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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

GROWTH PERFORMANCE OF *CEDRELA ODOROTA* IN TWO STANDS (PURE AND MIXED) OF INDIGENOUS SPECIES IN THE TANO OFFIN FOREST RESERVE

BY

BROBBEY, FELICIA

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IN

ENVIRONMENTAL SCIENCE.

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DECLARATION

I hereby declare that the results of these studies, except otherwise cited are my own work and have not been submitted for any degree other than that of my Master of Science in the Kwame Nkrumah University of Science and Technology.

Brobbey Felicia ……………………. ……………………
(STUDENT) Signature Date

Certified by:

Prof. Philip Kweku Baidoo …………………… …………….……
(SUPERVISOR) Signature Date

Certified by:

Dr. Matthew Glover Addo ….………………. ……….……………
(HEAD OF DEPARTMENT) Signature Date

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NYANSAPƆ WƆSANE NO BADWENMA

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DEDICATION

I dedicate this work to God Almighty, who gave me life and strength throughout my study and to my son, Samuel Adom Osei Mensah.

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ABSTRACT

In Ghana, establishing monoculture plantations using fast growing exotic species have been practiced over the years. However, combining these species with native ones in a mixed plantation is a relatively recent development. This study therefore provides vital information on the growth performance or interactive effect of the native species on the exotic species. The study investigated the growth performance of exotic species of *Cedrela odorata* in a pure and in mixed stand of indigenous species of *Terminalia superba* and *Khaya grandifolia*. The study was carried out in an eight year old plantation in the Tano-Offin Forest Reserve which lies in moist semi-deciduous forest zone of Ghana. Survival rate, height, diameter, stand density and volume of the species were determined. Results from the study indicated that pure *Cedrela odorata* stands had a high survival rate (97.09%) followed by *Cedrela odorata* mixed with *Terminalia superba* (95.48%) the least was *Cedrela odorata* mixed with *Khaya grandifolia* (95.34%) but no significant differences (p>0.05) were recorded among them. Between the two indigenous species *Khaya grandifolia* survived better than *Terminalia superba*, though no significant difference was recorded between them. The results of the study further revealed no significant differences (p>0.05) among growth and productivity of the pure *Cedrela odorota* stand and the mixed stands of the indigenous species. It was observed from the study that since all the three species used in the plantations are light demanding, the competition for above ground resources was high and the *Cedrela odorota* sp. being the fast growing species among the three was able to cast a shade over them resulting in their some what poor growth and survival. It can be concluded from the research that the indigenous species did not play any facilitative or competitive reduction roles in the growth performance of the *Cedrela odorata* species as *Cedrela odorata.* can perform in both monoculture and mixed stands.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Supply of high value timber throughout the world is becoming more limited due to excessive exploitation, forest conversions to agriculture and other forms of land uses and in protection of the existing forest. Recently, afforestation and replanting programmes using indigenous tree species have gained considerable interest as a mean to complement current tropical timber markets and to reduce the over- exploitation forest and its resources (Piotto, D., Viquez, E., Montagnini, F. & Kanninen, M., 2004).

Ford-Robertson (1971) defined plantation as a forest crop or stand raised artificially, either by sowing or planting. The establishments of forest plantations have increased worldwide and it accounts for about 5% of the world forest cover (FAO, 2001).

Development of plantation forest through the planting of foreign or native species would bring many benefits such as replacing the natural forest in the supply of timber, restore degraded landscapes due to deforestation (Evans, 1992) and also proving environmental service as carbon dioxide sequestration to reduce global warming (Brown, 1997). According to Evans (1992), forest plantation establishments have the potential to sequester large volumes of carbon.

Food and Agriculture Organization (2001) reported that, the importance of plantations in the production of timer for the wood market is undisputable as it provides 35% of global round wood. Their status in terms of ecological conservation has been positive, especially, where natural forest has been converted to plantations. However, this practice has been reducing, as large tracts of abandoned agricultural lands and other marginal lands available for afforestation purposes (Evans & Turnbull, 2004).

The importance of plantation forest in terms of its conservation value, carbon sequestration, restoration of disturbed areas and reducing logging pressures on the existing forests have been recognized. Because of these, plantation forests are now generally considered as one part of management triad-consisting of ecological reserves, managed natural forests, and high-yielding plantations, with the key question being how to allocate land among these three types on a landscape (Stanley & Montagnini, 1999).

Indigenous tree species are expected to produce high-value timbers, which are important for commercial products and local consumption. However, silvicultural techniques for indigenous tree species have not improved compared with those of exotic fast growing trees owing to limited experience and lack of information about site suitability and growth performance in a given environment (Montangini *et al*, 2005). Foli, E., Agyeman, V. K. & Pentsil, M. (2009) reported that the reduced interest in the use of native trees for plantation in Ghana was as result of diseases and pest infestations. It must be noted that many indigenous tree species apart from its commercial uses can also meet economic and social objectives (Ball, J.B., Wormald, T. J. & Russo, L., 1995). It is generally believed that the yield of mixed-stand plantations depends on the type of species to be used, silvicultural practices and the interactions between species on the site (Wormald, 1992). To understand why some mixed plantations have performed poorly than monocultures, it is important to assess the ecological interactions between species more closely. In theory, three types of interactions exist among species in mixtures, these are facilitation, competition and competitive reduction (Kelty, 2006). Competition is brought about as a result of interactions between species in such a way that one exerts negative effect on the other (Vanclay, 1994).

Competitive reduction in mixtures, also known as the competitive production principle occurs when the interspecific competition for a limiting resource is less than that in the monocultures (Kelty, 2006).

1.2 Problem Statement and Justification

The establishment Forest plantations have increased worldwide and it accounts for about 5% of the world forest cover (FAO, 2001). Most countries have provided incentives for establishing tree plantations and in Ghana, one of the priorities is to reduce the incidence of deforestation by raising about 200,000 hectares of both native and exotic species over a decade (Ministry of Lands and Forestry, 1996). According to Foli *et al*. (2009) plantation developments are some of the measures that have been adopted to reduce the overexploitation of commercial species and restore degraded areas in Ghana.

Forest plantation development programme in Ghana for many years have been skewed towards the planting of exotic tree species. The preference for exotic species can be attributed to their fast growing ability, largely free of pest and fire tolerance characteristics compared to many indigenous species. However, this trend has changed as forest policies recommend regenerating harvested areas with a mixture of tree species, preferably exotics and native species.

In the tropical and subtropical regions, there have been continuous interests in mixed plantation species among researchers and landowners (Piotto *et al.,* 2004. The shift in interest may be as results of advantages such as better utilization of sites, improved tree nutrition and fewer pests attack than monocultures. Forrester, D. I., Bauhus, J., Cowie, A., & Vanclay, J. K. (2006b) reported that as result of limited number of studies on mixed plantations, it is difficult to accurately predict success of mixed-species combination and sites, especially with regards to growth dynamics. To understand why some species combinations have yielded less than monocultures, it is necessary to examine the ecological interactions in pure and mixed species plantations of exotic and indigenous species more closely. *Cedrela odorata* has been used over the years in monoculture plantation in Ghana, however, there is little information on the growth performance of this exotic species in a mixed stand of native species. This study therefore, assessed the growth performance of *Cedrela odorata* in a pure stand and in a mixed stand of two indigenous species in the Tano - Offin Forest Reserve.

1.3 General Objective

The main objective of the study was to assess the growth performance of *Cedrela odorata*, in a pure and in a mixed stands of *Terminalia superba* and *Khaya grandifolia* in the Tano Offin Forest Reserve.

The specific objectives were to determine:

i. the survival rate of all the species ii. the growth performance of *Cedrela odorata* in the stands.

iii. whether the indigenous species composition affect the growth of the *Cedrela odorata* iv. the growth performance of the two main indigenous species.

CHAPTER TWO

LITERATURE REVIEW

2.1 Plantations Forestry Development

Plantations have been the subject of renewed interest in both the public and private sectors in recent years. Carle and Holmgren (2003) stated that, over several decades, there have been considerable attempts to define many concepts related to forestry and forest plantations. The earliest definition of forestry plantation which was adopted by (FAO 1967) define plantation forest as a forest stand raised artificially by afforestation on lands which did not previously have forest before or on land which has had forest before for the last 50 years or within living memory and had been replaced by a new or essentially different crop. According to FordRobertson (1971), plantation forest is a forest crop or stand raised artificially, either by sowing or planting. Plantations can also be defined as forest stands established by planting and/or seeding through afforestation or reforestation. They are either of exotic or indigenous origin which meets minimum area requirement of 0.5 ha; tree crown cover of at least 10% of the land cover and a total area height of adult trees above 5 m. FAO (2003) proposed a definition for plantation forest as a planted forest that have been establish and are (intensively) managed to produce wood and non-wood forest products for commercial purposes and also to provide environmental service such as erosion control, landslides stabilization and windbreaks.

Reforestation in tropical forest is becoming a major forestry activity in most tropical countries that depend on natural forest for the supply of wood upon realizing the need to embark on plantation projects to support the supplies from dwindling and unsustainable natural forests (Onyekwelu, C. J., Stimm, B. & Evans, J. 2011). Among species that feature predominantly are

Cedrela odorata (cedrela), *Terminalia superba* (Ofram), *Khaya ivorensis* and *Tectona grandis* (teak) because they are fast growing, perform well in Ghana and are also ranked high in terms of economic importance. The growth of species is not uniform and is affected by both physical and ecological factors (Evans, 1992). If a stand is left untouched from planting, its initial uniformity of similar size with equal growing space progressively disappears.

Forest Plantation establishment are done for different purposes and it differs in stand structure, composition and intensities of management practices. The nature of plantations are generally simple mostly, pure stands of the same age which are manage to improve productivity and other benefits which are important to the grower (Evans 1992). According to Onyekwelu *et al.,* (2011), the objectives of establishing plantations may fall under timber production for industrial and domestic purposes, environmental protection and rural development.

More than hundred tree species may exist for plantation projects, few ones are wildly use. *Acacia, Eucalyptus, Pinus* and *Tectona* were the widely used species for plantations before the year 2000 (Evans and Turnbull 2004). *Acacia, Eucalyptus and Pinus* account for more than 50% of all tropical tree plantations (FAO 2003). Native and exotic tree species are wildly used used for plantations establishment in the tropics and sub-tropics, with the exotic one being more common. The dominance of exotic species is attributed to their superiority in growth performance over their native counterparts, coupled with their ability to control weeds.

2.2 Forest Plantations in Ghana

In Ghana, plantation establishments begun in the late 1950s with the purpose of wood production, wildlife habitat protection and the improvement in the environmental quality. (Foli *et al*., 2009; Appiah, 2003). The Tuangya system were used to establish almost all of the plantations (Appiah, 2003; Odoom, 2002). Available records show that the Forest Services Division (FSD) had established 75000 ha of plantations as at 1990. Recent evaluation, however indicated that only about 21000 ha is useful and productive.

