Kenya's Water Towers Protection and Climate Change Mitigation and Adaptation (WaTER) Programme

PRODUCTION AND UTILIZATION OF FRUIT, FODDER AND BIO-ENERGY TREES

Component 4: Science to Inform Design of Community-Level Actions and Policy Decisions

Robert Nyambati and Sebastian Kioko
February 2018

This programme is funded
By the European Union

Kenya Forestry Research Institute
(KEFRI)

Disclaimer

"This document has been produced with financial assistance of the European Union. The contents of the document are the sole responsibility of the Kenya Forestry Research Institute (KEFRI), and can under no circumstance be regarded as reflecting the position of the European Union"

Table of Contents

1.0 INTRODUCTION 4
1.1 Background Information 4
1.2 Scope and opportunities for farmers benefiting from economic value of Fruit trees 6
1.3 Scope and opportunities for farmers benefiting from economic value of fodder trees 6
1.4 Scope and opportunities for farmers benefiting from economic value of bioenergy trees 6
1.5 Core Problem 7
1.6 Goal, objective and expected outputs 7
2.0 METHOD AND RESULTS 8
2.1 Results 8
2.2 Fruit trees Field demonstrations 8
2.3 Bio-energy trees field demonstrations 9
3 PRODUCTION AND UTILIZATION OF KEY FRUIT TREES 10
3.1 Production and utilization of Mango tree (Mangifera indica) 10
3.2 Production and utilization of Avocado tree (Persea americana 15
3.3 Production and utilization of pawpaw 20
4.0 PRODUCTION AND UTILIZATION OF KEY FODDER TREES 27
4.1 Common Agroforestry-Fodder Production Models 28
4.2 Trees suitable for fodder 29
4.3 Harvesting techniques of fodder trees 29
4.4 Pruning regimes of fodder trees 30
4.5 Feeding of fodder-trees to the animals 31
4.6 Production and utilization of Calliandra calothyrsus 33
4.7 Production and utilization of Leucaena leucocephala 35
4.8 Production and utilization of Sesbania sesban 36
5.0 PRODUCTION AND UTILIZATION OF KEY BIOENERGY TREES 37
5.1 Production and Utilization of Grevillea robusta 37
5.2 Production and Utilization of Cupressus lusitanica 37
CONCLUSION AND RECOMMENDATIONS 39
REFERENCES 40

PRODUCTION AND UTILIZATION OF FRUIT, FODDER AND BIO-ENERGY TREES

1.0 INTRODUCTION

1.1 Background Information

Agro-forestry is widely practiced in the world. Several forms of agro-forestry systems exist; improved fallow, Taungya, home gardens, alley cropping, growing multipurpose trees and shrubs on farmland, boundary planting, farm woodlots, orchards or tree gardens, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pastures, and apiculture with trees (Sinclair, 1999; Nair,1994). Fruit, fodder and bio-energy trees planted in agroforestry systems play important roles in providing basic needs of small scale and marginal farmers for food, feed, fodder, fruit, firewood, timber, among other benefits.

In Sub-Saharan Africa (SSA), growing both domesticated and wild fruit tree species on farms diversifies the crop production options of small-scale farmers and can bring significant health, ecological and economic revenues (Keatinge *et al.*, 2010; Weinberger and Lumpkin, 2005). At the local level, fruit trees both domesticated and indigenous play a critical role in food/nutrition security and income generation. Akinnifesi et al. (2008) showed the high potential of many wild fruit species from different African regions for undergoing domestication followed by successful on-farm production. Fruit markets in SSA are estimated to grow substantially due to economic and human population growth and increasing urbanization rates, e.g. by 5.7 per cent per year in Kenya (calculation of ICRAF based on Ruel *et al*., 2005). Women are often strongly involved in and benefit from fruit processing and trade, particularly with regard to indigenous fruits (Schreckenberg *et al*., 2006). With appropriate promotion, the contribution of fruits to the livelihoods and health of African farmers and consumers could be substantially increased.

