Scientific Research and Essays Vol. 5(22), pp. 3378-3383, 18 November, 2010
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 ©2010 Academic Journals

Full Length Research Paper

Assessing certain root characteristics among provenances of *Gnetum* spp. in South West Cameroon: Relevance for domestication and conservation

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Accepted 22 July, 2010

***Gnetum africanum* and *Gnetum bulchozianum* are two slow-growing, dioecious, and morphologically similar understorey lianas that are widely distributed in the humid tropical forests of West and Central Africa. Dwindling wild stocks of the widely consumed leafy vegetable are under persistent threat from deforestation, increasing demand and harvesting pressure. These factors militate in favour of domestication with recourse to vegetative propagation. The main objective of this study is to improve the species genetically based on a comparative assessment of rooting abilities among various provenances and ascertain implications for domestication and conservation. The experimental design was a completely randomised block. Twenty vines were randomly selected from each of five provenances and randomly assigned to 10 experimental blocks. Leafy stem cuttings extracted from the vines were inserted into a rooting medium of rotted saw dust. Rooting depth, number of roots and rooting percentage were parameters used in assessing rooting performance. Most of the variation in rooting characteristics was explained by within-provenance variability, highlighting the importance of clonal selection in genetic screening. The most variable quality trait and root length significantly differed ($p < 0.05$) among provenances. Furthermore, root length is an important predictor of sprout survival ($r = 0.32$), an important attribute in domestication.**

Key words: *Gnetum*, provenance, root characteristics, domestication, genetic improvement, conservation, South West Cameroon.

INTRODUCTION

Botanic, ecological and economic background of the species

Gnetum spp. is Gymnosperms of the family *Gnetaceae*. These are the only two members of the genus *Gnetum* found in Africa among thirty representatives existing in the tropics (Mialoundama and Paulet, 1986). These non-timber forest species (NTFP) are dioecious, slow-growing and understorey lianas. In Cameroon, evergreen and degraded forests and bush fallows are the major habitats of the species (Fondoun and Tiki, 2000).

The two species are morphologically very similar but taxonomically distinguishable based on the shape of the leaves and male reproductive organs (Lowe, 1984). They possess a tap root system, bearing numerous root hairs (Onguene and Kuyper, 2001), and they are capable of generating root suckers, as offshoots of lateral adventitious roots, demonstrated in other species (Halle et al., 1978).

These species are widely consumed leafy vegetables serving as sources of appreciable quantities of proteins (Busson, 1969, unpublished) and incomes. Consumption is estimated to contribute up to 30% of the daily intake of protein in some places in Central Africa (Nkefor 2001, unpublished). To a lesser extent, the leaves are used in the treatment of a broad range of diseases such as enlarged spleen, hemorrhoids and high blood pressure (Schippers, 2000, unpublished; Shiembo, 2008, unpublished).

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According to Mahop and Asaha (1999, unpublished) the price of ‘eru’ ranges between 250 - 300 FCFA per bundle in certain local markets in Yaounde - Cameroon depending on their availability in the villages where the price also ranges between 50 - 200 FCFA per bundle. It is estimated that 600 tons of *Gnetum* leave the port of Idenau in South West Cameroon to Nigeria with a local market value of 1 800 000 000 CFA (Bokwe and Ngatoum, 1994, unpublished). As much as 450 000 CFA / month is reported to have been made from the sale of *Gnetum* by one of the full-time traders on the product in the Idenau market, 1997 (pers. Com). This large volume of trade offers valuable employment to many young people in Cameroon and surrounding countries. Apart from exporting large quantities to Nigeria on a weekly basis, markets for the commodity also exist in France, Britain and USA (Besong et al., 2001). France and Belgium import annually over 100 tons of *Gnetum* worth 2 billion CFA frs (US$ 2.9 million) (Besong et al., 2001).

Rationale for genetic selection

Natural stocks of the vegetable are under persistent threat (Van Dijk, 1999; Sunderland et al., 2002). These emanate from; (1) increasing population (2) growing demand for the commodity (3) destructive and unsustainable harvesting methods in the wild and (4) genetic erosion. Yet, propagation of these species using seeds under nursery conditions has failed. Furthermore, there is a rarity of seeds for producing seedlings of the species while poor germination percentages have been recorded as it takes more than 12 months for the seeds to germinate (Shiembo, 1997; Okafor, 1997). With wildlings, planting has not been successful as the resulting plant growth is slow.

