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Full Length Research Paper

Assessment of regeneration potential of *Hibiscus sabdariffa* L. under established ecosystems in Cameroon

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***Hibiscus sabdariffa* is a non-timber-forest-plant (NTFP) that has the potential of producing fibers good in paper-making. Germination and growth potentials of *H. sabdariffa* under farmland, fallowland, plantation and forest ecosystems were studied. Seeds of *H. sabdariffa* were sown to assess germination percentage, germination rate, germination time and velocity coefficient on established plots of each ecosystem. Seedlings were randomly selected to measure growth and yield parameters of height, diameter, leaf number, fresh and dry weights. Data were subjected to ANOVA and means separated by LSD at P = 0.05. Values of germination percentage for fallowland (17.5) were significantly different from those of farmland (19.4) and plantation (19.1) ecosystems, while natural forest (18.9) had an interactive significance with farmland, plantation and fallowland. There was no significant difference between germination times among the ecosystems, but the coefficient velocity and rate of germination among the ecosystems were significantly different. There was a significant variation in growth and yield values among the ecosystems. However, only seedlings on farmland and fallowland survived with a survival rate of 96 to 86%, respectively. *H. sabdariffa* can thus, be sustainably regenerated on farmland and fallowland ecosystems for the extraction of stem fibres for paper-making.**

Key words: Non-timber-forest-plants, fibres, *Hibiscus sabdariffa,* ecosystems, growth, germination, yeild, regeneration, sustainability.

INTRODUCTION

All biotic and abiotic factors together within a certain area form an ecosystem (Edmonds, 1991). The structure and seasonality of the associated vegetation, complement with ecological data such as elevation, humidity, drainage, salinity of water and characteristics of water bodies are each determining modifiers that separate partially distinct sets of species (Vreugdenhil et al., 2003). In all ecosystems, there is a cycling of events from germination, growth, development and decomposition (Acquaah, 2004). Plant germination demarcates the transition from the seed being dependent on food sources from the mother plant, to an independent plant capable of taking up nutrients and growing independently (Schmidt, 2000). Hence, germination is the last link in the chain of seed handling processes. Germination proceeds when growth emerges from a period of dormancy leading to the development of a new plant (Raven et al., 2005). Environmental factors affecting germination and seedling establishment in different ecosystems may be positively correlated. However, spatial and temporal fluctuations in local variation in predation, competition and edaphic conditions can cause considerable discordance between seed bank longevity, germination and subsequent

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seedling survival (Mukhtar, 2008). This in turn can lead to weak correlations between seed germination parameters and adult plant distribution.

Elfry et al. (1980) observed that photoperiodic effect was quite significant on reactions of roselle varieties. Kumar and Echekwa (1985) observed that germination for five roselle (*Hibiscus sabdariffa* L.) varieties was quite successful and seedling emergence started on the 4th day after sowing. Growth on the other hand, is often thought of simply as an increase in size (Acquaah, 2004) and is also affected by both biotic and abiotic factors. These changes in form and structure could be measured at various levels of growth using a variety of growth parameters of which are stem height, diameter and leaf number (Elfry et al., 1980). This pattern follows both for timber and NTFP. The ecosystem of West and Central Africa are rich in natural resources and have tremendous biodiversity particularly wood and non wood species providing food, fuel, fibre, timber medicines, construction and building materials (Ayuk et al., 1999). *H. sabdariffa* is an NTFP of the tropical region that have contributed to rural poverty alleviation. It is cultivated by the local population for bast fibre obtained from the stem (Ogunsanwo and Scotannd, 1989). The fibre which stands at about 1.5 m long is used for cordages and as substitute for jute in the manufacture of burlap (Duke, 2003). Concern for its development for pulp and paper is not unconnected with this use. Attempts have been made on the potential of these and related species to supply long time pulp (Oluwadare and Scotannd, 2007). These efforts have produced encouraging results. For instance research has shown that *H. sabdariffa* has potential to supply long fibres with most fibre having length between 2.1 to 5.0 mm which is categorised under long fibre (Oluwadare and Scotannd, 2007). However, research on the evaluation of germination and growth potential under established ecosystems are not known nor documented.

