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Leaf Transpiration Study on Seven Selected Tree Species from Ogbomoso Nigeria for Afforestation of Dry Areas

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Abstract

Among the pragmatic approaches to addressing the issue of climate change is reduction of its anthropogenic causes (such as emissions from burning of fossil fuels and indiscriminate removal of vegetation cover) and making of conscious efforts toward increasing global vegetation cover. Based on the desirable qualities of afforestation species, this study aimed to quantify the rate of leaf transpiration in seven selected tree species in Ogbomoso Nigeria, with a view to ascertaining their suitability for afforestation of water stress habitats. The mean quantity of water transpired per cm^2 area of ten randomly selected mature leaves of seven tree species from the study location (8^0 10' 12.217''N, 4^0 15'12.607''E - 8^0 9' 45.834''N, 4^0 16' 6.209''E) was determined as a difference in the weight of a 4cm^2 dry cobalt chloride paper (DCCP) and wet cobalt chloride paper stuck to adaxial/upper and abaxial/lower leaf surfaces until the blue DCCP completely turned to pink, and the time taken for this to happen was recorded. The rate of transpiration was also calculated in mg/cm^2/min of each leaf surface by dividing the amount of water transpired/cm^2 area by the respective time taken, and the means for the seven tree species were obtained. Higher mean rates of water transpiration in mg/cm^2/min were recorded on the abaxial (18.6±2.4 – 30.6±1.8 in Psidium guajava and Ficus exasperata respectively) than the adaxial (14.4±1.8 – 25.2±6.0, also in P. guajava and F. exasperata) leaf surfaces. Evidence from the statistical analysis led to the conclusion that F. umbellata and F. exasperata are better atmospheric humidifiers than the other five tree species studied which instead, are better water conservers. The rate of leaf transpiration in four of the latter namely; Anacardium occidentale, F. benjamina, Mangifera indica and P. guajava are on a par with the fifth i.e. Azadirachta indica, the widely acclaimed afforestation species of dry lands. Therefore, the seven tree species studied are suitable candidates for afforestation of dry areas, the two humidifiers where increased atmospheric water vapour is desired, and the water conservers for water-stress environments.

INTRODUCTION

Forestry is the management of forest lands for wood, water, wildlife, forage and recreation (Sasaki and Putz, 2009). It is the science, art and practice of understanding, managing and using the natural resources associated with, and derived from forest lands judiciously (UBC Forestry, 2019). Wood and wood products are often regarded as items of major economic importance from forests, so, forestry has been chiefly concerned with timber management especially in regard to refforestation, maintenance of extant forest stands at prime condition, and fire control. Trees have been acknowledged as an important stabilizing agent in terrestrial ecosystems by protecting the soil against direct solar radiation and erosion. They conserve soil by encouraging percolation and discouraging surface runoff. They also humidify the environment by generating water vapour through the process of transpiration, thus lowering air temperatures.

Tropical forests store 120 – 400 tons of carbon per square hectare of vegetation, which is released in gaseous form into the atmosphere when the forests are burned or harvested (Laurence, 2007). Exploitation of trees for domestic, agricultural, industrial and developmental purposes has been indiscriminate and massive. There is increasing awareness of the link between deforestation and climate change, and deforestation in the tropics has been recognized as a multi-faceted threat to global climate. Climate change is a current world-wide crisis that requires creative and flexible regulatory solutions. It arises from global warming due to release of greenhouse gases into the atmosphere, human uses of fossil fuels, burning of plastics, human consumption pattern, deforestation and human travel patterns (Important India, 2017). In addition to releasing stored carbon, deforestation reduces the capacity of the remaining forest stands to absorb carbon from the atmosphere, thereby encouraging global warming (Abate and Wright, 2010).

One pragmatic approach to addressing the issue of climate change is reduction of its anthropogenic causes such as emissions from the burning of fossil fuels and indiscriminate removal of vegetation cover (Morris, 2010). Another approach is to make conscious efforts towards increasing global vegetation cover by way of afforestation (Reyer *et al.,* 2009; Abate and Wright, 2010). *Ficus* species and *Azadirachtaindica* are tree species commonly used in urban forestry in Nigeria. According to Dzomeku and Enu-Kwesi (2006), *A. indica*, an evergreen tree species is particularly noted for this purpose in being able to thrive well in almost all drought stress environments.

More than ever before, all stakeholders in environmental protection now take the issue of afforestation more seriously. The desirable qualities in any afforestation species had been enumerated to include rapid growth rate, high rate of leaf transpiration and ability to withstand long period of drought (Singh *et al*., 2017). The Amazon rainforest alone has been estimated to emit approximately seven trillion tons of water per year into the atmosphere, which ultimately turns into water vapor that has a significant cooling effect on global climate patterns (Moutinho *et al.,* 2005). Therefore, there is no doubt that the loss of tropical forests will have significant effects on our planet's natural climate stabilizers. On the basis of the desirable qualities of afforestation species enumerated, and the environmental protection benefits derivable from trees, this study aimed to quantify the rate of leaf transpiration in seven selected tree species in Ogbomoso Nigeria, with a view to ascertaining their suitability for afforestation, especially of dry areas.

