DISTRIBUTION, PROPAGATION AND SEEDLING GROWTH OF *Pentaclethra macrophylla* Benth. AND ITS ALLELOPATHIC EFFECTS ON MAIZE AND OKRA IN SOUTHEASTERN NIGERIA

BY

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ABSTRACT

Pentaclethra macrophylla (PM) is an indigenous leguminous tree whose seeds are used as spices in Nigeria. Declining population of PM in the wild and its low domestication has limited its use. The PM occurs in agroforestry and could influence growth of crops such as maize and okra. Previous studies focused on the PM food values, with limited information about its distribution, domestication and allelopathy. Therefore, PM distribution, propagation, seedling growth and allelopathic effects on maize and okra were investigated in Southeastern Nigeria.

Floristic survey of PM relative to other trees was conducted in Abia, Ebonyi and Imo States where PM is predominant. Using sampling proportionate to size, one-third of Agricultural Development Programme blocks in Abia (13), Ebonyi (4) and Imo (8) were randomly selected. A 10,000 m^2 plot was mapped out on each of three farms and fallows in each block (totaling 150 plots). Tree species growing within each plot were enumerated to determine Relative Importance Value-RIV (%). Stem Girth-SG (cm) of PM at breast height was measured. Seeds of PM (n=200), sourced from wild, were mechanically scarified and soaked in water (27°C) for 0 (control), 6, 12, 24 hours and assessed at 7 Weeks After Sowing (WAS) for germination. Seedling growth of PM on low nutrient 35 kg-pots soils (alluvium, Ferruginous Sandstones (FS) and sandstones) and Nursery Medium (NM) was evaluated for 24 weeks. Dry Weight-DW (g) and Number of Root Nodules (NRN) were determined using standard procedure. Seeds (2/pot) of maize and okra were sown in 12 kg-pots in screenhouse. At 2 WAS, PM Aqueous Leaf Extracts (ALE) at 0 (control), 10, 20, 40 and 80% were applied to the seedlings to evaluate allelopathy. Plant Height-PH (cm) and DW were assessed at 8 WAS. All experiments were laid out in completely randomised design with four replicates. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

The RIV of PM in farms was 10.6(Imo)>7.4(Ebonyi)>4.4(Abia), while on fallows it was 10.6(Imo)>8.7(Abia)>6.0(Ebonyi). *Elaeis guineensis* and *Encephalartos barteri* had highest and lowest RIV in Imo (33.7; 0.0)>Abia (31.6; 0.4)>Ebonyi (22.1; 0.0), respectively. *Pentaclethra macrophylla* stands with SG>150, 50-150 and <50 constituted 9.0, 50.0 and 41.0% of its population, respectively. Germination of seeds at control (76.0±16.7%), 6-h (84.0±16.7%) and 12-h (88.0±26.8%) were similar and significantly higher than 24-h (40.0±17.9%). The DW on

alluvium (10.8±2.0), FS (12.6±2.0) and sandstones (11.0±1.1) were similar but significantly higher than NM (8.4±1.3). The NRN on sandstones (17.0±3.4) and FS (21.0±7.8) were similar and significantly higher than alluvium (4.0±1.7) and NM (3.0±2.5). The PH of maize and okra seedlings ranged from 68.9±20.0 and 34.1±14.6 in control to 94.9±18.2 and 52.3±10.9 in 40%-ALE, respectively. Their DW ranged from 6.3±2.5 and 1.2±0.5 in control to 18.6±1.5 and 2.5±1.8 in 40%-ALE, respectively.

Pentaclethra macrophylla population was prevalent in Imo State. Scarification and soaking for 12 hours enhanced seed germination. Sandstone and ferruginous sandstone soils stimulated seedling growth and nodulation. Aqueous leaf extract of *Pentaclethra macrophylla* at 40% encouraged dry matter accumulation and plant height in maize and okra seedlings.

Keywords: *Pentaclethra macrophylla*, Indigenous leguminous tree, Floristic survey, Relative importance value

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DEDICATION

This research report is sincerely dedicated to JEHOVAH in whom I live and move and have my being.

CERTIFICATION

I certify that this work was carried out by Mr. Justin Ugochukwu Ogbu in the Department of Crop Protection and Environmental Biology, University of Ibadan

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INTRODUCTION

Over the years of human existence on earth, Plant Genetic Resources (PGR) had constituted the basis of development and sustainability of agricultural production systems. Humans have used close to 7,000 identified plant species in agriculture for food and fodder after 10,000 years of sedentary agriculture and the discovery of about 75,000 varieties of edible plants (Dhillon and Saxena, 2003; French, 2016). However, less than two percent of these are recognized as economically relevant at regional, national or global levels (FAO, 1996). Currently, only 30 cultivated plant species provide 90% of all the human food obtained from vegetations, while 12 plant and 14 animal species combined contribute 70% of the global human food needs (van den Bosch, 2010; Arora, 2014). Specifically, rice, wheat and maize constitute the staple food for two third of the world population (Jaramillo *et al*., 2011). According to CTA report on global agrobiodiversity, 75% of all known crops have disappeared in the past century (van den Bosch, 2010). On the other hand, the FAO has projected that unless the spiral loss of genetic diversity is slowed down, up to 60,000 plant species (quarter of the world plant capital) risked been lost by 2025 (WCMC, 2002; FAO, 2015).

Among the botanical families significant to humans is the Fabaceae, the legume group. The Fabaceae (Leguminosae) is the third largest family of angiosperms after Orchidaceae (orchids) and Asteraceae, and second only to Poaceae (grasses) in terms of agricultural and economic importance (ILDIS, 2006; FAO, 2016). With reference to the Magnoliopsida (Dicotyledonae) the legume group is the most important in terms of diverse economic values. Legumes have an array of domesticated species harvested as crops for food, feed, fiber, fuel, fertilizers, medicine, oils, timbers, chemicals and floriculture varieties (Lewis *et al*., 2005; Wojciechowski, 2006).

Legumes vary in growth habit and they include herbs, shrubs, trees, vines, and even a few aquatics. Also, they vary in life cycle including annuals and perennials. They

range in size from some of the smallest plants of deserts and arctic/alpine regions to the tallest of rainforest trees. Legumes are a conspicuous and often dominant component of most of the vegetation types distributed throughout temperate and tropical regions of the world. Legumes are particularly diverse in tropical forests and temperate shrub lands with a seasonally dry or arid climate (ILDIS, 2006). This preference for semi-arid to arid habitats is related to a nitrogen demanding metabolism (Sprent, 2001; Adams *et al*., 2010). Many species have the ability to colonize barren and marginal lands because of their ability to fix atmospheric nitrogen through a symbiotic association with root-nodulating bacteria. There are many leguminous trees of agronomic, horticultural and silvicultural significance, especially among the subfamilies Caesalpinioideae and Mimosoideae, with few from the Papilionoideae (Keay, 1989; Sprent, 1995; ILDIS, 2006; Wojciechowski *et al*., 2006; Adams *et al*., 2010).

Pentaclethra macrophylla Benth., commonly known as African oil bean, is a multipurpose indigenous fruit and potentially oil tree of the legume group. According to Angiosperm Phylogeny Group III (2009) - APG III system, the species belongs to sub-family Mimosoideae; family Fabaceae and order Fabales. It grows up to 35 m high and 100 cm in girth (Oboh, 2007; Agroforestry Tree database, 2011). The tree is found geographically distributed across the forest zone of West and Central Africa sub-regions, and on the islands of Sao Tome and Principe. This multipurpose tree is often protected as volunteer stand or occasionally planted on the fringe of compound farms mainly for its edible seeds and its constituent edible oil which can be extracted for various domestic uses, although it is still largely under-exploited by the industries. Seeds of African oil bean are processed into a local salad known as 'ugba' – a traditional food delicacy that is very popular and relished among the people of southeastern states of Nigeria (Okigbo, 1980; Okeke *et al*., 2009). It is also a major component of traditional agroforestry/homegarden system in the sub-region. Other products and services from the tree include supply of fuel wood from empty dry fruit pods, timber wood for carving of bowls and other household utensils, dyestuff obtained from burnt pods, seeds used as spices in soup, pot herbs and pottage preparations, medicine in traditional healing practices; application in soil fertility

management as nitrogen fixer, and as ornamental shade trees (Ladipo *et al*., 1993; Emebiri *et al*., 1995; Isu and Ofuya, 2000; Sprent, 2001; Onyeke and Acheru, 2002; Akindahunsi, 2004; Oboh and Ekperigin, 2004; Schrire *et al*., 2005; Ogbu *et al*., 2007).

Effective and significant use of *P. macrophylla* genetic resources has been hampered by paucity or near lack of definite tree improvement programme geared towards domestication of the species on farm and forest garden in the sub-region. As a result of deforestation, over-exploitation and conversion of land to mono-crop agriculture, the species population and its genetic resources are gradually depleting, and not much attempts have been made to reverse this trend. According to Plant Resources of Tropical Africa (PROTA) reports in Oboh (2007), the number of African oil bean tree stands has declined strongly in most areas of earlier distribution some four decades ago. With reference to Nigeria, stands are mostly confined to the states of south east and Niger delta regions as well as some in the southwest; and their regeneration rates were noted to be inadequate. The same report also revealed that no organized institutional collections of the species genetic resources exist. Hence deliberate tree improvement programme aimed at encouraging and enhancing domestication as well as conservation of the tree on farm was been advocated. Atu and Olowu (2005) identified African oil bean as one of the 'scarcely researched' useful fruit species of rainforest and derived savanna agroecological zones of Nigeria that is in dire need of research and development attentions.

Efficient development, promotion and utilization of the Indigenous Fruit Tree (IFT) species require the identification of the constraints to optimizing production, and implementation of solutions to overcome such challenges. Issues like paucity of quality planting materials, near lack of standardised propagation and production technology, and scarcity of relevant specific information have been identified as constraints to sustainable exploitation of the rich potentials of IFT genetic resources (Haq and Hughes, 2002; Akinnifesi *et al*., 2004; Jaenicke *et al*., 2006; Anon., 2008). With reference to African oil bean as a typical IFT species, not much domestication research and genetic resources assessment have been done, as the species is still considered underutilized, being faced by the common limiting factors of most IFT.

Crucial knowledge gap exists in the efforts toward tree improvement programme of the species. Although some research works had been done, they are more in the areas of phytochemical, food nutrient and processing studies of the plant's produce, when compared to its agronomy (Emebiri and Anyim, 1997; Isu and Ofuya, 2000; Onyeke and Acheru, 2002; Akindahunsi, 2004; Oboh and Ekperigin, 2004; Atu and Olowu, 2005; Grace *et al.*, 2008). Existing trees occur either as volunteer species protected by the landowners around the homegardens or surviving relics of wild population in community forests. As improved agrotechnique for the species multiplication and production is virtually unknown, regeneration and species survival rely mainly on slow pace natural re-seeding. Due to high economic value of the oily seeds, which are frequently harvested from the wild and protected stands, natural regeneration may not sustain the species' increasing demand. The seeds of *P. macrophylla* are known to be recalcitrant; storage at 15^{o}C can only improve longevity for about 3 months, beyond which the seeds loose viability (Emebiri *et al*., 1995). Thus, most seeds found in local markets are not likely to be viable for sowing. Even viable seeds, where available, exhibit dormancy tendency which ordinarily delays germination (Jaenicke, 1999; Verheij, 2004). These factors reduce seed setting and further compound the problem of natural regeneration of African oil bean. External factors like deforestation, over-exploitation and urbanization have also contributed negatively to the declining population of the species in southeastern Nigeria. The present research goal was formulated to contribute to *P. macrophylla* domestication, sustainable use and enhanced conservation of the species genetic resources, as well as promote interest in our indigenous plant research.

Therefore, the specific objectives of the research are to:

1. investigate the floristic distribution and ethnobotanical values of the African oil bean tree in Abia, Ebonyi and Imo States of Southeast Nigeria;

2. assess pre-sowing seed treatments effect on seed dormancy and seedling emergence of African oil bean;

3. evaluate the effect of phenology and rooting hormone on marcotting of *Pentaclethra macrophylla*;

4. assess the response of early seedling growth and root nodulation vigour of *Pentaclethra macrophylla* to soil media with contrasting fertility;
5. determine allelopathic potential of the African oil bean leaf extracts on seed germination and seedling growth of maize and okra

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CHAPTER TWO

LITERATURE REVIEW

2.1 The African oil bean (*Pentaclethra macrophylla* Benth.)

The oil bean tree (Plate 2.1) is among the three economic members of the genus *Pentaclethra* occurring naturally across the humid lowlands of central, east, southern and west sub-Saharan regions of the Africa continent. Similar species *Pentaclethra eetveldaena* De Wild. & T. Durand is found distributed in the wild as timber species mostly in central African sub-region, while *P. macroloba* (Willd.) Kuntze is native to South America (Ladipo and Boland, 1995; Grace *et al.,* 2008). The taxonomic grouping of *P. macrophylla* has been stated as follows according to the Angiosperm Phylogeny Group III (2009).

Kingdom - Planta

Phylum - Tracheophyta

Division - Magnoliophyta

Class - Magnoliopsida

Order - Fabales

Family - Fabaceae

Sub-family - Mimosoideae

Tribe - Parkieae

Genus - *Pentaclethra* Benth.

Species - *Pentaclethra macrophylla* Benth.

African oil bean is known by various vernacular names in West and Cental African sub-regions, *viz*: 'Ugba'/'Ukpaka', 'Nkpa' and 'Ukana' among the Igbo, Boki and Ibibio, respectively; 'Ukpakara' in Ijaw, 'Ukpaghan' in Itsekiri, 'Okpagha' in Edo; and

Plate 2.1. African oil bean (*Pentaclethra macrophylla* Benth.) tree situated in a cultivated farmland at Umuahia, Abia state Nigeria

‘Apara’ in Yoruba Nigeria; ‘Atawa’ or ‘Ataa bean’ in both Fula and Wolof (Okigbo, 1980; Keay, 1989; Emebiri and Anyim, 1997; Etukudo, 2000; Atu and Olowu, 2005).

Such linguistic records show remarkable antiquity of association of the species with various people of the forest belt in the sub-regions. The species is known to be endemic to the humid and some parts of sub-humid zones of West Africa. It is not known to thrive in high altitude locations above 500 m where temperatures may drop cooler than 18^{o}C. The annual range of temperature requirement is about 22 – 28^{o}C, and rainfall range between 1000 – 3500 mm (Agroforestry tree database, 2011). African oil bean natural distribution suggests that it is more adapted to relatively acid soils (Emebiri and Anyim, 1997; Oboh, 2007).

Although the tree can grow up to 35 m high, it has a peculiar low branching habit and an open crown which allows substantial light through its canopy. It is this property that accounts for the species regular inclusion in the traditional home garden farming system in south east Nigeria. The bole is usually crooked with low wide buttress. Straight-stemmed and less buttress trees are scarce in protected stands under cultivation. Bark is grayish to dark reddish brown, thin and patchy with irregular pieces flaking off. The leaves are characterized by stout angular petiole and compound bipinnate with 10–15 pairs of opposite pinnae (leaflets). The middle pairs are 7–13 cm long. Leaflets have rusty hairs along the central grove. There are usually 10–15 pairs of opposite sessile pinnules. Flowers are creamy-yellow or pinkish white and sweet scented. The whole inflorescence is finely velvety. Main flowering period is November – April (Oboh, 2007; Agroforestry tree database, 2011). Fruits are available at least most periods of the year due to the large woody pods that are persistent. The fruit, a pod, is brownish in colour and each measuring 30 – 45 cm long usually contains 4–8 flat glossy brown edible seeds (Keay, 1989; Ladipo and Boland, 1995). The seed is large sized with approximately 50 – 80 seeds per kg (Plate 2.2). The scarcity of the seeds for propagation may be attributed to its being edible. Proximate analysis of unfermented seed (per 100 g of the edible portion) is as follows: 2–10 g water, 557–607 kcal energy, 35–52 g fats, 12-13 g carbohydrate, 17–22 g protein and 2.5 g crude fibre (Oboh, 2007; Okeke *et al.*, 2009).

2.2 Economic importance of *Pentaclethra macrophylla* Benth.

I. For Vegetable oils production: The seed oil contents have been classified and catalogued as potential vegetable oil of both domestic and industrial values. Its fatty acid composition has been characterized thus: palmitic acid - 3-4%, stearic acid - 0-2%, arachidic acid - 4%, oleic acid - 19-29%, linoleic acid - 42-54%, lignoceric acid - 11-12%, linolenic acid - 0-3%, as well as certain long-chain fatty acids – octocosanoic acid - 1% and hexacosanoic acid - 5% (Oboh, 2007; Grace *et al*., 2008).

II. Food value: Seeds of oil bean tree are processed into high nutritional local food in many places where the species is distributed. In these places, seeds are eaten boiled or roasted. Among the Igbo and other neighbouring ethnic groups in Southern Nigeria, fermented grated seeds are further processed into a variety of highly proteinous local salads taking along with cassava flakes and other ingredients. Processed seeds are also used as condiment in certain traditional soup and potherb/pottage preparations (Isu and Ofuya, 2000; Okeke *et al*., 2009).

III. Traditional medicine: Many parts of the oil bean have been exploited in traditional healing system among various communities in areas of its ecological distribution. Crushed seeds, ashed leaves, leaf/stem bark, pod ashes, etc have been used in curing different ailments. For example, decoction of the barks are used in preparation of healing lotion for sores and as remedy for leprosy; bark and root are also used as laxative and as enema in the control of dysentery. The bark decoction is also used for its lactogenic effect and as liniment in the control of itching (Abbiw, 1990; Ladipo and Boland, 1995; Oboh, 2007; Agroforestry tree database, 2011).

IV. Environmental protection//beautification: *Pentaclethra macrophylla* is planted or protected as volunteer tree crop on the fringes of home gardens in southeastern Nigeria mainly for its edible seeds in addition to its environmental effect (Okigbo, 1980; Emebiri and Anyim, 1997). Leaves are shed during the dry season and farmers believed that these leaf droppings contribute to soil fertility within the garden. Farmers also protect the oil bean stand on farm because of its open crown architecture which does not adversely affect crops grown under its canopy. The trees were reported to

(i) 

(ii)   (iii)

Plate 2.2 Parts of African oil bean tree (*Pentaclethra macrophylla* Benth.): (i) Leaves, (ii) Inflorecence, (iii) pod and seeds

have been used to adorn major roads and control gully erosion menace in parts of Anambra and Imo States, Nigeria some decades ago (Ladipo and Boland, 1995; Emebiri and Anyim, 1997). In Niger Republic, the tree is used in road side tree planting (Nair, 2003; Agroforestry tree database, 2011). The low spreading canopy structure of African oil bean tree makes the species suitable for use as avenue tree and shade tree for ornamental planting in parks and gardens.

V. Sources of fuel wood and lumber for structural works: The wood of African oil bean tree is highly suitable for fuel wood and charcoal making. Remains of pod after seed dispersal are also gathered and used as fuel wood in households. Lumber of African oil bean tree is considered of high natural durability with up to 50 years longevity; hence it is much favoured for construction and carving works.

VI. Employment generation: The production and sales of various tangible produce (including seeds, fermented grated seeds, local salad made from processed seeds, wooden utensils among others) of commercial value derived from the oil bean tree have provided employment opportunity for a good number of people (especially youth, women and children) (Tsobeng *et al.*, 2013; Anyawu *et al*., 2016).

2.3 Conservation of Plant Genetic Resources

Plant Genetic Resources (PGR), as a vital segment of biodiversity in general and agrobiodiversity in particular, represents the genetic material of plants having value as a resource for present and future generation of human being (Ogbu *et al.*, 2010; FAO, 2015). The challenge of sustainable ecological and economic development is one of the most pressing issues that confront humans today; and diversity of biological resources provides the foundation block for that. Diversity rich ecosystems possess greater resilience and are able to recover and adapt more readily from natural calamities, and or human–induced habitat degradations. Plant biodiversity is the basis of sound development and sustainability of agricultural production systems (Dhillon and Saxena, 2003; Ogbu *et al*., 2010; FAO, 2015; Bailey, 2016). Reduction in the genetic diversity of crop represents an increase in vulnerability to new pests and diseases. The economic value of the reservoir of genetic traits present in wild varieties and traditionally grown landraces is very high for improving crop performance (The

National Academies, 2007; Jaramillo *et al*., 2011). As genetic resources, the PGR may be of reproductive or vegetative propagule such as seeds, roots, tissues, cells, pollens, DNA molecules, etc, containing the functional unit of heredity, in addition to corresponding information about their use. The categories of PGR range from landraces, farmers' varieties, modern improved cultivars, breeding lines and genetic stocks, wild relatives, weedy races, potential domesticate species, exotic as well as indigenous (LEISA, 2004; Ogbu *et al*., 2010; Ahuja and Ramawat, 2014).

The growing deterioration of natural and agricultural environments, and concerns for the loss of biodiversity, has resulted in rapid development of the discipline of Conservation biology. Thus, the WCMC (2002) explained conservation biology as the discipline that studies the use and management of biodiversity present in natural and cultivated ecosystems in order to guarantee their renewal, conservation and productivity, thereby providing benefits and opportunities for present and future generations. The main approaches used today in conservation biology include conservation strategies for undisturbed natural ecosystems, restoration strategies for disturbed ecosystems and sustainable use strategies (incorporating wild species domestication and re-introduction) for transformed ecosystems, which include agroecosystems (Awodoyin *et al*., 2015).

As earlier indicated, agrobiodiversity is currently threatened by the progressive loss of plant genetic diversity. This challenge has increased agriculture vulnerability and impoverished food provision for humans. The growing concern on genetic erosion has led to the establishment of germplasm conservation programmes worldwide. Such effort to save PGR is directed at cultivated, semi-domesticated and wild relative plant species (Jaramillo *et al.*, 2011; Bailey, 2016).

The major approaches to conservation of PGR are namely *ex situ* and *in situ*. Conservation outside native habitat is known as *ex situ* conservation, and it is particularly used to safeguard population of given PGR in danger of destruction, deteroration or replacement. Specimens of affected species are kept in centralized genebanks away from its origin. The various options available in *ex situ* conservation are arboretum, botanical gardens, DNA and pollen storage banks, field genebanks,

research centres and laboratories, seed storage banks as well as world heritage sites (Oldfield and Newton, 2012).

Maintenance of PGR in the natural habitat where they occur is known as *in situ* conservation. It could be in form of semi-cultivated and wild plant communities or crop cultivated varieties grown in farmer's fields as part of the local agroecosystems. *In situ* conservation of cultivated and useful wild plants mostly has to do with on-farm maintenance of agronomic and garden crops landraces (Rao, 2004). Its goal is to secure habitats of affected species so that some of its population can be sustained. Its objective includes allowing for multiple uses of the protected areas as well as enabling the system to preserve uncommon, endangered and threatened species. For such system, it is necessary to expand geographic distribution of target plant species and enhance the population structure; in addition to affecting the dynamics and genetic variability within and between its populations. Moreover, identification of threats to affected species in the wild and appropriate mitigation options including species recovery programmes need to be put in place (Rathore *et al.,* 2005; Awodoyin *et al*., 2015).

Stakeholders in PROTA reports identified conservation concerns for most of the 48 important vegetable oil species in tropical Africa, including *P. macrophylla* which has witnessed steady decline in the wild population due to various ecological threats (Grace *et al.,* 2008). The reports also recommended both *in situ* and *ex situ* conservation of the species in order to ensure sustainable harvesting of produce without threat to existing protected wild populations, and that the genetic resources are available for future use and development.

2.4 Tree domestication of underutilised Indigenous fruit species

Experts in agroecology, agroforestry, crop production and plant breeding have put forward various explanations of tree domestication (Simon, 1997; Altieri, 2000; Pauku, 2005; Akinnifesi *et al*., 2007). The salient point among the varied definitions is that domestication implies settling a species as a member of the homestead; or to naturalize such species. Therefore, tree domestication in this context is a human-driven change in the genetics of given tree species to conform to the agroecosystem and

people's needs (Jaramillo *et al*., 2011). Domestication of underutilized Indigenous Fruit Tree (IFT), by extention, involves human-induced accelerated procedure aimed at scaling up wider cultivation of target species through a market-led and or farmer-driven process(es). This procedure is iterative in nature which involves the identification, propagation, management and adoption of desirable tree germplasm (Dawson *et al*., 2012; Leakey *et al.*, 2010). Strategies for individual plant species vary depending on the peculiar biology, economic value and target environment. Generally, domestication process of any plant species involves selection, re-introduction and management by people, and is not necessarily about breeding, but certainly a component of the whole plant improvement. From IFT perspective, domestication therefore seeks to encourage cultivation of such species with identified agricultural potentials as economic crops. This will provide additional incentive to rural farmers to grow IFT with the potential of enhancing their revenue and guarantees more food production as well as nutritional security (Mithofer, 2005; Jaenicke and Henschie-Zeledon, 2006; Dawson *et al*., 2007).

Plan Tree improvement programme with defined domestication interventions for desirable plant traits has been advocated to sustain the time tested practice of *in situ* conservation and sustainable exploitation of IFT, including African oil bean, alongside the field crops (Emebiri and Anyim, 1997; O'Neil *et al.*, 2001; Jaenicke *et al.*, 2006; Grace *et al*., 2008). Considerable domestication research has been done in this regard on such similar IFT species like African star apple [*Gambeya albida* (G. Don) Aubrév. & Pellegr.], African pear [*Dacryodes edulis* (G. Don) H.J.Lam], Bush mango [*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.] and African breadfruit [*Treculia africana* Decne.] among others (Atangana *et al*., 2001; Kengue, 2002; Leakey *et al.*, 2002; Anegbeh *et al.*, 2003; Asaah *et al.*, 2003; Leakey *et al.*, 2005; Tabuna, 2007; Tchoundjeu *et al.*, 2010).

The prolonged gestation period of tree-based agriculture constitutes major impediment to some farmers in investing in planned cultivation of economic IFT species in their localities. Tree domestication through standardised vegetative (asexual) propagation protocol, however, can play vital role in ensuring that trees come into bearing at reasonably short duration. With this development, interested farmers/gardeners should

be able to have access to superior parent stocks for propagation and distribution, if they are to leverage on the economic potentials of such IFT cultivation as African oil bean (Jaenicke and Beniest, 2002).

Unlike African star apple (*Gambeya albida*), African pear (*Dacryodes edulis*), 'Ogbolo'/Bush mango (*Irvingia gabonensis*) and African breadfruit (*Treculia africana*) of our agroecological zone that have benefited from domestication intervention, a great deal of work is required to fully develop the propagation potentials of African oil bean (*Pentaclethra macrophylla*) genetic resources in Nigeria. Therefore, assessing factors that affect germination, seedlings production by natural seeding and vegetative technique would form vital steps toward successful domestication programme of African oil bean. In this study, the vegetative propagation technique of marcotting is considered for trials because of its versatility, adaptability and success rate recorded in other IFT improvement programme (Jaenicke and Beniest, 2002; Scrase, 2009; Tchoundjeu *et al.*, 2012).

2.5 Asexual propagation options in tree domestication

Asexual propagation (also known as regenerative or vegetative method) describes the regeneration and multiplication of plant kinds from vegetative parts, including buds, leaves, single cells/tissues as well as cuttings of roots and stems. It offers a wide array of applications in IFT domestication efforts and general PGR conservation programmes. With these applications, propagation experts are able select desired characters available in the wild tree population by fixating the genetic variation of such trees in the natural stands. Ultimately, the objective is to multiply large quantity of improved seedlings for interested farmers and other users (Tchoundjeu *et al.*, 1997: Verheij, 2004; Awodoyin *et al*., 2015).

The idea behind asexual propagation is that similar copy of genetic make up of mother plant is replicated almost indefinitely in the offsprings. Several reasons have been adduced to the possibility of this process in plants, namely; i, every living cell of plant has all the genetic information required to reproduce the whole plant (totipotency), ii, cell division in most plants persist during the normal growth and development processes, iii, cells possess capacity to reform a meristem, which divides and produces

any lacking part. Therefore, all offsprings produced by asexual propagation from a progenitor or initial stock plant are genetically identical (known as clones), except occasionally where chimeras (i.e. rare somatic mutations) happened and are perpetuated (Hartmann *et al*., 2007). Comparatively, sexual propagation (seeds) offers opportunity for variations, unlike vegetative propagation which seeks to mass produce identical plants with desirable agronomic, consumer and or market-demand attributes, and as such plays a very significant role in preserving a preferred plant trait (Dawson *et al.,* 2012).

Jaenicke and Beniest (2002) reported that the most viable vegetative propagation options for tree domestication programme are the regeneration by root or stem cuttings, budding/grafting, air-layering and micropropagation techniques. Induction of adventitious roots from stem cuttings is the commonest vegetative method used by gardeners and nursery managers. In stem cutting propagation, a section of plant shoot with axillary bud and nodal point is severed from the parent stock and placed then in highly humid environment. Few weeks after setting in the humid environment, root induction may start on the cutting leading to the production of independent plant from the stem section. Success with tree plants multiplication by stem cuttings is often high when propagules from young, vigorously growing and less lignified parts are used, such as seedlings or coppiced shoots (Chadha, 2009).

Budding and grafting are also popular techniques used to join portions of two or more plants to form a single plant and continue their growth as one plant. Both methods are used to preserved clones that may not be easily multiplied by similar regenerative propagation methods. The aim of grafting is to take advantage of given rootstock adaptation to introduce a selected variety used as scion. This is mostly applied in mass production of high value fruit trees and ornamental woody plants (Verheij, 2006; Hartmann *et al*., 2007).

Air layering, also known as marcotting, is an age long established method of vegetative propagation which still finds relevance in present day domestication, PGR conservation and routine plant multiplication efforts. Unlike in stem cuttings, the induction of adventitious roots on a stem is made possible while the stem remain

attached to the parent plant. The successful marcot stem is thereafter cut off to be independent plant growing from its own roots. The need of suitable/adapted rootstock does not arise in macotting, which gave it an edge over grafting. Since stem cuttings of full-grown tree experience hard to root tendency, marcotting therefore stands out as preferred option for vegetative propagation plan in domestication of IFT. Moreover, marcots are known to come into fruiting earlier than slower-growing stem cuttings or grafted trees, but possess a shallow root systems (Jaenicke and Beniest, 2002; Asaah *et al*., 2012; Awodoyin *et al*., 2015). Vegetative propagation techniques especially grafting, budding and marcotting, have also been used to achieve early fruiting and tree dwarfing. In addition, such dwarfing produces trees that are more compact at harvest, thus easying fruit collection (Akinnifesi *et al.*, 2009; Assah *et al.*, 2010).

