National Agency for Science and Engineering Infrastructure (NASENI) Call for Proposals (2025)

Project Title

Expanding cocoa production and productivity in Nigeria through enhancement of drought-tolerance planting materials with rootstock genotypes

Submitted by

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Executive Summary

Climate change has brought about a condition where drought has become a major environmental constraint affecting growth and production of cocoa in Nigeria and worldwide. However, it has been established that cocoa species or cultivars showed viability in their abilities to tolerate drought (Hadley, 1994) and generally differ morphologically and physiologically with a varied mechanism for survival and growth under limited water supply (Pinheiro *et al*., 2005). Rigorous experiments have been done in Nigeria to screen some cocoa species/cultivars for their abilities to perform effectively as either rootstocks and/or scions and evaluate all the possible effects such rootstocks would have on their scions (Ayegboyin, 2012). The identified drought-tolerant cocoa species/cultivars will be grated upon each other as rootstocks and scions to boost their abilities to withstand water stress and tolerant drought for the expansion of cocoa production to some marginal cocoa climates in Nigeria and as well improve cocoa tree productivity in the ideal cocoa environments in the 14 cocoa producing states of the country.

Background information

Cocoa is one of the most important perennial crops in the world. In some countries of Latin America, the crop is called cacao while their fruits and beans are called cocoa. However, in all West African countries including Nigeria, the trees, their fruits and their beans are called cocoa (Are and Gwynne-Jones, 1974). Cocoa is an under-storey tree species native to the lowland rainforest of the Amazon basin (Bartley, 2005) but currently its largest area of production is West Africa (FAO, 2011). Historically, the increase in demand brought about by the affordability of chocolate and other cocoa beverages required more cocoa to be cultivated (Lachenaud *et al*., 2007). This orchestrated the expansion of cocoa to other part of the world and eventual introduction of Amelonado cocoa from Brazil (Bahia) to West Africa, precisely into Principe in 1822, Sao Tomé in 1830 and Fernando Po, now in Equatorial Guinea, in 1854 where it was brought to Nigeria in 1874 and then to Ghana in 1879 (FAO, 2011). However, the earliest records showed that in 1847, Chief Squiss Ibaningo, planted some cocoa beans in the present day Rivers State of Nigeria, which he had obtained from Fernando Po (Are and Gwynne-Jones, 1974). Furthermore, records indicates the presence of other cocoa plantations established by the Christian missions and ran by the Coker family in Nigeria, even before 1874 (FAO, 2011). On the other hand, after previous attempts by the Dutch (1815) and the Swiss (1843) to introduce cocoa in Ghana had failed, Tetteh Quarshie and/or his apprentice Adjah, planted some cocoa seeds brought from Fernando Po in Ghana while in Cameroon, cocoa was introduced during the colonial period of 1925 to 1939 (FAO, 2011). It is unfortunate that though cocoa was introduced to Nigeria before Ghana,

Cameroun and Cote d'Ivoire, cocoa beans production is much any of these countries than in Nigeria!

Expansion of cocoa production began in Nigeria when more people went into cocoa cultivation. This later induced the interest of a company called Royal Niger Company into the establishment of some cocoa plantations at Asaba (now in Delta State of Nigeria) and by riverside locations in the vicinity of Onitsha (Anambra State) between 1888 and 1899 (Are and Gwynne-Jones, 1974). However, the earliest plantations were outside the present cocoa producing areas of Nigeria because most of the ventures failed due to a lack of understanding of the techniques for cocoa production and this killed the interest of the people around the area. As at present, cocoa is grown by 14 out of the 36 states in the country but there is a great potential for expansion to more states especially with the breeding of drought tolerant genotypes which could thrive in a lot of areas already identified as 'cocoa marginal area' in the country.

