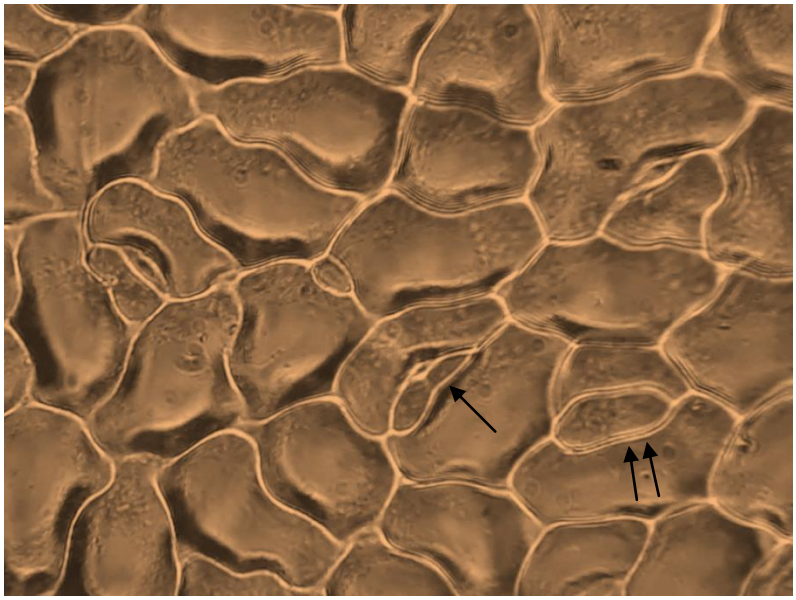


Fig. 16. Nail polish imprint of ventral surface of seedling leaflet. Stomata are in close proximity. Beside normal paracytic stomata an anisocytic stoma may also be seen in the mid region of the image. An adjacent paracytic stoma shows the budding of a cell from the large arrested pore apparatus (indicated by an arrow). Another stoma with large stomatal cell without differentiation of guard cells is shown by two parallel arrows. The contour of epidermal cells is straight to curvy.

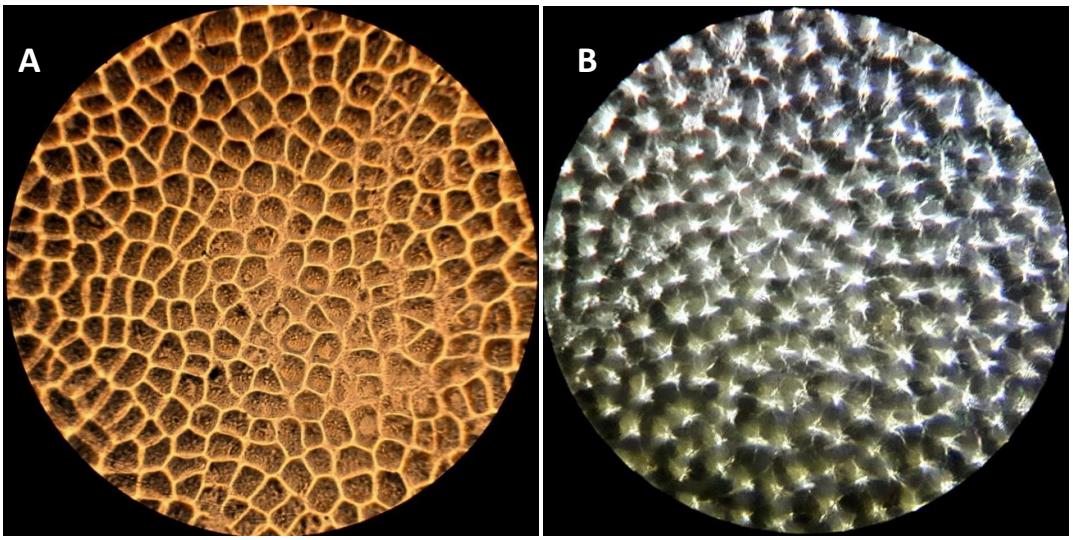


Fig.17. Nail polish imprint of dorsal surface of maturing leaflet of *A. lebbeck* tree collected from Oud Metha Park, Dubai. A, image showing the polygonal shape of epidermal cells with straight anticlinal walls; B, image focused to show the papillose (convex) nature of the epidermal cells. Deposition of cuticle appears to be on the apex of the cell first and then descending along the walls (see Fig. 18 D and E also).