The ecosystems at which this species can best be established for sustainably regenerated for continuous supply of fibres are not known. Therefore the objective of this study is to assess the sustainable regeneration of *H. sabdariffa* by evaluating its germination, growth and yield potential under farmland, plantation, fallowland and forest ecosystems, respectively.

MATERIALS AND METHODS

Study site

This work was carried out in Tombel locality situated in the tropical coastal rainforest South West Region of Cameroon at an altitude of 2064 m and lying between 4° 45 N and 9° 40 E (www.encater, 2008). Tombel is highly volcanic with an extinct plutonic mountain characterised by a wet period of nine months of abundant rainfall and 3 months of dryness. It receives an annual rainfall of 2,500 mm and has an average annual temperature of about 21.20°C (http://www.pgdrn – gtz-Cameroun.org).

Site preparation

This work was carried out between February and October, 2009. The different ecosystems were identified and experimental sites leased out by owners. Field guides were present to ease accessibility into respective ecosystem plots. Plots of 10 × 10 m were demarcated using a metric tape on each established ecosystem which included a natural forest, a cocoa plantation, a farmland from which crops had just been harvested and abandoned or fallowland which had not been cultivated for close to five years. These ecosystems were cleared using a machete and ploughing of the soil was done with a hoe.

Germination

Seeds of *H. sabdariffa* were bought from the markets. One hundred seeds were sown per plot of each ecosystem at a planting distance of 50 cm. Holes of 2.5 cm were drilled using drillers on the ridges and one seed hand-dropped into one hole (Figure 1). These holes were then slightly covered with soil. The number of seeds that germinated per ecosystem was counted cumulatively and the germination percentage, germination rate, germination time and coefficient velocity were calculated. Calculation of velocity coefficient was by Labouriaul (1983). Coefficient velocity of germination:

$$CVG = \left(\sum_{i=i}^{k} fi / \sum_{i=i}^{k} fixi \right) 100$$

Where fi = number of newly germinated seedling on day i, Xi = number of day from sowing and K = last germination time.

Growth

Measurement of growth parameters of *H. sabdariffa* commenced one month after seeds were sown. 10 uniform seedlings were randomly selected from germination beds and tagged for growth measurements. Weeding was done manually during this period once every month. The plants were consecutively disinfected at the 2nd, 8th, and 22nd weeks of growth by spraying with Beauchamp 72% WP fungicide (50 g/16l of H_2O) and Kunfu 5% WP insecticide (10 g/16l of H_2O) using Berthoud sprayer to control fungi and insect attacks, respectively. Watering was done on a daily basis during the first two months (since it was just the beginning of the rains). Measurement of the stem length and diameter were done using a regulated tape and the number of leafs counted cumulatively.

Yield

Eighteen weeks after planting, each plot was divided into four subplots in order to vary the harvesting intensity. The subplots were denoted subplots 1, 2, 3, and 4, respectively. Subplot 1 was harvested firstly. This constituted the 25% harvesting intensity. Twenty-one weeks after planting, subplot 2 was harvested, which constituted harvesting at 50% intensity. Subplots 3 and 4 were harvested 25 and 28 weeks respectively after planting, constituting harvesting intensities of 75 and 100%, respectively. The harvesting

Figure 1. Seeds of *H. sabdariffaba* ready for planting.

Table 1. Percentage seed germination of *H. sabdariffa* in different ecosystems.

Ecosystem	Germination (%)		
	Days after planting		
	4	5	6
Forest	67.5	20.5	6.5
Farmland	78.0	10.5	7.5
Abandoned	61.5	21.0	5.0
Plantation	74.5	15.5	5.5

was done using sharp cutters specially designed. Entire crop for each subplot of each ecosystem were harvested and carried to the laboratory where the stem, leaf and fruit components were separated and weighed using an analytical top loading electronic balance (Ohams) to determine the maximum fresh weight yields. Harvesting at different intensities of 25, 50, 75 and 100% was carried out to determine the optimum level of yield and sustainability of plant in the different ecosystems.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) as described by Cochran and Cox (1957) using statistical Microsoft Office Excel (2007). The treatment means were separated using least significant difference (LSD) for statistical significance at 5% confidence interval ($P<0.05$). Germination values were obtained as described by Oni and Gbadamasi (1998). Graphs were plotted to show the evolution of the growth parameters over time for each plant using Microsoft Office Excel (2007).