In Nigeria, production of cocoa is mainly in the hands of small farm holders, with farmers mostly using family labour (Aikpokpodion *et al.,* 2009), sometimes with most operations being performed manually (Are and Gwynne-Jones, 1974). While the economic life of cocoa tree is around 50 years on best cocoa soils (Are and Gwynne-Jones, 1974), its productive life depends on factors including establishment techniques, level of maintenance of the farm, disease/pest incidence and control as well as soil fertility (Wood, 1985). A cocoa farm can be said to be successfully established when the trees have formed an integrated closed canopy of leaves, which is unlikely to be adversely affected by the ensuing dry season (Atanda, 1975, Hadley, 1994). Thus the factors that would determine the establishment ability of a cocoa cultivar will not only be varietal but also environmental (Ayegboyin, 2012). Survival of cocoa after two years of planting, especially when the tree carries at least ten well-developed leaves is regarded as an acceptable criterion for assessing the establishment ability of a cocoa, at least, under Nigeria's conditions (Ayegboyin, 2012).

Breeding strategies in cocoa in Nigeria

Breeding of modern hybrid or varieties in cocoa started in Trinidad with the initiation of its research programme at the former Imperial College of Tropical Agriculture (Toxopeus, 1985) with the selection of some Trinitario populations to search for resistant cocoa trees to Witches broom disease in Trinidad around 1930 (Eskes and Lanaud, 2001). The result of the work was less successful since only a very few resistant trees could be identified, yet it revealed that hybrid vigour could be produced when Forastero is crossed with the 'local clones' in Trinidad as well as the identification of some higher-yielding clonal varieties still in use today (Eskes and Lanaud, 2001). The early objectives of breeding were

mainly to improve yield, disease and pest resistance or tolerance and the quality of cocoa produced (Atanda, 1975, Toxopaus,1985).

Many reports of an increase in cocoa production over the years has been due to a greater area being used for production rather than increases in cocoa tree productivity. In West Africa, cocoa breeding has largely depended on the selection of crosses between genetically unrelated parental clones which are being distributed to scientists/farmers for decades and represent about 35% of total cocoa acreage worldwide (Paulin and Eskes, 1995, Eskes and Lanaud, 2001)**.** Later, a further step was taken by crossing local selections from different countries and in Nigeria, a local selection 'N38' was crossed with selections derived from open-pollinated ICS parents (Toxopues, 1985). These crosses propelled the establishment of the first cocoa seed garden in Nigeria around mid-1950s.

Rootstock and drought-tolerance in cocoa

Combining two or more (in case of interstocks) different plants (genotypes) into one plant by grafting (one part producing the top and the other part the root system) usually produce growth patterns that are different from those that would have occurred if each component parts had been grown separately some genetic information are transmitted between the graft partners of the composite plant (Ohta, 1991; Hartmann *et al*., 2002). Such rootstock effects on tree vigour has long been recognised in Sweet cherry (Heuser, 1984), Citrus (Bitters, 1961), Pear (Gardner and Horanic, 1963) and many other species (Hartmann *et al*., 2002, Gardner and Horanic, 1963). For instance, the capsaicin level, which influences the 'hotness' of Chilli peppers (*Capsicum annum)* was altered by rootstocks (Yagishita *et al*., 1985) while Cucumber *(Cucumis sativus)* scions grafted on Fig leaf gourd rootstocks *(Cucurbita ficifolia)* produced much lower root-temperature resistance when compared with its own-rooted plants (Ahn *et al*., 1999). For many kinds of plants, rootstocks are used to enhance the tolerability of plants for the unfavourable soil conditions (Correia *et al*., 2010) and in the South-Eastern United States, where high temperatures and periodic flooding of soils are the norms, cultivars of Birtch (*Betula*), fir (*Abies*) and Oak (*Quercus*) are usually grafted onto rootstocks that tolerate these atmospheric and edaphic environments (Raulson, 1995). Rootstocks have been used to propagate scions of preferred cultivars, improve tree tolerance to environmental stress and control tree size (Webster, 2001). In Cocoa, Research has shown that rootstocks have some significant physiological effects on the scions that affect the rate of water movement (Reyes *et al*., 2002), nutrient absorption and translocation (Olmstead *et al*., 2006), which invariably determine the productivity of the scions (Fassio *et al*., 2009).

