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The Canopy effect of *Parkia biglobosa* (African Locust bean), *Quassia undulata* (Savanna quassia), *Khaya senegalensis* (Savanna mahogany) and *Daniellia oliveri* (African balsam) on the Herbaceous biomass production and Soil physico-chemical properties in Kogi State, Nigeria

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ABSTRACT

The Savanna, especially Derived Savanna, presently is under exploited because of inadequate information on vegetation composition. Therefore this research was designed to carry out ecological studies to determine the canopy effect of woody species on biomass production of the Derived Savanna around Egume, Kogi State, Nigeria, using normal random distribution methods and standard methods of soil analyses. The canopy effect of some woody species on understorey herbaceous plant species and soil properties were also investigated in the study area. Standing biomass and frequency of the understorey herbaceous plant species were significantly (P<0.05) higher in the open areas than within the canopies. A total of 22 herbaceous plant species distributed in 7 different families were recorded under the effect of the 4 different woody species canopies. Soils under the tree canopies had significantly (P<0.05) higher organic carbon and total nitrogen as well as % soil porosity than those in adjacent open areas. Since the canopy areas are rich in species and soil nutrients, the results therefore imply that the area is rich in species and soils nutrients which may give room for high yield of food production in the place.

Key words: Canopy, Soil, Physico-chemical, Herbaceous, Biomass production, Woody species.

INTRODUCTION

Woody plant canopies alter the microenvironment and physical and fertility conditions of the soil [1] Trees modify microenvironment in terms of reduced soil and air temperature, wind speed and irradiation ,resulting into reduced soil water evaporation and increased relative humidity [2, 3].While trees and herbaceous plants usually compete directly for water , deep rooted woody plants can benefit the understorey vegetation by transporting water from the deeper soil layer to drier surface soils through hydraulic lift, particularly during dry periods [4,5]. Trees also acquire nutrients from deeper soil layers and redistribute them at the surface through litter fall which enhances soil carbon and nutrients, benefiting the understorey plants. Interception of solar radiation is a predominant factor influencing the understorey. In tropical forests, light reaches perpendicular to the ground, and decreases in the gradient from gap center to edge to below-canopy location [6,7].Trees can either diminish or enlarge grass production by modifying the resources availability to ground flora [8]. Species differ in their response to shading. For example, [9] found that shading reduced the mean dry weights of warm season grasses, but up to 50% shading did not reduce mean dry weights of cool season grasses. Woody plants canopies provide a more stable microhabitat for the understorey, probably because of the protection against direct irradiance and overheating [10,11] direct solar radiation supplies energy which increases evaporative demand and potential for moisture stress [12,13]. The increase in radiation is often associated with a reduction in water availability resulting into reduced species richness [13].This research is aimed at determining the relationship between the canopy of the woody species and the herbaceous production based on herbage size. For this has been reported as a problem in grass land and other savanna ecosystems because increased woody cover may result in decreased herbaceous production and diversity.

MATERIALS AND METHODS

Determination of the Effect of Canopy on Herbage Species Size of the Vegetation

The herbage size of the vegetation was determined following [14] and [15] procedures. All herbs within $1m^2$ quadrat under the canopies and away of the four woody species were clipped at ground level, tied and weighed fresh using a spring balance attached to tree branch. Sub-samples of each were also weighed fresh and taken to the laboratory to be air-dried to constant weight and oven-dried at 80^0C to constant weight. The dry weight of each sub-sample of the herbaceous materials was used to estimate (calculate) the dry weight of the fresh herbaceous materials by simple proportion methods [15 and 16].

Soil Sampling

Soil samples were obtained at 0- 10cm depth along each of the four cardinal directions within the $1m^2$quadrat using soil auger (5cm diameter) from both within and away from the four canopies. All the soil samples were bulked together, mixed and sieved through a 2mm meshed wire. The soil samples were oven-dried at 70^oC for 24 hours and analyzed chemically for Organic carbon using the Walkley-Black method [17]; Total nitrogen by wet-digestion method, available soil phosphorus by the double acid method and the soil pH using the method described by Peech [18]. Soil samples were also analyzed physically for soil texture, structure, bulk density and soil porosity using standard methods by Ambasht [19].

Data Analysis

The data obtained during the study were subjected to Analysis of Variance (ANOVA) following the method described by [20] using a Statistical Software package for Social sciences (SPSS) version 19.