MATERIALSANDMETHODS

Plant Material

In the month of July 2016, branches of about 4 – 6 cm diameter were cut along with their leaves from seven tree species located within and around the Campus of Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria, geo-referenced 8^0 10' 12.217''N, 4^0 15'12.607''E - 8^0 9' 45.834''N, 4^0 16' 6.209''E. The cut end of each tree branch was stuck deep into a plastic bucket filled with humid loamy top soil to prevent it from dehydration, and immediately transported to the open space in front of Old Biology Laboratory of the University where the transpiration study was carried out between 13:00 and 14:00 hours Nigeria time.

Preparation of Cobalt Chloride Papers

Exactly 5g of laboratory grade Cobalt (II) Chloride salt was weighed and dissolved in 100ml of distilled water to obtain 5% solution of the salt. A few Whitman filter papers cut into square shapes size 2cm × 2 cm were serially numbered by means of a pencil and made to soak in the prepared solution for about 5 minutes in a petri dish thereby turning pink (Royal Society of Chemistry, 2016).A pair of fine forceps was used to pick the damp filter papers for drying on a warm place until the pink colour turned blue (American Chemical Society, 2006). The weight of each dry Cobalt Chloride paper (DCCP), with the pencil mark not obscured by colour change was determined by means of S.METTLER K-300g/0.001g balance and recorded against the serial number. Again using a pair of fine forceps, the DCCP was transferred into a dry bottle with airtight lid, ready for use.

Determination of Leaf Transpiration Rates

Ten mature leaves were randomly selected from each tree branch for leaf transpiration study. Using a pair of forceps, one DCCP was carefully positioned at the centre of each of the two leaf surfaces (adaxial/upper and abaxial/lower) and held in place with the aid of two glass plates made firm and airtight using the thumbs and fingers. A stop watch was immediately switched on, and the time taken for the DCCP to turn to pink (or completely wet) was recorded (American Chemistry Council, 2006). At the end of each successive transpiration study of a leaf, the weight of the two wet cobalt chloride papers (WCCPs) was determined and the difference from the initial weight was recorded as quantity(in milligrams) of water transpiredin 4cm^2 of adaxial and abaxial surfaces of leaf area. Each of these values was then converted to quantity of water transpired per cm^{2}of the leaf area. The rate of transpiration was also calculated for the ten leaves, and both surfaces as quantity of water transpired /cm^{2}divided by the respective time taken in seconds, but they were recorded in mg/cm^2/min after necessary conversions. Finally, the means of the ten replicated values of quantity of water transpired /cm^2 and of the rate of transpiration /cm^2/min for adaxial and abaxial surfaces were computed and reported.

Statistical Analysis

The ten replicated values of each of the two sets of data from both leaf surfaces were subjected to one-way analysis of variance across the seven tree species using the version 17.0 of the computer-based SPSS statistical package. The means were separated using multiple Duncan range test at alpha = 0.05.

RESULTS

The mean quantities of water transpired in mg/cm^2 by the leaf surfaces of the seven tree species studied are shown in table 1, ranging between 4.5mg/ cm^{2}on the adaxial, and 8.0mg/ cm^2 on the abaxial surfaces of *Azadirachtaindica* and *F. benjamina* respectively. More water vapour was generally transpired on the abaxial than adaxial leaf surfaces with the exception of *F. exasperata* and *Anacardiumoccidentale*. In these two species, more or less equal amount of water vapour was transpired on leaf surfaces i.e. 6.0mg/ cm^2 and 5.5 mg/cm^2 respectively.The rate of leaf transpiration also ranged between 14.4mg/cm^2/min on the adaxial leaf surfaces of *Mangiferaindica* and *Psidiumguajava*, and 30.6mg/cm^2/min on the abaxial surface of *F. exasperata*. The rates of water transpiration were higher on the abaxial than adaxial leaf surfaces in all the tree species examined (Table 1).

Table 1: Quantity and rates of water transpired by the leaves of the seven tree species studied

	Tree species	Mean quantity of water transpired (mg/cm^2)		Mean rate of transpiration (mg/cm^2/min.)	
		Adaxial	Abaxial	Adaxial	Abaxial
1	*Anacardiumoccidentale*L.	5.5^{b}± 1.74	5.5^{ab}±1.89	15.6^{ab}±1.8	16.2 ^{a}±2.4
2	*Azadirachta indica*A. Juss.	4.5^{ab}±1.39	5.0^{a}±1.89	15.6^{ab}±1.9	19.2 ^{a}±1.9
3	*Ficus benjamina*L.	7.5^{c}±2.55	8.0^{c}±2.90	17.4^{ab}±1.8	19.8^{a}±1.8
4	*F. exasperata* Vahl.	6.0^{bc}±1.68	6.0^{ab}±1.79	25.2^{b}±6.0	30.6^{b}±5.8

