CANOPY CHARACTERISTICS, STOMATAL ANATOMY AND TRANSPIRATION RATE IN SOME SHADE PLANTS

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ABSTRACT

Twenty shade trees namely *Daniellia oliveri, Azadirachta indica, Albizia lebbeck, Citrus sinensis, Citrus limon, Citrus reticulata, Citrus paradisi, Blighia sapida, Plumeria alba, Thevetia neriifolia, Terminalia catappa, Tectonia grandis, Mangifera indica, Delonix regia, Parkia biglobosa, Anacardium occidentale, Vitellaria paradoxa, Gmelina arborea, Acacia auriculiformis* and *Bridelia ferruginea* were studied to determine their canopy characteristics in relationship to stomatal features possessed and rate at which they transpire. The canopy characteristics vary in all species with *T. catappa* having widest canopy density (*CD*) and *T. neriifolia* with narrowest *CD*; leaf density (*LD*) is higher in *D. regia* and lower in *T. grandis*. Thirty five stands of each species were studied for canopy characteristics. In each species a total of 700 leaves and 1200 leaf segments were taken and observed anatomically to reveal stomatal features possessed by each of these trees. Some correlations were observed to occur between stomatal features and rate of transpiration; for instance, *T. catappa* and *A. auriculiformis* that possessed amphistomatic leaves with heterogeneous stomatal complex types (*SCT*s) transpired faster more than species such as *T. grandis, M. indica, A. occidentale* and *V. paradoxa* with hypostomatic leaves and homogeneous *STC*. Based on *CD, TR* and *LD*, the most preferable shade plants are *A. indica, D. oliveri, A. lebbeck, D. regia, A. auriculiformis* and *T. catappa*.

Keywords: canopy characteristic, environment, shade plants, stomata, transpiration

INTRODUCTION

The need for planting trees around houses, school environments, along major cities, recreation centres and other places is for many purposes among which include erosion controls like acting as wind break, soil protection, cleansing of atmosphere by accumulation of pollutants like carbon IV oxide, and provision of shade against sun and rain. Plants with dense canopy are usually used as shade plants. A plant that can effectively serve as a shade plant must possess many branches arising from a trunk, particularly; there must be dense leaves on such plant. This is to say that a plant with many branches but with loosely arranged leaves will not be considered as a shade plant because this gives room for much penetration of sun rays and raindrops.

Shade plants are primarily for people's relaxation either in front or at the back of the house but they can also be used to mitigate negative effects of the climate change. Afforestation programme and planting of ornamental plant species are some of the measures to actively control or reduce accumulation of greenhouse gases like carbon (IV) oxide in the atmosphere (AbdulRahaman and Oladele, 2008). As a means of effectively mitigating climate changes, especially in Africa, plants with high number of subsidiary cells on stomata complex types (*SCT*s) like tetracytic and anomocytic types open more often for transpiration as well as to allow influx of carbon (iv) oxide into the leaves for photosynthesis thus, cleansing the atmoshpehre (Obiremi and Oladele, 2001; Oladele, 2002; Oyeleke *et al*., 2004; AbdulRahaman and Oladele, 2008; AbdulRahaman and Oladele, 2009; Saadu *et al*., 2009). Consequently, these plants humidify the atmosphere with water vapour (Encarta, 2007; AbdulRahaman and Oladele, 2008).

In this study, canopy characteristics such as canopy density (*CD*), height of tree (TH), height of trunk (*HT*), trunk diameter (*DT*), number of main branch (*NMB*) and length of petiole (*LP*) as well as stomatal features like stomatal complex types (*SCT*), stomatal density (*SD*), stomatal index (*SI*) and stomatal size (*SS*), and transpiration rates (*TR*) in twenty shade plant species were studied in order to elucidate cooling effects of these trees. Attempt was made to relate canopy characteristics to the stomatal features and transpiration rate in the twenty species studied.

MATERIALS AND METHODS

Collection of Specimens

Leaves of some shade plants were collected from various parts of Kwara State, Nigeria (Table 1; Plate A). The plants were identified and kept for documentation at the Herbarium of Department of Plant Biology, University of Ilorin, Ilorin. Kwara State, Nigeria.

