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Mesomorphy and vulnerability indices of *Solanum melongena* and *Corchorus olitorius* in Nsukka metropolis

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Abstract

Global warming is no longer just a prediction. It is happening. Variability in climate is deeply rooted within the West African society. Understanding the response of plants to increased drought would be desirable in the light of global and regional changes, not only to forecast population dynamics in natural ecosystem, but also to adjust management practices in agriculture. This study evaluated the vulnerability and mesomorphic indices of two woody farm shrubs (*Solanum melongena* and *Corchorus olitorius*) from three locations (Odoru, Ogige, Odenigwe) using their anatomical structures. The sectioning of the plant stems was carried out in the anatomy laboratory of the department of Plant science and Biotechnology, University of Nigeria Nsukka. The result was significantly different ($P < 0.05$) in the vessel length of the two plants with *Corchorus olitorius* having longer vessels ($0.302 \pm 0.012\text{mm}$). Similarly, the vessel length varied significantly ($P < 0.05$) across the different locations. The vulnerability and mesomorphy indices observed across the plants from the different locations were < 1 indicating the xeromorphic nature of the plants. Therefore, both species can withstand drought conditions, but at different degrees.

Keywords: Global warming, Climate change, West African society, Drought, Adaptation

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INTRODUCTION

The hydraulic designs of trees, shrubs and vines have an influence on the overall movement of water within the plant body and it is one important factor used to determine the plant size, the vulnerability of stems to periods of drought, water storage capacity of the tissues (mesomorphy) and their geographical distribution (Dickson, 2000). By identifying species most at risk from effects of climate change, conservation and management efforts can be targeted to reduce these impacts, such as by protecting existing habitat or through assisted migration. The structure and function of the different types of cells and tissues found in plants are forces for water movement and transpiration in plants (Lopez and Barcay, 2017)

Mesomorphic plants are adapted to conditions of abundant water and relatively humid conditions and are designed to function optimally for water uptake and gas exchange in photosynthesis. The anatomy of a mature dicot plants generally reflects the habitat, especially the availability of water. Most of the structural diversity encountered within the secondary xylem of woody plants has a functional explanation and can be related to plant habits as well as to varying atmospheric conditions and soil moisture availability (Dickson 2000).

According to (Dickson, 2000), the vulnerability index of wood anatomy can be calculated by dividing the mean vessels diameter by the mean numbers of vessels per square millimeter. The lower indices appear in xerophytic taxa with narrow but very numerous vessels per unit area. The xylem formulation is much safer than the one that consist of wider and fewer vessels per unit area because it will restrict air embolisms to a smaller and more localized portion of the transpiration stem. Meanwhile, the wood anatomical mesomorphy index can be calculated by multiplying the vulnerability index by the mean length of the vessel elements. Plants that are considered mesomorphic on ecological and macromorphological grounds exhibits wood mesomorphy indices greater than 200, whereby xerophytic taxa hardly possess indices of xylem anatomical mesomorphy in excess of 75. (Dickson 2000). Drought stress is a factor that affects plant growth and development, both in terms of morphology, anatomy, and physiology. (Patmi *et al*, 2020). The aim of this study is to determine the mesomorphy and vulnerability indices of *Solanum melongena* and *Corchorus olitorius* and to establish through the study, the various

habitats where the two species can grow optimally.

MATERIALS AND METHODS

Study Area

The study area (Nsukka) lies between latitude 06° 52'E and longitude 07°N 24'N and at an altitude of 447m above sea level. The average daily temperature ranges between 29°C and 31°C, annual rainfall distribution ranges from 1155mm to 1955mm and a relative humidity that ranges from 69% to 79% (Uguru *et al.*, 2011). From the study of (Uguru *et al.*, 2011), there is a rise in temperature in the recent years with a record of warmer temperatures. There is also shift in rainfall pattern which resulted in drop in relative humidity. These showed that the ecology has warmed up over the years and the rate of warming increased over a decade.

