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*Full Length Research Paper*

# Comparison of qualitative and quantitative traits of some Advanced breeding lines of tomato (*Lycopersicon esculentum* L.)

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**Field trials and laboratory experiments were conducted on six advanced breeding lines of tomato (*Lycopersicon esculentum* L.) between 2004 and 2006 to genetically assess the organoleptic properties of the tomato lines, determine the relationships among tomato traits using correlation analysis and to estimate the fruit yield potential of the tomato lines. The trial was laid out in randomized complete block design with three replicates. Planting was done on four-row plots of 8 x 5 m using intra row spacing of 60 x 50 cm to obtain a plant population of 33,333 per ha. The results show that agronomic traits such as plant height, fruit weight and fruit yield differed significantly from one line to another, while significant differences exist in their organoleptic properties such as percentage titratable acid, organic acids, sugars and dry matter contents. Fruit yield ranged from 11.0 Mg/ha (CLN 1462B) to 30.0 Mg/ha (Manuella). The highest correlation coefficient (r=0.99) was found in the relationship between fruit weight and fruit yield. Titratable acids was highly and positively correlated with dry matter content, citric acid and malic acid, while malic acid among others was negatively and significantly correlated with fructose, glucose and pH.**

**Key words:** Advanced tomato lines, Organoleptic properties, qualitative traits, correlation coefficients biochemical properties.

## INTRODUCTION

Tomato (*Lycopersicon esculentum* L) is one of the most important fruit vegetables globally. In Nigeria, the most acceptable variety is Roma VF and generally adaptable to Nigerian Savanna ecology (Ibrahim and Dadari, 2002). Genetic improvement of tomato is a major thrust of many research Institutes in different parts of the globe. This research effort focused mainly on development of cultivars for higher yield potential, adaptation, and market value acceptability and enhanced organoleptic properties. Agong et al. *(*2000), used multiple correlation analysis to study relationship between some biochemical parameters and fruit weight in tomato; their results showed that most of the biochemical characters were negatively correlated with fresh tomato yields, suggesting that breeding programme may have to sacrifice larger fruit size to obtain or retain better quality. Mitchell et al. (1991) and

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**Table 1.** Mean squares (MS) for the agronomic traits and proximate analysis of the Tomato lines.

| Source of variation | Df | Plant height (cm) | Fruit weight (kg/plot) | Yield (Mg/ha) | Titratable acid (%) | Dry matter content (%) | Citric acid (%) | Malic acid (%) | Fructose (%) | Glucose (%) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicate | 2 | 1.19 | 0.0007 | 0.0002 | 0.00 | 0.003 | 0.0007 | 0.0005 | 0.0005 | 0.009 | 0.027 |
| Variety | 5 | 329.15** | 0.006** | 0.007** | 0.12** | 0.31** | 0.17** | 0.15** | 0.04** | 0.013** | 0.10** |
| Error | 10 | 67.08 | 0.0005 | 0.0007 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.0026 | 0.017 |
| Total | 17 | | | | | | | | | | |

**Significant at P<0.01.

Agong et al. (1997) confirmed the use of biochemical characteristics such as electric conductivity brix %, pH value and total titratable acidity as major criteria to judge the organoleptic and processing quality of tomato. Therefore, these properties should be of the selection criteria for improving tomato for better organoleptic properties.

In Nigeria, the major tomato production constraint is bacterial wilt caused by *Pseudomoans solanacearum*. This disease is a serious yield depressing factor in the endemic zones reducing fruit yield by as much as 70%, and in critical situations absolute crop failure have been reported (Olakojo et al., 2005). Breeding efforts at the Institute of Agricultural Research and Training (IAR&T) Obafemi Awolowo University Moor Plantation and National Horticultural Research Institute Ibadan have resulted in selection of some genotypes with considerable level of tolerance to bacterial wilt. The need to improve the fruit size therefore became important for it to be acceptable to end users. On the other hand, fruit sizes have been found to be negatively correlated with important organoleptic and biochemical properties of tomato (Agong et al., 2000). In order to strike a balance between fruit yield and quality traits, this study aimed at assessing the organoleptic properties of some advanced tomato breeding lines identified to be useful as parent materials to improve the fruit size of bacterial wilt tolerant materials.

The objectives of the study therefore were: (i) to assess the organoleptic properties of the tomato lines (ii) determine relationships among the agronomic and biochemical properties and (iii) to ascertain the possibility of using them to improve both the fruit size and organoleptic quality of bacterial wilt resistant genotypes in our national breeding programme.

## MATERIALS AND METHODS

Six advanced breeding lines of tomato (*L. esculentum* L) were evaluated in 2006 at the Institute of Agricultural Research and Training Obafemi Awolowo University Moor Plantation, Ibadan for yield potential and biochemical properties. These advanced breeding lines of tomato were collected from The National Horticultural Research Institute Idi-Ishin, Ibadan and Asian Vegetable Development Centre, China.

Filed was prepared mechanically by ploughing twice harrowing once during the early season of year 2006. Transplanting was done on flat surface of soil in four–row plots measuring 5 x 8 m with a spacing of 60 x 50 cm to obtain a population density of 33,333 plants/ha. Three weeks after transplanting, 150 kg $ha^{-1}$ of (NPK: 20-10-10) fertilizer was applied in granular form round the seedlings. The experimental design was a randomized complete block design with three replications. Weeding was done twice but as at when due. The seedlings were however not staked so as to conform to the farming system practice of Nigerian tomato farmers.

From the laboratory analyses, using the procedure of Food Chemistry Practical Manual, Bruce et al. (2006) (A University of Queensland Publication), vitamin C, titratable acid (TTA) which are acids that can be neutralized with any available base, citric acid, fructose, glucose, dry matter content and percentage moisture were determined. Other data obtained included plant height (cm), fruit weight (kg/plot) and fruit yield Mg $ha^{-1}$

Data were analysed using SAS software package for analysis of variance; correlation coefficients (r) were also computed to determine relationship among the tomato biochemical characters and yield related traits at P<0.05 and P<0.01.

## RESULTS

The results of the analysis of variance (ANOVA) are presented in Table 1. Mean square (MS) for all agronomic characters such as plant height, fruit weight, fruit yield as well as biochemical properties including percentage of titratable acid, dry matter content, citric acid, malic acid, fructose, glucose and pH values were highly significant at p<0.01. This great variability suggests a wide diversity in the tomato lines and their potential for meaningful varietal development that will enhance desirable biochemical properties. These varieties also lend themselves to supporting a broad gene pool for tomato genetic conservation for varied nutritional quality and greater utilization potential.

Mean agronomic characteristics of tomato are presented in Table 2. The plant height varied from 29.0-50.0 (for P3 – 12B) to 55.13 cm (for CLN 1462B). Mean across varieties for plant height was 42.97 cm with standard error of 1.93 while P3-12B was a dwarf tomato, TAS 1-12A, DT95/7401 and DT/95/3023 were of moderate height. Manuella and CLN 1462B (temperate

**Table 2.** Mean values of agronomic characteristics of the tomato lines.

| Tomato line | Plant height (cm) | Fruit weight (kg/plot) | Fruit yield (Mg/ha) |
|---|---|---|---|
| DT/95/8023 | 31.40 | 0.23 | 15.0 |
| P3 - 12B | 29.50 | 0.20 | 13.0 |
| Manuella | 51.40 | 0.38 | 30.0 |
| TAS 1-12A | 46.66 | 0.22 | 15.00 |
| CLN 1462B | 55.13 | 0.16 | 11.0 |
| DT 95/7401 | 43.75 | 0.28 | 20.0 |
| Mean | 42.97 | 0.24 | 16.0 |
| S.E. | 1.93 | 0.003 | 2.00 |

**Table 3.** Percentage of acid and sugar by proximate analysis for the Tomato lines (*Lycopersicon esculentum*).

| Tomato line | pH | Dry matter content | Titratable acid | Citric acid | Malic acid | Fructose | Glucose |
|---|---|---|---|---|---|---|---|
| DT/95/3023 | 4.06 | 5.71 | 1.10 | 1.29 | 1.24 | 0.69 | 0.89 |
| P3-12B | 4.36 | 4.97 | 1.02 | 1.19 | 1.14 | 0.63 | 0.95 |
| Manuella | 4.16 | 5.59 | 0.99 | 1.16 | 1.11 | 0.75 | 0.96 |
| TAS 1 - 12A | 4.46 | 5.05 | 0.60 | 0.70 | 0.67 | 0.81 | 1.08 |
| CLN 1462B | 4.56 | 4.92 | 0.69 | 0.81 | 0.77 | 0.73 | 0.99 |
| DT95/7401 | 4.30 | 5.11 | 0.81 | 0.95 | 0.90 | 0.80 | 1.04 |
| Mean | 4.32 | 5.23 | 0.87 | 1.02 | 0.97 | 0.74 | 0.98 |
| S. E. (0.05) | 0.03 | 0.01 | 0.09 | 0.11 | 0.01 | 0.01 | 0.01 |

origin) appear taller with a height of 50 cm. Fruit weight per plot ranged from 0.16 to 0.38 kg/plot. Mean weight across varieties were 0.24 kg/plot. Fruit yield varied from 11.0 Mg/ha (for CLN 1462B) to 30.0 Mg/ha (for Manuella). Although, Manuella recorded the highest fruit yield, DT95/7401 was equally good with 20 Mg/ha (Table 2).

