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Fruit and pulp production of the African grape *Lannea microcarpa* Engl. & K. Krause from dry and humid Sudanian zone in Northern Bénin, West Africa

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ABSTRACT

Lannea microcarpa, an Anacardiaceae species associated to croplands in West Africa is a multipurpose tree used in traditional medicine, human and animal feeding in Sudanian zone of Bénin. This study aimed at evaluating its fruits and pulp yield. Fruit and pulp production and dendrometric variables were collected on 21 and 27 trees respectively in dry and humid Sudanian zone. Data were analysed using two independents samples t-test and Pearson correlation to find out variation in production and relation between variables. Trees in dry Sudanian zone showed the largest crown. The number of fruit, fruit mass and pulp mass were highest in dry Sudanian zone. Also, trees with high diameter at 1.30 m above the ground had produced low number of grapes and fruit per grape. Pruning and debarking did not affect the fruit and pulp mass. In humid Sudanian zone, tree crown could be used as indicator of number of fruit per grape in the one hand and in other hand the number of tertiary branches could be used for fruit and pulp yield. This study highlighted that in northern Bénin, dry Sudanian zone could be preferable for *L. microcarpa* fruit and pulp production. The variations observed between zones deserve to be investigated.

Keywords: *Lannea microcarpa* production, Humid and dry Sudanian zone, Bénin, West Africa.

INTRODUCTION

The importance of native tree species in the livelihood of rural communities has been evidenced since decades (Larwanou et al., 2010; Fandohan et al., 2010). The emphasis has been on these species, not only for their role in sustaining rural livelihood, but also for their ability to meet the challenge of on-farm biodiversity conservation (Nyoka et al., 2014; Haarmeyer et al., 2013). They are raw materials supply source for food and medicine industries (Fandohan et al., 2010; Makalao et al., 2015). In tropical ecosystems, most of these tree species are cultivated or kept in semi-wild in agroforestry systems. In West Africa, and particularly in Bénin, they are found associated with crops in agroforestry parklands and sometimes protected in home gardens (Boffa, 2000; Sinsin and Kampmann, 2010).

While in Bénin, several research efforts have been made to unveil the potential of many wild fruit species to support local populations livelihood; examples are

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Tamarindus indica (Fandohan, 2010), *Vitellaria paradoxa* (Glèlè Kakaï et al., 2011), *Adansonia digitata* (Assogbadjo et al., 2005a, 2005b), *Sclerocarya birrea* (Gouwakinnou, 2013), others are still little known, albeit their contribution to local communities diet.

Lannea microcarpa (Engl & K. Krause) (Anacardiaceae) is one of the locally important tree species associated with crops in agroforestry parklands and also protected in home gardens in northern Bénin (Sinsin and Kampmann, 2010). Its fruits are consumed fresh or used to make juice and fermented drink. Its bark is used for dyeing cotton fabrics in red-brown, in traditional medicine, etc. (Market and Jansen, 2005). The seeds serve in vegetable oil production that is used in human and animals feeding and cosmetics (Bazongo et al., 2014). *L. microcarpa's* are also used for of Biodiesel production which physicochemical properties are similar to petro-diesel and that derived from *Jatropha curcas* (Yunus et al., 2013).

To assess ecosystem services of parklands, it is important to focus attention on its constituent species productivity (Ouédraogo et al., 2014). Yet, most studies of Bénin's agricultural systems fruit species have focused on their importance for alimentation, medicine, economy, and sociocultural importance (Vodouhê et al., 2008; Fandohan et al., 2010, Houéhanou et al., 2011; Koura et al., 2011). Very few studies have addressed local fruit species production performance and the influence of the various components of their environment on their production power. But assessing the productivity of economic species of interest is a basic step to assess their monetary value (Ouédraogo et al., 2014). Among Bioclimatic zones, environmental conditions are known to induce high spatial variability in the morphology and productivity of fruit trees (Glèlè Kakaï et al., 2011; Houètchégnon et al., 2015; Atefe et al., 2015). Rainfall, relative humidity and temperature may produce important patterns in trees morphological trait among populations (Assogbadjo et al., 2005; Gouwakinnou et al., 2011). Within the context of climate change, trees could express new characters as response to new stresses. Therefore, studies on the ecological adaptation of fruit trees along climatic gradient are important to predict their productivity in the future (Glèlè Kakaï et al., 2011). In addition, face to increasing interest in wild fruit trees domestication, knowledge about these trees production is still limited (Dao et al., 2012). It is a case of *Lannea microcarpa* that today, despite its great potential to contribute to rural poverty alleviation and the accelerating interest in its commercialization prospects for its fruits, the data on rates of fruit production from wild populations along climatic gradient remains unknown. Therefore, this study aimed at assessing the *Lannea microcarpa* fruit and pulp production performance under different climatic regions in Northern Bénin. The specific objectives were to (i) assess the morphological and fruit production characters of *Lannea microcarpa* along climatic gradient in Northern Bénin and (ii) to relate the morphological trait and fruit production of *Lannea microcarpa*.

