OPTIMIZATION OF *MELIA VOLKENSII* (GURKE) AS AN ALTERNATIVE MPTS IN DRY LAND AGROFORESTRY SYSTEMS FOR SOIL AND WATER CONSERVATION

BY

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DEDICATION

To the late son Ebby, Daughter Carolyn and Mother Nyalkada, who lost their lives because of my studies, I dedicate this work.

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ABSTRACT

KEY WORDS: - Semi-arid, agro forestry, *Melia Volkensii*, Optimization, Interactions

Melia volkensii is an indigenous multipurpose tree species endemic to sub-humid and semi-arid areas of Kenya, Somalia and Tanzania. This species is considered as a potential plantation and agroforestry tree species in semi-arid areas. However, it has not been widely planted because seedling production and other management protocols are not yet sufficiently developed. This study was initiated to look into the optimization of *Melia volkensii* at on-farms and how it interacts with food crops, live stock, wild animals and its management regimes in semi-arid parts of Kibwezi Division of Makueni District. The results obtained indicated that the small-scale farmers could optimize the maximum utility of *Melia volkensii* by domesticating it on their farms better than on fallow bushes. Soil moisture conservation was found to be high under *Melia* trees in dry season than under Baobab tree. Domestication and optimization of *Melia volkensii* as an indigenous MPTS can help to solve some of the socio-economic problems that are faced by rural people in ASAL regions, which limits agroforestry practices, while encouraging investments in farm-forestry through improved yields, better quality fodder, and shorter rotation periods.

Different propagation techniques were tried out at on-farm level, collection of wildings and root suckers were done at on-farms and other germination techniques were also tried at the ARIDSAK project at Kibwezi forestry research station.

The results obtained indicated that under field conditions seed propagation through different germination media were not successful, instead, wildings collection during the November/December long rains and then potted at on-farm tree nurseries, was the most successful method of propagation. Optimization and utilization of *Melia volkensii* as an indigenous MPTS by the small-hold farmers has actually led to its domestication in the semi-arid areas. This study evaluated the optimization and domestication of *Melia volkensii* (Gurke), as a means of improving yield on a sustainable basis and developed predictive models under dryland agroforestry systems as practiced by the local farmers in semi-arid parts of Makueni District (Kibwezi Division). It therefore recommends that suitable propagation techniques through wilding collection either from root suckers or from naturally germinated seeds, is the only cheaper alternative. which is farmer friendly method for raising seedlings.

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ACRONYMS AND ABBREVIATIONS

AFRENA	Agroforestry Research Network for Africa
AFRENA-ECA	Agroforestry Research Network for Eastern and Central Africa
ANOVA	Analysis of Variance
ARIDSAK	Agro forestry for Integrated Development in Semi-Arid Areas of Kenya
ASAL	Arid and Semi-Arid Lands
a. s. l.	Above sea level
BADC	Belgium Administration and Development Co-operation
CAM	Crassulacean Acid Metabolism
DM	Dry Matter
DW	Dry Weight
FRIM	Forestry Research Institute of Malawi
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
HVT	High Value Tree
JICA	Japan International Cooperation Agency
KEFRI	Kenya Forestry Research Institute
KENGO	Kenya Energy Non-Governmental Organization
LUE	Land Use Efficiency
MPTS	Multipurpose Trees and Shrubs
M^3	Cubic Meter
RUE	Resource Use Efficiency
SADC	South African Development Community
VAM	Vesicular Arbuscular Mycorrhizae
SLA	Specific Leaf Area
BTC	Belgium Technical Cooperation

CHAPTER ONE

1.0 INTRODUCTION

Agroforestry is a dynamic ecologically based, management system of natural resources that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users.

Agroforestry does not focus on a single agricultural crop or commodity but acts as a catalyst for more economically productive and sustainable agricultural system.

In the past, agroforestry in Kenya had relied heavily on a few exotic species that were selected for their fast growth and were based in the high potential areas. However, the growing of these species is not favored in semi-arid climatic conditions and also their apparent lack of adaptability to local environment, for example, the inclusion of *Leucaena leucocephala* in the agroforestry systems, is limited because of its susceptibility to insect diseases. An out break of leucaena psylid in the early 1990s has greatly, threatened the future use of *Leucaena leucocephala* as a potential MPTS, in Kenya.

The foregoing suggests that the future of sustainable agroforestry in dryland areas is likely to depend on indigenous MPTS species which have evolved alongside their natural enemies and are therefore less vulnerable to various threats from diseases and harsh climates unlike exotic species (Konuche, 1994). However, the domestication of indigenous tree species such as *Melia volkensii* in dryland agroforestry or afforestation programs is constrained by the scarcity of information pertaining to the production of their planting materials and silvicultural requirements.

This study therefore attempted to investigate *Melia volkensii* (Gurke) as a potential MPTS species for dry-land agroforestry systems in Kenya.

The inclusion of semi-arid areas in agroforestry projects is inevitable considering the prevailing competition for land use between human settlement and food production in Kenya. Indeed, this competition or land scarcity due to rapid population increase, has tended to shift land tenure towards rangelands after realising that the potential highlands are unable to cope with the increasing populations in the rural areas.

Melia volkensii is an indigenous tree species endemic to arid, and semi-arid lands (ASALs) of Kenya, Somalia and Tanzania (Dale and Greenway, 1961, Milimo, 1994). Under favorable environmental conditions, the tree can attain a height of 50m. However, the growth rate of this tree has not been ascertained although a rotation of 10-15 years has been documented (Blomely, 1994). This species is valued for high quality timber and poles that are termite resistant (Kidundo, 1997). Its timber compares with that of *Ocotea usambarensis* and *Vitex keniensis,* which are highly priced hardwood species from Mt. Kenya forests. Rural farmers have reported the use of leaf extracts to control ticks and fleas in goats (Blomely, 1994) and its traditional use has received scientific backing from entomological studies that reveals the ability of *Melia volkensii* in controlling insects (Mwangi, 1982, Mwangi and Mukiama, 1989).

Fruits and twigs of *Melia volkensii* provide valuable fodder for livestock and game while the flowers are sources of good quality honey. Despite its numerous utility potentials, *Melia volkensii* has not been adequately promoted in the agroforestry research programs. The fundamental constraints to its promotion have been inadequate propagation methods and lack of appropriate management guidelines.

This study endevoured to alleviate these bottlenecks with a view of promoting the optimization and domestication of *Melia volkensii* on farms in dryland agroforestry systems by the local communities in Kibwezi Division of Makueni District.

" ***A woody plant revolution technology***" needs to take over where the "***green revolution technology***" left off. Throughout the tropics, there are numerous perennial woody species that have provided indigenous (local) peoples with many of their needs for millennia e.g., fuel wood, building materials or construction poles, timber, fruits, clothes, dyes, gums, nuts, resins, fibre, pharmaceutical products, etc. These trees are cut down indiscriminately and are often commercially ignored in favour of a handful of exotic tree species.

Melia Volkensii associates with five genera of vesicular arbuscular mycorrhizae in its roots, these are: *Acaulaspora, Gigaspora, Scuttecospora, Glomus* and *Entroplospora*. The number of VAM spores associated with *Melia volkensii* was found to be higher in dry season as compared to wet season and in shaded sites than in open areas, (Mutabaruka, 1998).

The role of mycorrhizae, in growing MPTS has numerous benefits, since it increases the surface area of the roots for the absorption of nutrients and water, increases phosphorus uptake, drought resistance, control root pathogens, reserve nutrients and help nitrogen fixation by rhizobium bacteria, (Harley and Smith, 1983). *Melia volkensii* has the ability of absorbing more water than other agroforestry tree species due to its relationship between root structure and functions in association with mycorrhizae, hence making it one of the best agroforestry trees in maintaining mycorrhizal inocular potential for intercropping systems in semi-arid areas. It does not compete with food crops due to its deep roots of up to about 2m long, high VAM infection also influences the water storage capacity in its swollen roots which is used during high temperatures and low rainfalls. The major problem for dryland agroforestry systems is water stress or lack of soil moisture. In order to identify and assess the tree/crop genotypes and technologies with a high dry-matter productions for field sustainability in this ASAL region, the Neutron soil moisture probe was used to assess soil moisture status within the soil horizons both vertically and horizontally perpendicular to the *Melia volkensii* trees on farmers fields.

1.1 Optimization of *Melia volkensii*

Optimization is the maximum use of something. Farmers grow *Melia volkensii* because they maximize its uses in many different ways which includes both social and economic values. Finally, M*elia volkensii* is grown due to its high quality and close-grained timber, which is locally used for construction and furniture making. Traditionally, farmers required materials to make small rafters and withes for construction of their round dwellings. *Melia volkensii,* which is also termite resistant, was used for this purpose. Rural smallholders also use it as "**living banks**" that provide revenues in times of cash shortages. The abundance of leaves that *Melia volkensii* produces at the end of the dry season when other fodder sources are depleted, is highly valued among the farmers in the fragile lands

Seeds, fruit pulps, leaves and twigs contain high levels of crude protein, fat minerals and fiber (Milimo, 1994). Farmers can prune the trees and use the leaves and seeds as fodder for cows and goats just as other agroforestry tree species like *Calliandra calothyrysus* or *Leucaena leucocephala* is used in the highland areas. With the ever decreasing availability of undisturbed forest and the increasing demand for large trees that supply timber to build traditional barrel bee-hives, farmers engaged in apiculture in these areas have turned to *Melia volkensii* trees which have highly scented flowers that attract the bees (*Apis melifera*). Rural people also use an extract of *Melia volkensii* leaves on goat skins to control ticks and fleas. *Melia volkensii* (Meliaceae), is a valuable multipurpose agroforestry tree of semi-arid areas of Kenya such as Kibwezi, Mbololo, Taita, Samburu and Voi (Dale and Greenway, 1961). It is a fast growing tree used for intercropping with food crops, medicine, bee forage, fodder, soil reclamation, soil control, construction poles, fuelwood and strong valuable timber resembling mahogany. The study of optimization or optimal use of this tree would enhance knowledge on how to promote the productivity of the species for the stated multiple benefits. In arid and semi-arid areas such as Kibwezi where trees and crops are grown together, the competition for soil moisture is mostly responsible for the low observed production in crop yields

(Ong, *et al, 1991)*. There is thus growing interest on how trees compete with food crops in agroforestry set up through root growth and elongation in different soil horizons. The root competition Trial (**RAL**) with major emphasis on strategic research, helped in elucidating the processes underlying the tree crop interactions (ICRAF, 1990), showed that *Melia volkensii* has the ability of taking or absorbing more water than other species.

1.2 Justification

Dry lands in Kenya still possess a diversity of plant varieties. Wide use has been made of them though they have never been managed on an economic or ecological basis.

To counter deforestation and create a sustainably renewable multipurpose tree resources, it is necessary to increase the range of indigenous tree species which are drought tolerant like *Melia volkensii*, just like the AFRENA-ECA project has done with *Tithonia diversifolia* and *Crotalaria grahamiana* in improved fallow system in the Western highlands of Kenya (ICRAF,1998). This study therefore looked into how this species could be optimized at the on-farm levels (Farm Forestry), and its interactions with food crops and management regimes by the local farmers. Sustainable development which is defined as ***"economic activities that meets the needs of the present without compromising the ability of the future generations to meet their own needs"*** (UN, 1978), is as difficult to achieve as sustainable forestry.

The present rate of deforestation, if not checked, will jeopardize the needs of the present and future generations through loss of raw materials and genetic diversity. Plantation (**exotic**) Forestry, to answer the problem of soil nutrient depletion and forest resources in the tropics, has failed to address the real courses of deforestation which have their roots in the social-economic set up of the rural communities.

For example, the increasing rural population growth rate which has resulted in land grabbing in Kenya, land tenure, soil nutrient depletion, lack of alternative sources of fuel wood in rural areas, and shifting cultivation, are some of the contributing factors to forest degradation and depletion. Hence without adequately addressing these problems, it will be very difficult if not impossible to ensure sustainable supply of forest products and services.

Therefore, alternative indigenous agroforestry MPTS like *Melia volkensii* (Gurke) needs to be explored for their potentials for interactions with the already existing exotic agroforestry MPTS. Agroforestry system has been recognized as one of the most promising strategies for high productivity and ecological benefits for fragile ASAL regions (Kang and Attah-Krah, 1993). One of the major components in agroforestry are multipurpose trees and shrubs (MPTS) which are deliberately grown, kept and managed for preferably more than one intended products and services.

The success in agroforestry practices in these degraded lands depends on the productivity of these multipurpose trees. The productivity is in turn governed by species selection, spatial or temporal arrangement, management practices, edapho - climatic conditions and micro-organisms associations.

1.3 Hypotheses (H_O & H_A)

(i) **Ho:** Indigenous tree species are well adapted and optimized in semi-arid areas than exotic species.

(ii) **Ho:** *Melia volkensii* provides many uses and services to local community in terms of fodder, medicinal usage and soil productivity in ASAL regions than many exotic MPTS species

(iii) **Ho:** Optimization of *Melia volkensii* as an MPTS in dryland agroforestry systems can help solve some of the current socio-economic problems that limits afforestation, while encouraging investments through improved yields, better quality fodder and shorter rotation periods.

(iv) **Ho:** *Melia volkensii* has a higher water use efficiency (WUS) hence water retention in its swollen roots for survival during moisture stress periods as compared to other exotic MPTS species.

1.4 General objective

The main objective of this study was to evaluate the optimization and domestication of *Melia volkensii* (Gurke), to improve yield on sustainable basis and to develop predictive models under dryland agroforestry systems as practiced by the local farmers (Kamba people) in semi-arid parts of Kibwezi Division, Makueni District.

Specific objectives of the study were to:

1. Evaluate the propagation methodologies suitable for *Melia volkensii* large-scale dissemination through dryland agroforestry practices.
2. Recommend appropriate propagation methods of *Melia volkensii* in drylands.
3. Assess silvicultural management of *Melia volkensii* at on-farm level.
4. Assess water use efficiency **(WUE)** of *Melia volkensii* by studying the soil moisture status under Melia trees

CHAPTER TWO

2.0 LITERATURE REVIEW

Trees and shrubs are conserved or planted for two reasons: for productive reasons; e.g. production of fuel, food, fodder, medicines, etc and protective reasons; e.g. for soil erosion control, maintenance of soil fertility, shade, shelter, etc. Trees and shrubs have traditionally had a wide range of uses; they have always been multipurpose, (Bounkounou and Cantinot, 1998). Indigenous trees and shrubs in Semi-arid areas however are not being managed on a sustained yield basis at the present time. Desertification and the energy crisis of the past years have served to remind us of the importance of these plant communities. Yet little thought has gone into their future although they provide sources of energy, and food for livestock, as well as being buffer against desertification. As a result, their conservation and improvement have now become a primary objective for planners and policy makers.

Current agroforestry practices in Kenya rely heavily on exotic species. The success of this approach is limited because these plantations are not well received by rural communities who expect more from a forest community than just the production of wood. The use of indigenous species is problematic for other reasons, for example the optimal time for seed collection, suitable seed handling practices which minimizes inviability and pre-germination techniques to relieve seed dormancy are all unknown. It is within this framework that a reconsideration of indigenous species previously regarded as being of little use and no potential interest, is taking root in the minds of Kenyans. This interest is focused particularly on species that have reasonable growth of which *Melia volkensii* is one of those which is important for timber andfast growing, coppices well, and is xeric (Dale and Greenway, 1961). This species belongs to the family meliaceae, and is native to semi-arid parts of Kenya, Tanzania and Somalia. The main constraints in planting indigenous tree species is lack of long-term investment. In the case of *Melia volkensii,* this constraint has been exacerbated for many years by the lack of a clear understanding of the nature of seed dormancy and how to relieve it, (Teel, 1985). Unlike agricultural crops, trees are difficult to improve genetically because of their long generation times and the prevalence of out breeding. To improve yield and form, foresters have traditionally used provenance transfer methods.

People inhibiting dry areas (rangeland immigration) in Kenya, are clearing large areas of land to create space for agriculture. This unplanned clearing is a serious mistake. The ecology of the indigenous tree populations, some of which are endemic, must be studied before attempts are made to change or replace them with domesticated varieties. Unlike agricultural crops, most of our indigenous trees and shrubs are still growing in their natural environments, without man kinds assistance. Today, most of them are very close to their wild undomesticated beginnings. We can expect them to be better adapted to their environment than non-indigenous species, but ways must be found to improve yield on sustainable basis. In a domestication programme, outstanding trees in native populations or plantations, are located and their genes are gathered via grafts, rooted cuttings, or seedlings. This collection is called "*gene banks*" or *clone bank.* The possibility that these outstanding genotypes will be lost to logging, fire, diseases or when clearing to create space for agriculture, is thus reduced (Libby, 1973). The cost and administrative difficulties of keeping many widely scattered trees from harm is considerable. Yet once these genotypes are secured in one or more concentrated areas, the loss of original trees would be negligible. Domestication only proceeds rapidly when the bearer is able to provide new plants that is better than those available in existing stands economically and in large numbers, this is a subject for future research.

2.1 Propagation of *Melia volkensii*

Although extension agroforestry may have been constrained by inability to propagate melia seedlings (Dale and Greenway, 1961), a recent review on the subject suggest that farmers have various traditional ways of raising such seedlings (Kidundo, 1997). Traditional propagation methods included transplanting of wildings, use of root cuttings and spontaneous pretreatment of seeds that enhanced their germination under farm conditions. An international seed pre-treatment by farmers was done by spreading seed-borne animal manure on farms or through breaking hard stony endocarps with fire. During ploughing, the lateral roots are injured and tufts develop from the injured roots during rains. The tufts are thinned to one, which can later be transplanted to another site or left to develop in-situ. Usually wildings are transplanted after attaining a height of 30-35cm. Besides the traditional methods; reasonable efforts have been made to improve our knowledge on factors contributing to poor germination of *Melia volkensii* under nursery conditions (Milimo, 1986). Results from this study have been modified to fit green house/nursery conditions raising germination to between 61% and 74% (Kalumbu, J.K.1995) depending on the seed provenance and genetics. The seed pretreatment involves nipping the caruncle, followed by slitting the outer integument. Periodical observations have suggested that germination success also depend on the experience of the seed collector. Pre-treated seeds are sawn in green house traps filled with sterilized sand and watered once in a week. Germination occurs from the 14th day onwards with the maximum germination being achieved within 30-45 days. Seedlings are then pricked out into open-ended polythene tubes filled with sandy loam soils. The seedlings are kept under shed in the nursery for two weeks of shading, the seedlings are then exposed to full sunshine and watered twice a week. This watering schedule is maintained for about six months; thereafter the seedlings are hardened by watering them once a week until transplanting time. Another pre-treatment included boiling and soaking the hard nuts for three weeks, then sawing directly without extracting the hard woody seed coats. This boiling is said to reduce or extract the oil content of the cotyledon hence enhancing the germination.

2.2 Practical Utilization of *Melia volkensii*

Farmers grow this indigenous tree primarily because of its high quality and close grained timber, which is locally used for construction and furniture making. Traditionally, farmers required materials to make small rafters and withes for construction of their round dwellings. M*elia volkensii* which is also termite resistant, was used for this purpose. Rural small holder farmers also use *Melia trees* as "*living banks*" that provide revenues in times of cash shortages. The abundance of leaves that melia provides at the end of the dry season when other fodder sources are depleted, is highly valued among the farmers in the fragile ASAL lands.

Seeds, fruit pulp, leaves and twigs contain high levels of crude protein, fat, minerals and fiber (Milimo, 1994). Farmers can prune the trees and use the leaves and fruits as fodder for cows and goats just as other agroforestry tree species like *Calliandra calonthyrus* or *Leucaena lecocephala* in the high potential highland.

With the ever decreasing availability of undisturbed forest and the increasing demand for large trees that supply timber to build traditional barrel-bee-hives, farmers engaged in apiculture in these areas have turned to *Melia volkensii* trees which they plant on their farms. They curve the bee-hives from the *Melia* wood and hang them on *Melia* trees, which have highly scented flowers that attracts the bees. Rural people also use an extract of the leaves on goat skins to control ticks and fleas.

2.3 Managing *Melia volkensii* Trees

Farmers in semi-arid regions of Kenya plant *Melia volkensii* trees on croplands. Its deep roots besides pumping the soil moisture (soil nutrients) from the water table to the surface horizons to make it available for food crops, also minimizes interference with crops, and do not hamper ploughing.

If damage to its roots occur, it promotes suckering from root fragments. Trees that are to be used for timber can be pruned, side branches are removed to produce clean and straight boles free of knots and imperfections. Trees in croplands are pruned to prevent competition with crops, particularly for light.

Un-damaged tree canopy is broad and thick, shading crops such as millet, and sorghum, which are not shade-tolerant; hence farmers prune their trees heavily to avoid this. Trees are also pruned just before the rains when fodder is scarce. They harvest not just the new leaves that emerge at this time, but also the fruits to feed their cattle and goats. The remaining branches are then used for firewood.

2.4 Description of the tree

Melia volkensii (Gurke) belongs to the family Meliaceae.

It is a drought resistant tree, which thrives on well-drained soils from sandy loam to sandy clay. But it is intolerant of heavy clays (stewart and Blomeley, 1994), and black cotton soils. It is naturally found along watercourses and in *acacia/commiphora* woodlands. The tree grows up to 20m in height. The natural range of *Melia volkensii* is characterized by variable climatic conditions and soil moisture stress.

Physiographically, *Melia volkensii* occurs in a very gentle undulating erosion plains on basement rock systems. (Toubler, 1983).

Its local names are:

- Mukau (Kamba and Kikuyu)
- Bamba (Borana)

- Melia (English)
- Kirubutu (Digo)
- Maramarui (Samburu)
- Baba (Somali)
- Mukubutu (Taita)
- Mukowe (Taveta)

Melia volkensii (Gurke) is an indigenous deciduous tree always with an open canopy sometimes growing from 15m to 20m, widely scattered in lower Savannah areas in Kitui, Kibwezi, Machakos, Samburu, Taita Taveta area along Mbololo hills and Voi. It occurs as an emergent in the *Acacia* and *commiphora* deciduous bush lands, sometimes fringing seasonal water courses and on rock outcrops in altitudes between 350m to 1675m above sea level. With rainfall of about 300mm-800mm. Soils are sandy clay and shallow, stony soils of good drainage and aeration This species is also planted as an agroforestry (MPTS) as the leaves provide mulch and fodder, while the flowers encourage bee foraging. It is kept around homesteads and is noticeably green in dry seasons. It provides multiple uses as timber, construction wood, fuel wood, medicine (bark), fodder, fruits, green manure (leaves), soil reclamation, soil conservation and soil erosion control.