Percentage of neutralizable acids and sugar from the proximate analysis are presented in Table 3. The pH of the tomato lines though varied significantly from one line to another, it ranged from 4.06(DT/95/3023) to 4.56% (CLN 1462B). DT/95/3023 had the most acidic material with pH of 4.06. These levels of acidity though very mild are able to preserve the tomato paste for some time before further processing. The dry matter content of the tomato lines was quite high. It varied significantly between 4.92 (for CLN 1462B) to 5.59 (Manuella). Titratable acid was slightly high in DT 95/3023 and P3-12B lines with the values of 1.10 and 1.02%, respectively. The values for other lines were generally low with less than 1.0%. Significant differences also exist in citric acid content. The values ranged from 0.70 to 1.29 while DT/95/3023, P3 - 12B and Manuella were high in citric acid, TAS1 - 12A, CLN 1462B and DT 95/7601 had moderate citric acids with less than 1% (Table 3). Malic acid in this study assumed similar trend as in citric acid for all the tomato line.

Proximate analysis of sugar in this study revealed significant differences from one tomato line to another at $p<0.05$. Fructose content of the tomato was generally less than 1% in all the lines with a range of 0.63 (for P-12B) to 0.81% (for TAS1-12A). TAS 1-12A and DT 95/7401 had 0.81 and 0.80%, respectively for % fructose content (Table 3). Glucose content was high in TAS 1-12A and DT95/7401 (over 1.0%), however it reduced in other lines below 1.0%.

Based on results of chemical compositions, all tomato lines are safe for raw consumption, domestically in soup, and are suitable for tomato puree and paste production because the acid content are not injurious to human health. The results of correlation analysis are presented in Table 4. Correlation coefficient (r) among both agronomic and chemical properties were determined. Plant height was significant and positively correlated with percentage fructose and pH with coefficients (r) of 0.54 and 0.50 respectively. On the other hand, negative and significant correlations were obtained for plant height and percentage of titratable acid (-0.60, $p<0.01$) plant height and citric acid (-0.54, $p<0.05$) plant height and % malic acid (-0.56, $p<0.05$) respectively.

Fruit weight was positively and highly ($p<0.01$) correlated with fruit yield (0.99) and percentage of dry matter content (0.62), however, it was negatively ($r=0.50$) correlated with pH. Similarly, fruit yield was positively and

**Table 4.** Correlation Coefficient (r) among tomato agronomic and quality characters.

| Parameter | Plant height | Fruit weight | Fruit yield | % Titratable acid | % Dry matter content | % Citric acid | % Malic acid | % Fructose | % Glucose | PH |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant height | - | 0.18 | 0.l9 | 0.60** | -0.20 | -0.54* | -0.56* | 0.54* | 0.35 | 0.50* |
| Fruit weight | | - | 0.99** | 0.33 | 0.62** | 0.34 | 0.34 | 0.26 | -0.01 | -0.50* |
| Fruit yield | | | - | 0.32 | 0.60** | 0.34 | 0.34 | 0.26 | -0.01 | -0.50* |
| % Titrable acid | | | | - | 0.67** | 0.97** | 0.98** | -0.59** | -0.67** | -0.72** |
| % Dry matter | | | | | - | 0.66** | 0.67** | -.006 | -0.45 | -0.78** |
| % Citric acid | | | | | | - | 0.95** | -0.57* | -0.63** | -0.68** |
| % Malic acid | | | | | | | - | -0.62** | -0.71** | -0.68** |
| % Fructose | | | | | | | | - | 0.61** | 0.14 |
| % Glucose | | | | | | | | | - | 0.48* |
| pH | | | | | | | | | | - |

* and ** Significance at P<0.05 and 0.01, respectively.

highly (r<0.60, p<0.01) correlated with dry matter content, but negatively (r=-0.49, p<.05) correlated with pH. Percentage titratable acid was highly and positively correlated with dry matter content (r=0.67, p, <0.01), citric acid (r=0.97-, p<0.01) and malic acid (r=0.98-, p<0.01), but was negatively correlated with fructose percentage (-0.59-, p<0.01), glucose percentage (-0.67, p<0.01) and pH (-0.72, p<0.01), respectively (Table 4).

Percentage of dry matter content was positively and highly correlated with % citric acid (0.66) and malic acid (0.67), but negatively correlated with pH (-0.78). Percentage citric acid was only positive and significantly correlated with malic acid (0.95), but negatively correlated with percentage of fructose (-0.57) glucose (-0.63) and pH (-0.68) respectively. Malic acid was negatively correlated with tomato sugar such as fructose (-0.62) and glucose percentage (-0.71, p<0.01) and pH (-0.68). Percentage of fructose on the other hand was positively and significantly correlated with glucose percentage (0.61) but glucose percentage was significantly and positively correlated with pH (0.48). While traits with strong and positive relationships may be jointly selected by breeder to enhance quality of tomato for such traits, negative correlation coefficients among tomato characters is an indication that breeder may need to adopt other breeding approach in selecting for such traits in tomato improvement programme.

## DISCUSSION

This study reveals the organoleptic properties of the advanced breeding lines of the tomato. High variability of the agronomic and organoleptic properties will no doubt provide breeders with opportunity to select desirable genotypes when breeding for higher fruit yield and quality organoleptic properties. Fulton et al. (2002) have identified a total of 222 qualitative trait loci (QTL) for 15 tomato traits including sugar, glutamic acid and flavour suggesting the possibility of increasing fruit size without necessarily sacrificing the quality organoleptic traits using molecular genetics.

Percentage of glucose and fructose in this study were very close to the values obtained by Agong et al. (2000), in their study using other tomato varieties. Similarly, sucrose synthase activity and fruit size in tomato had been found to be linearly related by Jia-Hao et al. (1992); this further suggests that sucrose synthase can serve as an indicator of sink strength in growing tomato fruits. In another study by Causse et al. (2001), overall aroma intensity was positively correlated with sweetness and sourness as well as lemon, candy and citrus fruit aroma. This implies that positive and significant correlations among glucose and fructose (r=0.61, p<0.01) as found in this study will no doubt promote good aroma in resultant genotypes.

The significant importance of tomato organoleptic properties is currently attracting international research effort. Contreras et al. (2006) studied the effects of NPK fertilization and irrigation with quality on tomato fruit quality. They observed that increase in concentration of the fertilization solution increased marketable fruits and fruit citric acid in tomato, while high acidity water produced fruit with higher total soluble solid brix, titratable acid and fruit dry matter content.

In the same vein, Baldwin et al. (1991) reported that a complex mixture of sugars, acids, amino acids, minerals and volatile compounds contributes to the characteristic flavour of fresh tomato fruits. In fact, recent scientific findings regarding tomato fruit component have encouraged effort to improve these traits genetically (Paolo et al., 1009). The report of these workers have shown that a strong interconnected nodes among tomato organoleptic properties exist for dry matter, pH and Brix,

while a strong association was reported between some metabolic and sensory traits such as citric acid with tomato small, glycine with tomato smell and granularity with dry matter content. Dry matter content also showed a link with ascorbic acid and pH.