Collection and preservation of specimens

The first sample of *Solanum melongena* was collected in Ogige in Nsukka metropolis, the second sample was collected in Odenigwe in Nsukka metropolis, and the third sample was gotten from Odoru in Nsukka metropolis. The first sample of *Corchorus olitorius* was collected in Oduru in Nsukka metropolis, the second sample was collected in Ogige in Nsukka metropolis, and the third sample was collected Odenigwe in Nsukka metropolis. The stems of both plants were cut in their transverse section. The sectioning was done using Reieherth sledge microtome, the automatic microtome knife sharpener was used to sharpen the blade. The sections were collected using different petri dishes to preserve the sample for further anatomical studies.

The Petri dishes were properly labelled according to their contents. After the sectioning of the stems, a chemical solution was prepared. A solution of 70% alcohol was prepared by diluting absolute alcohol by adding 30 ml of water to 100 ml of absolute alcohol. The 70% alcohol was used for temporary preservation. A solution of formalin acetic acid (FAA) was prepared for permanent preservation. The solution was prepared by adding 90 ml of 70% alcohol, 5 ml of acetic acid and 5 ml of formalin to get 100 ml of FAA. The solutions were measured with a measuring cylinder and poured into a Bama bottle, the sectioned stems were then put inside the bottle, labelled, and covered.

Sectioning of stems

The sections were counter stained with 1% fast green for 5 minutes and washed three times in absolute alcohol. Fast green and safranin serve to identify a lignified and unlignified tissues. The sections were transferred into containing jar containing 50/50 alcohol and xylene in the ratio of 1:1 and washed until clear. Pure xylene was finally used to clear the sections further.

Temporary slide preparations and permanent slide preparations

Iodine solution was prepared by dissolving 1g of iodine crystals and 2g of potassium iodide in 300ml of distilled water and then the sectioned sample were mounted on a KARL KAPS asslar/Wetzlar Nr39805 microscope with 1-2 drops of iodine. Iodine was used because it detects the presence of starch granules in the sectioned sample; thereby forming blue-black stains which helps to identify tissues easily. After mounting of the slide with the sample, 1-2 drops of concentrated hydrochloric acid were added to identify the presence of lignin. The sectioned sample were transferred into a staining jar and stained with 1% safranin for 5 minutes, the sections were removed and washed three times in distilled water, two times in 97% alcohol and two times in absolute alcohol in order to dehydrate the samples.

Wood maceration

The method used for maceration in this study was that of Schluzer's according to Mahesh *et al.*, (2015). The bark of the air-dried stem discs was excised from the wood after which the wood was cut into tiny bits of blocks. The tiny bits of wood blocks (woodchips) were then placed in a well labeled test tube to which 1g of 5% chlorate and 10ml of nitric acids were added after which they were allowed to react in a fume cupboard until the lignin and middle lamella of the chips dissolved. Since potassium chlorate is a strong oxidizing agent, it accelerated instant reactions with nitric acid (HNO_3) to affect the maceration while the presence of lignin was revealed by the reddish-brown color of the test tubes. A white tissue appeared at the base of the test tubes indicating that maceration had taken place. The residual acid was decanted from the test tubes into a reserve receptacle after which distilled water was added to the test tubes, the test tubes were then covered with caps or stoppers and shaken vigorously to allow the tissue dissolve and also stop further reactions. The test tubes were left in a standing position for 24 hours, and the supernatant was decanted thereafter. The

macerated tissues were stored in specimen bottles where formalin was also added to prevent further fungal growth or decay of the tissue. Staining of the macerated tissues was done using 1% safranin solution.

Microscopic examination

The ordinary light microscope was used to study the vessel distribution in the transverse section. The prepared sections were viewed under the KARL KAPS asslar/Wetzlar Nr39805 microscope x100 magnification. The vessel characteristics were measured using a monocular microscope to which ocular micrometers were fitted in the eye-piece tubes. The ocular micrometer was first calibrated using a stage micrometer of 2mm range according to Adinde *et al.* (2016). The vessels were observed, and photomicrographs were taken.

Determination of Number of Vessels

The number of vessels for each of the species was counted within 1 square millimeter. The number of vessels that fell within a square millimeter were counted and recorded. A replication of 30 was made. Meanwhile, the square millimeter was prepared according to Adinde *et al.* (2016).