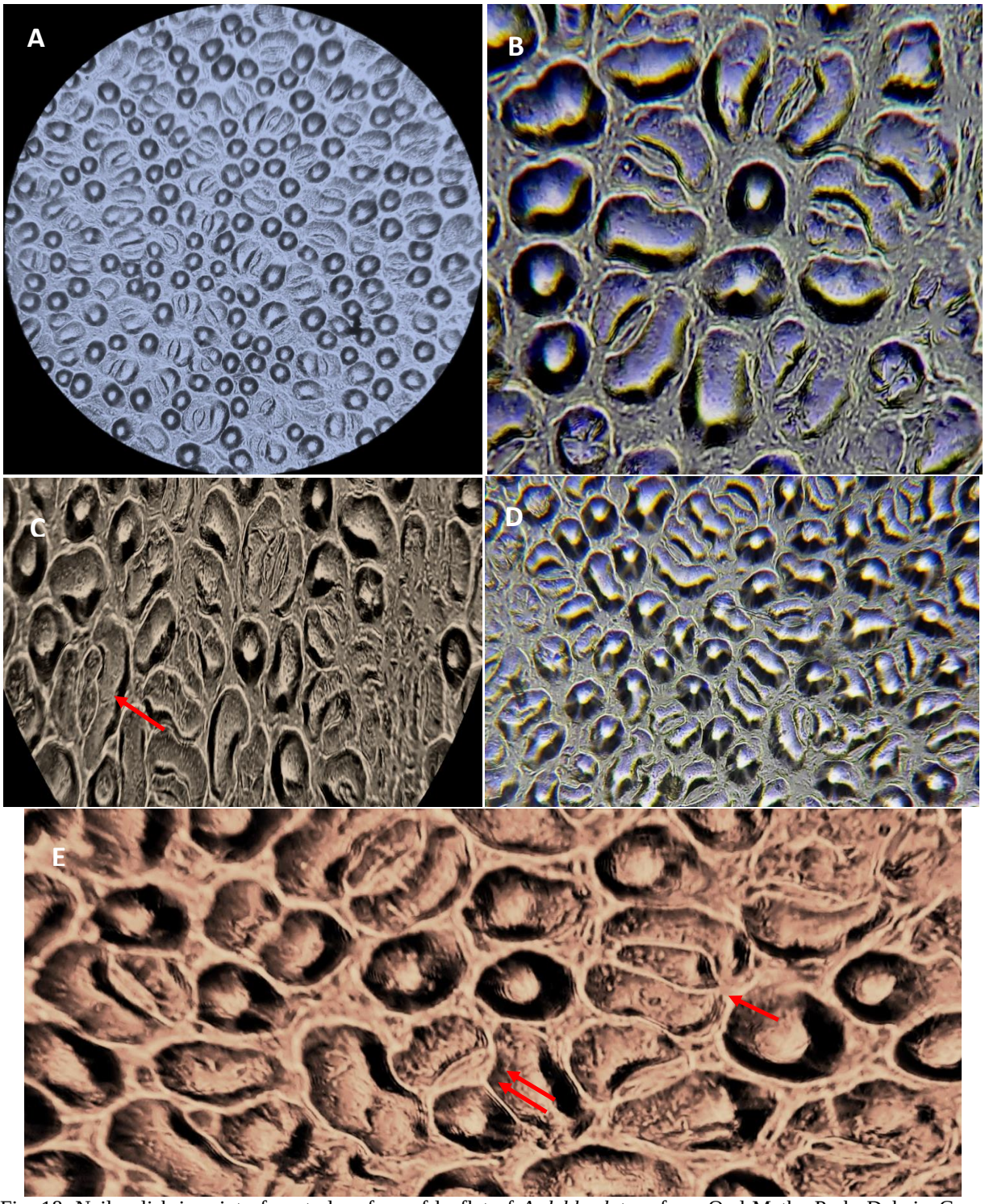


Fig. 18. Nail polish imprint of ventral surface of leaflet of *A. lebbeck* tree from Oud Metha Park, Dubai. General view of the surface showing paracytic stomata and papillose epidermal cells (Mag. 45 x 10 X). B, Stomata arranged in a ring around two papillose conical convex epidermal cells Max.: 45x10X, zoomed). There are also flat raised epidermal cells in view. C, Image showing deformation of pore – shown by an arrow (Mag.: 45x10X, Zoomed). D, A view of papillose (convex) epidermal cells showing cuticular deposition on top of cells and then descending along the walls (Mag.: 45x 10X, zoomed). E, A poreless stoma with arrested guard cell (shown by a single arrow) and anisocytic stoma (shown by double arrow) (Mag.: 45x10 X, zoomed).