## Conclusion

The organoleptic properties of the evaluated tomato lines, relationships among quality traits and their yield potential showed that they are good parental candidates that may be used in improving bacterial wilt tolerant varieties for enhanced fruit-size. In the same vein, the tomato breeding lines could serve as sources of gene for improving tomato crop for dry matter yield and various chemical composition. For example, dry matter content can be improved in tomato using DT/95/3023 and Manuella as parent lines, while glucose and fructose can be enhanced using parent lines TAS1-12A and DT95/7401 as sources of gene for breeding program specially designed to improve these tomato sugars.

## Conflict of Interest

The author(s) have not declared any conflict of interests.

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*Full Length Research Paper*

# Taxonomic significance of foliar epidermal characters in the Caesalpinoideae

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**A detailed morphological study of the leaf epidermis of some species in the genera *Bauhinia* Linn., *Caesalpinia* Linn. *Daniellia* Hutch. & Dalz. and *Senna* Linn in Nigeria was undertaken in search of useful and stable taxonomic characters. The study reveals several interesting epidermal features some of which are novel in the genera. Leaf epidermal characters such as epidermal cell types, stomata types and the presence of trichomes were constant in some species and variable in others, making them to be of great significance in determining the relationships among and within species. Stomata were amphistomatic in all the species except in *Senna alata, Senna siamea* and *Senna siberiana* which are epistomatic. The species showed variability in their stomata length, width, density and index, which was reflected in their taxonomic delimitations.**

**Key words:** Taxonomy, Leaf epidermis, *Bauhinia, Caesalpinia, Daniellia, Senna.*

## INTRODUCTION

Caesalpinoideae is a large sub-family of about 150 genera with 2200 to 3000 species of flowering plants in the order Fabales (Eddy, 1997). The genus *Senna* is native throughout the tropics, with a few species extending into the temperate region. Some *Senna* species, especially *Senna alata*, have been reported to be used in the treatment of skin infections. Species of *Senna* were formerly included among the approximately 600 species of *Cassia* (Irwin and Turner, 1960). Shifting taxonomic boundaries mark the history of traditional systematic treatments of *Senna.* These shifts are best explained by the difficult taxonomic interpretation of morphological variations in *Senna. Bauhinia* species are commonly found at lowland and medium altitudes in most woodland types and on anthills 150 to 1800 m high; their seeds serve as food and their shoot as vegetables. The roots and leaves of *Bauhinia* species are used for medicine, fodder, shade, firewood, tannin, fibres and rope; they also serve aesthetic purposes (FAO, 1983). The members of the genus *Caesalpinia* are planted as an ornamental as is common in gardens on the coast of East and West Africa. Some species of *Caesalpinia* also have extra floral nectars on their leaves or flower stalks, which attract ants (Marazzi, 2006). The species in the genus *Daniellia* have been reported to have medicinal properties. A decoction of leaves and bark of *Daniellia oliveri* is used as a refreshing lotion of bath, internally against colic and as a mouth-wash against toothache

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**Table 1.** Leaf morphological features of some species of sub-family Caesalpinoideae.

| Taxa | Apex | Shape | Trichome | Base | Leaf Length/Width ratio |
|---|---|---|---|---|---|
| *B. rufescens* | Em | R | - | Co | 1:1 |
| *B. tomentosa* | Em | Co | - | Co | 1:1 |
| *C. bonduc* | Ac | La | - | Obl | 2:1 |
| *C. pulcherima* | Re | O | - | Ob | 2:1 |
| *D. ogea* | Ac | La | - | Ac | 2:1 |
| *D. oliveri* | A | La | - | Ac | 2:1 |
| *S. acutifolia* | Ac | La | - | Obl | 5:1 |
| *S. alata* | Re | Ob | ++ | Obl | 2:1 |
| *S. fistula* | Ac | La | - | Obt | 2:1 |
| *S. hirsuta* | A | La | ++ | Obl | 2:1 |
| *S. obtusifolia* | Re | O | - | Obl | 1:1 |
| *S. occidentalis* | A | La | - | Obl | 2:1 |
| *S. podocarpa* | Ap | Ob | - | Obl | 2:1 |
| *S. siamea* | Ap | L | - | Obt | 3:1 |
| *S. siberiana* | Ac | La | - | Obt | 2:1 |

Em = Emarginate; Ac = Acute; Re = Retuse; A = Acuminate; Ap = Apiculate; R = Reniform; Co = Cordate; La = Lanceolate; Ob = Oblong; O = Obovate; L = Linear; Obl = Oblique; Obt = Obtuse; ++ = presence of trichomes; - = absence of trichomes.

(Irvine, 1961).

According to Stace (1965), the leaf is perhaps the most anatomically varied organ in angiosperms and it provides a variety of anatomical features that can be employed as useful taxonomic characters. Many research works have been done on the physiology, chemotaxonomy and medicinal use of the species of these genera and other genera in the family but information on the anatomy and taxonomy is still fragmentary. Therefore the aim of this work was to determine the taxonomic significance of leaf epidermis and other anatomical features with a view to further establishing a stable taxonomic character among the selected genera.

## MATERIALS AND METHODS

Plant specimens used were collected in different ecological areas in Abeokuta (Ogun State), Ibadan, Sepeteri and Iseyin (Oyo State) South-western Nigeria. The collected specimens are: *Bauhinia rufescens, B. tomentosa, Caesalpinia bonduc, C. pulcherima, Danielia ogea, D. oliveri, Senna acutifolia, S. alata, S. fistula, S. hirsuta, S. obtusifolia, S. occidentalis,* S. *podocarpa, S. siamea* and *S. siberiana.* Identification was done at Forestry Herbarium Ibadan (FHI) and University of Ibadan Herbarium (UIH). Voucher specimens were deposited in the two herbaria. Quantitative characters assessed include leaf length and width (taken at the widest point) while qualitative characters such as leaf shape, margin, base and apex were also assessed *in situ.* Micro-characters such as cell wall thickness, size of epidermal cell, stomata size and index were also measured.

### Preparation of leaf epidermal surfaces

Leaf epidermal morphology was studied using fresh specimens. About 5 $mm^2$ to 1 $cm^2$ leaf portions were obtained from the standard median portion of the leaves. Three to five specimens of each species were used depending on geographical spread of the species except for those known from only one or two localities. Epidermal peeling was carried out according to the procedure of Johansen (1940) as modified by Jayeola and Thorpe (2000). The peeled specimens were later stained with Safranin and counter stained with Fast green and then cleared in clove oil and mounted with DPX®. The slides were appropriately labeled and examined under a light microscope Olympus BX51 while photomicrographs of the micro-morphological features were taken at a magnification of X400 using a photomicrograph Olympus BX 51with installed digital camera optics.

For statistical analysis, 10 epidermal cells and 10 stomata were chosen randomly for each species and measured using a micrometer eyepiece. For each quantitative character, the mean and standard error were determined for all the taxa. The stomata index (SI) was calculated based on the formula derived by Metcalfe and Chalk (1979).

$$SI = \frac{S}{S+E} \times 100$$

Where, SI = Stomata index, S = Number of stomata per unit area, E = Number of epidermal cells in the same unit area.

## RESULTS

Tables 1 and 2 and Figures 1 to 4 show the results obtained from this study while Plates 1-30 show photomicrographs of the abaxial and adaxial surfaces of the plant specimens. Generally, the leaves of the genera (*Bauhinia, Ceasalpinia, Daniellia, Senna*) were alternate, rarely opposite and mostly entire (Table 1). Leaves were mostly glabrous in all species except in *S. hirsuta* and *S. alata* which were pubescent. The apices were emarginate,

**Table 2.** Epidermal characters of some species of sub-family Caesalpinoideae.

| Taxa | Cell shape | | Anticlinal wall pattern | | Stomata type | |
|---|---|---|---|---|---|---|
| | Adaxial | Abaxial | Adaxial | Abaxial | Adaxial | Abaxial |
| *B. rufescens* | Irr | Irr | C | S/S | Par | Par |
| *B. tomentosa* | Irr | Irr | C | C | An | An |
| *C. bonduc* | P | P | S/S | S/S | An | An |
| *C. pulcherima* | Irr | P | C | S/S | An | An |
| *D. ogea* | P | Irr | S/S | C | An | An |
| *D. oliveri* | Irr | P | S/S | S/S | De | -- |
| *S. acutifolia* | Irr | Irr | C | C | Par | An |
| *S. alata* | P | Irr | S/S | C | -- | Par |
| *S. fistula* | P | P | S | S | -- | An |
| *S. hirsuta* | P | P | S/S | C | Ani | Par |
| *S. obtusifolia* | P | P | S/S | S/S | Ani | -- |
| *S. occidentalis* | Irr | Irr | C | C | Par | Par |
| *S. podocarpa* | Irr | P | C | S/S | Par | -- |
| *S. siamea* | P | P | S/S | S/S | -- | An |
| *S. siberiana* | Irr | Irr | C | C | -- | An |

Irr = Irregular; P = polygonal; C = curved; S = straight; An = Anomocytic; Ani = anisocytic; Par = paracytic; De = Desmocytic; S/S= straight/slightly curved; - = Absent/not present.