Calculation of Vulnerability Indices

A replication of 30 was taken and the vulnerability of the wood specimen was evaluated using Calquist (1977) Vulnerability index = mean vessel diameter / Mean vessel number per mm

Calculation of Mesomorphy Indices

A replication of 30 was taken and the mesomorphy of the wood specimens was evaluated as stated by Calquist (1977). Mesomorphy index = Vulnerability index x Mean vessel length

RESULTS

Results on wood measurements and vessel characteristics

Vessel characteristics studied include the number of vessels, the vessel diameter, the vessel length which are used to get the vulnerability, and mesomorphy index. Plate 1 to 3 show the vessel length, vessel diameter and number of vessels of *Corchorus olitorius*. Plate 1 shows that the plant adapted better to the environment in terms of water conduction

compared to others from other location. The vulnerability of plate 1 will be higher compared to plates 2 and 3. Plates 2 and 3 are able to adapt to their location but at varying degrees. Plates 4 to 6 show the vessel length, vessel diameter and number of vessels of *Solanum melongena*. Plate 4 shows that the plant adapted better to the environment in terms of water conduction compared to others from other location. The vulnerability of plate 4 will be higher compared to plates 5 and 6. Plates 5 and 6 are able to adapt to their location but at varying degrees. Table 1 below shows the effect of the plant species (factor A) on the vessel characteristics irrespective of the location, those that showed the vessel length of *Corchorus olitorius* varies significantly to that of *Solanum melongena*, and the mesomorphy index of jute also varies significantly to that of garden egg by 0.002 mean difference. Table 2 below shows the effect of the location (factor B) on the vessel characteristics irrespective of the species, according to the study, it was seen that the vessel length between Odoru and Odenigwe were the same but varied significantly to that of Ogige, and the mesomorphy index varied significantly between Ogige and Odoru but showed similarity to that of Odenigwe. Table 3 shows the effect of factor A (plant species) and factor B (location) on vessel characteristics, according to the study carried out, the vessel characteristics showed significant difference in *Corchorus olitorius* collected from Odoru but no difference in that of Ogige and Odenigwe. Also, the variability in vessel characteristics showed significant difference in *Solanum melongena* collected in Odoru

DISCUSSION

According to the Dickson (2000), because vessel diameter appears to be functionally related to the volume of water being conducted through the xylem, differences in pore diameter in ring porous trees reflect difference in the amount of water transported at various times throughout the growing season. Plants with narrow vessel diameter but very numerous vessels per square mm are xerophytic and is theoretically safer than ones that consist of wider and fewer vessels per square mm because it will restrict air embolisms to a smaller and more localized portion of the transpiration stems. Drought stress is one of the most impacting factors which alter seriously the plant

physiology, finally leading to the decline of the crop productivity.

The result showed a significant difference in the vessel length of the two plants with *Corchorus olitorius* having longer vessels. The significant differences recorded in the vessel length of the plant could probably be attributed to the differences in plant species. Similarly, the vessel length varied significantly across the different locations which clearly indicate the effect of the environment on the plants. Drought stress causes in plants a set of morpho-anatomical, physiological, and biochemical changes, mainly addressed to limit the loss of water by transpiration with the attempt to increase the plant water use efficiency. (Dhriti *et al*, 2020). The vulnerability and mesomorphy indices observed across the plants from the different locations were <1 indicating the xeromorphic nature of the plants. The vulnerability and mesomorphy indices observed in these plants were much lower than the reported indices for *Gmelina arborea*, *Pentaclethra macrophylla* and *Ceibapentandra* collected from the Botanic Garden, University of Nigeria Nsukka by Adinde *et al*. (2016).

Many adaptations of woody plants have been identified in their stems, chief among them is the low resistance to water flow in vascular tissues (Kozlowski and Pallardy, 2002). Desert areas are characterized with low rainfall and shortage of soil water. Humidity is as well low. These suggest that rate of transpiration would also be high. For plants to survive in desert areas they must have some modifications to adapt to the harsh environment. Plants must absorb water efficiently to be able to compensate for the shortage of water and for the loss of water through transpiration. According to Carlquist (1997), based on the indicators used it is determined that vulnerability index lower than one reflects adaptation to drier areas, while values greater than three are found in plants living in areas with high water availability. From the research conducted, it can be deduced that *Corchorus olitorius* that are found within the region of Odenigwe in Nsukka metropolis with have more ability to adapt to drier areas compared to those found in Odoru and Ogige. The *Solanum melongena* found in Odoru in Nsukka metropolis similarly would adapt to drier areas compared to those found in Ogige and Odenigwe.

