

# Biomass, root structure and morphological characteristics of the medicinal *Sarcocephalus latifolius* (Sm) E.A. Bruce shrub across different ecologies in Benin

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## ABSTRACT

Medicinal plants play an important role in human livelihoods. However, the harvest of different organs may be destructive. *Sarcocephalus latifolius* is a species whose roots are harvested for medicinal purposes. This study was carried out to assess the root characteristics, biomass yield and morphological variations within different habitats of southern Benin. Forty-eight *S. latifolius* individual plants were randomly selected in three localities, representing four habitats for the species. Information collected was related to height, basal diameter, diameter at breast height, number, depth of insertion and the length and the diameter of the roots. Observations were also made on organ characteristics to identify morphologic variation. The study showed that the optimum development of the root system is established in fallow ground and savannas. The species presents two morphotypes at the stem and root levels. Root biomass varied according to the developmental stage and habitat. A model of root biomass estimation was established and can be used to determine the root biomass within habitats. Across habitat, the number of roots is the major determinant for root biomass yield. Therefore, harvest should take into consideration habitat and the developmental stage according to the use type.

*Keywords:* root system, biomass, morphological variation, *Sarcocephalus latifolius*, West Africa

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## 1. INTRODUCTION

Non-timber forest products (NTFPs) provide a range of medicinal, craft, nutritional, ritual and ecological uses for rural communities. Use and management of those plants are an integral part of rural life.<sup>1</sup> Many plants are harvested in the wild and used as medicine, food and for economic purposes.<sup>2-4</sup> Of all the plant-based NTFPs, medicinal plants are considered the most important and significant.<sup>5</sup> *Sarcocephalus latifolius* is one of the medicinal plants well-known and highly sought by rural communities. *S. latifolius* is a source of food and medicine.<sup>6-8</sup> Traditionally, leaves, fruits, stems and roots are used. Particularly the root has been used in the treatment of various infections such as malaria and stomachache.<sup>9-19</sup> Bark and root harvesting can affect species survival and regenerative dynamics. The extraction of NTFPs leads to a deterioration in the rate of survival, growth and reproduction of plants.<sup>20</sup> For example, the removal of *Caesalpinia bonduc* roots has been found to lead to the death of the species.<sup>21</sup> This calls for a need to understand more about the dynamics of the species and the harvesting impact on the regeneration capacity of natural populations.<sup>22</sup> Both quantitative and qualitative information on the effect of exploitation type or the harvesting of *S. latifolius* root on the regenerative capacity of the plant are lacking. This information should be generated to serve as a guide for the sustainable utilization of the plant species. Information on the quantity and frequency of root harvesting are important to minimize the dangers of over-exploitation. Root growth, mortality and decay are also dynamic processes that are highly sensitive to environmental change.<sup>23-25</sup> Yet, despite their importance in our understanding of ecosystem nutrient cycling and global biogeochemistry, there is relatively little information about the amount and spatial distribution of roots in terrestrial ecosystems.<sup>25</sup> Therefore it is important to have information on the root structure and biomass. The limited data available on root systems are not easily comparable because the expression of their morphology varies according to the combination of species-soils.<sup>26</sup> This adaptation can give different morphotypes. In fact, studies on native plants, such as *Adansonia digitata*<sup>27,28</sup> and *Detarium microcarpum*,<sup>29</sup> identified phenotypes on the basis of characteristic features in relation to environmental and abiotic factors. The relative information on these morphotypes is little documented in Benin, especially for *S. latifolius*. Due to the importance of this species it is vital to study the root system and how it is affected by different habitats. We hypothesize that there is a relationship between habitat type, root system and the biomass of *S. latifolius*. The aim of the study was to characterize root structure, determine the biomass according to habitat and identify morphological variation.

## 2. MATERIALS AND METHODS

### 2.1 Study area

The study was carried out in the Zagnanado district of Benin where the species occurs in abundance.<sup>30</sup> This district is located between latitudes 7° and 7°30' N and longitudes 2°15' and 2°30' E. The mean annual rainfall is 985 mm and the mean daily temperatures range from 20°C to 38°C. The soils are ferruginous, ferrallitic or rich in clay. Vegetation consists of woodland and savannah. Data was collected from three different localities (Banamè, Dovi and Kpédékpo) inside the district (Figure 1).