- **Bark:** Bark is grayish, fairly smooth, and have a pronounced, vertical fissures or furrowed with age.
- **Leaves:** Leaves are pale bright green up to 35cm long, less divided than in *Melia azadiratch*, very noticeable in dry, bush country, twice compounded with lance-shaped leaflets up to 4cm, always entire, large tapering to the apex. Margins are slightly serrated. Young shoots are densely hairy.
- **Flowers:** The flowers are small white fragrant placed on older branches in congested auxiliary inflorescent which are up to 12 cm long. Pollination is by insects especially the honey-bee (*Apis-melifera*); it is also a self-pollinating tree.

- **Fruits:** The fruits are large green oval droups with a very thick and ebony endocarp developed up to 4 cm long. It has a star-like 5-lobed apical depression and a rose-like 5 lobed basal depression. The clusters are often conspicuously seen on bare tree. Fruit pulp is edible to some wildlife animals like giraffe, and domestic ones like goats.
- **Wood:** The timber is pale reddish brown, resembling mahogany, strong and durable and locally valued for a variety of uses and is termite attack resistant. *Melia volkensii* wood has a wider and straight grains as compared to *Dalbergia melanoxylon*

Propagation from root suckers has proved more successful than germination from seeds, which is strangely erratic. Seed germination is very difficult to achieve, there are about 200 to 300 seeds per Kg. Seeds can be soaked in water or scarified with sandpaper or slit with a razor blade to break seed dormancy and enhance seed germination, or burn berries in a heap of trash as a pre-treatment.

The seeds cannot be stored for a longer time period before loosing their viability, and hence fresh seeds must be picked up from the tree. If propagated using root suckers and wildings, *Melia volkensii* is a fast growing species, and seed extract is used as an insecticide. *It* is a deep-rooted deciduous tree, which shades its leaves twice a year early in the dry seasons. Flowers and fruits become ripe at the end of the dry season as the leaves emerge. At two and a half, years they flower and set fruits (stewart and Blomeley, 1994). Trees on cultivated land retain their leaves and thrifty appearance well into the early dry season. *Melia volkensii* is a drought resistant tree, which thrives on well-drained soils from sandy loam- sandy clays and black cotton soils. It is naturally found along water courses and in Acacia/Commiphora wood lands. The natural range of *Melia volkensii* is characterized by variable climatic conditions and soil moisture stress. Physiographically, it occurs in a very gentle undulating erosion plains on basement rock systems, (Toubler,1983).

2.5 Agroforestry Technology

Agroforestry technology is an innovation or improvement that is applied with advantage in the management of an agroforestry system or practice concerned, (Von Carlowitz,1989), indicates that an agroforestry technology is a set of specifications for the roles, arrangement and management of **MPTS** and associated components.

The aim of the intervention being to improve the existing agroforestry practices rather than devising totally new ones. The opportunities offered by agroforestry technology includes:

- Longer cropping period with increased land use efficiency (LUE)
- Rapid and effective soil fertility regeneration through use of selective multipurpose trees like M*elia volkensii.*
- More intensive cropping with reduced requirements for externate inputs.
- Better soil conservations
- Supplementary feed (fodder) for animals through use of prunings for browse
- Provision of firewood and staking materials
- Provision of fruits, amelioration of climate and greening of the environs.

2.6: Indigenous Fodder

The advantage of indigenous fodder from trees like *Melia volkensii* is that they are deeper rooted than grasses, and are capable of producing green fodder during the dry season. Indigenous fodder trees have an advantage over exotic ones like the famous *Leucaena leucocephala*, in that they are well adapted to the environment and farmers tend to have a traditional knowledge about them better than researchers do,(Ralph, 1997).

2.7 Ecological interactions/ soil and water Conservation under *Melia volkensii* trees

The need for ecological interactions between trees and crops is part of the definitions of agroforestry, this means that these interactions should take place with respect to how the components of agroforestry utilize and share resources of the environment and how the growth and development of any of the components will influence the others.

Ecology is the science of relationship between living beings and their environment and it encompasses any type of relationships between the environment and its inhabitants.

Agroforestry is a form of land-use system which, in the context of a given production objectives, is based upon the optimum use of resource base and availability but not the maximization of one particular product.

The sustainability concern, i.e. the combining of production and conservation, is common to both agroforestry and "*ecological agriculture*" which aims at developing agro-ecosystems having a sound ecological equilibrium with reduced yield variance and a risk-spreading effect.

Dryland agroforestry is most geared to the development of technologies which can be easily developed by small scale farmers and which make a judicious use of socio-economic management resources such as labour and cash through the optimization of bio-physical processes, deals with these socio-economic factors influencing agricultural activities in semi-arid areas of Kibwezi Division. (Anderson et al, 1993). Fig.2.7 explains this scinario. Ecological interactions between *Melia volkensii* trees as an agroforestry component can be divided into two categories as follows:-

- Those regarding water, soil (organic matter, nutrient, soil conservation), and the space available for growth.
- Those regarding light, temperature and wind. (*Ong, et Al. 1991*)

Competition or complementarities between species growing together occurs because they have to share common growth resources like light, water and nutrients, which can be in excess or in limited quantities.

Water is always the number one limiting factor for plant growth under semi-arid climate. Roots of crops and trees, which grow in different soil horizons, do not compete for the same nutrients. In agroforestry, a good division of resources depend on the choice of species e.g. with due considerations of their tolerance spectrum, and their ecophysiological characteristics, e.g. in *Melia volkensii*, intercropped with pigeon pea (*Cajanas, cajan),* cowpea *(Vigna unguiculata)* and maise, (*Zea mays*).

Melia volkensii has a drought-resistant mechanism due to its associations with vascular abascular mycorrhizae **(VAM)** (Mutabaruka, 1998). Its deep roots helps in pumping water and nutrients from deep soil layers which are not accessible to food crops like maize and beans. A research work from ICRAF Machakos field station showed that maize utilizes only about 34% of the rainfall while *Melia volkensii* trees intercropped with food crops, can use about 50% due to their ability to absorb water from well below the top soil, especially during the dry season; (Ong, *et al* 1991).

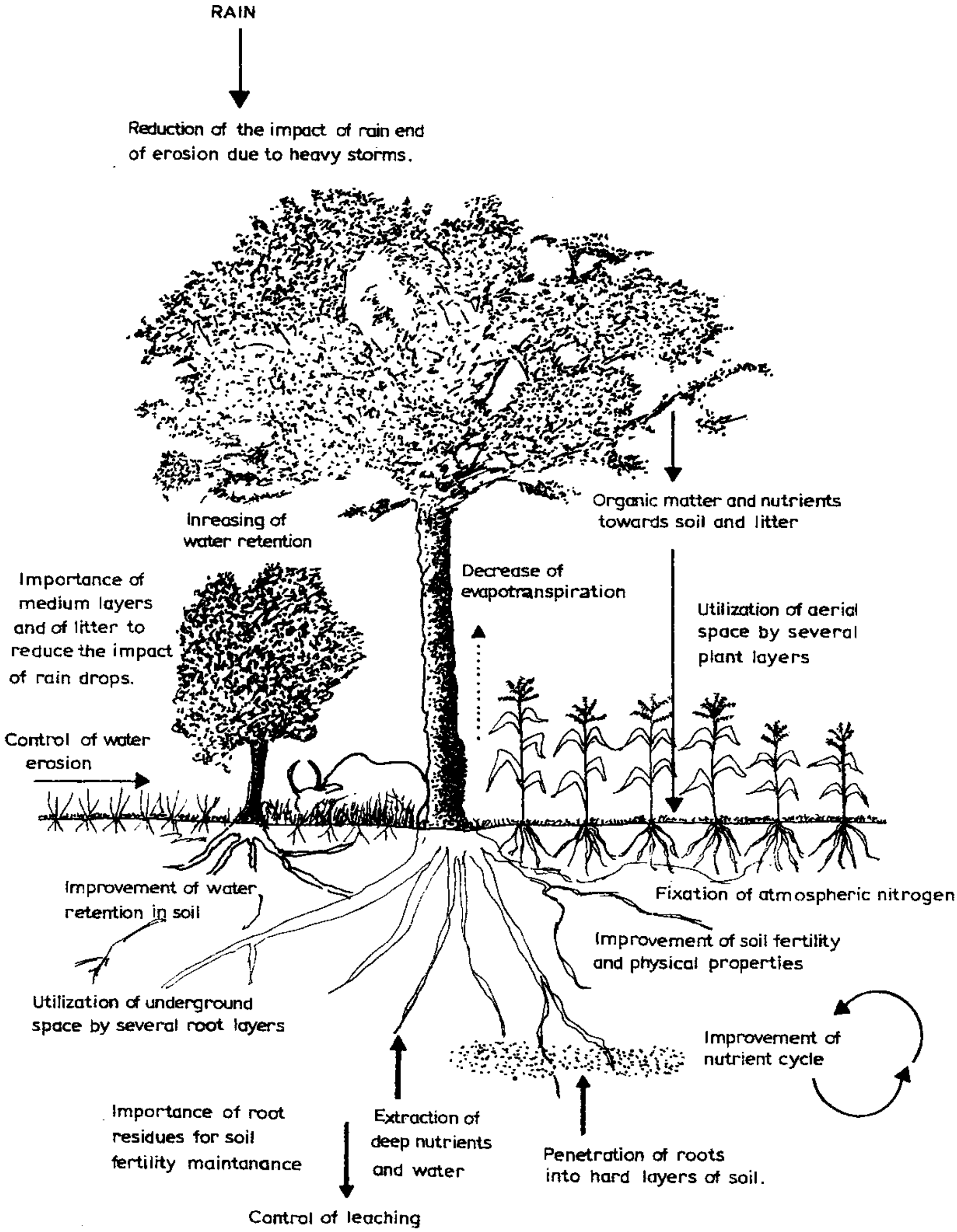


Fig. 2.7: *Melia volkensii* ecological interactions in agroforestry

2.7.1 Mycorhizal Association in *Melia volkensii*

Mycorhizal association is the symbiotic relationship between fungi and roots of higher plants whereby the fungi derives their carbohydrates and other growth factors from the plant in return, the fungi provide benefits to the plant, (Sieverding, 1991).

The role of Mycorhizae in growing *Melia volkensii*, has numerous benefits, i.e. it increases the surface area of roots for the absorption of nutrients and water, phosphorus uptake, drought resistance, control of root pathogens, reserve nutrients and help nitrogen fixation of rhizobium (Harley and Smith 1983).

Water deficits limit plant growth and survival, thus constituting a natural selection force that has led to evolution of plant strategies that prevent or modify the injurious effects of water stress, (Levitt, 972).

The influence of water stress on plants is expressed in many profound anatomical, phenological, morphological and physiological responses. These responses compromise a strategy, and a strategy can be defined as a "*combination or grouping of mechanically-linked responses and characteristics that compromise a particular type of behavior during periods of water stress*" (Ludlow, 1980)

2.7.2 Differences in drought resistant strategies

- **Interspecific studies** concerned with establishing ecological and physiological bases of plant distribution patterns and superior survival under drought, (Pallardy, 1993).
- **Intraspecific studies** have been carried out to provide information on, and in specific identification of, drought tolerant responses. The term drought refers to a restricted water supply as a result of low rainfall combined with a high evaporative demand that tends to reduce plant productivity. (Milimo, 1994).

2.7.3 Drought Resistance Strategy

Drought resistance is all mechanisms that maintains plant survival and production in drought conditions. In a natural ecosystem however, a drought tolerant species is one that has the ability to survive and reproduce in relatively dry environment. (Jones,1992).

There are three main types of plant drought resistance strategies in ASAL regions; drought escape, drought avoidance and drought tolerance, but more than one mechanism may operate in a species; i.e.

- Lethal relative water content (Ludlow, 1980)
- Moisture strain index, (Bryne, *et al.* 1987)
- Deficit time (Linder, *et. al.* 1987)
- Water stress integral (Myers, 1988)

2.7.4 Drought avoidance

Drought avoidance plants are very sensitive to degradation (Levitt 1972). They resist by avoiding a thermodynamic equilibrium with the stress, and this may involve more than one mechanism, all geared towards minimizing the occurrence of damaging water deficits (Jones, 1992), *Melia volkensii*) falls under this category, with some desert crassulacean Acid Metabolism (**CAM**) exhibital. Adaptations are that acid water conservations include stomata control and leaf adjustment (Givnish, 1984), while those that maximize water uptakes include increases in root absorption areas (Pallardy, 1993). The trade offs for gas exchange arises from the in escapable association that exists between carbon gain and water loss through transpiration. Hence benefits of a trait that increases the rate at which CO_2 diffuses into a leaf, must be weighed against transpirational cost resulting from increased water loss, which reduces energy gain by lowering leaf hydration and inhibiting plastid function directly or by bringing about an adjustment in dry weight allocation in favour of roots. The penalty for a water deficit avoidance strategy that depends on obtaining access to water deep in the soil horizons, or the up occupied part of the profile, is small compared to the large penalty incurred by the strategy that minimizes water loss, depending on whether the response is elastic or plastic. (Ludlow, 1989). Elastic responses that includes stomata closure and paraheliotrophic leaf movements, lowers carbon acquisition and as a consequence reduce vegetative growth during stress. Another elastic adaptation involves a morphological modification of the leaf to include growth of hairs around the stomata, which trap the air hence reduces air movement to bring about a reduced vapor pressure gradient between the inside and the outside of the leaf resulting in a transpiration reduction. Leaf stiffness is also an adaptation that prevents sclerophylls from being blown around in the wind and therefore reduces their water loss; (Grieve, 1953). Plastic response, enhances leaf area reduction by either leaf size, or leaf abscission. Plants with strategies based on water uptake (*water spenders*), keep their stomata open resulting in high photosynthetic rates and hence more rapid growth rates. *Melia volkensii* has a rapid growth rate and can be silviculturally rotated at 10 years through coppicing, due to its ability as a water spender. Water spenders are more successful than water savers, as long as water is available and have evolved from adaptation that aids rapid supply of water to the leaves (Levitt, 1972); These includes large rooting systems like in *Melia volkensii* to explore a larger volume of soil and therefore remove more total water by the time the wilting coefficient is reached,(Kramer and Kozlowski,1979). The ability to invest more photosynthates into roots, especially under drought stress conditions in association with a high root/shoot ratio, implying that it has the potential to continue sending out new roots into unexplored soil horizons during drought.

2.7.5 Drought tolerance

Drought tolerant plants have a greater capacity to withstand degradation than drought avoidance, including ability to endure loss of protoplasm water or low water potentials without lethal injuries. They are able to adjust their osmotic pressure, which allows the maintenance of cell turgor by an accumulation of sufficient solutes to produce a lower osmotic potential than water potential to the environment, so maintaining carbon fixation through maintenance of stomata openings, photosynthesis and leaf expansion (Ludlow, 1989). The distinction between a drought avoider and a drought tolerant is that the drought avoider must maintain a higher internal water potential inside of the low environmental water potential to which it is exposed. ; while the drought tolerant is able to withstand desiccation to about 30% of their normal weight. (Janick, et.al.1969).

2.8 Water Use Efficiency (WUE) of *Melia volkensii*

The "***buffer effects***" of *Melia volkensii* as an MPTS in agroforestry systems is, its ability to withstand variations in climate, or management. which is based upon its broad tolerance spectra, hence, its flexibility in optimum utilization. Nutrients used by MPTS, is not only a function of water availability, but also of soil structure, soil flora and fauna, and rate of fixation and release of the soil elements.

It is sometimes difficult to establish whether two species are competing for the same resource, which is in sufficient quantities but the species inconvenience each other in trying to acquire it. In order to find out the water use efficiency (**WUE**), and whether it competes with food crops for moisture (water and nutrients), and how far vertically, or horizontally, is the moisture located, a soil moisture hydro probe (neutron probe) was used to detect the soil moisture (hydrogen ions) available at different soil horizons along the soil profiles under which *Melia volkensii* trees were growing locally at on-farms.

In *Melia volkensii*, higher water use efficiency results in higher biomass production in the absence of increased water inputs, (Farquhar, et. al 1998).
Plant water use efficiency **(WUE)** and discrimination of carbon isotopes are related in that both processes are functions of the intercellular to ambient $\mathbf{CO_2}$ partial pressure ratio. *Melia volkensii* responds to water stress by greater investment in roots and increase tissue water contents in roots, stems and leaves.
Its seedlings or (Wildings from root suckers) are able to survive water limitations for longer periods, and survive to lower soil water potentials due to maintenance of higher water contents in swollen roots and succulent stems and leaves, even to very low soil water potentials (Mutabaruka, 1998), due to mycorrhizal root association in soils.
Water limitations (moisture stress), is the single most important factor affecting food production and life maintenance in semi-arid areas. Droughts are a common event in terrestrial ecosystem and affect productivity either through reduced CO_2 assimilation, or directly by desiccation (Jones, 1992). *Melia volkensii* associates with five genera of vesicular arbscular mycorrhizae. Dry season is associated with high production of vesicular arbuscular mycorrhizae spores (Mutabaruka, 1998), hence the survival at water limitations for longer periods, making it one of the best agroforestry tree in maintaining mycorrhizal inoculum potential for intercrops in the cropping systems in semi-arid areas. This is demonstrated by high growth rate of diameter, height increase and where topped or pollarded for fodder, high bushy succulent fresh leaves. Water storage in the fleshy swollen roots and stem of *Melia volkensii* increases with increase in water stress (Milimo,1994); observed long-term water use efficiency **(gDW)** Kg H_2O transpired) was negatively correlated with the stem appex $^{13}\mathbf{C}/^{12}\mathbf{C}$ isotopic ratio ($P<0.001$). But positively correlated with total dry matter **(DM)**, suggesting that water use efficiency may be improved by selecting for more productive tree species for semi-arid agroforestry practices.

The importance of drought resistance under net carbon loss hinges on the ability of meristems to tolerate desiccation in order to effect recovery on amelioration of the stress. Under limiting soil moisture conditions, potential productivity is greater for plants that possess mechanisms that enable them to maximize assimilation in relation to the amount of water used by the plants i.e. the water use efficiency, (Jones, 1992). Plant WUE and discrimination of carbon isotopes are related in that, both processes are functions of the intercellular to ambient CO_2 partial pressure ratio. Photosynthesis, transpiration and leaf conductance are all simultaneously decreased under conditions of limiting soil moisture responses that can be measured by decrease in carbon isotope discrimination (^{13}C), (Farquhar, et.al.1989).

2.9: Resource use efficiency (RUE) of *Melia volkensii* in Agroforestry System

In terms of resource use efficiency in agroforestry systems, *Melia volkensii* brings about resource captures as fig.2.7 shows:

- **Light:** A combination of trees and crops can intercept more radiation than either component alone. Appropriate upperstorey trees (open canopy like in *Melia volkensii*), may have no negative effects on under storey crops. i.e it improves light use efficiency, and when photo-inhibition of crops occur, shading may be beneficial. A dynamic light environment created by heterogeneous canopies of upper storey trees may improve photosynthesis efficiency of lower storey food crops (Pearcy, 1988)
- **Water:** Agroforestry combinations can use more water than crops or trees alone and increase water use efficiency (WUE) through microclimate improvement. Trees in agroforestry systems can use off-season rainfall.
- **Below ground interactions:** Deep rooted trees like *Melia volkensii* are not competitive with shallow-rooted food crops like maize and beans, for the

capture of soil resources. The arrangement and management of *Melia volkensii* trees in cropland can greatly influence root interference between the two components. Their deep roots are able to pump nutrients from deep soil layers and make them available to crops and can also reduce leaching of soil minerals

- **Wind:** Windbreak effects prevents damage to crops or desiccation and the presence of leaf mulch/litter fall, buffers temperature variations both in soil and above ground, especially under hot climates of the semi-arid regions where a slight decrease of temperature at germination improves early growth rate and hence final yields.

2.10: Silviculture of *Melia volkensii* seeds

Melia volkensii is a self-pollinating species. This leads to low genetic variations. Insects like the honey bee (*Apis melifera*), are also involved in pollination. Insect-pollination compared to wind-pollination not only lead to less pollen production but also results in a rather limited pollen dispersal (Levin and Kerster, 1974).
Since they can only cover short distances, which limits pollen, transfer over long distances. Genetic variations in insect pollinated trees is usually low compared to those that are wind pollinated. Increased genetic variations among wind-pollinated trees is explained by the larger effective neighborhood size with less fixation of genes by genetic drift, selection and more inter-population variations. (Hamrick, et al, 1979). Disjunction in the distribution of *Melia volkensii* and confinement within the Game parks, decreases the potential for long distance seed dispersal by games in East Africa (Milimo, 1994). *Melia volkensii* is a highly fecund species, with a seasonal yield of between 600 to 100,000 viable seeds per tree.
The relationship between genetic variation and fecundity is that, highly fecund species are capable of a large variety of recombinant progeny with a potential for reaching and surviving a wide variety of micro-habitat, and that selection is more intense than in less fecund. (William's, 1975). However, the expected high

genetic variation as a result of high fecundity in *Melia volkensii* is compromised by the effect of seed dominancy, which significantly reduces germination percentage. Seed dormancy problems are further compounded by poor seedling recruitment's. Age and size class distribution of *Melia volkensii* are abnormal since it has high frequency of mature trees and no seedlings. a typical age-class distribution is a result of browsing effect of goats, giraffe, orix, lesser kudu, and at on-farms, lopping or pruning for fodder (Levitt, 1972).

2.11 : Dormancy in *Melia volkensii*

The term dormancy is defined as the occasion when viable seeds show no, or only little germination within a certain time, although all environmental conditions are adequate for germination, (Albrecht, 1993). For many tree species, dormancy is a protection mechanism to prevent the seeds from germinating under environmental conditions, which are not favourable for the survival of the seedlings.