This is exemplified in some already developed indigenous fruit trees of the sub - Saharan Africa. Among the reviewed IFT reports include: *Allablackia spp*. (Jamnadass *et al.*, 2011), Baobab [*Adansonia digitata* L.] (Askira, 2008; Jamnadass *et al.*, 2011), Bush mango [*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill. and *Irvingia wombolu* Vermoesen] (Tchoundjeu *et al.*, 2010; Nzekwe, 2002), African star apple [*Gambeya albida* (G. Don) Aubrév. & Pellegr. (syn. *Chrysophyllum albidum* G. Don)], African pear [*Dacryodis edulis* (G. Don) H.J.Lam] (Kengue, 2002; Asaah *et al*., 2010), African bread fruit [*Treculia africana* Decne.] (Nzekwe, 2004), Sheanut [*Vitellaria paradoxa* C.F. Gaertn.] (Sanou *et al*., 2004), and Wild loquat [*Uapaca kirkiana* Mull.Arg.] (Akinnifesi *et al*., 2009). Also, in Nigeria, Awodoyin and Olaniyan (2000) reported air-layering in guava [*Psidium guajava* L.]. The above mentioned reports indicated how vegetative propagation techniques, including grafting and layering, have been used to develop successful protocol for mass multiplication of some of the indigenous tree species for research and commercial purposes.

Micropropagation is a technique of vegetative propagation which utilizes totipotent potential of plants to reproduce whole new individuals from miniature living tissue or single cell through *in vitro* culture under aseptic and controlled environments. The application makes it possible to mass produce pathogen-free seedlings/propagules from limited quantity of stock plant materials. It must be noted that due to large investment in equipment, materials and infrastructure requirements of

micropropagation, its practice is mostly justified in cases of high premium or rare/endangered plants where other vegetative propagation options have proved unsuccessful (Hartmann *et al.*, 2007; Chadha, 2009; Ahuja and Ramawat, 2014).

Vegetative propagation applied in the conservation and domestication of IFT essentially offers viable opportunities for research, sustainable development and use of plant resources. The aims of vegetative propagation options are summariesd as follow: solving challenge of poor seed germination and storage behaviour, reducing gestation period of fruit bearing species, maintenance of superior genotype, uniformity of orchards/plantations, fixing desired attributes of two or more plant genotypes into one plant stand as well as controlling phases of tree development, among others (Leakey, 2000). Among the indigenous fruit species of sub-Saharan regions that have benefited in marked reduction of their gestation periods and subsequent early fruiting, through enhanced use of vegetative propagation include *Dacryodis edulis* from 5 - 2 years; *Adansonia digitata* from 10 - 4 years; *Irvingia gabonensis* and *I. wombolu* from 7 - 3 years; as well as *Vitellaria paradoxa* from 20 to below 5 years (Jaenicke and Beniest, 2002; Jamnadass *et al.*, 2011).

2.6 Germination, Seed dormancy and dormancy-breaking techniques

Rao *et al.* (2006) defined seed germination as resumption of growth of the quiescent embryo and emergence of radicle from its covering structures. During the process, seed imbibes water, seed coat is ruptured and there are occurrence of cell division and elongation. Reserve foods in the seed nourish the growing embryo until the leaves are able to carry out photosynthesis and the roots are able to absorb water and minerals for the young plant. The appearance of radicle marks the end of germination and the beginning of seedling development, a period that ends when the seedling has exhausted the food reserves in the seed. For seed testing protocol in genebank, germination is not complete until the seedling can be judged as normal, having essential structures – well-formed roots, shoots and sufficient food reserves. Under such condition, seedlings with defects are classified as abnormal (Hong and Ellis, 1996; Rao *et al.*, 2006).

Basic requirements for seed germination are water, oxygen, light and suitable are water, oxygen, light and suitable temperature. Seeds of different species have different requirements/duration, and no general set of conditions can be relied upon to germinate seeds of all species. Fresh seeds of many tropical trees germinate readily during 14 – day germination tests. However, seeds of other species require much longer time to germinate. Although fresh seeds may germinate readily, once dried they may experience difficulty in germination because of hardened and, at times impervious seed coat, or loose viability due to recalcitrant tendency. Difficulty in germination is often observed with seeds of *Fabaceae* (*Leguminosae*), *Malvaceae*, *Cannaceae*, *Rhamnaceae* and *Tiliaceae* (Hong and Ellis, 1996), whereas germination failure due to recalcitrance is common with oil seeds like soya bean, okro, bush mango, e.t.c. Unless the hardened seed coat is overcome, such seeds could be taken as dead seeds when it fails to germinate. Seeds of some species are more tolerant and germinate in a wide range of conditions but complete germination can only be achieved under optimum conditions. Provision of the optimum conditions including appropriate growth medium for germination would normally produce expected seedlings, otherwise germination failure may be due to dead seeds. Dead seeds usually soften and rot within few days' time after sowing. Non-germinated seeds found to have firm embryos are potentially viable. A high percentage of these seeds indicate that germination conditions were not optimal or that seeds are dormant (Rao *et al*., 2006; Hartmann *et al*., 2007).

Seed dormancy is common in freshly harvested seeds and in many wild species of crop plants. In most of the tropical fruit crops, there are essentially hard seed coat and inhibitory biochemical dormancy. The first type of dormancy prevents availability of moisture to the embryo (Hong and Ellis, 1996; Rao *et al.,* 2006). On the other hand, presence of inhibitory substances usually within the embryo or surrounding tissues prevents normal germination in seeds of most temperate fruit species. Examples of embryo dormancy can be found in the *Apiaceae*, *Iridaceae*, *Liliaceae*, *Papaveraceae* and *Ranunculaceae* families. Apart from inhibitory effect of abscisic acid (ABA), higher concentration of pectin, gum, tannin and tryptophan have been found to induce dormancy in seeds of some temperate fruits. Also, dormancy can be caused by a combination of impermeable seed or fruit coats and physiologically dormant embryos.

For germination to occur, both types of dormancy must be broken (Acquoah, 2004; Chadha, 2009).

2.6.1 Dormancy–breaking techniques

In some seeds that are dormant at harvest, dormancy breaks down naturally over time. Other species require some forms of pre-treatment. There are several methods used for specific genus. Seed dormancy due to hard seed coat can be overcome by softening the seed coat, piercing through the seed coat, reducing thickness of seed coat and other covering tissues. This can be done by various forms of scarification (Awodoyin and Ogunyemi, 2003; Rao *et al.,* 2006; Hartmann *et al.*, 2007).

a. Scarification: It is the process of breaking, scratching, reducing thickness, altering or softening the seed covering to make it permeable to water and gas. Scarification can be achieved mechanically by piercing, nicking, chipping or filing with a knife, needle or sand paper; by soaking in hot water at 70 – 100^{o}C and allowing to gradually cool for 12–24 hours; by immersion of seeds in absolute alcohol or acid for varying period (2 – 60 minutes) depending on the species, in order to dissolve away or corrode the waxy materials that may have blocked water entry (Jaenicke, 1999; Agba *et al*., 2001; Awodoyin *et al.,* 2001; Fariyike *et al.,* 2008; Chadha, 2009). Toleration of acid scarification varied among species. Some have short duration tolerance of acid while some can tolerate acid treatment up to 120 mnutes, e.g. *Sesbania pachycarpa* DC (Egberongbe *et al.*, 2017).

b. Embryo dormancy: There are several recommended treatments to overcome embryo dormancy. These include pre-chilling (i.e. stratification) for temperate plants and those species from high-altitude locations in the tropics; preheating at temperature not exceeding 40^{o}C for up to seven days before germination; application of gibberellic acid (GA_3) at low concentration; addition of potassium nitrate (KNO_3) to the substrate; and exposure to light. The use of gibberellic acid and such oxidizing agent like hydrogen peroxide (H_2O_2) in breaking embryo dormancy have been used to obtain high level of germination rate in plants like Japanese red pine, Western larch, slash pine, *Sabal palmetto* and *Thrinaxx morrisii* (both ornamental palms), loblolly pine, among others (Sajeerukumar *et al*., 1995; Rao *et al*., 2006; Chadha, 2009).

2.7 Seedling development and nursery growth media

Most tree crop species are commonly established with seedlings raised in the nursery. This practice ensures economy of seeds, as well as permits intensive care that reduces problems of pests and diseases. Nursery practice also allows the manager to raise and select vigorous quality seedlings for transplanting. Studies have shown that field survival and productivity are related to the quality of seedlings used (Jaenicke, 1999; Awodoyin *et al*., 2001; Ugwoke *et al*., 2001; Baiyeri, 2002; Verheij and Lovenstein, 2004). Jaenicke (1999) described seedling quality as a function of such factors as the ability to produce new roots quickly, the speed with which seedlings get anchored in the ground and start assimilating and growing normally after planting out, a well-developed root collar diameter, a balanced shoot / root ratio, among others.

There are three phases in seedling development, namely: establishment, production and hardening. The establishment phase consists of seed germination and first root growth; production phase is manifested by rapid shoot growth; while hardening phase is characterized by gradual acclimatization of seedlings to field conditions.

For each and all of these phases, environmental conditions can be manipulated to facilitate seedling development. Various pre-sowing treatments can be used to accelerate the start of germination and/or shorten the germination period for all seeds so that germination is uniform rather than spreading over a long period of time. Most common pre-sowing treatment methods for seeds include soaking in cold water for 12, 24 or 48 hours; immersion in hot (70^{o}C) water, allowing to cool and soaking for 12, 24 or 48 hours; nicking/partial or complete removal of seed coat. A good nursery practice is to pre-treat seeds if they take more than a week to germinate. The method to use depends on the species and the seed. For instance, large hard seeds might require mechanical nicking and soaking, while small seeds might only need to be soaked (Wightman, 1999; Ren and Tao, 2004).

As soon as a seedling is established, either a few days after germination or after prickling out, both roots and shoots begin growing rapidly. This phase is as important as the establishment phase. Root development is important for efficient nutrient and water uptake and for planting out success. The number of fine roots with growing

points largely determines the ability of seedling to recover and start growing after transplanting. If the root system is small and/or distorted, the tree cannot anchor itself sufficiently in the ground and it will be prone to logging when waterlogged. The appearance of a healthy root system is different for species with a strong tap root, than it is for those with a mass of shallow roots. However, most tree seedlings have a straight, slightly tapering primary root and a large mass of fibrous roots. With reference to hardening and transplanting phase, seedlings need to get acclimatized to the conditions at a planting site. Thus, about 2 – 4 weeks before transplanting, the seedlings should be taken through hardening process by gradual reduction in watering to once a week as well as removal of shades (Jaenicke, 1999; Wightman, 1999).

Good seedling development to a large extent depends on growth medium used, including its physical and chemical properties. The physical composition of the growth medium can have profound effect on the supply of water and air to the growing plant, as well as affect anchorage, nutrient and water holding capacity of the medium. These physical features of nursery growth medium may indirectly influence germination, but directly affect the emergence and vigour of seedlings with consequent effect on quality of seedlings produced. Quality of seedlings transplanted will invariably influence their establishment at the permanent planting site, and consequently on the future productivity of the tree crop (Jaenicke, 1999; Baiyeri, 2002; Hartmann *et al*., 2007). Therefore, the fast-growing plant nursery industry requires specialized and proven techniques which will ensure production of good quality seedlings that can be transplanted at the proper time to enhance high survival rate. Poor physical and chemical conditions are very common growth inhibitors of seedlings. Nursery medium that is poorly aerated, poorly drained, tight and hard, causes stunted, slow and an uneven seedling growth. So, to improve the quality of seedling of tree crops and make nursery business, of especially indigenous fruit trees production, more profitable there is the need to evaluate and re-evaluate nursery media and seedlings produced from them (Verheij and Lovenstein, 2004).

2.8 Allelopathy and its impact in the agroecosystem

The allelopathy phenomenon has been described as the beneficial or harmful effects of one plant on another plant, whether crop or weed species, by the release of biochemical(s) substance known as allelochemical(s) from the releasing plant parts through leaching, root exudation, volatilization, residue decomposition and other processes in both agroecosystem and forestry systems (Inderjit and Callaway, 2003; Das *et al.*, 2012; Owoseni and Awodoyin, 2013; Shankar *et al.*, 2014). Allelopathy is a kind of interference mechanism, in which live or dead plant materials release chemical substances, which inhibit or stimulate the associated recipient plant growth (May and Ash, 1990; Jadhav and Gaynar, 1995). The allelopathic tendency in plants can affect many aspects of plant ecology, including species abundance, growth and plant succession, the structure of plant communities, dominance, diversity and plant productivity; allelopathy may also play an eminent role in the intraspecific and interspecific competition and may determine type of interspecific association among plant community (Siddiqui *et al.*, 2009).

In nature, plants have to face various biotic and abiotic stresses (Alagesaboopathi, 2011; Das *et al.*, 2012; Daniya *et al.*, 2014). The detrimental effects of allelochemicals on recipient plants are considered as biotic stress, otherwise called 'allelochemical stress' (Cruz-Ortega, 2002). Effects of leachates from plants, plant extracts and decomposing plant residues have been the focus of several investigators concerned with the role of allelopathy in agronomy and forestry. Plant residues often contain variety of toxins that are known inhibitors of seed germination or seedling growth (An *et al.*, 1997; Owoseni and Awodoyin, 2013; Shankar *et al.*, 2014). Leachates from some plants have been shown to suppress seed germination and vegetative propagules, as well as reduce early seedling growth of other nearby plants (Casado, 1995; Dhwan and Gupta, 1996; Babu and Kandasanmy, 1997). Higher concentrations of such leaf leachate also had negative effects on mean germination speed, seedling vigour index and seedling dry weight (Lydon *et al.*, 1997; Benyas *et al.*, 2010). Similar report by Das and Bandyopadhyay (2011) showed a decrease in seed germination simultaneously with mitotic index of *Allium cepa* L. roots by leachate of *Shorea robusta* Roth. Siddiqui *et al.* (2009) reported that different concentrations of *Emblica*

officinalis Gaertn. and *Acacia leucophloea* (Roxb.) Willd. extracts caused highly significant inhibitory effect on germination and root elongation of their test crop. Allelopathy has also been observed in other tree species including *Acacia auriculiformis* A. Cunn. Ex Benth. *Acacia mearnsii* De Wild., *Albizia lebbeck* (L.) Benth., *Anacardium occidentale* L., *Eucalyptus citriodora* Hook., *Gmelina arborea* Roxb. and *Tectona grandis* L.f. among others. *Leucaena leucocephala* (Lam.) de Wit, the tree promoted for reinvigoration of soil by alley cropping, contains a toxic non-protein amino acid (mimosine) in the leaves which inhibits growth of others but not its own seedlings. (Yeung *et al*. 2002; Shankar *et al*. 2014).

2.9 Leguminous trees nodulation and soil conservation

The value of legumes in improving and sustaining soil fertility has been known since ancient times and well researched and reviewed, especially for annual grain legumes and perennial forage legumes (Ezedinma *et al*., 1979; Sprent, 1995; Budowski and Russo, 1997; Franco and De Faria, 1997; Adams *et al.*, 2010). Many (but not all) species of legumes have nodules on their roots containing bacteria which possess the capacity of fixing atmospheric nitrogen, some of which are then available to the host plant and the soil nitrogen is increased by sloughed, disintegrated nodules as well as decomposed host plant litters (biomass) like leaf droppings (Sprent, 2001). In this association (symbiosis), the bacteria are in return supplied with carbohydrates by the host (Purseglove, 1984; Flynn and Idowu, 2015). This characteristic has made such legumes of great importance in agriculture and food production. They provide protein-rich food for humans and farm animals; they play vital role in crop rotation and are used in admixture with grasses in leys and pastures. Some are also used as cover crops and green manures (Brewbaker, 1987; Zahran, 1999; Diabate *et al.*, 2005; Meena *et al.*, 2018). In addition, afforestation and reforestation practices, establishment of shelter belts and restoration of soils with N-fixing legume trees/shrubs had been noted to constitute vital option in recovery of degraded land areas, besides other secondary benefits from non-timber forest products of such trees (de Faria *et al*., 2010; Chagas Junior *et al.*, 2012).

The bacteria (*Rhizobium spp*.), which are normally free-living in the soil when they do not fix nitrogen, are attracted to the roots of legumes from the seedling stage onwards. Therefore, legume nitrogen fixation starts with the formation of a nodule. The rhizobia bacteria in the soil invade the root and multiply within its cortex cells. The host plant supplies all the necessary nutrients and energy for the bacteria. Within a week after infection, small nodules are visible with the naked eye. In the field, small nodules can be seen 2–3 weeks after planting, depending on legume species and germination conditions. When nodules are young and not yet fixing nitrogen, they are usually white or gray inside. As nodules grow in size, they gradually turn pink or reddish in colour, indicating nitrogen fixation has started. The pink or red color is caused by leghaemoglobin (similar to haemoglobin in blood) that controls oxygen flow to the bacteria (Isichei and Awodoyin, 1990; Chen *et al*., 2003; Sprent, 2005; Flynn and Idowu, 2015). Nodules on perennial legumes are long-lived and will fix nitrogen through the entire growing season as long as field conditions are favourable. In contrast, nodules on annuals are short-lived and will be replaced constantly during the growing season. At the time of pod fill, nodules on annual legumes generally lose their ability to fix nitrogen because the plant feeds the developing seed rather than the nodule (Brewbaker, 1987; Zahran, 1999; Flynn and Idowu, 2015). Legume nodules that are no longer fixing nitrogen usually turn green and may actually be discarded by the plant. Pink or red nodules should predominate on a legume in the middle of the growing season. If white, gray, or green nodules predominate, little nitrogen fixation is occurring as a result of an inefficient rhizobia strain, poor plant nutrition, pod filling, or other plant stress (Walley *et al.*, 1996; Russelle *et al.*, 2007).

As has been indicated, N-fixation characterized most legumes (by distribution: over 90% of mimosoids and papilionoids, and 34% of caesalpinioids). At least 90% of these represent tropical centres of origin (Brewbaker, 1987; Sprent, 2005). Observation of nodulation in leguminous tree species native to the primary tropical rainforest in Guinea (West Africa) showed several genus/species in the Caesalpinioideae sub-family (including *Delonix regia* (Hook.) Ref. *Cassia* [2 spp], *Dialium* [4 spp], *Senna* [4 spp], *Afzelia africana* Sm. ex Pers. and *Afzelia bella* Harms., *Detarium* [3 spp] and *Anthonotha* [3 spp] among others) as non-nodulating. The few that were found with

root nodulation capacity in the sub-family included *Bussea occidentalis* Hutch., *Chamaecrista mimosoides* (L.) Greene, two species of *Erythrophleum ivorense* A. Chev. and *Erythrophleum suaveolense* (Guill. & Perr.) Brenan. (Diabate *et al.,* 2005). Among the Mimosoideae sub-family, few non-nodulating genus/species observed included *Parkia bicolor* A. Chev., *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don., *Newtonia* [2 spp] and *Adenopodia scelerata* (A.Chev) Brean; while majority of the species (including *Albizia* [6 spp], *Pentaclethra macrophylla* Benth., *Tetrapleura tetraptera* (Schumach & Thonn.) Taub. and others) were nodulating. The Papilionoideae also had fair mixture of more nodulating and fewer non-nodulating genus/species observed according to the reports (Diabate *et al.,* 2005; Sprent, 2005). Similar distribution of leguminous species and their nodulation status among the three sub-families in South American Amazon rainforest had been reported by de Faria *et al.,* (2010).

The uses of leguminous trees for a variety of food, livestock feed and fuel wood purposes in different regions of the world had been reviewed (Lewis *et al*., 2005; Wojciechowski, 2006). Tree legumes are widely distributed throughout the tropics and sub-tropical regions; and many of them are valuable for fixing atmospheric N_2 just as the herbaceous annual legumes. Among the essential nutrients for plant growth, N is the most expensive and energy-consuming, and potentially an environmental pollutant. Mixed crops with N_2-fixing trees (NFTs) have been thought to maintain biodiversity and sustainability of systems in the tropics (Dakora and Keya, 1997; Ng and Hau, 2009).

Agreeably, useful Nitrogen Fixing Tree species may contribute around 12 tons of dry litter and 190 kg of N ha^{-1} y^{-1} to renovate degraded soil (Franco and de Faria, 1997). For instance, the N_2 fixed (measured as a percentage of the total nitrogen) in the tree legumes *Leucaena*, *Albizia* and *Gliricidia* ranged from about 20 to 74, 28 to 72, and 44 to 84%, respectively (Kadiata *et al.,* 1996). In a similar development, certain tree legumes were found to fix about 43 to 581 kg of N per ha, compared to about 15 to 210 kg of N per ha for grain legumes (Dakora and Keya, 1997). This high N_2-fixing potential makes leaf pruning of these tree legumes an important component of

sustainability in agroecosystem and soil fertility management. Brewbaker (1987) in fact noted that the high-nitrogen leaf litter of such tree legumes used as nurse trees or woody hedges may indeed be more important to a crop than the shade or wind protection provided by the trees.

2.10 Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis technique

Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is a strategic planning method used to evaluate the strengths, weaknesses, opportunities and threats involved in a project, programme or in a business venture (Ommani, 2011; Armstrong, 2014). It involves considering the objective of the project and identifying the internal and external factors that are favourable and unfavourable to achieve that objective(s). In this regard, strengths implied present positive attributes inherent in the project that give it an advantage among others and make the project worth embarking on. Weaknesses are characteristics that place the project at a disadvantage relative to others. Weaknesses are controllable. They must be minimized and eliminated. Opportunities are external chances of the project to make greater and wider impact in the environment; while threats are external elements in the environment that could cause trouble for the project if they are overlooked or not adequately addressed. Planners and managers should be able to recognize opportunities in this context and carefully grasp them whenever possible in order to turn them into strengths. On the other hand, threats are uncontrollable factors, but their possible impact can be reduced or avoided by optimizing the project strengths and taking good advantage of the opportunities present in project's environment (Ommani, 2011; MSG, 2016).

The SWOT technique has been widely used as a planning and decision making tool in determining potentials viability of proposed project; and as an instrument in strategy formulation and selection. The tool may prove very useful in making a recommendation during a viability study/survey, explore new solutions to problems, and identify barriers that may limit project goals/objectives among others. Beyond its primary domain in management studies, the tool has found useful applications in various other disciplines, including environmental sciences, agroecology, agrcicultural

extension, agricultural marketing, engineering, biological sciences and social sciences (Diamantopoulou and Voudouris, 2008; FAO, 2011; Wakie *et al*., 2012; Ha, 2014; Mahmoodi *et al*., 2014; MSG,2016). The SWOT analysis is normally presented as a grid or matrix table, comprising four sections, one for each of the SWOT sub-headings: Strengths, Weaknesses, Opportunities and Threats (Chapman, 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Locations of study

3.1.1 Site of nursery experiments and ambient meteorological condition

Nursery experiments were carried out at the Teaching and Research Farm of the Federal College of Agriculture (FCA), Ishiagu, Ebonyi State, Nigeria. Ishiagu lies within the southeast derived savanna ecological zone of the country. It is located on latitude 05^{o} 52'N, longitude 07^{o} 35'E and altitude 57 m above sea level (FCA Agromet Centre, 2014).

The host community Ishiagu is known for its production of major crops like rice (*Oryza sativa*), okra (*Abelmoschus esculentus*), yams (*Dioscorea spp*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*) and cucumber (*Cucumis sativus).* The monthly rainfall distribution, maximum and minimum temperature ranges in the area are shown in Table 3.1. Rainfall distribution is bimodal with peaks in the months of July and September in 2013 and July and October in 2014. The dry season spans November to March or April with a characteristic cold dry dust laden interval known as harmattan, during the months of December to February (FCA Agromet Centre, 2014).

3.1.2 Source of African oil bean planting materials

Seeds and vegetative propagules of African oil bean (*Pentaclethra macrophylla*) for the experiments were sourced from Ishiagu and its environs where the species naturally thrives as well as constitutes part of the traditional home garden setting and food culture of the people. Matured seeds for seedling emergence trials were collected from the wild in the community, while vegetative propagation operation was carried

Table 3.1. Weather data of Ishiagu, SE Nigeria in 2013 and 2014

Month	2013 Rainfall (mm)	2013 Minimum Temp (^{o}C)	2013 Maximum Temp (^{o}C)	2014 Rainfall (mm)	2014 Minimum Temp (^{o}C)	2014 Maximum Temp (^{o}C)
January	2.0	21.0	33.0	94.5	22.0	34.0
February	79.2	24.0	33.0	20.9	25.0	34.0
March	10.6	25.0	35.0	79.6	24.0	34.0
April	156.9	24.0	33.0	159.0	25.0	33.0
May	223.4	23.0	31.0	277.1	23.0	32.0
June	247.6	23.0	30.0	194.0	24.0	31.0
July	299.7	23.0	29.0	310.0	24.0	29.0
August	266.0	23.0	29.0	154.4	25.0	29.0
September	379.1	23.0	29.0	208.0	24.0	30.0
October	212.1	23.0	31.0	347.3	22.0	31.0
November	72.0	23.0	32.0	13.0	23.0	32.0
December	0.0	22.0	33.0	83.4	23.0	32.0
Total	1948.6	-	-	1941.2	-	-
Mean	-	23.1	31.5	-	23.7	31.8

Source: AgroMet Centre, Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria

out on matured parent trees located in mixed tree crop plantation at Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria.

3.2 Ethnobotanical survey and Floristic enumeration

Field enumeration and survey were conducted to ascertain the ethnobotanical status and floristic distribution of *P. macrophylla* in three randomly selected states, namely Abia, Ebonyi and Imo of Southeast Nigeria. Existing structures of the respective state's Agricultural Development Programme (ADP) at the state agricultural zones, extension blocks and circles were adopted and followed in reaching out to the target ADP contact farmers in a multistage sampling procedure. The floristic enumeration and ethnobotanical assessment were carried out based on one third number of ADP extension circles in one third number of the ADP blocks in all the three Agricultural development Zones for each of the three randomly selected States.

3.2.1 Locations of field surveys

Survey of the floristic distribution and ethnobotanical values of African oil bean tree were conducted during 2013 and 2014 in selected ecosystems in Abia, Ebonyi and Imo States of southeast (SE) Nigeria (Plate 3.1).

Abia State comprises of 17 Local Government Areas (LGAs) and has a land area of 5,243.7 sq km. There are 38 Agricultural Development Programme (ADP) extension Blocks in the State which are grouped into three agricultural Zones. The state has predominantly tropical lowland rainforest vegetation (Ijioma, 2000; Mammaan *et al.*, 2000).

Imo State is made up of 27 LGAs, and has a land area of 5100 sq km. The State also is characterized by mainly tropical lowland rainforest vegetation. The three agricultural Zones in the state comprise of 25 extension Blocks (Mammaan *et al.*, 2000; Ogbonna, 2000).

Ebonyi State is located toward the northern part of southeast Nigeria, with relative drier weather conditions. The State has more of derived savanna vegetation, with a land area of 5,935 sq km, 13 LGAs and 12 extension Blocks across its three ADP Zones (Egbu, 2000; Mammaan *et al.*, 2000).

3.2.2 Field survey 1: Ethnobotanical survey of *Pentaclethra macrophylla* in southeast (SE) Nigeria

The ethnobotanical approach aimed at addressing the research questions listed below which were used in drafting the questionnaire (Appendix 1):

- how are the *P. macrophylla* trees owned, managed and used by the people across their different communities, socioeconomic classes and genders?
- what are the species seed production and revenue generation potentials?
- what are the prospects and challenges of enhanced domestication and conservation of *P. macrophylla*?

Drafts of semi-structured questionnaire were previewed by Deputy Director Extension Services Imo state ADP headquarters Owerri and validated in the Department of Agricultural Extension and Rural Development, University of Ibadan Nigeria. Semi-structured questionnaires containing relevant queries that addressed the listed ethnobotanical objectives were administered to the targeted ADP contact farmers in selected states during 2013 cropping season. Multistage purposive sampling technique was used in reaching out to the targeted audience. In this arrangement, each selected extension Block in various states ADP zones received twelve (12) questionnaires which consisted of one third (3) of the extension circles, and four (4) respondents per circle (Tables 3.2 a - c).

Completed questionnaires were collected, validated and analysed using descriptive statistics of frequency distribution, mean, mode, range and ranking. In addition, the ethnobotanical study was analysed using Strength-Weakness-Opportunity-Threat (SWOT) analysis (FAO, 2011; Ommani, 2011; Wakie *et al*., 2012; Ha, 2014).