Table 1: Botanical and family names and place of collection of some shade plants studied

Species	Family	Place of collection
Acacia auriculiformis	Fabaceae	Armti, Ilorin
Albizia lebbeck	Mimosaceae	Kwara Polytechnic, Ilorin
Anacardium occidentale	Anacardiaceae	Tanke, Ilorin
Azadirachta indica	Meliaceae	Tanke, Ilorin
Blighia sapida	Sapindaceae	G.R.A, Ilorin
Bridelia ferruginea	Euphorbiaceae	University of Ilorin, Ilorin
Citrus sinensis	Rutaceae	Offa
Citrus limon	Rutaceae	Offa
Citrus reticulata	Rutaceae	Offa
Citrus paradisi	Rutaceae	Offa
Daniellia oliveri	Ceasalpinaceae	University of Ilorin, Ilorin
Delonix regia	Ceasalpinaceae	Kwara Polytechnic, Ilorin
Gmelina arborea	Vertaceae	Kwara Polytechnic, Ilorin
Mangifera indica	Anacardiaceae	University of Ilorin, Ilorin

Parkia biglobosa	Mimosaceae	Kwara Polytechnic, Ilorin
Plumeria alba	Apocynaceae	University of Ilorin, Ilorin
Tectonia grandis	Verbanaceae	Armti, Ilorin
Terminalia catappa	Combretaceae	University of Ilorin, Ilorin
Thevetia neriifolia	Apocynaceae	G.R.A, Ilorin
Vitellaria paradoxa	Sapotaceae	University of Ilorin, Ilorin

Plate A: Photographs of *Daniellia oliveri* (1), *Azadirachta indica* (2), *Albizia lebbeck* (3), *Citrus sinensis* (4), *Citrus limon* (5), *Citrus reticulata* (6), *Citrus paradisi* (7), *Blighia sapida* (8), *Plumeria alba* (9), *Thevetia nerifolia* (10), *Terminalia catappa* (11), *Tectonia grandis* (12), *Mangifera indica* (13), *Delonix regia* (14), *Parkia biglobosa* (15), *Anacardium occidentale* (16), *Vitellaria paradoxa* (17), *Gmelina arborea* (18), *Acacia auriculiformis* (19) and *Bridelia ferruginea* (20).

Crown Diameter (*CD*)
To determine the *CD*, two measurements per tree were taken at plane parameter to each other. The mean diameter per tree was calculated using the formula: d1 + d2 / 2 = D.
Where d1 and d2 = measurement along perpendicular planes.
D = the average crown diameter

Area of Canopy (*CA*)
The *CA* was determined by calculating from the density of leaves with the formula: $D^2 \times ¾$.
Where D = density of leaves.

Number of Main Branches (*NMB*)
The *NMB*s on 30 trees were counted and the mean number determined for each tree species.

Density of Leaves (*LD*)
*LD*s were determined by placing the 25cm × 25cm quadrant over a certain area of the tree, then the leaves within the quadrant were counted.

Length of Petiole (*LP*)
The *LP*s was measured from every tree by using measuring tape.

Area of Leaf (*LA*)
The *LA* was determined by using the formula: L × B × K (Franco, 1939).
Where L = Length
B = Breadth
K = Franco's constant = 0.79

Height of Tree (*TH*)
The *TH* was determined by using improvised altimeter (Bennett and Hemphries, 1974). This was measured by putting the altimeter at eye level and ensuring that the vertical point is perpendicular to the ground surface, then look through the straw to the tree top, the point at which the feet is to the tree was measured. Then, the height of the measurer would be measured and added to the distance between the feet and the base of the tree. This was sum up to give the tree height.

Height of trunk (*HT*)
The *HT* was determined by measuring from the ground to the point where the tree spilt into branches.

Diameter of Trunk (*DT*)
The diameter of the girth at the breast height was measured using measuring tape.