Table 6. Diversity of stomatal types observed in seedlings of *Albizia lebbeck*.

Seedling organ	Stomatal type	Anticlinal cell wall
Hypocotyl surface (Fig. 9)	Anomocytic (six subsidiaries).	Straight
Cotyledon -5-day old seedling (Lower surface) - Fig. 10.	Anomocytic, paracytic, staurocytic and anisocytic stomata.	Straight
Cotyledon – 5-day old seedling (Upper surface) – Fig. 11 and 12.	Paracytic, Anisocytic, Paracytic with unequal obliquely placed guard cells, tetracytic and developing anomocytic stoma by lying down of cell walls in a subsidiary. Also paracytic and anisocytic stomata without guard cells.	Straight
Seedling Leaf let (Dorsal surface) - Fig. 14.	Paracytic, tetracytic, Anisocytic and several undifferentiated stomatal cells.	Curvy
Seedling Leaflet (Ventral surface) – Fig. 15 and 16.	Paracytic (Normal), Paracytic with large deformed stomatal cell (compressed in the middle), Paracytic stoma with two superposed stomatal cells, Paracytic stoma with budding stomatal cell and paracytic stoma without guard cells differentiation.	Curvy
Tree leaflet, Oud Metha, Dubai (Ventral surface) – Fig. 17 and 18.	Normal paracytic and anisocytic. Paracytic stoma with deformed stomatal cell (compressed in the middle) and paracytic stoma without guard cells differentiation.	Straight to Curvy