MATERIALS AND METHODS

Study area

Analysis of fruit production of *L. microcarpa* was conducted in northern Bénin (West Africa) in the Sudanian Zone. The study area extends from the Sudanian dry area in the northern part to the typical Sudanian zone in its southern part (Adomou et al., 2006). From a climate perspective, the Sudan zone of Bénin is characterized by a semi-arid climate with an average annual rainfall of 750 - 900 mm covering the period from April to October. In its southern part, the dry season lasts about seven months with a mean annual rainfall of 1000 mm and a temperature about of 28 °C. The northern driest part is characterized by eight months of drought and has an annual average rainfall of 750 mm with a temperature of about 30 °C (Gouwakinnou, 2011). The study was conducted in Karimama in the north and at Tanguiéta and Dassari for the southern part (Figure 1).

Study design and data collection

Fruit production was estimated for a year round period 2015 in the study. Annual produced were measured on 21 and 27 specimens randomly selected in the dry and humid Sudanian zone, respectively. Sampling was conducted when fruits were already ripe and the species had reached fruiting peak, i.e. during May in Humid Sudanian zone and June at dry Sudanian zone (Goudegnon E., Fields observations). Selected trees were at least 10 m distant. Because of the high number of fruits that could produce a *L. microcarpa* tree, counting fruit will be irksome. Fruit production per tree, expressed as kilograms of fruits and pulp produced per tree individuals, was estimated by three parameters: the number of tertiary branches, the fruit mass, the number of bunch and number of fruit per bunch. Mean fruit mass was determined by weighing 30 randomly selected ripe fruits from each tree. Fruit mass was expressed in fresh weight units. To estimate average number of fruits per branch, visual fruits counts was performed on three randomly selected tertiary branches per tree. Fruit production per tree was estimated by multiplying the number of fruit counted on three randomly selected tertiary branches by the total number of third-order branches on the tree (Glèlè Kakaï et al., 2011; Haarmeryer et al., 2013) and the mean fruit mass estimated above. Debarking and pruning marks on trees were recorded as indicator of anthropogenic stress on tree individuals. Relevant characteristics related to the size and morphology of the sampled trees was also recorded. Indeed, crown diameter, the height and the stem diameter at 1.30 m above the ground were recorded. In case of multi-stems individuals, quadratic diameter was calculated.

Statistical analysis

Data were statistically analysed using the software package R 3.0.3. Mean value ± SE was calculated for each parameter. The trunk diameter at 1.30 m above the ground and the number of tertiary branches were log-transformed while the number of fruits, the mass of fruits and the pulp produced per tree were square root transformed to reach normality (Shapiro-Wilk test) and variance equality (Levene test). Differences in fruit production between the dry and humid Sudanian zones were analysed by performing two independents samples t-test. Pearson correlation analysis was calculated and tested to assess the link between tree morphological characteristics and fruit production variables on each site.

RESULTS

Dendrometric and fruiting characteristics among population

Significant differences were detected between the two regions for only crown diameter among all variables measured ($P < 0.01$; $t = 3.15$). The dry Sudanian population had higher values (8.07 ± 0.44 m) than the upland population (5.78 ± 0.58 m) (Table 1). Fruiting variables also showed significant variations between populations ($P < 0.01$) except the number of fruit per bunch. The number of bunches produced per tree, the number of fruits produced per tree, the mass of fruit and pulp produced were substantially higher for the dry Sudanian population than the humid Sudanian population (Table 1). The number of bunches produced per tree, the number of fruits produced per tree, the mass of fruit and pulp produced in dry Sudanian zone was twice the one of the humid Sudanian zone.