Table 1: Mean differences in vessel characteristics, vulnerability and mesomorphy index between plant species

Vessel Characteristics	<i>Corchorus olitorius</i>	<i>Solanum melongena</i>	LSD
No of vessels per square mm	3.578 ± 0.327	3.367 ± 0.286	NS
Vessel diameter	0.070 ± 0.002	0.079 ± 0.006	NS
Vessel length	0.302 ± 0.012 ^a	0.177 ± 0.011 ^b	0.03
Vulnerability index	0.032 ± 0.002	0.034 ± 0.003	NS
Mesomorphy index	0.010 ± 0.0008 ^a	0.005 ± 0.0005 ^b	0.002

Data presented with means ± standard error. Means are separated using least significant difference test (LSD) at P < 0.05 with means with differential alphabets on each row representing significant differences; NS-Not significant

Table 2: Mean differences in vessel characteristics, vulnerability and mesomorphy index between locations

	Ogige	Odoru	Odenigwe	LSD
No of vessels per square mm	2.933 ± 0.266	3.767 ± 0.362	3.717 ± 0.467	NS
Vessel diameter	0.076 ± 0.008	0.076 ± 0.003	0.071 ± 0.003	NS
Vessel length	0.280 ± 0.013 ^a	0.204 ± 0.022 ^b	0.233 ± 0.007 ^b	0.033
Vulnerability index	0.034 ± 0.004	0.033 ± 0.004	0.032 ± 0.003	NS
Mesomorphy index	0.009 ± 0.0008 ^a	0.006 ± 0.0010 ^b	0.008 ± 0.0007 ^{ab}	0.002

Data presented with means ± standard error. Means are separated using least significant difference test (LSD) at P < 0.05 with means with differential alphabets on each row representing significant differences; NS-Not significant

Table 3: Variability in vessel characteristics of plant species collected from different locations

Plants	Location	No of vessels per square mm	Vessel diameter	Vessel length
<i>C. olitorius</i>	Ogige	2.600 ± 0.170	0.076 ± 0.003 ^{ab}	0.343 ± 0.020 ^a
	Odoru	4.267 ± 0.547	0.061 ± 0.003 ^b	0.323 ± 0.024 ^a
	Odenigwe	3.867 ± 0.777	0.074 ± 0.003 ^{ab}	0.239 ± 0.010 ^b
<i>Solanum melongena</i>	Ogige	3.267 ± 0.500	0.076 ± 0.016 ^{ab}	0.217 ± 0.007 ^b
	Odoru	3.267 ± 0.465	0.091 ± 0.004 ^a	0.086 ± 0.021 ^c
	Odenigwe	3.567 ± 0.531	0.068 ± 0.004 ^b	0.227 ± 0.011 ^b
LSD		NS	0.019	0.043

Data presented with means ± standard error. Means are separated using least significant difference test (LSD) at P < 0.05 with means with differential alphabets on each column representing significant differences; NS-Not significant

Below are plates showing the microscopic features of *Solanum melogena* and *Corchorus olitorius*