3.2.3 Field survey 2: Floristic enumeration of African oil bean tree (*P. macrophylla*) in Abia, Ebonyi and Imo states SE Nigeria

With the help of contact farmers encountered in field survey 1 at the various selected ADP circles in each of the three states, field visits and inventory of given farm and fallow land were conducted to assess *P. macrophylla* abundance and distribution in relation to other tree species. The floristic enumeration was conducted during 2014 cropping season from June 2014 to January 2015 across the various states' ADP

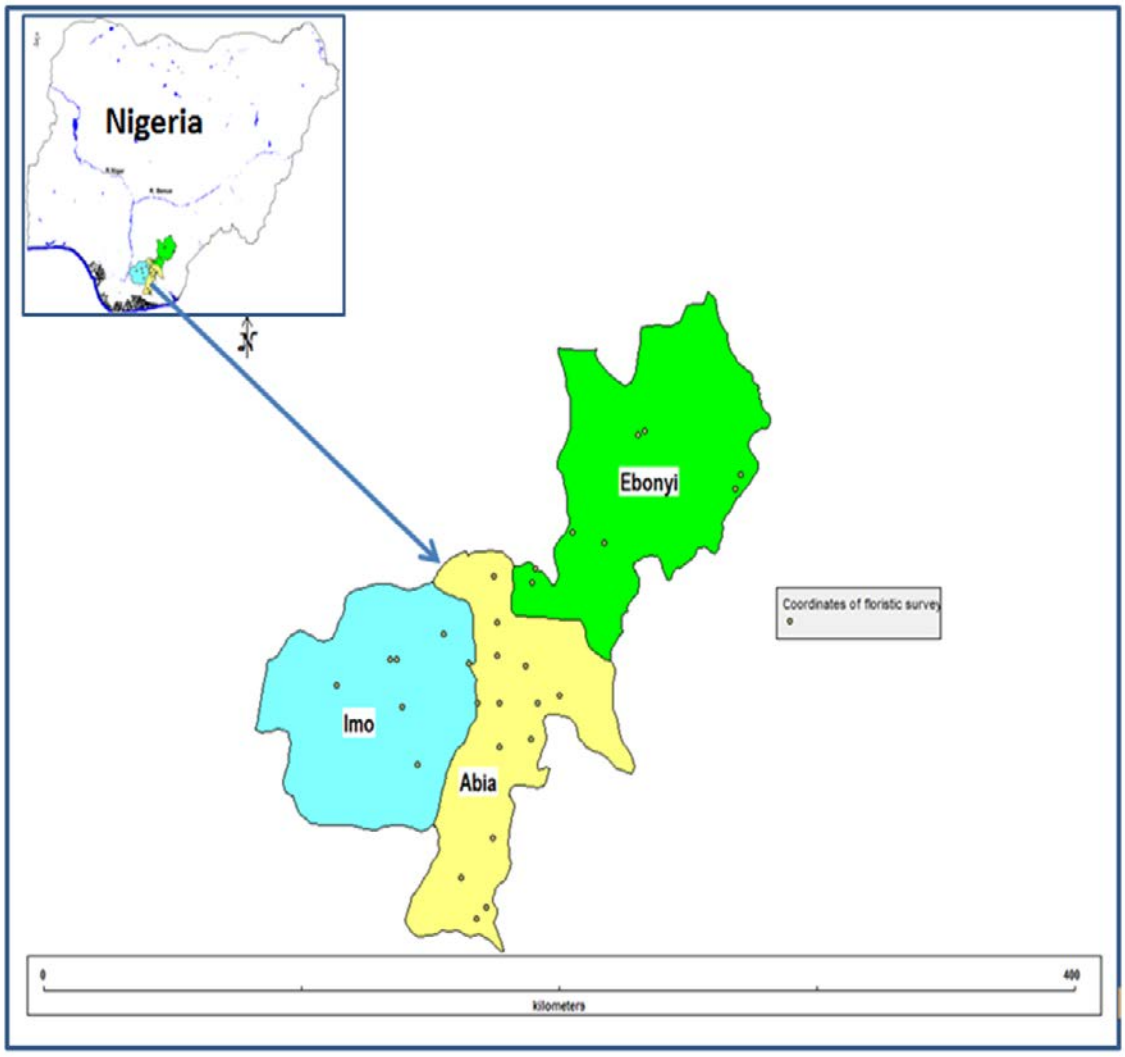

Plate 3.1 Map of Nigeria showing surveyed Agricultural Development Programme (ADP) extension Blocks in southeast States of Abia, Ebonyi and Imo

Table 3.2a The study locations within ADP Agricultural zones and extension blocks in Abia state Nigeria

Agricultural Zone	Extension Block	Number of questionnaire
Ohafia Zone (13 Blocks)	Isuikwuato*	12
	Arochukwu	
	Isuochi/Nneato*	12
	Bende	
	Nkporo	
	Abiriba	
	Uzuakoli*	12
	Abam*	
	Ohafia west	
	Ohafia south	
	Umuchieze/Uburu*	12
	Umunna	
Umuahia Zone (13 Blocks)	Ohuhu*	12
	Ikwuano north	
	Ikwuano south*	12
	Umuahia urban	
	Umuopara*	12
	Owerrinta	
	Omoba	
	Olokoro/Ubakala*	12
	Ibeku	
	Isiala Ngwa	
	Mbawsi	
	Ntigha	
	Nvosi	
Aba Zone (12 Blocks)	Azumini*	12
	Umuaro	
	Ogwe	
	Owerreaba*	12
	Ohanze	
	Uhie*	12
	Okpu Umuobo	
	Asa	
	Akwete*	12
	Umunneise	
	Agalaba	
	Aba urban	
Total = 38 extension Blocks	*13 extension Blocks	

Source: Ubani (2013); *= selected one third of the extension blocks (5 in Ohafia zone; 4 each in Umuahia and Aba zones)

Table 3.2b The study location within ADP Agricultural zones and extension blocks in Imo state Nigeria

Agricultural Zone	Extension Block	Number of questionnaire
Orlu Zone (8 Blocks)	Nwangele*	12
	Nkwerre	
	Njaba	
	Isu*	12
	Oguta	
	Orlu	
	Oru east	
	Oru west	
Owerri Zone (10 Block)	Aboh	
	Ahiazu	
	Ezinihitte	
	Ikeduru*	12
	Owerri municipal	
	Ngor-Okpala*	12
	Owerri north	
	Owerri west	
	Mbaitolu*	12
	Ohaji	
Okigwe Zone (7 Blocks)	Onuimo*	12
	Ehime	
	Mkpa	
	Uboma*	12
	Orsu	
	Obowo*	12
Total = 25 extension Blocks	*8 extension Blocks	

Source: Nnadi (2013); *= selected one third of the extension blocks (2 in Orlu zone; 3 each in Okigwe and Owerri zones)

Table 3.2c The study locations within ADP Agricultural zones and extension blocks in Ebonyi state Nigeria

Agricultural Zone	Extension Block	Number of questionnaire
Ebonyi north Zone (4 Blocks)	Abakaliki	
	Ohaukwu*	12
	Izzi	
	Ebonyi	
Ebonyi central Zone (4 Blocks)	Ikwo*	12
	Ezza south	
	Ezza north	
	Ishielu	
Ebonyi south Zone (10 Blocks)	Afikpo/Onuicha	
	Ohaozara*	12
	Afikpo south	
	Ivo*	12
Total = 12 extension Blocks	*4 extension Blocks	

Source: Nwaugba (2013); *= selected one third of the extension blocks (2 in Ebonyi south zone; 1 each in Ebonyi central and Ebonyi north zones)

Table 3.3a Location and coordinates of floristic survey sites in Abia States ADP circles of Nigeria

Extension block	Latitude (N)	Longitude (E)	Altitude (m asl)	Land use
	ABIA State ADP extension circle			
Akwete 1	04 ^{o} 53.692’	007 ^{o} 22.095’	23	Farm land
,, 2	04 ^{o} 53.653’	007 ^{o} 20.791’	22	,,
,, 3	04 ^{o} 53.752’	007 ^{o} 20.560’	20	,,
,, 4	04 ^{o} 53.641’	007 ^{o} 22.136’	17	Fallow land
,, 5	04 ^{o} 53.881’	007 ^{o} 20.610’	22	,,
,, 6	04 ^{o} 53.791’	007 ^{o} 20.495’	24	,,
Azumini 1	04 ^{o} 56.496’	007 ^{o} 22.940’	24	Farm land
,, 2	04 ^{o} 56.397’	007 ^{o} 28.037’	37	,,
,, 3	04 ^{o} 58.987’	007 ^{o} 27.608’	46	,,
,, 4	04 ^{o} 53.718’	007 ^{o} 22.058’	28	Fallow land
,, 5	04 ^{o} 56.421’	007 ^{o} 28.057’	47	,,
,, 6	04 ^{o} 59.006’	007 ^{o} 27.618’	46	,,
Owerreaba 1	05 ^{o} 02.704’	007 ^{o} 19.491’	53	Farm land
,, 2	05 ^{o} 02.591’	007 ^{o} 19.494’	56	,,
,, 3	05 ^{o} 02.530’	007 ^{o} 19.487’	56	,,
,, 4	05 ^{o} 02.625’	007 ^{o} 19.520’	59	Fallow land
,, 5	05 ^{o} 02.657’	007 ^{o} 19.470’	56	,,
,, 6	05 ^{o} 02.543’	007 ^{o} 19.443’	56	,,
Uhie 1	05 ^{o} 09.791’	007 ^{o} 25.725’	83	Farm land
,, 2	05 ^{o} 09.757’	007 ^{o} 25.683’	83	,,
,, 3	05 ^{o} 09.774’	007 ^{o} 05.655’	83	,,
,, 4	05 ^{o} 09.816’	007 ^{o} 25.741’	83	Fallow land
,, 5	05 ^{o} 09.751’	007 ^{o} 25.661’	82	,,
,, 6	05 ^{o} 09.769’	007 ^{o} 05.662’	79	,,
Umuopara 1	05 ^{o} 32.881’	007 ^{o} 26.913’	116	Farm land
,, 2	05 ^{o} 32.802’	007 ^{o} 26.503’	104	,,
,, 3	05 ^{o} 32.753’	007 ^{o} 26.696’	113	,,
,, 4	05 ^{o} 32.859’	007 ^{o} 26.357’	106	Fallow land
,, 5	05 ^{o} 32.685’	007 ^{o} 26.737’	104	,,
,, 6	05 ^{o} 32.722’	007 ^{o} 26.775’	111	,,
Ohuhu 1	05 ^{o} 34.420’	007 ^{o} 34.420’	112	Farm land
,, 2	05 ^{o} 34.403’	007 ^{o} 27.059’	123	,,
,, 3	05 ^{o} 34.288’	007 ^{o} 26.923’	112	,,
,, 4	05 ^{o} 34.650’	007 ^{o} 33.557’	110	Fallow land
,, 5	05 ^{o} 33.435’	007 ^{o} 28.475’	153	,,
,, 6	05 ^{o} 33.574’	007 ^{o} 25.715’	134	,,
Ubakala 1	05 ^{o} 26.371’	007 ^{o} 26.850’	125	Farm land
,, 2	05 ^{o} 27.926’	007 ^{o} 26.519’	154	,,
,, 3	05 ^{o} 27.705’	007 ^{o} 26.275’	152	,,
,, 4	05 ^{o} 26.192’	007 ^{o} 26.897’	123	Fallow land

Extension block	Latitude (N)	Longitude (E)	Altitude (m asl)	Land use
	ABIA State extension circle			
Ubakala 5	05 ^{o} 28.046`	007 ^{o} 26.554`	159	Fallow land
,, 6	05 ^{o} 27.731`	007 ^{o} 26.342`	150	,,
Ikwuano 1	05 ^{o} 27.343`	007 ^{o} 33.525`	166	Farm land
,, 2	05 ^{o} 26.896`	007 ^{o} 33.640`	146	,,
,, 3	05 ^{o} 27.153`	007 ^{o} 33.659`	162	,,
,, 4	05 ^{o} 26.720`	007 ^{o} 33.164`	162	Fallow land
,, 5	05 ^{o} 26.682`	007 ^{o} 33.382`	152	,,
,, 6	05 ^{o} 26.594`	007 ^{o} 33.312`	161	,,
Abam 1	05 ^{o} 35.419`	007 ^{o} 40.587`	104	Farm land
,, 2	05 ^{o} 35.409`	007 ^{o} 40.558`	122	,,
,, 3	05 ^{o} 35.364`	007 ^{o} 40.548`	106	,,
,, 4	05 ^{o} 35.402`	007 ^{o} 40.614`	98	Fallow land
,, 5	05 ^{o} 35.333`	007 ^{o} 40.575`	92	,,
,, 6	05 ^{o} 35.374`	007 ^{o} 40.585`	93	,,
Uzuakoli 1	05 ^{o} 40.743`	007 ^{o} 32.719`	105	Farm land
,, 2	05 ^{o} 40.737`	007 ^{o} 32.632`	108	,,
,, 3	05 ^{o} 40.718`	007 ^{o} 32.622`	105	,,
,, 4	05 ^{o} 40.738`	007 ^{o} 32.600`	108	Fallow land
,, 5	05 ^{o} 40.793`	007 ^{o} 32.639`	117	,,
,, 6	05 ^{o} 40.614`	007 ^{o} 32.804`	100	,,
Uturu 1	05 ^{o} 48.694`	007 ^{o} 26.668`	127	Farm land
,, 2	05 ^{o} 48.674`	007 ^{o} 26.695`	132	,,
,, 3	05 ^{o} 48.710`	007 ^{o} 26.673`	127	,,
,, 4	05 ^{o} 48.724`	007 ^{o} 26.655`	128	Fallow land
,, 5	05 ^{o} 48.740`	007 ^{o} 26.641`	129	,,
,, 6	05 ^{o} 48.761`	007 ^{o} 26.636`	135	,,
Isuikwuato 1	05 ^{o} 42.983`	007 ^{o} 27.887`	179	Farm land
,, 2	05 ^{o} 42.829`	007 ^{o} 27.896`	185	,,
,, 3	05 ^{o} 42.864`	007 ^{o} 27.828`	170	,,
,, 4	05 ^{o} 42.994`	007 ^{o} 27.893`	179	Fallow land
,, 5	05 ^{o} 42.959`	007 ^{o} 27.864`	172	,,
,, 6	05 ^{o} 42.849`	007 ^{o} 27.879`	166	,,
Umunnochi 1	05 ^{o} 55.186`	007 ^{o} 25.548`	124	Farm land
,, 2	05 ^{o} 54.914`	007 ^{o} 25.696`	108	,,
,, 3	05 ^{o} 54.887`	007 ^{o} 25.690`	110	,,
,, 4	05 ^{o} 55.230`	007 ^{o} 25.561`	120	Fallow land
,, 5	05 ^{o} 55.204`	007 ^{o} 25.489`	128	,,
,, 6	05 ^{o} 54.905`	007 ^{o} 25.690`	110	,,
Total	39 extension circles			78 sites

Table 3.3b Location and coordinates of floristic survey sites in Ebonyi States ADP circles of Nigeria

Extension block	Latitude (N)	Longitude (E)	Altitude (m asl)	Land use
	EBONYI State ADP extension circles			
Ishiagu 1	05 ^{o} 55.040`	007 ^{o} 33.026`	65	Farm land
,, 2	05 ^{o} 58.134`	007 ^{o} 34.245`	61	,,
,, 3	05 ^{o} 58.205`	007 ^{o} 34.264`	56	,,
,, 4	05 ^{o} 54.950`	007 ^{o} 33.474`	57	Fallow land
,, 5	05 ^{o} 58.371`	007 ^{o} 34.337`	58	,,
,, 6	05 ^{o} 58.121`	007 ^{o} 34.152`	60	,,
Ohaozara 1	06 ^{o} 02.338`	007 ^{o} 41.716`	53	Farm land
,, 2	06 ^{o} 02.358`	007 ^{o} 41.659`	51	,,
,, 3	06 ^{o} 02.387`	007 ^{o} 41.667`	53	,,
,, 4	06 ^{o} 02.298`	007 ^{o} 41.810`	56	Fallow land
,, 5	06 ^{o} 02.275`	007 ^{o} 41.967`	65	,,
,, 6	06 ^{o} 02.210`	007 ^{o} 41.900`	56	,,
Ohaukwu 1	06 ^{o} 23.357`	007 ^{o} 57.582`	100	Farm land
,, 2	06 ^{o} 22.461`	007 ^{o} 58.084`	99	,,
,, 3	06 ^{o} 22.352`	007 ^{o} 58.152`	103	,,
,, 4	06 ^{o} 23 400`	007 ^{o} 57.629`	98	Fallow land
,, 5	06 ^{o} 23.374`	007 ^{o} 57.669`	92	,,
,, 6	06 ^{o} 23.396`	007 ^{o} 57.686`	98	,,
Ikwo 1	06 ^{o} 12.231`	008 ^{o} 15.001`	57	Farm land
,, 2	06 ^{o} 12.195`	008 ^{o} 15.020`	58	,,
,, 3	06 ^{o} 12.474`	008 ^{o} 14.765`	59	,,
,, 4	06 ^{o} 12.244`	008 ^{o} 14.987`	56	Fallow land
,, 5	06 ^{o} 12.273`	008 ^{o} 14.976`	62	,,
,, 6	06 ^{o} 12.422`	008 ^{o} 14.840`	63	,,
Total	12 extension circles			24 sites

Table 3.3c Location and coordinates of floristic survey sites in Imo States ADP circles of Nigeria

Extension block	Latitude (N)	Longitude (E)	Altitude (m asl)	Land use
	IMO State ADP extension circle			
Uboma 1	05 ^{o} 41.622`	007 ^{o} 22.011`	90	Farm land
,, 2	05 ^{o} 41.628`	007 ^{o} 22.021`	91	,,
,, 3	05 ^{o} 41.721`	007 ^{o} 22.084`	86	,,
,, 4	05 ^{o} 41.639`	007 ^{o} 22.029`	91	Fallow land
,, 5	05 ^{o} 41.657`	007 ^{o} 22.049`	85	,,
,, 6	05 ^{o} 41.153`	007 ^{o} 22.109`	83	,,
Obowo 1	05 ^{o} 33.424`	007 ^{o} 23.732`	107	Farm land
,, 2	05 ^{o} 33.403`	007 ^{o} 23.755`	104	,,
,, 3	05 ^{o} 33.474`	007 ^{o} 23.820`	98	,,
,, 4	05 ^{o} 33.371`	007 ^{o} 23.756`	103	Fallow land
,, 5	05 ^{o} 33.503`	007 ^{o} 23.503`	92	,,
,, 6	05 ^{o} 33.529`	007 ^{o} 23.833`	96	,,
Onuimo 1	05 ^{o} 45.638`	007 ^{o} 14.829`	119	Farm land
,, 2	05 ^{o} 46.358`	007 ^{o} 15.068`	108	,,
,, 3	05 ^{o} 46.296`	007 ^{o} 15.171`	113	,,
,, 4	05 ^{o} 45.604`	007 ^{o} 14.869`	117	Fallow land
,, 5	05 ^{o} 46.340`	007 ^{o} 14.997`	107	,,
,, 6	05 ^{o} 46.280`	007 ^{o} 15.149`	120	,,
Ngor okpala 1	05 ^{o} 23.290`	007 ^{o} 08.789`	93	Farm land
,, 2	05 ^{o} 23.301`	007 ^{o} 08.773`	88	,,
,, 3	05 ^{o} 23.313`	007 ^{o} 08.747`	91	,,
,, 4	05 ^{o} 23.345`	007 ^{o} 08.795`	92	Fallow land
,, 5	05 ^{o} 23.284`	007 ^{o} 08.796`	96	,,
,, 6	05 ^{o} 23.358`	007 ^{o} 08.815`	90	,,
Mbaitolu 1	05 ^{o} 37.290`	006 ^{o} 59.262`	133	Farm land
,, 2	05 ^{o} 37.255`	006 ^{o} 59.279`	123	,,
,, 3	05 ^{o} 37.236`	006 ^{o} 59.315`	128	,,
,, 4	05 ^{o} 37.320`	006 ^{o} 59.220`	126	Fallow land
,, 5	05 ^{o} 37.290`	006 ^{o} 59.258`	127	,,
,, 6	05 ^{o} 37.299`	006 ^{o} 59.244`	133	,,
Ikeduru 1	05 ^{o} 34.892`	007 ^{o} 06.690`	153	Farm land
,, 2	05 ^{o} 34.945`	007 ^{o} 06.697`	151	,,
,, 3	05 ^{o} 35.005`	007 ^{o} 06.747`	151	,,
,, 4	05 ^{o} 34.905`	007 ^{o} 06.672`	153	Fallow land
,, 5	05 ^{o} 34.924`	007 ^{o} 06.670`	151	,,
,, 6	05 ^{o} 34.932`	007 ^{o} 06.674`	152	,,
Nwangele 1	05 ^{o} 42.417`	007 ^{o} 05.350`	176	Farm land
,, 2	05 ^{o} 42.444`	007 ^{o} 05.457`	174	,,
,, 3	05 ^{o} 42.258`	007 ^{o} 04.760`	174	,,
,, 4	05 ^{o} 42.043`	007 ^{o} 05.032`	177	Fallow land
,, 5	05 ^{o} 42.213`	007 ^{o} 04.730`	175	,,

,,	6	05 ^{o} 42.202`	007 ^{o} 04.728`	174	,,
Isu	1	05 ^{o} 42.897`	007 ^{o} 04.019`	167	Farm land

Extension block		Latitude (N)	Longitude (E)	Altitude (m asl)	Land use
		IMO State ADP extension circle cont.			
Isu	2	05 ^{o} 42.900`	007 ^{o} 04.100`	164	Farm land
,,	3	05 ^{o} 42.964`	007 ^{o} 04.065`	170	,,
,,	4	05 ^{o} 42.908`	007 ^{o} 03.967`	170	Fallow land
,,	5	05 ^{o} 42.926`	007 ^{o} 04.024`	171	,,
,,	6	05 ^{o} 42.908`	007 ^{o} 04.075`	173	,,
Total		24 extension circles			48 sites

extension circles. Coordinate points and altitudes of 150 sites (consisting of 75 farms and 75 fallow lands) in the three states (Table 3.3) were taken with the aid of Global Positioning System (GPS) model Etrex Legend Garmin.

Systematic sampling technique was applied according to Odebiyi *et al.* (2004) and Pelemo *et al*. (2011). Two sites surveyed, each measuring one hectare, were selected from each of the agricultural extension circles. All mature tree species stands that fell within each hectare quadrat were also enumerated and identified up to species level. They were identified following Keay (1989).

The specimens of species that could not be identified on the field were collected and kept in wooden press for identification at the Herbarium Unit of the Department of Botany, University of Ibadan, Ibadan Nigeria. Each stand of *P. macrophylla* enumerated was assessed for its stem girth [cm] at breast height (GBH; 1.3 m) using tape rule. Percent relative abundance of the species under different land use systems in each state surveyed was calculated using the formula (Odebiyi *et al.,* 2004):

$$\text{Relative abundance (\%)} = \frac{\text{(Number of stands of species in each GBH size-class)} \times 100}{\text{Total number of stands}}$$

The sampling procedure for enumeration of low growing plants (mainly saplings of *P. macrophylla*) involved laying of transects at interval of 40 m, along a baseline (determined on spot in the field) to cut through the sampling site, and laying the quadrats measuring 2 m by 2 m, at a regular interval of 10 m along each transect. Fifteen (15) quadrats were marked out per sample site for enumeration of *P. macrophylla* saplings present. The enumeration was carried out in farm and fallow lands at each site.

Floristic composition of the sites (mainly tree species) were also determined in each site and land use system, namely – (i) species richness [*S*], i.e. number of different tree species based on physical enumeration within a specified field area; (ii) species density, i.e. number of individual stand per tree species found in the given area. From the data, Relative Importance Value (RIV) of *P. macrophylla* for each state under the different land use systems was evaluated from the species relative density and relative frequency (Razavi *et al*., 2012; Awodoyin *et al.,* 2013; Kimondo *et al.,* 2014).

RIV (%) = [Relative Density (RD) + Relative Frequency (RF)] ÷ 2.

RD (%) = (Density of a given species ÷ Total Density for all species) x 100

Density = Number of individual stand of a given species ÷ Area sampled

RF (%) = (Frequency of a given species ÷ Total Frequency for all species) x 100.

Frequency (%) = (Number of quadrat in which a species occurred ÷ Total number of quadrat) x 100.

Relative density gives an idea of the total number of individual of given species in a plot; while Relative frequency shows the pattern of distribution of given species in the surveyed area (Martin, 1997; Nyambane *et al*., 2016).

3.3 Pre-sowing seed treatments and germination study of *Pentaclethra macrophylla*

3.3.1 Experiment 1: Effect of pre-sowing soaking in cold and boiling water at varying durations on germination of *P. macrophylla* seeds

The experiment was carried out in plant nursery at the Teaching and Research Farm of Federal College Agriculture (FCA), Ishiagu Ebonyi State Nigeria. It was set up in a Completely Randomised Design (CRD), with mixture of river sand + saw dust (1:1 w/w) serving as growth medium. Fresh matured seeds of *P. macrophylla* were collected from wild in Ishiagu and subjected to varying durations of soaking in water before sowing to evaluate germination responses – including speed, total germination and vigour (Igweneme, 1995; Aliero, 2004; Okunlola *et al.*, 2011). The treatments were:

i. Cold water treatment - seeds were soaked in water at ambient temperature (27^oC) for 6 hours (treatment one – T1), 12 hours (T2) and 24 hours (T3).

ii. Seeds were soaked in boiling water at 100^oC for 5 seconds (T4), 10 seconds (T5), 20 seconds (T6), 30 seconds (T7) and 60 seconds (T8) before sowing.

iii. None soaked seeds (T9) served as control for the germination studies.

This arrangement gave nine treatments which were replicated five times in a CRD format. Twenty-five seeds per treatment were sown in growth medium contained in 50 cm x 40 cm polythene bags; while each bag was filled with the mixture of river sand + saw dust (1:1; w/w) as growth medium. Germination was assessed as follows according to Wightman (1999) and Hartmann *et al.* (2007).

- Days to first germination: (i.e. number of day(s) from sowing that the first germination was recorded – Day after sowing [DAS]) per treatment. The emergence of hypocotyl at the growth medium surface was used as evidence of seed germination throughout the experiments (Awodoyin *et al.,* 2001).
- Days to 50% germination count [DAS]: This is the number of days it took half of the total seeds sown per treatment to germinate (Hartmann *et al.*, 2007). It is an indication of speed of germination.
- Germination count at 7, 21, 35 and 49 DAS, i.e. one to seven weeks after sowing (WAS). This was used to compute Cumulative Germination Percentage (CGP) over the period.
- Germination Percentage (GP) at 49 DAS = the number of germinated seeds from a seed lot /total number of seeds sown, expressed as a percentage.

3.3.2 Experiment 2: Effect of mechanical scarification and soaking in cold water at varying durations on germination of *P. macrophylla* seeds

Experiment 2 followed similar procedure as in experiment 1. The lay out was a 2 x 4 factorial experiment in CRD. Two factors examined were: two methods of mechanical scarification namely no scarification and scarification by nicking (abrasion); and four pre-sowing soaking durations in water (27^oC) for 0, 6, 12 and 24 hours according to Aliero (2004) and Okunlola *et al.* (2011). The eight treatment combinations were replicated five times. Twenty-five seeds per treatment were sown in growth medium comprising of river sand and saw dust mixture (1:1 w/w), contained in 50 cm x 40 cm polythene bags; while each bag was filled with the growth medium. List of the eight treatment combinations are shown in Table 3.4.

Sowing was done in mixture of river sand + sawdust growth medium (1:1 v/v) immediately after various soaking durations. Parameters measured are as listed in experiment 1.

3.3.3 Experiment 3: Effect of chemical scarification on germination of *P. macrophylla* seeds

The treatments comprised of (i) immersion in 96% concentrated tetraoxosulphate (VI) acid [H_2SO_4] for six varying durations of 10 minutes (treatment one – T1), 20 minutes (T2), 30 minutes (T3), 40 minutes (T4), 50 minutes (T5) and 60 minutes (T6) (Aref *et*

Table 3.4 List of treatment combinations for experiment two

Treatment number	Type of pre-sowing treatment combined
Treatment One (T1)	No scarification + no soaking (control)
Two T2	No scarification + 6 hour soaking
Three T3	No scarification + 12 hour soaking
Four T4	No scarification + 24 hour soaking
Five T5	Nicking scarification + no soaking
Six T6	Nicking scarification + 6 hour soaking
Seven T7	Nicking scarification + 12 hour soaking
Eight T8	Nicking scarification + 24 hour soaking

al., 2011; Afshar *et al*., 2014); (ii) soaking in 95% absolute ethanol [C_2H_5OH] for 10 minutes (T7), 20 minutes (T8), 40 minutes (T9) and 60 minutes (T10) (Masamba, 1994; Ren and Tao, 2004; Chadha, 2009). Pre-sowing soaking in cold water for 12 hours served as control (T11) in both chemical treatments. Thus, there were eleven treatments, replicated five times in a CRD. Seeds soaked in H_2SO_4 and C_2H_5OH were stirred in laboratory beakers for uniform contact and copiously washed under running tap water for 10 minutes before sowing in sterilized mixture of river sand + sawdust (1:1 w/w) growth medium. Germination parameters taken are as in experiment 1.

3.4 Study of phenology and rooting hormone effect on marcotting of *P. macrophylla*

The experiments involving marcotting technique were conducted on selected matured tree stands of *P. macrophylla* established in 2002 and located at the mixed tree crops plantation site of FCA Ishiagu, Ebonyi State, Nigeria.

3.4.1. Experiment 4: Response of *Pentaclethra macrophylla* marcots to varying concentrations of NAA and IBA hormones at marcot points

This experiment followed a 3 x 4 factorial experimental layout. Thus, there were three levels of Naphthalene acetic acid (NAA) concentrations (0, 500, 1000 mg/L) and four levels of Indol-3 butyric acid (IBA) concentrations (0, 1000, 2000, 3000 mg/L). This gave twelve treatment combinations replicated three times and laid out in factorial RCBD. The list of treatment combinations are as shown in Table 3.5. Each parent tree used constituted a block/replicate. Thus, there were three (3) tree stands representing the three blocks/replicates. Branches that were 1.0 ± 0.2 cm in diameter were selected for the study. Each branch was girdled at 40 cm length from its shoot bud by removing ring of bark (5 cm wide) to expose the cambial layer (Hartmann *et al*., 2007; Sthapit *et al*., 2016). Appropriate diluted solutions of the various concentrations of the plant growth hormones were applied to the girdled portion of the respective stems (1.0 ± 0.2 cm diameter) that were selected. Thereafter, the girdled portions were covered with moist growth medium held in polythene sheet and tied tightly with twine at its two ends. Mixture of river sand/ saw dust (1:1 v/v) served as growth medium. Parameters assessed included:

- per cent callus formation at eight Weeks After Marcotting [WAM],
- number of roots in successful marcots at 8 WAM;
- root length (cm) in successful marcots at 8 WAM.

3.4.2. Experiment 5: Evaluation of season on rooting ability of *P. macrophylla* marcots in Ishiagu southeast Nigeria

This study was set to span the vegetative and reproductive phases of the plant's phenology in a year (Awodoyin and Olaniyan, 2000; Tchoundjeu *et al*., 2010). The plot was laid out in a Randomised Complete Block Design (RCBD) and replicated three times (i.e. number of trees). Three branches of each tree replicate were marcotted at two-month interval across the year. Branches (1.0 ± 0.2 cm in diameter) were girdled by cutting a 5 cm wide ring of bark at the proximal end. Moistened mixture of river sand and saw dust (1:1; w/w) was tied around the girdled part using polythene sheet. The growth medium held in the polythene sheet around the girdled portion was kept moist by injecting 100 ml of distilled water into each marcot twice a week using hypodermic syringe. Administration of water was increased to four times per week during dry season. At eight weeks after each marcotting operation, the branches were detached from parent tree, untied and assessed for callus formation and adventitious root production, in terms of percentage of callus, number of roots per marcot and root length (cm) per marcot. Callus formation was assessed by visual observation of number of girdled branches that formed callus.

