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Assessment of water economic potentials among some tropical trees in relation to transpiration and stomatal features

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Abstract
The physiological and anatomical feature (rate of transpiration, stomatal density and aperture) which accounts for plants relation to available soil water were used as an experimental tool to weigh and assesses some tropical trees viz; *Acacia albida, Acacia senegal, Albizia lebbeck, Azadirachta indica, Balanites aegyptiaca, Cassia siamea, Eucalyptus camaldulensis* and *Prosofis juliflora* potentials to water economy. Based on the findings of research, there is significant difference (P<0.05) found in the plants rate of transpiration, volume of water lost per unit time and stomatal frequency but no significant difference (P>0.05) observed in the plants stomatal aperture. However, based on the findings, the plants have been categories into three groups. The first group consists of *E. camaldulensis* and *A. indica*, these plants were found to have highest rate of transpiration, volume of water loss per unit time as well as stomatal density and aperture (8.4cm/min to 16.4cm/min rate and 95.0ml/24hrs to 186.6ml/24hrs volume, 82.3 to 105.2 stomatal frequency and 118.3μm^2 to 119.3μm^2 stomatal aperture). These plants were considered as plants with no or less water economic potential among the plants examined in this research. The second group which consists of *A. lebbeck* and *B. aegyptiaca,* plants in this group was considered as plants with moderate water economy moderate group while third group contains *C. siamea*, *A. Senegal*, *P. Juliflora* and *A. albida* were considered as group with high water economic potential. The findings conveyed the relationship between rate of transpiration and features of the stomata where it was found that plants with higher stomatal density and size had the highest rate of transpiration and volume of water loss.

Keywords: Rate of transpiration stomatal feature, tropical trees

Introduction

Forest is a plant community predominantly of trees of other woody vegetation occupying an extensive area of land. Forest provides many social, economic and environmental benefits. In addition to timber and paper products, forests provide wildlife habitat and recreational activities, prevent soil erosion and flooding, help provide clean air and water and contain tremendous biodiversity. Again forests are an important defense against the global climate change. Through the process of photosynthesis forests produce life giving oxygen and consume huge amount of carbon dioxide, the atmospheric chemical most responsible for global warming, by decreasing the amount of carbon dioxide in the atmosphere, forests can reduce the effects of global warming (Mastrandrea and Schneider, 2009) [10]. Forest productivity is affected by some factors which include climate, soil type and water availability as well as other external disturbances as a result of man actions. These externalities exist and affect the performance and even threaten the survival of some forest species. Drought is the main reason for desertification; it is one of the most critical environmental stresses that affect the establishment, survival, growth and performance of shrubs and trees (Fernandez *et al.* 2015) [8]. Plants experienced drought stress either when water supply to the roots becomes difficult or when the rate of transpiration becomes very high. These two conditions often coincide under arid and semi-arid climate (Reddy *et al* 2013) [11]. To survive drought stress, a plant must either extract more water from the soil and or effectively control the amount of water it loses through transpiration. The efficiency of soil water uptake by the root system as well as control of stomatal aperture, are key factors in determining the rate of transpiration (Cruz *et al* 1992) [3]. Stomata are pore like structures located on the leaf surfaces of virtually all vascular, terrestrial plant leaves and are responsible for the uptake of photosynthetic CO_2 as well as for the potentially detrimental water loss (Transpiration) from inside the leaf (MacDonald 2002) [9]. Moreover the frequency of these structures on leaf surfaces can dictate the degree of gas exchange potential for both photosynthetic CO_2 uptake and transpirational water loss. In response to favorable environmental signals, stomata may open to facilitate carbon uptake or close to prevent tissue drying and the maintenance of higher water use efficiency at different times of the growth season or given time of day (Croxdale 2000) [2]. In view of the above literatures, this study therefore, aims to measure the rate of transpiration and determine the stomatal frequency and pore area of some tropical trees (*Acacia albida, Acacia senegal, Azadirachta indica, Balanites aegyptiaca, Cassia samea, Eucalyptus camaldulensis* and *Prosopis juliflora*) for afforestation in arid zones to subsequently control desertification.