Currently, fruit consumption in SSA–with a daily average of only 36 g per person in Eastern and about 90 g in Western Africa (WHO, 2002) – is far below the recommended daily amount of 200 g per person (WHO, 2003). In sub-Saharan Africa about 30 per cent of inhabitants, most of them women and children, suffer from malnutrition (UNSCN, 2010). Fruits offer not only easily available energy, but also micronutrients such as vitamins and minerals necessary to sustain and support human healthy growth and activity. There are, however, a variety of factors that constrain fruit consumption and production in Africa such as:Lack of consumer awareness on the health benefits of regular fruit consumption; Change of consumer preferences and loss of the traditional nutrition systems based on local agricultural biodiversity, which leads to erosion of both the plant genetic resources and the related traditional knowledge; Degradation of natural vegetation used for collecting indigenous fruits in the past; Lack of sufficient tree domestication techniques and their dissemination, especially of vegetative tree propagation methods; Lack of fruit processing facilities, which leads to high post-harvest losses and ;Poorly organised fruit marketing pathways along the value chain.

Most smallholder ruminant farmers in the developing countries cannot afford concentrates and almost entirely rely on browse fodders for feeding their livestock. African farmers have utilized wild browse or trees that grow naturally on their farms to feed their livestock for centuries (Le Houe´rou, 1980). Fodder tree/shrub legumes have the potential to provide feed during shortages and nutritional deficiencies experienced during dry season as opposed to the low-quality hay of the stored crop residues which are usually fed to livestock during dry spells which are fibrous and devoid of most essential nutrients including proteins, energy, minerals and vitamins that are required for increased rumen microbial fermentation and improved performance of the host animal. Under these ecological conditions, shrubs and fodder trees can withstand the drought, stay green, and provide a nutritious fodder for livestock. Inadequate nutrition in ruminant animals has often been associated with heavy economic losses to the farmers because of animal weight and condition losses, reduced reproductive capacity and increased mortality rates. In order to improve the productive and reproductive capacity of smallholder ruminant animals, there is a need to look at ways of ensuring the availability and quality of feedstuffs produced on smallholder farms. One potential way for increasing the quality and availability of feeds for livestock during dry season is the utilization of fodder trees and shrub legumes.

New agroforestry systems for feeding livestock have emerged involving the planting of mostly exotic species, grown most frequently in hedges along field boundaries or along the contours to limit soil erosion. *Calliandra calothyrsus, Leucaena diversifolia, Leucaena trichandra, Chamaecytisus palmensis*, and *Sesbania sesban* are the most commonly planted fodder tree species in Kenya. However, the key challenges constraining the uptake of fodder trees include limited species appropriate to different agro-ecological zones, shortages in planting material and inadequate capacity by farmers to grow them.

Fuelwood plays an important role in the lives of the poor and rural families, by providing a primary source of energy. Fuelwood has both domestic and industrial uses and is used in rural and urban regions of most economies of the developing world (Dovie et al. 2004). Seventy-nine percent (79%) of the total traditional energy (fuelwood, cow dung, biomass etc.) consumed in developing countries is fuelwood and between 60% and 69% of this is in sub-Saharan Africa (Adebimpe 2013). About 70% of the energy consumed in India is met by fuelwood collected from forests and marginal lands. Unsustainable harvesting of fuelwood from forests may lead to deforestation and degradation and consequently loss of environmental services and goods. If fuelwood species are grown on fallow land, such negative impacts can be avoided. Trees can then provide both fuel resources and help to address energy crises within a country (Jain 1994). Trees can be grown on agroforestry systems for biomass production. Here, various fast growing multipurpose fuelwood/firewood species are intercropped on or around agriculture lands in form of woodlots and boundary plantings (Mathukia et al., 2016). The primary objective is to produce

firewood and or biofuels. Tree species commonly used as fuelwood in Kenya are *Acacia nilotica, Albizia lebbeck, Cassia siamea, Gravellia robusta, Eucalyptus sp* among others.

1.2 Scope and opportunities for farmers benefiting from economic value of Fruit trees

Fruits in small holder farms in Kenya play a crucial role in food production systems through the provision of food and contribution to diversification of cash incomes. Apart from food and cash they also provide other benefits/products such as fuelwood and contribute to soil amelioration and conservation, depending on where they are planted. Promotion of fruit tree growing for small holder farms could be an attractive option due to the economic benefits which can be achieved within a relatively short time. Given the small farm sizes in the project area, fruit trees are considered important economically because they produce good yield in small areas and yet sell for high prices compared to most field crops. This combination of high yield and high prices means that in heavily populated areas, farmers can get good income even from small farms. Fruit tree cultivation can also generate substantial employment opportunities especially in production and processing enterprises. There are positive signs that farmers in the basin are up to the challenge. However, unavailability of quality germplasm and lack of information on potential markets remains a major hindrance facing their promotion. To improve their productivity, vegetative propagation techniques such as grafting, budding, cuttings etc. and other packages need to be developed and disseminated.