Determination of Transpiration rate (*TR*)

A Cobalt Chloride paper method was used to determine the *TR* of each specimen (Obiremi and Oladele; Dutta, 2003). Stripes of filter paper of 2cm × 6cm dimension was cut and immersed in 20% Cobalt Chloride solution. The stripes were thoroughly dried in an oven. The property of Cobalt paper is that they are deep blue when dried, but in contact with moisture, they turn pink. The blue, dried strips were placed in a sealed, air tight polythene bag and weighed (W1) using mettler balance. It was transferred quickly to the plastic containers and affixed with a string to the marked small branch (of the plant) with leaves. Two dried Cobalt paper was placed on the leaf, one on the upper and the other one on the lower surface of a thick healthy leaf and would be covered completely with glass slides this is to determine transpiration rate from the two surface of a dorsiventral leaf (Dutta, 2003). The time (in seconds) taken for the strips to turn pink was noted.

Once turned pink, the bag was quickly untied and sealed again, and transferred to the laboratory and weighed (W2). Weight of water transpired was determined as W2 minus W1. The surface area of leaves used was measured (i.e as described for the mean leaf area above). *TR* was expressed as $mol/m^{-2}/sec^{-1}$

Anatomical Study of the Leaf Epidermis

Isolation of leaf epidermal layers

In each species a total of 700 leaves and 1200 leaf segments were used for anatomical studies. Leaf segment of an area of 1cm square from each specimen was cut and immersed in concentrated solution of nitric acid or trioxonitrate (v) acid for maceration. The upper (adaxial) and lower (abaxial) surfaces were separated with dissecting needle and forceps, and rinsed with clean water.

Determination of Frequency of Stomatal Complex Types (*SCT*)

Using 35 fields of view at X40 objective as quadrats, the number of subsidiary cells per stoma was noted to determine the frequency of the different *SCT*s present in each specimen. Frequency of each *SCT* was expressed as percentage occurrence of such complex type based on all occurrences (Obiremi and Oladele, 2001). Terminologies for naming *SCT*s followed those of Dilcher (1974).

Determination of Stomatal Density (*SD*) and Index (*SI*)

The *SD* was determined as the number of stomata per square millimeter (Stace, 1965).

The *SI* was determined as follows: *SI* = S/E + S × 100.

Where SI = Stomatal index

S = Number of stomatal per square millimeter

E = Number of ordinary epidermal cells per square millimeter

Determination of Stomatal Size (*SS*)

The mean *SS* of a species was determined by measuring length and breadth of guard cells using an eye piece micrometer. A sample of 35 stomata was used. The method follows those of Franco (1939) and Wilkinson (1979).

SS = L x B x K
Where L = Length
B = Breadth
K = Franco's constant = 0.78524

Statistical Analysis
All data were reported and analyzed using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT). Computer software was used. A probability value 0.05 was used as bench mark for significant difference between parameters.

RESULTS
Acacia auriculiformis
Presence of very wide crown diameter, high density of leaves, high height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on both the abaxial and adaxial surfaces. Anomotetracytic, paracytic, tetracytic and anomocytic stomata complex types were found to be present on the abaxial surface while tetracytic and paracytic were present on the adaxial surface (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is very high in this species (Table 3).

Albizia lebbeck
Presence of very wide crown diameter, very high density of leaves, moderate height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic and tetracytic (Table 3; Figure 1). The epidermal cells on the abaxial surface are isodiametric while wavy is present on the adaxial surface. The transpiration rate is very high in this specie (Table 3).

Anacardium occidentale
Presence of very wide crown diameter, low density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on the abaxial surface are isodiametric while pentagonal is present on the adaxial surface. The transpiration rate is high in this species (Table 3).

Azadirachta indica
Presence of very wide crown diameter, high density of leaves, moderate height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be hexagonal. The transpiration rate is very high in this species (Table 3).

Blighia sapida
Presence of wide crown diameter, low density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex types present are anomocytic and staurocytic (Table 3; Figure 1). The epidermal cells on the abaxial surface are pentagonal while wavy is present on the adaxial surface. The transpiration rate is very high in this specie (Table 3).

Bridelia ferruginea
Presence of very wide crown diameter, low density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on both the abaxial and adaxial surfaces. Tetracytic and paracytic stomata complex types were found to be present on the abaxial surface while paracytic were present on the adaxial surface (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is very high in this species (Table 3).

Citrus sinensis
Presence of low crown diameter, high density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is very high in this species (Table 3).