The National Forest Plantation Development Programme of Ghana which was launched in the year 2001 with the aim of promoting the development of a sustainable forest resource base that will meet the demands of timber for industrial use and improve the quality of the environment. The modified Taungya system which differ from the conventional Taungya system was used to implement the programme. Under this system, farmers who participated in the programme will be co-owners of the plantation together with the forestry commission. Forest plantation programmes in Ghana for many years have been skewed towards the planting of exotic monoculture plantations. The preference of exotic species was mainly due its fast growing, largely, free of pest, and diseases and fire tolerance characteristics compared with many indigenous species. This trend has however changed as forest policies over the years recommend regenerating harvested areas with a mixture of tree species preferably exotic tree species with indigenous ones. Nanang (2012) stated that, for Ghana, the overarching strategic reason for promoting forest plantations are to ensure that the country is able to meet the demand for forest products for its growing population, mitigate the pressure on the natural forest and contribute to their sustainability. Plantation forestry in Ghana is one arm of the axes of policy tools to reduce deforestation, protect the natural forest resources base thereby reducing deforestation and ensure the availability of forest products to meet social, environmental and economic objectives.

2.3 Importance of Plantations

The natural forest has been able to supply our forest resources needs in the past. However the high population growth and the need for foreign exchange for our countries development have placed great demands on the natural forest to provide export earnings as well as to fulfil the country's own needs for timber and non-timber resources (Cobbinah, J. R., Wagner, M. R., Ofori, D. A. & Adu-Bredu, S. 2004). Ghana's population has traditionally relied on natural forest to provide its forest products. However, analyses of demand and supply of the forest resources suggest that in future, demand would outstrip supply and hence new resources needed to be created (Nanang, 2012). Currently, demand for treated poles for rural electrification projects exceeds the supply from the existing plantations. Cobbinah *et al.* (2004) also found out that in Ghana, the maximum volume of timber that sawmills can handle is greater than the volume of timber that can be made available to the industry without damaging the forests. They further stated that in 1999 alone, about 2000 timber trees equal to 3.7 million m^3 were removed from our forests. This is far greater than the Annual Allowable Cut of 1million m^3 (the volume of timber that our forest can provide on sustained basis). These industries depend on regular supply of raw materials which is becoming increasingly difficult to obtain from the natural forests.

It is now considered that tree plantations cannot be avoided if the forest resources being used up are to be resupplied and also reduce the urgent demands on the remaining natural forest. Monocultures and mixed stands have the potential to restore soils, forest structure biological diversity and contributing to the catalyzing of forest successions in degraded ecosystems (Carnus, J. M., Parrotta, J. & Brockerhoff, E., 2006). The establishment of plantations through afforestation or reforestation using exotic or native species have the potential of replacing the natural forest in meeting the demand of timber and reduction of global warming (Evans, 1999; Brown, 1997).

When plantation projects are planned properly can serve as reliable source of timber (Foli *et al*., 2009; Kelty, 2006) rehabilitation of disturb lands (Blay, D., Appiah, M, Damnyag, L., Dwomoh, F. K, Luukkanen, O. & Pappinen, A., 2008), protection of biological diversity (Sayer, J., Chokkalingam, U., & Poulsen, J. 2004; Lamb, 1998; Parrotta *et al*., 1997), poverty reduction and collaboration with communities to address forest related issues (Blay *et al*., 2008; Blay, 2004) and sequestration of carbon (Montagnini & Porras, 1998). Forest plantations may play many roles such as supply local industries with wood, provide wood for export, protect the soil and watershed and provide a suitable home for wildlife when combine with natural forest (Cobbinah, *et al*., 2004).

2.4 Species Selection in Plantation Development

The choice of species to be use is one of the most important factors to consider in plantation establishment. The choice depends on the purpose of the plantation, the available species for planting, which species will match the available site (Evans and Turnbull, 2004) In addition to choosing tree species to match their most productive sites, species are also chosen to fulfil the purpose of establishing the plantation (end-uses). There is also the question of whether the plantation should be a single species (monoculture) or multiple species (mixed). Each of these has their advantages and disadvantages. If the forest plantation is to provide only wood products, then most often, a single species suitable to the site may be sufficient. However, if the purpose of the plantation is to provide services such as aesthetic values, protection of wildlife habitats, biodiversity conservation and timber, multiple species plantations will be favored (FAO, 2002). According to Cobbinah *et al*. (2004) there is no restriction as to what to plant, as any tree species suited to the site and with commercial value may be planted. However, since tree plantations lock up investment over relatively longer period, it is important to seek technical advice on the following: site requirement for species, quality of planting materials, end use of the selected species, tending technique and possible market for selected species. The purpose for which the plantation is being established determines the species that is selected.

Species are also chosen based on the outputs desired. If fuel wood is the major need, then species that produce large amounts of biomass within short periods, and also coppice well would be the appropriate choice (Nanang, 2012). However, if the need is for building construction and electrification, then tree species that have straight boles and with natural durability would be more suitable. Tree species that are water intensive should neither be planted in the drier areas nor used as ecological restoration around rivers or streams. Species for restoring degraded lands and watershed protection would have characteristics that are consistent with their functions such as fast growth, provision of shade, litter production, deep-rooted, erosion resistance, etc. When it comes to ecological restoration, the use of exotic species has the potential to cause problems since they are often aggressive than the indigenous species and can alter ecosystem structure (Berger, 2006).

2.5 Site Selection for Plantation Development

A second important consideration is selecting the site for the plantation. Good site selection is one of the most important decisions that can lead to improved yields, reduced rotation lengths, and increased economic returns for plantations (Nanang 2012). In this case, the most important factor is to match species with the site in order to optimize productivity as every land has specific properties that affect the growth of what is planted. Furthermore, sites are selected to minimize the risk of plantation failure due to poor soil drainage, drought or inability to control weed competition. Cobbinah *et al.(*2004) indicated that trying to grow trees that are not well adapted to the land climate may delay or slow down their growth and increase the risk of pest attacks and diseases.

Soil drainage and depth , soil physical and chemical composition, soil moisture availability; frequency and nature of common and occasional winds, storms and fires; and the general climate of the area are some of the important site components that to be considered (FAO, 2001). The following questions can be helpful in selecting the best species for a particular site: the soil type (Soil texture- sandy, loamy, clayey), presence of restrictive layers (iron pans/hard pans) and depth of bedrock, soil properties (Acidic, neutral, alkaline), water holding capacity and rate of drainage, the rainfall pattern (Total annual rainfall and duration of the drought period). A general approach to assessing site quality is to examine the presence and importance of competing vegetation, and populations of animals such as insects and microorganisms that are either damaging or beneficial to the trees, which can affect the management of forest plantation sites (FAO, 2001).

Site selection may be limited by the availability of land for the investors. Most small-holder farmers would be restricted to planting trees on their own farmlands or family lands, which may not be the most suitable for forest plantations. This would reduce the productivity of such plantations, thereby requiring more land to achieve the same level of output. Community plantations rely on communal lands, while industrial plantation investors would acquire large tracks of land through purchasing or leasing. Industrial investors have the most flexibility in choosing the site, since they would be purchasing or leasing the land. Large scale investors would also need to consider the location of the plantations vis-à-vis processing facilities, markets for their products, cost of land preparation, labour force availability and available infrastructure.

The ability to match species with site is limited by the lack of technical information on many plantation species and the sites that optimize their productivity. Matching species with sites is complicated by the wide range of potential plantation species and infinite combinations of sites available to choose from. Consequently, a spatial map that shows the suitability of various plantation species for the different vegetation zones would be a useful tool for plantation forestry investors in Ghana.

2.6 Species Focus for Plantation Development in Ghana

In Ghana, under the forest plantation development project, five exotic tree species (*Tectona*, *Cedrella, Eucalyptus, Gmelina* and *Pinus*) and five native species (Ofram,Ceiba,Wawa,Emire and Kusia) have been selected for large scale planting. According to Nanang (2012), Tectona grandis (teak) consist of over 45% of the existing state plantations. *Cedrela, Gmelina, Mansonia* and *Terminalia* spp are some of the species that have been planted on a large scale. In Ghana, most exotic species outperform indigenous ones in terms of productivity and would be more favoured in afforestation projects. Nanang (2012) found out that most plantations in Ghana and other tropical countries use exotic tree species as it is believed that exotics are better suited for forest plantation than native species. In addition, exotic species offer wider range of choices, are often free from local diseases and pests, and usually their silviculture is better understood than indigenous ones (Evans & Turnbull, 2004). In terms of rotation, the 10 selected tree species for plantation development in Ghana could be grouped into short, medium, and long term rotation species.

Many tree growers have to decide whether to plant more than one species at one time or the other. The decision will be based on conditions at the site, how suited the species to be planted are on the site; the existence of several kinds of markets and on knowledge about silvicultural and management requirements of the different species.

2.7 Mixed Plantations

Many stakeholders in Ghana's forestry sector are becoming increasingly convinced of the potential role of mixed-species plantations, particularly over indigenous species in sustainable forest management in the country. The desires to establish mix-stands more than monocultures may be as motivated by reasons such as marketing opportunities, biodiversity protection or tolerant to diseases and pest (Vanclay, 2006).

Lamb & Gilmour (2003) reported that mixtures are able to utilize sites conditions better, improve tree nutrition, less attack from insect pest and diseases. Mixed tree plantations are able to accumulate above ground biomas and able to sequester carbon more than pure stands (Stanly & Montagnini, 1999).

2.8 Advantages of Mixed Stand Plantations

The advantages of mixtures are more than just economic or ease of management. It also includes, ecological, economic and even social benefits (Bosu, P. P., Cobbinah, J. R., Nichols, J. D., Nkrumah, E. E., & Wagner, M. R, 2006). Promoters of mixed stand plantations often outline three broad reasons that mixtures have over monocultures. These are greater tree production, Provision of environmental services and avoidance of risk. There are many reasons why mixed species plantations should be promoted. However some of the important advantages of mixtures are outlined below:

2.8.1 Efficient Utilization of Site

When the right combination of species in the mixture is selected, and arranged properly the site is more efficiently utilized than in a monoculture situation. For example, a mixture that includes shallow-rooted species is better able to utilize soil resources from various layers of soil than monocultures. Such a mixture is better able to stand against wind and storm action (Bosu *et al.,* 2006). Growth rates and stand level productivity of individual trees can increased potentially when tree are grown in mixtures because competition for fundamental growth regulating resources can be increased. (Forrester *et al.*, 2006a; Kelty, 2006).