Specifically, rootstocks have boosted the drought tolerance ability of some scions of Pistachio (*Pistacia vera*) (Gijón et al., 2010), Kiwifruit (*Actinidia* spp) (Clearwater *et al*., 2007), Grapevine (*Vitis vinifera*) (Koundouras *et al*., 2008) and Citrus (*Citrus* spp) (Mass, 1990). Rootstocks also influence net photosynthesis and growth characteristics of scion of *Prunus* species grown under drought (Ranney *et al*., 1991) while better tolerance to flooding is found in selected rootstocks of *Prunus* (Ranney and Birr, 1994) and Fir (*Abies*) probably due to physiological and/or morphological mechanisms (Drew and Stolzy, 1996) that allow these selected rootstocks to handle anaerobic conditions better than the others. In Cocoa, the water relations, photosynthesis and size control had been mainly influenced by their rootstock genotypes in Nigeria (Ayegboyin, 2012).

Justification of the Project

The goal of this project is to increase the production and productivity of cocoa through the use of identified drought tolerant cocoa genotypes.

Expected outputs

- Boost the survival and growth of cocoa in the prevailing climate change through the use of rootstocks in Nigeria
- Identify more cocoa clonal materials that could be best used as either rootstocks and/or scions for drought-tolerance.
- Increase cocoa production to some marginal cocoa areas in Nigeria.
- Improve cocoa trees productivity through the use of rootstocks across ideal and marginal growing environments.
- Develop a cocoa drought-tolerant germplasm in Nigeria

Materials and Methods

There were prior experience to guide on the selection of the cocoa materials that have potential for drought tolerance in Nigeria. For instance, the joint PhD research project sponsored by Ministry of Agriculture (NLV), Netherlands, International Institute of Tropical Agriculture (IITA), Ibadan, University of Reading, United Kingdom, Cocoa Research Institute of Ghana, Tafo and Cocoa Research Institute of Nigeria, Ibadan had identified some of the rootstocks as well as the scions to be used in the drought tolerance establishment of cocoa in Nigeria (Ayegboyin, 2012) with a few pictorial evidences shown in plates 1 and 2 below.

Plate 1: 18-month old cocoa composite trees grafted on rootstock in Owena

Plate 2: 18-month old cocoa composite trees grafted on rootstock in Ibadan

The present work will expand the scope of the project beyond Oyo and Ondo States and target all cocoa producing states using drought-tolerant cocoa genotypes already identified in Nigeria.

I. Hand Pollination of Cocoa

Hand pollination of intra-population crosses of identified drought-tolerant cocoa varieties to be used for the production of rootstocks will be carried out while fertilizing of the cocoa trees to be used as scion materials will commence. Thirteen cocoa genotypes will be used. There will be nine scions materials as follows: AMAZ 15, SCA 6, SCA 9, SCA 12, UF 676, SPEC 54, MAN 15, IMC 47, ICS 95, N 38 and MAN 15/2 while the three rootstocks materials will be N 38 * N 38, PA 7 * PA 150 and NA 32 * N32.

II. Seedlings Production, Profiling and Budding

Seedlings for rootstock would be mass produced for 6 months in the CRIN Central Nursery while cocoa profiling will be carried out in the greenhouse. Sample of all materials to be used as the rootstocks and/or scions will be extensively re-evaluated for their drought tolerant traits under a controlled

environment in the greenhouse at different water regimes. Measurement will be evaluated on their morphological, anatomical and gas exchange characteristics as described by Ayegboyin (2012). Patch budding of the identified cocoa drought tolerant scions will be effected on their identified cocoa drought-tolerant rootstocks to form different composite cocoa genotypes which will be released for field evaluation across selected cocoa growing states.