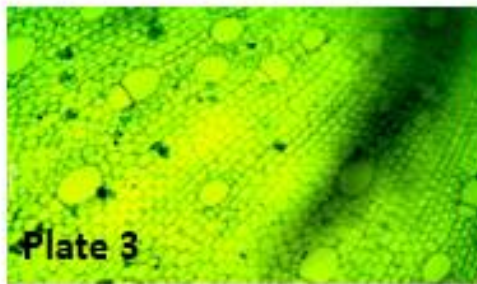
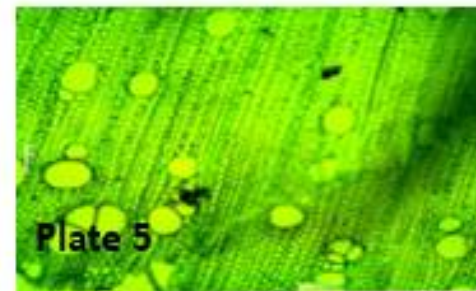
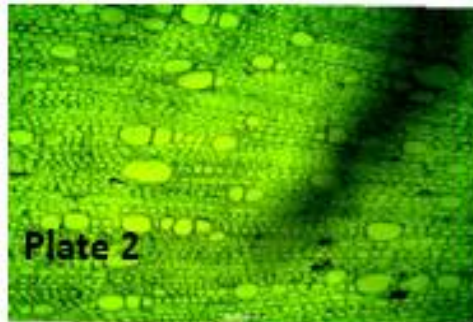
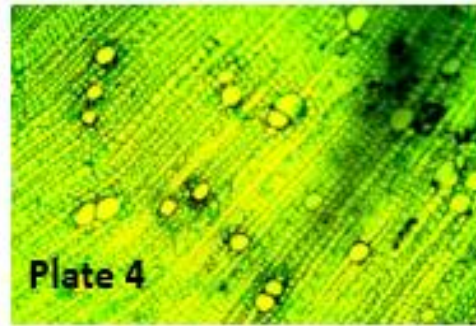
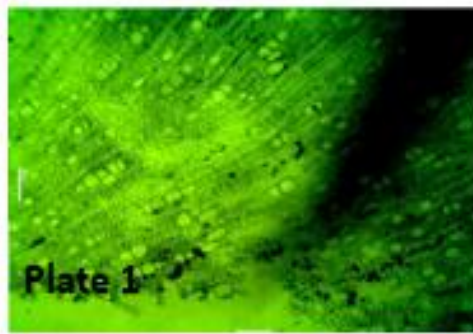


Plate 1-Transverse section (Ts) of *Corchorus olitorius* (Location- Ogige; Ts of *Corchorus olitorius* (location- Odoru), Plate 3- Ts of *Corchorus olitorius* (location-Odenigwe); Plate 4- Ts of *Solanum melogena* (location- Odenigwe); Plate 5-Ts of *Solanum melogena* (location-Ogige);Plate 6- Ts of *Solanum melogena* (location- Odoru). Magnification X100.

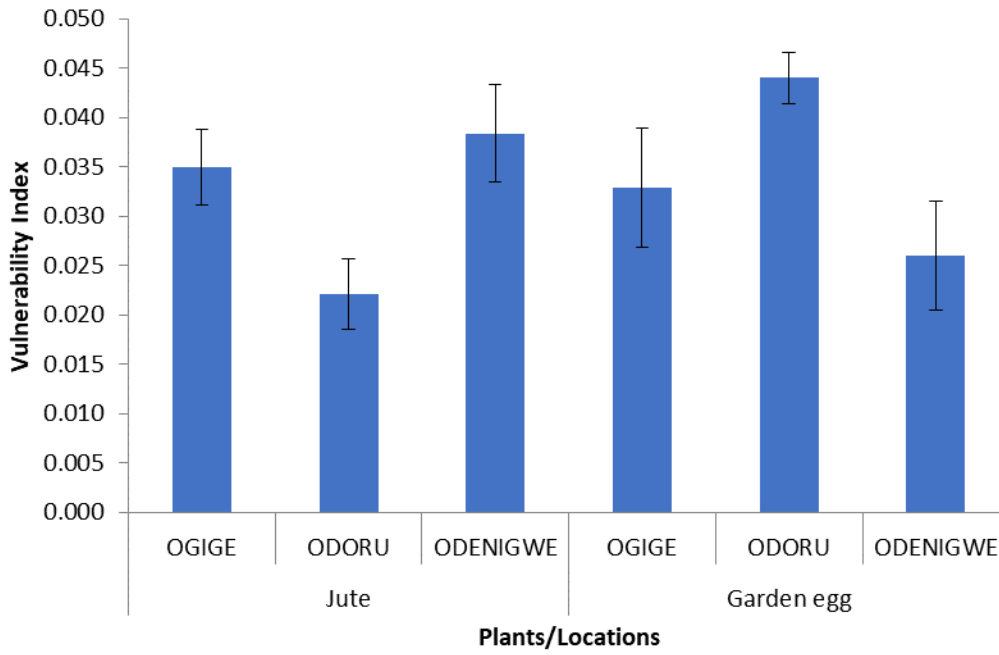


Figure 1: Vulnerability index of vessel characteristics on the two plant species in different location