Citrus limon
Presence of very wide crown diameter, high density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on the abaxial surface are pentagonal while hexagonal is present on the adaxial surface. The transpiration rate is very high in this species (Table 3).

Citrus reticulata
Presence of low crown diameter, high density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is high in this species (Table 3).

Citrus paradisi
Presence of very wide crown diameter, high density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is very high in this species (Table 3).

Daniellia oliveri

Presence of very wide crown diameter, low density of leaves, high height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is high in this species (Table 3).

Delonix regia

Presence of very wide crown diameter, high density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex types present are anomocytic and paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be wavy. The transpiration rate is low in this species (Table 3).

Gmelina arborea

Presence of very wide crown diameter, low density of leaves, high height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on both the abaxial and adaxial surfaces. The stomata complex type present is paracytic (Table 3; Figure 1). The transpiration rate is low in this specie (Table 3).

Mangifera indica

Presence of very wide crown diameter, low density of leaves, moderate height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on the abaxial surface are hexagonal while wavy is present on the adaxial surface. The transpiration rate is high in this species (Table 3).

Parkia biglobosa

Presence of very wide crown diameter, high density of leaves, high height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on both the abaxial and adaxial surfaces. The stomata complex type present on both surfaces is paracyic (Table 3; Figure 1). The epidermal cell on the abaxial surface is pentagonal while hexagonal is present on the adaxial surface. The transpiration rate is low in this species (Table 3).

Plumeria alba

Presence of wide crown diameter, low density of leaves, moderate height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is high in this species (Table 3).

Tectonia grandis

Presence of wide crown diameter, low density of leaves, high height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be isodiametric. The transpiration rate is low in this species (Table 3).

Terminalia catappa

Presence of very wide crown diameter, low density of leaves, high height of tree, high height of trunk and wide diameter of trunk (Table 2). Stomata are present on both the abaxial and adaxial surfaces. Anisocytic, tetracytic and paracytic stomata complex types were found to be present on the abaxial surface while tetracytic were present on the adaxial surface (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be wavy. The transpiration rate is very high in this species (Table 3).

Thevetia neriifolia

Presence of low crown diameter, high density of leaves, moderate height of tree, high height of trunk and narrow diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on the abaxial surface are wavy while pentagonal is present on the adaxial surface. The transpiration rate is high in this species (Table 3).

Vitellaria paradoxa

Presence of low crown diameter, low density of leaves, high height of tree, moderate height of trunk and wide diameter of trunk (Table 2). Stomata are present on the abaxial surface and absent on the adaxial surface. The stomata complex type present is paracytic (Table 3; Figure 1). The epidermal cells on both the abaxial and adaxial surfaces were found to be pentagonal. The transpiration rate is high in this specie (Table 3).

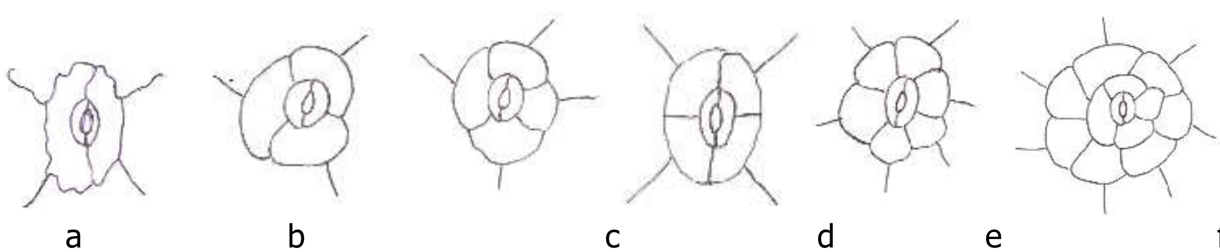

Figure 1: Diagrammatic sketches of leaf surface of *Acacia auriculiformis* showing paracytic, tetracytic, anomocytic and anomotetracytic stomata (a, c, e and f), *Albizia lebbeck* showing paracytic and tetracytic stomata (a and c), *Anacardium occidentale* showing paracytic stomata (a), *Azadirachta indica* showing paracytic stomata (a), *Blighia sapida* showing staurocytic and anomocytic stomata (d and e), *Bridelia ferruginea* showing paracytic and tetracytic stomata (a and c), *Citrus limon* showing paracytic stomata (a), *Citrus paradisi* showing paracytic stomata (a), *Citrus reticulata* showing paracytic stomata (a), *Citrus*