Two strategies governs this principle; first, the dormancy regulates the uniform germination of seeds to fit it with seasonal changes in environment by the interaction of physical factors like light and temperature. And two, the viability in the degree of dormancy and the varied release from dormancy of seeds spreads the germination over an extended period. Hence *Melia volkensii* seeds take up to two years before germinating in the wild. There are three main types of dormancies in forest tree seeds as follows:-

a: Exogenous Dormancy: (Seed coat dormancy), which includes:-

- Physical dormancy:- (cracking of the hard woody endocarp)
- Chemical dormancy
- Mechanical dormancy
- Biological dormancy

b: Endogenous dormancy: (Embryo dormancy)

Here only growth hormones can be used e.g. GA_3 in 50-100ml of distilled H_2O

c: Combination of morphological and physiological dormancy

Seed dormancy is caused by:

- The special quality of the seed coat, which in *Melia volkensii*, is the hard layers of cells (woody endocarp) and the water impermeable plastic-like cuticular cover which encompasses the soft embryo, and the existence of the germination inhibiting substances in the coat.
- An underdeveloped embryo -especially the first seed fall (Prematurely dropped seeds)
- Physiologically inhibiting mechanisms

CHAPTER THREE

3.0 MATERIAL AND MEHTODS:

3.1 Area of Study

The study was carried out at KEFRI Kibwezi Forestry Research Station located in Makueni District along Mombassa highway at a Latitude $1^0 33'S - 3^0 S$, a Longitude of $37^0 10'E$ _ $38^0 30'E$ to the Southern parts of Eastern Province. It borders Makindu Division to the North, Kajiado District to the West, Mtito Andei to the South and Kitui District to the East. (Fig.3.1abc) Kibwezi is on an altitude of 900m above sea-level with annual rainfall of about 600mm/year, with two peaks maximum Nov-Dec. long rains and minimum short rains in April-May. The main annual temperature of the site is 27 ^{0}C. The rainfall/evaporation ration (r/E_o) is less than 0.4%. This low r/Eo ration implies low rainfall and greater potential evaporation which is associated with greater soil moisture deficits. This makes Kibwezi to be classified as Semi-arid or ASAL region. The soil type is red sandy loam soils. The physiography of the area is very gently undulating erosional plains on basement rock system (Toubler, 1983).

Land use in this area (**ACZ V & VI**)-(Semi-arid), is mixed farming mainly sedentary along rivers Kibwezi and Athi, where irrigation of vegetables and fruits (horticultural crops) is carried out.The South-Eastern part of Makueni District forms part of Tsavo National park and is therefore set aside for wildlife conservation. Vegetation is mainly made up of *Accaia* and *Commiphora* species dotted with *Adonsonia digitata (*Baobab trees) and a few scattered *Melia volkensii* on farms and around homesteads. Here *Melia volkensii* is used in the provision of timber, building poles, fodder for Goats and wildlife animals and shade.

ARIDSAK project is currently operating in the area with a focus of development, dissemination and adoption of agrosilvipastoral technologies for soil moisture improvement, soil erosion control, improvement of animal production and food and income generation status.

Fig. 3.1a: Location of Makueni District

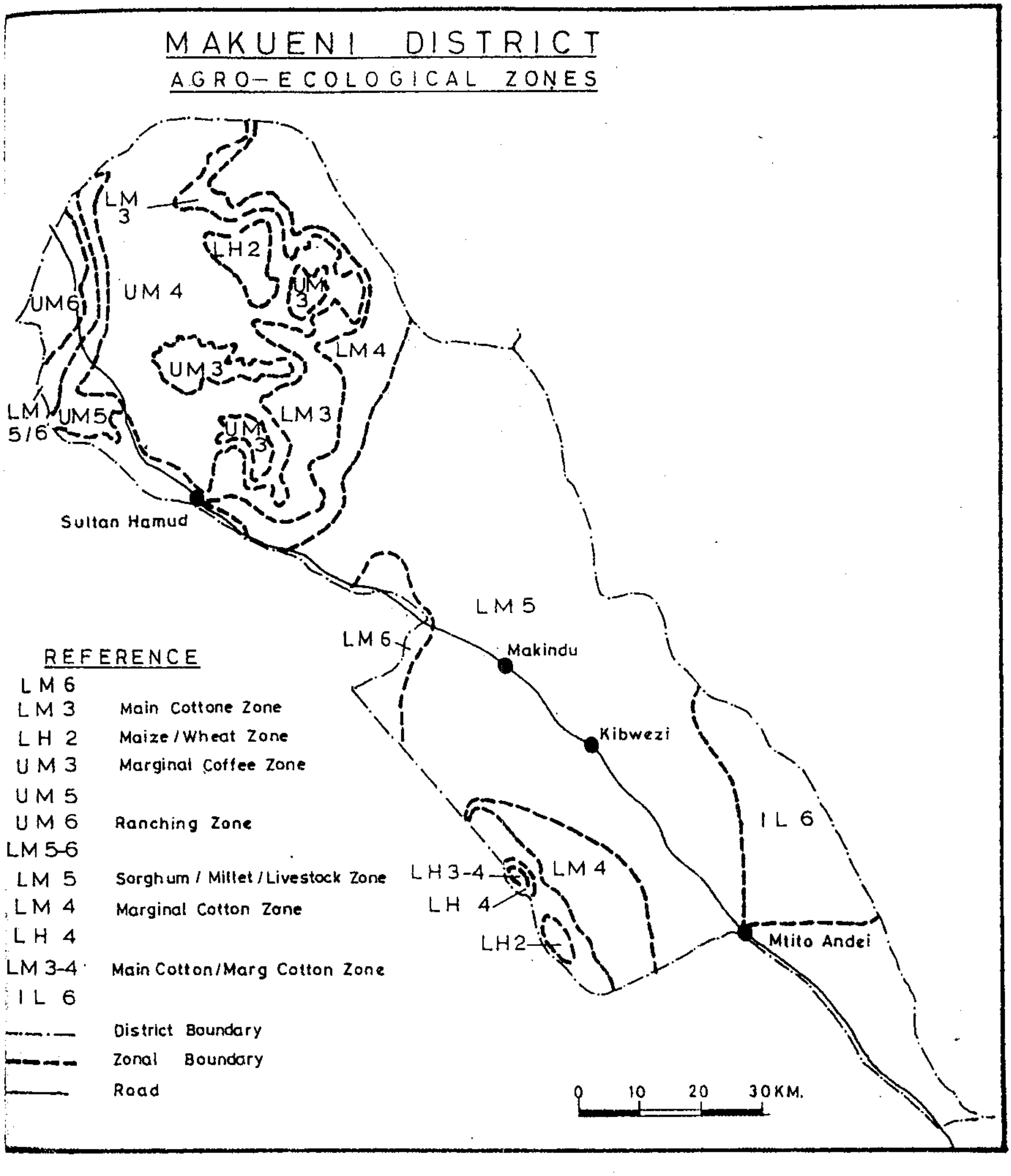
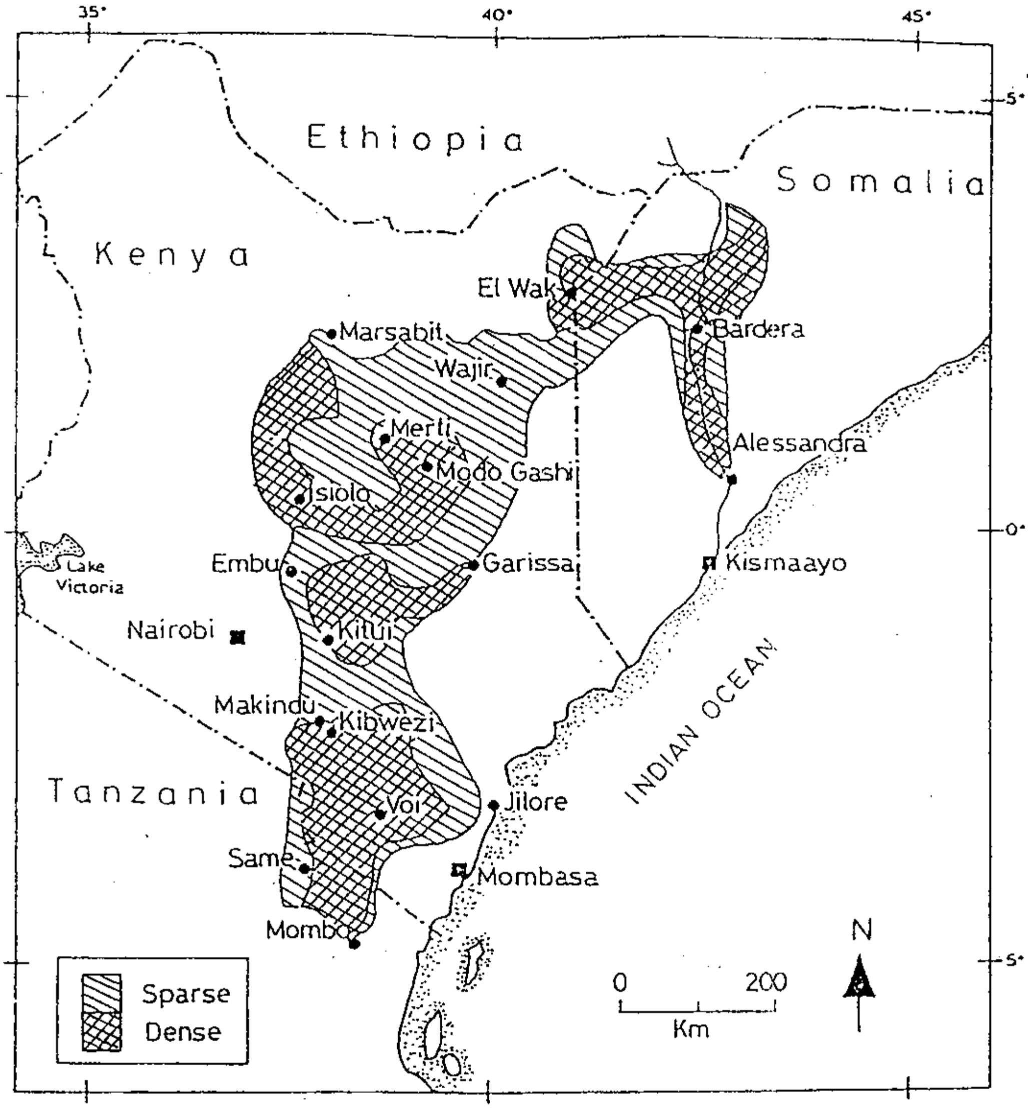


Fig.3.1b: Agro-ecological zones of Makueni District



. Natural distribution of *Melia volkensii* in Kenya, Tanzania and Somalia showing regions of sparse and dense stands.

Fig.3.1c: Origin and distribution of *Melia volkensii*

3.2 Experimental design and layout

3.2.1 Glass House Experiment

A polythene (Glass) house was erected at KEFRI Kibwezi forest research station, whereby the germination media were arranged as shown in (Fig.3.2.1) below.

The germination media consisted of: soils dug from under a big melia tree, sand which was acquired from the dry riverbeds, goat and cow dung which were got from ARIDSAK Project's contact farmers.

The treatment mixtures consisted of 5 kg at 1.1 ratio of:

- T1 = Soil + Cow dung
- T2 = Soil + goat dung
- T3 = Sand only
- T4 = Soil only
- T5 = Sand + goat dung
- T6 = Sand + Cow dung

These were replicated four times for each treatment. The seeds were picked from three different locations, which represented the provenances. These included Kivisuni in Kitui District, Kibwezi Division in Makueni District and Mbololo in Taita-Taveta District.

The provenances were coded as:

- P1 = Kitui Provenance
- P2 = Kibwezi provenance
- P3 = Mbololo provenance

After the pre-treatment of seeds were done, 100 viable seeds were selected and divided four times, 25 seeds were sown for each treatment and replicated four times in plastic troughs (Fig.3.2.1 and plate3.2.1).

This arrangement was again replicated in the open nursery where the humidity was not controlled. The watering regime was maintained at once after two days.
Sampling for elemental analysis was done for both the soil (germination media) and water (water used for watering in the nursery). Other propagation methodologies that were tried separately included :

- Root cuttings,
- stem cuttings,
- marcottage,
- air layering ,
- tissue culturing in a laboratory,
- use of copper-based fungicides like Benlate and Murtano,
- ponded leaves of *Azadratcha indica* (neem leaves)

Kibwezi			Kitui			Mbololo	
P_2T_1RIV	P_2T_1RIII		P_1T_1RIV	P_1T_1RIII		P_3T_1RIV	P_3T_1RIII
P_2T_1RI	P_2T_1RII		P_1T_1RI	P_1T_1RII		P_3T_1RI	P_3T_1RII
P_2T_2RI	P_2T_2RII		P_1T_2RI	P_1T_2RII		P_3T_2RI	P_3T_2RII
P_2T_2RIV	P_2T_2RIII		P_1T_2IV	P_1T_2RIII		P_3T_2RIV	P_3T_2RIII
P_2T_3RI	P_2T_3RII		P_1T_3RI	P_1T_3RII		P_3T_3RI	P_3T_3RII
P_2T_3RIV	P_2T_3RIII		P_1T_3RIV	P_1T_3RIII		P_3T_3RIV	P_3T_3RIII
P_2T_4RI	P_2T_4RII		P_1T_4RI	P_1T_4RII		P_3T_4RI	P_3T_4RII
P_2T_4RIV	P_2T_4RIII		P_1T_4RIV	P_1T_4RIII		P_3T_4RIV	P_3T_4RIII
P_2T_5RI	P_2T_5RII		P_1T_5RI	P_1T_5RII		P_3T_5RI	P_3T_5RII
P_2T_5RIV	P_2T_5RIII		P_1T_5RIV	P_1T_5RIII		P_3T_5RIV	P_3T_5RIII
P_2T_6RI	P_2T_6RII		P_1T_6RI	P_1T_6RII		P_3T_6RI	P_3T_6RII
P_2T_6RIV	P_2T_6RIII		P_1T_6RIV	P_1T_6RIII		P_3T_6RIV	P_3T_6RIII

Fig.3.2.1 Glass house layout at ARIDSAK nursery Kibwezi in the year 2000

Key :

Treatments:

T_1 = Soil + Cow dung

T_2 = Soil + goat dung

T_3 = Sand

T_4 = Soil

T_5 = Sand + goat dung

T_6 = Sand + Cow dung

Provenance

P1 = Kitui provenance

P2 = Kibwezi provenance

P3 = Mbololo provenance

Replicates:

RI = replicate one

RII = replicate two

RIII = replicate three

RIV = replicate four

Fig. 3.2.1a: Germination media arrangement in the glass house

Fig. 3.2.1b: Nursery arrangement of germination media

3.2.2 Seed pretreatment

After the collection/picking of mature yellowish-green seeds from the field, they were depulped using motor and pestle.

Cracking of the woody hard coats were done using a knife and a harmer, after which a floating test was done by soaking the seeds in warm water for 10 minutes and left for 24 hours/overnight. A similler treatment was also done in cold water. The following day, the seeds were nipped and slitted at the proximal end (plate.4.8diii) using a sterile scalpel blade, before sawing on the prepared media, both in the glass house and open nursery.

3.2.3 Laboratory Experiment

3.2.4 Plant nutrition laboratory

Laboratory propagation was done at KEFRI H/Q, in agroforestry plant nutrition laboratory. About 10 seeds from each provenance were nipped and slitted then sown in sterilized sand, vermiculite and moisten cotton wools, put in germination trays in a Germinator chamber where temperature and humidity were controlled. Seed pre-treatment in the laboratory consisted of:

- Soaking seeds in concentrated sulphuric acid for 10minutes then washed with distilled water,
- Soaking in cold water for 24hours,
- soaking in dumpy sand in sealed polythene bags,
- nipping and slitting the seeds

3.2.5 Seed pathology

Pathogen identification was carried out in forest pathology laboratory where 10 seeds per provenance were treated with:

- sterile seeds on sterile sand
- unsterile seeds on sterile sand

- unsterile seeds on unsterile sand
- sterile seeds on unsterile sand

The sand was steam sterilized using an autoclave and the seeds were sterilized with sodium hypochlorite. Some infected and healthy seeds were surface sterilized in 95% and 50% sodium hypochlorite as above and rinsed three times with distilled water, then planted on a 2% malt extract agar medium.

3.2.6 Seed physiology

Melia volkensii seed coat has three stage layers as follows:

- The hard woody (lignified) seed coat
- The papery (cutinized) plastic cover
- An oil-rich cotyledon

All the three phases of the seed were examined in the laboratory under the dissecting microscope at x40 magnification and the Ultra Violet light **(UV light),** after soaking the hard woody seed coat in ethernal for one week results are discussed under observation chapter.

3.2.7 Field Experiment

3.2.8 Wildings and Root suckers

At on-farms, ARIDSAK farmers and women groups were visited, surveyed and interviewed on how they do propagate *Melia volkensii*. After this, timing was done and just before the weeding of food crops (maize and pigeon peas) during the long rains, wildings were collected and potted with soils just from the *shambas* (cultivated plots). This was done in four different locations of Kibwezi division, namely, Masongaleni, Kyumani, Utiithi and Ngwata. The watering was done by farmers themselves using local water drawn from river-beds. Root suckers were also collected but this was during the dry season just before the onset of the long rains. (Fig. 4.8b)

3.2.9 Assessment of Soil Moisture under *Melia volkensii* trees

The major drawback in tree planting in dryland agroforestry system is water stress or lack of soil moisture. Soil moisture is one of the tools that can be used in screening agroforestry tree species suitable for dry lands or semi-arid agroforestry system. In order to identify and assess the tree/crop genotypes and a technology with a high dry matter production for field suitability, the Neutron soil moisture probe ***(type I. H III, SR. No. 326, Source No. 2869 NK)***, was used with aluminium access tubes of two meter length to assess the moisture status along the soil profiles under *Melia volkensii* trees.

The experiment was designed as randomized block design (RBD), with 4 replicates and three treatments consisting of access tubes placed at:

- 3 m within the tree canopy
- 10m away from the trunk
- 15 m away from the trunk.

All these were put on a horizontal distance and augered down to a depth of 2 m. Moisture readings were recorded at 0.3 m (30 cm) intervals down the profile.

One farmer per location was selected at different locations of Kibwezi division which represented the replicates, as follows:

Replicate	**Location**	**Farmer**
Rep I	Utiithi	Mr. Benard Nyamai
Rep II	Nguata	Mr. Mwandhi Matama
Rep III	Kyumani	Mr. Kimengele Ndua
Rep IV	Mikuyuni	Ex. Snr. Chief Mwololo

The soil moisture readings were recorded first in February, then in April and in July, 2000 respectively.

3.2.10 Surveys and Interviews Conducted

In order to get the local knowledge of the farmers, a questionnaire methodology was formulated and used as follows:-

1. General Information

   Both ARIDSAK contact farms and farmers with *Melia volkensii* trees on their farms in Masongaleni, Utiithi, Kyumani, Ulilizi, Ngwata, and Mikuyuni locations were visited at their homes and interviwed on different aspects concerning the uses, propagations etc of *Melia volkensii*
2. Seed Propagation

   How do you propagate *Melia volkensii* (mukau), through seeds, cuttings ?
3. Indigenous Methods of Propagation

   What indigenous methods are used by farmers to propagate Melia?
4. Problems related to seedling establishment

   What problems do you encounter when establishing seeds of Mukau?
5. Seed storage Longevity

   How do you store the seeds for planting?
6. How do farmers get seedlings for planting
7. How far away from the tree do you get seedlings?
8. How do you protect the seedlings?
9. How do you germinate *Melia volkensii* seeds?
10. How do you manage the trees?
11. What are the uses of *Melia volkensii* trees?
12. What diseases do you observe on either the wood or leaves of *Melia volkensii* tree?
13. How long do fruits stay before germinating in the soil?
14. What pre-treatment do you give to seeds before planting?

After these interviews were conducted and assessed, selection of farmers with *Melia volkensii* trees on their farms were done and the information pooled from various sources included:-

- Individual farmers with *Melia volkensii* on their farms
- Both individual farmers and group owners
- technicians and scientists who have had working experience or knowledge with the species
- in the case of farmers/ nurseries visited, discussions were held in their own environment within the premises of *Melia volkensii* stands. This facilitated visual observations to verify the informations obtained.

3.3 Data Collection (Parameters measured)

- Soil moisture under *Melia volkensii* trees at on-farm trials were measured using soil moisture gauge (***Neutron Probe,*** Type *1.H III, SR. No. 326, Source No. 286 NK*), with aluminum access tubes of 2m lengths. The moisture status along the soil profiles were assessed at an interval depth of 0.3m up to 2 m deep. This was done three times just before the onset of the long rains, during the rainy season and after the long rains.
- Socio-economic data collection was done using a questionnaire and survey methodology.
- Soil and water samples were done for nutrient analysis.

3.3.1 Data analysis

Computer soft ware packages used included :

- Statistical Analysis system (SAS) release 4.6, for analysis of variance (ANOVA)
- Microsoft excel for graphical drawings of both bar and line graphs.
- Lotus 1 2 3 was also used.

CHAPTER FOUR

4.0 RESULTS

4.1 Glass house and nursery observations

After the experiment was set up in both glass house (polyethylene house), (Fig..3.2.1a) and the watering done once after two days, the germination emergence was noticed 30 days later. Most of the seeds were rotten and had bad odour due to fungal infection. Some seeds showed sign of germination but the radical did not emerge above the medium level due to the cuticuler- water permeable – plastic-like cover, which encompasses the soft embryo. High germination was recorded in pure sand medium and soils dug under an old melia tree. The temperature ranged from 28°C at nights to 36°C during daytime. 100 seeds per provenance were sawn in four replicates each of 25 seeds. Out of these 100 seeds, only 10 to 20 seeds germinated but on sand media only.

In the open nursery, germination rate was very low, only 25% was realized, which were later on infected by fungal (Fusarum) wilt, which caused seedling dumping off in the nursery. In the polyethylene house where temperature and humidity was controlled, the germination rate was medium. The growth rate was high, about 30cm one week after germination was recorded. (Plate. 4.8div). After potting the seedlings were transported to the open nursery, two weeks later one seedling was excavated from each treatment and a fleshy swollen root was observed in each one of them. Each had a high tissue water content. This showed that there was mycorhizal association with *Melia volkensii* roots.

4.2 Laboratory observation

4.2.1: *Melia volkensii* seed pathology

Seeds that were sown both on sand and the once planted in media were not germinating instead there were mycelium spore growth on them, including fungal rot. In the pathology laboratory at KEFRI H/Q, *Melia volkensii* seeds were treated as follows:

i - sterile seeds on sterile sand

ii - unsterile seeds on sterile sand

iii - unsterile seeds on unsterile sand

iv - sterile seeds on unsterile sand

Three plating were done in total.