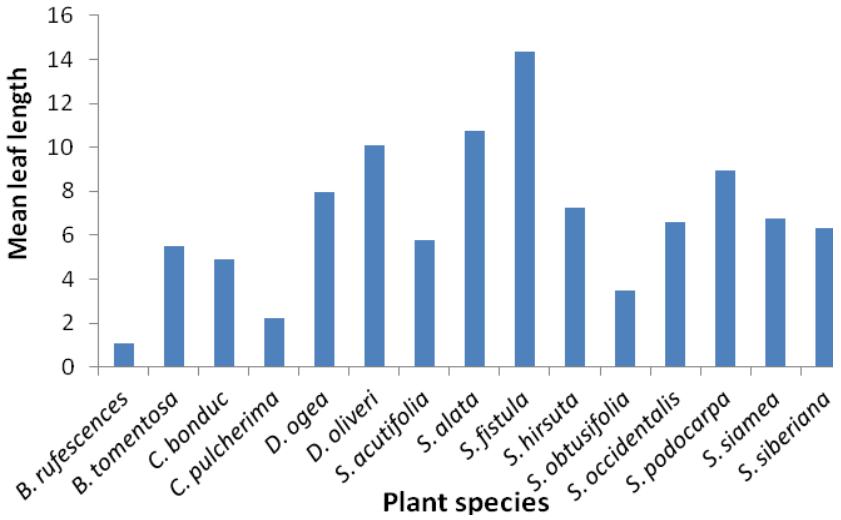


**Figure 1.** Mean leaf length of some species of sub-family Caesalpinoideae.

acute, acuminate, retuse, or apiculate. The leaflet sizes showed considerable variations within and among the genera with the largest recorded in *S. fistula* (14.8 cm) and the smallest in *B. rufescens* (0.8 cm) (Figure 1). The lowest leaf length/width ratio 1:1 was recorded in *B. rufescens, B. tomentosa* and *S. obtusifolia* (Table 1), while the highest was recorded in *S. acutifolia.* Trichome bases were, however, noticed in some species occurring on their adaxial or abaxial surface. The leaf epidermal cells were more often polygonal (Table 2) but sometimes irregular. Polygonal cells occurred most often on the abaxial surfaces but were also noticed on the adaxial surfaces of *C. bonduc, D. ogea, S. alata, S. fistula, S. obtusifolia, S. hirsuta* and *S. siamea* (Plates 1-30). Sometimes, polygonal cells were seen interspersed with irregular cells as seen in *C. pulcherima, D. ogea, D. oliveri, S. alata* and *S. podocarpa.* Stomata were amphistomatic in all the species and have commonly anomocytic, anisocytic and paracytic types apart from the rare to occasional occurrence of other stomata types and

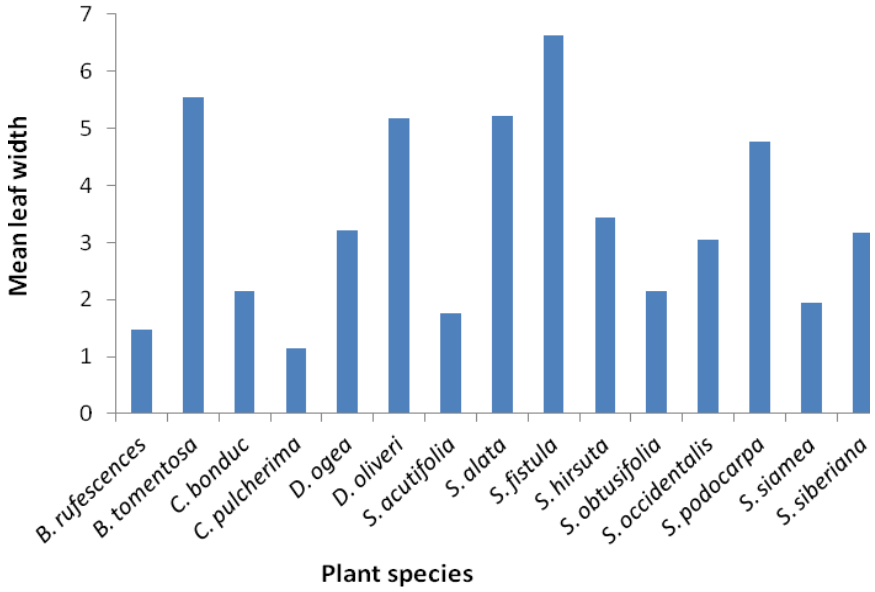


**Figure 2.** Mean leaf width of some species of sub-family Caesalpinoideae.

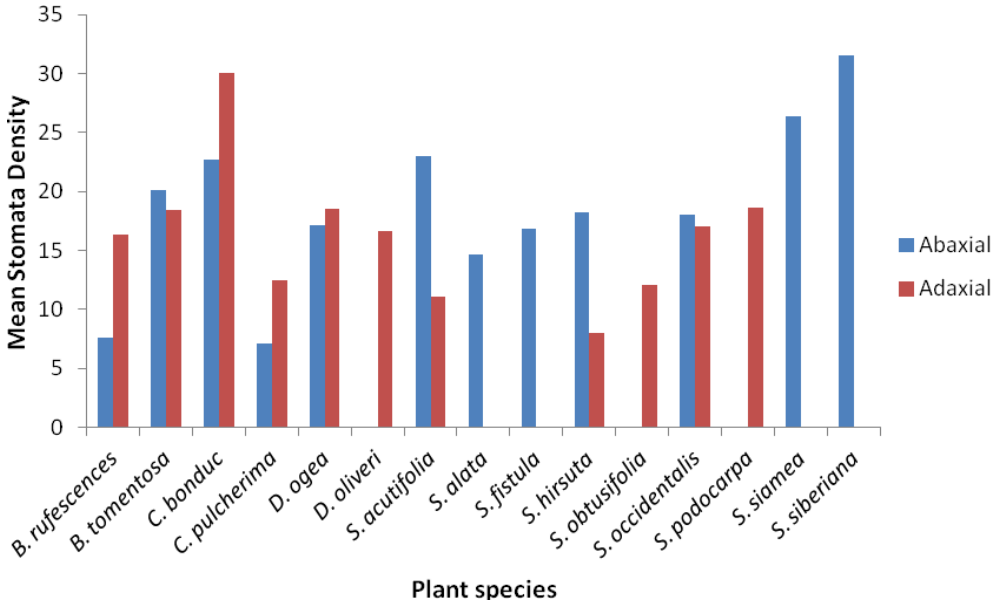


**Figure 3.** Mean stomata density of some species of sub-family Caesalpinoideae.

abnormalities found on the adaxial surface of *D. oliveri.* Trichomes were absent in most of the species except for the presence of whip-like and non-glandular trichomes found on both surfaces of *S. hirsuta* and *S. alata.*

## DISCUSSION

There was a wide variation in the number and distribution of stomata found in all the species. Classification of different types of stomata complexes was based on the number and position of the subsidiary cells and the ontogeny of the cell types. According to Richard et al. (2007), stomata comprise two elongated guard cells bracketing a stomatal pore, and often but not always, surrounded by one to many subsidiary cells. The presence of desmocytic stomata in *D. oliveri* distinguished it from other species. This was corroborated