3.5 Experiment 6: Assessment of early growth and nodulation performance of *P. macrophylla* seedlings on soils of contrasting fertility in Southeast Nigeria

In this early growth study of the plant, three local soil types of contrasting fertility and one regular nursery growth medium were collected and used for pot experiment (de Faria *et al.,* 2010; Chagas Junior *et al.,* 2012). The local soil types were: alluvium soil from alluvial plane forest vegetation within vicinity of nearby Ivo River in Ishiagu; sandstone soil from continuously cultivated land and ferruginous sandstone soil from site within the Federal College of Agriculture (FCA) Ishiagu. Nursery growth medium which was made of mixture of local topsoil, compost and river sand in ratio 1:2:3 respectively by volume was used. Therefore, there were four treatments namely:

Table 3.5 List of treatment combinations for experiment four

Treatment number	Plant growth hormones concentrations (mg/L) /combinations
T1 (control)	0 IBA + 0 NAA
T2	0 IBA + 500 NAA
T3	0 IBA + 1000 NAA
T4	1000 IBA + 0 NAA
T5	1000 IBA + 500 NAA
T7	2000 IBA + 0 NAA
T8	2000 IBA + 500 NAA
T9	2000 IBA + 1000 NAA
T10	3000 IBA + 0 NAA
T11	3000 IBA + 500 NAA
T12	3000 IBA + 1000 NAA

IBA = Indol-3 butyric acid; NAA = Naphthalene acetic acid

alluvium soil (T1), marginal sandstone soil (T2), ferruginous sandstone soil (T3) and nursery growth medium (T4); replicated four times and laid out in a completely randomised design. The different soil types and nursery growth medium (35 kg each) were bagged in 50 cm by 40 cm polyethylene bags accordingly. One hundred freshly harvested mature seeds from wild in Ishiagu were sown in nursery tray filled with local topsoil collected from site where matured *P. macrophylla* trees are situated at FCA Ishiagu tree crop plantation. At four weeks after sowing, 20 seedlings were randomly selected and assigned to each of the four treatments which were planted in the medium-filled polyethylene bags. The transplanted seedlings were mulched and watered every other day. Manual weeding and hand picking of insect pests were carried out as the needs arose. Physico-chemical analysis of samples of the different soil types were conducted at Soil laboratory of the National Root Crop Research Institute (NRCRI), Umudike, Abia State; while soil textural class was determined using USDA Soil Classification. Seedlings growth was monitored for six months from the date of sowing. Seedling vigour parameters and nodulation performance for assessment of treatment effects included:

- Plant height (cm) and stem diameter at 2, 4 and 6 months after sowing;
- Seedling sturdiness quotient at 2, 4, and 6 months (Jaenicke, 1999; Ahmadloo *et al*., 2012).

$$\text{Sturdiness quotient (SQ)} = \frac{\text{plant height (cm)}}{\text{stem diameter (mm)}}$$

- Number of leaves at 2, 4 and 6 months;
- Primary root length (cm) at 6 months;
- Number of nodules at 6 months after sowing;
- Seedling dry weight (g) at 6 months.

3.6 Preparation of leaf extracts aqueous solution for experiments 7 and 8

The leaf extracts aqueous solutions were prepared following Daniya *et al.* (2014) procedure with modifications as in Ngonadi (2012). In this experiment, matured leaves of *P. macrophylla* were harvested, shade dried and ground to powdery form. The ground plant materials were then weighted into 100 g, 200 g, 400 g and 800 g, and

soaked separately in 1000 mL of double distilled water in beakers to have 10%, 20%, 40% and 80% (w/v) concentrations respectively. The contents in beakers were thereafter covered with aluminum foils and kept at room temperature for 24 hours. The various concentrations were obtained by filtering the soaked dried leaf materials through muslin cloth and Whatman No. 1 filter paper separately. The extract solutions were stored in refrigerator at 15^{o}C.

3.6.1 Experiment 7: Allelopathic effect of *P. macrophylla* aqueous leaf extracts solution on germination of maize (*Zea mays*) and okra (*Abelmoschus esculentus*) seeds

Experiment seven was conducted to determine potential allelopathic effect of *P. macrophylla* leaf extracts aqueous solution on germination of maize and okra seeds. Seeds of Oba Super-4 maize variety and NHAe47-4 okra variety were obtained from the National Cereal Research Institute (NCRI) Sub-station, Amakama, Umuahia and National Horticultural Research Institute, Mbato Sub-station, Okigwe, Imo state respectively. The treatments for study comprised of five different concentrations of the aqueous leaf extract solution (80%, 40%, 20% and 10% w/v), including water as control (0%). The experiment was laid out in completely randomised design with four replicates. Experimental layout for this study comprised of 20 petri-dishes (for each crop) lined with moistened Whatman No. 1 filter papers, and ten seeds of the crop placed in each petri-dish. Five (5) mL of each treatment concentration was applied to its respective replicates in the petri-dishes daily using hypodermic syringe, while the control received only water accordingly. Germination of test crop seeds in the petri-dishes was observed on daily basis for seven days at laboratory room temperature of 27^{o}C. The protrusion of radicle and plumule was taken as evidence of complete germination. Parameters observed for assessment of treatment effect were: daily germination count for seven days, day to first germination, day to 50 percent germination, total germination percentage at seven days after sowing, seedling sprout length (i.e. sum of plumule and radicle lengths [cm]) and seedling dry weight, i.e. biomass (g) at seven days after sowing.

3.6.2 Experiment 8: Allelopathic effect of *P. macrophylla* aqueous leaf extract solution on early growth of maize (*Z. mays*) and okra (*A. esculentus*) in screenhouse

Experiment eight was performed to determine possible allelopathic effect of *P. macrophylla* aqueous leaf extract solution on early growth of maize and okra young plants according to Fatunbi *et al.* (2009) and Owoseni and Awodoyin (2013). Seeds of maize and okra were sourced from same location as in experiment 7. Local topsoil was collected from Teaching and Research Farm of FCA Ishiagu and filled into each plastic nursery pots (15 cm by 30 cm dimension) with 12 kg of the soil. This experiment followed similar pattern as in experiment 7 with five treatments (namely 80%, 40%, 20%, 10% and 0% concentrations of the aqueous leaf extract solution) and four replicates which were laid out in completely randomized design. Five seeds of maize and okra were sown separately per pot; and supplied with 200 ml of water daily for two weeks before thinning the emerged seedlings to two stands per pot. Thereafter, 200 ml of each treatment concentration of the aqueous leaf extract solutions were administered to the seedlings from two Week After Sowing (2 WAS) up to 8 WAS, during which the effect of the treatment applied were observed. Parameters monitored included: plant height (cm), stem diameter (mm), and number of leaves at 2, 4, and 6 weeks after treatment application (WAT); root length (cm) and seedling dry weight (g) at 6 WAT.

3.7 Data analysis

Data collected from the field and nursery experiments were subjected to analysis of variance (ANOVA), while mean separations were carried out using Fisher's Least Significant Difference (LSD) at 5% probability level. Descriptive statistics were also used where appropriate.

CHAPTER FOUR

RESULTS

4.1 Field survey 1: Ethnobotanical survey of *Pentaclethra macrophylla* in Southeastern (SE) Nigeria

4.1.1. Demographics of respondents

The survey showed a wealth of knowledge among farmers concerning the African oil bean (*Pentaclethra macrophylla* Benth.) status in the Southeast Nigeria agroecosystem. A total of 309 farmers completed the questionnaires during the investigation across the three selected states of Abia (157 persons), Ebonyi (56 persons) and Imo (96 persons). The respondents were made up of 28.8% adult females and 71.2% adult males (Table 4.1). These respondents cut across 75 ADP extension circles of the three states, different communities, socio economic classes, age groups, educational levels, marital status and occupations. Table 4.1 also showed that majority of the respondents belonged to the middle and upper age groups of 41 – 50 years (33.2%), 51 – 60 years (30.9%) and 61+ years (19.3%). Relatively fewer respondents were reported for the younger age groups of 21 – 30 years (6.6%) and 31 – 40 years (10.0%). Up to 73% of the respondents were married (219 persons), while the remaining 27% comprised of single individuals who had never married (7.0%), widow/widower (18.3%) and divorced/separated (1.7%).

4.1.2 Socio-economic characteristics of surveyed respondents

Educational background of the individual respondent showed that most of them had some levels of formal trainings (Table 4.2). The level of education ranged from respondents with primary education (45.3%), secondary education (29.9%) to those with tertiary education (9.4%); while only 15.4% of the respondents indicated that they did not possess any formal education. Concerning the major occupations of the people, results (Table 4.2) indicated that 64.2% of the respondents across the three surveyed states were mostly farmers, while the remaining were traders (24.1%),

Table 4.1 Demographics of surveyed respondents in Southeast Nigeria

Parameters		Abia (%)	Ebonyi (%)	Imo (%)	Total (n)	Percent (%)
Sex :	Male	71.3	66.1	74.0	220	71.2
	Female	28.7	33.9	26.0	89	28.8 (n =309)
Age class (Year):						
	21 – 30	7.2	12.5	2.2	20	6.6
	31 – 40	11.1	23.2	0.0	30	10.0
	41 – 50	28.8	35.7	39.1	100	33.2
	51 – 60	30.7	19.6	38.0	93	30.9
	61+	22.2	8.9	20.7	58	19.3 (n=301)
Marital status:	Single	4.5	20.8	4.2	21	7.0
	Married	75.2	58.3	76.8	219	73.0
	Widow	19.7	18.8	15.8	55	18.3
	Divorced/Separated	0.6	2.1	3.2	5	1.7 (n = 300)

Source: Field survey (2013).

Table 4.2 Socioeconomic characteristics of surveyed respondents in Southeast Nigeria

Parameters	Abia (%)	Ebonyi (%)	Imo (%)	Total (n)	Percent (%)
Educational level:					
No formal	18.3	16.1	10.1	46	15.4
Primary	49.7	37.5	42.7	135	45.3
Secondary	28.1	30.4	36.6	89	29.9
Tertiary	3.9	16.0	1.6	28	9.4
Sub-total:	153	56	89	298	
Major occupation:					
Trading	25.2	25.0	21.7	72	24.1
Civil service	6.0	5.4	7.6	19	6.4
Farming	64.9	57.1	67.4	192	64.2
Artisan	3.3	5.4	3.3	11	3.7
Teaching	0.6	7.1	0.0	5	1.7
Sub-total:	151	56	92	299	
Minor job:					
Farming	19.3	31.3	27.6	24	23.5
Trading	68.4	62.5	62.1	67	65.7
Artisan	12.3	6.2	10.3	11	10.8
Sub-total:	57	16	29	102	

Source: Field survey (2013).

civil servants (6.4%), artisans (3.7%) and teachers (1.7%). However, the results also showed that among those respondents that do not have farming as their major occupation, most of them (up to 65.7%) had trading as part time activity, followed by farming (23.5%) and artisan activities (10.8%).

4.1.3 Ownership system and species population distribution among respondents in Abia, Ebonyi and Imo states of Nigeria

The ethnobotanical study also sought to know the pattern of prevailing ownership system of African oil bean tree in SE agroecological zone of Nigeria (Table 4.3). It was discovered that existing African oil bean tree stands were either protected volunteer stands found growing in farmlands/fallow lands (43.9%), or inherited property from parents (38.6%). Few others were bought along with land upon transfer of ownership (9.2%) and/or were deliberately planted by the owner (8.3%). The frequency of African oil bean tree population distribution among ADP contact farmers interviewed (Table 4.4) showed that in Abia state 53.8% of the respondents owned at least one to five stands of the species in their distant farms or home gardens, with a mean of 6.9±2.1 tree stands. Results from Ebonyi state ADP zones indicated that 80.4% of the respondents there had at least one to five stands of African oil bean with a mean of 11.3±3.1 tree stands. While in Imo state, an appreciable higher percent of the respondents (85.37%) had at least one to five African oil bean trees in their various farms/home gardens, with a mean of 9.9±5.7 tree stands. On the average therefore, 73.2% of the entire interviewed respondents had at least one or more stand of African oil bean tree with mean of 9.4±8.3 tree stands across the agroecological zones.

4.1.4 Some ethnobotanical values of *P. macrophylla* among the respondents

Information on the various specific uses of African oil bean tree resources among the people of SE Nigeria were elicited from the respondents and collated. Highlights of the species traditional uses are stated below.

Seed: Seeds are processed into ‘ugba’ (i.e. cook shredded seeds that have been fermented) and used as spices in making soup, yam porridges, pot herbs and ugba salads. The ugba salad, otherwise known as African salad, is essentially made up of ‘ugba’ and shredded cassava (tapioca). Other condiments used include indigenous

Table 4.3 Frequency distribution of different ownership status of African oil bean tree in Southeastern Nigeria

Parameter	Abia (%)	Ebonyi (%)	Imo (%)	Total† (n)	Percent (%)
Inherited from parents	33.5	40.4	45.9	130	38.6
Bought with own land	7.4	9.6	11.9	31	9.2
Protected volunteer stands	48.9	38.5	38.5	148	43.9
Planted by self	10.2	11.5	3.7	28	8.3
Sub-total (n)	176	52	109	(n =337)	

Source: Field survey (2013); † Multi choice question.

Table 4.4 Frequency distribution of number of African oil bean trees owned by ADP contact farmers in Southeastern Nigeria

	ADP Contact farmers			
Number of tree stands owned	Abia	Ebonyi	Imo	Aggregate mean of States
1 – 5	48.2	42.2	37.8	
6 – 10	24.1	26.7	18.3	
11 – 15	15.7	8.9	13.4	
16 – 20	7.2	8.9	19.5	
21 – 25	2.4	2.2	6.1	
26 – 30	0.0	2.2	0.0	
31+	2.4	8.9	4.9	
Mean number of tree stand per farmer (±SD)	6.93±2.1	11.27±8.1	9.92±5.7	9.37±8.3
% of contact farmers owning tree stands	53.8	80.4	85.4	73.2

ADP = Agricultural Development Programme;

Sub-total (n) for States: 83 (Abia), 45 (Ebonyi), 82 (Imo); (Total n =210)

garden egg species (*Solanum gilo, S. macrocarpon*) fruits and its edible sliced leaves or sliced leaves of 'utazi' (Igbo) (*Gongronema latifolium*) or 'Ukazi' (Igbo) *Gnetum africanum*, hot pepper (*Capsicum annuum*), African nutmeg (*Monodora myristic*a) and some palm oil.

The ugba salad, most times, constitutes an integral presentation as light refreshment during traditional marriage ceremony, annual new yam festival, end of year special meetings of community and kindreds among the Igbos of Nigeria. It is also regularly sold at bars and restaurants where customers take it along with their drinks at relaxation time.

Leaf: Leaves serve as mulch materials, livestock fodders and in preparation of herbal medicinal concoction for treatment of malaria.

Pod peelings (wastes): serve as fuel woods for domestic cooking (Plate 4.1)

Timber: serves as structural materials for building construction, fence establishment, and staking on farm. The species timber is also used in carving of kitchen wooden stool, pestle, mortar, and other cooking utensils. In addition, the timber is known to yield high quality charcoal for domestic cooking and commercial use by cottage bakery industry.

Whole tree: serves as nurse/shade tree in the nursery and home gardens, and for road side planting as avenue trees. Some elderly people among the respondents reported that the road side planting with African oil bean tree used to be a community initiative in the olden days, and such trees were mostly owned and managed by the community.

Roots/barks: were reported to be of medicinal value in the treatment of some stomach ailments.

Flowers: Some respondents stated that species flowers yield good tasty nectars which are often relished by children. They also reported that the tree attracts lots of bees during its seasonal bloom.

Revenue generation: *Pentaclethra macrophylla* evidently showed bimodal distribution of seed production in a year, namely period from October to December and March to April. During these peak seasons of harvest and sales of African oil bean seeds at the local markets, a measure of local container scale (measuring 420 cm^3, shown in Plate 4.2) is sold between one thousand five hundred naira and three thousand naira (₦1500 – ₦3000 [= US$ 9.2 – US$ 18.4]) as at 2013/2014 cropping

Plate 4.1 The dry pods peels of *Pentaclethra macrophylla* Benth. useful as fuel wood

Plate 4.2 Local container scale (420 cm^3) used in the sale of African oil bean seeds in SE Nigeria markets; contents may weigh between 3 kg and 3.6 kg of seeds per unit volume of 420 cm^3

season depending on location, whether rural, semi-urban or urban markets. By weight, a full measure of the container scale may contain 3 - 3.6 kg of seeds. When processed into real shredded 'ugba' that is ready for use, the price for same unit of measurement appreciates greatly for a brief period, even though it does not store well for long (i.e. brief shelf life).

Table 4.5 displayed the revenue generation potentials of African oil bean tree seed production in the three southeast states of Nigeria. From the results, mean values of three years market survey (2013 – 2015) of the species seeds production/sales distribution indicated that a measure of the local scale (Plate 4.2) was sold two thousand naira (₦2000) for 3.052 kg seeds; i.e. equivalent of six hundred and fifty five naira (₦655) per kilogram of seeds.

In Abia state, the ADP contact farmers reported that a mature fruiting African oil bean tree could yield between 7- 10 measures of the local scale bucket, or equivalent of 21.4 – 30.5 kg of seeds per tree; and an average of 24.4 kg seeds valued at sixteen thousand naira (₦16,000) per tree. While in Ebonyi and Imo states, the farmers indicated range of 9.2 – 21.4 kg and 12.2 - 30.5 kg seeds per tree respectively, could be harvested within a season. These indications showed estimated revenue generation per tree as twelve thousand naira (₦12,000) and fourteen thousand naira (₦14,000) respectively for the two states. Therefore, mean seed yield per tree per season across the three states (Abia, Ebonyi and Imo) ranged from 3 – 10 measures of the local scale bucket or equivalent of 9.2 – 30.5 kg seeds per tree and an average of 21.4 kg seeds for estimated revenue of fourteen thousand naira (₦14,000) per tree. Moreover, considering that there are two peak seasons of harvest and collection of African oil bean seeds in a year, according to the survey reports, the farmers in this region may be harvesting much more seeds per tree, and invariably making more revenues than indicated in Table 4.5.

4.1.5 Challenges and prospects of enhanced conservation and domestication of *P. macrophylla*

The ethnobotanical survey showed some underlisted challenges confronting sustainable use and management of *P. macrophylla* in SE Nigeria.

Table 4.5 Seed production and revenue generation potential per tree of *P. macrophylla* in SE Nigeria

State	Seed yield per tree per season			Price per kg (₦)*	Estimated revenue (₦)/tree
	Local scale 420 cm^3 bucket	Equivalent of weight (kg)	Average weight (kg)		
Abia	7–10 measures	21.4-30.5	8 measures; (24.4 kg)	655	16000
Ebonyi	3–7 measures	9.2-21.4	6 measures; (18.3 kg)	655	12000
Imo	4–10 measures	12.2-30.5	7 measures; (21.4 kg)	655	14000
Range/ mean	3-10 measures	9.2-30.5	7 measures (21.4±2.49 kg)	655	14000

*Mean value of three years market survey (2013 – 2015) showed 420 cm^3 local scale sold @ ₦2000 (= US$ 12.27) for 3.052 kg seeds; i.e. ₦655 (=US$ 4.02) per kg. ₦ = Naira. US $ 1= ₦ 163 in 2014.

- Depletion of African oil bean trees in the wild due to deforestation and charcoal production,
- Low rate of deliberate replanting among the farmers,
- Most harvests of the species come from protected wild tree stands and volunteer stands in farmlands,
- Difficulty in gathering seeds upon natural shattering and dispersal,
- Loss of seeds through explosive dispersal by dry mature pods,
- Drudgery of manual processing method and non-availability of mechanized processing option,
- Storage pest and disease challenge,
- From technical view point, there are challenges of seed dormancy and recalcitrance which can slow down natural regeneration rate.

4.1.6 SWOT analysis of the challenges and prospects of enhanced conservation and domestication of *P. macrophylla* in Southeastern Nigeria

Strength Weakness Opportunity Threat (SWOT) analysis was used to assess strategies and priorities for enhanced conservation and domestication of *P. macrophylla* genetic resources in SE Nigeria in order to make the species resources more economically and ecologically sustainable. Favourable factors that can be harnessed as inherent strength of *P. macrophylla* genetic resources for conservation development include: the species has known ethnomedicine values, high nutritional food value of seeds and its products, proven viable sources of revenue generation from its produce/products, guaranteed local and regional markets for produce (Table 4.6).

On the other hand, existing opportunities in the sub-region waiting to be tapped into for the species conservation research and development (R&D) needs include: recognition as suitable agroforestry multipurpose tree for sub-Saharan Africa ecosystem, recent recognition of species numerous usefulness and potentials by ICRAF and PROTA in addition to the need for its conservation, as well as potential diversification of its products and markets in the sub-region. These positive attributes

(both external and internal factors) are already prevailing conditions, which can only be consolidated and optimized as strength, while the opportunities explored and exploited for sustainable resource utilization of the species for benefit of the people and environment. However, serious challenges threatening *P. macrophylla* genetic resources in the present context as highlighted (Table 4.6) should not be ignored.

Such negative factors as over exploitation of species seeds for direct human consumption, unregulated felling of whole tree for timber and charcoal, absence of deliberate replanting scheme and subsequent depletion of tree stands in the wild as well as near absence of improved propagation methods could impede efforts being made in the management of the species for sustainable use and conservation; or yet speed off further depletion of the species stands in the remaining areas of natural distribution. Nonetheless, the limiting factors can be avoided at most or their impacts minimized where possible.

The SWOT analysis was thereafter translated into priority actions considered strategic for enhanced conservation and sustainable use of *P. macrophylla* in the sub-region. The following are considered to be key priority areas at present:

1. Renew patronage of research and industrial interests/investments considering numerous known economic, ecological and socio-cultural values.
2. Development of improved nursery techniques for mass production of seedlings for planned replanting programme on farms, forest plantations and as amenity trees in rural and semi-urban landscapes.
3. Since seed dormancy and recalcitrance may affect mass seedling production, appropriate vegetative propagation technique has to be developed to encourage farmers in the replanting of the species in the agroecosystem.
4. Sampling, collection and selection of landraces with less pod shattering tendency that will guarantee enhanced seed gathering at harvest and minimal loss.
5. Diversification of the species value added products and value chain.

Table 4.6 SWOT analysis of *Pentaclethra macrophylla* genetic resources development in Southeastern Nigeria

Internal Factors		External Factors	
Strength	Weakness	Opportunity	Threat
- Area of natural distribution - Local preferences/ consumption of produce - Cultural value among the people - Available local/regional markets for produce - Form part of the traditional home garden farming system in the region - Viable source of revenue generation for low income rural dweller/farmer - High nutritional value of edible portion (seed) - Known medicinal values	- Neglected plant status - Harvest still mostly from wild stands - Rudimentary harvest, storage and handling techniques - Recalcitrant seed storage behaviour - Poor seedling production due to dormancy - Near absence of improved propagation method - Information, poorly documented or in grey literatures	- Potential demands for germplasms and products - Recent recognition of importance by NARs and PROTA - Potential diversification of products and markets - Satisfies need for crop diversification - Recognition as suitable agroforestry MPT species for the sub-region	- Over exploitation of species for seed, timber and charcoal - Depleting tree stands in the wild - Lack of deliberate replanting scheme - Low patronage of research/ industrial interest - Loss of essential plant genetic resources

4.2. Field survey 2: Floristic enumeration of African oil bean tree (*P. macrophylla*) in Abia, Ebonyi and Imo States Southeastern Nigeria

4.2.1. Tree species composition, species richness (*S*) and distribution

Field enumerations of *P. macrophylla* and other tree species in the selected three states revealed 95 tree species that belong to 30 families in both farms and fallow lands (Table 4.7). The families *Malvaceae* (6), *Rutaceae* (6), *Moraceae* (8) and *Fabaceae* (21) had highest number of species. Concerning tree species richness (*S*) per hectare in the study areas, the result showed a range from 6 – 8 species per hectare, with higher species richness recorded on farm lands (7 species/ha) than fallow lands (6 species/ha) in the states (Table 4.8).

On state aggregate basis, Imo state had more biologically diverse (tree species rich) agroecosystem on both farm lands (8 species/ha) and fallow lands (8 species/ha) than Abia and Ebonyi states which had less than eight species per hectare on either land use system (Table 4.8).

Abia state had highest number of enumerated species on both land use systems (57 and 47 species for farms and fallow lands respectively) (Table 4.9a), followed by Imo state which had 41 and 40 species respectively (Table 4.9b); while more northerly derived savanna Ebonyi state had 33 and 26 species for farms and fallows, respectively (Table 4.9c). Seven tree species including *P. macrophylla* were found common on both farms and fallow lands in the three states. The common tree species were *Dialium guineense* (velvet tamarind), *Elaeis guineensis* (oil palm), *Gambeya albida* (African star apple), *Irvingia gabonensis* (Bush mango), *Mangifera indica* (mango), *Nauclea diderrichii* (‘uburu’) as well as *Pentaclethra macrophylla* (African oil bean).

The three most abundant tree species based on the RIVs per state land uses included, in Abia state: *Elaeis guineensis* (32.0% farms), *P. macrophylla* (8.7% fallows), and *Hevea brasiliensis* (6.9% fallows) (Table 4.9a); while in Ebonyi state these comprised *Elaeis guineensis* (25.4% farms), *Gmelina arborea* (19.4 fallows), and *Berlinia grandiflora* (9.5% fallows) (Table 4.9b). Also, in Imo state, *Elaeis guineensis* (36.0% fallows), *P. macrophylla* (10.7% fallows) and *Treculia africana* (8.4% fallows)

Table 4.7 List of tree species composition on selected farms and fallow lands in Abia, Ebonyi and Imo States of southeastern Nigeria

S/no	Taxonomic grouping † Botanical family	Species composition
1	**ANACARDIACEAE** (4 spp)	*Anacardium occidentale* Linn.
		Mangifera indica Linn.
		Spondias dulcis Sol. Ex G. Forst.
		Spondias mombin Linn.
2	**ANNONACEAE** (4 spp)	*Annona muricata* L.
		Cleistopholis patens (Benth.) Engl. & Diels
		Dennetia tripetata Bak. F.
		Xylopia aethiopica (Dunal) A. Rich
3	**APOCYNACEAE** (3 spp)	*Alstonia boonei* D. Wild.
		Funtumia africana (Benth.) Stapf.
		F. elastica (Preuss) Stapf.
4	**ARECACEAE** (4 spp)	*Cocos nucifera* L.
		Elaeis guineensis Jacq.
		Phoenix reclinata Jacq.
		Raphia hookeri Mann & Wendland
5	**ASPARAGACEAE** (1 spp)	*Dracaena arborea* (Willd) Link
6	**BIGNONIACEAE** (2 spp)	*Crescentia cujete* L.
		Newbouldia laevis Seem ex. Bureau
7	**BOMBACACEAE** (1 spp)	*Bombax buonopocense* P. Beauv.
8	**BURSERACEAE** (2 spp)	*Canarium schweinfurthii* Engl.
		Dacryodes edulis (G. Don)H.J. Lam
9	**CHRYSOBALANACEAE**(2spp)	*Dactyledenia lohmbachii* (Engl) Prance & F. White
		Acioa barteri (Hook.f. ex Oliv.) Engl.
10	**CLUSIACEAE** (2 spp)	*Garcenia kola* Heckel
		Mammea africana Sabine
11	**COMBRETACEAE** (1 spp)	*Terminalia glaucescens* Planch ex. Benth.
12	**CUPRESSACEAE** (1 spp)	*Cupressus sempervirens* L.
13	**EBENACEAE** (1 spp)	*Diospyros mombuttensis* Gürke
14	**EUPHORBIACEAE** (3 spp)	*Bridelia artroviridis* Mull Arg.
		Hevea brasiliensis (A. Juss) Mull Arg.
		Maesobotrya barteri (Baill) Hutch
15	**FABACEAE** (21 spp)	*Afzelia africana* Sm. ex Pers.
		Albizia adianthifolia (Schumach) W. Wight
		Amphimas pterocarpoides Harms
		Anthonotha macrophylla P. Beauv.
		Baphia nitida Lodd.
		Berlinia grandiflora (Vahl) Hutch & Dalziel
		Brachystergia eurycoma Harms
		Daneillia ogea (Harms) Rolfe ex. Holland
		Detarium microcarpum Guill & Perr.
		Dialium guineense Willd.
		Erythrina senegalensis A. DC.
		Erythrophleum ivorense A. Chev.

		E. suaveolense (Guill & Perr) Brenan
		Gossweilerodendron balsamiferum (Vermoesen) Harms
		Parkia bicolor A. Chev.
		P. biglobosa (Jacq) R. Br. ex G. Don
		Pterocarpus osun Craib
		P. santalinoides DC.
		P. soyauxii Taub.
		Pentaclethra macrophylla Benth.
		Tetrapleura tetraptera (Schumach & Thonn.) Taub.
16	**IRVINGIACEAE** (2 spp)	*Irvingia gabonensis* (Auby-Lecomte ex O'Ronke) Baill
		I. wombolu Vermoesen
17	**LAMIACEAE** (2 spp)	*Gmelina arborea* Roxb.
		Vitex doniana Sweet
18	**LAURACEAE** (1 spp)	*Persea americana* Mill.
19	**MALVACEAE** (6 spp)	*Cola acuminata* (P.Beauv) Schott & Endl.
		C. lepidota Schum.
		C. nitida (Vent) Schott & Endl.
		C. pachycarpa Schum.
		Eribroma oblonga (Mast.) M. Bodard ex Hallè
		Hildegardia barteri (Mast.) Kosterm
20	**MELIACEAE** (3 spp)	*Azadirachta indica* A. Juss.
		Carapa procera DC.
		Entandrophragma cylindricum (Sprague) Sprague
21	**MORACEAE** (8 spp)	*Antiaris toxicaria* Lesch.
		Artocarpus altilis (Parkinson) Fosberg
		Ficus exasperata Vahl.
		F. saussureana C. DC.
		F. vogeliana (Miq.) Miq.
		Musanga cecropioides R. Br.
		Melicia excelsa (Welw) C.C. Berg
		Treculia africana Decne
22	**MORINGACEAE** (1 spp)	*Moringa oleifera* Lam.
23	**MYRISTICACEAE** (2 spp)	*Pycnanthus angolensis* (Welw) Warb.
		Staudtra stipitata Warb.
24	**MYRTACEAE** (3 spp)	*Psidium guajava* L.
		Syzygium malaccense (L.) Merr. & Perry
		Eucalyptus camaldulensis Dehnh.
25	**RUBIACEAE** (2 spp)	*Nauclea diderrichii* (De Wild & T. Durand) Merr.
		Sarcocephalus pobeguinii Pobég. ex Pellegr.
26	**RUTACEAE** (6 spp)	*Citrus aurantifolia* (Christm. & Panzer) Swingle
		C. limon (L.) Burm F.
		C. x *paradisi* Macfad.
		C. reticulata Blanco
		C. sinensis (L.) Osbeck
		Zanthoxylum gilletii (DeWild) P.G. Waterman
27	**SAPINDACEAE** (2 spp)	*Blighia sapida* K.D. Koenig

		Eriocoelum macrocarpum Gilg ex Radlk.
28	**SAPOTACEAE** (3 spp)	*Gambeya albida* (G. Don.) Aubrév. & Pellegr.
		Manikara obovota (Sabine & G. Don.) J.H. Hemsl.
		Vitellaria paradoxa C.F. Gaertn.
29	**SIMAROUBACEAE** (1 species)	*Hannoa klaineana* Pierre & Engl.
30	**ZAMIACEAE** (1 species)	*Encephalartos barteri* Carruth. & Miq.