RESULTS AND DISCUSSION

Herbage Species Size of Herbaceous Plant species under Four (4) Canopies and Open Areas

The mean and standard deviation of the herbage species size of herbaceous plant materials under and outside the canopies of four (4) woody species is presented in Table1. The results showed a significant ($P<0.05$) difference in biomass production between the open areas and the canopy (shaded) Areas for all the woody species with a higher biomass yield (1802.92 gm^{-2}) found in the open areas than the biomass yield (1420.12gm^{-2}) for all the four canopy trees. The mean herbaceous biomass production was significantly ($P<0.05$) highest (498.22gm^{-2}) under *Parkia biglobosa* canopies with the percentage (%) Dry matter (DM) of 38.8%, followed by, *Quassia undulata* (369.55gm-2), with the % DM of 31.0. While the lowest herbaceous biomass yields (262.72gm^{-2}) with the % DM of 23.4 was recorded under the canopies of *Daniellia oliveri*. The open areas also had a significantly ($P<0.05$) highest herbaceous plants cover (612.11 gm^{-2}) away from the canopies of *P. biglobosa*, followed by 526.33gm^{-2} away from *Q. undulata,* while the least herbaceous plants cover 321.22gm^{-2} was recorded away from the canopies of *D. oliveri.*

Herbaceous Plant Species Production under Canopies

A total of 22 herbaceous plant species, distributed in seven (7) different families under the effect of four (4) different woody species canopies. The result presented in Table 2 showed the % relative frequency of the herbaceous plant species under the canopies of dominant woody species of the area. Canopy3 had 21 herbaceous species and seven (7) families, canopy 4 had 19 herbaceous species and seven (7) families, canopy 2 had 19 herbaceous species and seven (7) families, while canopy 1 had recorded the least species (18 species) and five (5) families. Canopy 3 had recorded the highest total species (412), followed by canopy 4 (325). While the least number (243) of species were recorded under canopy 1, fourteen (14) herbaceous species of the total of 22 were common to all the canopy trees (table 2). *Chamaecrista mimosoides* dominated the entire herbaceous flora mostly in canopy 2 and 4 recording the overall total frequency of 99 in all the four canopy trees. *Andropogon gayanus* dominated the herbaceous flora in canopy 3 and co-dominated in canopy 4 with the total of 95 in all the canopy trees, *Impomea eriocarpa* dominated the herbaceous flora in canopy 1 and *Acroceras_zizanioides* had co-dominated the herbaceous flora in canopy 2 and 3 giving the overall total of 89 in all the four canopy trees.

However, *Tridax procumbens* and *Pennisetum unisetum* were found to be the rare species among the herbaceous flora giving a total of 15 and 13 respectively in all the canopies.

Physicochemical Analysis of Soil under Canopies and Open Areas

The result of chemical (soil organic carbon, total nitrogen, available phosphorus, and soil pH) and physical analysis of the soil (bulk density, porosity, texture and structure) under canopies and open areas are presented in Table 3. Soil organic carbon (1.34± 0.02) and total nitrogen (0.14±0.35) content of the soils were significantly ($P<0.05$) higher under the canopies than open areas (1.08±0.02 and .0.08±0.02) respectively. Soil under canopies had two-times as much total nitrogen as compared to the soils in the adjacent open areas. However, the available phosphorus and the soil pH in the open areas were significantly ($P<0.05$) higher than within the canopies. The results of physical parameters (soil bulk density, porosity, texture and structure) revealed that the bulk density of the soil in the open areas was higher (1.30±0.01) than the soil within the canopies (1.16±0.02). The % soil porosity and texture under canopies were relatively higher than the soil in open areas. The soil structure of the area is observed to be crumbing and relatively porous in nature.