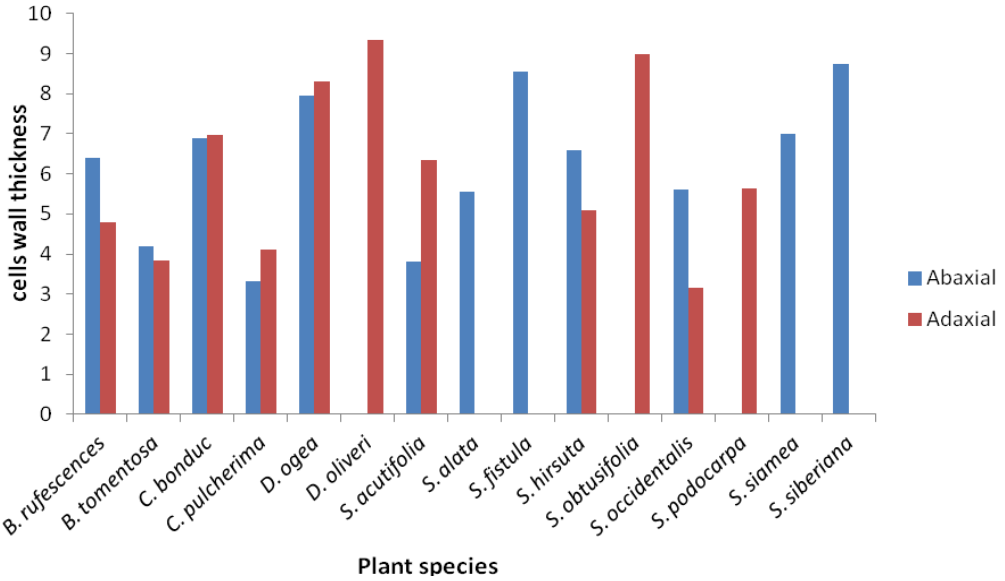


**Figure 4.** Cell wall thickness (µm) of some species of sub-family Caesalpinoideae.

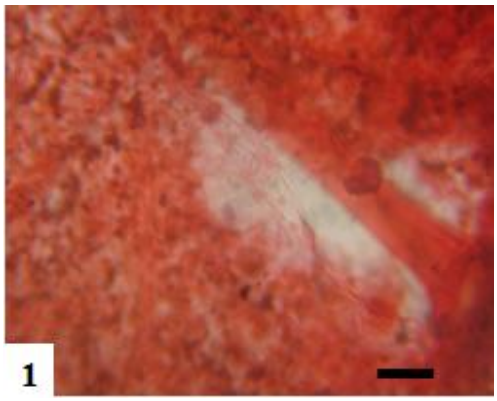


**Plate 1.** The adaxial surface of *B. rufescence* showing paracytic stomata and irregular epidermal cells.

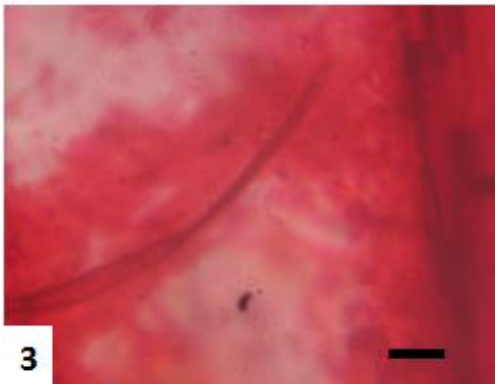


**Plate 3.** The adaxial surface of *B. tomentosa* showing anomocytic stomata and irregular epidermal cells.

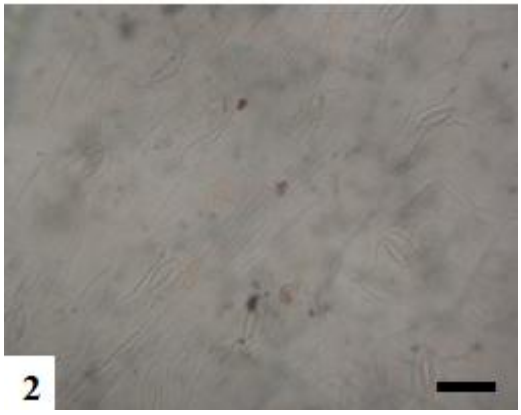


**Plate 2.** The abaxial surface of *B. rufescence* showing paracytic stomata and irregular epidermal cells.

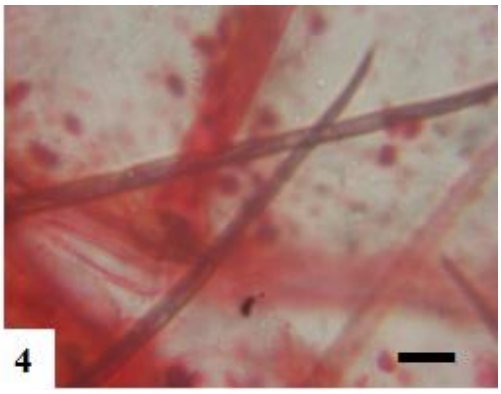


**Plate 4.** The abaxial surface of *B. tomentosa* showing anomocytic stomata and irregular epidermal cells.

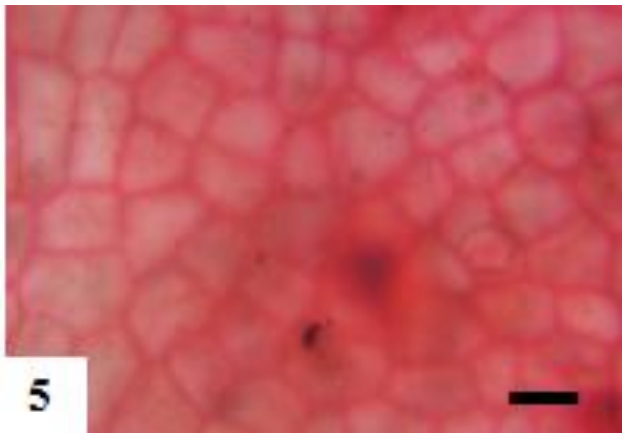


**Plate 5.** The adaxial surface of *C. bonduc* showing anomocytic stomata and polygonal epidermal cells.

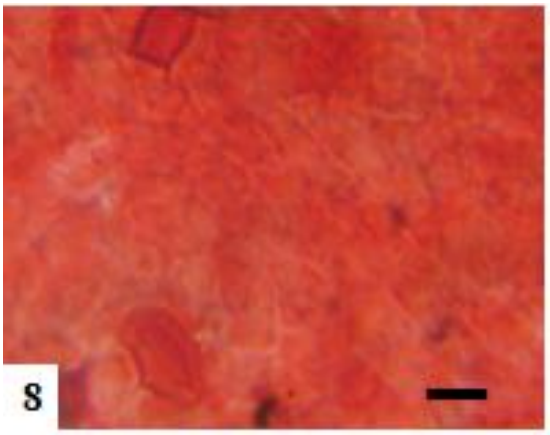


**Plate 8.** The abaxial surface of *C. pulcherima* showing anomocytic stomata and polygonal epidermal cells.

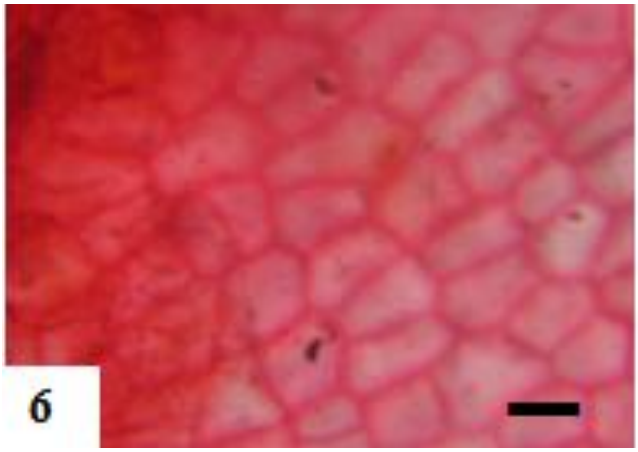


**Plate 6.** The abaxial surface of *C. bonduc* showing anomocytic stomata and polygonal epidermal cells.

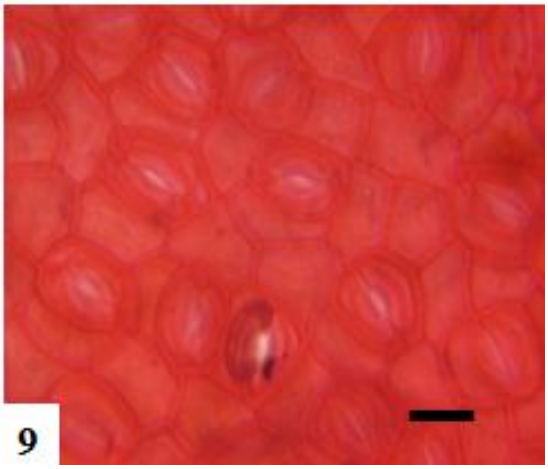


**Plate 9.** The adaxial surface of *D. ogea* showing anomocytic stomata and polygonal epidermal cells.

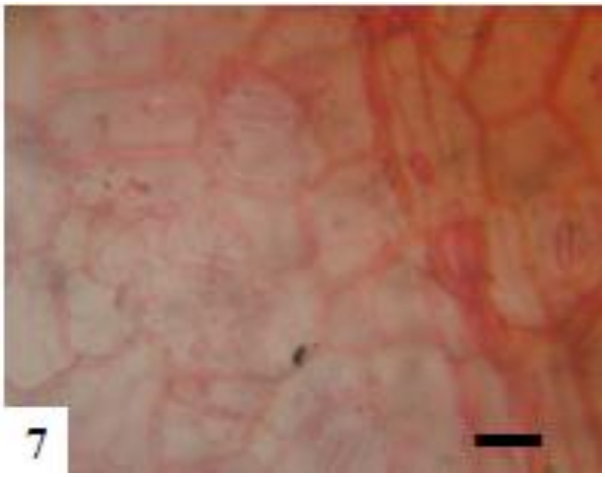


**Plate 7.** The adaxial surface of *C. pulcherima* showing anomocytic stomata and irregular epidermal cells.

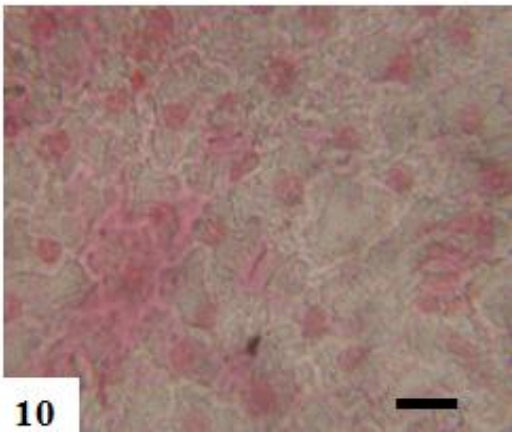


**Plate 10.** The abaxial surface of *D. ogea* showing anomocytic stomata and irregular epidermal cells.

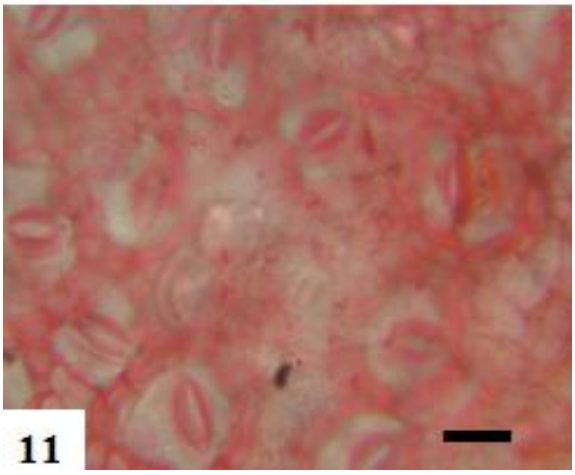


**Plate 11.** The adaxial surface of *D. oliveri* showing desmocytic stomata and irregular epidermal cells.

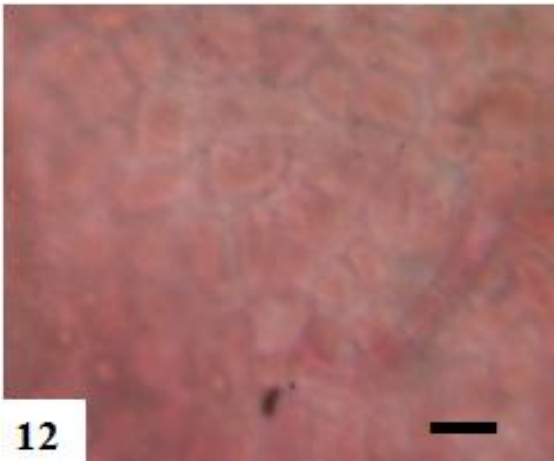