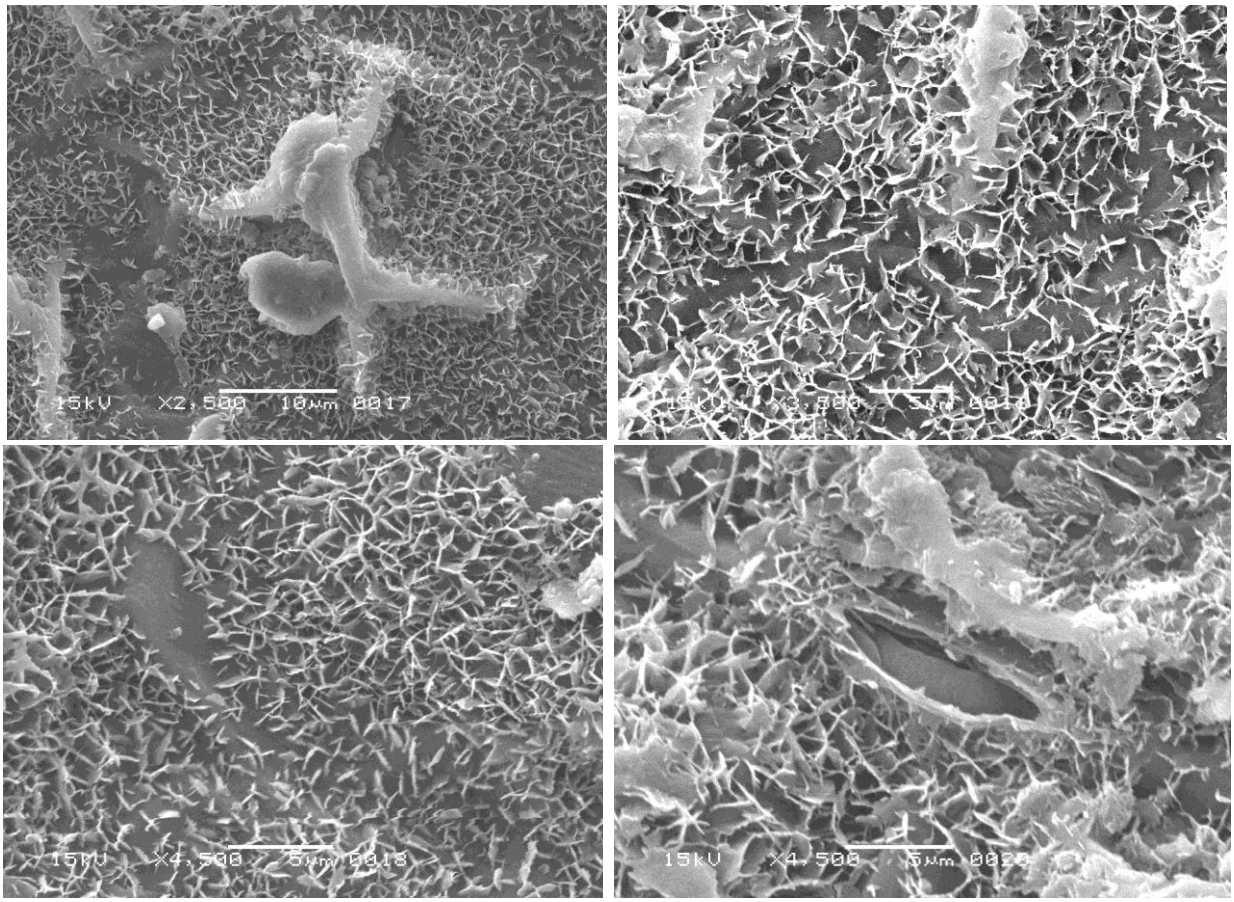


Fig. 19. SEM of surface of leaflet as viewed under various magnifications (2500, 3500, 4500 and 4500X – clockwise). Epicuticular wax crystalloids are dense all over the surface including outer stomatal ledges forming rosettes based on varying number of non-entire platelets (three or more). The platelets at times fuse to form lumps of various shape and size.

Table 7. Stomatal description of some Mimosacean species.

Species	Stomata type	Epidermal cell shape	Anticlinal wall contour	Reference	Country of cultivation
Acacia albida	Anomocytic, Anisocytic,	-	Straight	Abubakar and Yunusa (1998)	Nigeria
Acacia macrostachya	Paracytic, Hypostomatic	-	-		
Acacia sieberiana var. *sieberiana*	Anisocytic,	-	Undulate		
Acacia senegal	Paracytic,		Sinuous		
Adenanthera pavonia	Paracytic,	Irregular	Wavy	Partha and Rahaman (2015)	Bengal, India
Albizia lebbeck	Paracytic	Irregular	Wavy	Jasiem *et al.* (2019)	Iraq
Albizia lebbeck	Anomocytic, (Rare on adaxial surface)	Irregular, polygonal	-	Banerjee *et al.* (2004)	India
*Albizia lebbeck Seedlings**	Paracytic, Anisocytic, Anomocytic, tetracytic, Staurocytic and Abnormal paracytic Stomata (undifferentiated guard cells)	Irregular	Straight in cotyledons and curvy in the leaflet	Present study	UAE
Albizia lebbeck	Paracytic	Polygonal, Lower epidermis papillose	Wavy	Abdel-Ghani *et al. (*2015)	Egypt
Mimosa diplotricha var. *diplotricha*	Paracytic	Polygonal, irregular	Slightly, sinuate or arched , undulate	Begum and Borthakur (2013)	Assam, India
Mimosa himalayana	Paracytic, Few anisocytic	Tetrangular, Pentagular	Straight, arched, undulate		
Mimosa pudica	Paracytic	Polygonal, irregular	Slightly, sinuate or arched , undulate		
*Mimosa invisa***	Diacytic	Rectangular, Polygonal	-	Edeoga et *al.* {2008)	Nigeria
*Mimosa pigra***	Dicytic	Irregular	-		
Mimosa pudica **	Diacytic	Irregular	-		
Parkia clappertoniana	Paracytic, anomocytic	-	-	Oladale *et al.* (1985)	Nigeria
Prosopis cineraria	Paracytic	Polyhedral	Straight	Robertson *et al.*(2010)	UAE
Prosopis juliflora	Paracytic	Polyhedral	Straight		

*, organ-wise stomatal details is given in Table 5. **, Stomata are apparently misidentified since a number of paracytic stomata may be clearly seen in Fig. 1 and 2 of their referred paper.