III. Field Appraisal of Drought Tolerant Cocoa Genotypes

The drought tolerant cocoa genotypes will be established at Cocoa Research Institute of Nigeria (CRIN) headquarters in Ibadan and all states where CRIN substations are located (Ondo, Edo, Abia, Kogi, Taraba and Cross River states) as well as Osun, Ekiti, Ogun and Delta States.

IV. Parameters to be tested on Cocoa

A. Morphological/Agronomical parameters

For field evaluation, collection of data will be based on either the detachment of the leaves from the plants before sampling (destructive sampling) or measurement of the leaves in-situ, directly on the plants without any detachment (non-destructive sampling). While measurement of plant height, stem diameter, numbers of leaves as well as number of branches will be determined non-destructively, the leaf area will be done destructively within 24 hours of plant detachment. For greenhouse trial, leaf area will be determined the same way as for the field experiment during the growing period of the seedlings but at the harvests, the total leaf area of each of these seedlings will be determined. There will be two harvests for the greenhouse seedlings and all leaf areas determination will be done with an AM300 Portable Leaf Area Machine (ADC Bio Scientific Ltd).

B. Collection of Gas exchange parameters with Portable Infra-Red Gas Analyser

A portable infra-red gas analyser (ADC Bio Scientific, United Kingdom) will be used to measure the photosynthetic rate, stomatal conductance, transpiration conductance and water use efficiency and other gas exchange characteristics as demonstrated by Ayegboyin in Plate 3. The leaf for measurements on each plant will be between the 2^{nd} and 4^{th} fully expanded leaf on a given sun-exposed flush. Data will be collected between 12:00 pm and 3:30 pm during each sampling day in order to obtain an accurate indication of cocoa response to environmental stress (Medrano H. *et al*., 2003). Gas exchange characteristics of the cocoa plants in all the fields as well as greenhouse will be determined. While the plants will be sampled *in-situ* for the field experiments, seedlings in the greenhouse experiment will be tested when there is $\geq 300 \mu mol\ m^{-2}s^{-1}$ of sunshine in order to obtain an optimum

performance of the cocoa plants. The water use efficiency of all genotypes/clones will be calculated.

Plate 3: Gas exchange determination with IRGA machine on the budded plant by Ayegboyin

C. Cuticular transpiration determination (Laboratory)

The 2nd or 3rd apical leaf with its petiole will be detached from the plants and immediately covered with black polythene nylon. Then the samples will be taken to the laboratory where their fresh weights would be determined with a top loading Analytical Balance 210g x 0.0001gm 50Hz/1pa after their petioles must have been re-cut inside clean water. The petioles of the leaves will be immediately dipped into distilled water, cover with black nylon and be allowed to hydrate overnight at room temperature. After about 22-23 hours, the leaves will be removed from the water, mop of any moisture molecules on them and be weighed again to determine their turgid weights. The samples will be placed in a Gallenkamp Cooled Illuminated Incubator 0-50^{0}C/50Hz/1PH 80L capacity at 25^{0}C for 8 hours and leaves weights will be recorded at 30minutes interval. New weights will be subtracted from the previous to get the amount of moisture loss per leaf in 30 minutes. Other determination will be completed based on Ayegboyin (2012).

D. Relative Water Content measurement (Laboratory)

Leaves of approximately the same physiological age will be detached from the plants, mop of any moisture molecules and immediately will be covered with black polythene nylon bags. The leaves will be taken to the laboratory where 15 discs of 1.5cm diameter each will be punched out from every sampled leaf. Leaf discs will be immediately transferred into tagged covered petri dishes and be weighed to determine their fresh weight (FW). About 40ml of distilled water will

be added to leaf discs in each petri-dish, be covered and left to float for 24hrs at room temperature to allow then reach full turgor. Leaf discs will be extracted and the water be removed from the petri dishes. Both the leaf discs as well as the petri dishes will be dried of surface water using filter papers to adequately mop them up. The leaf discs will be returned into the petri dishes and be re-weighed for their turgid weight (TW). Subsequently, the discs will be transferred into clean brown envelopes before being dried in the oven at 65^0C for 3hrs. The dried leaf discs will be returned into the petri dishes and finally be weighed again to determine their dry weights (DW). The relative water content (RWC) of each cocoa plant will then be calculated using the method of Ayegbyin (2012).