In 1st plating, fusarium spore growth was consistent in all the four treatments.

In 2nd planting, treatment 1 had fusarium spores while others have muccor and bacterial contamination.

4.2.2: *Melia volkensii* seed physiology

In plant physiology laboratory at KEFRI H/Q both viable and unviable seed cotyledons were put under ultra-violet (UV light) and observation made was as follows:

- the cotyledons of the dead seeds appeared yellowish- white
- viable seed cotyledons appeared creamy -white under UV light.

This showed that cotyledons with their alfa-amylase enzymes oxidized yellowish-white cotyledons were dead seeds, which could not germinate. This means that on exposing the cotyledons of the seeds to oxygen, the *alfa-amylase enzyme* for enhancing germination is already oxidized and hence renders the seeds unviable.

4.2.3: Chemical soil analysis of the germination media used

Table 4.2: Chemical soil and water analysis of the germination media used

	pH	EC (s/m)	N (%)	P (ppm)	K (ppm)	Na (ppm)	Ca (ppm)	Mg (ppm)
Sand	7.96	18.30	0.063	0.88	9.80	17.75	1523.00	60.80
Cow dung	8.86	18.80	1.113	0.42	1431.10	69.00	5290.00	608.00
Goat dung	9.61	18.81	1.730	0.39	191.20	172.50	2645.3	48.64
Melia soil	7.73	18.60	0.189	0.49	93.80	17.25	4729.4	48.64
Nursery soil	8.06	18.73	0.259	0.47	273.70	69.00	8657.30	72.95
Water	7.5	0.15	-	0.01	0.79	17.40	0.60	36.48

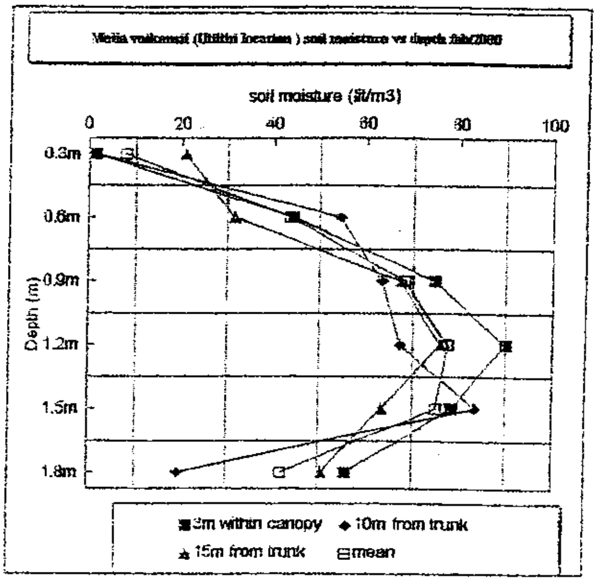
4.3: Soil moisture content under *Melia volkensii* canopy

Table 4.3: Soil moisture content readings taken during dry and wet seasons in the year 2000 in Kibwezi Division of Makueni District, Eastern Province, Kenya

		Feb			April			July		
		Horizontal distance (m)								
	Depth (m)	3m	10m	15m	3m	10m	15m	3m	10m	15m
Utiithi	0.3	1.3	1.3	20.7	39.2	29.1	32.9	40.5	13.9	19
	0.6	44	54.4	31.6	81	74.7	93.7	49.4	54.4	67.1
	0.9	75	63.3	67.1	67.1	63.3	89.9	62	60.7	74.4
	1.2	90	67.1	75.9	68.3	67.1	68.3	63.3	64.5	67.1
	1.5	79	83.5	63.3	54.4	81	53.2	65.8	74.7	54.4
	1.8	56	19.1	50.6	43	83.5	50.6	27.8	75.4	31.6
Ngwata	0.3	18	43	35.4	62	36.7	68.3	1.3	1.1	27.8
	0.6	49	63.3	62	73.4	75.9	86.1	39.2	29.1	62
	0.9	53	50.6	65.8	68.3	70.9	68.3	40.5	51.9	64.5
	1.2	62	51.9	58.2	76.9	36.7	54.4	48.1	48.1	55.7
	1.5	58	49.4	57	59.5	35.4	50.6	44.3	31.6	49.4
	1.8	51	41.8	63.3	65.3	31.6	55.7	39.2	32.9	53.2
Kyumani	0.3	10	17.7	62	47.8	1.3	48.1	6.3	1.5	25.3
	0.6	75	74.7	70.9	59.2	78.5	73.4	67.1	29.1	67.1
	0.9	91	84.8	87.3	54.5	91.1	69.6	88.6	75.9	70.9
	1.2	90	89.9	93.7	76.9	81	93.7	91.1	86.1	98.7
	1.5	89	89.9	96.2	86.1	89.9	93.7	89.9	96.2	97.5
	1.8	19	90.2	95.3	94.9	89.9	98.7	91.1	94.9	97.5
Mikuyuni	0.3	51	67.1	78.5	30.3	1.7	63.3	33	21.5	49.4
	0.6	65	77.2	59.5	46.7	82.3	82.3	64.5	25.3	68.3
	0.9	77	78.5	65.8	55.8	97.5	78.3	55.7	54.4	49.4
	1.2	90	106.3	78.5	50.6	77.2	60.7	55.7	68.3	54.4
	1.5	105	95.6	75.9	75.5	85.6	78.5	63.3	65.8	65.8
	1.8	91	99.1	105.1	78.2	90.1	68.3	81	75.9	67.1

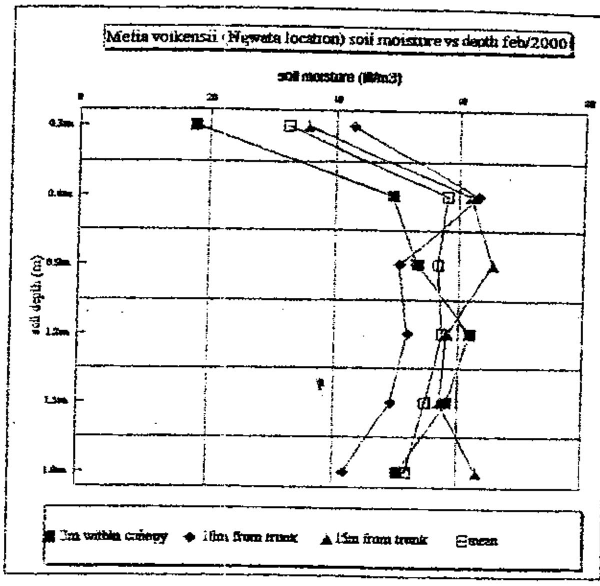
Utiithi location

0.3m	1.3	1.3	20.7	7.8
0.6m	44.3	54.4	31.6	43.5
0.9m	74.7	63.3	67.1	68.3
1.2m	89.9	67.1	75.9	77.6
1.5m	78.5	83.5	63.3	75.1
1.8m	55.7	19.1	50.6	41.8



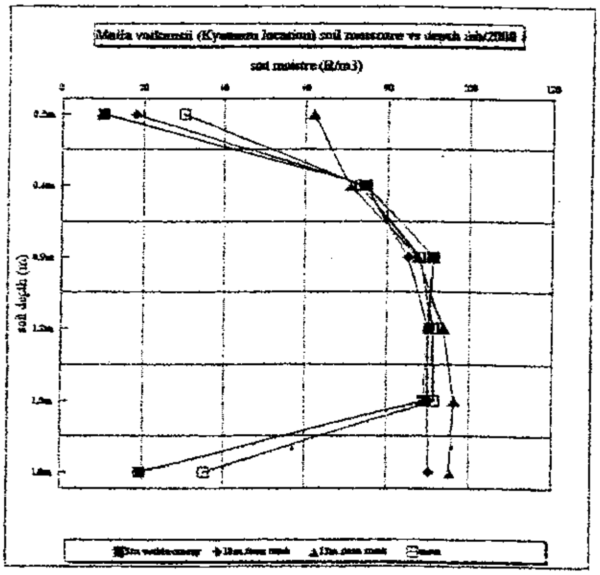
NGWATA LOCATION

0.3m	17.7	43	35.4	32.1
0.6m	49.4	63.3	62	58.2
0.9m	53.2	50.6	65.8	56.5
1.2m	62	51.9	58.2	57.4
1.5m	58.2	49.4	57	54.8
1.8m	50.6	41.8	63.3	51.9



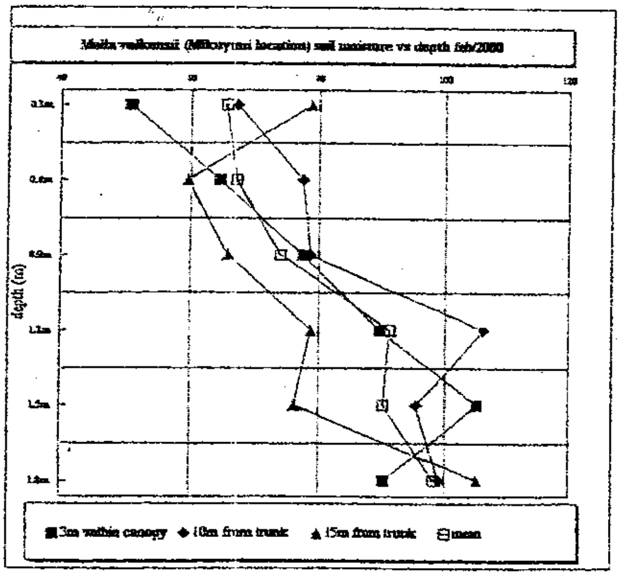
Kyumau

0.3m	10.1	17.7	52	29.9
0.6m	74.7	74.7	70.9	73.4
0.9m	91.1	84.8	87.3	87.8
1.2m	89.9	89.9	93.7	91.1
1.5m	88.6	89.9	96.2	91.5
1.8m	19.2	90.2	95.3	34.9



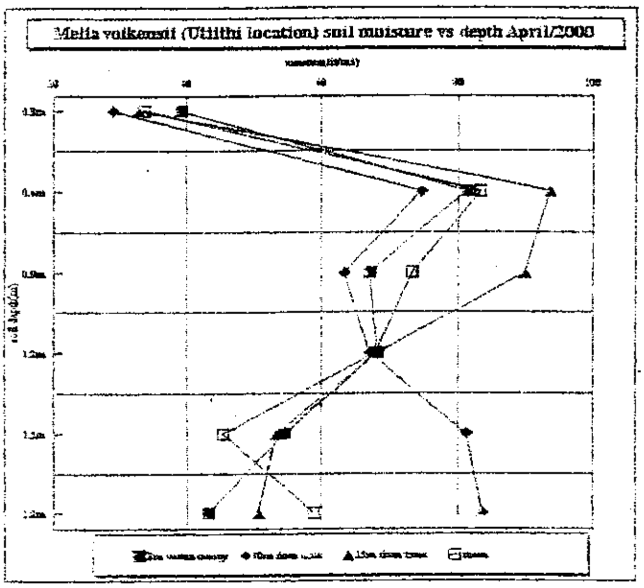
Mikuyuni

0.3m	50.6	67.1	78.5	65.4
0.6m	64.5	77.2	59.5	67.1
0.9m	77.2	78.5	65.8	73.8
1.2m	89.9	106.3	78.5	91.5
1.5m	105.1	95.6	75.9	90.5
1.8m	90.5	99.1	105.1	98.2

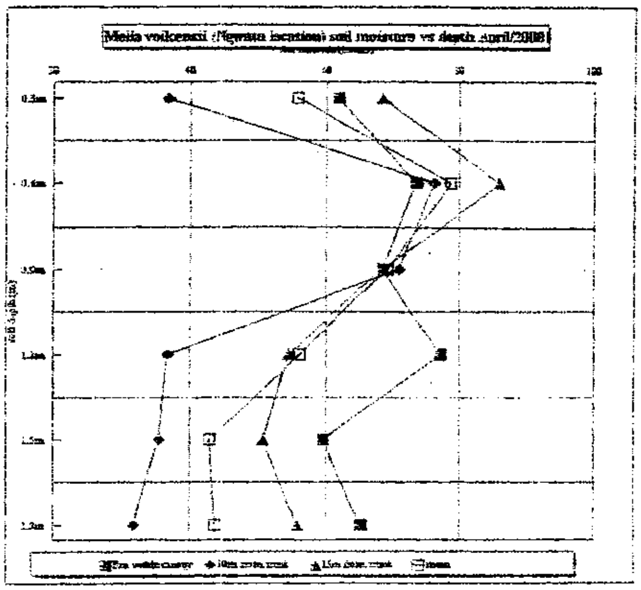


a: soil moisture in February 2000

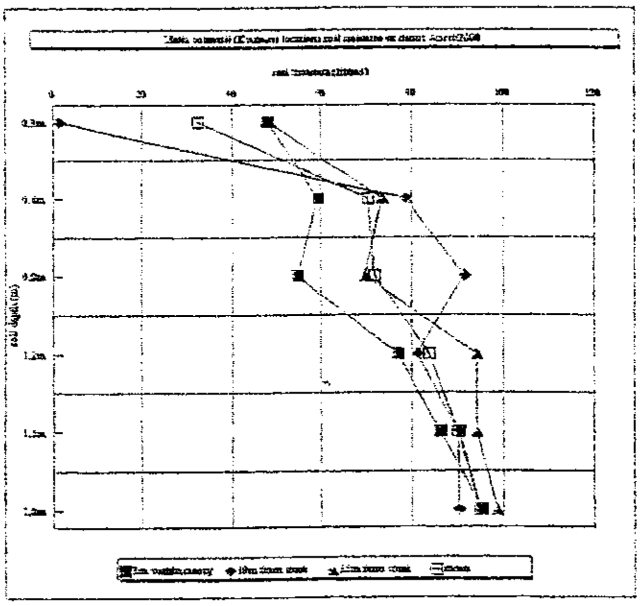
Utlithi April				
0.3m	39.2	29.1	32.9	33.7
0.6m	81	74.7	93.7	83.1
0.9m	67.1	63.3	89.9	73.4
1.2m	68.3	67.1	68.3	67.9
1.5m	54.4	81	53.2	45.3
1.8m	43	83.5	50.6	59



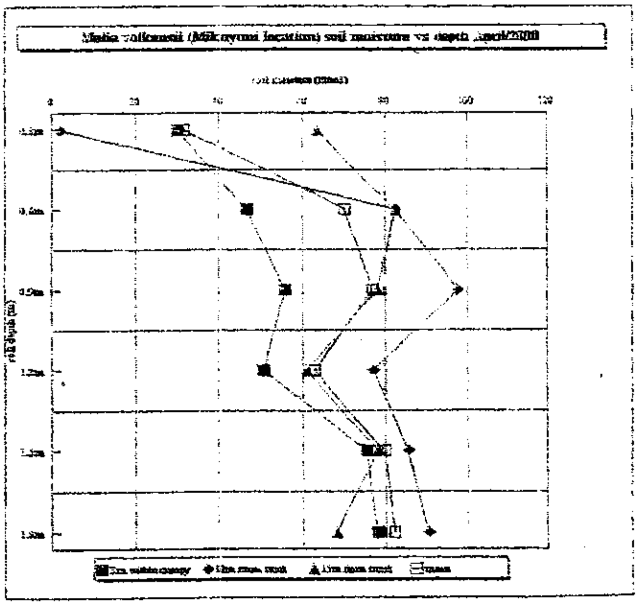
Ngwata April				
0.3m	62	36.7	68.3	55.7
0.6m	73.4	75.9	86.1	78.5
0.9m	68.3	70.9	68.3	69.2
1.2m	76.9	36.7	54.4	56
1.5m	59.5	35.4	50.6	43
1.8m	65.3	31.6	55.7	43.7



Kyumani April				
0.3m	47.8	1.3	48.1	32.2
0.6m	59.2	78.5	73.4	70.4
0.9m	54.5	91.1	69.6	71.7
1.2m	76.9	81	93.7	83.7
1.5m	86.1	89.9	93.7	89.9
1.8m	94.9	89.9	98.7	94.5



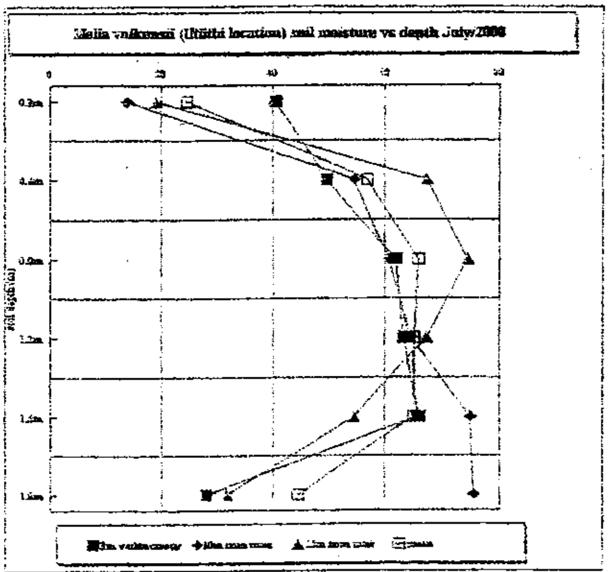
Mikuyuni April				
0.3m	30.3	1.7	63.3	31.8
0.6m	46.7	82.3	82.3	70.4
0.9m	58.8	97.5	78.3	77.2
1.2m	50.6	77.2	60.7	62.8
1.5m	75.5	85.6	78.5	79.8
1.8m	73.2	90.1	68.3	82.2

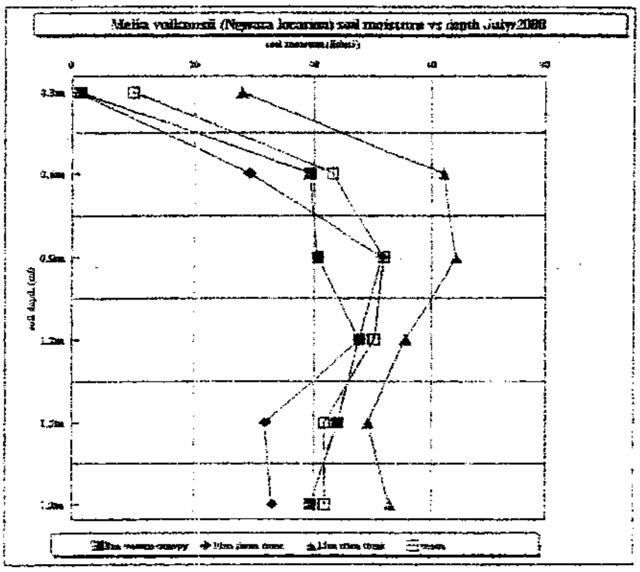


b: Soil moisture in April 2000

Utithi July	3m	10m	15m	mean
0.3m	40.5	13.9	19	24.5
0.6m	49.4	54.4	67.1	57
0.9m	62	60.7	74.4	65.8
1.2m	63.3	64.5	67.1	65
1.5m	65.8	74.7	54.4	64.9
1.8m	27.8	75.4	31.6	44.3

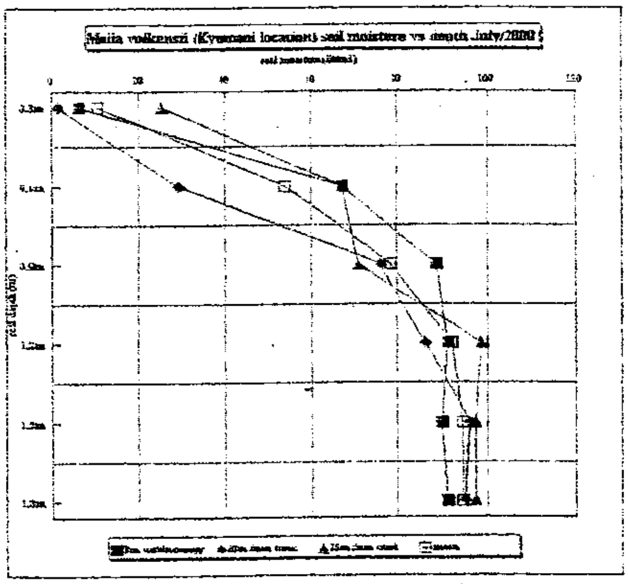
Ngwata July	3m	10m	15m	mean
0.3m	1.3	1.1	27.8	10.1
0.6m	39.2	29.1	62	43.4
0.9m	40.5	51.9	64.5	52.3
1.2m	48.1	48.1	55.7	50.6
1.5m	44.3	31.6	49.4	41.8
1.8m	39.2	32.9	53.2	41.8

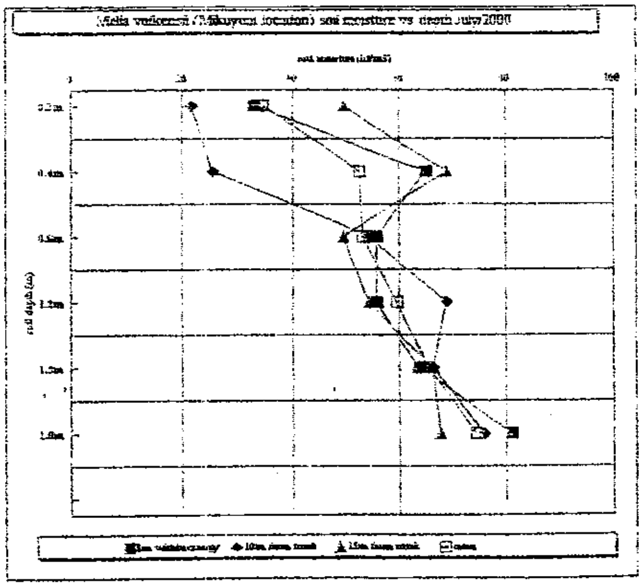




Kyumani July	3m	10m	15m	mean
0.3m	6.3	1.5	25.3	10.7
0.6m	67.1	29.1	67.1	54.1
0.9m	88.6	75.9	70.9	78.5
1.2m	91.1	86.1	98.7	92
1.5m	89.9	96.2	97.5	94.5
1.8m	91.1	94.9	97.5	94.5

Mikuyuni July	3m	10m	15m	mean
0.3m	33	21.5	49.4	34.6
0.6m	64.5	25.3	68.3	52.7
0.9m	55.7	54.4	49.4	53.2
1.2m	55.7	68.3	54.4	59.5
1.5m	63.3	65.8	65.8	65
1.8m	81	75.9	67.1	74.4





c: soil moisture in July 2000

Fig.4.3 Soil moisture variations along depth and horizontal distances occupied by *Melia volkensii* trees in the four locations of Kibwezi Division of Makweni District

4.4. Post Germination Problems

- Goat browsing on young growing seedlings is a major problem to the farmers who would like to have Melia trees growing on their farms. Some herbivores wild animals like Giraffes, also browse on leaves and twigs, which distabs sapling growth.
- Melia seeds had high oil content in their cotyledons which renders them susceptible to fungal attack, and rotting hence cotyledons were manually removed to allow shoot to come up above the soil (hypocotyl (plumule) emergence above the soil level). *Melia volkensii* has an epigeal emergence
- Fusarium wilt caused the post germination dumping off and the Trichoderma bacterial family caused rotting
- Seedlings whose cotyledons did not turn green. died while those whose cotyledons turned green survived up to pricking stage. All benlate (untifungicides) treated seeds germinated and died before pricking out. All neem leaf treated seedlings survived.