Table 8. Stomatal density of *A. lebbeck* on dorsal and ventral surface of leaflets (c 2.0 x 0.6 cm in size).

Statistics	Seedling Leaflet		Cotyledon		Tree leaflet
	Dorsal surface	Ventral surface	Lower surface	Upper surface	Ventral
N	60	60	50	80	55
Mean	3.7678	156.936	14.744	93.990	164.23
SE	0.4487	5.266	1.439	2.119	9.6812
Median	-	152.349	9.829	98.289	157.2636
CV (%)	159.96	25.99	69.01	20.16	43.72
Minimum	zero	88.46	Zero	49.14	49.14
Maximum	19.96	265.38	39.32	147.43	422.65
G1	1.377	0.671	0.230	0.91	1.967
Sg1	0.309	0.309	0.337	0.337	0.310
G2	0.873	0.118	-0.638	0.079	5.175
Sg2	0.608	0.638	0.662	0.662	0.601
K-S t*	0.417	0.152	0.205	0.150	0.193
P	0.0001	0.002	0.0001	0.007	0.0001
Shapiro-Wilk test	0.638	0.953	0.902	0.635	0.809
P	0.0001	0.022	0.001	0.057	0.0001

Acronyms:
SE = Standard error of mean
CV (%) = Coefficient of variation (%)
G1 = Skewness
Sg1 = Standard error of skewness
G2 =Kurtosis
Sg2 = Standard error of Kurtosis
K-S t = Kolmogorov-Smirnoff test with
Lilliefors correction of significance (Test for normality)
Shapiro-Wilk test = test for normality testing.

p = probability of significance

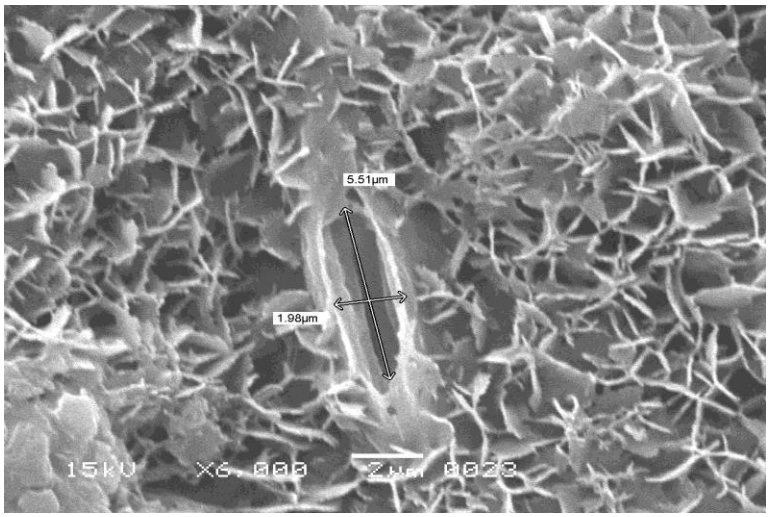


Fig. 20. Outer stomatal ledges are highly developed to form an incomplete dome. Epicuticular crystalloids in form non-entire platelets arranged in rosettes. B) Stomata are small, narrow and elongated – stomatal ledge aperture measuring 5.51 x 1.96µm in size. Magnification: 6000X.

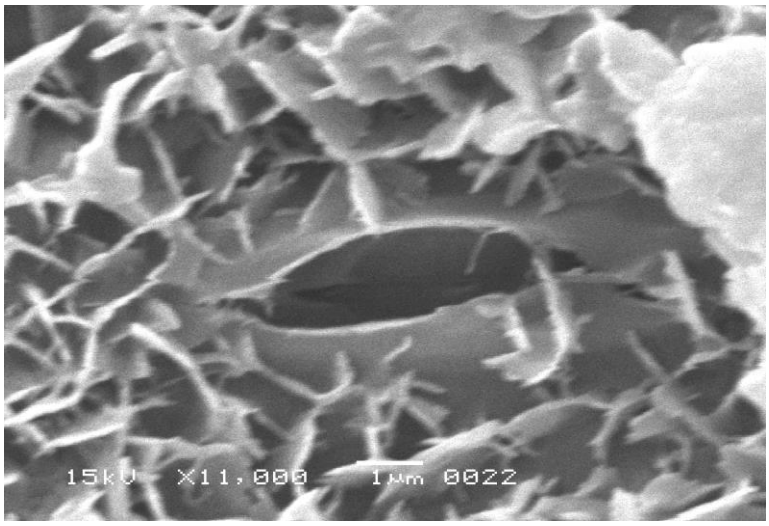


Fig. 21. SEM under high magnification of 11000X showing an incomplete dome formed by outer ledges of stoma with inner pore slit (black streak) and non-entire platelets even on the dome of stomatal outer ledges.