1.3 Scope and opportunities for farmers benefiting from economic value of fodder trees

Fodder feed contain high content of protein, minerals and vitamins which in consumption result in increased weight gains and milk production. Their availability in the dry season tends to complement the feeding of crop-residues and natural pastures. Additionally, tree/shrub legumes are available on-farm and can also be used as a source of food, timber and medicines at village level. It is recommended to supplement the basic diet of livestock with concentrates, for example, dairy cows (dairy meal), which contain enough protein (about 160 gram in 1 kg). However, farmers generally don't follow this advice because of lack cash to buy concentrates and transport to the farm. Fodder tree leaves contain high quantities of protein, ranging from 10-30% of the 'Dry Matter' (DM). For example: 1 kg fresh leaves, with 25% DM (which is 250 gram, depending on the maturity of the leaves), contains 25- 75 gram protein. Fodder tree leaves can thus replace concentrates to a great extent and become a cheap source of protein supplementation. Legumes have also been shown to improve soil fertility through their ability to fix atmospheric nitrogen. This results in improved nitrogen and organic matter status of the soil.

1.4 Scope and opportunities for farmers benefiting from economic value of bioenergy trees

Agro-forestry can make a significant contribution toward the provision of fuel wood. Plantations/woodlots and or boundary plantings established specifically for bioenergy production offer several benefits over natural forest stands as sources of biomass: Trees grown in natural

forests usually take 40 to 100 years to mature. Those grown in use-specific plantations that is, to produce biomass suitable for converting to bioenergy, usually grow in 3 to 15 years. Surplus or marginal land not economically or biologically productive for agriculture may be well suited for forest biomass crops/trees, providing landowners and farmers with additional incentives.

1.5 Core Problem

The core problem that the Water Towers protection and climate change mitigation programmne aim to address is the complex relationship between increasing poverty, particularly among rural populations, food, and accelerated degradation of natural resources. These problems have been identified by several stakeholders to threaten food security, human welfare and environmental stability. One of the important options the project intends to promote is the need to intensify fruit, fodder and bioenergy tree production as an alternative source of livelihood, to address rampant poverty in the region. The project promotes a wide range of technology packages for their production and utilization. Emphasis is given to the need for farmers to adopt improved tree and fodder husbandry and appropriate harvesting, processing technologies and marketing so as to intensify farm production. Fast growing and high yielding fruit trees such as grafted mangoes, avocadoes, pawpwas were promoted. Similarly fast growing bioenergy trees such as *Gravellia robusta, Eucalyptus grandis* and *Cupressus lusitanica* will be promoted as well as fodder trees including *Calliandra carlothyrsus, Gliricidia sepium, Leucaena trichandra/leucocephala* and *Sesbania sesban.* As a way of sustaining production, enterprise development in germplasm development will be promoted.

1.6 Goal, objective and expected outputs

The main goal of this activity is increase production of trees/fruits and fodder banks in farms and landscapes hence contributing to poverty alleviation, sustainable natural resource and biodiversity conservation and environmental protection. The purpose and objectives of the activity is to develop and implement strategies for improved information package for farm forestry and fruit, fodder and bioenegy tree for sustainable improvement of livelihoods of small holder and the natural resource base in the region. The main objective is to promote production and utilization of fruits, fodder and bioenergy trees. The expected outputs are; a list of key fruit, fodder and bioenergy trees, and a report on production and utilization of the key trees.

2.0 METHOD AND RESULTS

A survey was carried out to identify the key fodder, bioenergy and fruit trees in the project area using structured questionnaires. This was followed by a feasibility survey by KEFRI technical team in collaboration with staff from the Ministry of Agriculture. The main objective of the survey was to ascertain the suitability of the proposed sites for establishment of fruit, fodder and bioenergy trees on-farm.