**Plate 12.** The abaxial surface of *D. oliveri* showing no stomata and polygonal epidermal cells.

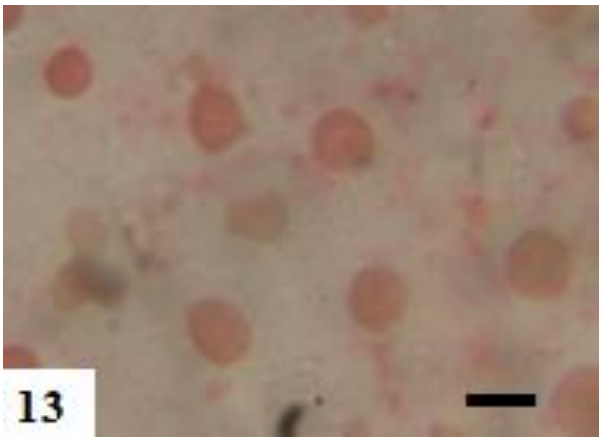


**Plate 13.** The adaxial surface of *S. acutifolia* showing paracytic stomata and irregular epidermal cells.

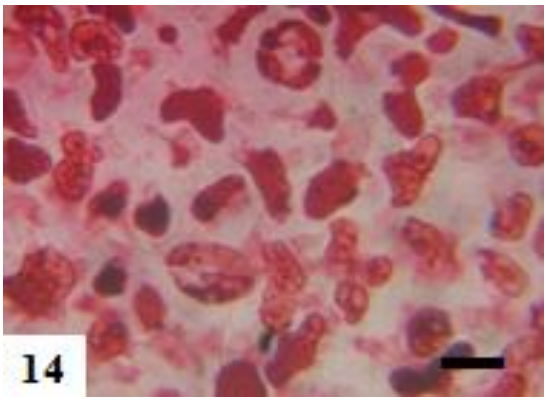


**Plate 14.** The abaxial surface of *S. acutifolia* showing anomocytic stomata and irregular epidermal cells.

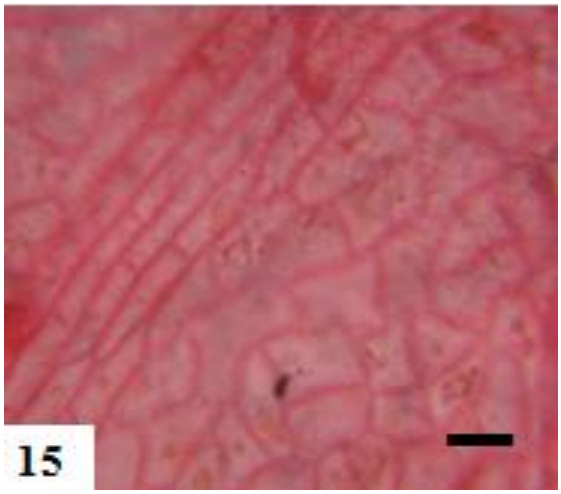


**Plate 15.** The adaxial surface of *S. alata* showing no stomata and polygonal epidermal cells.

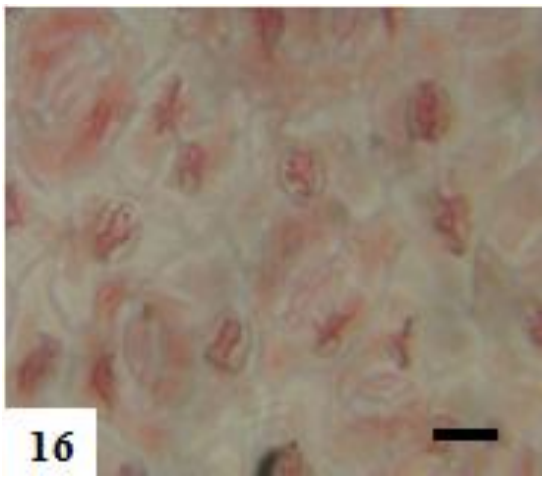


**Plate 16.** The abaxial surface of *S. alata* showing paracytic stomata and irregular epidermal cells.

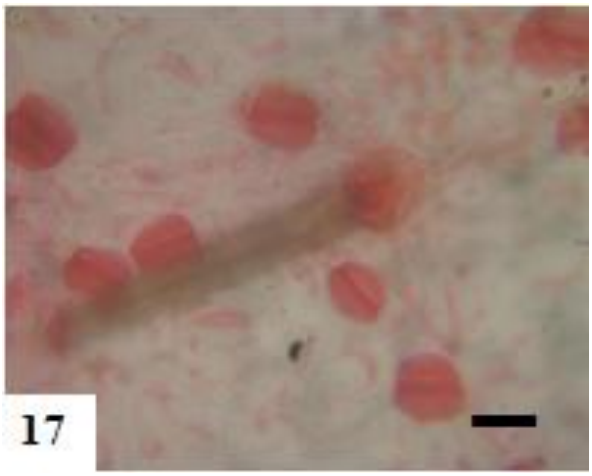


**Plate 17.** The adaxial surface of *S. fistula* showing no stomata and polygonal epidermal cells.

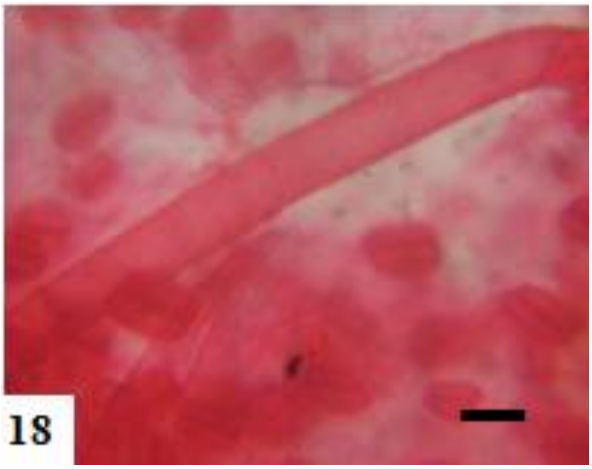


**Plate 18.** The abaxial surface of *S. fistula* showing anomocytic and polygonal epidermal cells.

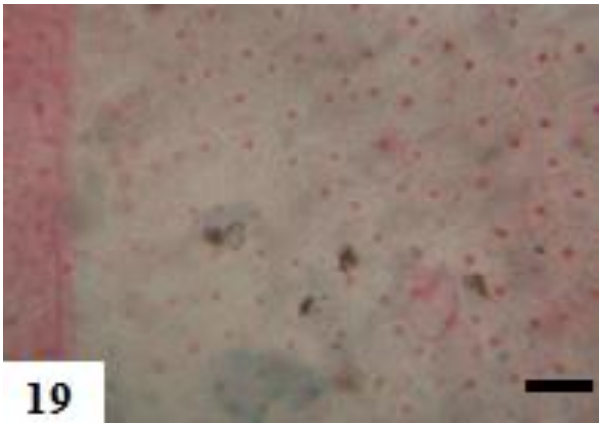


**Plate 19.** The adaxial surface of *S. hirsuta* showing anisocytic stomata and polygonal epidermal cells.

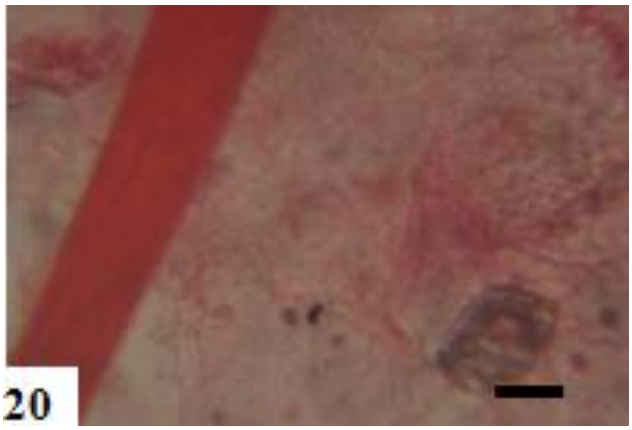


**Plate 20.** The abaxial surface of *S. hirsuta* showing paracytic stomata and polygonal epidermal cells.

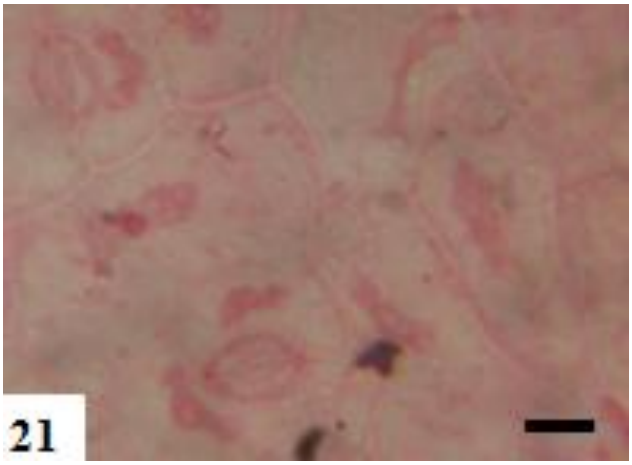


**Plate 21.** The adaxial surface of *S. obtusifolia* showing anisocytic stomata and polygonal epidermal cells.

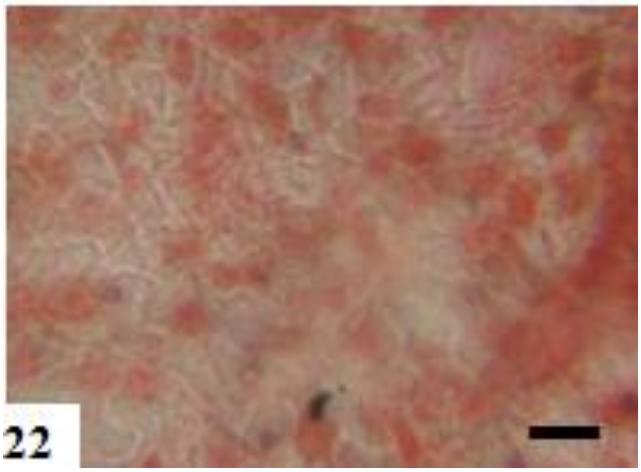


**Plate 22.** The abaxial surface of *S. obtusifolia* showing no stomata and polygonal epidermal cells.

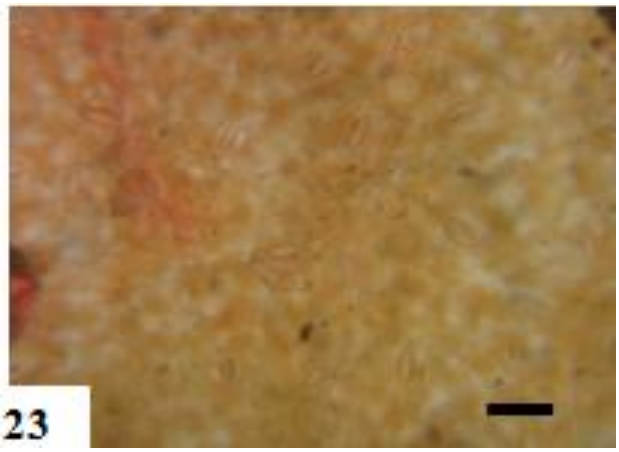


**Plate 23.** The adaxial surface of *S. occidentalis* showing paracytic stomata and irregular epidermal cells.

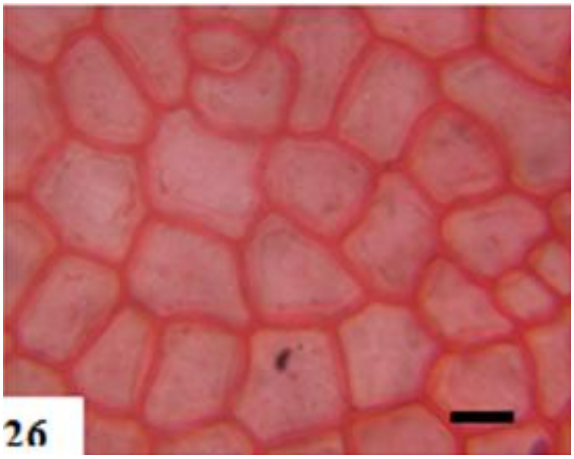