2.8.2 Lower Risk of Loss Due to Fire Outbreak, Pest and Diseases

Trees are less susceptible to insect and diseases when they are planted in mixtures (Nichols, J. D., Ofori, D. A., Wagner, M. R., Bosu, P. & Cobbinah, J. R., 1999; Nichols, J. D., Rosemeyer, M. E., Carpenter, F. L., & Kettler, J. 2001; Bosu *et al.*, 2006). The effect of damaging insects and pathogens on some vulnerable species are reduced substantially when planted in the matrix of other species. A mixed plantation species have a lower risk of destruction by pest since not all the species may be vulnerable in the event of a major pest outbreak. Thus, mixed species plantations provide some form of insurance against complete failure due to the effect of pest and of the damaging agents (Bosu *et al*., 2006). The incidence of fire in forest (including plantation) is growing. Fire hazards may be reduced through various interventions (firebreaks, prescribe burns, etc.). The discontinuity created by incorporating species with low flammability in mixed plantations would slow the spread of fire.

2.8.3 Improvement of Soil Conditions

Roots of different plant species can occupies different soil strata and also capture greater amount of solar energy when planted together since different canopy strata have different optimum light requirements(Jose, S., Williams, R. & Zamora, D., 2006; Forrester *et al.*, 2004; Hunt, M. A., Battaglia, M., Davidson, N. J. & Unwin, G. L., 2006). The phenologies of roots or shoots growth may differ, therefore competition for soil resources will be less compared to the pure stand plantations. Bosu *et al.* (2006) found that mixtures that include nitrogen fixing species can be used to enhance soil fertility which will facilitate the growth of other species in the plantation. Piotto (2008) also found that the rate of diameter growth in mixed plantations were higher because trees that were able to fix nitrogen had a positive impact on the diameter growth of non–fixing species. The study further suggests that species combinations can increase tree growth in plantations. Experience indicates that mixed species plantations have a higher probability to survive on poor soils than most monoculture plantations.

2.8.4 Enhancement of Biodiversity

Mixed-species plantations are widely acclaimed as more environmentally friendly and sustainable forest plantation system than monoculture plantation. Mixtures of indigenous species are regarded as being ecologically closer to ’natural’ forest ecosystems than monocultures. Species mixtures can be designed in various ways to enhance ecological diversity at stand or landscape scale. Apart from planting different species, biodiversity can be enhanced by using multi-age block planting, or by inter-planting seedlings in the matrix of naturally occurring indigenous trees or shrubs in the field, or by leaving blocks or strips of natural vegetation on the site. These do not only promote vegetation diversity but also wildlife diversity.

2.8.5 Increased Benefits from Thinning and Other Silvicultural Operation

Thinning from monoculture plantation may be of little economic value in terms of timber, but could be used to defray the cost of managing the plantations. Through enrichment thinning and pruning, competition between trees are well managed and proper spacing of pioneer tree species can promote wood quality (Dickinson, G. R., Leggate, W., Bristow, M., Nester, M., & Lewty, M. J., 2000).

2.8.6 Multiple Forest Products

Mixtures can be designed to provide a range of forest products that include timber, poles, fruit, spices and other non-wood forest products (Forrester *et al.*, 2006a).

2.8.7 Disadvantages of Mixed-Species Plantations

There are a number of studies supporting mixed stand plantations (Wormald, 1992; Ball *et al*., 1995; Hartley, 2002; Kelty, 2006; Erskine *et al*., 2006; Forrester *et al*., 2006a), however, there are also a number of unsuccessful commercial industrial polyculture plantations. According to Lamb (1998) and Hooper *et al.,* (2005) mixed stand plantations are not preferred to pure stands when it comes to restoration activities. Nichols *et al*. (2006) reported that although there established silvicultural requirements for successful mixed stand plantations, challenges still exist in managing this type of plantations (FAO, 1993; Wormald, 1992). This is because, mixed plantations may demand other silvicultural measures in throughout their growing phases compared to pure species plantations (Nichols *et al*., 2006). Managing mixtures can be demanding and will normally require more attention (Wormald, 1992). This study further revealed that managing mixed stand plantations successfully will require a set of clearly defined objectives.

2.9 Indigenous Tree Species

In Ghana and other tropical countries, exotic species plantations dominate most of the existing plantations (Odoom, 2002, Evans, 1999). Indigenous tree species is defined as a variety of woody plants that are found growing naturally in a specific habitat in an ecological zone of a country (Taylor, 1962). They germinate, regenerate, grow and flourish naturally under prevailing climate conditions. Indigenous plantation is partly due to the concern that, the promotion of monoculture in place of naturally diverse forest would accelerate the loss biodiversity. Reforestation projects, currently, seek to promote the cultivation of indigenous species as a desirable alternative to exotic stands in as attempt to enhance and sustain biodiversity of the forest ecosystem (Prebble, 1997).

Recently indigenous species have been found to perform well than some of the exotics (Foli *et al*., 2009; Butterflies, 1995). Evans and Turnbull, (2004) outlined some of the advantages of indigenous species as:

* the growth of indigenous species in natural stands gives an indication of their potential, reducing the risk of complete failure when grown in plantation;
* indigenous species are naturally adapted to their environment and developed resistance to known diseases and pests;
* indigenous species play ecological roles, and may be critical habitats for local animals and plants; and
* plantations of native species conserve the native flora, especially in areas of deforested or degraded forests

According to Foli *et al*. (2009) and Haggar, J. P., Briscoe, C. B. & Butterfly, R. P. (1998) some of the native tree species are not slow growing as suggested earlier but through the use of selected and improved germplasm, some may have the potential of exceeding the productive potential of most exotic species.

2.10 Problems Associated With the Use of Indigenous Tree Species

Various efforts to use native trees in plantation establishments, over the years, have been unsuccessful because of insufficient information about their biology, ecology, silvicultural requirements and problems of pest and diseases (Wagner, M. R., Cobbinah, J. R. & Bosu, P. P. 2002; Feyera, S., Beck, E. & Lüttge, U. 2002; Butterfield, 1995). Indigenous tree plantations suffer more damages from pest and diseases because they are generally susceptible to foreign and native pest and pathogens (Ciesla, 2001; Gadgil & Bain, 1999). These occurrences may be as results of the changes in the ecological conditions brought about by competitions between species, site characteristics, stand density and other management practices (Hosking, 1983). Foli *et al*. (2009) reported that the low interest in the use of native trees is as a results of pests and diseases attack. For example most of the mahoganies grown in the country have been inhibited by the larvae of the shoot borer moth, *Hypsipyla robusta* (Odoom, 2002; Opuni-Frimpong, E., Karnosky, D. F., Storer, A. J., & Cobbinah, J. R. 2008) and also *Milicia* species have been severely affected by gall-forming psyllids *Phytolama lata* (Wagner *et al.,* 2008; Bosu *et al*., 2006; Nichols *et al*., 1999).

2.11 Advantages of Monoculture Plantation

Monoculture plantations have the advantages of concentrating resources on one species, simplicity and uniformity (Evans & Turnbull, 2004; Kelty, 2006). Pure stand plantations are uniform and relatively easy to harvest compared to mixed stands (Hunt *et al*., 2006; Kelty, 2006; Nichols *et al.*, 2006). Because of these factors, species like eucalyptus are grown in pure plantations for pulp and paper industry. Marginal lands that are not good for agricultural activities are used to establish these industrial plantations. Management techniques, nutrient inputs and matching site preparations are some of the efforts to improve productivity in monocultures. Nutrients inputs in the establishment stages are some of the common operations in plantations (Florence, 1996; Schroth & Sinclair, 2003). Removal of biomass during harvesting results in high exports of plant nutrients which can leads to serious nutrient deficiencies in the preceding rotations and this requires further increases of nutrients inputs in the second and third rotations. Such intensive silvicultural management generates questions about long term site productivity and sustainability of such plantations (Evan, 1999; Binkly, 2005).

2.12 Disadvantages of Monoculture Plantations

Inspite of the wide spread of these plantations, many concerns have been raise about their continuous expansion because of their perceived negative effects such as less support for biological diversity (Stephens & Wagner, 2007; Carnevale & Montagnini, 2002; Lamb, 1998) and lower levels of products diversifications (Lamb *et al.,* 2005; Odoom, 1998). Some of the disadvantages of Monocultures are;

2.12.1 Less Support to Biodiversity

Pure stand plantations may have lower biodiversity than that of existing forests and in most cases, it is also lower that biodiversity of meadows. Monocultures have contributed less to the conservation, studies and use of biological diversity (Carrere & Lohman, 1996).

2.12.2 Soil Deterioration, Erosion and Infertility

Companies in the forestry sector argue that plantations do not have serious effects on soils compared to intensive agriculture. World Rainforest Movement (1999) reported that fast growing trees have an extractive effect on soil fertility and that they tend to impoverish the soil and unbalance its structure. Furthermore, some species may inhibit the growth of other species through the release of certain chemical substances. *Eucaluptus* tend to acidy the soil whiles *Gmelina* inhibits the growth of other plants of other species. Land preparations before planting, harvesting and other practices in monoculture plantations also favours erosive processes I areas with steep slopes.

2.12.3 Low Levels of Product Diversification

Timber production is not the only product people demand from plantations (Blay *et al*., 2008; Lamb *et al*., 2005). Non timber product for domestic uses apart from timber production are some of the reasons forest fringe communities embark on tree plantation projects (Blay *et al.,* 2008). However, pure stand forests do not provides non timber forest products and other environmental services to communities (Erskine *et al*., 2006).

2.12.4 Deterioration of Hydrological System

Physiological and morphological structure of tree plantations differ from natural forest or other ecosystems and its ability to absorb or releases water varies depends on climatic conditions and tree type. Presence of undergrowth is one the aspects which mostly influences the hydrological cycle when it comes to forests ecosystems. The understory act as sponge in the shade which retains water without evaporations and release it slowly to the soil.