Correlation between dendrometric and fruiting variables according to zone

For the dry Sudanian population, the diameter at 1.30 m above the ground had a good negative and significant correlation with the number of grapes produced per tree and the number of fruit per bunch (Table 2). The correlation was negative. The number of tertiary branches exhibited a positive correlation with all fruiting characteristics except the number of grape produced per tree and the number of fruit per grape. Some of the dendrometric variables showed strong correlation with fruiting characteristics, although the correlation was not significant. Pruning showed negative correlation with Mass of fruit and pulp produced per tree but this correlation was not significant while correlation between debarking and fruiting characteristics was weak and non-significant.

With regards to the humid Sudanian population, the crown diameter had good, positive and significant correlations with only the number of fruit per grape (Table 2). The correlation between the number of tertiary branches and the mass of fruit and pulp produced per tree was strong and positive. Debarking showed strong and positive correlation with the number of fruit per grape and fairly good and positive correlation with the number and mass of fruit produced per tree.

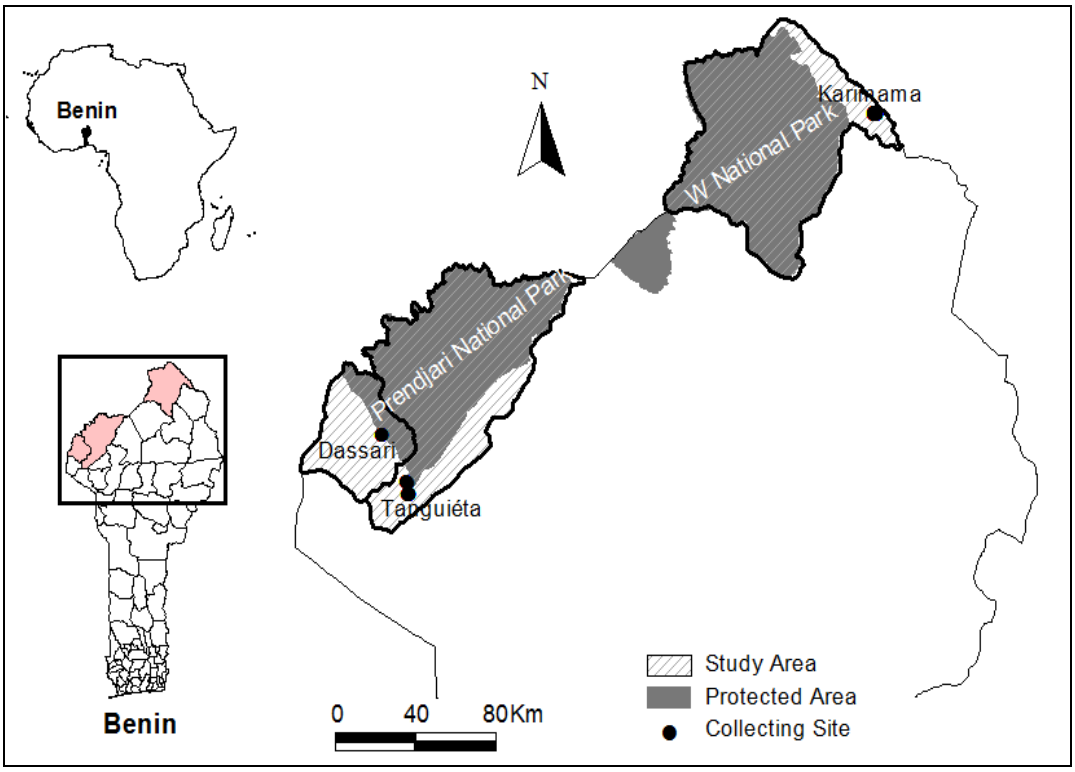

Figure 1: Map showing location of collecting sites.