Persistent reliance on diminishing wild stocks (Van Dijk, 1999; Tekwe et al., 2003), notwithstanding, the availability of domestication techniques, could suggest that the opportunity cost incurred in harvesting the resource is grossly outweighed by capital required for its operational-scale cultivation. This points to the fact that while the case for domestication is cogent and overwhelming, its implementation may not be cost-effective. Hence there is need to direct investment on *Gnetum* domestication towards plants selected in terms of desirable traits (e.g. fast growth, low mortality and high yield).

The role of vegetative propagation techniques in the capture of genetic variation inherent in wild populations and rapid multiplication of selected genotypes has been emphasized (Leakey et al., 1993). In this light, root characterization among provenances of the species could potentially serve as a premise for genetic selection (e.g. for fast growth and low mortality) accompanying the domestication process (Leakey and Tchoundjeu, 2001). While genetic selection comprises various facets including progeny, clonal and provenance selection forms an integral part of the domestication process (Leakey et al., 1993; Allaby, 1998; Tchoundjeu et al., 1998). Little or no formal research has been carried out on many of the hitherto wild species to assess their potential for genetic improvement (Leakey and Tchoundjeu, 2001).

The main objective of this study is to improve the species genetically based on a comparative assessment of rooting abilities among various provenances and ascertain implications for domestication and conservation. The hypothesis to be tested is that provenances assimilated to distinct gene pools, have differing rooting aptitudes.

MATERIALS AND METHODS

Study site

The experimental site is located within the Multipurpose Research Station of Barombi Kang, Kumba, South West Cameroon with an altitude of 198 m above sea level. It harbours a low-cost non-mist propagator, which is split into 10 compartments, each measuring 1 × 1 m.

The base and lid of the propagator are made of polythene sheets. This creates a greenhouse condition within the propagator. The base is underlain with a rooting medium made up of six-months old rotted sawdust to a depth of 15 cm. Prior to planting and cuttings, the rooting medium is disinfected with an insecticide and filled with water up to a few centimeters below it and the level maintained by daily watering where applicable.

Sampling procedure

Data collection took place between March and May, 2002. Twenty vines were randomly collected from bush fallows in each of five randomly selected provenances (Mamfe, Tombel, Kumba, Matoh, Mbonge), situated at least 30 km apart. These provenances were distinguished by various co-ordinates as shown in Table 1. The vines were transported in an ice box to ensure that they were well preserved prior to propagation in the rooting medium.

Statistical method

The experimental design was a Complete Randomised Block. Every block was equivalent to each of the 10 compartments embodying the propagation unit. Two vines of each provenance were randomly assigned to 2 distinct lines per block. Each line consisted of 10 leafy stem cuttings generated from a single vine and inserted into equidistant (3 - 5 cm) finger-deep holes created in the rooting medium.

Data collection and analysis

Twelve weeks after planting, cuttings were carefully removed from the propagator and characterized for root length, number of roots and rooting percentage (survival rate) prior to potting in poly bags. Analysis of Variance (ANOVA) was carried out among provenances with respect to each of the response variables followed by correlations among variables with the aid of a SYSTAT 11 Statistical package.

Table 1. Sampling sites or Provenances of *Gnetum* germplasm in south West Cameroon.

Provenance	Plot (farm)	Altitude (m.asl.)	GPS waypoints
	1	110	N 05^{0} 41' 905" E 009^{0} 18' 181"
	2	110	N 05^{o} 42' 991" E 009^{0} 18' 614"
Mamfe	3	110	N 05^{o} 42' 885" E 009^{o} 18' 510"
	4	110	N 05^{o} 42' 931"E 009^{o} 18' 510"
	5	110	N 05^{o} 42' 991"E 009^{o} 18' 536"
	1	290	N 04^{o} 43' 524" E 009^{o} 43' 163"
	2	300	N 04^{o} 43' 499" E 009^{o} 43' 158"
Tombel	3	290	N 04^{o} 43' 500" E 009^{o} 43' 141"
	4	310	N 04^{o} 43' 489" E 009^{o} 43' 135"
	5	320	N 04^{o} 43' 497"E 009^{o} 43' 142"
	1	135	N 04^{o} 34' 855" E 009^{o} 26' 843"
	2	90	N 04^{o} 34' 644" E 009^{o} 26' 592"
Barombi -KangKumba	3	120	N 04^{o} 34' 653"E 009^{o} 26' 806"
	4	180	N 04^{o} 34' 653" E 009^{o} 27' 621"
	5	160	N 04^{o} 34' 761" E 009^{o} 27' 558"
	1	310	N 04^{o} 40' 274" E 009^{o} 25' 719"
	2	330	N 04^{o} 40' 619" E 009^{o} 25' 512"
Matoh	3	315	N 04^{o} 40' 925" E 009^{o} 25' 382"
	4	330	N 04^{o} 40' 940" E 009^{o} 23' 470"
	5	365	N 04^{o} 41' 309" E 009^{o} 41' 309"
	1	60	N 04^{o} 34' 563" E 009^{o} 08' 064"
	2	95	N 04^{o} 33' 739E" 009^{o} 08' 229"
Mbonge-Small Nganjo	3	110	N 04^{o} 34' 734"E 009^{o} 08' 359"
	4	120	N 04^{o} 35' 010"E 009^{o} 08' 526"
	5	110	N 04^{o} 35' 001" E 009^{o} 08' 623"