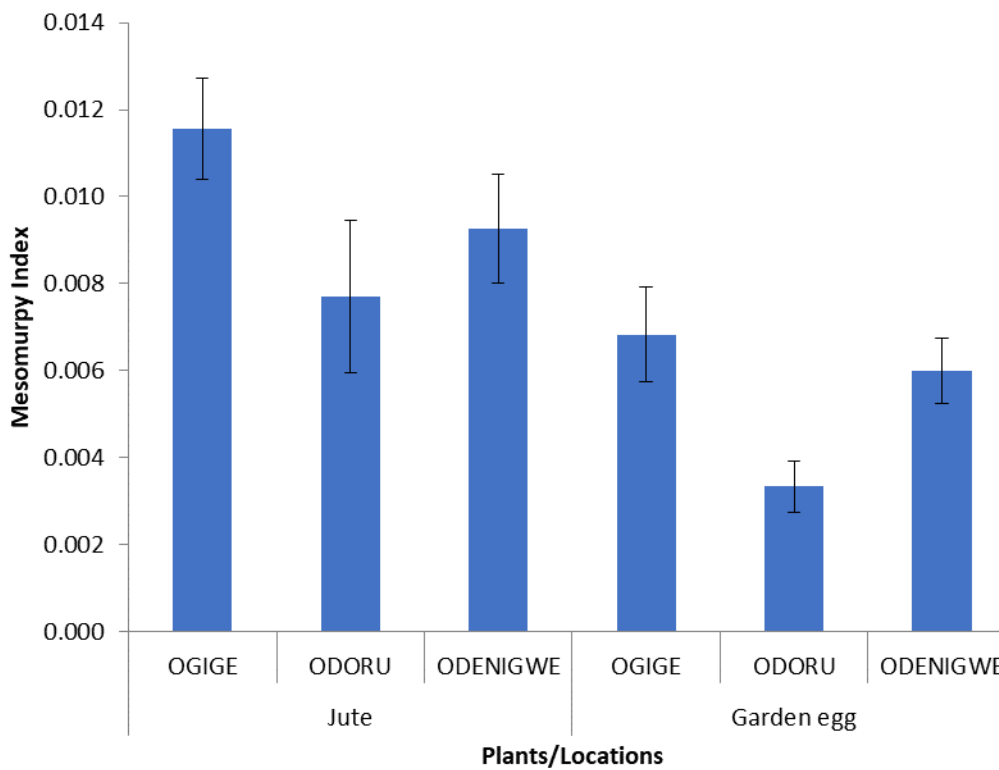


Figure 2: Mesomorphy index of vessel characteristics on the two plant species in different location

CONCLUSION

The research showed that the *Corchorus olitorius* found in Ogige have higher mesomorphy index compared to those found in Odoru and Odenigwe but still <1. *Solanum melongena* have shown to have less mesomorphy indexes but the species gotten from Ogige region have more mesomorphy index compared to those found in Odoru and Odenigwe. However, both plants can adapt to drier areas but at different degrees. Mitigation and adaptation are the two principal ways of dealing with the threat of climate change (Ozor *et al.*, 2010). Understanding the response of plants to increase drought would be desirable in the light of global and regional changes, not only to forecast population dynamics in natural ecosystem, but also to adjust management practices in agriculture. The research can be diversified by using both field work and lab work approach to understand the various habitats where different species can grow optimally and understanding the impact of anatomy on the physiology of trees and crop plants. Physiology and anatomy are tightly correlated, as cell and tissue structure has changed with respect to the evolution of novel functional mechanisms. (Simpson, 2019). Morpho-anatomical characters supporting the resilience of a plant under certain environmental conditions cannot be interpreted individually but thoroughly along with the physiological factors to determine the ability of plants to survive in the drought environment. (Salsinha *et al.*, 2020).

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Conflict of interest

The authors declare no conflict of interest.

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