Materials and methods

Study area

The experiment was conducted at the laboratory and biological garden of Umaru Musa Yar'adua University Katsina. Katsina state is geographically located between latitude 12.5139^{0}N and longitude 7.6114^{0}E. It has a total land area of 23,930sq km. The state is located within three agro-ecological zones i.e. Sahel in the extreme north, Sudan savannah in the center and the northern Guinea savannah in the south. Rainfall ranges between 600 – 700mm; temperature between 21 ^{0}C- 36 ^{0}C. The textural class of Katsina soil was extremely sandy (90.3% sand, 4.3% silt and 5.4% clay) (Ladan and Rumah 2011) [5].

Seeds Collection

Healthy and vigorous seeds were collected from the mother trees.

Sowing

Seventy (70) pots were filled with substrates composed of manure (cow dung) mixed with sand at 2:1 followed by watering for three days to make the media suitable for sowing. Before sowing, the hard seeds were treated with two different treatments (Scarification and Acid (H_2SO_4) treatment) to enhance quick germination. Five seeds with replicates of five of each species were sown in the pots and daily watering continues. The experiment was monitored till seeds germinated.

Measurement of the rate of transpiration

The rate of transpiration of the selected tree species was measured using Ganong' spotometer. The apparatus was filled with water and closed from the stopper. The open end of the tube was closed. Fresh and leafy twigs of each species were cut under water and inserted into the vertical rubber tube to be fitted with mouth opening. The apparatus was set air tight. The closed end of the tube was opened; then stop watch was set on immediately the movement of water along the tube reached zero mark on the graduated scale. The movement of water was noted and the distance travelled was calculated at an interval/period of time with the aid of graduated scale on the tube length. The movement of water along the tube is the rate of transpiration and the amount of water transpired was calculated using formula $V=\pi r^2L$, where V= Volume or water lost, π=22/7 r = radius of the tube, L= Distance travelled by the water respectively. The number of leaves in each twig were counted and calculated the leave surface area uniformly (Gupta and Gupta; 2005).

Determination of stomatal frequency and size

Matured leaves for the study of the stomatal frequency and size were collected randomly between10-12pm and transferred into formalin acetic acid alcohol (FAA) instantly to be fixed and preserved.

Epidermal peeling, staining and mounting

The preserved leaf specimens were cut in pieces and inserted into the test tube containing a solution of 5ml water and 2ml concentrated HNO_3. The mixture boiled on flame till epidermal peel up (the appearance of air bubbles on a leaf indicates the readiness of the epidermis to be separated). The samples were transferred into petri dishes and washed several times to remove the HNO_3 then mounted on the glass slide and stained with safranin for microscopic observation.

Determination of the stomatal frequency and pore area

The frequency of the stomata in each species was determined as a number of occurrences per microscopic field of view at 100× magnification of light compound microscope. The stomatalarea were determined using a computerized system.

Statistical Analysis

The data recorded were analyzed statistically using descriptive statistics to calculate Mean, Mean standard error (SE), Standard deviation, Variance, Minimum and Maximum values. The results obtained were subjected to Analysis of Variance (ANOVA) at P = 0.05.