Table 1: Mean (x) Herbage Size of Herbaceous Plant Materials under Four Canopies and Open Areas

Species	**Mean ($\bar{x}$) Herbage size (gm-2)**		**%DM**
	Within the canopy	**Away from the canopy**	
Daniellia oliveri	262.72 ± 25.3	321.22 ± 24.8	23 2/5
Khaya senegalensis	289.63 ± 20.4	343.26 ± 21.4	26 1/5
Parkia biglobosa	498.22 ± 14.8	612.11 ± 11.8	38 4/5
Quassia undulate	369.55 ± 31.0	526.33 ± 13.9	31
Total	1420 1/8	1803	

***%DM** = Percentage Dry Matter*

Table 2: Relative Frequency (%) of Herbaceous Plant Species under Four Canopies

Species	**Family**	**% frequency in Canopy**				
		1	**2**	**3**	**4**	**Total**
Acroceras zizanioides	*Poaceae*	14	28	34	13	89
Ageratum conyzoides	*Asteraceae*	2	10	30	5	47
Andropogon gayanus	*Poaceae*	20	11	40	25	95
Andropogon tectorum	*Poaceae*	16	10	33	18	77
Aspilia africana	*Asteraceae*	3	13	14	10	40
Asystasia gangetica	*Acanthaceae*	-	20	18	20	58
Chamaecrista mimosoides	*Caesalpiniodeae*	9	30	29	31	99
Cyperus esculentus	*Cyperaceae*	10	18	22	20	70
Dactyloctenum aegyptium	*Poaceae*	4	10	12	-	26
Desmodium mauvitianum	*Poaceae*	-	-	15	20	35
Emilia coccinea	*Asteraceae*	11	8	11	13	43
Eragrostis ciliaris	*Poaceae*	14	6	7	8	35
Euphorbia granulata	*Euphorabiaceae*	8	18	24	14	64
Euphorbia heterophylla	*Euphorabiaceae*	13	20	15	20	68
Ipomoea eriocarpa	*Convolulaceae*	30	16	20	21	87
Paspalum scrobiculatum	*Poaceae*	16	19	20	15	70
Pennisetum unisetum	*Poaceae*	-	4	9	-	13
Solanum nigrum	*Solanaceae*	13	22	21	15	49
Solanum welwichii	*Solanaceae*	20	-	20	18	58
Sporobulus pyramidalis	*Poaceae*	20	24	-	16	60
Tridax procumbens	*Asteraceae*	-	10	5	-	15
Vernonia cinerea	*Asteraceae*	10	-	13	20	33
Total		**243**	**297**	**412**	**325**	

Canopy 1 = Daniellia oliveri *Canopy 3 = Parkia biglobosa*
Canopy 2 = Khaya senegalensis *Canopy 4 = Quassia undulate*

Table 3: Physicochemical Parameter of Soil under Canopies and Open Areas

Soil Parameter	Under Canopies	Open Areas
% Organic carbon	1.34 ± 0.02	1.08 ± 0.02
% Total Nitrogen	0.14 ± 0.35	0.08 ± 0.02
Available Phosphorus	672 ± 0.01	724 ± 0.02
Soil pH	6.02 ± 0.10	6.38 ± 0.10
Bulk density (gm^{-3})	1.16 ± 0.02	1.30 ± 0.01
Soil porosity	46.30%	45.20%
Soil texture	45.0% (sandy loam)	44.3% (sandy loam)
Soil structure	Crumb	Crumb

Above ground Standing Crop Biomass of Herbaceous Plants Species and Physiochemical Properties of Soil within and outside the Canopy

The higher total herbage size of the herbaceous materials outside the canopies of the four different tree shades than within the canopies indicate that, canopies inhibit the production of under storey plant species as also reported by [21]. The lower total biomass productions under these tree shades have more negative effect on the herbaceous plants found under *Daniellia oliveri* and *Khaya senegalensis* than *Quassia undulata* and *Parkia biglobosa*. Usually, *Quassia undulata,* and *Parkia biglobosa* have crowns that are shallower and more hemispherical in shape while *Daniella oliveri* and *Khaya senegalensis* have deeper and more global crowns giving rise to higher shade intensity that reduces the rate of photosynthesis of the under storey herbaceous plants, resulting in the lower biomass production [22]. It was reported [21] that, the architectural and allometric differences between the canopies of woody species may be important factors as far as light transmission to the under storey plants species is concerned. The result agrees with the findings of earlier workers [22, 23] who reported lower biomass production of herbaceous plant species under tree canopies than the open areas. It was reported [21 and 24] that, the roots of some woody species may extend downward and laterally and affect the soil moisture regime under the canopy. It was also reported [21, 25] that the extensive lateral root system of some woody species such as *Daniellia oliveri* and *Khaya senegalensis* occupy the same soil horizon as the grasses. These trees may extract water rapidly from the upper part of the root zone close to the tree trunk. This implies that, the roots of those woody species may exert stronger "pull" on the soil water than the grasses. This could also explain the lower biomass of herbaceous plant species observed under the canopies of these trees. It is well-know that grasses are photo-phylic and may perform poorly under shade.
Despite the soaring rates of species extinction which may usually be caused by anthropogenic activities of the area [26], yet the various species (i.e. herbaceous and woody species) observed during the study were recorded in relatively high percent (%) frequencies and were distributed in both canopies and away from canopies. The differences in herbaceous plant species composition between the canopy zones and adjacent open grass land was attributed to differences in carbon assimilation rate and water use efficiencies among the herbaceous plant species [27]. Therefore, selective grazing, phyto-toxic effects of the leaves, shading and competition for soil moisture are some of the most important factors that might have contributed to the low grass species under the canopies of the woody species [21].