### 2.2 Sampling and data collection

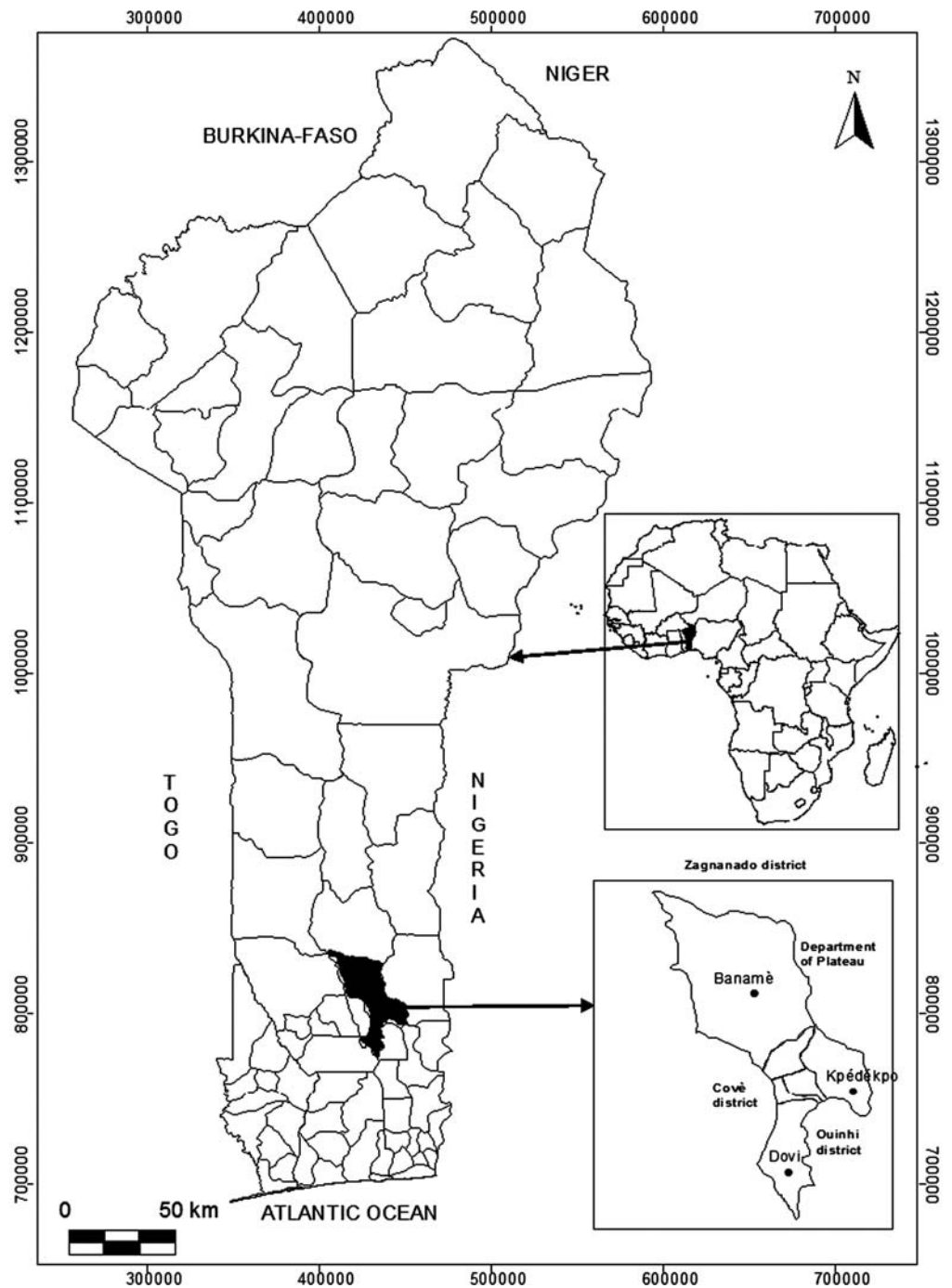
#### 2.2.1 Plant material

In each locality, principal habitats of the species were identified during a prospecting and the presence or absence of the species was recorded. Four types of habitat were investigated: Field, fallow, shrub savanna and savanna woodland. In each habitat type, a haphazard selection of four individuals of *S. latifolius* consisted of two juveniles with a diameter at breast height (dbh) < 5 cm and Height (Ht) < 1 m and two adults with dbh ≥ 5 cm and Ht > 1 m was made. Overall 48 individuals (4 × 4 × 3) were harvested. Data was collected from November 2011 to January 2012. Diameter at breast height, basal diameter and height were recorded for each individual plant.