4:5. *Melia volkensii* as an indigenous fodder

Among the indigenous fodder preferences, the people living in semi-arid regions of Eastern province in Kenya give preference to *Melia volkensii*. The advantage of fodder from Melia tree is that, *Melia volkensii*. being deeper rooted than grasses, can produce green fodder during the dry season when all other fodder grasses are dry. Indigenous fodder trees have an advantage over exotic ones like the famous (Leucaena *leucosephala*), in that they are well adopted to the environment and farmers know them better than the researchers. (Ralph, R. *et. Al.* 1997). The following table 4.5, shows farmers indigenous fodder preference in descending order.

Table. 4.5 Indigenous fodder preferences by Farmers in Kibwezi Division, Makweni District during year 2000

spp.	Growth after establishment	Regrowth for goats	Palatability	Fattening of animals	Milk production in goats
Melia volkensii.	good	good	Good	medium	high
Mossanbiciensis aspilia	good	good	good	Low	good
Acacia atoxacantha	medium	medium	medium	poor	medium
Acalypha frutcose	medium	medium	poor	low	low
commiphora goodiiformis	good	medium	good	good	good
Grewia tembensis	medium	medium	good	poor	good
Indigofera lupatana	good	medium	good	good	poor
Lantana camara	good	good	good	poor	good
Mytenas putterlickiodes	medium	good	medium	poor	poor

4.6 Field survey and questionnaire:

In order to get the knowledge of the farmers, a questionnaire methodology was formulated and results recorded as follows:

4.6.1 Seed propagation

All farmers (90% interviewed) confirmed that *Melia volkensii* seeds are very difficult to germinate, some said that they only find growing seedlings in the cultivated lands especially during weeding.

A farmer in Mbololo Division of Taita-Taveta District confirmed that (Kirumbutu) seed can only germinate after staying for a very long time in the soil, but not the current or newly fallen fruits (seeds).

4.6.2 Indigenous methods of propagating *Melia volkensii*

Locally, root suckers (seedlings) are got from root sprouts or coppices from the cut stumps. Most farmers in this District use oxen plough to till their lands, as they do this, the *Melia* roots are disengaged from the main root.

The suckers then sprout into newly young seedlings of about 10-15 crowded together. Farmers then uproot these and transport round their homesteads. Since these suckers are under ground and the roots are not visible to the farmers, the farmers then tend to think that it is the previous season's fallen seeds which have germinated. The figures below show what was found on a farmers land in Masongaleni Division of Makueni District This farmer showed "naturally germinating seedlings" on his farm, but when carrying out root phenology by digging and observing the origin, by excavating, the roots went up to the main root of the growing old Melia tree trunk. (fig.. 4.8a).

All farmers interviewed confirmed that seedlings are only found growing near or where there have been a big Melia tree stump. One farmer, of Masongaleni location has transported over 100 seedlings (root suckers) from Kasayaani, her former home in 1992 when the Masongaleni scheme was being divided to local farmers. Her home now looks green in the dry jungle (bush land) dominated only by thornless Baobab tree *(Adonsonia digitata)*, and *Comiphora* species.

Few farmers have tried to raise seedlings from cuttings but failed. This failure was also experienced at the on-station research carried out in Kebwezi and Kitui by (Milimo, 1986 and Kidundo, 1997)

4.6.3. Problems related to seedling establishment of *Melia volkensii*

Melia volkensii is a problematic tree when it comes to seed germination, but once established, it grows fairly quickly even in scarce soil moisture.

A few problems sited out by the farmers concerning establishment were:-

- The hard fruits are difficult to crack, hence makes germination difficult
- Fallen seeds do not germinate because they are still premature (aborted seeds)
- Seeds have to stay for more than two to four seasons in the soil before they can germinate. This may be to enhance physiological maturity in the seeds.
- Seed vigour and seed viability is not known by the farmers of this region

- Physiological dormancy enhanced by the plastic-like papery layer around the cotyledons does not allow moisture to penetrate through the nut
- *Melia volkensii* seed storage longevity is not known properly. The cotyledons have high oil content, which gets oxidized and hence killing the amylase enzyme, which is responsible for germination. This enzymatic action stops the **ATP** which provides the germination energy from functioning and hence causes fungal attack (rotting) on the cotyledons.

4.6.4. How do farmers get planting materials of *Melia volkensii?*

melia stumps in their farms but they do not understand how the seedlings come about. Some think that they germinate from goat droppings after the goats are fed with Melia fruit pulps, (most farmers from Kitui District maintain this idea), but what the goats do is that they depulp the fruits (chewing the curd), then regugitate the Most if not all farmers transplant the root suckers found sprouting near the old hard nuts out. It was found out that it is the disengaged roots from the main stamp (injured roots) in the ploughed garden, which sprouts up or coppices from the cut stumps that the farmers collect and transplant in their plots,(fig. 4.8a).

4.6.5. How far from the tree do farmers get *Melia volkensii* seedlings?

Most farmers interviewed accepted that they do get their seedlings from within the outreach of either a standing Melia tree or old stumps. For the cut stumps "*coppices*", the sprout comes out congested together, but for the root suckers, the distance is as far as the root length of lateral roots. Since *Melia volkensii* tree is known to have deep roots in some shallow soil depths, the lateral roots runs a few meters away from the stump. As the farmers plough their shambas, they unknowingly injure the roots at different lengths hence, the sprouting root suckers comes out (germinates) at different distances and directions within the gardens. They then transport them at a place of their choice, i.e. around homesteads and within the plot, hence the distances is not specific but at least within the periphery of the old stump.

4.6.6. How do farmers protect seedlings?

Seedling protection is mainly to control the goats not to forage on the bark and leaves.

This is done by:

- keeping away the goats
- smearing the young stems with cow dung
- fencing young seedlings with thorny branches of Acacia species (Fig.4.10.ii)

4.6.7. How do farmers germinate *Melia volkensii* seeds?

Most farmers have failed in germinating *Melia volkensii* seeds.

In Mbololo area, of Taita-Taveta District, farmers dump Melia seeds with farm composed for a long time before observing natural regenerations. Some farmers burn the farm litter, then piles them somewhere for a long time before observing germination (wilding or natural regenerations), though they all agreed on the principle that currently fallen seeds do not germinate.

4.6.8. How do farmers manage *Melia volkensii* trees?

Apart from protecting *Melia volkensii* trees from damage by the goats, farmers also manage the trees differently by:

- Pruning of which the leaves are used as fodder. mulch for soil fertility and twigs as fire wood, trees that are to be used for timber are pruned and side branches are removed to produce a clean and straight bole free of knots. Trees on croplands are pruned heavily at planting time to reduce competition with food crops particularly for light. Pruning is also done to coincide with the time when fodder is scarce to provide feed for livestock.
- Pollarded to enhance big diameter growth (increase) for good timber and more bushy succulent fresh fodder for goats in the dry seasons.

- Thinning is done to enhance diameter growth for those trees destined for timber (see diagrams under management). This is only done in trees raised through coppicing and there is no commercial thinning done as trees are quite scattered in the field.

4.6.9. How do farmers use *Melia volkensii*?

To the local people of Eastern and Coastal provinces, *Melia volkensii* (Mukau - Kamba, or Kirumbutu- Taita), is a tree of many purposes (MPTS). Its uses ranges from leaves to roots, flowers, bark and the wood, and from traditional medicine to soil fertility maintenance from windbreak to boundary planting and ornamental homestead shading. Generally, different parts of *Melia volkensii* tree is used differently as follows:

- **Roots:**

- Roots are the main sources of natural regenerations through root suckers,
- Dry-rotten roots release nutrients and the fresh roots also fix nitrogen in the soil, hence improving soil fertility and also pumps water from below the soil horizons and also resists drought through the association with mycorhizae
- Traditionally roots are pounded and boiled then drunk to treat gonorrhea and other venereal diseases.

- **Leaves:**

The main uses of *Melia volkensii* leaves are:-

- As fodder for goats during the driest months
- Leaves are used as mulch to preserve soil moisture
- Medicinally pounded leaves are used in water bath to treat chicken pox among the Kamba people
- Leaf extract controls ticks and fleas on goat skins.

- **Bark:**

- Pounded bark is used to wash the goats against goat-skin disease (Unguu-Kamaba, Upele-Kiswahili)
- The bark is also burnt and the ash is licked to treat leumonia (Wau wa kate-Kamba) Goats forage on *Melia volkensii* bark, walking in the gardens, one sees white peeled tree barks as goats feed on them

- **Wood:**

Timber from *Melia volkensii* trees is the most expensive in Taita -Taveta, Makueni and Kitui Districts. It has a high quality and close grained timber, used locally for construction and furniture making and it is also termite and rot resistant. Harvesting and marketing when well managed. melia timber can be used from year seven after planting. Melia logs are sawn and sold locally on the markets for door, window frames and timber for furniture. The value of Melia timber is high and markets is readily available. The local supply can not meet the market demand. Wood is also a living bank that provides revenues in times of cash shortages (round wood sale for timber industry). Traditional barrel bee-hives for apiculturing activities are also curved from Melia wood. Its charcoal have a lot of energy and burns slowly providing enough heating energy.

4.6.10 Diseases of *Melia volkensii* trees

a. Canker disease

Canker disease in *Melia volkensii* tree is caused by fusarium fungal rotting. It renders the tree susceptible to wind throw, i.e. the branches or stems break at the canker infected points and drops down and the tree trunk can even end up dying. (Fig. 4.9c). Resine exudates are visible as they flow downwards and get dry on the stems.

b. Wind throw

On shallow soils where the roots cannot penetrate the soils to the lower horizons, especially on sandy soils, during heavy rains like the "El-Nino rains," normally destroys Melia trees through wind throw. (fig. 4.9c)

c. Pests

Goats are the major pests of *Melia volkensii* trees. They destroy trees by feeding directly on the barks, which they peel, and chew, also goats break branches as they jump to get fruits and leaves to feed on. (plate 4.9a)

d. Insect pests

Some moths (not yet identified) affect flowers causing premature fruit formations and abortion of seeds. This results in immature pulpy fruits which drops down under Melia tree canopy. Picking these seeds for germination, they do not germinate, as they had not fully reached physiological maturity. This has resulted in the major *Melia volkensii* germination problem throughout the semi-arid regions.

4.6.11. How long do seeds stay before germinating?

Most farmers confirmed that freshly dropped fruits do not germinate. According to these farmers, Melia seeds can only germinate after long stay in the soils i.e. 3-4 years, hence they always collect the wildings, which they do not know when exactly did the seeds fell from the branches. But this study found out that under laboratory conditions using sterilized sand as the germination medium and fully matured fruits picked from the tree, not under the tree, Melia seeds can take about 17 days to start germinating and continues until after 35-40 days. A forester at Kibwezi-ARIDSAK's nursery at one time got germination after 60 days with Melia seeds. Scientifically this was due to physiological dormancy caused by premature seed dropping before attaining the full physiological maturity while still on the branches. Seed viability is a major constraint to this species.

4.6.12. What pre-treatments are given to seeds?

- Locally, farmers gather the hard woody depulped fruits with farm litters and burn, and then heap them in composed around their farms
- Some farmers leave the fruits for ants to eat or forage on the lignified woody seed coats for at least three seasons before observing germinations
- In Kibwezi different soil media were used as a pre-treatment to *Melia volkensii* seed germination.
- Seed extraction is done by depulping using a mortar and pestle, the dry nuts are then cracked using knife and harmer, after which they are just broadcasted in the farms without turning them under the soil

4.7: Tree calendars for *Media volkensii* activities

The production of cropping and labor calendars for the agricultural systems in Kibwezi Division was undertaken to provide a clear representation of the system as a whole for the understanding of how *Melia volkensii* tree and its management fits into farmers timing for agricultural activities and work load. Figure 4.7below shows how the local farmers do manipulate and domesticate melia tree on their farms without interfering with their farming activities.

Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Partial leaf fall												
Planting												
Prune for timber & crops												
Flowering												
Rains												
Prun for fodder												
Weeding												
Watering												
Fig. b: Agricultural calendar												
land preparation												
Terracing,fencing,cutting pegionpea												
tractor ploughing												
1st season planting pegionpea,maize												
Cowpea & beans												
1st & 2nd weeding of cowpea,beans												
3rd weeding of maize												
2nd season planting maize,beans,cow pea												
1st & 2nd weeding beans & cowpea												
Harvesting beans & cowpea												
Harvesting maize												
Harvesting Pegionpea												
Land preparation cut pegionpea												
Terracing												
Rains												
land preparation, burning,digging, fencing												
Fig.c: combined activities for both tree management and agricultural												
Land preparation												
Planting												
Weeding												
Harvesting												

Fig. 4.7 Tree management activities calendar for ***Melia volkensii***

4.8: Propagation of *Melia volkensii*

4.8.1. Root suckers

Root suckers provide natural regeneration for this species in the semi-arid areas. The lateral roots of *Melia volkensii* grow horizontally several meters (about 4-5 m) away from the main stump, within the farms. During the cultivation, using ox-plough or hand hoes, these roots are injured or cut. The injured roots then sprouts into several suckers which are attended by either uprooting and transplanted somewhere else or thinned to one or two stems and left to grow. The diagrams below show the findings of this study:

4.8.2. Wildings of *Melia volkensii*

Melia volkensii seeds are known to stay for more than two to four seasons in the soil before germinations. Since *Melia volkensii* is a heavy seeder, the seeds drops seasonally in the cultivated fields. The mature, vigor and viable seeds then germinates naturally (natural regeneration) after a heavy rainfall season November/December rains in the cultivated fields just before the weeding of maize takes place. (plate 4.8b). These wildings were then collected and potted in the women groups nursery for further dissemination to other farmers and to Kibwezi Forest tree nursery.

4.8.3. Coppicing regeneration of *Melia volkensii*

The coppice system involves reproduction by stools, shoots or suckers. When Melia tree is felled near the ground level, it reproduces at the centre of the stump, shoots and stool. These shoots are known as coppice shoots, which arise from dormant buds near the side of stool or from adventitious buds arising from the combial layer round the periphery of the cut surface. The objective of low cutting is to cause the shoots to appear at the ground level to form independent roots to prevent wind throw. Several shoots arise which are thinned after three months to 2-3 stems for timber and polls production at on-farm level (farm forestry practices) and also for domestic uses like fodder production for goats and firewood for heating purposes. A by-product of coppicing system in melia tree is the production of mulch which falls in the cultivated land and improves soil fertility and prevents wind erosion. The following figures show the coppicing characteristics of *Melia volkensii*

4.8.4. Seed propagation in *Melia volkensii*

Seed maturity and vigor must be observed by picking mature brownish-green fruits up from the tree branches directly, (fig. 4.8di). A good mother tree which grows fast, and have straight stems with bushy succulent leaves was chosen for seed picking which was done in Kibwezi, Kitui and Mbololo in Taita-Taveta Districts.

After the fruits were picked, they were depulped using mortar and pestle, then tne nuts were sun-dried, then cracked using knife and a plunck of wood. The seeds were then nipped, soaked in cold water overnight, then the outer cover was slitted longitudinally with a sharp razor but taking care of the cotyledon not to be damaged. (fig.: 4.8dii).

Germination trays were then filled with the selected media (sterilized sand in the case of glass house). The seeds were then sawn and watered thoroughly once and the polyethylene house was closed to maintain high humidity to enhance germination while in the open nursery the humidity was not controlled. The following plates (fig. 4.7 d i-iv) shows how the above described processes of seed pre-treatment before germination could be achieved.

i) Uprooting root suckers from lateral Melia roots in the cultivated garden.

ii) Uprooted root sucker having part of the lateral root where it came from

iii) Tracing the origin of the root suckers from the original tree trunk

iv) New stem raised from root sucker from the old stem

Fig. 4.8a: Root Suckers of *Melia vonkesii*

i. Wildings germinating in Maize garden

ii. Potted wildings at Kibwezi agro forestry tree nursery

iii. Ported wildings at on-farm nursery (farmer managed)

Fig.4. 8b: Wildings of *Melia volkensii* found in the maize/bean plots

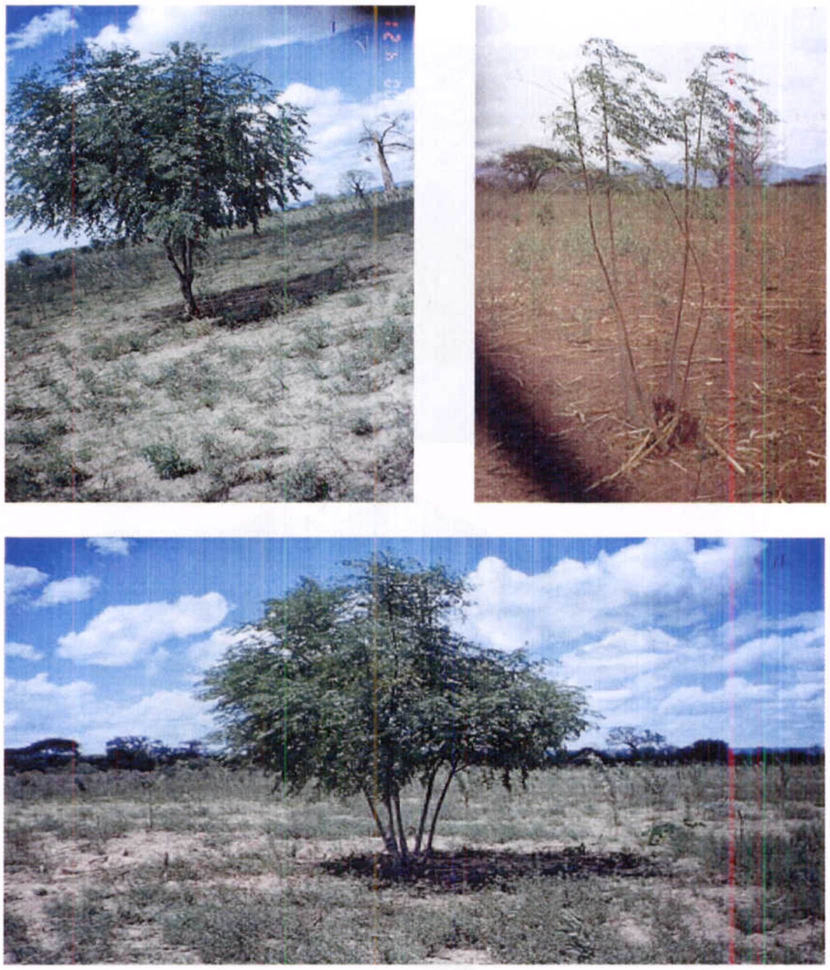


Fig. 4.8 c: Coppicing propagation of *Melia volkensii*

Fig. 4.8d: Seed propagation in *Melia volkensii*

4.9: Economic value (uses) of *Melia volkensii*

Melia volkensii is a multi-purpose tree (MPTS) producing a range of products. The main reasons given by farmers for cultivating it are to provide both products and services needed by the farmers of this region. It provides sawn timber and poles. While timber is frequently sold to meet pressing cash needs like fees, uniforms, food etc, poles are more generally used within the homestead for building purposes. The producers themselves also largely consume subsidiary products. Table 4.8 shows the product ranking obtained randomly from five locations of Kibwezi Division.

Table 4.9: Farmers reasons for planting *Melia volkensii*

Product priorities (% respondent)

Ranking use	Kibwezi	Mikuyuni	Utiithi	Ngwata	Kyumani
1. Timber	70	5	10	10	5
2. Poles	15	10	15	50	10
3. Fodder	20	10	30	20	20
4. Wood curving	10	10	40	30	10
5. Medicinal	15	30	20	15	20
6. Beehives	20	10	20	40	10
7. Mortar	-	20	50	20	10
8. Fuel wood	20	20	15	30	15
9. Windbreak	5	15	10	50	20
10. Shelter	10	20	20	20	30
11. Boundary planting	35	15	20	15	15
12. Soil erosion	15	20	25	10	30
13. Home gardens	10	10	10	20	50

For the local people of Eastern and Coastal Provinces, *Melia Volkensii* is a tree of many purposes (MPTS). Its uses ranges from leaves to roots, flowers, bark, wood and from traditional medicine to soil fertility maintenance, windbreak to boundary planting and ornamental homestead shading. Woodlots, fodder banks, improved fallows rangeland improvement, multistorey planting, rehabilitation of degraded sites and live fences around homesteads. Different parts of this golden tree are used locally as follows:

i: Timber production

ii. Round wood of *Melia volkensii*

iii. Apiforestry for honey production

Fig. 4.9: Economic value (uses) of *Melia volkensii*


iv. Pollarded for Goat fodder


v. Pollarded for fodder, mulch and soil fertility


vi. Firewood from *Melia volkensii*

Fig. 4.9: Economic value (uses) of *Melia volkensii* (cont.)

vii. Pollarded for firewood and to enhance big dbh growth

viii. Mulching and soil fertility

Fig. 4.9: Economic value (uses) of *Melia volkensii* cont.