The accumulation of the organic carbon and total nitrogen under canopies of the woody species may be due to litter fall and reduced leaching under the tree canopy [21]. The residential herbivores and birds of this vegetation could also be responsible for the higher organic carbon and total nitrogen observed under the canopies due to their high percentage urination and defecation [28]. Higher concentration of carbon and nitrogen in the soil within the canopies than the soil in the adjacent open areas has been reported [21, 22, 29 and 30]. They attributed the enrichment of carbon and nitrogen under canopy to organic matter accumulation and reduced leaching under the tree canopies. Trees also act as "wind breaker" resulting in loose organic debris swept from open areas between trees being trapped and retained beneath the tree canopies [21].

The lower available phosphorus content under canopies in this study could be attributed to the continuous biological processes that take place between the *Rhizobium* bacteria and roots of leguminous plants. The *Rhizobium species* utilize the phosphorus in the synthesis of their own protein and hence the low level of phosphorus under the canopies of trees [31].

Soil under the canopies of these woody species is more acidic than soils in open areas. The slight acidity of soil within the canopy areas could be attributed to leaches and exudates from the litter fall and roots of the trees. These findings are in agreement with those of earlier researchers [21, 32].

The lower soil bulk density and higher soil porosity observed under the tree canopies than the adjacent open areas could be attributed to tree canopies that protect the soil from the forces of rain drops. The lower soil bulk density within the canopies has been reported [33] to be as the result of improved macro porosity of the soil. Conversely, higher bulk densities and lower porosities could be as a result of trampling of soil by large animals seeking for shade or forage or rain drop effect [21]. There is a clear indication that *Daniellia oliveri*, *Khaya senegalensis* and *Quassia undulata* may function to improve the physiochemical properties of the soil beneath their canopies.

CONCLUSION

Conclusively, this research had generated baseline information on the canopy effect of woody species on herbaceous biomass production of the Derived Savanna around Egume, Kogi State, Nigeria, using normal random distribution methods and standard methods of soil analyses.

The canopy effect of some woody species on understorey herbaceous plant species and soil properties were investigated in the study area. Standing biomass and frequency of the understorey herbaceous plant species were significantly ($P<0.05$) higher in the open areas than within the canopies. A total of 22 herbaceous plant species distributed in 7 different families were recorded under the effect of the 4 different woody species canopies. Soils under the tree canopies had significantly ($P<0.05$) higher organic carbon and total nitrogen as well as % soil porosity than those in adjacent open areas. These results indicate that the area is rich in species and soil nutrients.