Table 1: Mean and standard error of *L. microcarpa* tree morphological characteristics, fruit and pulp produced per tree according to two phytodistricts of Sudanian zone in Bénin.

Variables	Dry Sudanian population (n=27)		Humid Sudanian population (n=21)		P
	Mean	**Sd**	**Mean**	**Sd**	
Number of grapes produced per tree	195.9	10.3	90.62	9.42	< **0.001**
Number of fruit per grape	9.75	0.52	10.12	0.73	0.680
Number of fruit produced per tree	111261	13461	53276	9308	**0.001**
Mass of fruit produced per tree (kg)	106.1	13.2	51.12	9.40	**0.001**
Mass of pulp produced per tree (kg)	60.67	8.03	28.00	5.47	**0.001**
Height of tree (m)	8.10	0.45	8.56	0.52	0.512
Diameter at 1.30 m above ground (cm)	25.08	1.93	25.56	2.04	0.812
Crown diameter (m)	8.07	0.44	5.78	0.58	**0.003**
Number of branches per tree	59.78	6.55	51.24	6.74	0.272

Table 2: Matrix of correlation between trees phenotypic traits, debarking, pruning and fruit and pulp production variables.

Dendrometric variables	**Fruiting characteristics**				
Dry Sudanian zone					
	Nbg	**Nbf**	**Pf**	**Mpf**	**Maspt**
Htot	-0.287	-0.264	0.013	-0.032	0.001
$D_{1.30}$	-0.536**	-0.535**	0.178	0.222	0.266
Dcrown	-0.250	-0.235	0.311	0.294	0.318
Nbc	-0.323	-0.323	0.529**	0.503**	0.494**
Ec	-0.004	-0.011	0.064	0.085	0.117
Em	0.107	0.094	-0.23	-0.342	-0.350
Humid Sudanian zone					
	Nbg	**Nbf**	**Pf**	**Mpf**	**Maspt**
Htot	-0.280	-0.213	-0.314	-0.316	-0.325
$D_{1.30}$	0.165	0.252	0.376	0.350	0.273
Dcrown	0.345	0.451**	0.385	0.319	0.239
Nbc	0.366	0.186	0.858	0.870***	0.870***
Ec	0.273	0.688***	0.445*	0.448*	0.386
Em	-0.089	0.390	0.009	0.053	0.077

Nbg= Number of grapes produced per tree; **Nbf**= Number of fruit per grape; **Pf**= Number of fruit produced per tree; **Mpf**= Mass of fruit produced per tree; **Maspf**= Mass of pulp produced per tree; **Htot**= Height of tree; **D_{130}**= Diameter at 1.30 m above ground; **Dcrown**= Crown diameter; **Nbc**= Number of branches per tree; Ec= Debarking; Em= pruning; * significant ($p < 0.05$); ** significant ($p < 0.001$); *** significant ($p < 0.0001$).

DISCUSSION

This study highlights the performance of fruit production along climatic regions and the link between trees morphological traits and fruits production of *L. microcarpa* in northern Bénin.

L. microcarpa population from the dry Sudanian zone was composed of specimens with larger crown and many branches while the tallest and biggest individuals were in the humid Sudanian zone in spite of the lack the significant differences for the three last variables. Differences observed in trees crown diameter may be due to the fact that humid Sudanian zone (about 900 mm) is more watered than the dry Sudanian zone (750 mm) (Adomou et al., 2006). The non-significant between the others tree morphological variables may be related to the fact that these morphological trees traits are not affected by climate differences at phytodistrict level. In addition, sampled individuals in humid Sudanian zone were located on arable cultivated soil while in dry Sudanian zone almost all the trees were in fallow and on rocky soil. Also, in both areas, farmers used to select trees size to cut down in their field. According to Haarmeyer et al. (2013), local people preferably cut the trunks of trees with small size, because they are suitable for construction. This suggests that structure and spatial distribution of *L. microcarpa* population deserve to be investigated under land use in Bénin. Agbogan et al. (2015) reported that *L. microcarpa* are represented by aging populations, low population densities and low regeneration potential.