sinensis showing paracytic stomata (a), *Daniellia oliveri* showing paracytic stomata (a), *Delonix regia* showing paracytic and anomocytic stomata (a and e), *Gmelina arborea* showing paracytic stomata (a), *Mangifera indica* showing paracytic stomata, *Parkia biglobosa* showing paracytic stomata (a), *Plumeria alba* showing paracytic stomata (a), *Tectonia grandis* showing paracytic stomata (a), *Terminalia catappa* showing paracytic, anisocytic, tetracytic stomata (a, b and c), *Thevetia neriifolia* showing paracytic stomata (a) and *Vitellaria paradoxa* showing paracytic stomata (a) X1200

Table 2: Canopy characteristics of some shade plants

Species	Crown Diameter (cm)	No of Main Branches	Density of leaves (m^{-2})	Length of Petiole (cm)	Height of tree (cm)	Height of trunk (cm)	Diameter of trunk (cm)
Acacia auriculiformis	1049.67±293.15	2.21±0.41	149.60±10.84	1.27±0.58	1087.00±109.12	128.10±34.92	123.37±40.01
Albizia lebbeck	1502.0±197.79	3.13±0.73	386.50±99.92	12.58±3.09	927.20±217.53	161.33±53.16	234.40±41.38
Anarcadium occidentale	1287.62±268.19	3.33±0.88	42.60±4.56	1.48±0.46	636.43±95.75	83.93±23.79	260.47±74.47
Azadirachta indica	1560.13±111.71	3.07±0.69	187.83±34.06	0.6767±0.21	687.70±137.60	118.87±45.36	190.87±32.29
Blighia sapida	1056.32±369.44	3.10±1.03	36.17±11.44	1.03±0.59	695.23±110.62	94.47±17.17	248.53±59.48
Bridelia ferruginea	1434.78±195.58	2.43±0.50	38.77±4.99	10.83±2.67	688.37±96.63	75.37±19.43	312.53±80.23
Citrus limon	1406.52±334.24	3.07±0.74	139.70±26.00	4.37±1.43	482.73±78.91	64.07±17.88	191.97±76.78
Citrus paradisi	1225.13±262.09	3.34±0.82	158.07±21.25	3.42±0.72	498.40±85.72	68.27±16.59	219.48±20.87
Citrus reticulata	926.33±259.02	3.37±0.56	163.33±14.97	2.93±0.78	476.40±75.73	66.57±17.59	128.80±21.22
Citrus sinensis	702.07±182.59	2.60±0.49	168.40±27.97	5.43±1.16	509.00±120.59	58.33±15.77	222.13±90.97
Daniellia oliveri	1568.58±251.55	2.70±0.70	53.00±14.15	9.80±1.99	1140.77±127.05	182.77±69.13	287.30±67.57
Delonix regia	1613.27±335.39	3.50±0.68	1096.30±211.08	21.27±3.68	438.13±82.26	99.57±35.12	231.03±66.98
Gmelina arborea	1613.27±335.59	2.73±0.91	33.63±5.69	34.08±5.31	1029.20±201.03	108.43±41.51	394.17±186.19
Mangifera indica	1217.23±383.75	3.90±0.71	49.37±9.53	32.11±6.22	631.40±104.71	90.03±36.11	270.93±98.11
Parkia biglobosa	1992.25±272.66	3.30±0.59	576.63±124.14	22.27±4.22	935.63±192.93	143.03±56.97	330.6±88.94

Plumeria alba	1039.57±225.97	3.42±0.49	34.53±5.37	71.63±22.72	687.47±780.72	101.80±33.80	157.07±51.43
Tectonia grandis	1082.93±186.33	3.43±0.63	8.27±1.89	5.03±1.03	1063.77±130.04	117.53±57.82	103.0±44.39
Terminalia catappa	2278.50±160.91	3.37±0.49	32.53±4.33	5.53±1.67	1040.83±135.30	171.23±51.77	200.57±42.52
Thevetia neriifolia	554.33±67.92	3.57±0.63	151.97±16.27	0.34±0.14	538.6±93.18	56.73±8.59	47.60±15.11
Vitellaria paradoxa	894.53±110.89	3.03±0.56	69.47±9.42	11.9±2.34	809.63±195.46	74.33±12.71	143.73±44.31