RESULTS

Table 2 indicates that a comparatively small fraction (33, 20 and 15%) of the total population variation in relation to various rooting characteristics (root length, rooting percentage and number of roots) respectively, was attributed to provenances. The smallest source of variation could be traced to blocking. Much of the remaining variation was accounted for, within-treatment (provenance) variability. The most variable quality trait was root length, which was even more striking when referring to intra-provenance variability exhibited by each provenance (Table 3).

There was some evidence that root lengths were significantly different ($p < 0.05$), the highest and lowest values being attained by the Matoh and Mamfe provenances, respectively (Table 4). The other rooting characteristics were unimportant indices of rooting performance among provenances. The blocking effect was not significant for all rooting characteristics. Table 5 depicts weak significant correlations among rooting parameters with the strongest correlation shown between rooting depth and number of roots per cutting ($r = 0.43$).

DISSCUSSION

Blocking effect

Variation, resulting from blocking could have undergone a further reduction if leafy cuttings from each vine were randomly assigned to all the blocks. However, the absence of statistical significance of mean values ascribed to the blocking effect among all indicators of rooting performance which suggests that blocking was unnecessary and that a ‘simple randomized design’ was adequate.

Intra-provenance variability

Imputation of within-treatment variability values entirely to

Table 2. The relative importance of statistical variation among various rooting characteristics expressed in percentage (N = 100).

Rooting characteristic source of variation	Rooting depth	Rooting percentage	Number of roots
Block	7	12	7
Treatments (provenances)	33	20	15
Error	60	68	78
S.E.	0.535	0.038	0.217

Table 3. Intra provenance variability among provenances in relation to rooting characteristics. Rooting percentage is expressed in terms of survived leafy cuttings per vine (N = 100).

Rooting characteristic Source of variation	Rooting depth	Number of roots	Rooting percentage
Matoh	888	252.48	0.43
Mbonge	968.32	359	0.52
Tombel	1114.68	260.7	0.14
Kumba	332.19	173.31	0.52
Mamfe	181.62	72.76	0.26

Table 4. Mean values indicated by various provenances in relation to rooting characteristics. Means followed by the same letter are not significantly different by post-hoc test at $p< 0.05$ significance level. Rooting percentage is expressed in terms of survived leafy cuttings per block (N = 100).

Rooting characteristic/provenance	Rooting depth	Rooting percentage	Number of roots per cutting
Matoh	6.30 a	0.52 a	3.00 a
Mbonge	5.63 ab	0.47 a	2.81 a
Tombel	4.79 abc	0.43 a	2.60 a
Kumba	4.34 bcd	0.53 a	2.56 a
Mamfe	3.43 cd	0.44 a	2.80 a
S.E.	0.535	0.038	0.217

Table 5. Pearson's correlation coefficients among various rooting characteristics significantly but weakly correlated at $p < 0.05$. Rooting percentage is expressed in terms of survived leafy cuttings per vine (N = 100).

	Rooting percentage	Number of roots
Rooting depth	0.32	0.43
Number of roots	0.1	1

intra-provenance variation was based on the assumption that experimental error recorded during sampling and experimentation was negligible. To some extent, this variability may reflect local distribution or relative proportion of representation of the two *Gnetum* species in the various provenances. Increasing the size of the experiment by inclusion of additional treatments (provenances) can improve the accuracy of the experiment (Cochran and Cox, 1957). This might enhance prospects for producing significant results in terms of number of roots and survival rates among provenances.

Intercorrelations among rooting parameters

The root length increases are moderately associated with the number of roots generated per cutting ($r = 0.43$, $p < 0.05$, Table 5). While this relationship appears to be functional, it might also reflect a non-uniform distributional pattern exhibited by lateral roots along the entire root length of sprouts. Very often, lateral roots tend to cluster around the distal end of the main root. Implicitly, root length increases with the proliferation of lateral roots which are neither strongly linear nor influence their spatial allocation along the main root.