The number of grapes produced per tree, the number of fruits produced per tree, the mass of fruit and pulp produced in dry Sudanian zone is twice as much than in humid Sudanian zone. This difference could be related to climate and soil conditions and human activity. Indeed, in Burkina-Faso, *L. microcarpa* trees growing on communal land bore more fruits than those on protected areas, whereas fruit production on arable land was more than twice as much as on non-arable land (Haarmeyer et al., 2013). Our finding is also consistent with other study that showed that environmental variables may affect trees production (Assogbadjo et al., 2005; Lamien et al., 2007; Fandohan et al., 2011). The variation in fruit and pulp production according to zone may be linked to genetic characters as reported by Assogbadjo et al. (2006) for baobab.

Pearson correlation between fruit production variables and human activities (pruning and debarking) showed that only debarking affect the number fruit per grape, fruit number and fruit mass in Humid Sudanian zone. This result is contrary to the findings of Haarmeyer et al. (2013) in Burkina-Faso who noticed that pruning and debarking affect negatively fruit bearing. It could be suggested that the trees respond to these stresses by reallocating their resources to produce better quality of fruit (bigger and juicier). Our finding could be explained by the fact that in humid Sudanian zone, trees are located in field and hence accessible and vulnerable to intense uses while in the other areas, trees are located at respectively remote place, hence less vulnerable to intense uses. In addition, in this area, local population used to consume and sell fruits of *L. microcarpa*. This result suggests that lower fruit and pulp production in humid Sudanian zone could be linked to environmental conditions. However, usage and importance of *L. microcarpa* and environment impact on its production should be taken into account in further studies. It is known that plant organ cutting affect trees physiology. Bark and branch cutting increase the risk of infection and expose plants to predators, fire and dehydration (Haarmeyer et al., 2013) which ultimately affect its fruit production. In spite of the risks to which human pressures expose *L. microcarpa* individuals, negative impact on their production depends on the intensity of the debarking and pruning. Thus, the currents findings could be explained by the fact that local population pressure level is not yet sufficient to affect trees production and trees succeed to withstand. This study did not take into account the intensity of debarking and pruning that deserve to be investigated by further studies and this may explain the weak correlation observed between these last human pressure index and the fruiting variables. Correlations between dendrometric variables and fruit production suggest that the diameter at 1.30 m above the ground is a good predictor for many bunches with many fruits in dry Sudanian zone. It is followed by the crown size. For both zones, the number of tertiary branches appeared as variables which could be used as fruit and pulp production predictor. This finding is important for further studies that will model the trees productivity as reported by Lamien et al. (2007) for the shea-trees fruit production. Indeed, shea fruit production can be predicted on base of dendrometric variables. The positive correlation between the tertiary branches and fruit and pulp production could be explained by the fact that flower buds are bored at the ending of branches and more is the number of branches that bear flower many should be the number of fruit produced.

Limitation of the study

Several approaches for fruits produced estimation are used as visual count and tree diameter at breast height and tree crown volume as predictors (chapman et al., 1992). Visual counting consists, in the one hand of collecting the mature fruits dropped under tree shed until the end of fruiting period (Lamien et al., 2004; Lamien et al., 2006) and in the other hand, consists of estimating the number of fruits on some representative branches and multiplying by the average number of counted branches (Haarmeyer et al., 2014). According to Chapman et al. (1992), the accuracy of the used method of fruit produced estimation depends on the type of the fruits and visual count is appropriate for large fruits as they are big enough to be observed. For this study, we used visual count as used by Haarmeyer et al. (2014) to estimate the fruit production of *L. microcarpa* in Burkina Faso. Such method used neglects the number of unconsumed fruits fell under the trees and the part remove by frugivorous during fruiting period.

Conclusion

Our study highlighted the fruit and pulp production variation, link between trees production and its morphological variables and the impact of harvesting mode in two Sudanian zones. Dry Sudanian zone appeared as suitable for fruit and pulp production. *Lannea microcarpa* seems to be under high harvesting pressure in humid Sudanian but trees debarking have not shown negative impact on trees production. Variations observed between zones deserve to be investigated in relation to genetic diversity.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

EOAG design the study protocol with the help of GNG. Statistical analysis and manuscript writing was done by EOAG with the assistance of GNG; LGH and MO revised the final draft of manuscript. All authors read and approved the final manuscript.

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