Number of botanical family = 30 **Number of species** = 95

† Botanical families, genus and species names were verified for current nomenclature from Keay (1989), Angiosperm Phylogeny Group III (2009), PROTA (2010) and Beech *et al*. (2017).

Table 4.8 Tree species richness (*S*) by state and land use system in three states agroecosystems of Southeastern Nigeria

Location/land use system	Tree species richness/hectare
Abia - farm lands	7
Abia – fallow lands	6
Ebonyi – farm lands	7
Ebonyi – fallow lands	7
Imo – farm lands	8
Imo – fallow lands	8
Abia state	7
Ebonyi state	7
Imo state	8
Farm lands	7
Fallow lands	6
Mean	7

ranked the three most abundant tree species by their RIVs (Table 4.9c).

With regard to *P. macrophylla* RIVs, Imo state had highest RIV of 10.7% for farms and 10.6% for fallow lands (Table 4.9c). In fact, apart from *Elaeis guineensis* that was most abundant and widely distributed economic species on both farms and fallow lands in the three states, *P. macrophylla* proved to be the second most common tree species found in the agroecosystems of these states (Tables 4.9a - c). However, unlike *E. guineensis* that had higher RIVs on farms than fallow lands, the *P. macrophylla* had higher RIVs on fallow lands than farms across the states

4.2.2 Density and pattern of distribution of *P. macrophylla* population

4.2.2.1 Tree stands density

Density of mature *P. macrophylla* trees and its saplings showed that they were unevenly and sparsely distributed across the states and land use system (Table 4.10). Tree densities in study areas ranged from 1.0 tree/ha on farm in Abia state to 3.8 trees/ha on fallows and farms in Imo state. When aggregated on state basis, Abia state had the least mean tree stands of *P. macrphylla* per hectare (1.5 trees/ha); while Ebonyi state and Imo state had 2.7 trees/ha and 3.8 trees/ha respectively. From the results, farming system in Imo state seemed to encourage retention of more *P. macrophylla* tree stands as well as other tree species (richness) in the agroecosystem than the two other states per unit area of enumeration (Table 4.10). Comparison of the two land use systems studied indicated that fallow lands had 2.9 trees/ha that was more than farm lands with 2.4 trees/ha.

4.2.2.2 Sapling density

Sapling densities were generally low, which ranged from 0.3 and 0.4 stand per hectare on farms in Ebonyi and Abia states respectively, to 1.5 – 1.8 stands per hectare on fallow lands in Imo and Ebonyi states respectively (Table 4.10). State mean sapling density still indicated low population density of *P. macrophylla*, with Abia state having less than one stand per hectare; while Ebonyi and Imo states had marginally higher 1.1 and 1.5 stands per hectare respectively. On fallow land sites, mean sapling density showed twice more number of saplings (1.4 stands/ha) than there were in farm lands (0.7 stand/ha) across the states.

Table 4.9a Relative Density (RD), Relative Frequency (RF) and Relative Importance Value (RIV) of tree species composition on selected agroecosystems in Abia State of southeastern Nigeria

		Farms			Fallows		
S/no	Tree species	RD	RF	RIV	RD	RF	RIV
1	*Acioa barteri*	0.3	0.7	0.5			
2	*Amphimas pterocarpoides*	0.3	0.4	0.4			
3	*Anacardium occidentale*	0.3	2.2	1.3	0.6	2.3	1.5
4	*Annona muricata*	1.0	2.6	1.8	0.6	2.3	1.5
5	*Anthonotha macrophylla*	0.3	0.4	0.4			
6	*Antiaris toxicaria*	0.3	0.4	0.4	0.3	0.9	0.6
7	*Artocarpus altilis*				0.3	0.5	0.4
8	*Baphia nitida*	0.3	0.4	0.4	0.3	0.5	0.4
9	*Berlinia grandiflora*	0.3	0.4	0.4	0.3	0.9	0.6
10	*Blighia sapida*	0.3	0.4	0.4			
11	*Bombax buonopocense*				0.6	0.5	0.6
12	*Brachystergia eurycoma*	0.3	0.4	0.4			
13	*Canarium schweinfurthii*	0.3	0.4	0.4			
14	*Citrus limon*				0.3	0.5	0.4
15	*Citrus aurantifolia*	0.3	0.4	0.4			
16	*Citrus reticulata*				0.3	0.9	0.6
17	*Citrus sinensis*	1.3	2.6	2.0	0.3	1.4	0.9
18	*Cocos nucifera*	2.3	4.4	3.4	1.2	2.3	1.8
19	*Cola acuminate*	0.3	0.7	0.5			
20	*Cola lepidota*	1.0	2.2	1.6	0.3	0.5	0.4
21	*Cola nitida*	1.9	3.0	2.5	0.9	3.7	2.3
22	*Cola pachycarpa*	0.3	0.4	0.4	0.6	0.9	0.8
23	*Crescentia cujete*	0.3	0.4	0.4	0.3	0.5	0.4
24	*Cupressus sempervirens*	0.3	0.4	0.4			
25	*Dacryodes edulis*	3.2	7.0	5.1	1.2	3.2	2.2
26	*Dactyledenia lohmbachii*	0.3	0.7	0.5	0.9	0.9	0.9
27	*Dennetia tripetata*	1.6	0.7	1.2	0.3	0.9	0.6
28	*Detarium microcarpum*	0.3	0.4	0.4			
29	*Dialium guineense*	2.9	3.7	3.3	6.2	5.2	5.7
30	*Dracaena arborea*	4.2	3.3	3.8	3.2	4.1	3.7
31	*Elaeis guineensis*	49.2	13.0	31.1	49.3	14.7	32.0
32	*Encephalartos barteri*	0.3	0.4	0.4			
33	*Erythrophleum ivorense*	0.3	0.4	0.4			
34	*Erythrophleum suaveolense*				0.3	0.5	0.4
35	*Eucalyptus camaldulensis*	0.3	0.4	0.4			
36	*Ficus exasperata*	0.3	0.7	0.5			
37	*Gambeya albida*	0.6	2.6	1.6	0.6	1.8	1.2
38	*Garcenia kola*	0.3	0.7	0.5	0.3	0.9	0.6
39	*Gmelina arborea*	0.3	0.4	0.4			
40	*Gossweilerodendron balsamiferum*	0.3	0.4	0.4	0.3	0.9	0.6

41	*Hannoa klaineana*	0.3	0.7	0.5	0.3	0.5	0.4
42	*Hevea brasiliensis*	0.3	1.5	0.9	12.0	1.8	6.9
43	*Irvingia gabonensis*	1.0	0.4	0.4	0.6	1.4	1.0
44	*Irvingia wombolu*	0.3	0.4	0.4	0.3	0.9	0.6
45	*Maesobotrya barteri*	0.3	0.4	0.4	0.3	1.8	1.1
46	*Mangifera indica*	1.9	5.9	3.9	1.5	5.2	3.4
47	*Melicia excelsa*	0.3	0.4	0.4	0.6	2.3	1.5
48	*Musanga cecropioides*	0.3	0.7	0.5	0.3	0.9	0.6
49	*Nauclea diderrichii*	0.6	0.5	1.1	0.3	0.9	0.6
50	*Newbouldia laevis*	2.3	1.1	1.7	0.3	0.9	0.6
51	*Pentaclethra macrophylla*	3.2	5.6	4.4	5.9	11.5	8.7
52	*Persea Americana*	1.6	4.8	3.2	1.2	3.2	2.2
53	*Psidium guajava*	2.3	2.6	2.5	1.5	3.7	2.6
54	*Pterocarpus santalinoides*	0.6	0.7	0.7	0.3	0.5	0.4
55	*Pterocarpus soyauxii*	2.9	3.7	3.3	1.8	2.3	2.1
56	*Raphia hookeri*	2.3	2.6	2.5	0.9	1.8	1.4
57	*Sarcocephalus pobeguinii*	0.3	0.7	0.5			
58	*Spondias dulcis*	0.3	0.7	0.5	0.3	1.4	0.9
59	*Spondias mombin*	0.6	1.5	1.1			
60	*Staudtra stipitate*				0.3	0.5	0.4
61	*Syzygium malaccense*	0.3	1.5	0.9	0.3	0.9	0.6
62	*Treculia africana*	1.0	2.2	1.6	0.6	1.4	1.0
63	*Vitex doniana*	0.3	0.4	0.4	0.6	2.3	1.5
64	*Xylopia aethiopica*				0.3	1.8	1.1
Number of species:				**57**			**47**

† Botanical families, genus and species names were verified for current nomenclature from Keay (1989), Angiosperm Phylogeny Group III (2009), PROTA (2010) and Beech *et al*. (2017).

Table 4.9b Relative Density (RD), Relative Frequency (RF) and Relative Importance Value (RIV) of tree species composition on selected agroecosystems in Ebonyi State of southeastern Nigeria

		Farms			Fallows		
S/no	Tree species	RD	RF	RIV	RD	RF	RIV
1	*Afzelia africana*	2.1	4.1	3.1	0.5	3.8	2.2
2	*Anacardium occidentale*	6.9	4.1	5.5	8.0	5.0	6.5
3	*Annona muricata*	2.6	1.3	2.0			
4	*Azadirachta indica*				0.5	2.5	1.5
5	*Berlinia grandiflora*				15.1	3.8	9.5
6	*Brachystergia eurycoma*	3.7	2.7	3.2	0.8	2.5	1.7
7	*Bridelia artroviridis*				0.2	1.2	0.7
8	*Canarium schweinfurthii*	0.3	1.3	0.8			
9	*Cocos nucifera*	0.4	1.3	1.2			
10	*Cola acuminate*	0.1	1.3	0.8			
11	*Dacryodes edulis*				0.3	1.2	0.8
12	*Dactyledenia lohmbachii*	0.3	1.3	0.8			
13	*Daneillia ogea*	0.1	1.3	0.8			
14	*Dialium guineense*	0.5	2.7	1.6	0.3	1.2	0.8
15	*Diospyros mombuttensis*	0.3	1.3	0.8			
16	*Dracaena arborea*	1.1	2.7	1.9			
17	*Elaeis guineensis*	37.3	13.5	25.4	25.0	12.5	18.8
18	*Eriocoelum macrocarpum*				1.4	1.2	1.3
19	*Erythrina senegalensis*	0.3	1.3	0.8	0.2	1.2	0.7
20	*Funtumia elastica*	0.3	1.3	0.8			
21	*Gambeya albida*	0.3	1.3	0.8	0.3	2.5	1.4
22	*Gmelina arborea*	6.1	9.5	7.8	28.7	10.0	19.4
23	*Gossweilerodendron balsamiferum*	10.3	6.8	8.6	3.6	3.8	3.7
24	*Hildegardia barteri*	0.3	1.3	1.1	0.2	1.2	0.7
25	*Irvingia gabonensis*	3.7	4.1	3.9	2.9	6.3	4.6
26	*Mangifera indica*	2.1	8.1	5.1	2.0	10.0	6.0
27	*Manikara obovota*	0.5	1.3	0.9			
28	*Melicia excelsa*	0.3	1.3	0.8			
29	*Moringa oleifera*				0.2	1.2	0.7
30	*Nauclea diderrichii*	0.3	1.3	0.8	1.2	3.8	2.5
31	*Parkia biglobosa*	0.8	4.1	2.5	0.5	2.5	1.5
32	*Pentaclethra macrophylla*	6.6	8.1	7.4	4.4	7.5	6.0
33	*Persea Americana*				0.3	2.5	1.4
34	*Phoenix reclinata*	0.3	1.3	0.8	0.2	1.2	0.7
35	*Psidium guajava*				0.2	1.2	0.7
36	*Pterocarpus santalinoides*	3.7	1.3	2.5			
37	*Pterocarpus soyauxii*				0.6	1.2	0.9

38	*Spondias mombin*	0.3	1.3	0.8			
39	*Tetrapleura tetraptera*	0.3	1.3	0.8			
40	*Treculia africana*	1.6	2.7	2.2			
41	*Vitellaria paradoxa*	0.3	1.3	0.8			
42	*Vitex doniana*	4.8	2.7	3.8	1.9	6.3	4.1
Number of species:				**33**			**26**

† Botanical families, genus and species names were verified for current nomenclature from Keay (1989), Angiosperm Phylogeny Group III (2009), PROTA (2010) and Beech *et al*. (2017).

Table 4.9c Relative Density (RD), Relative Frequency (RF) and Relative Importance Value (RIV) of tree species composition on selected agroecosystems in Imo State of southeastern Nigeria

		Farms			Fallows		
S/no	Tree species	RD	RF	RIV	RD	RF	RIV
1	*Alstonia boonei*	0.3	1.1	0.7	0.2	1.1	0.7
2	*Anacardium occidentale*	0.3	1.1	0.7			
3	*Baphia nitida*				0.2	0.6	0.4
4	*Berlinia grandiflora*	0.3	1.1	0.7	1.9	1.7	1.8
5	*Bombax buonopocense*	0.3	0.6	0.5	0.5	2.3	1.4
6	*Brachystergia eurycoma*				0.2	0.6	0.4
7	*Canarium schweinfurthii*	0.5	2.3	1.4			
8	*Citrus reticulata*	0.6	1.1	0.9			
9	*Citrus sinensis*	1.8	3.3	2.6	0.5	1.1	0.8
10	*Citrus* x *paradisi*	0.3	0.6	0.5	0.2	0.6	0.4
11	*Cocos nucifera*	1.2	3.3	2.3	0.7	2.3	1.5
12	*Cola acuminate*	1.2	2.8	2.0	0.7	2.3	1.5
13	*Cola lepidota*	0.9	3.9	2.4			
14	*Cola nitida*	0.9	1.7	13	0.5	1.7	1.1
15	*Cola pachycarpa*	0.3	0.6	0.5			
16	*Dacryodes edulis*	6.0	7.7	6.9	2.4	5.2	3.8
17	*Dennetia tripetata*	1.5	2.8	2.2	0.9	2.3	1.6
18	*Dialium guineense*	0.9	1.7	1.3	0.5	1.7	1.1
19	*Dracaena arborea*	1.8	2.8	2.3	2.4	1.7	2.1
20	*Elaeis guineensis*	49.5	13.3	31.4	59.3	12.6	36.0
21	*Entandrophragma cylindricum*	0.3	0.6	0.5	0.2	0.6	0.4
22	*Eribroma oblonga*	0.3	0.6	0.5			
23	*Ficus exasperata*	0.7	1.7	1.2			
24	*Ficus saussureana*	0.3	0.6	0.5	0.2	0.6	0.4
25	*Ficus vogeliana*	0.2	0.6	0.4			
26	*Funtumia africana*				0.2	0.6	0.4
27	*Funtumia elastica*	0.3	0.6	0.5			
28	*Gambeya albida*	0.3	1.1	0.7	0.7	2.9	1.8
29	*Garcenia kola*	0.3	1.1	0.7	0.2	0.6	0.4
30	*Hannoa klaineana*				0.2	0.6	0.4
31	*Irvingia gabonensis*	1.2	2.8	2.0	0.7	2.9	1.8
32	*Irvingia wombolu*	0.3	0.6	0.5	02	1.1	0.7
33	*Maesobotrya barteri*	0.3	0.6	0.5	0.9	1.1	1.0
34	*Mangifera indica*	0.9	3.9	2.4	0.9	4.6	2.8
35	*Melicia excelsa*	0.9	3.3	2.1	1.2	4.0	2.6
36	*Musanga cecropioides*	0.3	0.6	0.5	0.2	1.1	0.7
37	*Nauclea diderrichii*	0.9	1.1	1.0	0.5	1.1	0.8
38	*Parkia bicolor*				0.2	0.6	0.4

39	*Pentaclethra macrophylla*	11.4	10.0	10.7	9.0	12.1	10.6
40	*Persea Americana*	1.5	3.9	2.7	0.5	1.7	1.1
41	*Psidium guajava*	1.2	2.2	1.7	0.2	1.1	0.7
42	*Pterocarpus osun*	0.3	0.6	0.5	0.2	0.6	0.4
43	*Pterocarpus soyauxii*	1.2	2.2	1.7	0.7	0.6	0.7
44	*Pycnanthus angolensis*	0.3	0.6	0.5	0.2	0.6	0.4
45	*Raphia hookeri*	2.7	4.4	3.6	3.3	5.7	4.5
46	*Terminalia glaucescens*				0.2	0.6	0.4
47	*Treculia africana*	6.3	10.0	8.2	5.9	10.9	8.4
48	*Xylopia aethiopica*				0.2	0.6	0.4
49	*Zanthoxylum gilletii*				0.2	1.1	0.7
TOTAL species:				**41**			**40**

† Botanical families, genus and species names were verified for current nomenclature from Keay (1989), Angiosperm Phylogeny Group III (2009), PROTA (2010) and Beech *et al*. (2017).

4.2.2.3 Relative Density and Relative Frequency of *P. macrophylla*

Table 4.10 also showed *P. macrophylla* relative density (RD) and relative frequency (RF) of the study areas. Mean total RD (%) for both land use systems throughout the states was 6.8% occurring in 9.2% (RF) of all the enumerated areas. Unexpectedly, fallow lands had lower RD (6.4%) than farms (7.1%) across the states. In addition, this result showed that Imo state had highest RD of 10.2% and frequency of occurrence (RF) of 11.1% across both farm and fallow lands. Least RD of *P. macrophylla* was recorded in Abia state (4.6%), followed by that of Ebonyi state (5.5%). However, in terms of per cent occurrence (RF), Abia state had a relatively more even distribution of the species (8.6%) across its different land use systems

than Ebonyi state that had 7.8% of its enumerated plots having the species. The Relative Importance Value (RIV) of *P. macrophylla* ranged from 4.4% in Abia state to 10.7% in Imo state; and from 7.5% on farms to 8.4% on fallow lands.

4.2.3 *Pentaclethra macrophylla* population structure in Abia, Ebonyi and Imo States Southeastern Nigeria

Pentaclethra macrophylla populations sampled from the three states were generally dominated by trees within the range of 50 cm to 150 cm girth at breast height (GBH), with up to 50% of the trees (Table 4.11). Large trees (> 150 cm GBH) contributed mean of 9% of the species population across the states (with a range of 6 – 12 %). Sapling class contribution to the stand population ranged from 32% in Ebonyi state to 44% in Abia state. From the result, a comparison of *P. macrophylla* population structure across the states showed that Abia state had highest number of large tree stands (>150 cm GBH) (12%), followed by Ebonyi state (9%) and the least was Imo state (6%). On the basis of land use system and its impact on the species population structure, large trees stands (excluding saplings) dominated the population (55%) on both farms and fallow lands, with variations in their sapling and large trees (> 150 cm GBH) stands. There were more sapling stands (43%) recorded on fallow lands, although relatively less large trees were present; whereas there were more large trees (6%) and less sapling stands (39%) enumerated on farm lands. Furthermore, the result showed that Ebonyi state *P. macrophylla* populations were more depleted of large trees (> 150 cm GBH) on its farm and fallow lands than the other two states.

Table 4.10 The Relative Importance value of *Pentaclethra macrophylla* by states and land use systems in three states of southeastern Nigeria

Location/land use system	Density (stands /ha)		RD/ha (%)	RF/ha (%)	RIV (%)
	Trees	Saplings			
Abia - farm lands	1.0	0.4	3.2	5.6	4.4
Abia – fallow lands	2.0	0.9	5.9	11.5	8.7
Ebonyi – farm lands	2.5	0.3	6.6	8.1	7.4
Ebonyi – fallow lands	2.9	1.8	4.4	7.5	6.0
Imo – farm lands	3.8	1.4	11.4	10.0	10.7
Imo – fallow lands	3.8	1.5	9.0	12.1	10.6
Abia state	1.5	0.65	4.6	8.6	6.6
Ebonyi state	3.7	1.1	5.5	7.8	6.7
Imo state	3.8	1.5	10.2	11.1	10.7
Farm lands	2.4	0.7	7.1	7.9	7.5
Fallow lands	2.9	1.4	6.4	10.4	8.4
Grand mean	2.6	1.1	6.8	9.2	8.0

RD = relative density; RF = relative frequency; RIV = relative importance value; ha = hectare

4.3 Pre-germination treatments of seeds of P. macrophylla

4.3.1 Experiment 1: Effect of soaking seeds in cold and boiling water at varying durations on germination in *P. macrophylla*

Result of the cumulative germination of seeds of *P. macrophylla* treated by soaking in cold and boiling water for varying durations is shown in Table 4.12. The observation was carried out over seven weeks after sowing. There was evidence of germination by third week after sowing (3 WAS) in most of the treatments. At 5 WAS, only seeds pre-treated with soaking in cold tap water at ambient room temperature for six hours had exceeded 50% germination, which was significantly different ($p<0.05$) from other comparable treatments. Seeds treated with boiling water by quick immersion for various durations (5 seconds to 60 seconds) before sowing, showed poor germination, with treatment for 30 and 60 seconds having no germination. Increasing duration of seed immersion in boiling water before sowing proved to be rather harsh to the thin impervious seed coat of African oil bean. Similar trend was also observed with pre-sowing soaking in cold water, as the germination rate dropped from 60%. to 24% for 6 hours to 24 hours soaking respectively. At 7 WAS, results of the germination progression clearly showed that cold water soaking for 6 hours improved germination of the species ($p<0.05$) more than other treatments. The forty percent germination recorded at 7 WAS for 5 seconds boiling water treatment was not significantly different ($p<0.05$) from the directly sown seeds (control) which gave 36% germination.

The day to first germination was earliest (20.4 DFG) in seeds given 6 hours soaking in cold water, which was earlier than the control (21.2 DFG) and boiling water treatments as shown in Table 4.13. The 6 hours soaking in cold water was also significantly higher ($p<0.05$) in total germination (60%) than five seconds soaking in boiling water (40%) and direct sowing (control) which gave 36% germination at 7 WAS.

4.3.2 Experiment 2: Effect of mechanical scarification and soaking in cold water at varying durations on germination of *P. macrophylla* seeds

Table 4.14 shows the cumulative germination of *P. macrophylla* seeds treated with a combination of mechanical scarification and pre-sowing soaking in cold water at ambient temperature for 0, 6, 12 and 24 hour durations. From the result, it was clear that seeds given scarification and soaked in cold water for 12 hours gave highest

Table 4.11 Distribution of *Pentaclethra macrophylla* population structure according to girth size classes and land use patterns in three states of southeastern Nigeria (Percent relative abundance in parenthesis)

GBH(cm)	Abia State		Ebonyi State		Imo State					Farm	Fallow
Class	FM	FL	FM	FL	FM	FL	Abia	Ebonyi	Imo	Land (FM)	Land (FL)
≤50	8 (20)	14 (18)	3 (17)	8 (14)	17 (19)	18 (19)	12 (18)	6 (15)	18 (19)	9 (20)	13 (18)
51-70	3 (8)	2 (3)	1 (6)	4 (7)	9 (10)	13 (13)	3 (5)	3 (8)	11 (11)	4 (9)	6 (8)
71-90	4 (10)	4 (5)	2 (12)	6 (10)	12 (14)	13 (13)	4 (7)	4 (10)	13 (13)	6 (13)	8 (11)
91-110	0	6 (8)	3 (17)	8 (10)	4 (5)	7 (7)	3 (5)	6 (15)	6 (6)	2 (4)	7 (10)
111-130	0	4 (5)	1 (6)	6(10)	8 (9)	5 (5)	2 (3)	3 (8)	7 (7)	3 (7)	5 (7)
131-150	3 (8)	2 (3)	1 (6)	1 (2)	0	0	3 (5)	1 (3)	0	1 (2)	1 (1)
151-170	3 (8)	0	0	1 (2)	1 (1)	1 (1)	2 (3)	1 (3)	1 (1)	1 (2)	0
171-190	2 (5)	2 (3)	0	0	2 (2)	1 (1)	2 (3)	0	2 (2)	1 (2)	1 (1)
191-210	0	1 (1)	2 (12)	0	1 (1)	1 (1)	1 (2)	1 (3)	1 (1)	1 (2)	0
211-230	0	0	0	0	0	1 (1)	0	0	1 (1)	0	0
231-250	0	2 (3)	0	2 (3)	0	0	1 (2)	1 (3)	0	0	1 (1)
≥251	1 (2)	1 (1)	0	0	1 (1)	1 (1)	1 (2)	0	1 (1)	0	0
Sapling	16 (40)	38 (50)	4 (24)	22 (38)	34 (38)	37 (38)	27 (44)	13 (32)	36 (38)	18 (39)	3 (43)
Total	40	76	17	58	89	98	61	40	97	46	74

Table 4.12 Cumulative germination (%) of *P. macrophylla* seeds at 3, 5 and 7 weeks after sowing (WAS) for cold and boiling water pre-sowing soaking treatments.

Week after sowing	Direct sowing (control)	Cold water treatments (in hours)			Boiling water treatments (in seconds)					
		6	12	24	5	10	20	30	60	$LSD_{(0.05)}$
Wk 3	12.0±0.9	28.0±0.7	12.0±8.0	4.0±1.4	8.0±0.7	4.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	7.36
Wk 5	28.0±4.3	60.0±2.9	32.0±3.9	24.0±4.3	40.0±3.6	16.0±4.2	4.0±4.2	0.0±0.0	0.0±0.0	15.90
Wk 7	36.0±9.0	60.0±2.9	32.0±3.9	24.0±4.3	40.0±3.6	16.0±4.2	4.0±4.2	0.0±0.0	0.0±0.0	15.54

Values are mean ± SD (n = 25)

Table 4.13 Effect of pre-sowing soaking in cold and boiling water at varying durations on germination of *P. macrophylla* seeds at 7 weeks after sowing.

Pre-sowing treatments	DFG	TG%
Direct sowing (control)	21.2±4.7	36±8.9
6 hr soaking in cold water	20.4±1.1	60±28.3
12 hr ,, ,,	21.6±2.2	32±26.8
24 hr ,, ,,	22.5±9.1	24±16.7
5 sec soaking in boiling water	21.3±8.9	40±26.1
10 sec ,, ,,	23.3±11.8	16±14.5
20 sec ,, ,,	24.0±9.6	4±1.6
30 sec ,, ,,	0.0±0.0	0±0.0
60 sec ,, ,,	0.0±0.0	0±0.0
$LSD_{(0.05)}$	2.23	19.18
CV (%)	8.50	10.91

DFG = Day to first germination; D50%G = Day to fifty per cent germination; TG% = Total germination. Values are mean ± SD (n = 25)

Table 4.14 Cumulative germination percent (%) at 3, 5 and 7 weeks after sowing for mechanical scarification and soaking in water (27°C) treatment of *P. macrophylla* seeds.

Week after sowing (WAS)	No soaking	Without scarification+duration (hours) of soaking in water			No soaking	With scarification+duration (hours) of soaking in water			$LSD_{(0.05)}$
	0	6	12	24	0	6	12	24	
3	28.0±0.7	48.0±0.8	20.0±1.9	16.0±1.9	32.0±1.1	36.0±2.4	56.0±1.7	16.0±1.6	21.54
5	68.0±2.1	64.0±2.2	48.0±4.4	48.0±3.3	76.0±3.7	84.0±3.3	88.0±3.6	25.0±5.4	27.99
7	72.0±4.8	68.0±5.2	60.0±8.8	52.0±5.9	76.0±3.7	84.0±3.3	88.0±3.6	40.0±10.6	24.12

Values are mean ± SD (n = 25)

percent germination (88%), followed by those soaked for 6 hours after scarification (84%). Without scarification, germination of *P. macrophylla* seeds in this experiment was fairly high (ranging from 52% to 72%) at 7 WAS, although not uniform over the period of observation unlike the scarified seeds. By third week after sowing, only seeds that received scarification in addition to pre-sowing soaking in cold water for 12 hours had exceeded 50% germination which was markedly better and different ($p<0.05$) from no soaking/no scarification treatment among others. Moreover, all the seeds that received scarification and soaked for varying durations (0, 6 and 12 hours, excluding 24 hours soaking) had more than 70% germination at 5 WAS, and thus gave a more massive and uniform germination. The result also showed that 24-hour pre-sowing soaking with or without scarification significantly ($p<0.05$) slowed down germination rate (40 and 52% respectively) up to 7 WAS.

Day to first germination (DFG) of *P. macrophylla* seeds was evidently affected by interaction of mechanical scarification and cold water soaking ($p<0.05$). Earliest germination (at 17.4 day after sowing – DAS) was recorded among seeds given scarification treatment and cold water soaking for 12 hours, whereas directly sown seeds (control) had mean of 20.2 DAS for same parameter (Table 4.15).

However, single effect of either scarification treatments or soaking duration treatments did not show significant effect on day to first germination. Scarified seeds that were also soaked in cold water for 12 hours prior to sowing exhibited shortest days (22 DAS) to 50% germination which was earlier than directly sown seeds (control) with 26.6 DAS and other treatments ($p<0.05$). The results also showed that scarified seeds soaked for six hours before sowing or were sown directly without soaking, attained 50% germination earlier than none scarified seeds. Both single and interaction effects of the factors (scarification and soaking duration) indicated significant difference on day to 50% germination of the various treated seeds ($p<0.05$).

High percent total germination (88%) was exhibited by seeds given scarification and 12 hour soaking treatment, followed by similar scarified seeds soaked for six hours (84% total germination) as at seven weeks after sowing (Plate 4.3). Moreover, single and interaction effects of the factors on total germination were significant ($p<0.05$).

From the results shown in Table 4.15, soaking duration exerted more positive influence on enhancing germination of *P. macrophylla* seeds than scarification, with the exception of 24 hours soaking duration which generally showed retarding effect on the germination parameters assessed, and was found less effective than non-treated seeds (control).

4.3.3. Experiment 3: Effect of chemical scarification on germination of *P. macrophylla*

Results obtained from seed pre-sowing treatment with tetraoxosulphate (vi) acid (H_2SO_4) and ethanol showed that germination was greatly impaired by high concentration of the acid and alcohol (Table 4.16). Almost all the durations of soaking in H_2SO_4 results had near zero germination of *P. macrophylla* seeds during 7 WAS monitoring; while absolute ethanol gave a maximum of 43.3% total germination at 4 hours pre-treatment duration for the same period of observation. None of the treatments in the experiment reached fifty percent germination at 7 WAS.

