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THE RELATIONSHIP BETWEEN CANOPY WIDTH, HEIGHT AND TRUNK SIZE IN SOME TREE SPECIES GROWING IN THE SAVANA ZONE OF NIGERIA

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ABSTRACT
In this study, the relationships between canopy – width, height and trunk size of the following tree species growing in Kano (12°N, 8.5 – 8.7°E), a town located in the Sudan Savanna Zone of Northern Nigeria were examined: Parkia biglobosa, (Jacq-Benth), Khaya senegalensis (A. Juss), Eucalyptus species, Adansonia digitata (Linn). Cassia siamea (Lam), Azadirachta indica (A. Juss), Delonix regia (Boj, ex Hook) and Acacia nilotica (Linn). Twenty trees of each species ensured to be free from obvious ecological disturbances were selected for the study. Analyses of the data obtained indicate that, with the exception of Eucalyptus sp. and A. digitata, the relationship between height and trunk size is linear. A linear relationship between canopy width and trunk size was also observed in the eight tree species studied, except A. digitata. The canopy width/height study showed a linear relationship in all the tree species. The results are discussed in the context of their adaptive significance and use in determining suitability of the trees for afforestation, forest regeneration and establishment of shelter belts to arrest desertification.

Keywords: savanna trees, canopy width, trunk size, tree height

INTRODUCTION

Trees show considerably variation and flexibility in their shape and size of crowns, height and trunk diameters (Givnish, 2002; Kuppers, 1989; http:www.ncbi.nlm.nih.gov/.mcm189.pdf). These are governed by an inherited developmental tendency, which may in turn be modified by the environment where the tree grows. The size of a tree canopy and it's height above the ground is significant to a tree in that it determines the total amount of light that the tree intercept for photosynthesis (Midgley, 2003; Russel *et al.,* 1989). Natural selection must generally be expected to favour trees that increase the amount of light that falls on the plant and since competition for light is often important in groups of trees, in the same respect, natural selection must tend to favour trees that grow high quickly (King, 1991; http:www.jstor.org/stable/2462315: The adaptive significance of tree height). Jahnke and Lawrence (1965) have shown, through a mathematical model, that the higher a tree is the more light it intercepts during the course of the day. The tree trunk size also has its own adaptive significance to a tree. It must be strong enough to withstand the forces that act on it. These forces are the weight of the tree and the drag exerted on it by the wind, as demonstrated by Fraser (1962). Experimentally, wind has been found to be much more important than weight in determining what thickness of trunk is necessary for a tree (Alexander, 1968).

The objective of this study was to examine the relationship between canopy width, height and trunk size amongst eight tree species growing in Kano and to determine the significance of these relationships on adaptation of the trees.

MATERIALS AND METHODS

Twenty specimens each of *Parkia biglobosa* (Jacq – Benth.), *Khaya senegalensis* (A. Juss). *Eucalyptus species, Adansonia digitata* (Linn), *Casia siamea* (Lam), *Azadirachta indica* (A. Juss), *Delonix regia* (Boj; ex Hook) and *Acacia nilotica* (Linn) trees were considered for the study. It was ensured that all the trees selected had intact parts. They were, in particular, devoid of bark – peeling and obvious signs of branch-cutting. In addition, only trees growing in areas free from ecological disturbances (such as over – grazing, anthropogenic factors, bush burning, etc) were selected. The following measurements were conducted on each specimen:-

Canopy Width (CW)

Each tree was viewed from all sides to determine the side where the canopy was widest. Two range poles were then erected to mark the extreme edges of the canopy. The distance between the two poles was measured with a measuring tape and recorded as the canopy width (in meters).

Tree Height (TH)

Measurement of tree height may be carried out by direct or indirect techniques depending on the position of the tree. Height of felled trees is measured directly with linear tape or graduated pole. An indirect method is the most commonly used for standing trees, because the tip is often inaccessible. Moreover, climbing with tape or graduated pole is dangerous (King, 1991). Using a range finder (Abney) calibrated in meters, the distance from a squatting position to the highest point on the tree crown was measured.

The distance from the same spot to the tree base was also measured with a measuring tape. Based on the Pythagora's Theorem of right angled triangles, the tree height was finally computed (http://online.anu.edu.au/forestry/mensuration/height.htm).