2.13 Plantation Stand Dynamics

Understanding and predicting the behaviour of forest stand dynamics is one of the significant tools of forestry practice and these tools are limited for a majority of trees species grown in plantations in Ghana today (Nanang, 2012). Smith *et al*. (2001) stated that a forest stand may seem static but it is really a dynamic, ever changing, living structure. Forest stand dynamics is the change in forest structure, composition and function through time including stand behavior before and after disturbances (Oliver & Larson, 1996). The usefulness of understanding forest dynamics is to be able to make reliable predictions about how forest will change over time and in the face of natural anthropogenic factors (Nanang, 2012). Disturbances constantly influences forest stands and when these disturbances are lethal, new vegetation or remaining trees occupies the spaces created. Lethal disturbances can either be natural (fire or wind) or human induce (harvesting or herbicide) events where trees are killed. The future development of the stand will be dictated by the structure of the stand, time, magnitude and intensity of the disturbance. A given aggregation of trees of a single age class or cohorts proceeds from birth to death through a sequence of developmental steps (Oliver & Larson, 1996). These must be recognized if understanding of stand dynamics is to be used to achieve management objectives by imitating, guiding or altering natural process in silvicultural treatments. After disturbances have created a unit of vacant growing space, the trees that become establish in it do not fully occupy the space until there is an additional plant to fill the empty spaces. Often the plants that filled the newly vacant spaces are herbaceous annuals or other short lived species that may come and go quickly

2.14 Growth in Plantations

Growth is the increase in particular stand characteristics over a period of time which may include increases in height, volume, diameter, crown and any other forest attributes of a tree stand (Nanang, 2012). According to Nkyi (2007) growth rate of a tree is the increase in the lateral and epical size and length of a species which takes place simultaneously and independently in different parts of a tree. Longman & Jenik (1987) also defined tree growth as the changes that occur in the life of an individual or single tree with time. Individual tree grows by means of photosynthesis through adding woody biomass to parts of the tree stem, branches and roots. Most of the growth are different but are not impossible to measure on the field (Davies, S. J., Nur Supardi, M. N., LaFrankie, J. V. & Ashton, P. S. 2003). In single species plantations, mortality is easier to estimate than in natural forest where there is species diversity. Depending on the purpose of measurement, growth can be categorized into total growth, potentially usable growth and growth that is actually removed and used (Davis *et al*., 2003).

Total growth refers to all biomass produced by the trees, including roots, stump, bole branches and leaves. Potentially usable growth refers to woody components that could be used by a manufacturer, given current technology, while the amount of the growth that is actually removed and utilized constitutes the third kind of growth. Growth measurement is complicated by mortality, because the increase in volume, between any two measurement periods has to consider that some trees might have died in that time, while within that interval some trees might have grown into the measurable size as well (Davis *et al.,* 2003). Ofosu (1997) indicated that environmental factors largely determine the actual growth of a tree whiles the genetic make-up determines potential growth. The importance growth parameters that are usually measured are diameter and height.

2.15 Diameter Growth

Tree diameter growth is one the most important measure observed on a tree. It may be taken to determine the characteristics of the stand structure (diameter distributions or number of trees by diameter classes) and for the estimations of tree volumes or weight. Diameter growth of most trees has the typical sigmoid curve form, although the growth stages are not markedly separate as in height growth (Nkyi, 2007). The first stage is usually short except in the species with wellmarked S juvenile growth. Growth in diameter particularly, the bole of trees is of critical importance in forestry as it determines the rate of production of logs sawn out of trees especially in the tropics where many timber species may be considered not merchantable until they have attained a certain minimum diameter size (Chapman & Demerritt, 1986).

Diameter growth varies greatly with species, age of trees and prevailing environmental conditions. Diameter growth of an individual tree primarily depends upon site factors and stand density. Since stand density can readily be controlled, diameter growth is also subject to effective management control (Nwoboshi, 1984). Some of the tools used to measure tree diameter are calipers, diameter tape, and Biltmore stick.

2.16 Height

It shows a general brief juvenile period followed by a period of very rapid growth and ending with a relatively long period of slow almost negligible height growth in the old trees (Nkyi, 2007). Most trees growing under favourable conditions conform to this pattern. The rates of height development by trees vary considerably depending on both inherent and external factors which control the rapid and duration of growth.

2.17 External and Ecological Factors That Influence Tree Growth.

Data on the productivity of trees is site-species specific and also the growth of species is affected by genetic and environmental factors (Ford, C. R., McGuire, M. A., Mitchell, R. J. & Teskey, R. O. 2004). The list of abiotic factors having ecological effects on plants can be long. The more widely important factors include temperature, light and moisture (Brewer, 1994).

2.17.1 Light

Solar radiation provides almost all the energy in the tropical forest. Plant growth is affected by light intensity, duration of exposure to light and light quality. Plant species vary in shoot growth as a response to light intensity. Light intensity affects the growth of shoot, both directly and indirectly. Direct effect is exerted on photosynthesis, stomata opening and chlorophyll synthesis. Indirect effects may be reflected in leaf desiccation as a result of excessive transpiration when exposed to high light. Light is essential for normal development of leaf and quite often low intensities are sufficient to ensure normality in shape and size, and that largest leaves are those which grow in the shade (Treshow, 1970). More trees differ in their tolerance to light and shade levels to such a degree that subjective classification has been made (Miller, 1972). The classification identifies pioneer tree species which are light demanders and will not establish well in deep forest shade. Such species are suitable for plantation conditions. They show favourable growth in gaps and are classified as such. Generally, pioneer species show the fastest growth rate and continue to respond to light than non-pioneer species (Longman & Jenik, 1987).

2.17.2 Temperature

Temperature is important in controlling the rate of processes inside an organism (e.g. plant) and thereby its activity. Temperature controls plant growth and development by regulating the rate of the numerous physical, biological and chemical processes that are part of the physiology of a plant. Though the light phase of photosynthesis is not temperature dependent, the dark reaction of photosynthesis is temperature dependent and may limit the rate of the overall photosynthesis process (Brewer, 1994).

2.17.3 Competition

Competition may be simply a matter of each individual taking as much as it can get of some resources called exploitation. Plants compete for resources such as nutrient, light, moisture with its neighbors. Planted trees which are about the same size will become less inferior to its neighbours when it fails to compete successfully for nutrients, light and moisture. If a stand is left untouched from planting, its initial uniformity of similar size seedlings with equal growing space progressively disappears. Intra-competition depends on the species growth rate and initial spacing. Competition occurs when the presence of neighbouring trees begins to show a tree's own development. Showing in development may occur first from competition between root systems or only once branches touch and shade on another. Evans (1992) found that competition between trees occurred in *Pinus patula* stands planted at 2.74 x 2.7 m interval, at about 5-6 years of age when trees were about 7 m tall, competition appears to have an effect from about the time of canopy closure. Diameter increments of individual trees began to show effect of between- tree competitions at a time which corresponds closely, the effect appearing last in the most widely spaced plots (Evans, 1992).

2.17.4 Forest Canopy

Tree canopy is the habitat found at the topmost levels of forests. Tree canopy can be defined as the tallest layer of a tree in a forest which distinguishes from secondary trees which occupies lower ecological niche. According to Philip (1994), canopy closure is the proportion of a unit area of ground covered by a vertical projection of tree crowns. Canopy of a rainforest is typically 10 m thick and can intercept around 95% of sunlight.

2.17.5 Crown Shape and Size

The tree crown is the organ which supports the photosynthesizing tissue absorbing and employing radiant energy in the living processes. The crown organizes the position of the current photosynthetic area and provides for its renewal. It is therefore expected that trees of particular species with large crowns will grow faster than others of the same species with small crowns (Philip, 1994).

2.18 DESCRIPTION OF SOME OF THE FOCAL TREE SPECIES

2.18.1 Cedrela odorata

2.18.1.1 General Description

Cedrela odorata belongs to the family Meliaceae. It is a deciduous tropical tree that grows to a maximum height of about 30-40 m and it is widespread in seasonally dry tropical and subtropical forests. About two-thirds of the bole is clear without branches and the wood has a strong aromatic odour with a woody capsule fruit which contains very small winged seeds which spread when the when the ripened fruit split open. *Cedrela* is a medium-sized tree up to 33 m high, back smooth, leaves pinnate, leaflets 9-10 pairs, strongly scented especially after rain ; leaflets lanceolate, acuminate, unequal-sided; flowers (March-June) small, greenish white; fruits (December-February) siphon-shaped; seeds winged (Irvine,1960). In large trees the bole often bears plank buttresses that can extend up to a 3 m in height; it is usually straight, cylindrical and often free of branches up to about 20 m above the ground; the crown is very broad and sparse and therefore does control weeds (Lamprecht, 1989). *Cedrela* can be pollinated by insects and has wind dispersed seeds (Carvers *et al.*, 2004). The species flowers annually but good seeds occur every 1-2 years. *Cedrela i*s listed in the category of species that face a high risk of extinction in the wild in the medium term due to over exploitation.

2.18.1.2 Ecology and Silviculture

In Ghana it has widely been planted in plantations in the high forest zones in the Western, Eastern and Central Regions, and also avenue trees in towns (Agyeman, V. K, Senaya, J., Anglaaere, C. N. L., Dedjoe, D. C., Foli, E. G. & Acquah, B. S. 2010). *Cedrela odorata* stocks best on the driest, best-drained sites in the evergreen and semi-deciduous rain forests. It is nutrient demanding and does not do well in water logged areas. The species according to Orwa, C., Mutua, A., Jamnadass, R., & Anthony, S. (2009) tolerates soils rich in calcium, and prefers fertile, free drained and weak acid soils. In Ghana *Cedrela* has been successful in the few plantations established in the moist evergreen and semi-deciduous zones (Geoffrey & Geoffrey, 1992). The root system of *Cedrela* is superficial and this makes the tree subject to wind damage especially after thinning. Transplanting of naturally regenerated seedlings and stem cuttings are the most common propagation methods. In the natural forest, it is therefore a species of the overstorey and regenerates well in forest clearings, on abandoned agricultural sites, and on favourable sites even under a light canopy. Natural regeneration can be encouraged by removing the canopy around seed trees and gradually lightening the over wood (Lamprecht, 1989). The most serious insect pest of *Cedrela* is the mahogany shoot borer *Hypsipyla grandella.* The larvae of this moth eat the pith just behind the growing tip of fast growing shoots, causing death of the apical meristems, which slows seedlings and sapling growth and may ruin tree form.

2.18.1.3 Uses of *Cedrela odorata.*

Cedrela odorata is widely harvested for use as timber by virtue of its durability, excellent work, qualities and appearance. It is a redwood of fine texture and uniform grain with high luster and a distinct cedary odour; the timber is durable, easy to work and easy season without degrade (Geoffrey & Geoffrey, 1992). It is moderately resistant to decay and works easily with all tools, and finishes well. It is used for veneer and plywood production, indoor and outdoor construction, furniture, lathe turning, musical instruments and domestic utensils; it is the best wood for building canoes and sporting boats. *Cedrela* tree has many lower branches and spreading crown, which make them suitable for use to provide shade and windbreak in courtyard gardens and in cocoa and coffee plantations (Orwa *et al.,* 2009). The species can also be planted for ornamental purposes along roads and in parks.