4.4 Experiment 4: Response of *P. macrophylla* marcots to application with varying concentrations of NAA and IBA growth hormones

4.4.1 Simple effect of hormone treatment concentrations on percent callus formation

At the end of this study, none of the branches air-layered produced noticeable roots, but most of them callused freely (Plate 4.4), which is a definite sign of rooting although somewhat delayed. Results obtained from two seasons trials (Table 4.17) showed that the application of IBA and NAA growth hormones significantly ($p<0.05$) impacted on callus formation, although there were not visible root productions at 8 WAM. At the various hormone treatment combinations applied, most of the girdled branches formed callus tissues ranging from 33.3% - 100% in both trials. The treatment 2000 IBA+0 NAA gave the highest (100%) callus formation which was significantly different ($p<0.05$) from the second highest percent callus formation (66.7%) in the two trials. At 1000 mg/L of the growth hormones concentration, NAA showed more impact than IBA on callus formation in the two trials.

Table 4.15 Effect of mechanical scarification and soaking in cold tap water on germination of *P. macrophylla* Benth. seeds at 7 weeks after sowing (WAS).

Treatments	Mean DFG	D50%G	TG%
Scarification+soaking			
No scar, no soaking	20.2±1.6	26.6±8.3	72.0±20.4
No scar + 6 hour soak	19.4±1.4	25.2±8.9	68.0±32.5
No scar+12hour soak	18.8±2.8	32.6±7.4	60.0±14.1
No scar +24hour soak	17.8±2.2	27.0±7.9	50.0±29.9
+Scar, no soaking	19.6±1.8	23.0±5.1	76.0±16.7
+Scar+ 6hour soak	18.4±3.7	23.4±2.5	84.0±16.7
+Scar+12hour soak	17.4±2.2	22.0±2.3	88.0±26.8
+Scar+24hour soak	23.6±10.6	31.8±13.9	40.0±17.9
$LSD_{(0.05)}$	3.20	2.0	8.18
Type of scarification			
No Scarification	19.1±0.9	27.9±2.8	63.0±8.4
+ Scarification	19.8±2.4	25.1±3.9	72.0±19.8
Soaking duration			
0 hour soaking	19.9±0.3	24.8±1.8	74.0±2.8
6 hour soaking	18.9±0.5	24.3±0.9	76.0±11.3
12 hour soaking	18.1±0.7	27.3±5.3	74.0±19.8
24 hour soaking	20.7±2.9	24.4±2.4	45.0±7.1
$LSD_{(0.05)}$	ns	1.35	7.78
Scar x Soak	**	**	**
CV (%)	11.70	15.41	27.71

DFG = Day to first germination; D50%G = Day to fifty per cent germination; TG% = Total germination. Values are mean ± SD (n = 25).

Plate 4.3 ***Pentaclethra macrophylla*** **Benth. seedlings (at seven weeks after sowing - 7 WAS) in the nursery at Federal College of Agriculture, Ishiagu Ebonyi state, Nigeria**

Table 4.16 Effect of chemical scarification with tetraoxosulphate (vi) acid and ethanol on germination of *P. macrophylla* seeds.

Duration of soaking in Scarification	Mean DFG	TG%
10 min in H_2SO_4	0.0±0.0	0.0±0.0
20 min ,, ,,	0.0±0.0	0.0±0.0
30 min ,, ,,	15.0±7.1	3.3±1.2
40 min ,, ,,	0.0±0.0	0.0±0.0
50 min ,, ,,	0.0±0.0	0.0±0.0
60 min ,, ,,	0.0±0.0	0.0±0.0
1 hour in C_2H_5OH	21.0±7.5	13.3±9.4
2 hour ,, ,,	14.7±2.9	20.0±4.3
3 hour ,, ,,	12.0±3.7	36.7±16.3
4 hour ,, ,,	10.3±3.4	43.3±12.5
5 hour ,, ,,	9.0±4.7	6.7±2.4
12 hour in cold water (control)	16.2±5.7	37.3±8.2
$LSD_{(0.05)}$	2.00	5.05
CV (%)	44.8	55.9

DFG = Day to first germination; D50%G = Day to fifty per cent germination; TG% = Total germination. Values are mean ± SD (n = 25)

4.4.2 Main effect of IBA and NAA growth hormones on percent callus formation

It is apparent from Table 4.17 also, that the *P. macrophylla* treated branches responded directly to increased concentrations of IBA and NAA growth hormones as reflected in the percent callus formation. However, impact of increased concentrations of NAA did not elicit significant response from the two trials; unlike IBA increased concentrations that indicated significant effect ($p<0.05$) on percent callus formation among similar treated branches at second trial only. Combination of the two hormones had highly significant interaction effect on the branches callusing ability.

4.4.3 Mean percent callus formation from two trials

Table 4.17 also showed that although visible roots were not formed from the hormone treated branches of *P. macrophylla* for air-layering at various concentrations, callus tissue was mostly produced which is a particular evidence of belated rooting. Only application rate of 2000 IBA+0 NAA was able to give mean 100% callusing at 8 WAM, the least mean (50%) callusing was produced by 1000 IBA+0 NAA and 2000 IBA+500 NAA. There is also clear evidence of higher percent callusing with increased in the hormones concentrations except in 3000 IBA application which indicated drop in mean number of callused branches.

4.5 Experiment 5: Evaluation of season on rooting ability of *P. macrophylla* marcots

4.5.1 Period of the year and percent callus formation

The period of the year showed remarkable effects on the performance of air layering as a means of vegetative propagation of *P. macrophylla*, especially with reference to percent callus formation of the branches. From Table 4.18, it is evident that percent callus formation increased from 25% in January to 100% in July and September, and thereafter dropped in November, as the season progressed from dry to wet weather, as the tree switches from flower bloom (reproductive) phase to end of fruit set (vegetative) phase. In other words, 100% of the branches formed callus and some proceeded to form adventitious root by eight weeks after marcotting (WAM). The result also revealed that callus formation and subsequent root growth were minimal (gave as low as 25% and 41.7% for 2014/2015 and 2013/2014 trials respectively)

Plate 4.4 Callused branches of *Pentaclethra macrophylla* Benth. air-layered seedlings (arrows indicated callus portions)

Table 4.17 Effect of varying concentrations of IBA and NAA growth hormones on percent callus formation of *P. macrophylla* marcots at 8 WAM in 2015.

Treatments (mg/l)	First trial	Second trial	Average
Factor IBA: 0 IBA	77.8±15.7	77.8±19.2	77.8
1000 IBA	66.7±0.0	77.8±15.7	72.3
2000 IBA	77.8±19.2	100.0±0.0	88.9
3000 IBA	66.7±27.2	55.6±15.7	61.2
Factor NAA: 0 NAA	66.7±0.0	75.0±27.6	70.9
500 NAA	75.0±27.6	75.0±14.4	75.0
1000 NAA	75.0±14.4	83.5±16.7	79.3
$LSD_{(0.05)}$	ns	9.33	
Interaction: IBA x NAA	**	**	
0 IBA+0 NAA	66.7±11.8	100.0±0.0	83.4
0 IBA+500 NAA	66.7±9.4	66.7±2.3	66.7
0 IBA+1000 NAA	66.7±23.6	100±0.0	83.4
1000 IBA+0 NAA	66.7±4.7	33.3±11.7	50.0
1000 IBA+500 NAA	100.0±0.0	66.7±9.4	83.4
1000 IBA+1000 NAA	66.7±2.4	66.7±16.5	66.7
2000 IBA+0 NAA	100.0±0.0	100.0±0.0	100.0
2000 IBA+500 NAA	33.3±11.8	66.7±2.4	50.0
2000 IBA+1000 NAA	66.7±11.7	66.7±4.8	66.7
3000 IBA+0 NAA	66.7±2.3	100.0±0.0	83.4
3000 IBA+500 NAA	66.7±9.4	100.0±0.0	83.4
3000 IBA+1000 NAA	100.0±0.0	66.7±11.8	83.4
$LSD_{(0.05)}$	16.88	13.19	
CV (%)	29.39	28.81	

Values are mean ± SD (n = 9). IBA = Indol-3 butyric acid; NAA = Naphthalene acetic acid; WAM = Weeks after marcotting

during the dry season months which spanned from November to March in the study location.

4.5.2 Period of the year and percent adventitious roots formation

None of the girdled branches produced adventitious roots at January operation period during which the local weather was quite dry (with mean of 48.3 mm rainfall) and hot with mean atmospheric maximum temperature of 34^{o}C (Table 4.18). Percent root formation significantly peaked at July (75% and 66.7% for 2013/2014 and 2014/2015 trials respectively) which apparently had the highest mean monthly rainfall of 304.9 mm and least mean day temperature of 29^{o}C. Just like percent callus formation (which may be regarded as early stage of emerging root system), the adventitious root production responded positively and significantly ($p<0.05$) to increased moisture content in the atmosphere and reduced day temperature. However, not all callused branches successfully strike roots depending on season.

4.5.3 Period of the year and number of adventitious roots per successful marcot

The numbers of roots produced at eight weeks after marcotting were only marginally different across the wet and dry season weathers, and were non-significant for both trials (Table 4.19). However, July and September girdled branches still showed more number of root formation per successful marcot branch than other periods, as both had 2.1 and 1.5 roots respectively.

4.5.4 Period of the year and length of adventitious roots per successful marcot

Root length of successful marcot branch showed significant response ($p<0.05$) to season (Table 4.19). Branches marcotted in July and September had relatively more profuse and extended roots ranging from 10.8 to 34.2 mm and 20.3 to 30.3 mm respectively. *Pentaclethra macrophylla* marcot seedlings that produced least adventitious root lengths (0.0 to 2.3 mm) came from those branches girdled during dry season (November - March) in the study area which also coincided with major flower blooming phase of the test plant.

Table 4.18 Basic weather data, percent callus and adventitious root formation of *P. macrophylla* Benth. marcots across different months in Ishiagu southeast Nigeria[†].

	Local weather data		Callus formation (%)		Adventitious root formation (%)	
Months of marcotting	Rainfall (mm)	Max. temp.(^{0}C)	2013/2014	2014/2015	2013/2014	2014/2015
January	48.3	34	41.7±11.8	25.0±4.1	0.0±0.0	0.0±0.0
March	45.1	35	100.0±0.0	83.3±4.7	33.3±11.7	8.3±2.4
May	250.3	32	100.0±0.0	91.7±11.8	16.7±4.7	8.3±2.4
July	304.9	29	100.0±0.0	100.0±0.0	75.0±20.4	66.7±15.5
September	293.6	30	100.0±0.0	100.0±0.0	16.7±4.7	33.3±4.7
November	42.5	32	100.0±0.0	83.3±9.4	0.0±0.0	33.3±9.4
$LSD_{(0.05)}$			32.71	25.37	23.20	15.22
CV (%)			30.75	35.71	26.81	23.09

[†]Main flowering period of *P. macrophylla* is March – April, with smaller flushes in November (Keay, 1989). Callus and root formation (%) taken at 8 weeks after marcotting (WAM). Values are mean ± SD (n = 9)

Table 4.19 Effect of period of the year and root production of *P. macrophylla* Benth. marcot seedlings at 8 WAM in Ishiagu southeast Nigeria[†].

	Mean number of roots		Mean root length (mm)	
Months of marcotting	2013/2014	2014/2015	2013/2014	2014/2015
November	0.0±0.0	1.0±0.12	0.0±0.0	12.8±3.0
January	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
March	1.0±0.4	0.2±0.02	7.8±1.6	2.3±0.62
May	1.5±1.4	0.3±0.1	25.0±4.1	5.3±1.24
July	2.2±0.8	2.1±0.82	34.2±8.7	10.8±1.34
September	1.5±1.4	1.5±0.41	20.3±4.1	30.3±6.24
$LSD_{(0.05)}$	Ns	ns	10.42	6.60
CV (%)	27.79	37.43	25.07	20.9

WAM = Week after marcotting; [†] As in table 4.15 above; ns = non-significant. Values are mean ± SD (n = 9)

Table 4.20 Pre-sowing physico-chemical properties of soil samples and nursery medium used

Soil property	Alluvium soil	Sandstone soil	Ferruginous sandstone soil	Nursery medium
pH water	3.6	4.4	5.4	6.0
Available P (mg/kg)	9.24	7	5.1	23.4
Organic matter (%)	1.54	0.98	1.51	1.65
Carbon (%)	0.92	0.46	0.50	0.96
Nitrogen (%)	0.14	0.12	0.12	0.23
Exchangeable bases (cmol/kg) Ca	1.60	4.20	4.00	8.00
Mg	1.8	1.8	0.8	3.2
K	0.16	0.07	0.1	0.35
Na	0.02	0.08	0.1	0.26
Exchangeable acidity (cmol/kg)	2.10	2.5	2.2	2.0
Cation exchangeable Capacity (cmol/kg)	9.88	6.0	7.0	13.82
Base saturation (%)	40.0	80.0	69.0	85.39
Particle size (g/kg) Sand	18.0	77.0	73.0	65.8
Silt	50.0	12.0	18.0	17.4
Clay	32.0	11.0	9.0	16.8
Textural class	Sand clay loam	Sandy loam	Loamy sand	Sandy loam

4.6 Experiment 6: Assessment of early growth and nodulation performance of *P. macrophylla* seedlings on soils of contrasting fertility in Southeast Nigeria

4.6.1 Physico-chemical properties of soil samples and nursery medium used

The physical and chemical properties of local soil samples and nursery medium used as growth substrates in this experiment are presented in Table 4.20. The soil samples pH values varied from extremely acidic 3.6 (in alluvium soil), to strongly acidic 4.4 (in sandstone soil) and moderately acidic 5.4 (in ferruginous sandstone soil as well as nursery medium composed of 1:2:3 of local topsoil, compost and river sand). Organic matter contents of the sandstone and ferruginous sandstone soils were low (0.98% and 1.51% respectively), unlike the alluvium soil and nursery growth medium that had higher proportion of organic matters (1.54% and 1.65% respectively) in the respective samples. Similarly, the Cation exchange capacity (CEC) of the two sandstone soils were also least (6.0 and 7.0 cmol/kg respectively) among the soils. Percent nitrogen contents of the sandstone derived soils were only moderate (0.12%), as against medium and moderately high level nitrogen in alluvium and nursery growth medium respectively. Available phosphorus is also low in both sandstone soil (7 mg/kg) and ferruginous sandstone soil (5.1 mg/kg), in comparison to nursery medium with 23.4 mg/kg and alluvium soil which had 9.24 mg/kg.

Number of leaf

Number of leaf produced by the seedlings was only significantly different at 16 WAS among the soil types. In this regard, alluvium and ferruginous sandstone soils produced highest number of leaves (8.13) at 16 Weeks After Sowing (WAS) as well as (10.62 and 10.37 respectively) at 24 WAS (Table 4.21). Seedlings raised on alluvium soil produced highest number of leaves at 24 WAS, although with wider variations among the individual seedlings (10.62±3.07) unlike the less fertile sandstone and ferruginous sandstone soils that produced comparable mean number of leaves that are more uniform (10.12±2.85 and 10.37±1.85 respectively).

Plant height

Seedlings grown on less fertile ferruginous sandstone soil were consistently taller (37.75 cm ±9.36) than other seedlings after 16 week of growth and beyond. It is apparent from Tables 4.21 that alluvium soil and nursery growth medium which had higher percent nitrogen, available phosphorus and organic matter contents produced shorter seedlings (36.38cm ±6.25 and 29.63cm ±7.23 respectively) at 24 WAS, although the soil types did not indicate any statistical difference at both 16 and 24 WAS.

Stem diameter and sturdiness quotient

Seedlings raised in ferruginous sandstone soil also showed relatively larger stem diameter (12.33 mm ±2.26) than the ones grown on other soil types at 24 WAS. However, seedlings stem diameter at 24 WAS were statistically similar on the various soil types (Table 4.22). Comparatively, alluvium and sandstone soil types produced sturdier seedlings (4.01±0.42 and 4.03±1.23 respectively) than seedlings on other soil types, although there was no statistical difference among the various soil types during the 24 week of seedling growth monitoring.

Root length

Significant differences were recorded in the root length of seedlings on various soil types at 24 WAS (Table 4.23). In terms of root length, nursery composed growth medium produced seedlings with extended root length (32.88 ±4.44 cm) at 24 WAS; followed by seedlings grown in sandstone soils with mean root length of 29.37 ±4.31 cm. By textural classification, both nursery medium and sandstone belonged to sandy loam soil textural class (Table 4.20). Seedlings grown in both sandstone and ferruginous sandstone soils did not differ significantly ($p<0.05$) in their root lengths, although they are of different soil classes (sandy loam and loamy sand respectively).

Number of root nodules

Mean number of root nodules were considerably more in seedlings raised on less fertile (sandstone and ferruginous sandstone) soils with 17.37±3.42 and 20.62±7.84

Table 4.21 Effect of soil types on *P. macrophylla* Benth. seedlings number of leaf and plant height across 24 WAS.

Soil types	Number of leaf			Plant height (cm)		
	8WAS	16WAS	24WAS	8WAS	16WAS	24WAS
Alluvium soil	4.38±1.51	8.13±1.64	10.62±3.07	29.88±3.26	34.53±4.81	36.38±6.25
Sandstone	4.75±0.71	7.75±2.38	10.12±2.85	27.06±3.05	33.38±9.63	33.69±14.06
Ferruginous sandstone	4.88±1.46	8.13±1.36	10.37±1.85	24.13±4.39	34.13±6.35	37.75±9.36
Nursery medium	5.38±1.51	7.25±1.67	9.0±3.07	22.31±4.71	28.0±4.75	29.63±7.23
$LSD_{(0.05)}$	ns	0.87	ns	3.67	ns	ns
CV (%)	18.37	16.14	18.0	15.28	14.96	22

Values are mean ± SD (n = 8)

Table 4.22 Effect of soil types on *P. macrophylla* Benth. seedlings stem diameter and sturdiness quotient across 24 WAS.

	Stem diameter (mm)			Seedling sturdiness quotient (SQ)		
Soil types	8 WAS	16 WAS	24 WAS	8 WAS	16 WAS	24 WAS
Alluvium soil	9.23±1.77	9.06±4.04	9.78±1.93	3.28±0.29	3.65±0.80	4.01±0.42
Sandstone	10.16±1.64	8.21±138	11.88±1.98	2.71±0.32	2.95±0.98	4.03±1.23
Ferruginous sandstone	7.93±3.29	9.87±2.97	12.33±2.26	3.31±1.13	3.03±0.18	3.83±0.34
Nursery medium	6.92±3.01	8.26±1.55	12.01±2.16	3.95±2.35	2.51±0.47	3.40±0.59
$LSD_{(0.05)}$	ns	ns	ns	ns	Ns	ns
CV (%)	26.16	26.00	16.02	4..99	25.73	19.81

Values are mean ± SD (n = 8)

nodules respectively (Table 4.23); and least on more fertile alluvium soil and nursery growth medium with 4.12 and 3.37 mean number of nodules respectively at 24 WAS ($p<0.05$). It is also obvious from Table 4.20 that the soils with lesser nitrogen and available phosphorus contents produced seedlings with more number of nodules in their roots and vice versa (Table 4.23). In fact, nursery medium with highest soil nitrogen content (0.23%) and available phosphorus (23.4 mg/kg) had seedlings with lowest mean number of root nodules which were significantly different ($p<0.05$) from that of sandstone soil and ferruginous sandstone soil. Plate 4.5 showed seedling of *P. macrophylla* with root nodules at 24 WAS. A cross section of nodule sample showed evidence of activity by its pink coloration due to presence of leghaemoglobin (Plate 4.6).

Seedling Dry weight

Sandstone derived soil produced seedlings with highest mean dry matter (12.62 g ±1.95); followed by seedlings grown on ferruginous sandstone soil with 11.0 g ±1.07. On the contrary, the least dry matter recorded was by nursery growth medium (8.36 g ±1.31). Dry matter production of the seedlings were significantly different ($p<0.05$) at 24 WAS on all the soil types used as well as nursery growth medium.

From Table 4.23, it is quite apparent that seedling dry matter production followed similar trend as observed in number of root nodules in response to the various soils physicochemical status.

4.7 Experiment 7: Allelopathic effect of *P. macrophylla* aqueous leaf extracts on germination of maize (*Zea mays*) and okra (*Abelmoschus esculentus*) seeds

Day to fifty percent germination

The control treatment (0% concentration) had the earliest day to 50% germination in maize (3.0 DAS), just like seeds treated with 10% and 20% concentrations of the aqueous leaf extract (Table 4.24). However, the various treatments effects were not significantly different ($p<0.05$) among maize seeds with regard to day to 50% germination, although germination seemed to be delayed in those seeds that received higher concentrations of 40% and 80% of the aqueous leaf extract. It took longer time

Table 4.23 Effect of soil types on *P. macrophylla* seedlings root length, number of nodule and seedling dry weight at 24 WAS.

Soil types	Root length (cm)	Root nodule count	Seedling dry weight (g)
Alluvium soil	28.50 ± 2.98	4.12 ± 1.65	10.82 ± 2.03
Sandstone	29.37 ± 4.31	17.37 ± 3.42	12.62 ± 1.95
Ferruginous sandstone	27.60 ± 5.85	20.62 ± 7.84	11.00 ± 1.07
Nursery medium	32.88 ± 4.44	3.37 ± 2.5	8.36 ± 1.31
$LSD_{(0.05)}$	2.12	5.71	2.05
CV (%)	8.60	7.86	20.00

Values are mean ± SD (n = 8); WAS=Week after sowing

Plate 4.5 African oil bean (*Pentaclethra macrophylla*Benth.) seedling displaying its root nodules along secondary roots as indicated by arrows

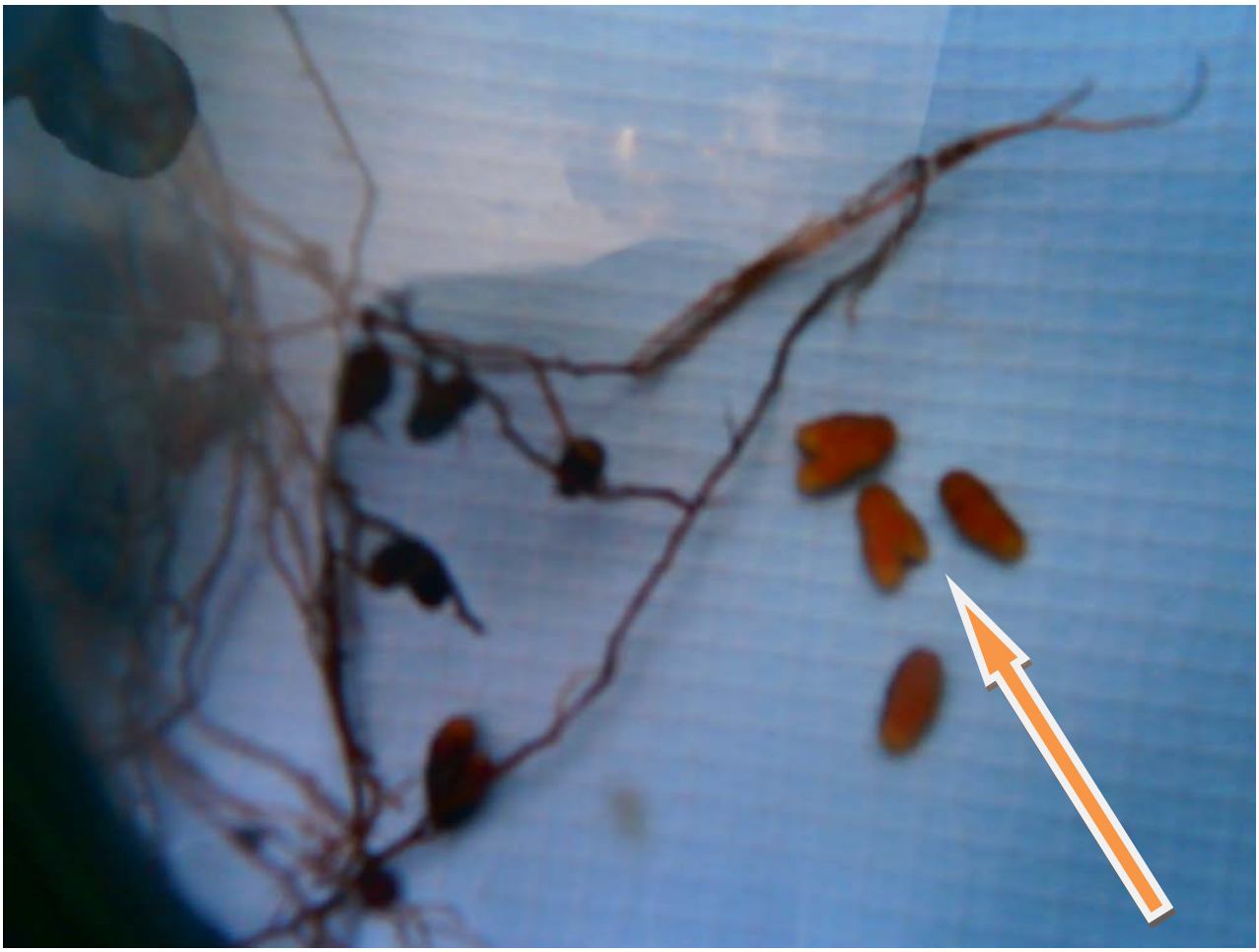

Plate 4.6 Cross section of root nodules of *Pentaclethra macrophylla* Benth. with pinkish coloration

for germination in maize to attain 50% when seeds received 40% and 80% concentrations of the leaf extract aqueous solution. Therefore, adverse effect of the *P. macrophylla* leaf extract application on maize germination is evident, although marginal.

Okra seeds had prolonged days to 50% germination (from 2.75 – 4.50 DAS) with increasing concentrations of the aqueous leaf extract solution which were also significantly different ($p<0.05$) among the treatment means. It took 4.50 and 4.30 DAS for seeds treated with 40% and 80% concentrations of leaf extracts respectively to reach 50% germination of the number of seeds sown. Higher concentrations of the leaf extract application delayed germination in okra seeds than lower concentrations in days to 50% percent germination (Table 4.24).

Total germination

Maize seeds did not show marked impact of the aqueous leaf extract application at various concentrations on its total germination at 7 DAS (Table 4.24). Despite the fact of 100% germination of maize seeds treated with 80% concentration of the leaf extract, it took longer time to reach this complete germination than with similar 100% germination recorded at lower leaf extract concentration (10%), although the treatments were not statistically different ($p<0.05$).

From Table 4.24, okra seeds also proved to be more sensitive to probable inhibitory effect of the leaf extract application on its germination capacity (with a decreasing total germination count from 90% - 42.5% germination as the leaf extract concentration increased from 10 to 80%). The treatments were significantly different ($p<0.05$).

Seedling Sprout Length (SSL)

From Table 4.25, it is obvious that the leaf extract application impacted negatively on maize SSL, which dropped from 12.54 cm to 2.59 cm in inverse manner to concentrations (0% to 80%). The treatment effects of the various concentrations were significantly different ($p<0.05$).

Table 4.24 Effect of *P. macrophylla* Benth. aqueous leaf extract on germination count (%) and day to 50% germination of maize and okra seeds.

Extract concentrations	Maize seed		Okra seed	
	D50%G	TG%	D50%G	TG%
0 % (control)	3.00±0.00	97.50±5.00	2.75±0.50	77.50±9.57
10 %	3.00±0.00	100.00±0.00	3.00±0.50	90.00±8.66
20 %	3.00±0.00	97.50±5.00	2.75±0.50	72.50±16.39
40 %	3.25±0.50	97.50±5.00	4.50±1.73	55.00±30.82
80 %	3.50±0.58	100.00±0.00	4.30±2.06	42.50±26.30
$LSD_{(0.05)}$	ns	ns	0.73	1.08
CV(%)	11.63	3.72	27.38	3.26

D50%G = Day to fifty percent germination; TG% = Total germination percent at 7 days after sowing. Values are mean ± SD (n = 40)

Similarly, the leaf extract application had adverse effect on okra SSL, as the length decreased steadly from 5.56 cm for 0% (control) to 0.10 cm for 80% concentration which were also significantly different ($p<0.05$) (Table 4.25). Evidently, seeds of okra exposed to increased higher concentrations of *P. macrophylla* aqueous leaf extract application experienced initial slow growth of seedlings depending on the concentrations apart from the control treatment.

Seedling dry weight

Response of maize and okra seedlings dry weight to application of varying concentrations of *P. macrophylla* aqueous leaf extracts was not significant ($p<0.05$) as shown in Table 4.25. However, maize seedlings dropped marginally in dry weight (from 3.225 – 2.975 g) as the leaf extract concentrations increased from zero to 80%. Similar trend was also shown by okra seedlings which barely decreased from 0.53 – 0.43 g dry weight (Plates 4.7 and 4.8). Therefore, it is obvious that there may be noticeable negative effect of the leaf extract solution application on the seedlings, but this was not impactful and significant enough to cause remarkable depreciation in dry matter production.

4.8 Experiment 8: Allelopathic effect of *P. macrophylla* aqueous leaf extracts on early growth of maize (*Zea mays*) and okra (*Abelmoschus esculentus*) seedlings in screenhouse

Effect of *P. macrophylla* leaf extract aqueous solution administered on growing maize and okra seedlings were examined for 8 weeks after planting using seedling number of leaves, stem diameter, plant height, root length and dry matter production.

Seedling number of leaves at 4, 6 and 8 weeks after sowing (WAS)

The seedling number of leaves used to assess the two test crops responses did not show significant difference ($p<0.05$) among the treatments at 4, 6 and 8 weeks after sowing (Table 4.26). Both maize and okra seedlings mean number of leaves increased with increasing concentrations (0% to 80%) of the leaf extract solution across the six weeks of regular applications on the crops. For maize seedlings, mean number of leaves increased steadly from 8.0±1.12 to 9.6±1.50 with increase in leaf extract

Table 4.25 Effect of *P. macrophylla* Benth aqueous leaf extracts application on maize and okra seedling sprout length† (cm) and seedling dry weight (g) at 7 DAS.