$C = (a^2-b^2) X ½$

Where

a = the distance to the highest point on the tree crown (hypotenuse)

b = the distance to the tree base and

c = the tree height

Trunk Size

Trunk size was considered as the diameter at breast height (d.b.h). To determine the d.b.h., the girth at breast height (g.b.h) or circumference of the tree was measured by tightly wrapping a tape around the tree main trunk at a height of 1.3m from the ground. The d.b.h was then determined using the Mathematical conversions.

$2 \Pi r = X$

$r = X/2\pi$

but d.b.h. = 2r = $\frac{X.2}{2\pi}$

Where r = radius

X the d.b.h

and π = 3.143

Statistical Analysis

To assess the closeness of the apparent linear relationships and test their significance at population level, a regression analysis was performed. To achieve this, the product moment correlation coefficient, r, was computed from the formula.

$$r = \frac{\sum xy}{\sqrt{(\sum x^2 y^{-2})^{1/2}}}$$

Degrees of freedom (d.f) = N – 2

At P<0.05, r = 0.4438

For any value of r which is significant, the regression coefficient, b, was estimated by:

$$b = \frac{\sum xy}{\sum x^2}$$

This is equivalent to the slope

The intercept, a, was computed by substituting the estimated value of b in the equation:

a = y = bx

In order to obtain the regression line, the a and b values were rearranged in the equation as follows:

y = a + bx

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y = a + bx

Two convenient values of x were selected and the corresponding y – values computed from the straight – line equation.

RESULTS AND DISCUSSION

For each of the eight tree species sampled, the means of the canopy width, tree height and trunk size measurements were calculated. The standard error for all the sample means was also computed and the results are given in Table 1. The results of the regression analysis for CW/DBH, CW/TH and TH/DBH relationships are summarized in Tables 2, 3 and 4 respectively.

The raw data obtained from the measurements of the parameters indicated in Table 1 was used to plot CW/DBH, CW/TH and TH/DBH relationships. All the relationships plotted appeared to be rectilinear.

The relationship between tree height (TH) and diameter at breast (d.b.h) appeared to be a linear one in all the eight tree species studied (Table 1). That is taller tress have larger trunks while shorter ones have smaller trunks. The linearity of this relationships was further confirmed by regression analysis, which showed the calculated r values for all the tree species to be greater than the tabulated value of 0.4438 (P<0.005, d.f. = 19). This relationship is of coherent adaptive significance since a tree trunk should be strong enough to withstand the twin forest of wind pressure and the tree's own weight, as earlier reported by Fraser (1962).

The slopes of the regression lines that the height d.b.h. ratio is more or less the same irrespective of the tree species. However, *A. digitata* and *Eucalyptus* spp. showed a deviation from this trend with *A. digitata* having a very small ratio and *Ecualyptus* species having a very large one.

This observation implies that the former has a trunk size more than what is required to buttress its height while the latter's trunk is too small to perform the same function. The deviation shown by *A. digitata* could be attributed to the fact that its tapering trunk is known to, in addition to giving support, serve the dual functions of water storage and resistance to desiccation. Hence, *A. digitata*'s trunk size may not necessarily be proportional to its height. *Eucalyptus* species on the other hand, is an exotic species recently introduced to the habitat and it might not have fully adapted to the Savanna. This is the most likely season why *Eucalyptus* trees are very often uprooted by windstorms during the rainy season in the Savanna region of Nigeria.

A prefect linear relationship was observed between canopy width and d.b.h. for the entire tree species studied except *A. digitata* ($P < 0.05$, $r = 0.4438$). That is, trees with larger trunks have wider canopies. This relationship is of adaptive significance to the trees because canopy size also contributes immensely to a trees total weight. Thus, huge trunks can enable trees support wide canopies (Horn, 1976).

The relationship between canopy – width and tree – height is likewise linear in all the tree species (Table 3). In other words, taller trees have wider canopies. Also, the slopes of the regression lines do not differ significantly, meaning that importance of photosynthesis in plants, natural selection must be expected to favour developmental characters geared towards maximum light interception. As a tree increases in height, its metabolic and growth requirements would increase too. As data for these increase requirements, it is likely that trees have evolved wide canopies so as maximize light interception and thus increase their photosynthetic rate (Jahnke and Lawrence, 1965). Moreover, competition for light is important, especially in groups of trees. To tackle this problem, trees with wide crowns have probably evolved high postures. Thus, the linearity of the canopy versus height relationship is possibly an adaptation favoured by natural selection.