Table 3: Stomatal features and transpiration rates in some shade plants

Species	Leaf Surface	Stomata Complex Types (SCT)	Frequency (%age)	Stomata Density (*SD*) (mm-2)	Stomata Size (*SS*) (μm)	Stomata Index (*SI*) (%age)	Transpiration rate (*TR*) $(mol/m^{-2}/s^{-1})$
Acacia auriculiformis	Abaxial	Anomotetracytic	9.28	21.35d	73.75c	8.44d	6.62×10^{-6} a
		Paracytic	10.06				
		Tetracytic	50.25				
		Anomocytic	30.41				
	Adaxial	Tetracytic	71.62	8.62g	58.32e	6.93fg	2.67×10^{-6} a
		Paracytic	28.48				
Albizia lebbeck	Abaxial	Paracytic	58.62	17.50e	32.69g	4.21h	3.69×10^{-6} a
		Tetracytic	32.14				
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Anacardium occidentale	Abaxial	Paracytic	100.00	24.33d	73.71c	6.98fg	2.67×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Azadirachta indica	Abaxial	Paracytic	100.00	30.33bc	52.14ef	29.62b	3.35×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Blighia sapida	Abaxial	Anomocytic	68.00	22.67d	42.62f	8.63d	3.21×10^{-6} a
		Staurocytic	32.00				
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Bridelia ferruginea	Abaxial	Tetracytic	40.38	12.22f	51.68ef	7.94d	3.52×10^{-6} a
		Paracytic	59.62				
	Adaxial	Paracytic	100.00	15.75e	48.58f	6.32g	2.16×10^{-6} a
Citrus limon	Abaxial	Paracytic	100.00	26.52c	30.29g	9.30d	3.61×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil

Citrus paradisi	Abaxial	Paracytic	100.00	32.33b	39.18fg	25.11b	3.86×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Citrus reticulata	Abaxial	Paracytic	100.00	24.00d	38.29fg	7.48df	2.76×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Citrus sinensis	Abaxial	Paracytic	100.00	36.00b	36.39g	26.40b	3.20×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Daniellia oliveri	Abaxial	Paracytic	100.00	40.33a	137.30b	36.40a	1.84×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Delonix regia	Abaxial	Anomocytic	39.54	8.25g	46.99f	9.25d	3.30×10^{-7}b
		Paracytic	60.46				
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Gmelina arborea	Abaxial	Paracytic	100.00	9.75g	43.35f	8.43d	8.53×10^{-7} b
	Adaxial	Paracytic	100.00	2.20h	22.17	3.08	7.62×10^{-7} b
Mangifera indica	Abaxial	Paracytic	100.00	28.00c	62.57de	17.72c	2.85×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Parkia biglobosa	Abaxial	Paracytic	100.00	17.75e	68.63cd	7.02f	8.94×10^{-7} b
	Adaxial	Paracytic	100.00	9.28	53.60ef	4.01h	6.37×10^{-7} b
Plumeria alba	Abaxial	Paracytic	100.00	15.00e	152.21a	4.56h	2.65×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Tectonia grandis	Abaxial	Paracytic	100.00	16.67e	50.48f	3.29h	6.42×10^{-7} b
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Terminalia catappa	Abaxial	Anisocytic	17.14	9.00g	66.17c	6.23g	4.65×10^{-6} a
		Tetracytic	50.00				
		Paracytic	32.86				
	Adaxial	Tetracytic	100.00	12.03f	47.50f	5.54g	2.12×10^{-6} a
Thevetia nerifolia	Abaxial	Paracytic	100.00	15.75e	48.58f	6.32g	2.16×10^{-6} a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil
Vitellaria paradoxa	Abaxial	Paracytic	100.00	27.00c	61.55cd	19.84c	2.84×10^{-6}a
	Adaxial	Nil	Nil	Nil	Nil	Nil	Nil

Means with same letters are not significantly different at $p < 0.05$

DICUSSION

A morphological survey of the twenty shade species (Table 1) was conducted in order to identify some characteristics of their canopies which could make them suitable for use as shade plants. In selecting a plant as shade plant or as cover plant for the soil as against erosion among other features, it must possess wide crown diameter, wide canopy area, high number of main branches arising from the stem, high leaf area, high leaf density which reduces the penetration of direct sunlight and raindrops and low tree height and short petioles for firm grip of leaves (Finnigan and Raupach, 1987).