Results

The rate of transpiration significantly varied ($P<0.05$) among the selected species on *E. camaldulensis* the rate of transpiration was considerably high reaching about 16.4cm per minute (16.4cm/min), *A. Indica* with 8.4cm/min, *A. lebbeck* 3.1cm/min, *B. aegyptiaca* 1.6cm/min, C. siamea 0.86cm/min, *A. Senegal* 0.73cm/min, *P. Juliflora* 0.66cm/min. while in *A. albida* the rate of transpiration was found to be low with 0.54cm/min. As the rate of transpiration varies among the species the volume of water lost by the plant per unit time also varied under uniform leave surface area (1000) respectively (Fig1a). Analysis of variance indicated that there is significant difference on the rate of transpiration and volume of water lost by the plants among the species at 5% level of probability ($P<0.05$). (Fig1b). There is significant difference ($P<0.05$) in the stomatal frequency of the plants and all species are hypo amphistomatic i.e. having high percentage of stomata on the lower epidermis than on the upper epidermis. In *E. camaldulensis*, the stomatal density was frequently high reaching about 105.2 (38.6 upper epidermis and 66.6 lower epidermis), in *A. indica* 82.3 (29.3 upper and 53.0 lower),*A. lebbeck* 63.6 (17.0 upper and 46.6 lower), *B. aegyptianca* 61.6 (20.6 upper and 41.0 lower), *C. siamea*46.9 (12.6 upper and 34.3 lower), *A. senegal* 37.3 (9 upper and 28.3 lower), *P. juliflora* 31.6 (8.6 upper and 23.0 lower) and the frequency was found to be low in *A. albida* with 20.6 (2 upper and 18.6 lower) per microscopic field of view (100X). (Fig2a). There is no significant difference ($P>0.05$)

in the stomatal size of the species even though some possesses slightly larger stomata than others. The wider stomatal size is 119.3µm² in *E. camaldulensis*, 118.3µm² in *A. indica*, 115.1µm² in *B. aegyptiaca*, 102.4 µm² in *C. siamea*, 102.3µm² in *A. lebbeck* 100.4µm²in *A. senegal*, 94.2 µm² in *P. juliflora* and 84.8 µm² in *A. albida* (Fig3).