#### 2.2.2 Root structure, biomass and morphological characteristics

To characterize root structure, the baring of the roots was made using lateral disengaging<sup>31</sup> with machetes, hoes and axes. Measurements relative to root structure included the length of the secondary roots, the depth of insertion and the number and diameter of the roots.

Biomass assessment was made by weighing the roots. The fresh mass of all secondary roots was recorded. A sample of 300 g was taken and labeled (habitat type, development level, soil type, root



**Figure 1.** Location of the district of Zagnanado. This district was selected because of the abundance of *S. latifolius*.

color). Each sample was oven-dried to a constant weight in order to determine the roots dry weight. Morphological characteristics for each individual *S. latifolius*, based on their stem (arborescent, acaulescent), leaf (length, color) and root (color, architecture) were also recorded.

### 2.3 Data analysis

The root system analysis on secondary roots was based on number of roots, length, depth of insertion and diameter. To assess correlations between various plant traits and the biomass, a stepwise selection of variables was performed. Per habitat type, allometric relations were performed using Minitab 14.<sup>32</sup> It was then possible to establish prediction models of the biomass from morphometric

variables retained by stepwise selection. The normality and the residual homogeneity of the regressions were checked to evaluate the quality of the various models obtained. Finally, a three way analysis of variance (development stage, habitat and soil) was performed on diameter at breast height, height, basal diameter and the dry mass of roots.

### 3. RESULTS

#### 3.1 Root system

Significant differences ( $P > 0.05$ ) were obtained on the depth of insertion, mean diameter and mean length of the roots between adults and juveniles within a given habitat. The highest values for most parameters were obtained for fallows and shrub savanna. The minimal and maximum mean values for depths of insertion are  $5 \pm 0$  cm and  $31.25 \pm 3.19$  cm (Mean  $\pm$  SE), respectively. The mean diameter of the roots ranges from  $0.17 \pm 0.78$  cm to  $3.55 \pm 2.24$  cm. The mean length was  $104.8 \pm 16.87$  cm.

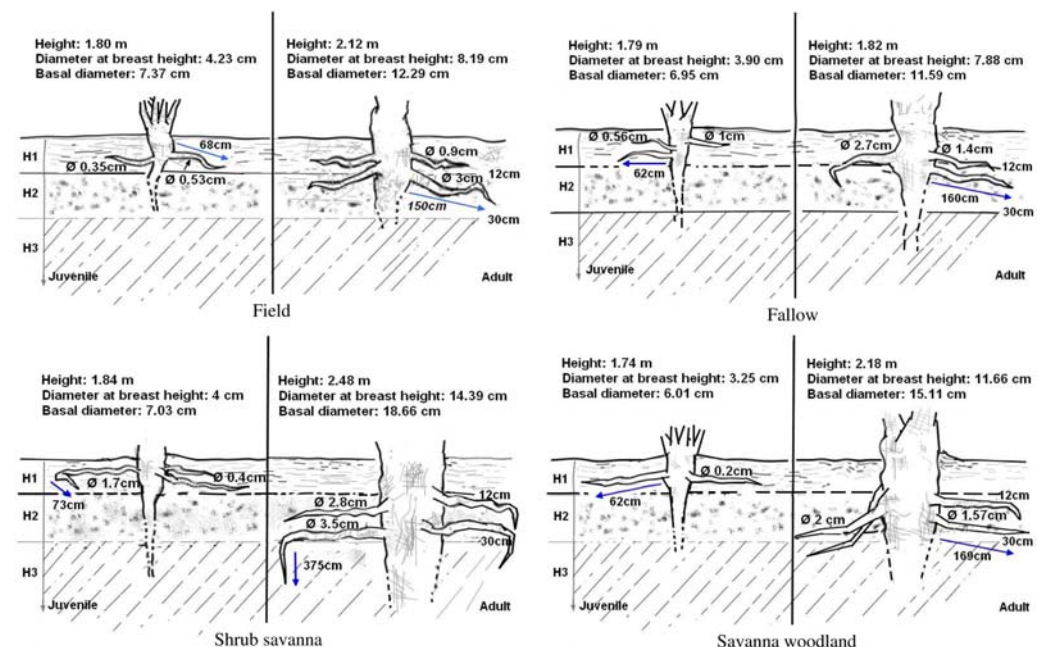
The analysis of variance carried out on the root number ( $P = 0.037$ ), depth of insertion ( $P < 0.001$ ), the root diameter ( $P < 0.001$ ) and the root length according to the development stage revealed significant differences ( $P = 0.001$ ). With regard to the types of habitat and the soil type, there was no significant difference ( $P > 0.05$ ) between variables (Table 1). For biomass, the type of habitat and developmental stage are the determining factors (Table 1).