2.18.3 *Terminalia superba* (OFRAM)

2.18.3.1 General Description

Terminalia superba locally known as ofram belongs to the family Combretaceae. It is a commercial species of abundant occurrence, very high production and regular export. The tree is large and grows up to 50 m high, a girth of 3m, with a straight bole and a spreading crown. The buttresses are up to 2.5 m high, bark silvery-grey; loose and scaly with yellow slash, branching system is horizontal and almost in regular whorls, leaves simple up to 18cm long and 10cm broad; obovate; glabrous; acuminate at the tip with long petioles, flowers (January-June) yellowish-white; loose pendulous axillary spikes 10 cm long, samara fruits about 3 cm by 6 cm; mature in November, each being one-seeded with two lateral wings. It has fine texture to moderately coarse with low luster and wood is fairly hard, medium dense (Oteng-Amoako, 2006). Older trees have tall, well defined buttresses often running 4-5 m up to the bole. The bark and buttresses of the old of the trees of Ofram make it easily distinguishable from *Terminalia ivorensis.*

2.18.3.2 Ecology and Silviculture

Terminalia superba is a deciduous tree and is widely spread throughout the high forest zone, but is more common in the drier areas and secondary forest than in the wetter areas where it is generally rare. It grows well in areas with rainfall between 1000 mm and 300 mm with a dry season lasting from one to four months. Provided the rainfall is adequate, Ofram has a reputation for tolerating a wide variety of soils. It does well in alluvial soils but it is also found on other soils. Thus the species will grow on light, medium and heavy textured soils and on a wide soil pH ranging from acidic neutral through to alkaline soils. The young plant tolerates slight shade at first, but requires full overhead light for good development. Growth is fast after the 1st year and is widely used as a plantation species in Ghana and West Africa where height increment of 1.5 to 3 m has been recorded after 4 years and a girth of 10cm at breast height after 13 years (Taylor, 1960). On good sites Ofram is expected to reach a diameter (at breast height) of 60-70 cm in 40 years.

2.18.3.3 Uses of T*erminalia* S*uperba*

Terminalia superba is non- durable wood used for furniture, cabinet works, interior joinery, frames and trims panellings, claddings and molding. It is also used for rotary, decorative veneer and plywood (Oteng-Amoako, 2006). The wood of Ofram has excellent technical properties and has many end uses including core and face veneer for plywood production, internal and external joinery and furniture making. According to Agyeman *et al. (*2010) Ofram has some potential for pulp and paper production; hence its thinning could be utilized in the pulp and paper, as well as the particleboard industries.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was carried out in Compartment 60 of the Tano-Offin Forest Reserve in the Mankranso Forest District of Ashanti Region. The reserve is one of the three upland evergreen forests of Ghana (Hall and Swaine, 1981), situated within the Atwima-Mponua and Ahafo Ano South District Assemblies. The Tano -Offin Forest Reserve lies between longitudes 1°57″ and

2°17″ West and latitudes 6°54″ and 6°35″ North, covering an area of 413.92 km² (Fig.1). This reserve was named after the rivers Tano and Offin. The reserve is the source of numerous streams, which drain eastwards into the River Offin and westwards into River Tano.

3.1.1 Vegetation

Tano-Offin Forest Reserve falls within the semi-deciduous forest zone of Ghana with 34,100 ha of the reserve occurring as an Upland Evergreen forest (Ntiamoa-Baidu *et al*., 2001). Reports by Forestry Commission (2007) noted that the average maximum height of trees in the reserve is about 45 m. The dominant timber species include *Pterygota macrocarpa*, *Mansonia altissima* and *Terminalia superba*. The Tano Offin Forest Reserve recorded a Genetic Heat Index of 176.4 during the 2001/2002 botanical survey by the Forestry Commission of Ghana and a total of 17 Gold Star species, 3 black star species, as well as the rare tree fern (*Cyathea manniana*) were identified (FC, 2007). This underscores the conservational attention given to this reserve.

3.1.2 Climate

The reserve is within the tropical humid climate zone, characterized by a two peak rainfall seasons (June and October). The first rainfall is between April and June and the second, September and October. The mean annual rainfall is between 1400 mm-1525 mm. A period of marked dry season is between November and March. The reserve area has a mean temperature ranging from 22.0 ºC to 31.1 ºC. The mean monthly relative humidity is 80% (FC, 2007).

3.1.3 Geology

The Tano Offin Forest Reserve has some part that is found on an elongated mountainous range with numerous steep slopes, particularly is the Nyinahin Hills (Ntiamoa-Baidu *et al*., 2001). Although the general relief of Ghana lies below 600 m (NBSG, 2002), elevation of Tano Offin reserve measures between 200 m and 740 m above sea level (FC, 2007; Hall and Swaine, 1981; Ntiamoa-Baidu *et al*., 2001) with Aya Bepo as the highest point (740 m) which serves as tributaries for the Tano and Offin rivers (Birdlife International, 2011)

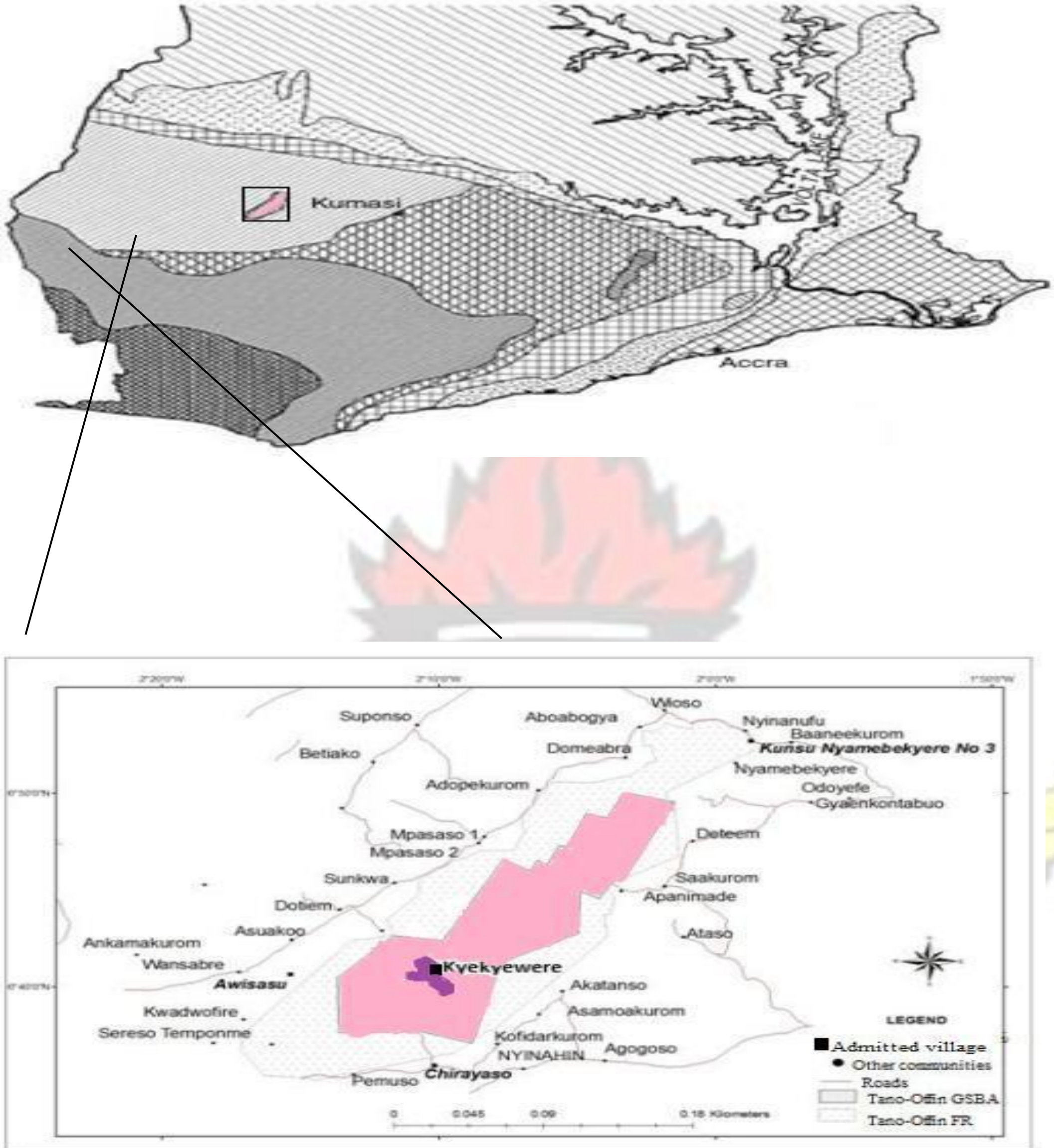

Fig 1: Map Of Tano Offin Forest Reserve

3.2 Methodology

3.2.1 Reconnaissance survey

A reconnaissance survey was conducted in the study area to obtain first hand information of the site, species planted and size of the plantations. This was to provide a fair idea of how best to lay the sample plots, the experimental design and the sampling method to use.

3.2.1.1 Species under study

Two main indigenous tree species, *Terminalia superba,* Khaya *grandifolia,* and one exotic species, *Cedrela odorata,* were studied to determine their growth performance and the survival rate. The species were selected based on their economic value and preference by farmers.

3.2.2 Experimental Design and Data Collection

The plots for this study were arranged in a Completely Randomized Design with three treatments and fifteen replicates. The treatments included a pure *Cedrela odorata* stand, *Cedrela odorata* stand mixed with *Khaya grandifolia* and *Cedrela odorata* mixed with *Terminalia superba* species. The entire study area had a total size of 11 hectares (110000 m^2) and was divided into five (5) plantations; mixed *Cedrela odorata* and *Terminalia superba*, mixed *Cedrela odorata* and *Khaya grandifolia,* pure *Cedrela odorata,* pure *Terminalia superba* and pure *Khaya grandifolia.* Each stand had a size of 2.2 hectares (22000 m^2). Each plot was subdivided into fifteen (15) subplots by size 36 x 84 m (3024 m^2). The data was taken within a period of 3 month (February to April 2014). Approximately, 220 trees were measured in each plot for diameter and height. The diameter (cm) of each tree sampled was measured at breast height (1.3 m above ground level) using diameter tape (Plate 2).

3.2.2.1 Collection of field measurement

Height (m) of each tree (above ground level) was also measured using graduated poles. Other parameters such volume, survival rate, stand density, mean annual increments and basal area were estimated. The volume was calculated using the method of Newbould (1967).

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3.2.2.2 Determination of Tree Volume

Volume = *a* x B*dbh* x *H*,

Where, *a* is the stem form factor, Bdbh is the basal area and H is the total height

The value of *a* was set to 0.5 as following Ugalde (2000).

3.2.2.3 Determination of Survival Rate

Survival rate, stand density, means annual increment and basal area were estimated following Nkyi, (2007) as follows;

$$\text{Survival Rate(\%)} = \frac{\text{The number of individual trees survived}}{\text{Total number of trees planted}} \times 100$$

3.2.2.4 Determination of Stand Density

$$\text{Stand Density(ha)} = \frac{\text{The number of individual trees in the plot}}{\text{The area of the plot}} \times 10{,}000\text{m}^2$$

3.2.2.5 Determination of Mean Annual Increment

Mean Annual Increment (MAI) =Y (t)/t   where Y (t) is yield at time t.