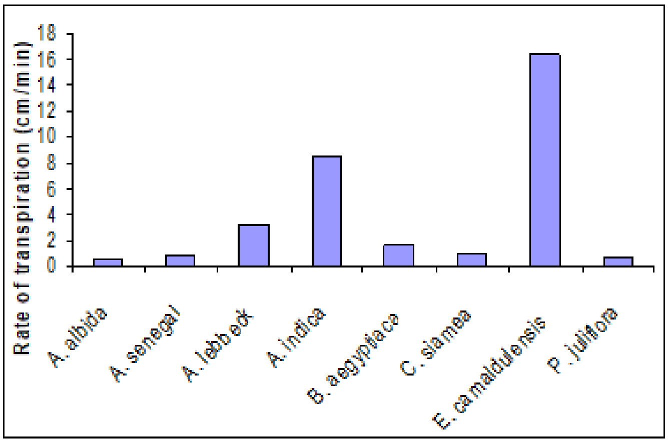

Fig 1a: Shows the rate of transpiration of the species

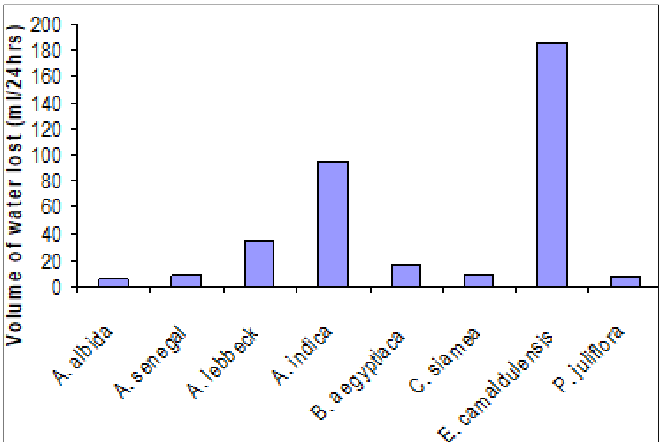

Fig 1b: Shows the volume of water lost by the plants

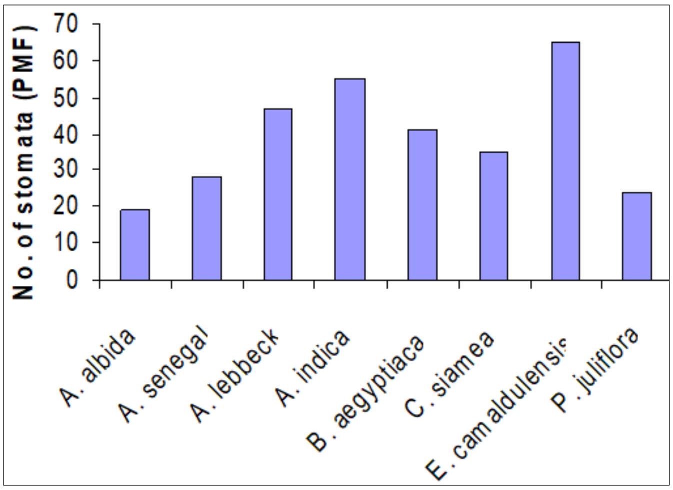

Fig. 2a: Shows stomatal frequency on lower epidermis

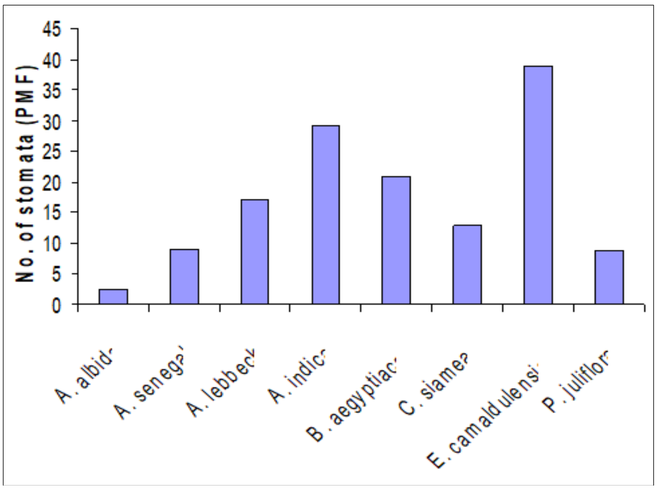

Fig 2b: Shows stomatal frequency on upper epidermis

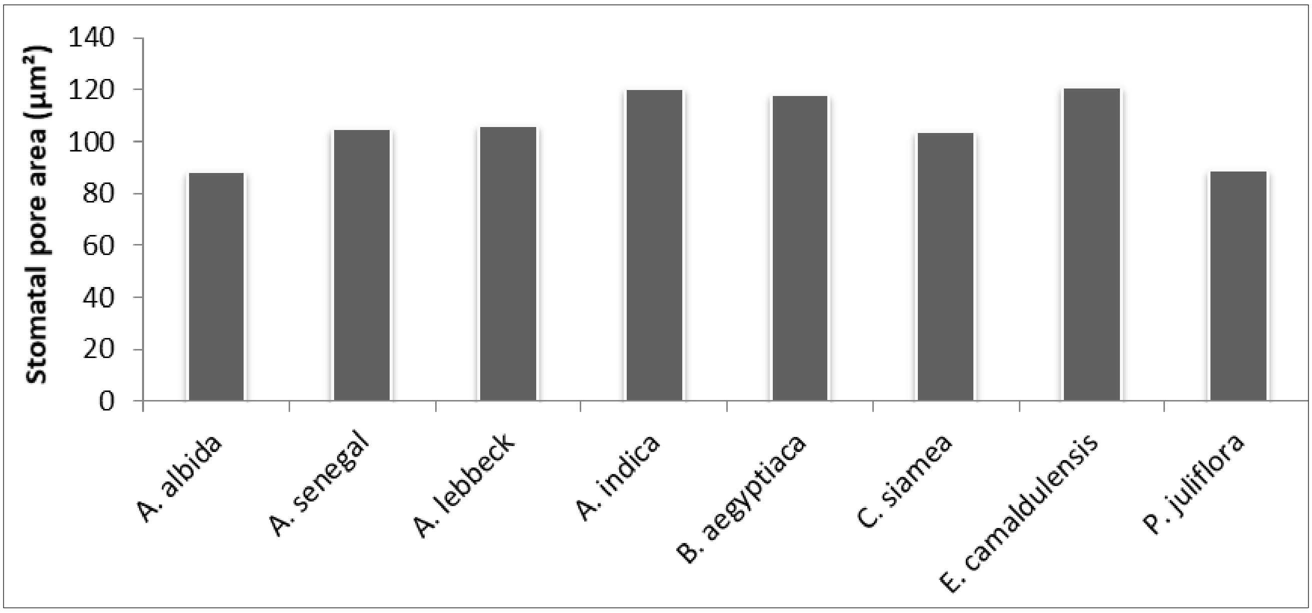

Fig 3: Shows stomatal size of the plants

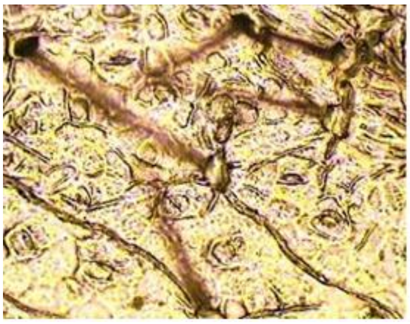

Plate 1: *Acacia albida*

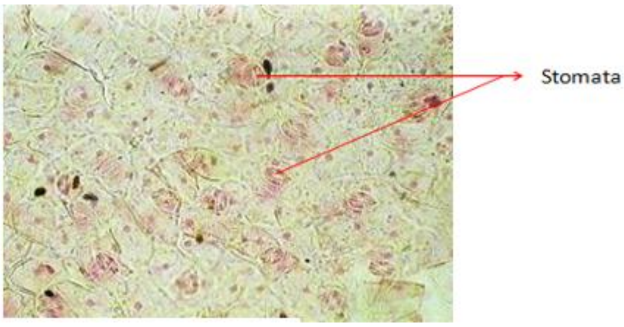

Plate 2: *Acacia senegal*

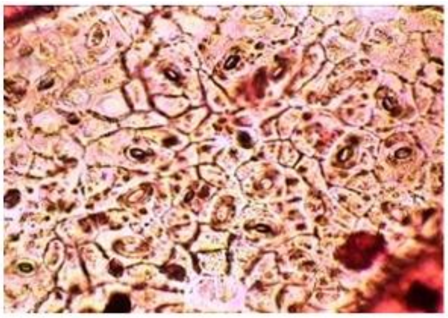

Plate 3: *Albizia lebbeck*

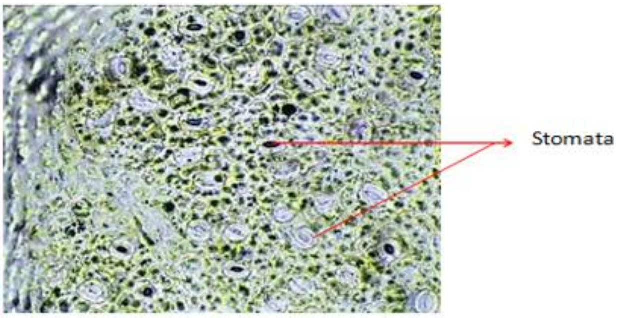

Plate 4: *Azadirachta indica*

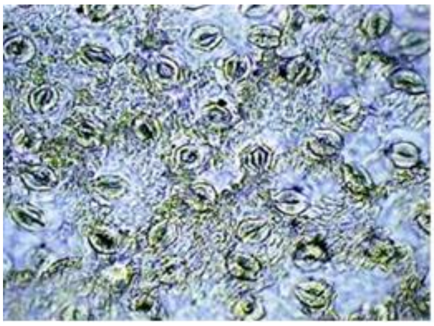

Plate 5: *Balanites aegyptiaca*

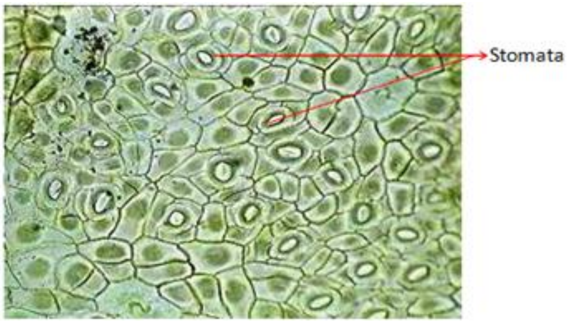

Plate 6: *Cassia siamea*

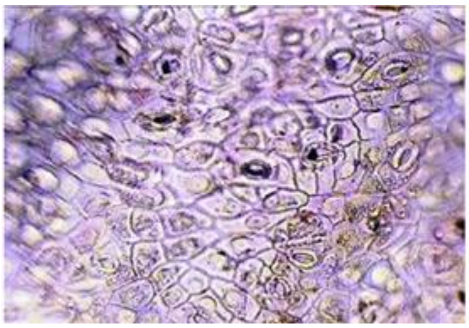

Plate 7: *Eucalyptus camaldulensis*

Plate 8: *Prosopis juliflora*

Plate I-VIII: Shows the distribution of stomata on leave of the species

Discussion

Drought is an environmental condition affecting physiological process and morphological structures of plants (Waggona and Simond, 1997). The physiological and anatomical features which accounts for plants adaptability to the dry environments were studied in eight species of tropical trees (*Acacia albida*, *Acacia senegal*, *Albizia lebbeck*, *Azadirachta indica*, *Balanites aegyptiaca*, *Cassia siamea*, *Eucalyptus camaldulensis*, and *Prosofisjuliflora*). This is to screen-out their drought tolerance and their