Canopy characteristics

Based on the parameters observed in this study, *T. catappa* has the widest canopy while *T. neriifolia* has the narrowest canopy as seen from Table 2. The wide canopy in *T. catappa* was also confirmed by AbdulRahaman and Oladele (2010). Density of leaf (*LD*) is highest in *D. regia* and it is lowest in *T. grandis;* canopy of *D. regia* will provide more shade by blocking penetration of sun rays and rain drops than in all other species while *T. grandis* would be more susceptible to sun rays and rain drops than other species. With shortest length of petiole (*LP*) in *T. neriifolia* leaves are likely to be firmly attached to the stem than in *P. alba* with longest *LP*. The tree height (*TH*) is tallest in *D. oliveri* and shortest in *D. regia*; the height of trunk (*HT*) is longest in *G. arborea* and shortest in *T. neriifolia*, and the diameter of trunk (*DT*) is widest in *D. oliveri* and narrowest in *T. neriifolia* (Table 2).

The longer trunk of *G. arborea* will make it prone to wind damage than *T. neriifolia*; *D. oliveri* is most likely has the ability to withstand the pressure of stress of heavy wind blowing and other forces also than *T. neriifolia*. In this respect, *T. neriifolia* is the least prefer shade plant apart from its short petiole that may enable it to retain its leaves for longer time. Having some of these plants in our residential houses, offices, along major streets in the cities and recreation centers will not only provide shade for relaxation, it will also help in combating environmental hazards like accumulation of greenhouse gases. They could also humidify the atmosphere. These two events i.e. cleansing and humidification of the atmosphere are through the stomata present on the leaf surface of these plants (Edwards *et al*., 1998; Hetherington and Woodward, 2003; Oladele, 2002; Caird *et al*., 2007; Nilson and Assmann, 2007; AbdulRahaman and Oladele, 2008). These plants could also aid cloud formation and rainfall, through the transpiration process and humidification of the atmosphere.

Along with the canopy characteristics of these plants, their *SCTs, SD, SS, SI* and rate of transpiration were studied to confirm their cooling effects as humidifiers and cleansers of the atmosphere. Some of the stomatal features studied in this work were discovered to have some correlations with transpiration rates. These include:

Homogeneity and heterogeneity of stomatal complex types (*STCs*)

Different types of *SCTs* present in a species are a factor in its rate of transpiration. For instance species like *T. catappa, A. auriculiformis, B. ferruginea* and *B. sapida* with at least two types of *SCTs* transpired faster than species with homogenous *STC* especially paracytic type such as *T. grandis, G. arborea, C. sinensis, C. reticulata* and *P. alba.* Though there are some species in latter group which transpired faster than those in the former group (Table 3). Reason for this may be possession of some other stomatal features such as *SD*, *SS* and *SI*. Meanwhile, Carr and Carr (1990) had earlier reported that stomata with many subsidiary cells open more rapidly than those with little subsidiary cells. This claim was confirmed by Obiremi and Oladele (2001), AbdulRahaman and Oladele (2003), Oyeleke *et al*. (2004) and Saadu *et al*. (2009) in stomatal complex types of some species of *Citrus,* vegetables, afforestation tree and tuber species where those stomata with large number of subsidiary cells transpired faster than those with small subsidiary cells.

Amphistomatic and hypostomatic leaves

Occurrence of stomata on one or both surfaces of the leaf is visible evidence that influence rate of transpiration in studied species. In the hypostomatic leaves (e.g. in *T. grandis, D. regia, M. indica* and *D. oliveri*), transpiration rarely takes place on the adaxial or upper surface whereas in the amphistomatic leaves (e.g. in *T. catappa, A. auriculiformis* and *B. ferruginea*), transpiration takes place on both leaf surfaces (Table 3). Thus plants with amphistomatic leaves transpired more and therefore release more water to the atmosphere. Similar works on some other plants species also revealed that much of transpiration occurred on leaf surface with occurrence of stomata and rarely occurred on surface without stomata (AbdulRahaman, 2009; Oyeleke *et al*., 2004; Saadu *et als*, 2009).