E. Stomata counts determination (Greenhouse and Field evaluations)

Stomata count of cocoa will be determined and slides be prepared using the methods described by Ayegboyin 2012 and be read as below:

1. The prepared slides will be observed under an *Axioscope* 2 microscope with an *Axiocam* camera attached (*Carl Zeiss*, Jena, Germany) at 40X magnification. Image will be saved from 3 different fields for each slide and then be transferred into computer.
2. The number of stomata openings in the JPEG image will be counted with the aid of ImageJ (Java-based image processing programme) as shown in Plates 4, 5 and 6 of the previous Ayegboyin 2012.

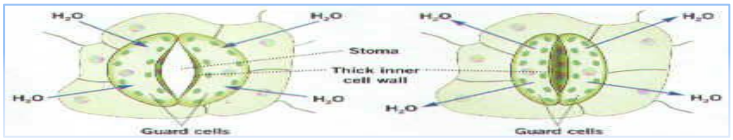

Plate 4: A cocoa stomata when opened (left) and closed (right)

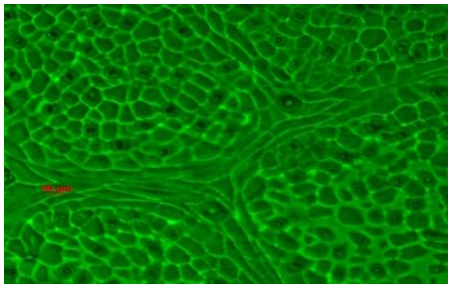

Plate 5: Cocoa leaf structure with most of its stomata closed (Ref: Ayegboyin, 2012)

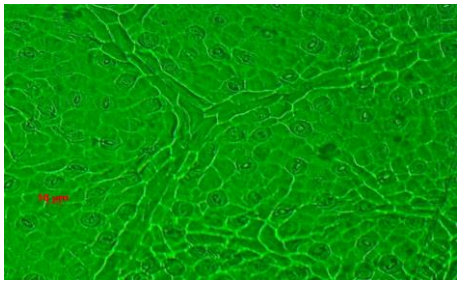

Plate 6: Cocoa leaf structure with most of its stomata opened (Ref: Ayegboyin, 2012)

Conclusion

The project will establish drought tolerant germplasm directly in Ibadan and each of the CRIN substations in Ondo, Edo, Kogi, Abia, Cross River and Taraba States. It will provide farmers with a sustainable drought tolerant cocoa for improving cocoa production, productivity and export competitiveness in Nigeria.

Budget: The budget outline is presented in Table 1.

Table 1. Budget Outline for the Project

S/No	Materials, Equipment and Activities	Amount (₦)
1.	Cocoa Pollination	10,000,000
2.	Seedlings Production and Budding	18,000,000
3.	Greenhouse trials	20,000,000
4.	Laboratory Consumables and Reagents	5,000,000
5.	Laboratory Equipment	10,000,000
6.	Field trials Equipment	20,000,000
7.	Field Establishment (Materials and Activities)	35,000,000
8.	Project Management and office supplies	5,000,000
9.	Capacity Building and Extension	10,000,000
10	Local travels (Research Officers and others)	35,000,000
11.	Transportation of materials to sites	40,000,000
12.	Project Monitoring and Report Writing	10,000,000
13	Total Cost	218,000,000
14.	Contingency (10% of total costs)	21,800,000
	GRAND TOTAL	239,800,000

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