Basal Area (m^2/ha) = 0.00007854 x DBH^2 where, 0.00007854 is a constant

NYANSAPƆ WƆ SANE NO BADWENMA

Plate 2: An eight-year old pure *Cedrela odorata* stand in Tano-Offin Forest Reserve

Plate 3: An eight-year old Mixed stands of *Cedrela odorata* and *Terminalia superba* stand in Tano-Offin Forest Reserve


Plate 4: An eight-year old Mixed stands of *Cedrela odorata* and *Khaya grandifiolia* stand in Tano-Offin Forest Reserve

3.3 Data analysis

Data obtained from the field measurements were entered into excel spreadsheet, and Analysis of variance (ANOVA) was conducted at significance level of 5 % using student edition Statistix 9 statistical package. LSD pair wise comparison test was used to determine differences of means among the various species combinations.

CHAPTER FOUR

RESULTS

4.1 General Growth and productivity characteristics of the stands

Growth and productivity characteristics of the species in terms of stand density, basal area, volume and mean annual increments in the plantations are presented in the tables.

4.1.1 Stand Density

The result of the stand density is presented in Table 1. Results from the study showed that *Cedrela odorata* grown in a pure stand had higher (1138.70) stand density and also significantly different ($p < 0.05$) from the others grown in a mixture of *K. grandifolia* and *T. superba*. The lower (77.43) stand density was recorded in *T. superba* mixed with *C. odorata.*

Table 1: Stand density of all the species

Species	Stand Density(tree/ha)
C. odorata (pure)	1138.70±9.95a
C. odorata (mixed with *K. grandifolia*)	1065.40±9.10b
C. odorata (mixed with *T. superba)*	1022.50±4.99c
K. grandifolia (pure)	78.29±1.58d
T. *superba* (pure)	77.43±2.14d

Within columns means with the as letters are not significantly different ($p > 0.05$)

4.1.2 Basal Area

Table 2 shows the basal area of the species combinations. *Cedrela odorata* planted in a mixed stand of *K. grandifolia* had the largest (1.99) basal area whiles the least (0.45) basal area was recorded in *T. superba* mixed with *C. odorata*. Significant differences ($p<0.05$) were, however, recorded among them.

Table 2: Basal Area

Species	Basal Area ((m^2/ha)
C. odorata (pure)	1.89±0.10a
C. odorata (mixed with *K. grandifolia)*	1.99±0.04a
C. odorata (mixed with *T. superba*)	1.81±0.12a
K. grandifolia (pure)	0.49±0.02b
T. superba (pure)	0.45±0.02b

Within columns means with the as letters are not significantly different ($p> 0.05$)

4.1.3 Volume

The volume of all the various species are given in Table 3. The highest (10.28) volume was recorded in pure *C. odorata* stand whiles the lowest (6.56) was found in *T. superba* mixed with *C. odorata*. There was a significant difference ($p<0.05$) recorded in terms of volume between pure *Cedrela* and the mixtures the species in the plantations.

Table 3: Volume of all species

Species	Volume(m^3/ha)
C. odorata (pure)	10.28±0.08a
C. odorata (mixed with *K. grandifolia*)	9.567±0.13b
C. odorata (mixed with *T. superba)*	9.67±0.12b
K. grandifolia (pure)	7.16±0.09c
T. superba (pure)	6.56± 0.13c

Within columns means with the as letters are not significantly different (p> 0.05)

4.1.4 Mean Annual Increments

The Mean annual increment (both in diameter and height) is shown in Table (4). Pure *C. odorota* stand recorded the largest (1.17) means annual increments in diameter and height whiles the lowest (0.98) was observed in *T. superba* mixed with *C. odorata*. Significant differences ($p < 0.05$) were recorded among them (Table 4).

Table 4: Mean Annual Increment of all species

Species	MAI (cm/yr) DBH	MAI(m/**yr)** height
C odorata (pure)	1.17±0.02a	1.17±0.04a
C. odorata (mixed with *K. grandifolia*)	1.10±0.03ab	1.10±0.02ab
C. odorata (mixed with *T. superba)*	1.09±0.03ab	1.09±0.02ab
K. grandifolia (pure)	1.08±0.03a	1.08±0.02ab
T. superba (pure*)*	0.98±0.03c	0.98±0.02c

Within columns means with the as letters are not significantly different (p> 0.05)

4.2. Survival Rate for the species in the stands

The survivals of the species in the stands are indicated in Table 5. The overall survival rate of the stands varied among the species. Generally the survival rate was high for the *C. odorata* species as survival ranged from 97% in the pure stands to 95% for mixed stands of the same species. Survival rate was highest in pure *C. odorata* stand whiles the least survival rate was recorded in the *C. odorata* mixed with *T.* s*uperb*a species (Table 2). Further analysis of the data revealed no significant differences in the survival rate.

There was a high mortality rate of *K. grandifolia* and *T. superba* species planted in the stands of *C. odorata*. *K. grandifolia* recorded 55.49% survival rate compared to the *T. superba* (50.89%) however no significant difference was observed between them (Table 5).

Table 5: Survival Rate of all species

Species	percentage of survival (%)
C. odorata (pure)	97.09±0.44 a
C. odorata (mixed with *K. grandifolia*)	95.34±0.72 a
C. odorata (mixed with *T.superba)*	95.48±0.77a
K. grandifolia (pure)	55.49±3.33b
T. superba (pure)	50.89± 3.63b

Within columns means with the as letters are not significantly different (p> 0.05%)

4.3 Diameter of *Cedrela odorata* in pure and mixed stands with *K. grandifolia* and *T. superba*

Diameter of *Cedrela odorata* in monocultures and mixed stands is shown in Figure (1). Measurements in the plantation at eight years of age revealed differences in species in terms of diameter growth. *Cedrela odorata* in a mixed stands with *Terminalia superba* had the largest diameter (9.91cm). The least diameter (8.68cm) was recorded in pure monoculture of *C. odorota*.

There was a significant difference ($p<0.05$) between the mixed and the pure stand of *C. odorota.*

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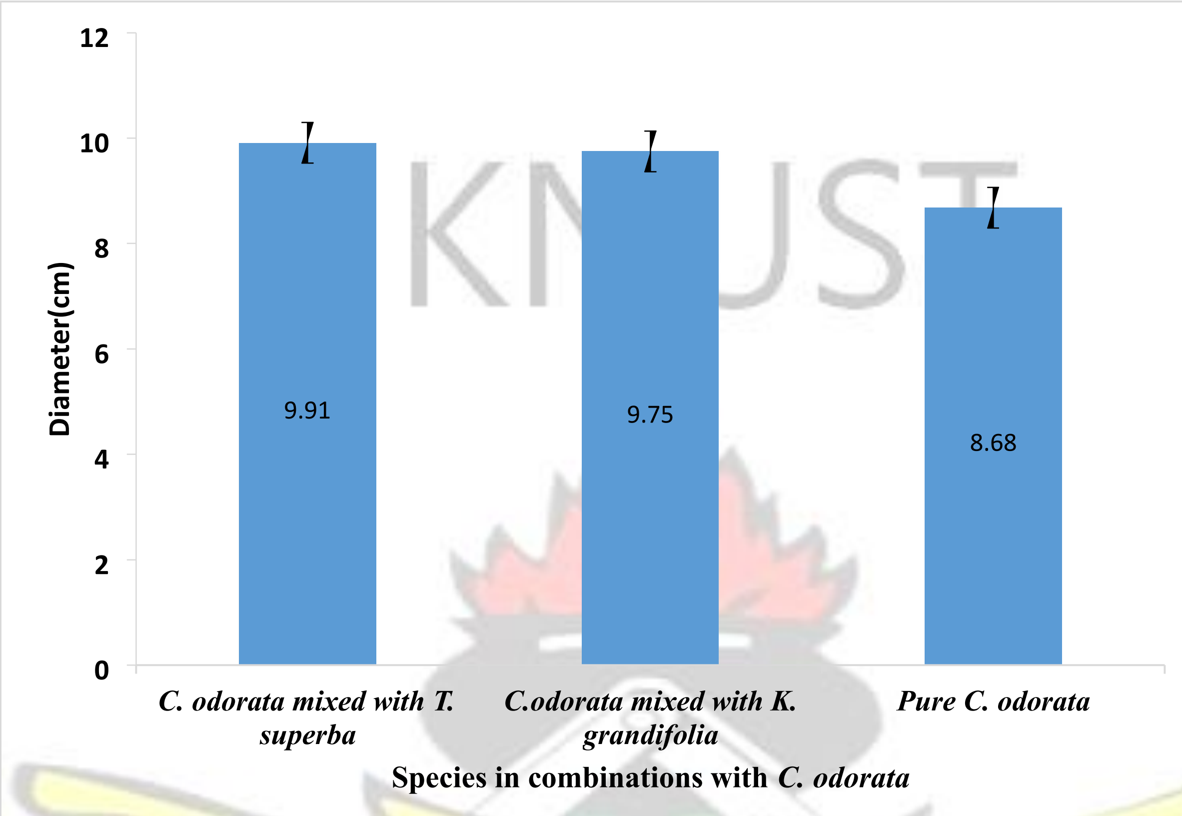

Fig1: Diameter Growth of *Cedrela odorata* in pure and mixed stand with *T. superba* and *K. grandifolia.*

4.3.1 Diameter growth of *C. odorata* in pure and in mixed stands with *Khaya grandifolia* and *Terminalia superba.*

Diameter growth of *Khaya grandifolia* and *Terminalia superba* in a mixed stand with *Cedrela odorata* is shown in Figure 2. Results of the study showed that *Khaya grandifolia* recorded a larger mean diameter (6.55 cm) than *Terminalia superba* (5.77 cm), but no significant difference was found between them.