Stomatal size (SS), stomatal density (SD) and stomatal index (SI)

Stomata in the 20 species studied can be described as large because according to pataky (1969), stomata whose guard cells are less than 15µm are called "small" while those in which guard cells are more than 38µm are known as "large"; guard cells of 15µm – 37µm are designated as "moderate" (AbdulRahaman, 2009). Stomata in the studied species were all more than 15µm with *A. auriculiformis* having larger size (73.75µm) while *D. regia* possessed the smaller size (47.00µm). The *SS* of all the various species studied showed that *T. catappa* has highest *SD* of 91.00mm^2 while *D. regia* has the lowest *SD* of 8.25mm^2 (Table 3). Earlier studies by Metcalfe and Chalk (1988) and Beerling and Woodward (1997) showed that large stomata resulted in low *SS* while small stomata gave high *SS*. The work of AbdulRahaman and Oladele (2003) also showed this pattern where large stomata actually gave low stomata density and small stomata gave high density in some vegetable species. It has been shown in this study that there were and were no correlation between *SS* and *SD* (Table 3). Stomata occupied larger area on leaf surface in *D. oliveri* and least area in *G arborea*. Unlike situations in some ornamental plants studied by AbdulRahaman (2009), the *SI* has no direct influence on the rate of transpiration in the species studied in this work.

Observation of different rates of transpiration among the 20 species may be due to variations in their *STC*s, *SD, SI* and *SS* as well as occurrence of stomata either on one surface or both surfaces of leaves and on homogeneity or heterogeneity of *SCT*s (AbdulRahaman and Oladele, 2004; Oyeleke *et al*., 2004). Transpiration rate was highest (6.62×10^{-6} mol/m^{-2}/s^{-1}) in *A auriculiformis,* followed by *T. catappa*, *C. paradisi*, *A. lebbeck*, *C. limon*, *B. ferruginea*, *A. indica*, *B. sapida*, *C. sinensis*, *M. indica*, *V. paradoxa*, *C. reticulata*, *A. occidentale*, *P. alba*, *T. nerifolia*, *D. oliveri*, *P. biglobosa*, *G. arborea*, *T. grandis*, and was lowest in *D. regia* (3.30×10^{-}

^{7} mol/m^{-2}/s^{-1}) as shown in Table 3. This translates to mean that *A. auriculiformis* releases more water in the form of vapour to the atmosphere than every other species while *D. regia* releases the least water. The reason for this behaviour can be traced to the stomata features possessed by each of the 20 species studied. Stomata size and density also influences the rate of transpiration. From the work carried out in the course of this work, it has been shown that there are correlations between the *SS*, *SCT*s and occurrence of stomata on leaf surfaces and transpiration rate than SD, SI and canopy characteristics in all the species studied.

Based on the canopy characteristics and stomatal features possessed by each of these shade plants as well as their rate of transpiration, species such as *A. indica, D. oliveri, A. lebbeck, D. regia, A. auriculiformis* and *T. catappa* are the most preferable shade plants.

In conclusion, humidification potential of the studied species is relatively high as shade plants. Therefore with this quality, these plants apart from serving as a shade plant will also provide a fresh, conducive atmosphere by cleansing and humidifying the atmosphere where we live in. Also, one of the measures of preventing further deterioration effects of climate change, global warming and desertification is planting of afforestation plant species. The plants studied are capable of absorbing carbon (IV) oxide via their stomata for production of sugar and starch and thus cleans the atmosphere of impurities (AbdulRahaman and Oladele, 2008; Oladele and AbdulRahaman, 2008). Also, by humidifying the atmosphere, these plants play a major role in global water cycle. Water vapour released from plants as a result of transpiration, helps in cloud formation and rainfall which in turn checks drought and the process of desertification (Oladele, 2002; Keay, 1989) especially in the arid and semi-arid environments where ornamental plants are planted for beautification of the environment.

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