Extract concentrations	Maize seedling		Okra seedling	
	Seedling sprout length (cm)	Seedling dry weight (g)	Seedling sprout length (cm)	Seedling dry weight (g)
0 % (control)	12.54±4.78	3.23±0.13	5.56±2.86	0.53±0.04
10 %	10.43±3.62	3.18±0.05	2.55±0.90	0.45±0.15
20 %	8.34±4.44	3.06±0.05	0.30±0.47	0.35±0.09
40 %	5.52±2.54	3.10±0.14	0.23±0.41	0.43±0.13
80 %	2.59±0.77	2.98±0.22	0.10±0.28	0.43±0.08
$LSD_{(0.05)}$	3.00	ns	0.79	ns
CV(%)	5.33	4.81	12.79	28.18

†Seedling sprout length = plumule length + radicle length. Values are mean ± SD (n = 40); DAS = Days after sowing

Plate 4.7 Germinating maize seeds (at 7 DAS) administered with varying concentrations of *Pentaclethra. macrophylla* Benth leaf extracts aqueous solution

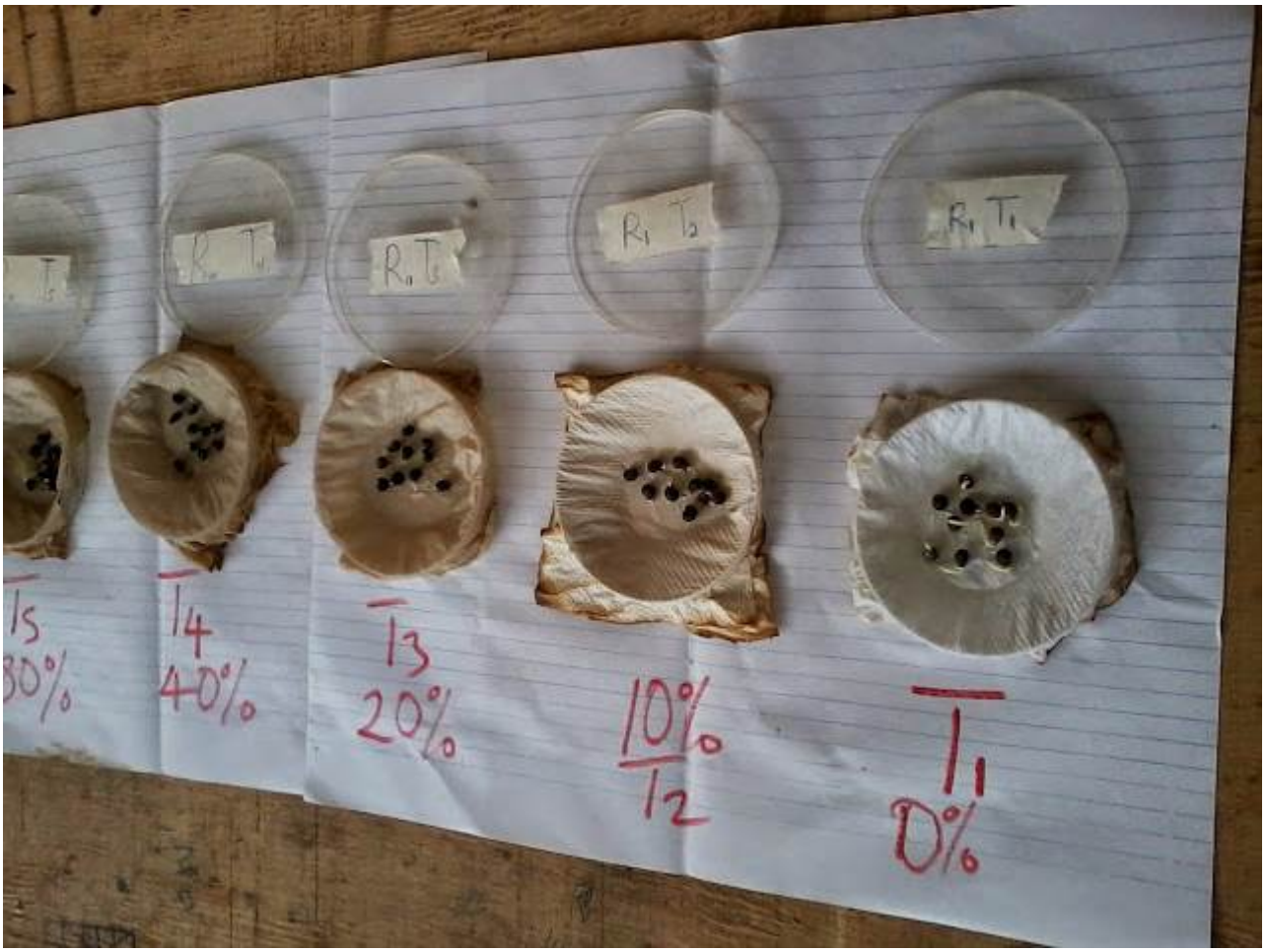

Plate 4.8 Germinating okra seeds (at 7 DAS) administered with varying concentrations of *Pentaclethra macrophylla* Benth leaf extracts aqueous solution

Table 4.26 Effect of *P. macrophylla* aqueous leaf extracts application on maize (*Zea mays*) and okra (*Abelmoschus esculentus*) seedlings number of leaves.

Extract conc. (%)	Maize seedling no. of leaves			Okra seedling no. of leaves		
	4WAS	6WAS	8WAS	4WAS	6WAS	8WAS
0%(control)	6.0±0.71	6.5±0.53	8.0±1.12	4.8±1.90	4.3±1.79	4.9±1.79
10%	6.6±0.70	6.0±3.54	7.0±4.15	4.9±1.27	4.5±1.66	4.8±1.30
20%	6.5±1.12	8.3±1.09	8.8±3.80	4.4±1.56	4.8±2.38	5.3±2.45
40%	6.6±0.69	8.4±0.70	9.5±1.07	5.3±0.97	5.4±0.99	5.5±1.12
80%	7.1±0.60	7.8±0.97	9.6±1.50	4.9±0.78	5.5±0.71	5.6±0.68
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	ns
CV(%)	8.98	22.19	23.64	15.10	18.92	15.46

WAS = Week after sowing. Values are mean ± SD (n = 8)

Table 4.27 Effect of *P. macrophylla* aqueous leaf extracts solution on maize (*Zea mays*) and okra (*Abelmoschus esculentus*) seedlings stem diameter.

Extract conc. (%)	Maize stem diameter (mm)			Okra stem diameter (mm)		
	4WAS	6WAS	8WAS	4WAS	6WAS	8WAS
0%(control)	4.6±1.4	6.7±1.4	5.2±1.5	4.8±2.8	8.8±7.1	7.3±3.2
10%	6.3±1.7	7.5±4.7	1.5±1.4	5.8±2.0	5.9±2.9	8.6±3.6
20%	6.5±1.1	9.1±1.8	2.1±2.2	5.5±2.4	6.3±4.3	8.9±5.7
40%	6.3±0.9	9.9±1.4	3.8±2.1	6.2±2.0	7.1±2.4	7.6±2.4
80%	6.7±1.1	8.8±1.8	5.3±1.9	7.3±2.9	7.0±3.3	6.9±2.1
$LSD_{(0.05)}$	ns	1.834	2.151	ns	ns	ns
CV(%)	21.74	21.08	16.90	47.12	34.13	30.64

WAS = Week after sowing. Values are mean ± SD (n = 8)

concentrations at 8 WAS. While okra seedlings had mean number of leaves increased from 4.9±1.79 for control treatment (0%) to 5.6±0.68 for 80% concentration of the *P. macrophylla* aqueous leaf extract at 8 WAS.

Seedling stem diameter at 4, 6 and 8 weeks after sowing (WAS)

Results from Table 4.27 indicated that maize seedlings stem diameters responded directly to increased concentrations of the leaf extract solutions applications across the 8 WAS. At 4 WAS, there was no statistical difference among treatment means of the various levels of leaf extract solutions given to maize seedlings, although the direct incremental response (from 4.6 mm – 6.7 mm) to increased concentrations (0% to 80%) was evidence. However, by 6 WAS and 8 WAS, the maize seedlings showed significant difference ($p<0.05$) among the treatment means which also reflected similar direct positive relationship. This result of positive response of stem diameter of maize seedlings may be a pointer to some beneficial effects of the *P. macrophylla* leaf extract solutions.

On the other hand, application of the various concentrations of the leaf extract solutions did not show remarkable effect on okra seedlings stem diameter across 8 WAS (Table 4.27). The okra seedlings mean stem diameter at 4 WAS increased from 4.8 mm to 7.3 mm as leaf extract concentrations increased from 0% to 80%. There were also observed direct relationship between the increased leaf extract concentrations applied and okra seedling stem diameter growth responses at 6 WAS and 8 WAS, although not statistically significant ($p<0.05$).

Seedling plant height at 4, 6 and 8 weeks after sowing (WAS)

Generally, both test crops seedlings plant heights indicated clear direct relationship to increased concentrations of the *P. macrophylla* leaf extracts (Table 4.28). At 4, 6 and 8 WAS, maize seedlings consistently grew taller (from 23.0 – 28.3 cm; 43.8 – 54.1 cm and 68.9 – 94.9 cm respectively) with increase in concentrations of the leaf extract treatments (0% - 40%). None the less, there was no significant difference among the treatment means. There was sharp drop in the mean seedling plant height between 40% and 80% leaf extract concentrations across the period of assessment.

Okra seedlings followed similar pattern, apart from mean seedling plant height at 4 WAS which indicated significant effects ($p<0.05$) of the leaf extract applications (Table 4.28). At 4 WAS, okra seedlings mean plant height grew from 11.7 cm for control (0%) treatment to 23.5 cm for 40% concentration, and thereafter dropped to 15.8 cm for 80% concentration. The same trend was maintained at 6 and 8 WAS, except that there was no significant difference ($p<0.05$). There was also observed sharp drop in the mean seedling plant height between 40% and 80% leaf extract concentrations across the period of assessment.

Seedling root length at 8 weeks after sowing (WAS)

Root length showed inverse relationship to increased concentrations of the *P. macrophylla* leaf extracts application (Table 4.29) on both test crops seedlings. Maize seedlings administered with the control treatment (i.e. water only) had most extended mean root length (23.5 cm) at 8 WAS, while the least root length (17.7 cm) was recorded in the maize seedlings given 10% of the leaf extract. There was no significant difference among the various treatment means ($p<0.05$).

On okra seedlings administered with water only gave highest mean root length (17.1 cm); whereas least mean root length (8.8 cm) was observed among seedlings given 20% concentration of the leaf extract solution. The treatment means were significantly different ($p<0.05$) for okra seedlings. Remarkably for both test crops, there were noticeable abrupt decrease in their seedlings mean root lengths between 40% and 80% concentrations of the leaf extracts (from 21.8 – 18.9 cm for maize and 15.7 – 13.6 cm for okra).

Seedling dry matter production at 8 weeks after sowing (WAS)

Seedling dry matter production in maize showed direct response to increased leaf extract concentrations application (Table 4.29). All the treated maize seedlings had higher dry matter production than the untreated seedlings (control) which produced the least dry matter (6.3±2.46 g). In addition, seedlings that received 40% leaf extract concentration yielded the highest dry matter (18.6±1.47 g) among the treatments during the period of assessment.

Table 4.28 Effect of *P. macrophylla* aqueous leaf extracts on maize (*Zea mays*) and okra (*Abelmoschus esculentus*) seedlings plant height.

Extract conc. (%)	Maize seedling plant height (cm)			Okra seedling plant height (cm)		
	4WAS	6WAS	8WAS	4WAS	6WAS	8WAS
0%(control)	23.0±3.40	43.8±6.96	68.9±20.04	11.7±7.88	28.1±11.56	34.1±14.56
10 %	26.3±2.03	37.9±22.8	74.8±45.53	19.8±3.44	38.6±13.16	41.5±14.43
20 %	25.5±3.09	51.3±7.56	86.0±48.15	18.7±8.42	42.5±22.16	46.5±26.28
40 %	28.3±2.22	54.1±5.28	94.9±18.21	23.5±2.83	46.8±5.12	52.3±10.86
80 %	25.8±2.69	44.6±5.91	75.4±21.59	15.8±3.13	35.4±8.89	41.5±8.79
$LSD_{(0.05)}$	ns	ns	ns	4.54	ns	Ns
CV(%)	10.14	22.76	35.19	23.09	38.55	31.27

WAS = Week after sowing. Values are mean ± SD (n = 8)

Table 4.29 Effect of *P. macrophylla* aqueous leaf extracts application on maize and okra root length (cm) and seedling dry matter production (g) at 8WAS.

Extract conc. (%)	Seedling root length (cm)		Seedling dry weight (g)	
	Maize	Okra	Maize	Okra
0 %(control)	23.5±10.63	17.1±12.03	6.3±2.46	1.2±0.46
10 %	17.7±11.24	11.4±3.50	10.7±3.51	1.6±1.49
20 %	23.1±11.31	11.8±5.50	10.5±3.78	1.8±1.16
40 %	21.8±3.49	15.7±5.46	18.6±1.47	2.5±1.81
80 %	18.9±5.00	13.6±5.47	8.3±2.62	1.4±0,96
$LSD_{(0.05)}$	ns	4.87	ns	ns
CV(%)	30.42	35.51	37.50	8.11

WAS = Week after sowing. Values are mean ± SD (n = 8)

Okra seedlings showed similar response to increased leaf extract concentrations application in its dry matter production. All the treated okra seedlings that received leaf extract application at various concentrations performed better than the untreated seedlings (control) which also had least dry matter (1.2±0.46 g). Similarly, okra seedlings that received 40% leaf extract concentration produced highest dry matter (2.5±1.81g) among the various treatments. Although the observed responses of maize and okra seedlings dry matter production to the leaf extract application of *P. macrophylla* were not significantly different from the control, it is suggestive from the results of some stimulatory allelopathy of *P. macrophylla* with both arable crops.

CHAPTER FIVE

DISCUSSION

Agricultural Development Programme (ADP) contact farmers that constituted the bulk of respondents were mostly informed matured individuals. From the respondent backgrounds, it could be deduced that they are more likely to have valid information from experience and traditional practices concerning the ethnobotanical values of African oil bean tree (*Pentaclethra macrophylla*) in their various localities. Current traditional uses of *P. macrophylla* established the facts that the species is highly cherished by the people of southeast Nigeria for numerous economic, ecological and sociocultural reasons. Okigbo (1980) and Okeke *et al*. (2009) reported the specific significance of the species in the Igbo traditional food and farming systems which include uses as spices, potherbs, snacks, mulching materials from pruned leaves/branches and nurse tree. The high nutritional value of 'ugba' - a value added product from the species seeds, had been well documented by many researchers (Enujiugha, 2003; Onyeke and Acheruo, 2003; Oboh and Ekperigin, 2004; Okeke *et al.,* 2009; Anyanwu *et al*., 2016). The medicinal value of *P. macrophylla* indicated by the respondents corroborated the reports by Abbiw (1990) and Oboh (2007), who documented uses of the species in the treatment of ailments such as convulsion, diarrhoea, infertility, itching and wounds among other similar applications.

Pentaclethra macrophylla seed is regarded as one of the most valued resources of the species by the respondents, and as such mostly young people, children and rural women engage in pod harvesting, seed picking as well as storage, and value addition processes for home use or often times for sale to the public. Also, most of the ADP farmers practiced long duration seed storage for up to 6 – 12 months, in order to maximize seasonal price appreciation at peak period of demands. However, it should be noted that due to the recalcitrant nature of the species' seeds, the long stored seeds

for market distribution cannot guarantee its sustained viability for use in propagation of the species (Hong and Ellis, 1996; Oboh, 2007; Agroforestry tree Database, 2011). The ownership pattern of African oil bean tree and the way it is being managed by farmers in southeast Nigeria showed that most existing trees of the species are volunteer or wild stands that are usually protected during land cultivation. Okigbo (1980) had before now identified the species as food tree species for outlying farms in the rainforest belt of southeast Nigeria, and that the tree grows either wild or semi-domesticated with no organised cultivation in plantations or orchards in Nigeria (Ladipo and Boland, 1995). The *P. macrophylla* population distribution and mean number of trees owned per farmer showed that more than 70% of the contact farmers in Abia, Ebonyi and Imo states of southeast Nigeria owned at least one or more stands of the tree (mean 9.37 stands) in their various farms. This high percent occurrence could be seen as advantageous for the species on-farm conservation in SE Nigeria. This is in view of the wide spread acceptance and accommodation of the species in the people traditional practices (including cultural festivals, food values, farming systems, herbal healings and so on). Similarly, the mean number of trees owned per farmer was highest in Imo state, followed by Ebonyi state and least in Abia state. In other words, Abia state had sparser population of African oil bean trees on farm than the other states in the same geographical contiguity of the country.

However, despite the wide spread ownership of *P. macrophylla* trees on farms in these states generally, only small percent (9.05%) of the ADP contact farmers acknowledged possessing up to twenty or more stands of the species in their respective farms. This observation is consistent with the reports of Emebiri and Anyim (1997) as well as Grace *et al.* (2008), which had raised concerns on the slow but steady loss and increasingly sparse distribution of *P. macrophylla* existing stands in the areas of its original spread in Nigeria, through deforestation and unsustainable exploitation of the species for charcoal and timber. This situation is made worst by the fact that most of the farmers interviewed seemed to rely mainly on natural regeneration for replenishment of the species population in their communities, with barely eight percent of the people having deliberately planted some of their existing stands.

Revenue generation potentials of *P. macrophylla* seed production per tree per year showed clearly and reinforced the need for conservation and domestication of the test plant. The seed yield per tree per season was estimated to reach up to 30.5 kg seeds per tree in a season which translated into revenue of fourteen thousand naira (₦14,000) for same period according to the prevailing market price during 2013–2014 survey. Furthermore, when the seeds are processed into shredded 'ugba' that are ready for direct consumption according to local cuisine, the price for same unit of measurement appreciates greatly for a brief period, even though it has short shelf life (Anyanwu *et al.,* 2016).

In view of the huge existing market and other favourable opportunities identified in the SWOT analysis for the produce/product of the species, one can state that investment in the improvement of the species holds great promises for the farmers and general users in the affected localities and beyond. These positive factors about African oil bean status can only be optimized for sustainable resource utilization and benefits to the people and environment. However, challenges like recalcitrant nature of the seeds and poor seedling production/establishment due to dormancy, paucity of deliberate replanting scheme, over exploitation of existing dwindling wild population among others could pose serious threat to the tree improvement if not tackled.

The generally high tree species richness of the various agroecosystems may be ascribed to their location in the rainforest vegetation belt (especially Abia and Imo state) of Nigeria, and favorable accommodating traditional agroforestry systems that protect some tree stands on farms. Admittedly, the tree species richness were relatively less in Ebonyi state for both fallow and farm land sites (26 and 33 tree species, respectively) than the other states due to its more northerly location and prevailing derived savanna vegetation belt. The occurrence and degree of abundance (richness) of given tree species in a tropical agroecosystem had been reported to be a function of the prevailing farming system, availability of its seeds or other propagules and favorable microclimate for germination and field establishment (Turner, 2001). Furthermore, the abundance or rarity of tree species, especially if they possess obvious economic value, is a function of the intensity and pattern of exploitation which they are subjected to

(Udo *et al*., 2009; Wakie *et al.*, 2012). In addition, the relative high number of tree legumes (22%) occurrence in the three states and land use systems conforms to the tree species distribution pattern of similar tropical rainforest ecosystem (Diabate *et al*., 2005; Sprent, 2005; de Faria *et al*., 2010). Also, the Fabaceae has been reported to be the most represented botanical family in terms of species diversity among trees of the West African natural rainforest in Ivory Coast (Dupuy *et al.*, 1997).

Seven species, including *P. macrophylla*, *Treculia africana*, *Dialium guineense*, *Mangifera indica*, *Elaeis guineesis*, *Irvingia gabonenesis* and *Nauclea diderrichii* were found to be most commonly occurring on both farm and fallow lands across the region. Such frequent occurrence of these tree species, most of which are indigenous to the region, could be attributed to the preference of the local farmers for native tree species inclusion and protection in their farm settings for various beneficial reasons they had observed over time. Other indigenous fruit trees like *Gambeya albida*, *Dacryodes edulis*, *Dennettia tripetata*, and the Monkey kolas (*Cola lepidota and C. pachycarpa*) are also often protected or occasionally planted for similar reasons. Many farmers in southeast Nigeria practised traditional agroforestry combined with mixed cropping in which some of the indigenous fruit/food trees (planted or protected volunteer stands) are left to exist among the field and garden crops in their localities (Okigbo, 1980; Nair, 2003).

With reference to *P. macrophylla* distribution and percent occurrence, there were agreement and similarities in the ethnobotanical enquiry about mean number of mature tree stands owned by individual farmers and the floristic physical enumeration of the species across the states different land use systems. Aggregate percent occurrence of *P. macrophylla* showed more than 50% and 60% occurrence of the species present on both farms and fallow lands, respectively. Understandably more stands of the species might had been allowed to grow on fallow lands for obvious reason that the tree could help in reinvigorating soil fertility during fallow period, than on lands under cultivation of field or garden crops. Probably, some of the *P. macrophylla* mature stands are pruned for mulching/green manure as reported by Okigbo (1980) and Brewbaker (1987), or severely cut down to open up space for the cultivated crops. On

state basis, Imo state had highest percent occurrence (82%) of African oil bean tree in its agroecosystem, while Ebonyi state recorded least 42% occurrence irrespective of the prevailing land use system.

The spatial distribution of *P. macrophylla* did not show evidence of any form of organised plantation among the states. Mature tree and sapling densities per hectare were rather low and sparsely distributed. The disproportionately few sapling density per hectare (grand mean = 1.1 sapling/ha) recorded in this research may be attributed to the intensive massive harvest of the seeds for direct consumption, in addition to the inherent problem of recalcitrant nature of the species seeds. These obstacles combined to pose serious danger to the species natural regeneration rate in the region. Earlier, SWOT analysis of the challenges and prospects of sustainable exploitation of *P. macrophylla* genetic resources identified the above listed obstacles and others like depleting tree stands in the wild, as limiting factors.

Farmers in Imo state tend to protect and allow more *P. macrophylla* stands and other trees to grow along with their seasonally arable crops, unlike their fellow farmers in the other southeast States of Nigeria. This is also evidence in tree species richness/ha where Imo state recorded the most diverse tree species occurrence of more than seven tree species per hectare. By its southern most location among the southeast States in Nigeria, Imo State has almost entire of its land mass located within the tropical lowland rainforest belt with characteristic high annual rainfalls that favour tree crops (Ogbonna, 2000). On the basis of plant density vis-à-vis land use, there were evidently higher *P. macrophylla* tree and sapling density per hectare on fallow lands than on cultivated fields. This record agrees with Udo *et al.* (2009) who had reported *P. macrophylla* low density of 4.0 tree/ha in a community forest ecosystem in Akwa Ibom State of Nigeria. Kimondo *et al.* (2014) observed similar pattern among indigenous *Vitex payos* population densities on farm and fallow lands in Kenya. Surprisingly, cultivated lands in Abia and Imo states had more tree species richness (including *P. macrophylla*) per hectare than that recorded on fallow lands. The observation may be due to additional fruit trees some farmers in these localities do

establish deliberately apart from the protected volunteer and wild indigenous tree stands which are also allowed to grow along side with the arable crops.

Relative density (RD) per hectare showed that 6.8% of the tree species stands in the agroecosystem comprised of *P. macrophylla.* The relative density also showed that there were fewer *P. macrophylla* trees per hectare on fallows than on farm lands. In addition, Abia and Ebonyi states had scarcely half the species relative density as there were in Imo state. Therefore, juxtaposing the ethnobotanical survey and floristic enumeration reports, there are vivid indications of more depletion of African oil bean trees in Abia state than in the neighbouring Imo and Ebonyi states where this species also flourished in their agroecosystems.

By the relative frequency (RF) of *P. macrophylla* in SE Nigeria, 9.2% of enumerated agroecosystems have *P. macrophylla* tree stands occurrence, with more frequency of occurrence in fallow lands than farms. Base on States RF, Imo State had highest RF of *P. macrophylla* across both land uses; and was followed by Abia State and Ebonyi State. The weather of Imo State which favours tree crop growth as earlier adduced in RD, may also be ascribed the reason for higher RF of the species in the State. Similar explanation may also be attributed to the lesser RF of the species in Ebonyi State located in derived savanna belt than in Abia State parts of which are located in tropical rainforest belt.

The grand Relative Importance Value (RIV) of *P. macrophylla* was barely average (8.0%) across the states and land use patterns. Recall that the species is one of the most widely spread and frequently occurring tree species, only second to *Elaeis guineensis* in SE Nigeria agroecosystem, due to its deliberate protection among other sociocultural and economic values. Actually, farmers in these study areas did identify diverse ethnobotanical functions of the species during preliminary survey, hence the recorded fairly average RIV. However, there were wide gaps in the RIV of *P. macrophylla* among the three states and between the two land use patterns. These variations may be pointer to the degree of exploitation and depletion of the species; or otherwise the intensity of species protection and deliberate establishment by the people (Awodoyin *et al.,* 2013).

Generally, all size classes of *P. macrophylla* population structure were unevenly represented in the two land use systems enumerated throughout the sample states. The large sized trees (>150 cm Girth at Breast Height - GBH) were relatively more abundant on farms than fallow lands. Conversely, there was more relative abundance (%) of saplings and young trees below 150 cm GBH on fallow lands than on farm lands. Thus, there is clear evidence here that land use patterns influenced to some extent the species population structure. By implication, the local farmers seemed to slash or even rogue out some saplings during seasonal cropland preparation and routine weeding operations, while allowing mature stands of the species to remain or at most prune them down to open up space for the major arable crops (Kimondo *et al*., 2014). Also, saplings are by virtue of their sizes greatly affected by intensity and frequency of disturbance they are exposed to in given agroecosystems (Duchok *et al.,* 2005). Apparently, more harvest of the species timber seems to be going on in fallow lands in anticipation that natural regeneration will replenish fell stands. Therefore, land use system that least impact disturbance to the saplings growth would provide more conducive environment for young plants to flourish.

Comparatively, the population structure of *P. macrophylla* among the states in south east Nigeria show that Abia state has relatively most abundant of large size class trees (> 150 cm GBH) of twelve percent, and equal distribution of saplings as well as young mature tree class (< 150 cm or ≥ 50 cm GBH). However, Ebonyi and Imo states have more than fifty percent of their population structure within young mature tree class, and less than ten percent large size class trees. It can therefore be deduced from analysis of *P. macrophylla* population structure, distribution and relative density that:

1. In a stable forest tree population, the number of saplings should be higher than mature trees (Duchok *et al*., 2005; Kimondo *et al.,* 2014), but the reverse is the case with *P. macrophylla* in southeast Nigeria. In fact, the ratio of sapling to mature tree classes is 1: 2.6 respectively. This situation may suggest that sapling survival under the parent tree is low. This may be due to intensive collection of seeds by farmers in the localities thereby warranting likelihood of low number of saplings in the agroecosystem.

2. The low sapling density per hectare which ranged from 0.3 – 1.5 sapling/ha across the region agroecosystems and states, suggests that the species regeneration and replenishment rates are poor.
3. Present low density of the species (ranged between 1.1 – 4.8 trees/ha) and scantly distributed large mature trees in the region agroecosystem may be ascribed to the extensive local exploitation of the tree for seeds, timber, fuel wood and charcoal production; as well as loss of stands through urbanisation. Coupled with these anthropogenic factors, are inherent specific biological challenge of recalcitrant nature of the seeds and implication of generally poor seedling establishment which have retarded natural regeneration rate of the species.
4. Admitted that the species enjoys certain degree of protection in the region due to some affinity with the culture of Igbo-speaking states of Nigeria (Okigbo, 1980; Emebiri *et al.,* 1995; Okeke *et al.,* 2009; Anyanwu *et al.,* 2016), the high rate of depletion resulting from massive exploitation by the people cannot be presently sustained with natural regeneration alone. Therefore, improved propagation method and seedling establishment have been advocated (Oboh, 2007).
5. Moreover for its various ethnobotanical values and income generation status, the species can be further domesticated in plantation or grove setting given improved propagation technique and wide dissemination to the local farmers.

In line with developing and optimizing the needed propagation technique for enhanced seedling production and field establishment, series of experiments on pre-sowing treatments were conducted whose result gave very useful hints on overcoming dormancy of *P. macrophylla* seeds. Brief soaking in hot water at 100 ^{o}C for up to 30 seconds or more proved to be quite deleterious to the species seed germination, although shorter duration of soaking (5 seconds) was only of marginal benefit than the untreated seeds in terms of mean day to germination and total germination. Soaking in cold water at room temperature for six hours significantly improved all the germination parameters assessed. This observation may be attributed to the thin impervious coat of *P. macrophylla* seeds which would only require mild but effective

pre-sowing treatment to be ruptured for water imbibition and subsequent germination (Bewley, 1997). Therefore, harsh treatments like long pre-soaking in hot water will likely act swiftly to hurt the tender embryo; while soaking in cold water longer than six hours seemed to suffocate the seeds and therefore becomes unhealthy for germination.

Leveraging on the apparent positive effect of soaking in cold water, the combined effect of nicking (a kind of mechanical scarification) and soaking in cold water proved to be remarkably beneficial to germination of *P. macrophylla* seeds. Significant interaction effect of scarification and soaking treatments reduced mean day to first germination and day to fifty percent germination (i.e. a faster, more uniform germination response), as well as increased mean total germination up to 88% at four Weeks After Sowing (WAS). The evidences suggest that thin impermeable physical barrier in form of seed coat may be major factor implicated in the *P. macrophylla* seed dormancy which nicking treatment was mild enough and effective to handle unlike use of soaking in water alone. In addition, the earlier use of pre-sowing soaking only could not be a better option due to the lignin and suberin contents of the test plant seeds that made the seed coat waterproof (Hong and Ellis, 1996). Thus, scars brought about by nicking operation would normally create opening through the barrier for moisture imbibition that trigger rapid response to germination. The present report is an improvement on previous works by Tsobeng *et al.* (2013) who recorded 46.33 % maximum germination count at 15 WAS for *P. macrophylla* seeds scarified with sand paper prior to sowing. Ehiagbinare and Onyibe (2008) had earlier reported 86% germination at 4 WAS obtained from seeds soaked in cold water for ten days with daily replacement of the water. Therefore, the present report has demonstrated that with simple readily available materials and guarantee freshly harvested seeds, dormancy challenge can be overcome to improve germination speed and increase total germination count of African oil bean seeds to 88 % by nicking (mechanical scarification) and pre-soaking in cold water for 12 hours. It also shows that combining different pre-sowing treatments proved to be a better option for enhanced germination of dormancy bound seeds than single action of any good similar pre-treatment.