potential abilities in adjusting water loss (Transpiration) in arid and semi-arid zones. Plant undergoes drought stress either when water supply to their roots become difficult or when the rate of transpiration become very high and this has influence to the wilting of plants. On the basis of the transpiration rate, the transpirational water loses of the species was found to be varied. The result indicated that the rate of transpiration is considerably greater in *Eucalyptus camaldulensis* and *A. indica*, moderate in *A. lebbeck*, *B. aegyptiaca*, *C. siamea* and less in *A. albida*, *A. senegal* and *P. juliflora*. The finding reflect directly to the early permanent wilting observed in *E. camaldulensis* and *A. indica*, this also make no contradiction to the concept that, transpiration and stomatal opening can be influenced by change in soil moisture, hence attributed to the wilting point of the plants (Bandt and Canny, 2002) [1]. From the analysis of stomatal frequency, the result shows the high number of stomatal occurrence in *E. camaldulensis* and *A. indica,* moderate in *A. lebbeck, B. aegyptiaca, C. siamea, A. senegal,* and shows lower number in *A. albida* and *P. juliflora.* Since the increase in stomatal aperture and distribution enhanced rapid moisture uptake and rate of transpiration, Shinishi, (1965) [12]. Contrary to the report of MacDonald, (2002) [9] he also stated that stomata are responsible for the potentially detrimental water loss (transpiration) from inside the leave. This idea is in consistent with the report that leave surfaces with greater stomatal frequency