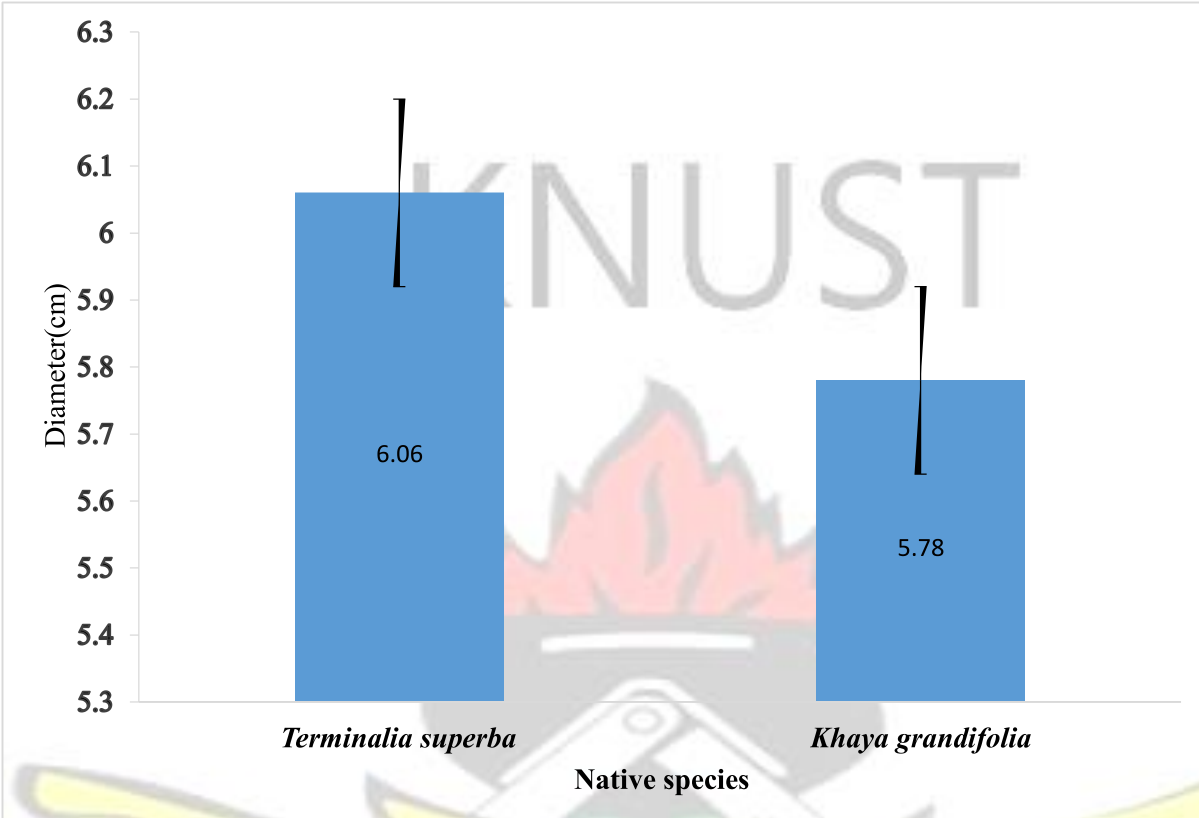

Fig 2: Diameter of *Khaya grandifolia* and *Terminalia superba*

4.4. Height of *Cedrela odorata* species in a pure and mixed stands.

Mean height of *Cedrela odorata* species planted in a monoculture and in a mixed stand with *Khaya grandifolia* and *Terminalia superba* is presented in Figure 3. Although no significant difference was recorded among them, C. *odorata* in pure stand recorded the largest (8.98 m) mean height while the least (8.69 m) was recorded in C*. odorata* with *Khaya grandifolia* combinations.

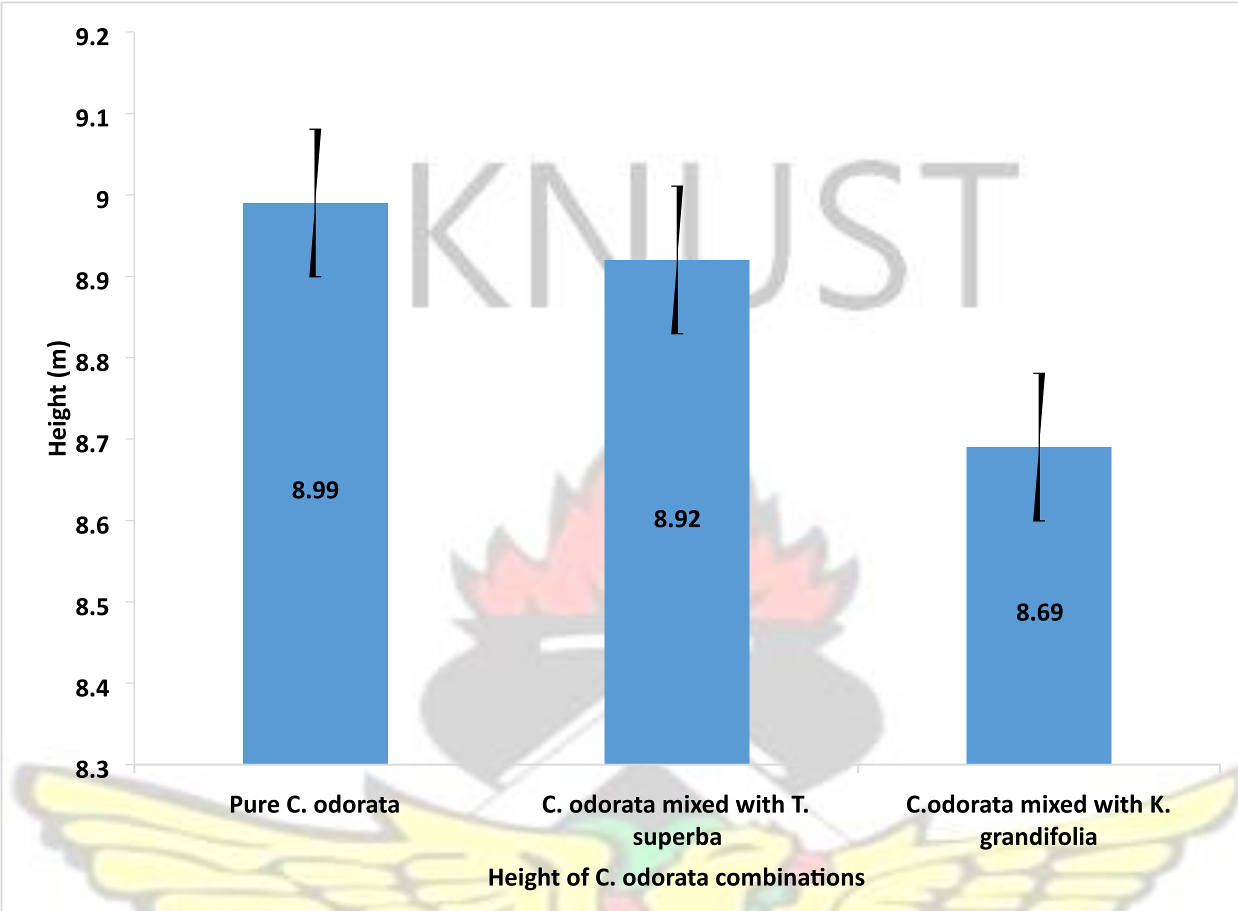

Fig 3: Height of *Cedrela odorata* in a pure and mixed stands

4.4.1 Increase in height of the indigenous species

Results of the study revealed that *Terminalia superba* had higher mean height (8.48m) than *Khaya grandifolia* (7.87m) when both were planted in mixed stand of *Cedrela odorata* species. Significant differences were recorded between the two species.

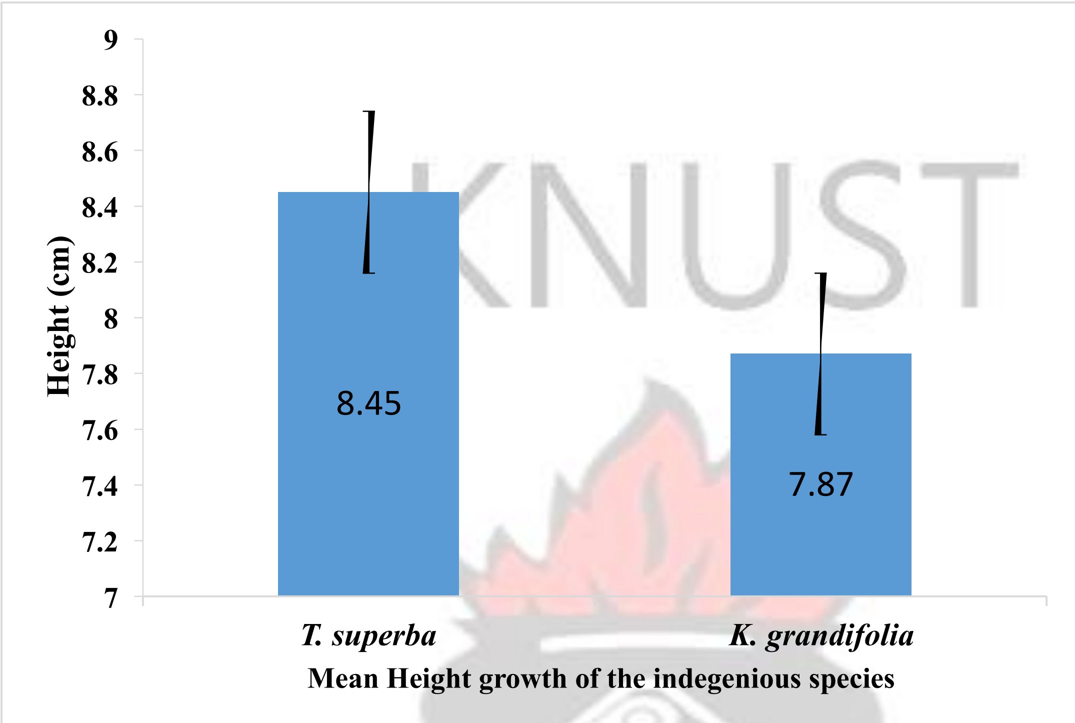

Fig 4: Increase in height of the two Indigenous species

CHAPTER FIVE

DISCUSSION

5.1 Growth and Productivity characteristics of *Cedrela odorata* in the two stands

Growth is the increase in a particular stand characteristics over a period of time which may include increases in height, volume, diameter, crown and any other forest attribute of a tree stand (Nanang, 2012). In studying the growth performance of *Cedrela odorata* in both stands, the results of the study revealed no significant differences in the growth of height and diameter of *Cedrella* in pure and in a mixed stand. However, *Cedrela odorata* planted in the mixed stand of *Khaya grandifolia* and *Terminalia superba* had a larger mean diameter and height growth than the pure *Cedrela* stands. This may be due gaps or spaces created by the *Khaya grandifolia* and *Terminalia* species as a result of high mortality rate recorded for these two species (Table 2) which created less competition between the species. Lamprecht (1986), remarked that tree species take advantage of the available growing space. Nketia (2002) suggested that ensuring correct spacing of trees in plantations results in the improvements of diameter growth as well as wood quality compared to trees grown in the open.

The rate of diameter growth varies greatly with species, age of trees and prevailing environmental conditions. Diameter growth of an individual tree primarily depends upon site factors and stand density. Thus when stand density is high diameter growth will be low since competition among trees will be high. From the study, the stand density of pure *Cedrela* was higher than *Cedrela* in mixed stand. This also accounted for better diameter growth of C. *odorata* in a combination of *K. grandifolia* and *T. superba*.