REFERENCES

[1] Weltzin, J.K and Coughenour, M.B. Savannah *Journal of Vegetation Science*, **1990**; 1:325-334
[2] Jose, S., S.C Allen & P.K.R. Nair. Tree-crop interactions: lessons from temperate alley- cropping systems. pp. 15-36 In: D.R. Batish, R.K. Kohli, S. Jose & H.P. Singh (eds.) Ecological Basis of Agroforestry. CRC Press, Boca Raton, Fl; **2008**.
[3] Rao, M.R., P.K.K. Nair & C.K.Ong. Biological interactions in tropical agroforestry systems. Agroforestry Systems; **1998**.38: 3-50.
[4] Burgess, T.L. Desert grassland, mixed shrub savanna, shrub steppe, or semi desert shrub? The Dilemma of coexisting growth McClaran and desert grassland. Edited by M.p. Tuscon, Arizona; **1996**. pp 31-67.
[5] Ong, C.K., J.D. Deans, J. Wilson, J. Mutua, A.A.H. Khan & E.M. Lawson. *Agroforestry Systems* **1999**; 44: 87-103.
[6] Chazdon, R.L. *Journal of Ecology* **1986**;74: 995-1012.
[7] Denslow, J.S. *Annual Review of Ecology &Systematics* **1987**; 18: 431-451.
[8] Vetaas, O.R. *Journal of Vegetation Science* **1992**; 3:337-344.
[9] Lin, C.H., R.L. Mc Graw, M.F. George & H.E. Garrett. **1999**. *Agroforestry Systems* 44: 109-119.
[10] Baskin, C.C. and Baskin J.M. Seeds: Ecology,Biogeography, and, Evolution. Second Edition Academic Press. San Diego, USA; **2014**. pp1573.
[11] López-Pintor, A., T. Espigares, J.M. Rey-Benayas & A. Gómez-Sal. *Journal of Mediterranean Ecology* **2000**; 1: 219–226.
[12] Moro,M.J., Pugnaire,F.Haase,P.and Puigdefabregas,J. *Ecography* **1997**; 20:175-184.
[13] Pausas, J.K. and Austin, M.P. *J.Veg. Sci.* **2001**;14:661-668
[14] Usman, S.S..Maximum herbaceous standing crop at Opi Lake Savanna Woodland *Unpublished Ph.D. Thesis*, University of Nigeria, Nsukka, Nigeria. **1990**.
[15] Sagar, R. Archita Singh and Singh, J.S. *International Society for Tropical Ecology* **2008**; 49(2): 189 – 197.
[16] Aina, D.O., Okayi, E.and Usman, S.S. *Journal of pharmacy and Biological Science* **2013**; 5(2): 5-9.
[17] Black, C.A, Evans, D.D., Ensminger, L.E.and White, J.L., and Clark F.E. (Eds). Methods of Soil Analysis. *Agronomy of American Society*, Madson, Wisconsin; **1965**. pp1569.
[18] Peech, M. *Hydrogen ions activity.* In: C.A Black (Ed) Methods of soil Analysis (Part II). *Agronomy of American Society*, Madson, Wisconsin; **1965**, pp920-921.
[19] Ambasht, R.S, and Ambasht, N.K. *A Text Book of Plant Ecology*. Kluwer Press, Amsterdam, Elsevier Scientific Publ **2006**. pp427.
[20] Steel, R.G.D and Torrie, J.H. *Principles and procedures of statistics*. Mcgraw-Hill book Co., New York;**1980**. pp40.
[21] Kahi, C.H, Ngugi, R.K, Mureithi, S.M. and Ngethe, J.C, *Tropical and Subtropical Agroecosystem* **2009**; Vol.10 pp44.

[22] Belsky, A.J., Mwonga, S.W., Amundson, R.G. Duxbury, J.M. and Ali, A.R. *J.Appl. Ecol.***1993**; 30: 143-155.
[23] Frost, W.E., and Edinger,S.B. *Journal of Range Management*, **1991**; 44: 286 – 288.
[24] Belsky, A.J. Amundson, R. G., Duxbury, J.M., Riha, S.J., All, A.R. and Mwonga, S.M. *J. Appl. Ecol.***1989**; 26:1005-1024
[25] Tiedmann, A.R. and Klemmedson, J.O. *Soil Science of America Journal*, **1977**; 50: 472-475.
[26] Cable, D.R. *Journal of Range Management* **1976**; 29: 286 – 289.
[27] Kinyamario, J.I, Trilica M.J. and Njoka T.J. *Journal of African Ecology* **1995**; 33:114 – 123.
[28] Miyazaki, S., Hirata, Y.M., and Veno, M. *Journal of Japanese Society of Grassland Science* **1987**; 33:121-127.
[29] Garcia – Moya, E. and Mckell, C. M. *Ecology***, 1970**; 51:81-88.
[30] Wasonga, V.O. *Effect of Balanites glabra canopy cover on soil organic matter, soil moisture and selected grass species production* in Isinya Kajiado, Kenya. Msc. Thesis, University of Nairobi, Kenya; **2001**.
[31] Young, A. *Agro-forestry for soil managemen*t 2nd ed. CAB-ICRAF, Nairobi. **1989**.
[32] Bhatia, N.P., Adholeya, A. and Sharma, A. *Biology and Fertility of Soils* **1998**; 26: 208 – 214.
[33] Joffre, R. and Rambal, S. *Acta Ecologica*, **1988**; 9:405-472.