2.1 Results

A list of priority fruit tree species include: Avocados (*Persea Americana),* Mangoes (*Mangifera indica),* Guavas (*Psidium guajava),* Paw paw (*Carica papaya),* Jack fruit (*Artocarpus heterophyllu*), Oranges (*Citrus aurantium),* Zambarau (*Syzygium guineese)* and Bananas (*Musa acuminata).*

The key bioenergy trees are presented in Table 1 below with preference sites for planting;

Table 1: Preferred Bio-energy tree species and location

	Preferred niche					
Species	**Boundaries**	**Homestead**	**Woodlot**	**Intercropping**	**Riverine**	**Scattered**
Eucalyptus	39.5%(175)	3.2%(14)	47.4%(210)	0%(0)	2.7%(12)	7.2%(32)
Cypress	64.9%(48)	28.4%(21)	5.4%(4)	0%(0)	1.4%(1)	0%(0)
Mangoes	2.8%(1)	94.4%(34)	0%(0)	2.8%(1)	0%(0)	0%(0)
Tsimbego	21.4%(3)	71.4%(10)	0%(0)	7.1%(1)	0.00%	0%(0)
Pines	42.5%(34)	13.8%(11)	42.5% (34)	0%(0)	1.3% (1)	0%(0)
Grivellea	60.5%(225)	32%(119)	5.4%(20)	2.2%(8)	0%(0)	0%(0)
Oranges	4%(1)	96%(24)	0%(0)	0.00%	0%(0)	0%(0)
Avocado	7.8%(4)	90.2%(46)	0%(0)	2%(1)	0%(0)	0%(0)
Elgon teak	0%(0)	71.3%(62)	28.7%(25)	0%(0)	0%(0)	0%(0)
Kumukhonge	100%(56)	0%(0)	0%(0)	0%(0)	0%(0)	0%(0)
Kumusunu	0%(0)	100%(59)	0%(0)	0%(0)	0%(0)	0%(0)
Kumsangura	0%(0)	0.00%	100%(30)	0%(0)	0%(0)	0%(0)
Sub total	**41.2%(547)**	**30.1%(400)**	**24.3%(323)**	**0.8%(11)**	**1.1%(14)**	**2.4%(32)**

The priority fodder trees in the region were found to be;

2.2 Fruit trees Field demonstrations

Mangoes (*Mangifera indica)* was found to be the most suitable (prevailing environmental conditions) and therefore recommended for promotion in Siaya and Busia counties of Mt. Elgon ecosystem. Equally in Cherangany ecosystem, Mangoes (*Mangifera indica*), Avocado (*Persea*

americana), Oranges (*Citrus sinensis*), and Pawpaw (*Carica papaya*) were found to be ecological suitable for the region. However, *M. indica*, *P. americana* and *C. papaya* were prioritized for planting due to seedlings availability.

Through consultative meetings with community leaders and staff from the ministry of Agriculture, farmers were sensitized the need to engage in fruit tree production. In Mt. Elgon ecosystem, Twenty six farmers (26) and two institutions (Siaya and Busia ATC) were identified as appropriate sites where the first demonstration plots were established (Appendix 1). Mango orchards established in ATCs were to act as mother blocks for the supply of scions and as resource Centre for training. In Cherangany ecosystem each of the on-farm beneciary farmer (85 farmers) were planted with ten avocado trees. Additionally, the WaTER project worked in collaboration with "Action against Hunger (ACF)" supported local groups with fruits. The ACF is a Non-Governmental Organization (NGO) partly funded by the EU that deals with saving lives of severely malnourished children while helping vulnerable communities become self-sufficient. They have programs in nutrition, food security and livelihood, and water, sanitation and hygiene. It works with over 40 Mother-to-Mother Support Groups (MtMSGs) in West Pokot County on matters of maternal and child health and nutrition. Four MtMSGs namely; Kapeitum and Kapkarawai in Pokot South, and Chelokotetwo and Aminito in Pokot West were supported with fruit trees. A total of 1,034 fruit tree seedlings comprising 622 mangoes and 412 pawpaws were purchased and planted with the MtMSGs groups.

2.3 Bio-energy trees field demonstrations

Three high value tree species: *Eucalyptus grandis*, *Cupressus lusitanica* and *Grevillea robusta* were promoted in the two ecosystems. The trees were planted as woodlots or boundary plantings. A total of 24 ha were planted on-farm as demo plots for various agro-forestry technologies in West Pokot (11 ha), Elgeyo-Marakwet (10 ha) and Trans Nzoia (3 ha) counties in Cherangany hills ecosystem. A total of 25 ha were planted on-farm as demo plots for various agro-forestry technologies in Siaya (6 ha), Vihiga (7 ha) and Bungoma (12 ha) counties respectively. Trees on woodlot establishment were planted at an espacement of 2.5 x 2.5 m while espacement on boundary planting was 4-5 m apart.