Density of cotyledonary and foliar stomata of seedlings and the parent tree

Stomatal density in *A. lebbeck* is presented in Table 8. Stomata were present on the both surfaces of the cotyledons but the stomatal density was quite low on the lower side 14.74 ± 1.44 per mm^2, N = 50) compared to that on the upper surface (93.99 ± 2.12 per mm^2, N = 80) exposed to sun. Around 81% of the cases the stomatal density on upper surface varied between 76 and 125 stomata per mm^2.

Stomata were rare on dorsal surface of seedling leaflet but moderate in number on ventral surface averaging to 156.96 ± 5.266 stomata per mm^2 varying around 25. 99%. There were no stomata on dorsal surface of leaflet of parent tree and on ventral surface stomatal density averaged to 164.23 ± 9.612 stomata per mm^2 with comparatively larger variation of 43.72%. At some places of lamina-island, the density was, however, quite high due to decrease in neighbourhood distances amongst stomata. In 72.8% of the observations, stomatal density varied between 101 and 200 stomata per mm^2. Al-Obaidy *et al.* (2019) have reported decline of stomatal density in *A. lebbeck* from 115.02 per mm^2 in unpolluted conditions to 92.50 per mm^2 under polluted conditions of SO_2: 0.465 ± 0.062 ppm, 0.33 – 0.63; NO_2: 0.648 ± 0.20 ppm, 0.20-1.23 and total sampled particulate matter: 173.63 ± 20.55 $\mu g/m^{-3}$ of Egypt. Stomatal density in the present case was, however, higher than that estimated by Al-Obaidy *et al.* (2019). This may presumably the result of very high transport density around Oud Metha Park, Dubai. Crispim *et al.* (1969) have reported increase in stomatal density under conditions of higher vehicular density. The results regarding variation in stomatal density reported under air pollution are not consistent. Gostin (2009) reported increase in stomatal size but increase in stomatal density in some Fabaceae species. Verma *et al.* (2006) reported significant decrease in stomatal density in *Ipomoea pes-tigridis* when exposed to coal smoke pollution. Aves *et al.* (2008) reported decrease in stomatal density in *Tillandsia unsneoides* exposed to air pollution in Sao Paulo city of Brazil. Similarly, in relation to air pollution, Sharma (1989) found decrease in stomatal in *Salix nigra* and *Quercus alba*. On the contrary, Evans *et al.* (1996) reported an increase in stomata in plants exposed to air pollutants. Larcher (2000) has suggested that increase in stomatal density is always followed by a reduction of stomatal size to maximize closure efficiency of stomata.

Stomatal size

Stomata in *A. lebbeck* seedling leaflet were quite smaller in size admeasuring 5.51 x 1.96 µm (Fig. 20) and averaged to 19.36 ± 0.36 x 6.62 µm on ventral surface of leaflet of the parent tree which happened to differ significantly from the stomatal size of 8.20 x 1.62 ± 0.19µm reported by Banerjee *et al.* (2004). Stomatal size in three species of *Mimosa* (stem genus of Mimosaceae) is reported from Assam (India) to be as follows (Begum and Borthakur, 2013) - *Mimosa diplotricha* var. *diplotricha* – Abaxial – 15.8 x 10.6 µm; Adaxial: 16.9 -13.3µm; M. *himalayana* – abaxial: 19.1 x- 10.6µm; Adaxial: 17.7 x 13.3 µm and M. *pudica*: Abaxial: 19.5 x 12.5 µm; Adaxial: 15.8 x 12.2 µm. The size statistics of *Mimosa* spp. appears to be comparable with that of *A. lebbeck*.