RESULTS

Germination

The seeds of *H. sabdariffa* started emerging from the soil 4 days after they were sown in all four ecosystems. The highest germination percentage was observed on day 3 of 78% for the farmland ecosystem (Table 1). No significant difference was observed between the farmland (19.4) and plantation (19.1) ecosystems; but these were significantly different from the fallowland (17.5) ecosystem. The fallowland ecosystem was not significantly different with the forest ecosystem (18.9) as seen on Table 2. Table 3 shows the values of germination time, germination rate, velocity coefficient of all the four ecosystems. The velocity coefficient was significantly different from the means of the germination

Table 2. Mean values for seed germination percentage variations of *H. sabdariffa* in ecosystems.

Ecosystems	Seed germination
Farm	19.4[a]
Plantation	19.1[a]
Natural forest	18.9[ab]
Fallowland	17.5[b]

Means values with the same letter from the different ecosystem are not significantly different at P<0.05.

Table 3. Mean values for germination time, rate and velocity coefficient.

Ecosystem	Germination parameters		
	Time (days)	Rate	Velocity coefficient (%)
Forest	3.4	0.19	29.8
Farmland	3.3	0.19	30.6
Abandoned	3.4	0.75	29.8
Plantation	3.3	0.19	30.6

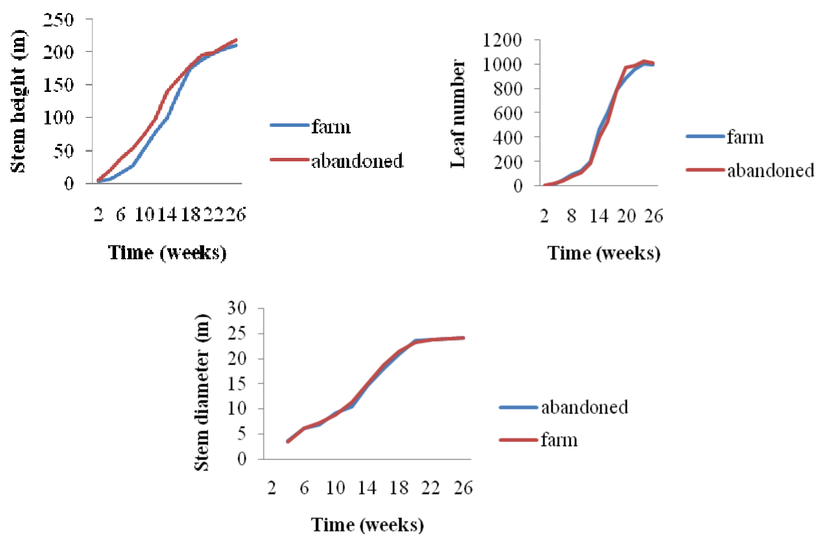

Figure 2. Growth evolution of stem height, leaf number and stem diameter of *H. sabdariffa* in farmland and fallowland ecosystems.

time and germination rate while the values of the means of germination rate were significantly different among the ecosystems.

Growth

Growth parameters of *H. sabdariffa* were observed from April to September as observed in Figure 2. These values varied among all four ecosystems. Only the plants in the farmland and fallowland ecosystems survived or were able to complete their life cycle, that is, germination, growth and the production of seeds. None of the plants in the forest and plantation ecosystems survived after the 4th week of germination. The plants in the farmland and fallowland ecosystems completed their life cycles 5 months after germination. Growth was slow for the first 6 weeks after germination but this rapidly became

Table 4. Mean values for growth parameters of *H. sabdariff* in ecosystems.

Ecosystem	Stem height (cm)	Leaf number	Stem diameter (mm)
Fallowland	121.66^{a}	474.60^{a}	14.47^{a}
Farmland	106.91^{a}	1167.47^{a}	$14. 23^{a}$
Plantation	2.24^{b}	1.04^{b}	0.16^{b}
Forest	0.75^{b}	0.23^{b}	0.00

Means with the same letter are not significantly different at P<0.05 using LSD.