When competition is less, a fast growing species like *Cedrela odorata* will take advantage of the environmental factors and the available resources to grow (Orwa *et al.*, 2009). Ofosu (1997) indicated that the growth potential of a tree is determined genetically, but actual growth is determined largely by the environment. According to Vanclay (1994), factors that affect growth and survival of trees within its environment include soil nutrients, sunlight and shade. Competition for these resources affects productivity. Less competition for resources might have led to the good performance of *Cedrela odorata* in the mixed plantation. For mixed species plantations to be more productive and improve in growth, resources needed for growth should be provided whiles reducing competition among species (Piotto, 2008; Forrester *et al*., 2006). This means that strong competitions can reduces productivity in mixed stands (Richards *et al.,* 2010;
Callaway, *et al.,* 2002). In a study of mixed versus monoculture plantations in Costa Rica, Montangnini *et al*. (1995) and Montangnini & Porras (1998) found that the growth of focal species

was more fast in mixed than in pure plantations, and that mixed plantations had higher volumes and biomass production in comparison with pure stands.

In terms of height growth, the pure *Cedrela odorata* stand recorded a better height growth than the *Cedrela odorata* in mixed stand though no significant difference was found among them. Since *C. odorata* is a light demanding species, competition for light among them in the pure stand will be greater than in a mixed stand. This accounted for the results obtained for the height growth. Height development by trees varies considerably depending on both inherent and external factors which control the rapid and duration of growth. Plant species vary in shoot growth as a response to light intensity. Generally, pioneer species show the faster growth rate and continue to respond to light than non-pioneer species (Longman and Jenik, 1987). The present result showed that companion species did not play any facilitative or competitive reduction roles in the growth performance of the *C. odorata* which was the focal species (Plath *et al*., 2011b). Generally, in Ghana *Cedrela odorata* has been successful in plantations established in the wet evergreen and semi-deciduous zones (Geoffrey and Geoffrey, 1992).

These results are in agreement with other studies (Parrotta, 1999, Addo Danso *et al.,* 2012). The results however disagree with other studies which recorded improved growth and productivity in some trees in pure stands compared to mixed stands. Petit and Montagnini (2006) reported *Calophyllum brasiliense*, *Virola koschnyi* and *Hyeronima alchorneoides* significantly did well in pure stands than in mixed stand. Piotto *et al*. (2004) found in the dry tropics of Costa Rica that *Tectona grandis* planted in monocultures was the most productive compared to mixtures with other species with other species.

5.2 Growth and Productivity of indigenous species in the mixed plantation

Competitions for resources in a mixed stands is one of the factors that determines growth of trees in plantations. Among the two plant species, growth performance of *Terminalia superba* was better than *Khaya grandifolia* when the two were planted in mixed stand of *Cedrela odorata,* though no significant difference was recorded between them. This is because *Terminalia superba* is a faster growing species than *K. grandifolia*. *C. odorata, K. grandifolia and T. superba* are pioneer species (Hawthorne, 1993; Orwa *et al*., 2009), and therefore competitions among them in mixed stands for particularly light and other resources have the potential to reduce the growth of the other species (Petit & Montagnini, 2006). In a combination of *C. odorata* and indigenous species, since *C. odorata* is a faster growing species than the native species, it's potential to compete for sunlight and other resource is better thereby reducing the growth of the native species. Moreover, *Cedrela odorota* has the potential to form early dense crown which can shade any other trees growing around it.

It is known that crown structure is also important determinant of growth (De Lucia *et al.,* 1998) as it is not only associated with solar energy capture, but also evaporation and transpiration and growing space (Foli *et al*., 1999; Foli *et al.,* 2003). It is evident that crown projections area are associated with good growth in height and diameter. Tree crown organizes the position of the current photosynthetic area and provides for its renewal. It is therefore expected that trees of particular species with large crowns will grow faster than others of the same species with small crowns. According to Orwa *et al*. (2009) *Cedrela odorata* is known to displace native plants by blocking out sunlight with its large leaves. Opoku (2012) also reported that *Khaya grandifoliola* might not do well when it is planted in combinations with fast growing species like *C. odorata* and that the appreciable differences in growth may reduce its interest to be use in mixed plantations. Piotto (2008) noted that mixtures can have either encouraging or discouraging effects on the growth of trees. Results obtained from the principal species were expected because of the ecological features of the tree in plantations. Binkley (2005), indicated that the constant supply of resources and the species selected determines the overall growth of trees in a stand. In addition, competition between individual trees deepens as the similarities between them increases morphologically and physiologically (Hunt *et al*., 2006) reducing growth of the species in the long term (Boyden *et al*., 2008). This result is in conformance with other works which showed improved growth and productivity of exotics over their native counterparts (Opoku, 2012; Piotto *et al*., 2004). In comparing growth of *T. grandis* to *K. grandifolia* in semideciduous forests of Ghana, Opoku (2012) found that *Tectona grandis* proved superior in terms of growths and productivity than K. *grandifoliola*. A research comparing the growths and survivals of 13 indigenous trees, in monocultures and mixtures to T. *grandis*, Piotto *et al*. (2004) revealed that monoculture plantation of Tectona grandis was more productive in comparison with all other species in the plantation. Omer *et al*. (2004) also concluded that the overall performance of an exotic species (*Eucalyptus camaldulensis*) was better than other species.

5.3 Survival Rate of the Species

Generally mortality rate was low for *Cedrela odorota* planted in both pure and mixed stands. Even though no significant difference was recorded, *C. odorata* in pure stand survived better than the mixed stand. This shows that the species adapted well and also competed for environmental resources in the two plantation types. The finding of this study is in conformity with other studies that found C. *odorota* to survive well in mixed plantation combinations (Addo- Danso *et al*., 2012). This finding may be as a result of interactions from biotic and abiotic factors in the habitat. Biotic and abiotic factors as well as certain process can either act own their own or interact in a complex manner to have a an effect on the survival and growth of plants species (Lin *et al.,* 2004; Meiners

& Handel, 2000). Pest damages from insect herbivory competition and environmental heterogeneity have longed being recognized as factors that can have additive and non-additive impacts on tree mortality and growth (Wagner *et al*., 2008; Bosu *et al.*, 2006; Nichols *et al.,* 1999; Montagnini *et al*., 1995; Potvin & Gotelli, 2008*).* Evans (1992) reported that variation in the survival percentage of tropical trees is attributed to adaptation, damages caused by biotic agents, or to site conditions and other environmental factors. Mortality in *Cedrela odorata* plantations can be caused by pest and diseases (Menalled *et al.,* 1998).The shoot borer (*Hypsipyla robusta)* is the most serious pest of *C. odorata* and is also a pest of many trees in the family Meliacea. Soil characteristics and climate conditions as well as other site conditions have also been found to influence mortality in *C. odorata* by favouring disease conditions. Orwa *et al.* (2009) reported die-back disease in a stand of *C. odorata* in the Central America and the Caribbean due to insufficient aeration caused by poor climatic or soil conditions.

Survival rates for the indigenous species was generally poor compared to the exotic species. From the results, *K. grandifolia* survived better than *T. superba* but no significant difference was found among them*.* These findings contrast with that of Bosu *et al*. (2006) that reported very impressive survival rate for *T. superba* established in mixed plantations. These outcomes may be due to attack from pest and diseases, competitions for resources, climatic and site conditions as well as other factors. Foli *et al.* (2009) reported that the reduced interest in the use of native species for plantations in Ghana is result of infestations of pest and disease. Insect herbivory damages can generally lead increased mortality (Bosu *et al*., 2006). According to Ciesla, (2001) Indigenous tree plantations suffer more damages from pest and diseases because they are generally susceptible to both exotic and native pests and pathogens. These occurrences may be as results of the changes in the ecological conditions brought about by competitions between species, soil conditions, tree density and other management practices (Hosking, 1983). *K. grandifolia* and *T. superba* are high valued indigenous species which are attacked by pests. In Ghana, most mahogany plantations established have been constrained by the larvae of the shoot borer moth, *Hypsipyla robusta* that kill the main stem of young trees, causing excessive branching and contributing to mortality (Opuni-Frimpong *et al*., 2008). In addition, variegated grasshopper (*Zonocerus variegatus*) has also been found to cause mortality in these species through defoliation (Addo- Danso *et al*., 2012).

Apart from insect attack, competition is another factor considered as important source of mortality in plantations (Boyden *et al*., 2005). Interactions take place as component species attempt to capture both above and below ground resources required for growth. Both intra- and interspecific competition can therefore affect growth and survival when allowed to operate (Jose *et al*., 2006). Therefore high mortality in trees can be expected when competition become intense. High mortality rate in the two indigenous species observed may be influenced by interspecific competition from C. *odorata* in the mixed stand.

Site factors such as climate and soil as well as variation in topography, soil properties and drainage of a site can either amplify or diminish effects of species diversity on insect herbivore incidence and damage. Variations in site characteristics and abiotic conditions are important in determining individual plant's performance; therefore the influence of these factors on mortality may be considered important (Potvin and Gotelli, 2008). The results from this study and field observations showed that survival rates could have been affected by the general site conditions and variability in site characteristics such as soil conditions, topography and drainage.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In Ghana, establishing monoculture plantations using fast growing exotic species have been practiced, over the years, however, combining these species with native ones in a mixed plantation is a relatively recent development. This study therefore provide vital information on the growth performance or interactive effect of the native species on the exotic species as it investigates the growth performance of *Cedrela odorata* in a pure and in a mixed stand of *Terminalia superba* and *Khaya grandifolia*. In terms of growth and survival, no significant differences was found among the *Cedrela odorota sp.* species planted in the pure stand and the ones planted in a mixed stand of *Khaya grandifolia* and *Terminalia superba* as *Cedrela odorota sp*. performed well in terms of growth and survival both in the pure and in the mixed stands. It can be concluded that the indigenous species did not play any facilitative or competitive reduction roles in the growth performance of the *Cedrela odorata* species. It also confirms earlier observations that *Cedrela odorota* can perform in both monoculture and mixed stands.

Between two indigenous species, *Terminalia superba* performed better than *Khaya grandifolia*. Mortality rate for the indigenous species was quite high as the study recorded low survival rate for the two. It was further observed from the study that since all the three species used in the plantations are light demanding, the competition for above ground resources was high and the

Cedrela odorota being the fast growing species among the three was able to cast a shade over them resulting in their somewhat poor growth and survival. However for *Khaya grandifolia* and *Terminalia superba to* fully benefit from mixtures, it is important to combine them with shade tolerant species to increase positive interactions and reduce competitive processes.

6.2 Recommendations

The following recommendations were made based on the findings and conclusions above:

i. Since this planting scheme was replicated in the other forest reserves in Ghana it is recommended that further studies considers growth and productivity of these planting combinations in those reserves in order to make empirical conclusions about this species combinations

 Introducing nitrogen fixing trees into the mixed plantations can help improve the productivity of the site thereby improving the survival rate of the indigenous species

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