Abnormal stomata

Some stomatal aberrations were observed in *A. lebbeck* generally with respect to the stomatal cell. Stomata without guard cells differentiation (arrested development of guard cells) were observed on both surfaces of cotyledons (Fig. 11 and 12) and leaflet of seedling (Fig. 14, 15, 16) as well as on mature leaflet from the tree (Fig. 17, 18). Such stomata were sometimes larger in size and sometimes showed the stomatal cell compressed in the middle and even divided in two superposed more or less round cells due to faulty cell division (no guard cells differentiation). In addition to it, there was budding of a cell from the undifferentiated stomatal cell wall (Fig. 16). Frequency distribution of arrested stomata (without guard cells differentiation) on upper surface of young five-day old seedling in 40 frames of microscopic vision is presented in Fig. 13. Around 27.5% of the frames showed no arrested stomata while remaining 72.5% frames showed the occurrence of 1-4 stomata without guard cell differentiation per frame. Overall stomatal density of stomata with undifferentiated guard cells averaged to 16 stomata per mm^2 on upper surface of cotyledons of 5-day old seedling against the total stomatal density of 93.99 ± 2.12 stomata per mm^2. In normal course of stoma formation a pair of cells derived as a result of division of stomatal mother cell, develop into a pair of guard cells. In arrested stomata, stomatal mother cells do not develop into guard cells. Inamdar and Patel (1969) have reported stomata which were arrested in their development at various stages during their ontogeny - the arrested development of stomata is reported to be common on the mature epidermis of *Cestrum nocturnum* and *Withania somnifera* (Solanaceae). Sometimes, stomata may be poreless - two types of poreless stomata have been described by Takahashi (1962) in bracken fern. – Poreless epidermized stomata and poreless multicellular (multiple guard cells) stomata lacking pore.

Several environmental factors including humidity, temperature, drought, salinity, wounding, pathogens, stress-related molecules and hormones often bring changes in stomata. Humidity confers stomatal clustering (Beering and Chaloner, 1993; Casson and Gray, 2008; Lake and Woodward, 2008; Gan *et al.*, 2010; Zheng *et al.*, 2013). Stomatal abnormalities are suggested to be the result of environmental stress like drought and salinity (Gan *et al.*, 2010 and

CO_2 concentration and temperature (Beering and Chaloner, 1993). Warming may significantly decrease the average nearest neighbourhood distance between stomata (Zheng *et al.,* 2013). CO_2 concentration and temperature also affects the stomatal density.

Motor vehicles discharge a large amount of exhaust emission like Carbon monoxide, Sulphur dioxide, Nitrogen oxides, volatile organic compounds, aliphatic and polyaromatic hydrocarbons, heavy metals like lead and particulate matter in urban areas. Plants show diverse morphological, biochemical, anatomical and physiological responses to air pollutants. They have mutagenic and carcinogenic characteristics (Umbuzeiro *et al.,* 2008). Al-Obaidy *et al. (*2019) has reported that Air pollution decreases not only stomatal density but also the epidermal cell number in *A. lebbeck* but not the stomatal index when grown in the Baghdad city of Iraq.

The alteration of stomatal function or distribution is one of the many flexible processes that allow plants to minimize the impacts of a stressful environment. Light plays an important role in stomatal development. CO_2, similar to light plays a role in the regulation of both stomatal opening (Hashimoto *et al.,* 2006) and development (Gray *et al.,* 2000).

Stomatal development is a complex process. It has been reviewed by several researchers (Bergman *et al.,* 2007; Casson and Hetherington, 2010; Hepworth *et al.,* 2018; Pillitteri and Torii, 2012). At least 34 genes are known to be involved in this process (Pillitteri and Torii, 2012) in *Arabidopsis thaliana*.

Tradescantia is considered to be the most efficient and sensitive plant to biomonitor the genotoxic agents. *Tradescantia pallid*a was investigated in the city of Dourados (Mato Grosso do Sul State of Brazil) by Crispim *et al.* (2012) against a gradient of ~ 20 vehicle/ h to ~ 1900 vehicle / h transport density. Plants growing in localities with more vehicular traffic had greater quantity of micronuclei as well as higher stomatal density as compared to that in plants of lesser traffic indicating the presence of atmospheric contaminants that damaged their DNA. Similar results were reported earlier from Varanasi (India) by Prajapati and Tripathi (2008) in the presence of atmospheric contaminants – SO_2: 30µg /m^3 and Ozone: 60 µg /m^3. According to them NO_2 should not be higher than 30 µg/m^3 in the atmosphere.