**Table 1. Significance of analysis of variance (ANOVA) for different root parameters.**

Source	Depth of insertion	Root diameter	Root length		Number of roots	Biomass
			<i>P</i>			
Development stage	< 0.001	< 0.001	< 0.001		0.037	< 0.001
Habitat	0.318	0.454	0.131		0.403	0.021
Soil	0.059	0.353	0.288		0.897	0.442

*P* = Residual probability value.

The species showed a tap root system with principal and side secondary roots (Figure 2). The roots presented a horizontal extension with two types of profile: straight and/or slightly curvilinear. The lateral root system is plastic with centrifugal development. Roots move according to the ground texture. The rooting occurs in the first soil horizon at any stage of development and habitat. However the differences were remarkable.



**Figure 2. Root morphology according to habitat and developmental stage of *S. latifolius*.**

### 3.2 Modeling of growth allometry

Since there were significant differences ( $P < 0.05$ ) in the measurement of variables from one habitat type to another, the modeling of biomass production was made per habitat. The coefficient of determination ( $R^2$ ) for each equation was high and significant ( $P < 0.05$ ; Table 2) suggesting that it would be possible to predict the dry weight of the roots based on the significant parameters. Therefore on fields, the dry mass was found to be dependent on the height of the tree, the root number, the length, the diameter and the depth of insertion of the roots. In the fallow, dry mass was linked to the diameter at breast height and the number of roots. In shrub savanna, the dry weight was most influenced by the diameter at breast height and the insertion depth of the roots. Finally, for savanna woodland the dry weight of the roots depended on the total height, the diameter at breast height and the root number. It should be noticed that for all models, except that for shrub savanna, the root number is a dominant parameter.

**Table 2. Modeling of root biomass according to different habitats.**

Habitats	Regression equation	S	R <sup>2</sup>	R <sup>2</sup> ajt	P
Field	$Ps = -592 - 0,33 Lg + 219 Dr + 6,3 Pi + 4 Ht + 215 Nbr$	229	82	67	0.031
Fallow	$Ps = -761 + 84,5 Dbh + 238 Nbr$	205	81	77	0.001
Shrub savanna	$Ps = -1919 + 161 Pi + 169 Dbh$	1072	87	85	0.000
Savanna woodland	$Ps = -1868 + 75,7 Dbh + 597 Ht + 322 Nbr$	341	92	88	0.000

Ps = Biomass; Dbh = Diameter at breast height; Pi = Depth insertion; Ht = Height; Nbr = Number of roots; Lg = Root length; Dr = Root diameter, S = Residual standard deviation; R<sup>2</sup> = Coefficient of determination (%); R<sup>2</sup>ajt = Coefficient of determination adjusted (%); P = Residual probability value.

### 3.3 Morphological characteristic of *Sarcocephalus latifolius*

Little tree-to-tree variation was observed. Leaf features (for example, form and color) did not differentiate individuals, because different sizes, forms and color could be found on a single tree. There were individuals of *S. latifolius* with either crawling or erect stems. However the crawling aspect can be related either to the developmental stage (regeneration, juvenile), or to the fact that the optimal ecological conditions are not yet met (presence of tutor, pedological requirements). For erect stems we distinguished the arborescent type of stem (35 individuals), with dark color and a rough aspect; and for the acaulescent type of stem (13 individuals), smooth with a light color (Figure 3). We have found two types of variations: the ecophenotypic variation and the individual transitory variation related to the developmental stage. In addition, at the time of root harvesting we observed a color variation on the roots. With regards to the root color, three forms were distinguished: dark yellow, light yellow and white (Figure 3). These color-traits are linked to the type of soil. Indeed, the white color was observed for the roots present in sandy soils while the yellow color was observed in predominantly clay soil.