**Plate 26.** The abaxial surface of *S. podocarpa* showing no stomata and polygonal epidermal cells.

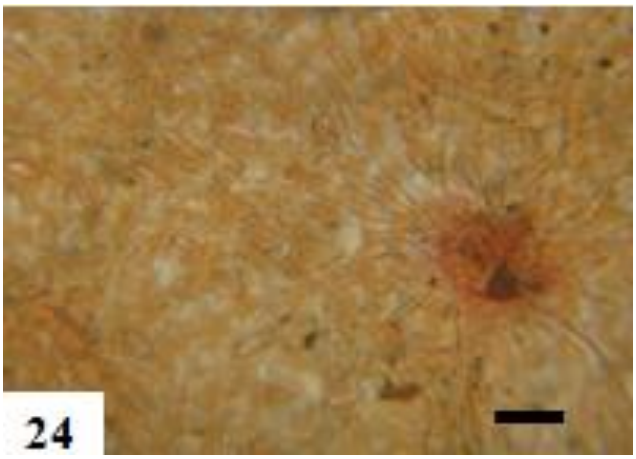


**Plate 24.** The abaxial surface of *S. occidentalis* showing paracytic stomata and irregular epidermal cells.

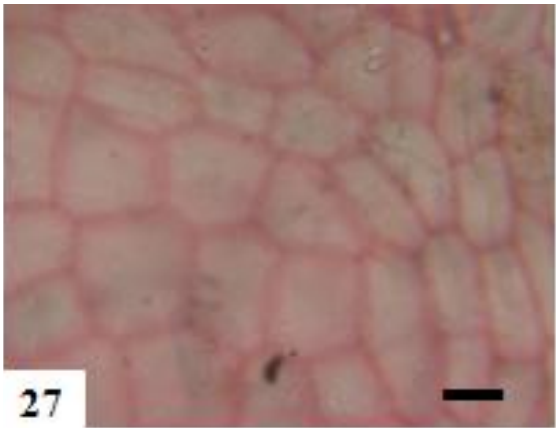


**Plate 27.** The adaxial surface of *S. siamea* showing no stomata and polygonal epidermal cells.

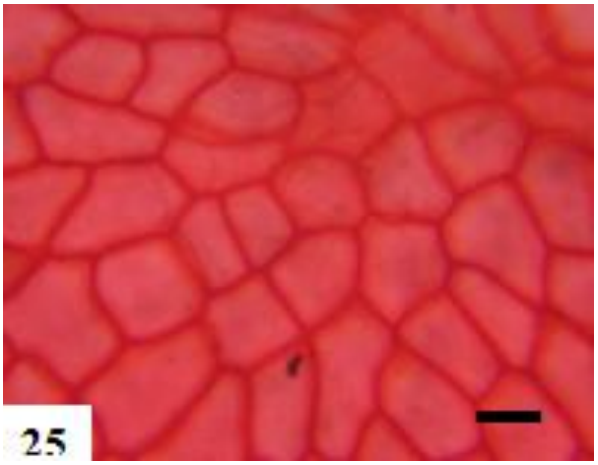


**Plate 25.** The adaxial surface of *S. podocarpa* showing paracytic stomata and irregular epidermal cells.

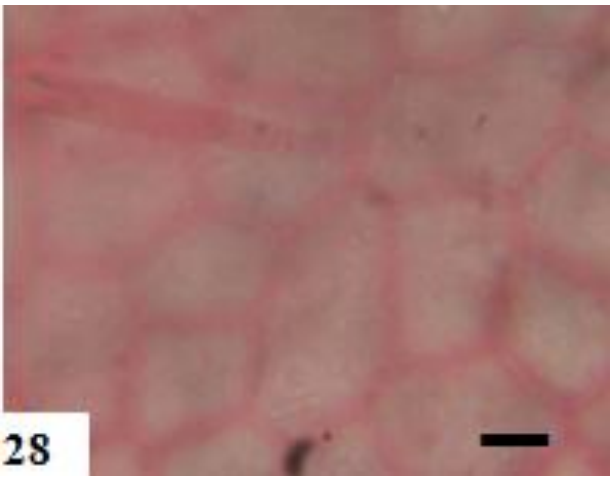


**Plate 28.** The abaxial surface of *S. siamea* showing anomocytic stomata and polygonal epidermal cells.

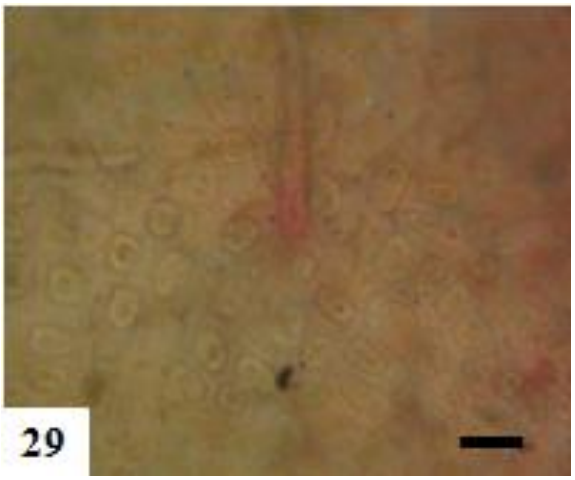


**Plate 29.** The adaxial surface of *S. siberiana* showing no stomata and irregular epidermal cells.

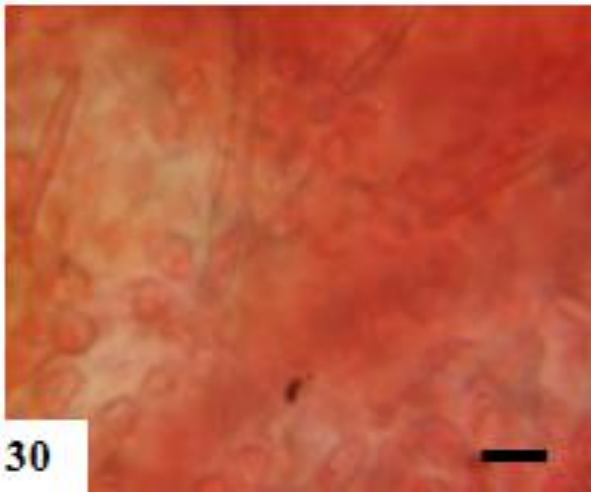


**Plate 30.** The abaxial surface of *S. siberiana* showing anomocytic stomata and irregular epidermal cells.

by the findings of Metcalfe and Chalk (1979). Also, absence of stomata on the adaxial surfaces of *S. alata*, *S. fistula, S. siamea,* and *S. siberiana* made them distinct from other species in the genus. The cell shape and cell wall patterns vary considerably among these genera and based on these two characters, the species of the genera was divided into groups of five; those with curved anticlinal wall, straight anticlinal wall, curved and straight anticlinal wall, irregular and polygonal cell shapes.