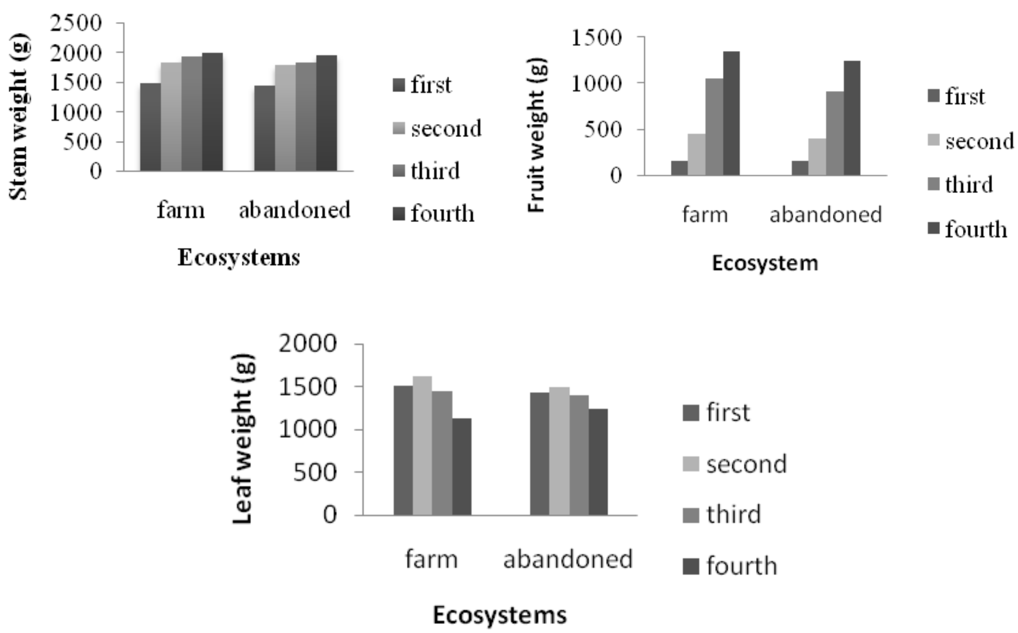

Figure 3. Stem, fruit and leaf yields of *Hibiscus sabdariffa* in farmland and plantation ecosystems.

exponential as from the 10th to about the 28th week of growth. At P < 0.05, no significant differences was observed between the values of stem height, leaf number, and stem diameter for fallowland and farmland ecosystems but these values were both significantly different from the plantation and forest ecosystem for stem height, leaf number and stem diameter at the earlier phases of observation (Table 4).

Yield harvest

Figure 3 shows the histograms for stem, fruit and leaf yields of *H. sabdariffa* in farmland and plantation ecosystems. The stems harvested at 25% intensity at subplots 1 had the least weight in both the farmland and fallowland ecosystems. These weights increased for subplots 2, 3, and 4 at harvesting intensities of 50, 75, and 100%, respectively. The weight of the fruits harvested also increased progressively from 25, 50, 75 and 100% harvesting intensities. The farmland and fallowland ecosystems recorded mean stem and fruit weights which were significantly different at P <0.05 though stem and fruit yields were higher for farmlands (2003 g for stem yield and 1350 g for fruit yield), than for fallowland (1956 g for stem yield and 1280 g for fruit yield). The farmland and fallowland ecosystems recorded leaf weights which were not significantly different at P <0.05 (Table 5).

DISCUSSION

The results of germination of *H. sabdariffa* seeds in this study are in agreement with those observed by Kumar and Echekwa (1985) for this species. He confirmed the observation that seedlings of *H. sabdariffa* emerged from the soil 3 or 4 days after sowing. Elfry et al. (1980) concluded that fewer or more days may be required for seedlings to emerge under ideal soil moisture and

Table 5. Yield weight variation of *H. sabdariffa.*

Ecosystem	Stem weight (g)	Fruit weight (g)	Leaf weight (g)
Farmland	1826.25[a]	751.50[a]	1421.75[a]
Fallowland	1765.75[b]	674.75[b]	1388.25[a]

Mean values with the same letter superscript are not significantly different for the ecosystems at P<0.05.