4.9.1: Timber and poles of *Melia volkensii*

The durable and termite resistant timber has a coarse texture, with close-grained wood , works easily, planes well and has a density of about 0.62 (Dale and greenway, 1961). Carpenters compare it favorably with *Ocotea usambarensis* and *Vitex keniensis* locally. The heartwood is termite and decay resistant. The timber is valued locally for window and doorframes, doors, shutters, rafters and furniture. A bed of *Melia volkensii* in Kibwezi is sold at Ksh.8000.00. Its timber is the most expensive in Taita-Taveta, Makueni and Kitui Districts. It is also a living bank that provides revenue in times of cash shortage, and the traditional bee -hives for apiculturing practices are also curved from the wood. Timber is converted insitu by pit sawyers or by contractors using tractor mounted bench saws. Poles are defined as round wood of approximately 2.5 x 0.15m. Such poles provide the corner and door posts of square constructions, the central roof support of circular huts and posts for boma constructions, the poles are normally sunk untreated some 0.5m into the ground due to its termite resistant capability. Its charcoal have a lot of energy and burns slowly providing enough heating energy for industrial fuel wood in brick burning and domestic fuel for heating as charcoal and fire wood.

4.9.2: Medicinal (phytochemistry) uses of *Melia volkensii*

The survey conducted in different locations both in makueni and Taita -Taveta Districts through questionnaire indicated that farmers commonly use leaf preparations as flea and fly repellants, this concoction is particularly effective on goat skins. These findings are also supported by (Brokenshaw and Riley, 1988) who found it to treat goat kids. Various extracts from *Melia volkensii* are widely reported in the literature to possess antifeedant and growth inhibitory effects, Rajab and Bently, 1988), also reported an anti-feedant activity against *Schistocerca greggaria*_ (the desert locust).

Larvicidal and growth inhibitory effects have been also observed against mosquitoes (*Culex pipiens*) by Sharook, Balan, Jiang and Rembold (1991), while

Milimo (1990) also reports very favourably on the effects of *Melia volkensii* leaf extracts on *Anopheles arabiensis*, (a major malaria vector).

Among the Kamba people, different diseases are treated with different parts of (Mukau) *Melia volkensii* as follows:

- **Goat skin disease:** *Unguu*-Kamba or *Upele*- Kiswahili; pounded bark extract is used to wash the goat skin. The bark is also burnt and the ash is licked by people to treat (*Wau wa kate*-Kamba) leumonia. Goats also forage on Melia tree bark. Walking in the cultivated lands, one sees white peeled melia tree barks as goats feed on them.
- **Venereal diseases (gonhoria):** Pounded roots and boiled leaf extract is drunk, the patient then urinates yellowish urine as a symptom
- **Chicken pox:** Pounded leaves are used in water bath to treat chicken pox in children.
- **Back ache and pains:** Boiled leaf extract is drunk to relieve and back-aches in elderly people.
- **Active ingridients in *Melia volkensii:*** Extracts from leaves contains a number of active ingredients. Compounds which have been bioassayed for their potentials as insecticides and acaricides with considerable success includes four active fractions which have been obtained from fruits and two from leaves. Methanol to water ratio of 80:20 is the most effective solvent for the extractions of these compounds (Mwangi, 1989).

Two new minor *tetranortriterpenes. 2,3,-dihydrosalannin* and *1-detigloyl -1-isobutylsalannin*, have been isolated from fruits of *Melia volkensii.* Their structures were established by spectroscopic and chemical methods and they belong to the ring-c cleaved class of tetranortriterpenes. (Rajab. M.S. and Bentley, M.D. 1992), have also isolated from *Melia volkensii* fruits three new tetranortriterpenes in addition to the known *ohchinin - 3- acetate* [3] namely:

- *1-cinnamoyltrichilinin [4]*

- *1-tigloyltrichilinin [5]*
- *1-acetyltrichilinin* [6]

These are biosynthetic precursors of the salannin type limonoids. The bioactivity - directed fraction of the root bark of *Melia volkensii* have also resulted in the isolation of two new natural products known as-:

- *Melia volkinin* (1)
- *Melianin* c (3)

together with two known compounds

- *1,3,- diacetylvilasinin* (2)
- *Melainin B* (4)

while Jones oxidation of 4, gave the following compounds:

- *23, 24 - diketomelianin B* (5) and
- *16, 23, 24 - triketomelianin* B (6)

The structures of the new compounds were elucidated by spectral and chemical data. Compounds 1-6 all showed marginal cytotoxicites against certain human tumor cell lines, while 5 showed selective cytotoxicities for the human prostante (PC-3) and pancreatic (PACA -2) cell lines with potencies comparable to those of adriamycion as was also reported by (Rogers, L.L. et. al. 1998).In radio bioassay - guided search for antimycobacterial compounds from high plants, (Cantrell,C.L.et.al.1999), chemically investigated methanolic extracts of seeds of *Melia volkensii* chromatographic fractions provided two new *euphane (*20R) - type triterpenoids. The structures of the new compounds, 12β-hydroxykulact one (1) and 6β-hydroxykulactone (2), were elucidated by 1D and 2D NMR (^{13}C, ^{1}H, ^{1}H-^{1}H COSY, HMQC, HMBC, Spectra) and FABMS studies showed to be hydroxyl derivatives of Kulactone (3). In a radiorespirometric bioassay against mycobacterium tuberculosis, compounds1,2, and 4 exhibited moderate inhibitory concentrations of 16, 4 and 16μg/ml respectively.

4.9.3 Honey production (Apiculturing/Entomoforestry)

Honey is traditionally an important commodity among the Kamba people, both for sale and for making local brew (*uuki/muatini*), while medicine men use it to sweeten some bitter herbs for their herbal medicine practices. Entomoforestry (Apicultring or rearing of (*Apis melifera*), the honeybee, is therefore one of the oldest traditional farming activity among the Kamba people. It is a common observation along Mombasa road from Sultan Hammud through Makindu, Mtito Andei upto Voi for one to notice honey being sold in bottles by the roadside. *Melia volkensii* wood is also used to curve log hives (beehives) possessed by most farmers of this region (Fig.: 4.9iii), because the wood is easily worked, shaped and is resistant to fungal rot. For similar reason it is used in making acoustic drums, containers and motors, while its highly scented flowers provide excellent bee forage. Pharmaceutical industries uses bees wax from the honeycombs and other synthetic oils for industrial uses. Grade one honey in most of big Cities supermarkets comes from Ukambani (Kambaland) as a by- product of *Melia volkensii*

4.9.4 *Melia volkensii* as a fodder tree

All farmers questioned believed that *Melia volkensii* fodder is of high quality for both cattle and goats. A survey in the Tsavo East National Game Park also revealed that Giraffes prefer *Melia volkensii* forage than thorny Acacias. The tree comes into leaf, and is pruned for fodder towards the end of the dry season, a time when fodder is extremely scarce for both domestic and wildlife animals. Local farmers manage this tree silviculturally by pruning and pollarding in order to produce more bushy secculent fodder for their animals, see (Fig. 4.9 iv a & b) below. The large fleshy drupes (Fig.4.8dii a) are also eaten by goats after they fall from the trees. Goats also peel the bark of young melia trees and forage on them (Fig.: 4.10). The fruit pulp is reported to contain 10% crude fat and more than 12% crude protein while the mature leaves contain more than 5% crude fat and more than 21% crude protein (Milimo, 1990).

4.9.5 Fuel wood from *Melia volkensii*

Branches lopped during routine silvicultural management to provide fodder are often left to dry in the field before being used as industrial fuel wood for brick burning or as domestic fuel for heating as charcoal or firewood (Fig. 4.9v a, b).

4.9.6 Agroforestry/Tree-Crop interactions management of *Melia volkensii*

Most farmers in the study area believed that *Melia volkensii* is compatible with all crops grown. This however, is dependent upon good silvicultural practices, which reduces the shading effect of canopies which would otherwise adversely affect light loving crops such as sorghum and millet. Farmers also observed that *Melia volkensii* is capable of increasing crop yields due to heavy leaf fall during the later stages of crop development. Due to the deep rooting nature of *Melia volkensii* interference from the roots with cultivation and ox-ploughing is minimal. As an agroforestry tree species, *Melia volkensii* is locally used by local farmers in different agroforestry practices and technologies, some of which includes:

- Alley farming (Goat fodder)
- Soil erosion prevention (mulching)
- Wood lot
- Soil fertility (Nitrogen fixation)
- Boundary planting (windbreak and shelter belts)
- Home gardens

4.9.7 Agroforestry practices: Denotes a specific land management operation of an agroforestry nature. it is a distinctive arrangement of agroforestry components in time and space, (Nair, 1985; Young, 1989). The following observations (Fig. 4.9 vi) were made as a result of on-farm survey through a questionnaire methodology in Kibwezi and Mbololo areas.

i: Boundary planting and wind break

ii: Windbreak and shelterbelt

iii: Home gardens,pawpaw fruits and pegeon pea forms an understory

vi: Soil moisture studies under *Melia volkensii*

Fig. 4.9.6: Agroforestry/Tree-crop Interaction and management under *Melia volkensii*

v. Pollarded to provide mulching

vi: Wood lot and improved

vii: Scattered *Melia volkensii* and *Adonsonia digitata* trees intercropped with maize and beans

Fig. 4.9.6: Agroforestry/Tree-crop Interaction and management under *Melia volkensii (cont.)*

4.10 Problem domain of *Melia volkensii*

4.10.1 Seedling establishment related problems:

Melia volkensii (Mukau) is very difficult to germinate, this statement was given by almost 90% of the farmers interviewed. A few problems sited by the farmers includes:

- **The hard nut** (fruit) is difficult to crack and can take up to four years in the soil before it can germinate naturally
- **Fallen seeds** do not germinate with ease. most seeds fall prematurely or are aborted, hence cannot germinate
- **Seed vigor and viability** is not known locally by the farmers. The farmers also do not understand or are ignorant of *Melia volkensii* seed dormancy
- **Physiological dormancy** in M*elia volkensii* which is enhanced by the plastic-like (cuticle) layer around the cotyledons does not allow moisture to penetrate through.
- **Seed storage longevity** is very short due to the high oil content of the cotyledon. This oil gets oxidized easily hence killing the amylase enzymes, which is the enzyme responsible for seed germination. This makes the cotyledon to appear brownish under the Ultra Violet **(UV)** light, instead of creamy-white colour displayed by the viable cotyledons. This enzymatic action stops the ATP, which provides the "*germination energy*" from functioning. This results in rotting of the cotyledons as a result of fungal actions.
- **Protection of young growing (sapling)** trees from goats and wild animals like giraffes which usually forage on either the leaves, bark peeling or debarking or the green pulpy fruits, is a major draw back in raising or growing *Melia volkensii* at on- farm level.(Fig.:4.10). The farmers do carry out the protection by: - keeping away the goats, smearing the young stems with cow dung and - fencing the young seedlings with branches of thorny Acacia species.

4.10.2 Diseases of *Melia volkensii* includes:

- **Canker disease:** Caused by the (Fusarium) fungal family, is the major disease of *Melia volkensii* (Fig. 4.10c). It renders the tree susceptible to wind throw, hence the branches or stems break at the attacked points and drops down and the trunk can even die, this causes economic lose to the farmer.
- **Pests:** Goats and Giraffes are the major pests of *Melia volkensii* trees. They destroy the trees by feeding directly on the barks which they peel and eat, they also break the branches as they jump to get the pulpy fruits and leaves.
- **Insect pests:** Some moths (not entomologically identified during this study), affect the flowers and cause pre-mature fruit formations and droppings. This results in immature pulpy fruits which drops down under the canopy. If these seeds (first seed fall) are collected for nursery germination, they do not germinate because they had not fully reached physiological maturity and these are the aborted seeds. This has resulted in the major germination problem of this tree species throughout the ASAL regions.
- **Wind throw:** On shallow sandy soils, *Melia volkensii* trees are susceptible to wind through.
- **Dumping off:** In the nursery, high mortality rate is caused by fusarium wilt due to heavy watering. Die back was also observed.

i. debarked or peeled barks by goats as they forage on melia bark

ii. cow dung is smeared, thorny Acacia branches are tied around melia tree up to about 2 m to prevent goat foraging on the bark

iii. Melia canker: caused by the fungal family fusarium, attacks the tree at the pruned or pollarded sites

Fig: 4.10: Domestication problems of *Melia volkensii*

iv: *Melia volkensii* is susceptible to wind throw on shallow sandy soils

v. Mass seedling die- back and dumping off in the nursery

Fig: 4.10: Domestication problems of *Melia volkensii* (cont.)

CHAPTER FIVE

5.0 DISCUSSIONS

5.1: Glass house, Nursery and Laboratory work

5.1.1 Seed pre-treatment:

Once seeds are extracted, they must undergo pre-treatment before sowing. The seeds are first nipped at the tip with a razor, then soaked in cold water overnight. The seeds should then be slitted with a clean razor before being sown in sterilized sand as a germination medium. The sown seeds are then covered with a polythene sheet to maintain high humidity and warmth since *Melia volkensii* seeds are susceptible to fungi hence it is advisable to sterilize the germination medium by using fungicides or by burning the sand. The six germination media used in both glass house and open nursery were not sterilized in this study, hence failed to adequately resolve the question of provenance differences.

5.1.2 Seed pathology:

Results of mechanical scarification in the laboratory and under normal nursery conditions were very poor, with the seeds rotting and having bad odour due to Fusarium rot; when the cotyledons were examined under the Ultra Violet light in the laboratory, the cotyledons whose alfa-amylase enzymes have been oxidized turned deep-yellowish-brown in colour and were therefore not viable enough to enhance germination.

Typical infection of herbaceous host by a vascular wilt pathogen is characterized by initial wilting of the leaf laminae with subsequent leaf chlorosis and eventual desiccation and necrosis. These symptoms affect each leaf in acropetal succession. Wilt is loss of tugor of leaf laminae, progressive desiccation of the leaf tissues is an indicative of dehydration of leaf mesophyll cells or indicator of water stress within the host as (Hall and McHardy, 1981) also indicated. Fusarium vascular wilt is confined within the non-living xylem elements of the host tissues, hence inducing water stress in infected *Melia volkensii* seedlings in four categories as follows:

- Decrease water uptake by the roots
- Impair water transport within the infected xylem
- Impair water absorption from the xylem to surrounding tissues
- Increase water loss from transpiring leaf surface

5.1.3 *Melia volkensii* seed physiology

Under ultra violet (**UV light**), in the laboratory, the damaged cotyledons looked deep green while viable cotyledons appeared creamy-white. Observation with naked eyes showed the dead cotyledons as brown. This was due to the cotyledons oil content having been oxidized on exposing the cotyledons to oxygen. The enzymes responsible for germination enhancement in *Melia volkensii* is Alfa-amylase enzyme. Oxidation of the cotyledons oil content kills this enzyme and hence renders the seed inviable. Such seeds do not store longer even though the hard nuts can be stored for a longer period but the seed will not be viable, since the **ATP** that provides the germination energy will be absent. *Melia volkensii* has an orthodox seeds and hence seed longevity is next to zero. This is why its seed storability should be done in air-tight containers at a temperature of 30^0C (11-15% MC) but not open air (Albretch, 1993).

This finding supports the fact that seeds collected under canopy or fallen seeds/ ground collection, cannot germinate. It also seems to support why the wildings on cultivated land germinates but not on the bush-fallow. This is because on cultivated lands the seeds are immediately turned under the ground, i.e. stored under soil temperature. During this incubation of seeds in soils, the physiological seed dormancy seems to be broken, and at the on-set of the long rains (Nov./Dec.), when the land is tilled again, the germination of these incubated seeds are enhanced. The farmers then collect these wildings and pot them in on-farm nurseries then later transport them on their farms.

5.1.4 Germination rate and seedling vigour

Vigour is the vitality or the growth potential of seeds. Low-vigor seeds like those of *Melia volkensii,* show slow and irregular germination and exhibits high proportion of abnormal and weak seedlings which are more vulnerable to unfavorable conditions. Self-pollination usually leads to the production of low-vigour seeds. Isolated trees like *Melia volkensii,* or clusters of related individuals bear a high risk of producing low vigor seeds. Few isolated old trees (mother or plus trees), usually produce a lot of low-vigour seeds , which normally drop pre-maturely. As seeds age, their vigor declines as a result of natural catabolism which depletes food reserves, accumulation of chemical inhibitors, denaturization of enzymes and degradation of phytohormones. These affects the physiological, chemical and morphological status of the seeds. Infestation of seeds by either diseases or insects also affect the general physiology and physical structures of the seeds. All these affects adversely the seedling vigour and consequently the germination rate in *Melia volkensii* seeds as was also found by (Kozlowski, 1972).

5.1.5 Overcoming Dormancy in *Melia volkensii* seeds

Seeds of *Melia volkensii* are dormant, i.e. viable seeds which fail to germinate when exposed to presumably favorable conditions of the environment. To relieve this dormancy, the following pre-germination treatments were conducted:

i. Breaking (nipping) the caruncles

ii. Soaking the nipped seeds in cold water overnight (for 24 hours)

iii. Slitting the soaked seeds before sowing on sterilized sand on germination trays, moisten, then cover with polyethylene sheet to keep the seeds humid.

Seeds of *Melia volkensii* mature in 11 to 13 months, but phases of fruit development lacks a seasonal pattern. Change in fruit color from green to yellowish green (Fig. 4.8 d), appears to be the most practical indicator of seed maturity. Lignification and cutinization of integuments, and their growth to form a caruncle starts early in ontogeny, (ontogeny - origin and development of an individual) but major structure changes like deposition of nutrient reserves in the embryo and endosperm, persistence and crushing of the nucleolus in mature seeds, the thickening of endosperm cell-walls that characterize mature seeds do not occur until late in ontogeny. The embryos and endosperm's main constituents are crude fat (54% and 49% respectively oleic and linoleic fatty acids are the main components of crude fat) as was found by (Milimo, 1986), and crude proteins (35% and 26% respectively). Integuments are mainly composed of cutin and lignin (60%). These changes play a major role in establishing and maintaining the state of dormancy. One way in which integuments, perisperm and endosperm inhibit germination is by not allowing the embryo to absorb sufficient water (moisture) for the start of cell division. In both the glass house and open nursery experiments conducted, it was observed that radicles tend to be trapped (glued) in the seed coats, this encouraged rotting and bad odour especially in the glass house (polythene house). This, in addition to limiting the amount of water absorbed by the embryo, they also restrict radicle protrusion mechanically. To account for the germination behavior of *Melia volkensii* seeds subjected to various integuments, perisperms and endosperms treatment and experimental conditions, three mechanisms are concerned as follows:

The endosperm does not allow the embryo to absorb adequate water for cell division to start.

The embryo does not acquire sufficient imbibition pressure to break mechanical restraining action of the integuments

In nature, a mechanical weakening of the integuments is needed in addition to the removal of the perisperm effects, in order that embryos can be able to absorb enough water to enhance cell division, and hence, embryo dormancy.

During transformation into seeds, the ovule undergoes changes in form, structure and histochemistry that occurs late in the ontogeny of the ovule. These changes include:

- endosperm cell wall thickening
- compression and persistence of the nuclear tissue with its distinctive cuticle in mature seeds
- the accumulation of insoluble, none-polar and non-swelling storage materials in the embryo and endosperm

5.1.6 Types of dormancy in *Melia volkensii*

Melia volkensii exhibits all the three types of dormancies as follows:-

- **Innate or primary dormancy**:- dormancy of seeds at the time of dispersal or harvest
- **Induced or secondary dormancy**:- caused by some experience of the seed after ripening
- **Enforced or quiescence dormancy**:- this implies the arrest of retardation of metabolism and growth due to unfavorable environmental influences. (Bewley and Black, 1982).

5.1.7 Seed structure and histochemistry

The ovule of *Melia volkensii* seeds grows from the placenta as a round protuberance. At origin, the ovule has a symmetrical growth, the funiculurs and micropyle have a straight orientation, hence the ovule is "*orthotropous*". But during development, the ovule body bends and becomes completely inverted, bringing the mycropyle close to the funiculus, hence this condition is described as "*anatropous*" (Milimo, 1986).In the cause of maturation, various tissues change in thickness and the tip of the integuments develop to form a caruncle. Late in ontogeny, the embryo and endosperm starts to accumulate storage materials. Although the micropylar end is a small part of the total surface of the seed, it is one area which commonly causes germination inhibition and therefore, the degree of its specialization enhances dormancy.

5.1.8 Morphological, structural development of *Melia volkensii* fruit& seed.

Seed and fruit development is without a seasonal pattern in *Melia volkensii* around Kibwezi Division, taking up to 13 months to mature. Different reproductive stages of development were observed on a single branch of the same tree at most times of the year. This makes it difficult to ensure that only mature seeds are collected in bulk for germination purpose, but different exocarp colour and mesocarp structure serves as indicators of stages of maturity. Accordingly, when exocarp colour changes from green to yellowish-green, this is a fairly reliable indicator of maturity. However, fruit colour at maturity also depends on the amount of cork on the fruits. When deposition is heavy, fruit colour varies from grayish-yellow to gray. As a result, the ability to distinguish between mature and immature fruits is dependent on the knowledge of the productive cycle, and the morphological characteristics pertinent to each of these phases.

5.1.9 Embryo excision in *Melia volkensii*

The main categories of seed dormancy are distinguished as:-

- those related to structures external to the embryo
- those related to the properties of the embryo itself

Excision of embryos from seeds with physical dormancy (impermeability to water and gases) or from chemical dormancy (impermeability of seed coats to leachable chemical inhibitors), or from mechanical dormancy (prevention of radical protrusion), allows germination to proceed. This was also found out by (Nikolaeva, 1969). Excised embryos germinate significantly better than do intact seeds. In this study, seeds were nipped, then slitted to enhance this and allow smooth germination. See also (Fig.4.8d), under propagation in chapter four.

5.1.10 Permeability of integument to water

The first stage in the process of seed germination is water absorption. The three factors influencing this process are:-

- Availability of water in liquid or gaseous form
- Permeability of integuments, perisperm and endosperm to water,
- The chemical composition of the seed

Water relations of the seed tissues are also influenced by their chemical composition. The main storage tissues in *Melia volkensii* seeds are the cotyledons and the endosperms, their main nutrients reserves being crude fats and crude proteins. The process of germination involves water uptake and swelling which results in the production of considerable inhibition pressure, which is of great importance in the process of germination as it leads to the breaking of integuments, perisperm and endosperm.

If the embryo can not imbibe water to bring about sufficient imbibition pressure to surmount the mechanical restraint of integuments, perisperm and endosperm, then it must remain un-germinated.