5	*F.umbellata* Vahl.	5.5^{b}±1.78	6.0^{ab}±1.78	23.4^{ab}±5.4	26.4^{ab}±4.8
6	*Mangifera indica*L.	6.0^{bc}±1.94	7.0^{c}±1.77	14.4^{a}±1.8	18.6^{a}±2.4
7	*Psidium guajava*L.	5.0^{b}±1.96	6.0^{ab}±2.21	14.4^{a} ±1.8	18.6^{a}±2.4

The means in the same column with the same superscripts are not significantly different ($p \geq 0.05$), while the means in the same column with different superscripts are significantly different ($p \leq 0.05$). Adaxial = adaxial or upper leaf surface; Abaxial = abaxial or lower leaf surface

DISCUSSION

From the results obtained, *F. exasperata* can be identified as the species capable of transpiring the highest quantity of water in a minute from its adaxial (25.2mg/cm^2/min) and abaxial (30.6mg/cm^2/min) leaf surfaces. This species thus appears to be a better afforestation species to humidify environments than any of the other six species studied. Judging by the results of the statistical analysis, *F. exasperata* is followed closely by *F. umbellate* with 23.4mg/cm^2/min and 26.4mg/cm^2/min as rates of leaf transpiration on its adaxial and abaxial surfaces respectively. These results imply that *F. umbellata* can be a substitute for *F. exasperata* if humidification of environments is a factor for consideration.

On the contrary, the lowest rates of leaf transpiration were observed on the adaxial (14.4mg/cm^2/min) and abaxial (18.6mg/cm^2/min) surfaces of both *Mangiferaindica* and *Psidiumguajava*, the values that are not significantly lower, especially on the abaxial surfaces, than those *Anacardiumoccidentale*, *Azadirachta indica and F. benjamina*. It is noteworthy that *A. indica* is a tree species that has been acknowledged as successful afforestation species of dry locations in Nigeria, India and other parts of Asia (Ogbuewu *et al*., 2011), and indeed, other parts of the globe (Tinghui *et al*., 2001). Reduced leaf transpiration is a water conserving mechanism (Blanken and Rouse, 1996), which is desirable for success on dry areas. Hence, the results of this study are not only confirmatory of *A. indica* as afforestation species of water stress environments, they are also suggestive of possible use of these four tree species as alternatives to *A. indica* in this regard.

Observations of higher quantities and rates of water transpiration on the abaxial leaf surfaces of the seven tree species can most likely be attributed to the presence of stomata only on this part of their leaves (Iroka *et al*., 2014; Ramos *et al*., 2015; Ogunkunle and Oladele, 2008; Abdulrahaman *et al*., 2016; Sajjekhan *et al*., 2011; Kundu and Tigerstedt, 1998). The relatively lower amounts and rates were therefore expected on the adaxial surfaces because only cuticular transpiration was possible (Schuster*et al*., 2017). In addition to the leaves of these species being hypostomatic, the leaf stomata have been reported to be relatively smaller in size in comparison with trees adapted to moist environments (Mandal *et al*., 2000; Ogunkunle and Oladele, 2008), pointing to their ability to conserve water better.

Ficus species or fig trees are known to possess stronger suction force to draw water from the soil than many other tree species (Mbuya *et al*, 1994). According to Beentje (1988), most, if notall, species of *Ficus* possess an extensive roots ystem. This allows several species, which seem to be obligatory terrestrials, to grow in localities which are too dry for most other plants. There is also a possibility that fig trees havea capability of picking up moisture from dew, mist, and moisture-saturated air at night. By means of the aerial root system which is often present. This large suction force might be the reason why *Ficus* species do not suffer invasion of parasitic plants, and being latex-containing plants, they are not affected by fluoride toxicity (Beentje, 1988). The relatively higher rate of leaf transpiration in two of the three species of *Ficus* studied (i.e. *F. exasperata* and *F. umbellata*) can therefore be explained by the possibility of the suction force, which was transmitted along the whole length of the vessels as transpiration pull (Tanner and Beevers, 2001). Additionally, the acclaimed resistance of *Ficus* species to parasitic plants and environmental toxicity has lends further credence to their successful use as afforestation species. The other four tree species studied (namely, *M. indica, P. guajava, A. occidentale* and *A. indica*) generally exhibited lower rates of leaf transpiration probably due to lack of such outstanding suction pressure.

CONCLUSION

Evidence from the results obtained along with the outcome of the statistical analysis led to the conclusion that *Ficus. umbellata* and *F. exasperata* are better atmospheric humidifiers than the other five tree species studied, which instead, are better water conservers. The rate of leaf transpiration in four of the water conservers namely; *Anacardium occidentale*, *F. benjamina*, *Mangifera indica* and *Psidium. guajava* are on a par with the fifth i.e. *Azadirachta indica*, the widely acclaimed afforestation species of dry lands. Therefore, this study has confirmed *A. indica* as a tree species adaptable to dry habitats, and recommends the other six species studied as suitable candidates for afforestation of dry areas. While the better environmental humidifiers i.e. *F. umbellata* and *F. exasperata* are desirable for increased atmospheric water vapour, the four water conservers are endorsed for water-stress environments.

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