On the other hand, the poor total germination count obtained from concentrated tetraoxosulphate (vi) acid and absolute ethanol pre-treated seeds show that these chemicals may be rather too harsh just like boiling water pre-treatment, for thin layer impervious seed coat of *P. macrophylla*. None of these treatments gave up to 50% germination by 7 WAS. Even with reduced 90% concentrated tetraoxosulphate (vi) acid treatment for shorter period of soaking (5 minutes), only 35% maximum germination count could be recorded by six weeks after sowing (Ehiagbonare and Onyibe, 2008), while seeds pre-treated in concentrated acid gave 33 % maximum germination for same period of soaking and 6 WAS.

Results of the experiment on combined effects of IBA and NAA on rooting of air-layered branches showed that both auxin treatments had generally unimpressive root production effect on *P. macrophylla* at eight weeks after girdling, although the branches fairly callused, which is a definite indication of ensuing rooting process that might have been delayed. Interaction of the two hormones showed synergism as evidenced by significant effect on the branches callusing ability, despite the absence of visible adventitious root production on the air-layered branches. In the same vein, single effect of IBA treatment proved to have slightly suppressive influence on callus formation and invariably on root production with increasing concentrations from 0 to 3000 mg/L IBA, unlike the NAA. This observation is in consonance with Tchoundjeu *et al.* (2010), Yeboah *et al.* (2010) and Akwatulira *et al.* (2011) reports, although on different tree species. These authors equally reported the suppressive effect of high concentrations of IBA on percent root production of layered branches. On the contrary, low IBA concentration is reported to enhance rooting of *Irvingia garbonensis* cuttings with optimal performance at 250 µg concentration (Schiembo *et al.*, 1996). Similar response has also been reported by Awodoyin and Olaniyan (2000) on the positive effect of low auxin concentrations on adventitious root production of air-layered guava (*Psidium guajava*) branches with optimal performance at 100 ppm IBA. Thus, the negative impact of both rooting hormones, especially IBA, observed in this study, may be due to high levels of these auxin substances ranging from 1000 to 3000 mg/L (equivalent to 0.1 – 0.3% IBA) used, apart from the role of season which could be quite crucial as well.

With regard to the effect of season on rooting success of *P. macrophylla* in layering operation, the best rooting was obtained in July, followed by those of September. It is apparent from the result, that adventitious root formation by marcotted branches of *P. macrophylla* required high humid condition which is naturally guaranteed during the peak of wet season weather, and vice versa. Obviously, this behaviour may be attributed to the prevailing high moisture and cool temperature associated with the period of peak rainfall. In other words, July was the coolest and wettest month of the year at the study station, followed by September. The poor root formation obtained in the month of May when rainfall was also fairly high could be an indication that roots formation and elongation in African oil bean air-layering is not determined only by weather condition, but also by interplay of intrinsic specific factors including the tree reproductive and vegetative growth cycle in the season. It has been long established that root formation is influenced by auxins produced by the plant itself (Awodoyin and Olaniyan, 2000; Jaenicke and Beniest, 2002; Hartmann *et al.,* 2007). The period between November and January coincides with the period of reproductive cycle of the Afrcan oil bean tree, with minor blooming in April; while the period from May to September coincides with the season of active vegetative growth (Keay, 1989; Oboh, 2007). The physiology of tree growth phases shows that as plant undergoes active vegetative growth cycle, buds release endogenous auxins that moves basipetally to stimulate root production (Jaenicke and Beniest, 2002; Leakey, 2004). Therefore, by implication and in response to the deliberate wounding caused by girdling in layering operation, branches of the species began formation of adventitious roots. This is an affirmation of similar reports by Awodoyin and Olaniyan (2000), Leakey (2004) and Hartmann *et al.* (2007) stated that wounding of stem brings about auxin-induced stimulation of vascular meristematic tissues to form adventitious roots in cuttings and layering techniques.

On the other hand, when plants undergo period of reproductive cycle, anti-auxin substances are release that make active vegetative growth to be suspended and the buds appear to enter state of dormancy. Therefore, shoots marcotted or collected for stem cuttings at such reproductive phase may largely be unresponsive to formation of adventitious roots due to inhibiting endogenous factors (Jaenicke and Beniest, 2002;

Hartmann *et al.,* 2007; Chadha, 2009). This may explain the poor callus formation and root production observed among *P. macrophylla* stems air-layered from November to March.

In the experiment that evaluated natural nodulation ability and seedling growth of *P. macrophylla,* the results affirmed the test plant capacity to fix nitrogen via its root nodules (Ogbohodo and Odu, 1992; Ladipo *et al*., 1993; Diabete *et al*., 2005) on soils of contrasting fertility which are mostly acidic in nature, ranging from extremely to moderately acid soil pH in southeast Nigeria. Ohiri and Ano (1985) had reported that soils in southeastern states of Nigeria are characterized by low pH, low organic carbon and low exchangeable cations. In legumes, most nitrogen-fixing bacteria are not very active in strongly acidic soils (Miller and Donahue, 1992). Root nodulation was not much on seedlings grown in alluvium soil with extremely low soil pH, but was quite high on seedlings raised on the two sandstone derived soils. This is a case of inverse relationship between root nodule production and fertility status of the growth medium/soil in nitrogen-fixing legumes (Chagas Junior *et al.,* 2012; Flynn and Idowu, 2015).

Root nodulation and dry matter production were quite significant in the low fertility sandstone soils than in the apparently fertile alluvium soil with high organic matter, moderate available phosphorus and medium nitrogen content; and the formulated nursery growth medium characterized by similar high fertility profile. The above ground seedling growth parameters assessed were largely non-significant for six months of monitoring with reference to stem diameter and seedling sturdiness quotient, although number of leaf was significant only at 16 WAS. This shows that *P. macrophylla* can thrive on both good and poor fertility soils of southeast Nigeria tropical rainforest and derived savanna vegetation. It also has the capacity to adapt to erosion prone, highly leached soil types prevalent in the region (Ohiri and Ano, 1985; Ijioma, 2000). Moreover, this may be partly the reason (in addition to economic value) why most farmers in southeast Nigeria protect wild and volunteer stands of the species as well as allow them to coexist with agronomic and garden crops in their agroecosystems.

The differences among the contrasting soil types and nursery growth medium with regard to seedling survival rate (upon transplanting) measured by sturdiness quotient, is partly due to differences in the physical characteristics such as porosity, water holding capacity as well as fertility status. The mean sturdineess quotient range (3.40 to 4.03) of the seedlings at 24 WAS on all the various soil types are within acceptable scale range of well-built seedlings that possess high post transplant survival percent. Mean sturdiness quotient of the seedlings were less than six, which is within acceptable level to guarantee high out planting survival rate. A sturdiness quotient greater than six has been reported as an indication of physiological imbalance resulting in spindle leggy seedlings; while an extreme small sturdiness quotient implies difficulty in seedling establishment (Mexal and Landis, 1990; Jaenicke, 1999).

It is a common practice among these farmers to prune branches of *P. macrophylla* trees in their farms during seasonal land clearing operation. Leaf litters from the cut branches as well as the ones naturally shed by the plant on routine basis make up important sources of organic matter and nitrogen for enrichment of surrounding host farm/garden soil. In this regard, it has been reported that leaf pruning of nitrogen-fixing tree legumes constitutes vital component of sustainability in agroecosystem as well as soil fertility management (Meena *et al.,* 2018). In addition, the high nitrogen leaf litters of such tree legumes used in agroforestry system as nurse trees or woody hedges may be indeed more important to crops than the shade or wind protection provided by the trees (Brewbaker, 1987).

The aqueous leaf extracts of *P. macrophylla* were tested for their allelopathic effect on seed germination of maize and okra under laboratory condition. There was no serious inhibitory effect of the applied leaf extract aqueous solutions at its various concentrations on day to fifty percent germination and total germination of Oba Super – 4 maize variety. Seeds of maize administered with both 0% (control) and various other concentrations of the leaf extract solution reached more than ninety seven percent total germination at seven day after sowing (DAS), although day to fifty percent germination was slightly delayed in higher concentrations of 40% and 80% of the leaf extract, but this was not significantly different from the control (0%). The non-

significant effects of the leaf extract application on the earlier mentioned maize germination parameters as well as on its dry matter production implied that maize is probably adapted to or tolerant of potential allelopathy impact of *P. macrophylla* aqueous leaf extract. However, the leaf extract treatments appeared to have significant inhibitory effect on maize seedlings plant height, with most pronounced impact at 80% concentration.

Okra seeds and seedlings on the other hand, obviously showed reduced germination in response to the leaf extract treatments. The NHAe47-4 okra variety seeds experienced significant delay in day to fifty percent germination as well as significant drop in total germination at as the concentrations increased from control (0%) to 80%. Similar inhibitory effect of *P. macrophylla* leaf extract aqueous solution was recorded on okra seedling plant height which showed inverse response to increasing extract concentrations application. The control (0%) treatment recorded longest mean seedling plant height and highest dry matter production at 7 DAS. Nonetheless, dry matter of both crops seedlings at 7 DAS indicated non-significant effect of the aqueous leaf extract application; thus, showing that some attribute of the crops could withstand inhibitory impact of the allelochemical that may be present in the tree leaf extract solution. This finding could only suggest probable presence of inhibitory biochemical substance in *P. macrophylla* leaf extract leachate, even though some crops like maize may be able to tolerate its apparent adverse effect without remarkable decline in its germination and seedling early growth performance, while other crops may not.

However, it should be noted that the allelopathic effects observed depend on leaf extract concentrations as lower concentrations of 10% and 20% did not show pronounced negative responses on the growth parameters assessed unlike higher concentration of 40% and 80%. Admittedly, leaf extract solutions of some leguminous trees (including *Albizia lebbeck*, *Acacia auriculiformis*, *A. leucophloea* and *A. mearnsii* among others) in the Mimosoideae sub-family have been reported to possess allelochemicals that exert inhibitory effects on germination and seedling early growth of some annual crops (Bora *et al.*, 1999; Fatunbi *et al*., 2009; Das *et al*., 2012),

but this phenomenon may not be generalized after all considering the selective effect of *P. macrophylla* leaf extract solution.

Further nursery investigations were carried out on early growth of maize and okra seedlings responses to application of leaf extract solutions for verification of probable inherent allelopathic property of *P. macrophylla* leaf litters. The results largely indicated non-significant effects of the leaf extract treatments (applied for six weeks growth period) on number of leaf, plant height, stem diameter and dry matter production. Okra seedlings also showed significant negative impact of the leaf extract higher concentration treatment on its root length, unlike maize seedlings that received same treatment. Noticeable trend in the seedling growth parameters in both maize and okra point to the fact that despite the non-significant effect of the leaf extract application generally, the higher concentrations of the extract aqueous solution boosted the seedling growth and were as good as the control (0%) if not better in all the parameters assessed except root length. Present finding in this study has proved that the aqueous leaf extract of *P. macrophylla* even at higher concentrations may be rather beneficial than inhibitory to the arable crops exposed to its treatment once the crop seedlings have established. This is in consonance with the nitrogen-fixing capacity of *P. macrophylla* (as earlier pointed out) which the local farmers in southeast Nigeria exploit through seasonal leaf pruning of on-farm stands of species as well as the naturally shed leaves to enrich their farm/garden soils and manage their agroecosystems. Therefore, by inference of the combined laboratory and nursery investigations of probable allelopathy property of *P. macrophylla* leaf extract solution, concrete and persistent inhibitory allelopathic impact could not be established, instead the extracts upon increasing concentrations were found to enhance the tested maize and okra seedling growth parameters.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

Investigations were carried out on the ethnobotanical status and floristic distribution of African oil bean tree (*Pentraclethra macrophylla*) in Abia, Ebonyi and Imo states of southeastern Nigeria; its propagation, early seedling growth and nodulation, and its possible allelopathic effects on maize and okra between 2013 and 2015.

To accomplish the set objectives, semi-structured survey questionnaires and scheduled interviews containing relevant questions about *P. macrophylla* ethnobotanical status were administered to the targeted ADP contact farmers across the selected states ADP agricultural extension zones and circles, between May and July 2013. The preliminary ethnobotanical approach was to assess how the species genetic resources are being owned, managed and used, and the species population distribution among the farmers, estimate seed yield and revenue potential of the tree from the farmers' seasonal harvests as well as determine the prospects and challenges of enhanced domestication/conservation of the species.

Floristic enumeration of *P. macrophylla* and other tree species stands were conducted during 2014 cropping season in 75 farms land use and fallow land use each across the selected three states ADP agricultural zones and extension circles. This was to establish, on the basis of state and land use system *P. macrophylla* spatial distribution pattern, relative abundance, density and population structure.

Low percent germination and seedling establishment were reported to be serious challenge of the species due to inherent seed dormancy and recalcitrance, thus making natural regeneration grossly slow and inadequate to meet the rate of its exploitation. To proffer solution to this limitation, series of nursery experiments were carried out at the Teaching-Research Farm of Federal College of Agriculture (FCA) Ishiagu Nigeria to

evaluate benefits of some pre-sowing treatments in breaking dormancy of *P. macrophylla* seeds and enhancing germination. The pot experiments involved the use of pre-sowing soaking treatments in water of varying temperatures combined effect of soaking in water and mechanical scarification by nicking; as well as the use of chemical scarification with concentrated tetraoxosulphate (vi) acid and absolute ethanol. Field experiments involving air layering operation on selected mature trees of *P. macrophylla* located at the tree crops plantation site FCA, Ishiagu Nigeria were conducted in 2013 and 2014 to study effect of season and rooting hormones application on success of marcotting.

Also, nursery experiment was conducted in 2015 to assess early growth and root nodule production of *P. macrophylla* seedlings on soils of contrasting fertility in Ishiagu south east Nigeria. Lastly laboratory and screen house experiments were conducted in 2015 to assay potential allelopathic effect of *P. macrophylla* leaf extract aqueous solutions on germination and early seedling growth vigour of maize and okra as test crops.

The results showed that;

1. *Pentaclethra macrophylla* seed is regarded as one of the most valued resources of the species by the people of SE Nigeria. As such, many rural dwellers, mostly women and children engage in pod harvesting, seed picking as well as storage and value addition processes for home use and/or for sale to the public.

2. Harvested seeds may be stored up to 6 – 12 months in order to maximize seasonal price fluctuation and appreciation at peak season of demands. However, most of the stored seeds may not be fit for germination due to loss of viability, being recalcitrant.

3. Despite the actual and potential usefulness of *P. macrophylla* in SE Nigeria, only 8.31% of the ADP contact farmers indicated that they deliberately planted the tree. Most existing stands are protected in the wild.

4. More than 70% of the contact farmers owned *P. macrophylla* on their farms (mean of 9.37 stands). The mean number of farmers was highest in Imo state (85.37%) followed by Ebonyi state (80.36%), and least in Abia state (53.84%).

5. There are two peak seasons of harvest of the seeds in a year, namely October - December and March - April. The mean seed yield per tree per season was estimated to reach up to 21.4 kg or more per tree in a season which translated into revenue of ₦14,000.00 according to the prevailing market price during 2013 – 2015 survey in SE Nigeria.

6. The SWOT analysis of *P. macrophylla* genetic resources development in SE Nigeria demonstrated that despite the identified challenging threat and weak factors, investment in the improvement programme of the species holds great tangible and potential benefits for the farmers, general users as well as the environment.

7. Sapling densities are disproportionately low, ranging from 0.3 and 0.4 stands per hectare on farm lands in Ebonyi and Abia states respectively, to 1.5 and 1.8 stands per hectare on fallow lands in Imo and Ebonyi states respectively; and grand mean of 1.1 stands per hectare for the region.

8. The fact of prevailing very low sapling density per hectare of the tree in SE Nigeria suggests serious threat to the natural regeneration and re-stocking rates of loss stands in the agroecosystem and depleting wild populations. Underlying factors to this challenge are identified to include the intensive massive harvest of the species seeds for direct consumption, and recalcitrant seed nature that render most stored seeds non-viable after sometimes.

9. The grand Relative Importance Value (RIV) of the species in SE Nigeria was 8.0% across the different land use systems. At state level, the RIV ranged from the least (6.6%) in Abia state to highest (10.7%) in Imo state; and from 7.5% on farm lands to 8.4% on fallow lands.

10. *Pentaclethra macrophylla* population structure were generally dominated by trees within the range of 50 cm to 150 cm Girth at Breast Height (GBH), with

up to 50% of the trees. Large trees (with more than 150 cm GBH) contributed nine percent of the species population among the states. Sapling class contribution to the species population ranged from 32% in Ebonyi state to 44% in Abia state. On the basis of land use system and its impact on the species population structure, it was observed that large sized trees (> 150 cm GBH) were relatively more abundant on farms than on fallow lands. Conversely, there was relatively more abundance of sapling and young tree below 150 cm on fallow lands than on farm lands.

11. The combined effects of mechanical scarification by nicking and soaking in cold water for 12 - hour duration proved to be best option for enhanced mass and uniform germination (88 %) of *P. macrophylla*.

12. Other pre-sowing treatment practices including chemical scarification and boiling water, were not effective enough to bring about early germination and achieve high percent germination within shortest possible time.

13. Single and combined effects of IBA and NAA rooting hormones application (in the range 1000 mg/L – 3000 mg/L and 500 mg/L – 1000 mg/L respectively) on air layered branches of *P. macrophylla* showed that both auxin treatments had little adventitious root production at eight weeks after girdling. However, the branches fairly callused which is a definite mark of ensuing rooting process.

14. The air-layering done in July and September performed best in the formation of adventitious roots. These periods coincided with the two peaks of rainfall in the area studied. Also, phenology of *P. macrophylla* showed that the species undergoes active vegetative phase during June – September; while period between November and April coincides with the reproductive (flower set) cycle of the species.

15. Early growth and natural nodulation ability of *P. macrophylla* seedlings show the species capacity to produce functional root nodules for nitrogen fixation, in addition to accumulation of substantial dry matter on marginal soils.

16. There were little evidence to attest to potential adverse allelopathic effect of *P. macrophylla* leaf extract solution on germination and seedling growth of maize and okra. Seeds of okra showed greater sensitivity to inhibitory impact of the leaf extract application at high concentrations than maize seeds that were almost indifferent. The present findings may prove that protection of the tree stand on farmland will not negatively interfere with the arable crops in agroforestry system.

CONCLUSIONS

From the foregoing research findings, the following conclusions are drawn: *Pentaclethra macrophylla* is utilized by the people of southeastern Nigeria for numerous economic, ecological and sociocultural reasons. Seed production and revenue generation potential of the species could reach up to 21.4 kg or more per tree in a season which translated into revenue of ₦14,000.00 by 2015 market price survey. Mean tree density per hectare ranged from 1.1 trees/ha on farm lands to 4.8 trees/ha on fallow lands; while relative density and frequency of the species per hectare were estimated to be 40.5% and 59% respectively. Low sapling density per hectare (0.3 – 1.8 saplings/ha) in the region poses serious threat to natural regeneration and re-stocking rates of loss stands of the species population. Concerns for *P. macrophylla* organised conservation programme was justified by observation and record of very low sapling density across the region and states agroecosystems; confirmed multipurpose status of the species ability to fix atmospheric nitrogen through its nodules, even on poor soils; and stimulatory allelopathic potential property of the species leaf litters on common arable crops. High uniform germination percent [> 80%] and speed can be achieved within four weeks after sowing by use of mechanical scarification (nicking) and pre-sowing soaking in cold water for 12 hours.

RECOMMENDATION

The tree *Pentaclethra macrophylla* is ideal for agroforestry practice in the sub-region since leachate from the decomposing leaf litters may not inhibit the growth and yield of arable crops. Research into performance and response of other crops to *P.*

macrophylla leaf litter is recommended. Moreover, as major challenges of the species included poor natural regeneration rate and attendant low sapling density in the agroecosystem due to intensive harvest of the seeds for economic benefits, in addition to inherent recalcitrance nature, farmers may be encouraged to consider establishing groves/plantations for sustainable production. Improved propagation technique by marcotting developed in this study is recommended to make this possible.

CONTRIBUTIONS TO KNOWLEDGE

This study has contributed to the existing knowledge in the following areas:

- The Relative Importance Value (RIV) for *Pentaclethra macrophylla* trees were fairly high, which may be a result of some degrees of protection on farms and in fallows due to utilization of its seeds. The RIV of *P. macrophylla* was highest in Imo State, followed by Ebonyi State and least in Abia State. *Pentaclethra macrophylla* stands were more abundant on fallows than farm lands.
- Pre-sowing treatment by mechanical scarification (nicking) combined with soaking in water for at most 12 hours was effective for breaking seed dormancy in *P. macrophylla* and gave 88% germination at four weeks after sowing.
- Marcotting carried out in July and September showed best adventitious root production for clonal multiplication of *P. macrophylla*
- Seedling growth and root nodulation of *P. macrophylla* was encouraged in ferruginous sandstone and sandstone derived soils with low nutrient status.
- Aqueous leaf extract of *P. macrophylla* at 40% concentration did not inhibit growth performance of maize and okra.

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APPENDICES

Appendix 1: Google earth satellite imagery of Nigeria (top) and some cities in southern Nigeria (down) showing location of Abia, Ebonyi, and Imo states where floristic distribution of African Oil bean was surveyed (Google Inc satellite imagery, 2016)

Appendix 2: Questionnaire on how communities in Igbo land Southeastern Nigeria manage, use and conserve African oil bean ('UGBA')

Attention: Please, fill in or tick as appropriate. Thanks for cooperation.

SECTION A

1. [a] Oil bean ('Ugba') farmer [……]; [b] Ugba processor […..]; [c] Ugba marketer […..]

Note: you may tick more than one in question (1) above.

2. Community name: ……;
LGA:……; State……

3. Male …… or Female ……

4. Age :……

5. Marital status: [a] single …… [b] married …….. [c] widow ……. [d] divorced/separated ……

6. Highest educational level: [a] no formal education…….;
[b] primary school [….] not completed [….] completed
[c] secondary school [….] not completed [….] completed
[d] higher institution [….] not completed [….] completed.

7. Present occupation: [a] major occupation…….

[b] Others (if any, specify)……..

SECTION B

8. How do you own the ugba tree in your place? [a] inherited from parent [ ]; [b] bought with land [ ];

[c] found growing in my farmland on its own [ ]; [d] planted by me [ ].

9. How many Ugba tree do you have?

10. What are the specific uses of parts of ugba tree in your community?

Plant part	Use(s)	Explanation
(a) seeds		
(b) leaves		
(c) fruit pod peelings		
(d) wood/timber		
(e) roots/barks		
(f) flowers		

11. What is the level of your involvement in ugba collection/gathering, processing and marketing?

Level of involvement	Always	some times	None
(a) Collection only - (b) Processing - (c) Marketing -			

12. For commercial scale producer, tick correct option(s) that best describe your market:

Description	Always	Sometimes	None
(a) sale raw harvested pods (b) sale seeds only (c) sale processed sliced and wrapped ugba (d) sale processed ugba and other native food			

13. If you process your own ugba for home use or for sales, how long (i.e. number of days) does it take to process collected seeds? …….

14. Do you store seeds/pods of ugba for later use or sales? Yes [ ] no [ ].

15. What method(s) do you use in storage of collected ugba? (a) in basket or bucket [ ]; (b) in drum or pot [ ]; (c) in bag or sack [ ]; other way [ ] (please specify)……

16, How long can you store collected ugba using your method(s)? .....

17. Do you ever experience spoilage of your ugba produce during storage? Yes [ ] no [ ].

18. If yes, what is the cause of spoilage? (a) Insect attack [ ]; (b) rat attack [ ]; (c) rot [ ]; (d) others (please, specify) ……..

19. What quantity of ugba seeds are you able to collect per tree during harvesting season in a year using the local custard bucket container?

20. Which month(s) of the year do you have highest collections of ugba?
……..

21. Which month(s) of the year do you have most sales and consumer demands of ugba? .....

22. What problem(s) do you encounter in the gathering, processing and sales of ugba produce? List

……

……

Appendix 3. List of tree species composition in cultivated and fallow lands across three states of SE Nigeria – their common and vernacular names in Igbo†

S/no	Family and species composition	Plant common name	Plant vernacular name (Igbo)
1	**ANACARDIACEAE** (4 species)		
	Anacardium occidentale	Cashew	-
	Mangifera indica	Mango	-
	Spondias dulcis	June plum	Plom
	Spondias mombin	Hog plum	Isikara/Isikere
2	**ANNONACEAE** (4 species)		
	Annona muricata	Sour sop	Chop chop
	Cleistopholis patens	-	Ojo
	Dennetia tripetata	Pepper fruit	Mmimi
	Xylopia aethiopica	African guinea pepper	Uda
3	**APOCYNACEAE** (3 species)		
	Alstonia boonei	-	Egbu
	Funtumia africana	-	Mba mmiri
	F. elastica	-	Orumba
4	**ARECACEAE** (4 species)		
	Cocos nucifera	Coconut	Aki beke
	Elaeis guineensis	Oil palm	Nkwu
	Phoenix reclinata	Wild date	Ngala
	Raphia hookeri	Raphia palm	Ngwo
5	**ASPARAGACEAE** (1 species)		
	Dracaena arborea	-	Odu
6	**BIGNONIACEAE** (2 species)		
	Crescentia cujete	Calabash tree	-
	Newbouldia laevis	-	Ogirisi
7	**BOMBACACEAE** (1 species)		
	Bombax buonopocense	Kapok	Apu /Akpu
8	**BURSERACEAE** (2 species)		
	Canarium schweinfurthii	Incense tree	Ube agba
	Dacryodes edulis	African pear	Ube
9	**CHRYSOBALANACEAE** (2 spp)		
	Dactyledenia lohmbachii	-	Ukan
	Acioa barteri	Monkey fruit	Ahaba
10	**CLUSIACEAE** (2 species)		
	Garcenia kola	Bitter kola	Aki ilu
	Mammea africana	African apricot	Ekpili
11	**COMBRETACEAE** (1 species)		
	Terminalia glaucescens	-	Edo
12	**CUPRESSACEAE** (1 species)		
	Cupressus sempervirens	Cypress pine	-
13	**EBENACEAE** (1 species)		
	Diospyros mombuttensis	Ebony	Okpu ocha
14	**EUPHORBIACEAE** (3 species)		
	Bridelia artroviridis	-	Aga

	Hevea brasiliensis	-	Okwe
	Maesobotrya barteri	Bush cherry	Ubenne / uvene
15	**FABACEAE** (21 species)		
	Afzelia africana	African mahagony	Akparata
	Albizia adianthifolia	-	Avuru / avu
	Amphimas pterocarpoides	-	Awa
	Anthonotha macrophylla	-	Ububa uhie
	Baphia nitida	-	Aboshi
	Berlinia grandiflora	-	Ububa ocha /ubakiriba
	Brachystergia eurycoma	-	Achi
	Daneillia ogea	-	Awarogu
	Detarium microcarpum	-	Ofor
	Dialium guineense	Velvet tamarind	Icheku /nkwa
	Erythrina senegalensis	-	Echichi
	Erythrophleum ivorense	Eringi	Inyi ewu
	E. suaveolense	-	Inyi
	Gossweilerodendron balsamiferum	-	Achi aro /agba
	Parkia bicolor	-	Oke akpaka
	P. biglobosa	Locust bean	Ogiri okpi
	Pterocarpus osun	Barwood	Ubie
	P. santalinoides	-	Nturukpa
	P. soyauxii	African camwood	Uha
	Pentaclethra macrophylla	African oil bean	Ugba/ukpaka
	Tetrapleura tetraptera	Aidan tree	Uhiakirihia/ahirihia
16	**IRVINGIACEAE** (2 species)		
	Irvingia gabonensis	Bush mango	Ugiri
	I. wombolu	Bush mango/dika nut	Ogbolo
17	**LAMIACEAE** (2 species)		
	Gmelina arborea	Gmelina	Melina
	Vitex doniana	Black plum	Mbembe/ucha koro
18	**LAURACEAE** (1 species)		
	Persea americana	Avocado	Ube beke
19	**MALVACEAE** (6 species)		
	Cola acuminata	Kola nut	Oji igbo
	C. lepidota	Monkey kola (yellow)	Achicha/ochiricha
	C. nitida	Kola nut	Oji gworo
	C. pachycarpa	Monkey kola (white)	Achicha ocha
	Eribroma oblonga	-	Ebelebe
	Hildegardia barteri	Parachute tree	Ufuku
20	**MELIACEAE** (3 species)		
	Azadirachta indica	Neem	-
	Carapa procera	-	Nkpaku
	Entandrophragma cylindricum	Sapele	Awala
21	**MORACEAE** (8 species)		
	Antiaris toxicaria	-	Ohu oji
	Artocarpus altilis	Bread fruit	Ukwa beke

	Ficus exasperata	Sand paper tree	Asisa
	F. saussureana	-	Ebu
	F. vogeliana	-	Obu
	Musanga cecropioides	Corkwood	Nru/oro
	Melicia excelsa	Iroko	Orji
	Treculia africana	African bread fruit	Ukwa
22	**MORINGACEAE** (1 species)		
	Moringa oleifera	Moringa/drum stick	Okwe bekee
23	**MYRISTICACEAE** (2 species)		
	Pycnanthus angolensis	-	Akwa miri
	Staudtra stipitata	-	Ichala
24	**MYRTACEAE** (3 species)		
	Psidium guajava	Guava	-
	Syzygium malaccense	Rose apple	-
	Eucalyptus camaldulensis	Eucalyptus	-
25	**RUBIACEAE** (2 species)		
	Nauclea diderrichii	Brimstone tree	Uburu / Uvuru
	Sarcocephalus pobeguinii		Uvuru ilu
26	**RUTACEAE** (6 species)		
	Citrus aurantifolia	Lime	Oroma nkirisi
	C. limon	Lemon	-
	C. x *paradisi*	Grape	-
	C. reticulata	Tangerine	-
	C. sinensis	Orange	Oroma
	Zanthoxylum gilletii	-	Uko
27	**SAPINDACEAE** (2 species)		
	Blighia sapida	Akee apple	Okpu
	Eriocoelum macrocarpum	-	Okpu ocha
28	**SAPOTACEAE** (3 species)		
	Gambeya albida	African star apple	Udara
	Manikara obovota	-	Okpichi / ukpi
	Vitellaria paradoxa	Sheanut butter	Osirisa
29	**SIMAROUBACEAE** (1 species)		
	Hannoa klaineana	-	Ogburuo
30	**ZAMIACEAE** (1 species)		
	Encephalartos barteri	Cycad	-
TOTAL: 30 families (95 species)			

†Note: most of the vernacular names are as list in Okigbo (1980) and Keay (1989), in addition to updates from personal communication with informed ADP farmers during the floristic survey (2014/2015).