The occurrence of curved walls in most of the species agreed with the suggestion of Stace (1965) and Richard et al. (2007) that curved wall was a mesomorphic character and that environmental conditions such as humidity play a significant role in determining the pattern of anticlinal wall. The relative abundance and variation of the trichomes was of taxonomic importance in the genera. Almost all the species in these genera were glabrous which distinguished them from other species which were pubescent. However, the presence of simple, long, interwoven trichomes which covers the epidermal cells and stomata in *S. alata* and *S. hirsuta* distinguished them from other species in the same genus. The presence of many short non-glandular trichomes in *B. tomentosa* and *S. siberiana* makes it easy to be separated from other species. Metcalfe and Chalk (1979) opined that trichomes frequency and size are environmentally controlled while Stace (1965) reported that hairs are constant in species, and when present showed a constant range of form and distribution useful in diagnosis. Some overlap features noted in some species and genera within the sub-family perhaps still explain the affinity in their relationship despite the recent taxonomic divergence.

Preponderance of stomata on the abaxial surfaces than adaxial surfaces is a mechanism to reduce water loss through transpiration (Adegbite, 2008). The foliar epidermal features of some members of the genera of the sub-family Caesalpinoideae is of taxonomic importance since they can be separated and classified according to their stomata and cell wall shape. Based on the striking similarities and differences noted in the morphological and anatomical features, it is hereby suggested that further research such as phytochemical analysis and molecular studies be carried out to further delimit the species, as this work serves as baseline upon which other research could stand.

## Conflict of Interest

The author(s) have not declared any conflict of interests.

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