## 4. DISCUSSION

### 4.1 Root system and biomass

The root systems of plants are generally regarded as a very important factor in relation to its considerable agronomical and ecological characteristics.<sup>33</sup> This study was carried out to highlight the relationship between habitats, development stage and root system of *S. latifolius*. The target species was found in Field, Fallow, Shrub savanna and Savanna woodland. According to the different parameters measured in each habitat type, the root system of *S. latifolius* presented highest values in fallow and shrub savannas because these kinds of habitats are open and provide the relevant sunlight for the species which is heliophilous.<sup>34</sup> On the other hand, the low values of parameters obtained in field, also an open habitat, are likely to be due to the cutting down of the species. In fact, *S. latifolius* produces shade and farmers prefer to remove it to gain light and space for crops. The results of the study also revealed that phenotypic traits of adult plants exceeded those of juveniles and can be explained by the increase of physiological needs with age. Thus, adult plants had many roots with larger diameters ( $d > 10$  mm) that help to accumulate enough water and nutrients. This kind of age influence on root traits has been showed in Czech Lucerne varieties.<sup>33</sup> The secondary roots spread laterally in the topsoil horizons. The root insertion depth was more important in savannas and fallow



**Figure 3.** Morphological characteristics of *S. latifolius* A) Crawling stem, B) arborescent type of stem C) acaulescent type of stem. Colour of root: D) dark yellow, E) light yellow, and F) white.

habitats. This would help explain the competition between other species, search for nutrients and water in lower horizons.. This is in accordance with, findings that show spatial configuration of the root system (number and length of lateral organs) varies greatly depending on the plant species, soil composition and particularly on water and mineral nutrients availability.<sup>35,36</sup> In the field, roots were more linear than in other habitats. This could be explained by 'tilling effect', which might have softened the soil. Our findings suggest that the root system of *S. latifolius* depends on habitat and development stage. Moreover, the difference in the root biomass, according to the development stage and habitat, is likely due to the ecological conditions, which is not the same as habitat types. Local people harvest the plant irrespective of habitat and development stage for local use and sale in local markets.<sup>37</sup> Following the allometric relations between biomass and plant organs, it would be appropriate to sensitize local populations on the necessity to direct the harvest of the species toward adult individuals in savanna to

ensure higher biomass yield. However, the predictive equations generated must be used with caution, due to the local character of the study, and the fact that the same parameters do not influence the root biomass by habitats. Variability of factors at the spatial scale is known to affect ecological processes.<sup>38,39</sup> Given that our study regions are small, it would be challenging to identify factors that had a greater effect on the significant variation in root biomass found between habitats. The effect of harvesting on a plant species is of particular concern when the roots, fruiting bodies or other reproductive organs are removed.<sup>40</sup> According to harvesters, they cut one or two laterals roots and leave the primary root. This could negatively affect the species' survival. Extraction intensity of reproductive structures causes a delay in regeneration and a harvesting rate of over 25% is already harmful to the species.<sup>41–43</sup> Further studies are needed to know the impact of root harvesting on regrowth and mortality of *S. latifolius*. However, bacteriostatic and bactericidal profiles of extracts militate in favour of leaves used as root substitutes, which constitute a contribution to conservation of *S. latifolius* wildy harvested.<sup>44</sup>

#### 4.2 Morphological characters

Based on aspect and stem color, we identified morphotypes within the *S. latifolius* species. They were also distinguished on the basis of the root color, which varies from white to yellow when one moves from a sandy soil towards a clay soil. According to the field observation, this variation of the root color could be linked to the variation in soil color and calls for further investigation. *S. latifolius* can be climbing or crawling in nature. In the absence of stakes, the species spread out and evolve along the ground. These observations are related to the developmental stage and the type of soil. While various types of stems (acaulescent or arborescent) have been identified for the *Encephalartos* species, according to their geographical distribution,<sup>45</sup> the present study did not provide enough information to relate the morphological variations observed to habitats, nor to environmental or genetic factors. It will be necessary to undertake quantitative morphotypes and genetic studies in order to assess the basis of stems aspect variability within *S. latifolius*.

#### 5. CONCLUSION

Results from this study show that the root biomass of *S. latifolius* varies according to the specific habitat, with determinant key factors being number of roots, diameter at breast height and depth of insertion. There are also significant differences between juvenile and adult plants. The nature of the allometric relationship found in this study will allow harvesters to select individual plants according to their needs. Since the roots of *S. latifolius* are wildy used, conservation strategies must be developed. Firstly, harvesters should reduce number and intensity of root harvesting; secondly harvesters should be convinced to use for the same purpose leaf or others non-reproductive organs, instead of the root. Further studies are necessary to define optimum harvest practices to maximise *S. latifolius* root yield and develop economic models for its sustainable utilization by local communities.

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#### Authors' contributions

CAG designed and performed the field work, analyzed and drafted the manuscript. AEA and GNG gave conceptual advice, read, corrected the language and improved the drafted manuscript. RLKG gave conceptual advice, read and corrected the drafted manuscript. SC read the manuscript and improved the English language. BS supervised the works and improved the manuscript. All authors have read and approved the final manuscript.

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