are also more efficient at repelling water (Smith and Mclean, 1989) [13]. Similarly, Darwin, (1904) [4] also considered that stomata play a predominant part in the control of transpiration. From the analysis of this study the result found that the presence of large number of stomata in *E. camaldulensis* and *A. indica* attributed to the high transpirational water loses that they cannot be able to adjust according to available soil moisture and this has influence to their early permanent wilting and for plants to survive drought stress the plants must extract more water from the soil and or control the amount of water it loses through transpiration. (Cruz *et al.,* 1992) [3]. The sizes of the stomatal aperture has also been recognized as a factor concerned in the regulation of the rate transpiration. The stomatal pore areas of the species were found to be wider in *E. camaldulensis* and *C. siamea,* moderate in *A. lebbeck, A. indica, B. aegyptiaca* and narrow in *A. senegal, P. Juliflora* and *A. albida.*

Conclusion

E. camaldulensis and *A. indica* had high stomatal number with wider aperture which leads it to lost high amount of water through transpiration while *A. albida* and *P. juliflora* were found to have less. It was observed that species with more of this features cannot adjust their transpirational loses related to the available soil moisture. Therefore, for sustainable afforestation in arid zones these findings indicated that, *E, camaldulensis* and *A. indica* are not suitable for afforestation in arid zones.

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