5.1.11 Mechanical resistance to embryo growth (*Mechanical dormancy*)

In *Melia volkensii*, modes of seed germination observed both in the glass house and in the open nursery seemed to suggest that mechanical properties of integuments, perisperm and endosperm also play a role. Integuments not only appeared to limit the rate and the amount of water absorbed by seeds, but they also prevented the radical from protruding mechanically, (Fig. 4.8d). Mechanisms for the release of radicle growth resistance in nature for *Melia volkensii* seeds are not yet researched on but it seemed likely that injury acts by the breaking or the weakening of the integuments, perisperm and endosperm, enhances the imbibed and swelling radicle to emerge. Therefore, to account for mechanical restriction of integuments, perisperm and endosperm to embryo growth, the following two mechanisms are proposed:-

- that the embryo does not acquire sufficient imbibition pressure to surmount the mechanical restraint of the integument, perisperm and endosperm
- that a chemical weakening of the perisperm or endosperm, or both in addition to the imbibition force of the embryo is needed.

5.2 Soil chemical analysis of germination media used

The germination media used in this experiment were as follows:

i pure sand

ii cow dung

iii goat dung

iv soils dug under *Melia volkensii* tree canopy

v nursery soils (potting mixture)

In general, PH-values ranged from 7.5 - 9.0. This means that macro-elements like K, Ca, Ma, and Na were available while micro-elements e.g. Cu, Zn, Co, and Mn could be non-available at this range. Nitrogen was therefore decreased due to bacterial activity while phosphorous could be insoluble at this range. The electrical conductivity values showed salt content of more than 65% hence, this was described as "strongly alkaline media". E.C. of water is useful indicators of the total concentration of solutes in the sample. Since water samples had conductivities much less than one Mho/cm, $EC10^3$ or siemen/meter (s/m), the EC of aqueous salt solutions increases with increase in temperature (about 2%/ ^{0}C). The results of Nitrogen (N%) in both cow dung and goat dung were very high as a result of urine from the animals, while it was very low in pure sand forest nursery soils and soils dug from under an old melia tree respectively. Very low N% in sand medium resulted in good germination. Phosphorus values were very low indicating P-deficiency, (Table 4.2).

5.3: Soil moisture status under *Melia volkensii*

Identifying tree and crop genotypes which are resistant to drought (high water use efficiency) and high yielding has become an environmental issue, as environmental friendly as sustainable agricultural practices coupled with the need for improved natural resource management have considerably received high priority world wide. Water stress is the only most important limitation in water scarce arid and semi-arid areas. One of the difficulties in determining plant water use efficiency as a trait for identifying genotypes superior in performance under moisture deficit conditions, is the difficulty in accurately assessing water use efficiency (**WUE**) in the tree-crop interactions in the field. Conservational methods for determining soil moisture content such as gravimetric soil sampling method and the gypsum block, have proved to be inaccurate and expensive in terms of labour, time, need for frequent calibration as well as susceptibility to errors. These problems were eliminated by using the neutron soil moisture probe with permanently installed access tubes at varying depths in the soil profile. This allowed regular or seasonal monitoring in changes of soil water status within the plant rooting zone during the growing season. The water balance model (volumetric water content), was then used to estimate water consumption of both the crop and the tree genotype (provenance).

5.3.1 Principles of water resource capture in *Melia volkensii*

The principle of water resource was employed in this study due to the agroforestry technology of intercropping *Melia volkensii* with food crops like maize, sorghum, *cajanas cajan*, etc., where the main emphasis was the interaction of below ground resources, like moisture and nutrients; (Nyamai and Juma, 1996). In environments in which the limiting factor is water, like semi-arid areas of Makueni District, it was important to quantify overall dry matter/biomass production (**B**) in terms of the amount of water (**Q**) and the productivity per unit of water or transpired water use efficiency (**e**).

Hence, **B= Q.e** (1)

Where **B** is expressed in g/m^2, **Q** in mm of water and **e** in g/mm. The water use efficiency (**WUE), e**, is inversely proportional to the evaporative demand or mean saturation vapour deficit (D expressed in KPa), such that

e=K/D (2)

Where **K** is specific, with average values of about 4g/mm/KPa for C^3 species like beans and trees (*Melia volkensii*), and average values of 8g/mm/KPa for crops like maize and sorghum.

Q = BD/K (3)

assuming that **e** is not influenced by microclimate modification by trees.

Once the water use of trees and crops are calculated, a comparison of the water cost of the trees with the amount of water saved by increased infiltration caused by tree roots is made. The total amount of water captured by the particular system can be partitioned into that used by the vegetation, stored in or depleted from the soil. In standard hydrological analysis, water balance is commonly expressed in mm or as a percentage of the total rainfall (**p**) received, as:

P = E+T+D+R+S (4)

Where **E** is soil evaporation

T is transpiration

D is deep drainage

R is runoff

S is storage

Deep drainage, **D**, is seldomly measured and is usually assumed to be zero in dry land conditions. In practice, agroforestry systems have the potential to influence the water balance by reducing **E** through shading and mulching, to reduce **D** by trees with deep roots like *Melia volkensii*, to lower **R** by slowing the velocity of surface water movement and by mechanical barrier effect, and to increase **S** by improving infiltration rate. In dryland, seasonal **E** ranges from 30-60% of rainfall, **T** from 0-30%, **D** and **S** are seldomly measured.

If *Melia volkensii* trees are used primarily to reduce runoff, then average transpiration by trees, **Tt**, should be less than or equal to the reduction in **R.** In order to understand the principle of soil and water conservation in agroforestry system under *Melia volkensii*, the neutron soil moisture gauge which contains a fast neutron radioactive source, Americium/ Berilium which emits fast neutrons into the surrounding soils was used. Collisions with the nuclei of the soil atoms, predominantly those of hydrogen in the soil water, causes the neutrons to scatter, to slow and to lose energy. When they have slowed to thermal energy level, they are absorbed by other nuclear reactions. Thus, a cloud of slow neutrons is generated within the soil around the source. The density around this cloud, which is largely a function of the soil-water content, is sampled by a slow neutron detector in the probe. The electrical pulses from the detector are amplified and shaped before passing up the cable to the counter unit where their mean count rate is displayed. The count rate is then translated into soil moisture content (by volume) using an appropriate calibration curve.

The results on table 4.3 and figures 4.3 a,b, c show how the soil moisture varied with depths and horizontal distances of *Melia volkensii* roots. The water content of *Melia volkensii* roots, stems and leaves increased with increased water stress leading to an increase in succulence in all plant components. Water storage in the fleshy swollen roots and stem of *Melia volkensii* increased with the increase in water stress, hence draught resistant, mechanism exhibited in *Melia volkensii* Tugor potential, rather than total water potential in growing cells provides the driving force for cell expansion as was also found by (Jones, 1992), that the accumulation of osmotic solutes in melia occurs when it is exposed to water stress, causing adjustment in osmotic potential so that the tugor and physiological functions are maintained to lower levels of leaf water potentials; hence the extent to which seedlings maintain tugor at low water potentials to withstand draught.

5.3.2 Response of *Melia volkensii* to water stress

Melia volkensii seedlings develops a fleshy swollen tap root which retains a higher water content under deficit irrigation. It also maintains higher shoot water potentials and a larger stomatal conductance as compared to that of *Melia azedarach*, (Milimo, 1994), while (Ludlow, 1989) found out that leaf shedding and adjustment in dry weight allocation enables *Melia volkensii* to avoid dehydration and maintain turgor, hence adapting to moisture stress conditions. The ability of plant to adjust its architectural deferential for maximum exploitation of diminishing growth resources in a given habitat has been fixed in the cause of evolution by natural selection. Therefore, when pattern of dry matter distribution varies among population within a species, then this is an adaptive trend, as (Ledig, 1983) puts it. Environmental gradients that influence the pattern of dry weight distribution includes latitudes, soil moisture, and elevation. The main root of *Melia volkensii* becomes swollen within four weeks after germination.

These acts as storage organs for water which can be drawn upon (Mesic to Zeric state) at times of need. (Milimo, 1994) found out that in *Melia azedarach* seedlings (which do not develop fleshly swollen roots), the amount of water per unit of live leaf area increased under defict irrigation, hence providing a source of water not available to the seedlings. Swollen root systems, or xylopodia, have been reported in other species in the native savanna areas of Central Brazil, for example *Kickmegera coriacea, Daucus corota, Carycar brasiliensis, Andira humilis ETC.* This is responsible for the smaller reduction in stomatal and canopy conductance in *Melia volkensii* subjected to water limitations. Specific Leaf Area (**SLA**) increase occur due to translocation of metabolites from leaves associated with leaf senescence prior to abscission.

Morphological and physiological characteristics in *Melia volkensii* are important in its relative ability to survive and grow under water limiting conditions, for example, the nature of its fleshy roots, the maintenance of smaller shoot/root and live leaf/ root ratios, higher shoot water potentials and smaller stomata and canopy resistances under water deficit areas suggests that they may be better adapted to survive and grow in arid and semi-arid conditions.

Considering plant production under draught stress and the ability to recover when soil moisture is limiting, two domains of draught resistance needs to be recognized, for example:

- The maintenance of net carbon gain in spite of water deficit
- The onset of net carbon loss and drought resistance which involves the ability of meristems to tolerate desiccation and successfully recover upon rehydration.

One mechanism by which *Melia volkensii* meets transpirational demand is by reducing carbon partitioning between leaves (leading to reduced transpiration), and increasing it in roots, (leading to increased water absorption). This was also experienced by (Blums, 1987 and Givnish, 1984). Preferential investment in root growth ensures that pockets of untapped soil water are accessed, while control of water loss is effected through leaf area reduction, hence, *Melia volkensii* is a more drought avoider and maintains a higher tissue water potential to "**avoid**" the consequences of drought. Drought tolerant plants in this case *Melia volkensii* posses large quantities of collenchymas and has vacuoles that solidify on drying thus preserving the structure of the plant under periods of severe drought.

Tissue water content in *Melia volkensii* was observed to have increased with increasing water deficit, i.e. stems, roots and succulent leaves highly increased under increasing soil water stress. This was confirmed by the high rate of seedling mortality under nursery conditions (Watered daily) at Kibwezi- ARIDSAK nursery, but less deaths occured at on-farm nursery conditions where farmers only occasionally watered their melia seedlings.

In this study, *Melia volkensii* could also be described as a *pheatophyte* i.e a plant that can absorb water from a permanent water table (phreatic zone). This was shown by the soil moisture data taken by the use of Hydro probe soil moisture instrument during the dry season, more soil moisture was found at 1.6m deep than in the upper soil horizon at 0.5m root zone. The deep roots feed or withdrew moisture (soil water) as deep as 1.8 m depending on the soil depth and profile. This study also proved or showed that there was no competition against resources (soil moisture and nutrients) between *Melia volkensii* trees and food crops (maize, millet, *Cajanas cajan* beans and cowpeas) due to the fact that the crops have shorter roots and hence feeds on the upper soil horizons 30-60 cm unlike melia roots which went up to more than 1.5m deep. There was moderate water use efficiency at 3m horizontally away from the *Melia volkensii* but within the canopy radius as compared to 10m away from the canopy. A high soil moisture content at 15m horizontally indicated that the roots did not reach or go beyond this point. It is therefore necessary to classify *Melia volkensii* as a pheatophyte.

5.4 Post Germination Problems of *Melia volkensii*

Goat browsing on *Melia volkensii* bark is a serious problem found by farmers in the semi-arid regions. Farmers in Kibwezi and Mbololo Divisions, are using cow dung to smear the stems of *Melia volkensii* trees on their firms, in order to prevent goat browsing. They also use thorny Acacia and Combretum species to fence around *Melia volkensii* trees especially during the dry season when green fodder is scarce. It was observed both in the nursery and in the glass house that too much watering of seedlings causes high death rate of seedlings. Since *Melia volkensii* seeds have high oil content in their cotyledons which renders them susceptible to fungal attack and rotting, it is better to remove the cotyledons manually in the nursery to prevent seedling death, the soil and water chemical analysis also revealed that there are a lot of calcium salts (Ca – 1352.7ppm, table 4.2). Since a lot of calcium salts decreases the VAM activities in root associations, this leads to withering and death of seedlings.

5.5 Indigenous fodder

The domestication of *Melia volkensii* in the semi-arid regions of Kenya is highly affected by the browsing animals especially the goats and giraffes, which not only forage on melia leaves but also on both pulpy fruits and the bark . Hence one observes white woody stems as you pass by a plantation of melia trees. Farmers also lop, pollard and prun the trees heavily in order to generate or to enhance high bushy succulent fodder for their animals. This tree is the major source of green fodder (feed) for goats during the dry seasons, especially in and around Kibwezi Division. The farmers value this tree very much to an extent that every home has at least 2-10 *Melia volkensii* trees.

Apart from providing fodder, it also provides shade to the animals, who spend whole day under melia trees, in order to avoid the hot scourging sun. The leaf fodder has high protein content and the large fleshy drupes eaten by goats after they fall from the trees. The fruit pulp contains about 10% crude fat and more than 12% crude protein while the mature leaves contain more than 5% crude fat and 12% crude protein. (Milimo, 1990). *Melia volkensii* is very popular with farmers and would be widely grown on farms if propagations were not difficult (Kidundo, 1997). Farmers would like to plant indigenous fodder species on their farms if seedlings were availed to them, but the propagation technicalities have been a bottle neck to this much-desired species. Rated among other indigenous fodder species, it scores high max in more milk output in goats as was observed in this study (Fig. 4.5).

5.6 Field survey and questionnaire

Field survey and questionnaire methodology was used here in order to get the actual status of this tree and the feeling of the farmers who domesticate it in their own farms by using different silvicultural practices. A field monitoring technology was used to supplement field surveys, as away to complement/confirm in formations based on methodological approach for specialized studies on MPTS under the existing agroforestry system/technology. Monitoring is usually done at one go as in surveys, or data is collected over time either at regular intervals or when important activities such as planting, flowering, fruiting, harvesting, etc. take place. The improvement of agroforestry trees in dryland regions is as much a social and practical challenge, as a biological one. To develop and promote a tree-planting culture among a starving and cash-strapped client group of resource poor farmers, around Kibwezi Division is a very crucial and taxing activity.

ARIDSAK Project has tried to understand many diverse issues, ranging from germplasm demand and supply, to the way that farmers take decisions on both trees and crops on their farms. Hence, most farmers here prefer high value trees (**HVT**) like high value fruit and fodder trees (grafted mangoes, - *Mangifera indica*, Pawpaw - *Papaya carica*, *Annona cherimoya, Melia volkensii*, etc). This study found out through this methodology that domestication efforts must be focussed first on priority species that were determined following rigorous characterization methodologies and which farmers themselves have seen as the most valuable and profitable. It must be remembered that priority or preferences vary tremendously for different farmers and even overtime period for an individual farmer. Most farmers were found to prefer *Melia volkensii* not only as a "**living bank**" that provides revenues in terms of cash, but also as fodder for animals and environmental soil and water conservation. It produces abundance of leaves at the end of the dry season when other fodder sources are depleted. By using survey and questionnaire methodology, the informations were obtained or pooled from various sources which included:

- Individual farmers with *Melia volkensii* trees growing on their farms
- Both individual and group nursery owners
- Technicians, extension officers and scientists who have had working experience with the species, individual medicine men, timber merchants and wood curvers were visited and discussions held in their own environments within the premises of *Melia volkensii* tree stand. This facilitated visual observation to verify any information obtained.

5.7 Tree calendars

The calendar of activities observed in this region included the management activities of *Melia volkensii*, agricultural activities and the combination of both tree and agricultural activities under agroforestry practices during the rainy and dry seasons. A month of January is for weeding of both melia trees, cowpea and beans, while harvesting of pigeon pea coincides with pruning for fodder in August. March to April and September to October are the rainy seasons in Kibwezi Divisions. Fig. 4.7, shows how farmers manipulate these activities for both food crops and *Melia volkensii* trees in their local farming system depending on the climatic conditions prevailing in the region. *Melia volkensii* being a perennial tree, is capable of providing different services to the farmers and animals both during the dry and wet seasons, hence its wide domestication and integration in the farming systems in the semi-arid regions of Kenya.

5.8 Propagation and silvicutural management of *Melia volkensii*

The interviews conducted through the field survey and questionnaire revealed an active silvicultural management of *Melia volkensii* by the local farmers in different categories and techniques locally developed and un-influenced by either agricultural or forestry extension services. It was also observed that it is difficult to find *Melia volkensii* growing naturally on heavy clays. Experience indicates that high and rapid seedling mortality is higher at the onset of rainy seasons on such soils, hence it is not recommended to heavily water melia seedlings in the nursery, only water once a week. Silvicuturally, *Melia volkensii* is irregularly planted in a dispersed order within crops, generally at spacing in excess of 10-15m or along boundaries and around homesteads.

High level of tending this tree enhances good form and growth rate. Lateral branches are pruned from the first year onwards in order to maintain, clean and straight boles (Fig. 4.9.i &ii). When the crown is fully developed, it is thinned heavily to reduce shading of understorey crops such as Pigeon pea, sorghum and millet. This is done towards the end of the dry season in September – October (Fig. 4.7) to provide clear conditions at planting time. Pruning coincides with the flush of new leaves and fruits at a time when green fodder is scarce. Pollarding induces bigger diameter increment (Fig. 4.9), just as is done with *Grevillea robusta* around Embu and the Mt. Kenya regions in the high potential areas.

5.8.1 Wildings

Transplanting of wildings from arable land during the rainy season, which is highly emphasized by this study, is the most common and efficient way of raising *Melia volkensii* tree stands around homesteads. Participatory Rural Appraisal methodology **(PRA)** was the most important tool in this technology development and transfer. It required the active involvement and consideration of the farmer as a partner and not just as a client. Indigenous knowledge of farmers on the use and management of trees, and the actual role the trees play in their farming systems and daily lives are the basic foundation stones for both domestication, optimization, adaption and adoption of this tree species. The ARIDSAK contact farmers and women groups are now willingly collecting *Melia volkensii* wildings (seedlings) and potting them locally in dried fruits of *Adonsonia digitata* (Baobab kernels) which they are now using as potting containers instead of the commercial polyethylene potting tubes, which are expensive locally. This development was not only a success to this study but also a break through to ARIDSAK Project whose contact farmers are now having *Melia volkensii* seedlings in their locally managed tree nurseries. (fig. 4.8 biii), in Utiithi, Masongaleni, Nguata, Kyumani, Ulilinzi and Mikuyuni locations of Kibwezi Division.

5.8.2 Root suckers

Plantlets arising or sprouting from accidentally or deliberately damaged roots could also be transplanted (fig. 4.8 ai-v). This is a type of natural regeneration methodology which has been very successful with farmers; the suckers are then up-rooted and transplanted somewhere else. Mycorhizal associations with *Melia volkensii* roots enhances protection and growth of young seedlings to resist drought. Lateral roots were also found to grow horizontally within the farm 4-5m away from the main tree trunk. See also soil moisture studies (Table 4.3.1 and Fig. 4.3). Ox-plough is commonly used by farmers in this region hence causing root injury which in the end results in suckers sprouting from the injured lateral roots. The resprouting ability of *Melia volkensii* helps to retain turgid leaves at the tip, which enables it to re sprout from the base.

5.8.3 Scarification of seeds

Seeds were traditionally scarified by fire through dry litter or dung at the farm or around homestead. Some farmers were found to spread dry, naturally depulped stones (hard nuts) across uncleared land prior to burning and cultivation. The treated stones are then ploughed underground during land preparation and the germinants transplanted to the appropriate locations. This scarification was done to over come seed dormancy. Natural cracking takes two seasons (2 years), where by in the first season, the fleshy drupes dries up leaving the hard seed coat which cracks in the second season, due to the dry heat of the environment. This study found out that seeds should be slitted and nipped in order to enhance good germinations under controlled glass house conditions on a sterilized sand or vermiculite. See also (Fig. 4.8 d iii & iv). Propagation of *Melia volkensii* is difficult, because the seeds exhibit dormancy posing a great problem to nursery personnel.

This is supported by the absence of *Melia volkensii* seedlings in the forest department nurseries. It was also noted that aborted seeds which already have their *alfa-amylase enzyme* oxidized cannot germinate though the seed will stay in the seed coat for a longer time but not viable. Goat regurgitated seeds also did not germinate as suggested by (Blomley, 1994). Other suggestions that goat urine could inhibit fungal growth, which attacks seeds during mitosis, was also disapproved by this study when goat dung (goat manure) was used as one of the germination medium and all the seeds sown in it got rotten and failed to germinate. Only the seeds sown on pure sand medium germinated with a very low germination percent. Blomley's argument that "hard seed coats are broken down in the digestive system of the animals and that the seeds are extracted into the litter of the boma, or corral, where by the warmth of the decaying manure stimulates germination", (Blomleys, 1994), was also disapproved by this study, when goats were physically feed with fresh green pulpy fruits. It was observed that the goats only depulp the fruits by peeling off the green flesh (Fig. 4.8d), the hard stones (nuts) are thrown down. A comparison was also made of the goat drops in terms of size against the hard-woody depulped *Melia volkensii* seeds and found that goat drops are far much smaller in size than the endocaps. Hence, the goats can not swallow or pass the seeds through their alimentary canal and further more, nuts cannot be broken (cracked) by the goats teeth.

5.8.4 Coppicing in *Melia volkensii*

The coppicing regeneration ability displayed by ***Melia volkensii*** is of high standard, economical and a shorter period of only five-years rotation. (Fig. 4.8ci, ii & iii), Shows how much fodder and building poles can be enhanced through coppicing practices.

The coppice system has the following advantages on this golden tree:-

- It is very simple in application, and reproduction is usually more certain and cheaper than reproduction from melia seeds
- Coppice growth is more rapid and produces straight poles than the ones raised from seeds, hence coppicing is higher or superior to high forest

- Shorter rotation period with less capital tied up in the growing stock. This is suitable for the small holder poor farmers for raising farm forestry
- Conservation values are high due to a variety of habitat provided by different stages of worked coppice.