Stomatal aberrations observed in the seedlings obtained from *A. lebbeck* of Oud Metha Park (Dubai) and the mother tree as well may probably be attributed to the adverse genotoxic effects of the vehicular exhaust pollution due to very high traffic density around the park on reproductive physiological and genetic processes of the plant which may be inherited by the seeds. The hypothesis needs further investigation.

Epicuticular wax crystalloids

Cuticular wax crystalloid forms seen on ventral surface of *A. lebbeck* leaf are presented in Fig. 19, 20 and 21. They were composed of irregular platelets (rosettes of platelets) as per terminology of Barthlott *et al.* (1998). The number of platelets per rosette varied quite substantially and appeared to fuse with each other forming lumps. Rosette type of epicuticular waxes pattern has also been reported in *Bauhinia fornicata* by Lusa and Bona (2009) and *Cassia fistula* (Khan and Zaki, 2019). This type of pattern of epicuticular waxes is also reported by Barthlott *et al.* (1998) in leguminous *Calliandra haematoma*. The rosette-like pattern is also referred to as "Faballes-type" (Ditsch *et al.,* 1995). Cuticular wax in *Trifolium pretense* and *T. hybridum* is also reported to be in form of platelets with irregular edges (Zoric *et al.,* 2009). Neves *et al.* (2016) have reported rosette type of epicuticular wax crystalloids from abaxial surface of *Dalbergia ecastaphyllum* leaf. Rosette pattern of wax crystalloids were also found in families Counaraceae, Malpighiaceae, Erythroxylaceae (Ditsch and Barthlott, 1997) and Asteraceae (Barthlott, 1998). Thirty-two species of genus *Gethyllis* studied for epicuticular wax morphology yielded quite diverse results (Weiglin, 2001) – Non-entire platelets were observed in 12 species, entire platelets with transitions to granules in 7 spp., membranous platelets in 9 spp. and smooth layer in 8 species. Weiglin (2001) suggested that epicuticular characteristics may be employed for further division of the genus. Non-entire plates have also been reported in *Odosicyos* spec. (Cucurbitaceae). Wax micromorphology bears close relationship with chemical composition and therefore significant meaning in the eco-hydrology of the plant (Baker, 1962; Meusel *et al.,* 1999).

The cuticles of plants provide a multifunctional interface between plants and their environments. The cuticle with its associated waxes forms a protective layer that minimizes water loss by transpiration and provides several functions such as hydrophobicity, light reflection and adsorption of harmful radiations. Wax coating shows self-healing of voids on the surfaces (Koch *et al.,* 2009). Epicuticular waxes bring the "lotus effect" i.e. cleansing effect of leaves from debris (Barthlott and Neinhuis, 1997). Leaf epicuticular wax is considered to be an antixenotic factor in Brassicaceae for flea beetle (*Phyllotreta cruciferae*) rate and pattern of feeding (Badnaryk, 1992). In *Leucadendron lanigerum* (Proteaceae), it has been suggested that the presence of wax on epidermis and at the entrance of the stomata, in addition to restricting water loss, may also provide some protection against photodamage. The leaves of this plant show seasonal modification of epicuticular surface wax transformation from plate form into a flattened form. The reflectance of light from leaves of *L. lanigerum* was recorded to be 4% greater than that in leaves without wax (Afshar-Muhammadian (2005).

Wax composition of a species may vary for different parts of the same plant and also with season, locality and age of the plant (Tomaszewski and Zielińsky, 2014; Eglinton and Hamilton, 1967). The occurrence of well-formed epicuticular waxy pattern on leaflets of *A. lebbeck* seedlings indicates that formation of waxy encrustation starts quite early in the life of plants. This agrees with Tomaszewski and Zielińsky (2014).

Variation of form of foliar epicuticular waxy crystalloids is reported from *Phormium tenax* cultivars which may be useful as a diagnostic tool in cultivar identification (Carr *et al.,* 2009). They have, however, pointed out that it remains to be determined whether a given cultivar growing at different locations could retain the wax crystal morphology. Various species of genus *Albizia* may be investigated for their epicuticular wax morphology and composition.

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