Table 1: Sample Means for Canopy Width, Tree Height and Trunk Size (S.E in Parentheses)

Tree Species	Canopy Width (m) ± S.E	Tree Height (m) ± S.E.	d.b.h. (m) ± S.E.
Parkia biglobosa	9.20 (0.86)	10.10 (1:09)	0.32 (0.034)
Khaya senegalensis	9.62 (0.73)	11.78 (0.94)	0.40 (0.050)
Eucalyptus species	6.36 (0.45)	10.78 (0.61)	0.17 (0.013)
Adansonia digitata	6.86 (0.36)	9.50 (0.43)	0.94 (0.050)
Cassia siamea	8.39 (0.45)	9.11 (0.67)	0.69 (0.260)
Azadirachta indica	8.18 (0.67)	8.81 (0.43)	0.21 (0.020)
Delonis regia	5.13 (0.36)	4.01 (0.26)	0.14 (0.010)
Acacia nilotica	4.51 (0.28)	3.89 (0.42)	0.13 (0.005)

Key: d.b.h. = diameter ate breast height, S.E. = Standard error

Table 2: Regression Analysis for Canopy Width Vs. Diameter at Breast Height Relationship

Tree Species	r	b	A	Y = bx + a
P. biglobosa	0.824	18.942	3.500	18.94x + 3.50
K. senegalensis	0.898	14.421	3.780	14.42x +3.78
Eucalyptus spp.	08.15	28.522	1.545	28.52x+1.55
A. digitata	0.857	6.543	0.696	6.54x + 0.70
C. siamea	0.840	15.188	5.023	15.19x+5.02
A. indica	0.903	35.020	0.881	35.02x+0.88
D. regia	0.759	24.940	1.612	24.94x+1.61
A. nilotica	0.484	15.525	2.550	15.53x+2.55

Key: r = product moment correlation coefficient, b = regression coefficient/slope,
A = intercept, Y = regression line

Table 3: Regression Analysis for Canopy Width Vs. Tree Height Relationship

Tree Species	r	b	A	Y = bx + a
P. biglobosa	0.38	0.740	1.723	0.74x + 1.72
K. senegalensis	0.845	0.655	1.905	0.66x + 1.91
Eucalyptus spp.	0.697	0.520	0.950	0.52x + 0.95
A. digitata	0.819	0.690	0.281	0.69x + 0.28
C. siamea	0.804	0.532	3.503	0.53x + 3.50
A. indica	0.848	1.308	3.342	1.31x – 3.50
D. regia	0.50	1.065	0.857	1.07x +0.86
A. nilotica	0.519	0.599	2.186	0.60x +2.2

Key: r = product moment correlation coefficient, b = regression coefficient/slope,
A = intercept, Y = regression line

Table 4: Regression Analysis for Tree Height Vs. Diameter at Breast Height Relationship

Tree Species	r	b	A	Y = bx + a
P. biglobosa	0.929	27.556	1.433	27.56 + 1.43
K. senegalensis	0.950	19.657	3.841	19.66x3.84
Eucalyptus spp.	0.911	48.677	1.809	48.68x + 1.81
A. digitata	0.8812	8.022	1.950	8.02x + 1.95
C. siamea	0.766	20.188	4.700	20.19x + 4.69
A. indica	0.820	20.610	4.513	20.16x + 4.51
D. regia	0.783	18.117	1.456	18.12x +1.50
A. nilotica	0.588	16.364	1.817	16.36x + 1.82

Key: r = product moment correlation coefficient, b = regression coefficient/slope,
A = intercept, Y = regression line

CONCLUSION

In sum, the relationships between TH/DBH, CW/DBH and CW/TH in the eight tree species are, with few exceptions linear and appear to have adaptive values. With the exception of *Eucalyptus* species, which is poorly adapted to the savanna probably because it was recently introduced to the habitat from Australia, and it would take quite sometime to properly adapt, all the tree species are adapted to the savanna in terms of ability to withstand windstorms and to support their own weight and could therefore be suitable for use in afforestation, reafforestation, or establishment of shelter belts to arrest desert encroachment.

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