temperature as was the case in all four ecosystems where 61.5 to 78% of seedlings emerged from the soil three days after sowing in all four ecosystems with an average germination time of 3.31 days. More than half of the total number of seeds germinated on the third day after sowing indicating that the environmental factors, temperature, water, oxygen and light were favorable (Raven et al., 2005). The germination percentages of the seeds of *H. sabdariffa* were not significantly different at P< 0.05. The different soil compositions in the different ecosystems had little or no effect on the germination percentage because all four ecosystems recorded very high germination percentages with very slight differences which varied from 87% in fallowland ecosystem to 96% in the farmland ecosystem. This was in accordance with Edmonds (1991) who postulated that *H. sabdariffa* requires rich loamy soils although they may grow on a variety of soils including new and old alluvium and lateritic loam as was the case of our experimental site. The values for stem height of *H. sabdariffa* were significantly different at P< 0.05 in all four ecosystems. Only the plants in the farmland and fallowland ecosystems survived or were able to complete their life cycle having an average height of 210 cm which is slightly different from 204 cm obtained by Morton (1987).

The plants in the forest and plantation ecosystems respectively did not survive after 4 weeks of growth probably due to the fact that *H. sabdariffa* is a heliophyte, thus needing sufficient light for growth (Elfry et al., 1980). Thus, owing to shade effect created by the trees in the forest and the plantation ecosystems, these seedlings could not survive. The leaf number and stem diameter, just like the stem height evolution, also varied significantly in farm and fallowland ecosystems. This can be explained by the fact that *H. sabdariffa* plants are not adapted to grow under shade due to the physiological nature of their leaf. Only 2% of the light incident on the forest canopy reaches the floor (Edmonds, 1991). The leaves of heliophytes are not adapted to conduct photosynthesis at this low light intensity (Raven et al., 2005), which is necessary for growth hence obviously led to the wilting of the *H. sabdariffa* seedlings at this stage in the plantation and natural forest ecosystems. Duke (2003) observed that *H. sabdariffa* started producing flowers as from 120 to 130 days after sowing which is in accordance with our observation. This is in accordance with Elfry et al. (1980) that *H. sabdariffa* exhibits marked photoperiodism. This is true because the plant in the farmland and fallowland ecosystems started producing flowers in mid- September with short day-length of 11 h. Kumar (1985) stated that *H. sabdariffa* has two distinct phases of growth like other crops. These are the vegetative and reproductive phases. During the vegetative phase the energy of the plant is concentrated on the development and maturation of vegetative parts like stem, leaves and roots. At this early phase, the plant absorbs water at a rapid rate and often takes in most of the nitrogen, potassium and phosphorus that is utilized for growth and development. At the reproductive phase, there is the formation of flowers and the development of fruits and seeds of the plant leading to a drop in the number of leaves and slowing down in stem height.

Plant yield harvested after the 18th week (25% intensity) of growth had the lowest stem, leaf and fruit yields in both farmland and abandoned farmland ecosystems. This varied through the 50, 75 and 100% harvesting intensities for all the growth features. The leaf yield harvest increased from the 25% harvest intensity to the 50% harvesting intensity. As from the 50% harvesting intensity, this leaf yield dropped probably due to the fact that during this period the number of leaves that fell off the plant was higher than the number of leaves that developed from the plant. At P<0.05, the plant yield significantly varied in both ecosystems. This result were reported by Duke (2003) who concluded that the early harvest of *H. sabdariffa* gives low yield while late harvesting yields a substantial quantity and quality of stem fibers and fruits.

However; higher yield parameters for the farmland compared to fallowland ecosystems is probably due to the fact that continuous tillage, in addition to mixing and stirring of soil breaks up aggregates and exposes organo+mineral surfaces otherwise inaccessible to decomposers (Post and Kwon, 2000). Also, Alvarez and Alvarez (2000) observed that organic matter enriches the soil providing a good percentage of nitrogen for plant rapid growth. Meanwhile, on abandoned farmlands; the soil texture is not sufficiently aerated and mineral nutrients are not readily available to plants; thus in conclusion, *H. sabdariffa* exhibited very significant values in growth parameters in the farmland and fallowland ecosystems and since there were significant variations at different harvesting intensities, this species can be sustainably regenerated for long periods in the farmland and fallowland ecosystems.

As for germination, *Hibiscus* can germinate in all the ecosystems, that is, farmland, fallowland, plantation and forest. However, being a heliophyte, the possibility of transplanting the germinated seedlings and the period of transplating to appropriate ecosystem can be investigated.

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