5.9: **Economic values of *Melia volkensii***

The local people of Eastern and Coastal province view *Melia volkensii* as a tree of many purposes (MPTS). Its uses ranges form leaves to roots, flowers, bark, wood and from traditional medicine to soil fertility, ornamental homestead shading to improved fallow and woodlot stands. When well managed, *Melia volkensii* timber can be harvested from year five after planting. The logs are sawn and sold in the local markets for door and window frames and for timber (furniture) industries. The value of *Melia volkensii* timber is high and market is readily available and the local supply can not meet the demand. i.e. the demand is higher than the supply. Timber is mainly used as construction wood, very strong with good reddish-color, hard, wearing, termite, rot and weather resistant and lasts longer unlike wood from the surrounding Comiphora/Acacia species. Silvicutural prunings for fodder is one of the most important activities and more economical to farmers during the dry spell. Leaves, fruit pulp and the bark are the main forage for goats in this region. *Melia volkensii* leaves can be sold as fodder while twigs are firewood providing energy to the local brick industry. Medicinally, pulverized *Melia volkensii* fruits are dried at 40^0C, provides methanolic extract which is an insect growth regulator in *Aedes aegyptii* (mosquito) larvae as was also reported by (Mwangi and Rembold, 1986), and antifeedant/growth regulating activities against the desert locust, *Schistocerca gregaria*, (Mwangi, 1982).

Its roots are pounded together with the leaves and boiled, the extract is drunk to treat gonorrhea and other venereal diseases. Leaf extracts controls ticks, flies and fleas on goat skins and chicken pox in children. Ash from the burnt bark is licked to treat leumonia among the Kamba people of Eastern Province. It was also indicated by (Barr and Mathews, 1991), that eye wash infusions acts as antibacterial prophylitic, abdominal pain, (Kokwaro, 1993), found out that an overdose of this can be fatal, yet controls mites in chicken. Sap from the injured bark can be used as glue.

5.9.1: Tree-crop interaction / agroforestry Nature of *Melia volkensii*

The main effects of tree-crop interactions revealed by this study can be summarized as follows:

Increased productivity
Improved soil fertility
Nutrient cycling
Soil conservation
Micro-climate improvement
Allelopathy
Weed control
Sustainable and stability
Pests and diseases
Environmental protection
Competition, etc.

Most of the soil fertility improvement projects are based on widely scattered, slow growing trees in arid and semi-arid environments. Although *Melia volkensii* has an ability of taking water from soils, it does not compete with food crops due to its deep roots, hence popularity in intercropping as an agroforestry tree species (MPTS). *Melia volkensii* is also a ***Pheatophyte*** plant, for example, it is capable of absorbing water from a permanent water table (***Phreatic zone***). Drought tolerant plants like *Melia volkensii* possess large quantities of Collenchyma and has vocuoles that solidify on drying thus preserving the structure of the plant under periods of severe drought. Restoring, maintaining and increasing soil fertility are major agricultural priorities, particularly in the ASAL region of Kibwezi Division, where soils are inherently poor in plant nutrients and the demand for food and raw materials is increasing rapidly. In this area, there is need to intensify tree/crop (agroforestry) production to meet the demand for agricultural products without using former land fallow practices. A fertile soil provides a sound basis for flexible food production systems that, within the constraints of soil and climate, can grow a wide range of crops to meet changing needs.

In agroforestry ecosystem, the supply of nutrients at least compensates losses from runoffs, leaching and volatilization, and in favorable conditions, nutrients accumulates in the perennial vegetation and in the topsoil. Most farmers in the study area believed that this tree is compatible with crops grown here. This however is dependent upon good silvicultural practices that reduces the shading effect of canopies, which would otherwise adversely affect light demanding crops such as sorghum and millet. Most farmers interviewed indicated that this tree **(Mukau)**, is capable of increasing crop yields due to heavy leaf fall **(mulching)** during the later stages of crop development. Due to its deep rooting, there is minimal interference from the roots during cultivation with ox-plough. Hence farmers have developed a number of tree husbandry techniques for propagation and management for its maximum benefits and use. There is evidence that traditional knowledge is being utilized, and supplemented with research findings of this study, will enable the continuing development of agroforestry systems which will improve productivity outputs of the semi-arid farming system. The impetus for this innovation probably arises from changing socio-economic circumstances and is influenced by formal agents of change and development.
With inevitable increased pressure on available arable land, sustainable diversification and intensification of farming systems in this area would provide the best hope for feeding the population, increasing the welfare of the farming house holds, alleviate the wide spread poverty and severe soil degradation.

It is overwhelmingly clear from the analysis that the twin factors, environmental degradation and poverty, promotes food and nutrition insecurity/high mobility and mortality rates in the area. It is therefore anticipated that the following benefits will be realized in the medium to long-term periods:

- Integrated soil fertility improvement strategies developed for wider applications
- Sustainable tree/shrub (**MPTS**) or high value trees (**HVT**), in this case, *Melia volkensii,* for soil erosion control, be identified and recommended to farmers.
- More trees and fruit trees on-farm and in other rural landscapes be introduced
- Sustainable availability of forest products and services on private farms (**Farmforestry**) and from other forestry rehabilitated rural landscapes be achieved.
- Ecological balance improved
- Agricultural activity improved
- Food and nutrition security improved
- Increased agri-based and off-farm enterprises and employment created
- Increased agro forestry based business opportunities and linkages created
- Biophysical environmental resilience enhanced.

5.9.2 Environmental Protection

A more sustainable and rational use of the available natural resources like trees, is exactly one of the underlying principles of agroforestry development. As such, the developed agroforestry technologies aiming at soil fertility replenishment or maintenance, soil erosion control and diversified production (agricultural as well as tree related products), are not at all detrimental to the environment, but on the contrary, enhances environmental protection. In this respect, not only the tree products but also the tree and forest services are important.

5.9.3 Agroforestry technology transfer

"*Development on-farm-research approach*" involves the introduction of the technology into farmer communities, while monitoring how and why farmers adapt, adopt and, or reject the technology and identifying major problems and opportunities arising out of farmer testing the technology. This will enhance the introduction and domestication of *Melia volkensii* at on-farm levels.

The methodology of farmers collecting their own wildings and silviculturally attending the trees was not only a success to this study but also a major breakthrough for the ARIDSAK Project, as a result of involvement of its contact farmers from Utiithi, Ngwata, Masongaleni, Kyumani, Ulilinzi and Mikuyuni locations of Kibwezi Division, to whom the technology package was introduced.

5.10 Problem domain of *Melia volkensii*

Although *Melia volkensii* exhibits a fast growth rate, its establishment has been problematic. The propagation methods used currently have achieved poor results. The genetic basis of the materials used for propagation is not known and the data on genetic variation is lacking. The issue of cash and food security on semi-arid local farmers is a serious one. Field interviews conducted in four locations indicated that most house holds run out of food before the next harvesting season and are cash-strapped throughout the year. Due to lack of enough soil moisture, both food crops and fodder for animals is a daily household problem. In a bid to assist this situation through agroforestry technologies, and grants from ARIDSAK Project, this study, undertook studies to help understand how the propagation of indigenous tree species for both fodder and cash can be improved, and the optimum use of this (Mukau) *Melia volkensii*, which is a local indigenous (MPTs) species in this area.

The importance of trees in farming systems is of high priority within Kenya as emphasized by the (Kenya Forestry Master Plan, 1994), that fast tree growth in areas of medium to low potential production should be enhanced to make tree growing a feasible use of agricultural land. Tree planting is problematic in semi-arid lands where ecological constraints are paramount, and livestock fodder is mainly provided by natural vegetation. Hence, *Melia volkensii* can best be incorporated in to the farming systems where little or no competition occurs with the agricultural crops. This study revealed that it is only the local recognition of the values of *Melia volkensii* and its ability to fulfill farmers needs, that has retained the farmers interest in the difficulty propagation of this species (Unruh, 1994), despite the problems it entails. The only hindrance to the domestication of *Melia volkensii* apart from seed dormancy, is goat forage (peeling the bark or debarking) of the sapling. Fusarium fungal wilting of seedlings in the nursery, and to a lesser extent; shading effects on crops, but farmers overcome this by pruning and pollarding the trees heavily for both fodder and firewood. (Fig. 4.9a-e) shows how farmers try to overcome or control these problems. *Melia canker* and shallow sandy soils enhances wind throw which blows off the branches of this tree, while in the nursery, watering once a week helps to control seedling dumping off.

The domestication of indigenous tree species like *Melia volkensii* is usually problematic due to lack of enough data like:

- Optimal time of seed collection
- Suitable seed handling practices which minimizes inviability

- Pre-germination techniques to relieve seed dormancy
- Lack of long-term investment.

These constraints have been exacerbated for along time due to lack of a clear understanding of the nature of seed dormancy in *Melia volkensii* and how to relieve it as (Teel, 1985), also argued, but this study found out how this should be overcome.

In most semi-arid or dryland areas, tree establishment is constrained by shortage of soil moisture and termite damage. *Melia volkensii* has overcome this by its physical chemical characteristics. e.g. its swollen roots which store water, and is able to absorb water from a permanent water table (phreatic zone) hence, under ground space utilization. (Fig. 2.7), the physiology of its stomatal opening and the fact that it is able to change from mesic to zeric state as the weather changes from humid to semi-arid and arid states. Its chemical composition (active ingredient) makes it become resistant to termite attack and insect repelant, hence less insect pests. The other genetic problem is that trees growing from root injuries (root suckers) and wildings are genetically similar hence the danger of inbreeding of the species. However, the method has the potential to solve the seedlings availability in the short run.

CHAPTER SIX

6.0 GENERAL CONCLUSIONS

The goal of this study was to promote the adoption, adaption, propagation and optimal use of *Melia volkensii* on a sustainable management basis by local farmers; in terms of cost benefits or willingness to pay as compared to traditional systems of tree use. Seed is the principal means for perpetuation of most trees and many woody species from one generation to the next. The life of the seed is a complex series of biological events beginning with the initiation of the flower, and concluding with germination of the mature seeds. Farm woodlots for fuel wood, poles and fodder are important in semi-arid regions. Shelter belts and dispersed planting for soil stabilization, habitat improvement, urban and rural amenity, all benefits the human environment. With such a variety of planting purposes among the dryland farmers , *Melia volkensii* is regarded as the golden tree. The current increased interest in agroforestry opens up a whole range of species for trial. The ability to grow in symbiotic relationship with agricultural crops is an essential characteristic of *Melia volkensii* and involves criteria such as rooting habit, ability to fix atmospheric Nitrogen and its multipurpose uses such as fodder, medicine, wood, shelter, mulch, etc. These new developments have introduced new opportunities and new problems in seed collection, species propagation and domestication.

Melia volkensii is very popular with farmers and would be widely grown on farms if propagation was not difficult. Farmers would like to plant indigenous fodder species on their farms if seedlings were available but propagation of much desired *Melia volkensii*, is a bottle neck to its cultivation.

6.1 Conclusions

This study found out that the following conclusions can be withdrawn from the research work:

- Seed pre-treatment by breaking the carunicle at the mycropyle end, breaking the inner and outer integuments and soaking over night (24 hrs) at ambient temperature, enhances a good germination rate
- Improvement of soil condition requirements in terms of soil moisture retention capacity is achievable under *Melia volkensii* canopy
- *Melia volkensii* is not labor intensive, does not require external inputs and does not compete with other food crops, hence it is easy to domesticate at on-farm level with less labor force requirements.
- Pure sterilized sand or vermiculite must be used as a medium for germination
- *Melia volkensii* nuts (cotyledons) rot when exposed to high moisture conditions, hence seedling elimination in the forest nurseries
- Determination of physiologically mature fruits must be done before collection and the seeds must be collected from the tree branches before they fall down. No ground collection for this species.
- The only alternative farmer-friendly propagation technology of *Melia volkensii* is through wilding collection (uprooting) either from root suckers or naturally germinated seeds
- *Melia volkensii* retains their leaves longer into the dry season on cultivated land than in the bush fallows
- Fitness-of-purpose of *Melia volkensii* as an MPTS species remains the prime objective of optimization, utilization and domestication in semi-arid regions which must be farmer-centered and farmer-driven
- For improved indigenous agroforestry trees to reduce deforestation and environmental degradation, there must be both adequate delivery of germplasm and engendering of a tree-planting culture among farmers; since researchers

can not design and develop a technology in isolation of the farmers if it is going to appeal to and adapted by the farmers

- "Bottom-up" methodology was found to be the only successful technology transfer for *Melia volkensii* adaptability by farmers. From this study it can be concluded that it is the local recognition of the values of *Melia volkensii*, and its ability to fulfill farmers needs, that has retained the farmers' interest in the propagation of this species despite the problems this entails
- *Melia volkensii* is a more drought avoider and maintains a higher tissue water potential to "avoid" the sequence of drought, than a drought tolerant
- This study also found out that high calcium salt content decreases the vascular-arbuscular mycorhizal (VAM) in root association hence leading to withering and death of *Melia volkensii* seedlings in the nursery. Chemical analysis of both nursery soil and water samples showed a higher ppm of calcium salts.
- *Melia volkensii* seedlings were characterized by fleshy swollen roots in both pure sand and soils that were dug under old *Melia volkensii* trees. This proved the mycorrhizal association with melia roots. Melia tree has a high tissue water potential under water stress conditions.
- Melia seeds are orthodox seeds, i.e. tolerant to drying to allow moisture content without loosing viability and can be stored in airtight containers at a temperature of $3^{O}C$ for several years

ASAL regions posses a diversity of indigenous plant communities of which use has been made although they have not been managed and optimized on an economic or ecological basis. In order to counter deforestation, increase optimal use and create a sustained renewable MPTS plant resource, it is necessary to increase the range of species grown commercially. This study presents the work on optimization of *Melia volkensii* (Gurke) as an alternative MPTS in dryland agroforestry systems for soil and water conservation. Its optimum use and domestication of *Melia volkensii* by local farmers in semi-arid regions can help to solve some of the current economic and social problems that limits developments at on-farm level, through improved local industry and soil fertility status.

6.2 Recommendations

Melia volkensii is a species with great potential, a tree that can fulfill a variety of needs at on-farm household level in marginal areas. Timber from this species is highly valued and is resistant to fungal rot and insect attack. It has a short rotation period of about five years when intensively managed. Due to its ability to resist drought, and to be implemented into agroforestry systems with less competition to food crops, *Melia volkensii* should be placed among the top priority MPTS in the semi-arid agroforestry systems. Its potential as a fodder tree for livestock in semi-arid areas is yet to be fully tapped. It is against these potentiality that the following strategies are recommended from this study-:

- Quality of timber production from *Melia volkensii* needs to be improved by using proper silvilcultural technologies, and non-timber products from this tree should be fully tapped
- ARIDSAK Project should be encouraged to enhance large-scale potting of wildings at on-farm levels and the exchange of these wildings between sitesin order to counter check the problem of genetic variation.

6.2.1 Seed storage:

Mature and properly dried seeds should have 11-15% moisture content and be stored in airtight containers at 3^0C temperatures; but not in the open air.

6.2.2 Seed collection:

Melia volkensii seeds should be collected around July-August, above from the branches (mature fruits appear yellowish-green in color), of good mother trees. Seed viability should be timed just as the fruits reach physiological maturity, before they start turning yellowish-brown on the trees. Fallen seeds have two problems;

- physiological maturity is not yet reached as some seeds fall pre-maturely due to abortion or insect attack.
- Pre-mature seeds can stay for up to three years in soil before germinating due to physiological dormancy.

6.2.3 Seed extraction

Fruits pulps should be depulped using a mortar and pestle, sun-dried then cracked using a knife and a plunk wood or machine extraction tool from KEFRI.

6.2.4 Pre-germination treatment

Pre-germination treatment recommended is by nipping the seeds, soaking in cold water for 24 hours, slitting the cuticular cover longitudinally with care not to damage the cotyledon. The seeds should then be sown on moistened sterilized sand or vermiculite medium in germination trays and covered with a polyethylene sheet to maintain high humidity, and not to water until germination starts.

6.2.5 Nursery management

Pricking out should be done as soon as the germination commences and the potting medium should have high sand percentage. The potted seedlings should be kept under shade for at least two weeks before exposing to the open nursery, and only water once if the dryness is noticed. *Melia volkensii* seedlings are sensitive to high moisture conditions; hence hardening-off is necessary before planting, i.e. reduced watering regime.

The following silvilcultural managements should be adopted and practiced in order to achieve maximum yield from *Melia volkensii*:

- Pruning of fodder which enhances straight bole free of knots and also to reduce shading of intercropped crops
- Pollarding to enhance big diameter growth, while providing fodder and firewood.

- Commercialization of *Melia volkensii* fodder in the local markets should be encouraged in order to generate cash to the house hold, especially during the long dry spell. The dry leaves (leaf hay) should therefore be harvested during the rainy season and be preserved for marketing in the dry season, just as is done by maize stovers in the area.
- Coppicing system of propagation should be encouraged by both the farmers and agroforestry extensionists so as to maintain *Melia volkensii* tree stand at on-farm forestry (Farm Forestry) with a rotation of five years, just like is done in Tea Zone (High potential highlands) with Eucalyptus species.
- For large-scale dissemination of *Melia volkensii* seedlings to farmers and local Forest Department nurseries, this study recommends that ARIDSAK contact farmers and women groups be encouraged to collect wildings and pot them in their nurseries before distributing them out for planting to the interested groups.

- Participatory Rural Appraisal (PRA) methodology, which is the most important tool for technology development and transfer, is highly recommended by this study as it requires the active involvements and consideration of the farmer as a partner and not just as a client. Indigenous knowledge of farmers on use and management of trees, and the actual role that the trees play in their farming system and daily lives, are the basic foundation stones for both domestication, optimization, adoption and adaption of *Melia volkensii* at on-farm level.

Introduced exotic tree species have brought a lot of havoc to the timber industry in Kenya for example, cypress aphid (*Cinara cupressi*), which has totally destroyed *Cupressus lusitanica*, a tree which has been valued for its timber for almost half a century. This study therefore recommends that Forest Department should liaise with KEFRI's ARIDSAK Project in Kibwezi, and JICA in Kitui, so as to set up a stand of *Melia volkensii* trees raised from wilding collection. This will give a Forest plantation of an indigenous tree stand like is done in Kakamega Forest with *Maesopsis eminii*; (Engl). Paper industries can then benefit from *Melia volkensii* as it is doing currently with *Cupressus lusitanica* since *Melia volkensii* is also a soft wood.

- ARIDSAK Project should introduce an alley-farming technology with its contact farmers, especially in Kyumani, to monitor mulch and fodder production, this will contrast with the zero-grazing practices in high potential highlands being done with *Calliandra callothyrsus*, and exotic species.

An improved understanding of the tree/crop interaction might enable the extension workers to assist farmers in the choice and management of crops and with the dissemination of technology within the community.

Providing good advice to farmers and enhancing their decision-making capacity is the best way to promote sustainable intensification of agro forestry, such advice requires:

- A good knowledge of farmers' cropping systems, socio-economic conditions and decision making processes
- Agroforestry extension officers' should use farmers' participation to identify and test suitable inovations
- Decision making should include long-term suggestions for accumulating nutrients on farm lands and improving soil fertility, and must promote sustainability within the farm level.

Expected outputs/benefits from *Melia volkensii* includes:-

- Cash sale from the produce (poles, posts, honey, fuel wood, timber, fodder and seeds)
- Indirectly from the savings realized by substituting garden produce for purchased vegetables and improved nutrition from new types of food i.e. fruits, vegetables, cereals e.t.c. grown under *Melia volkensii* canopy
- Environmental amelioration through soil improvement by litter produced by the tree/crop species
- Fodder, shade and aesthetics among others
- For timber production purposes, *Melia volkensii* should be planted at a spacing of 4mx4m.

6.3 Future research

In this study, a lot of other problems affecting the propagation of *Melia volkensii* as an important indigenous MPTS species were encountered. But due to time limits and the objectives of the study, all these problems could not be studied. It is therefore against this that the following activities /studies should be undertaken in future in order to fully understand the nature of this tree.

- Tissue culturing propagation technology should be carried out in order to have enough planting materials that can satisfy the needs of semi-arid farmers
- Cloning should also be done, this may help in the understanding of the genetic variation within the different provenances of *Melia volkensii* in semi-arid zones. Greater genetic gains and uniformity have been achieved in South Africa through a Clonal forest of *Eucalyptus camadulensis* at *Mondi Forest Institute,* since phenotypic properties of a plant is given as:-

  Phenotype = Genetic + Environment, *Melia volkensii* environment have been understood but not the genetic base. Despite *Melia volkensii* ecological and economic importance, its genetic diversity is not well researched on.

  Effective domestication and optimal utilization of genetic resources in any system is achieved only if a detailed understanding of the extent and distribution of genetic variation within a species is known. Since the Kenya Government has targeted ASALS as its top priority in agricultural development and aforestation, genetic evolution and development of propagation techniques will facilitate its faster integration and adoption in the arid and semi-arid lands.
- *Melia volkensii* propagation and management manual should be prepared and made available to the farmers.

Future research should incorporate *Melia volkensii* in dry land agroforestry practices as follows:

- Trees scattered on farms/pastures
- Woodlot establishment
- Boundary planting, wind break and shelterbelt establishment
- Home gardens
- Alley-farming, as is done in the high potential highlands with *Leucaena leucocephala* and *Caliandra calothysus.*
- Soil erosion prevention
- Improved fallow
- Soil fertility improvement
- Fodder banks
- Range land improvement
- Multistorey planting
- Wood curving
- Rehabilitation of degraded sites
- Live fence
- Home stead planting
- Urban forestry programme
- Entomoforestry

* Future research work should be carried out specifically on the oil content of the cotyledon of *Melia volkensii* seeds. It should be identified whether it is edible or for industrial use. Identification of the insect pest, which seems to attack the seeds during flowering hence causes a lot of aborted seed droppings, should also be researched upon. DNA test should also be carried out on the germination enhancing enzyme (alfa-amylase enzyme).

The papery cuticular layer which covers the cotyledon should be researched on as it is the major blockage to moisture entry into the cotyledon for the enhancement of germination.

- Biomas transfer experiment should be undertaken, this involves harvesting biomas from *Melia volkensii* trees from outside the field, and spreading them as green mulch on farms. Due to heavy pollarding which results in bushy succulents of regrowths, the green leaves should be transferred to other plots to improve soil organic matter for high value cereals like maize and sorghum.

6.4 Contribution to Science

The major contribution to science of this study was the domestication of *Melia volkensii* as an agroforestry tree, which involves accelerated and human-induced evolution to bring indigenous wild species into a wider cultivation through farmer-driven or market-led process. As an agroforestry technology transfer, "**Development on-farm-research approach**" involves the introduction of the technology into farming communities, while monitoring how and why farmers adapt, adopt and, or reject the technology, and identifying major problems and opportunities arising out of farmer testing the technology.

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