The percentage of leafy cuttings (generated per vine) surviving during the rooting phase of vegetative propagation is virtually independent of the average number of roots produced by survived cuttings ($r = 0.1$, $p < 0.05$, Table 5) and only weakly dependent on average root length ($r = 0.32$, $p < 0.05$, Table 5). This may imply that root elongation is a more important factor in explaining sprout survival than number of roots. By contrast, the proportion of leafy stem cuttings rooting and root number per cutting, increased as a function of leaf area with no rooting recorded in completely defoliated cuttings (Shiembo et al., 1996).

Interpreting the existence of disparities in root length recorded among provenances of *Gnetum spp.*

The significant relationship established between survival rate of cuttings and leaf area, underlines the role of leaves in inducing rooting in *Gnetum spp.* mediated by endogenous hormones (Horgan, 1984) in conjunction with carefully controlled environmental conditions (light, temperature, humidity). Even so, the allocation of foliar surface area accompanying foliar trimming of leafy cuttings, which intend mainly to minimize evapotranspiration during vegetative propagation, is random and therefore, of no consequence to the resulting differences in root length observed among provenances. Rather, once roots are formed, root elongation appears to be correlated with light increases, inferring from results obtained elsewhere with jack pine seedlings (Noland et al., 1997).

Hence, the significant differences in root length that discerned among cuttings of diverse origin, under green house conditions prevailing in the propagator, may be symptomatic of (I) differing capabilities and rates of capturing and utilizing light for photosynthesis and (II) varying amounts of the resulting assimilated carbohydrates available for translocation to the roots ultimately serving in root development. Both phenomena are probably behavioral adjustments in response to their physiological needs (Cheng et al., 2005) under induced environmental conditions.

Implications for germplasm selection

Whatever indicator is used (e.g. root length, rooting percentage), the origin of planting material is not an obvious criterion for genetic selection in relation to the rooting phase of vegetative propagation, considering the relatively small values attributed to inter-provenance variability (Table 2).

To the extent that the surface area of contact between the roots and the soil commensurate with the amount of absorbed raw material and their transportation to the leaves (Loveless, 1983), root elongation may be an important consideration in the photosynthetic process. The intensity of the photosynthetic activity determines leaf biomass accumulation, the ultimate goal in *Gnetum* domestication. Yet, the scope for implementing root length as a gauge for clonal selection in terms of high biomass yield, may be limited by several factors, among which is the fact that only a portion of the entire root system lends itself to intense assimilation of raw materials (Kolet and Kozinika, 1992). Besides, root elongation could serve as a measure of the extent to which a plant is firmly anchored in the soil flowing from the correlation between average root length and survival rate per vine accruing from vegetative propagation (Table 5).

Conclusion

The conclusion reached by this study is predicated on data provided by the rooting phase of vegetative propagation. Pending investigation to elucidate the role of rooting behaviour on leaf growth, genetic screening applicable to newly formed rooted cuttings should be limited to clonal selection on the basis of vine quality (fast growth and robustness) regardless of plant origin. Moreover, clonal selection has speed advantage over more traditional methods of tree improvement based on provenance selection (Leakey et al., 1993). However, root length is an important predictor of sprout survival, an important attribute in domestication. The relative importance of other root parameters or forms of architecture (e.g. diameter of root collar, rooting intensity in relation to mycorrhizal infection, root weight) as determinants of plant robustness or other traits have to be taken into consideration when devising a viable genetic selection scheme for *Gnetum* sprouts.
Whatever the case, selection would ensure that:

1. Investment on future growth should be directed towards robust or fast-growing sprouts, thereby guaranteeing a measure of cost-effectiveness for the domestication of the species amidst of scarce resources.

2. The widest possible range of genetic variability in terms of interesting characteristics can be salvaged from the wild and set aside in gene banks to serve as source of germplasm for future domestication (Allaby, 1998).
3. There is an increase in the production and marketability of the species by improving the yield and quality of products that are derived from them (Leakey et al., 1993).

RECOMMENDATIONS

There is need to experiment with best rooted clones on farmers' fields with a view to perform an economic analysis on the ensuing *Gnetum* domestication and hence come up with recommendations to farmers. This could facilitate farmers' rapid adoption and accelerate the domestication process which is really lagging behind in Central Africa.

Also, it would be interesting to ascertain the role of rooting depth in root development, sprouting success/ survival and leaf biomass yield in a separate experiment. Potentially, this might lead to recommendations on optimum planting depths in terms of maximizing survival rates and leaf biomass yields for *Gnetum* spp.

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