3 PRODUCTION AND UTILIZATION OF KEY FRUIT TREES

3.1 Production and utilization of Mango tree (Mangifera indica)

Introduction

Mango belongs to the Anacardiaceae family. Although the mango tree is not indigenous to Kenya, it has been cultivated at the Kenyan Coast for centuries. Traders in ivory and slaves brought seed into the country during the 14th century. Mango trees were reported in Somalia as early as 1331. The mango is one of the most important fruit crops in the tropical and subtropical lowlands. It is native to India, Bangladesh, Myanmar and Malaysia, but can be found growing in more than 60 other countries throughout the world (Salim *et al*., 2002).

The mango is best adapted to a warm tropical monsoon climate with a pronounced dry season (>3 months) followed by rains. However, information from other countries indicates that crops cultivated for a long time over an extended area show a high degree of diversity due to varied environmental influences. This was likely also true for the mango seedlings first introduced in Kenya which were all polyembryonic. They can be multiplied by seeding and generally produce true-to-type progeny. Some of these are still productive, e.g. along the Tana River, and some of them have been given names which to this day are still valued. Kitoovu, Kimji, Klarabu, Punda and Mayai are of poor quality but better known are cultivars like Apple, Ngowe, Boribo, Batawi and Dodo. Of these, a few have steadily lost ground to a generation of cultivars introduced in the 1970s and 1980s distinguished by greater resistance to anthracnose (Colletotrichum),powdery mildew(Oidium),their very attractive colour and good shelf life.

Propagation

Mangoes are propagated either vegetatively or by seed. Seedlings are grown sometimes to produce new cultivars but mainly for use as rootstocks or to reproduce known polyembryonic cultivars. Mono-embryonic types, however, require vegetative propagation to retain all of the desired characteristics. It is also known that trees grafted on selected rootstocks remain smaller than the rootstock, and bear better and earlier.

The selection of suitable rootstock is as important as the selection of the scion cultivar. It has a strong influence on the growth, yield, fruit maturity and soil adaptability, among other things. In Kenya, the uniform seeds of the polyembryonic cultivars Sabre, Peach and Dodo are routinely used successfully. Seeds must be taken from ripe fruits and should be as fresh as possible at the time of planting. Before planting, the hard woody endocarp should be removed to examine the seed for disease or any damage caused by the mango weevil (Sternochetus). Freshly sown seeds should be protected from high temperatures and dessication by providing shade. Once seedlings emerge the shade is removed to harden the plants and produce a sturdy stem for grafting.

Once the seeds have germinated, the seedlings are carefully lifted and culled. This may be about one month after planting when they have reached the 3-5-red-leaf-stage. After transplanting the seedlings into containers not smaller than 18 x 35 cm they remain there until they are of pencil

thickness at about 20 cm above soil level. There are many techniques used to graft mango seedlings, but the most common methods are side-graft, side veneer and wedge- and whip-graft. A mango tree must never be transplanted while it is flushing or when the leaves are still tender; the best time to transplant is after the second flush has hardened. The top-working of fruit trees is a normal orchard practice and is necessary to replace old cultivars/seedlings with improved selections which are developed from time to time. Top-worked trees will start bearing within 2-3 years, i.e. much earlier than a newly planted tree. Furthermore, the survival of newly planted trees is not always guaranteed (drought, fire, animals etc.).

Figure 1: Farmers receiving mango seedlings- Funyula Busia County

Establishment

Mango is successfully grown on a wide range of soils. The trees do well in sandy soils at the coastline as well as on loam, black cotton and even murram soils at other elevations. The essential prerequisites for good development of the trees are deep soils (at least 3 m), appropriate rainfall (500-1000 mm), good drainage, suitable altitude (0-1200 m) and preferably a pH value of between 5.5 and 7.5. The tree itself is not difficult to grow and, once well established, is relatively tolerant of drought, occasional flooding and poor soil condition. Irrigation in the first years after planting promotes flushing (and suppresses flowering), so that tree size increases quickly. Irrigation also widens the scope for intercropping, for example, with papaya, banana, pineapple or vegetables, during the establishment phase. When the trees are big enough to produce a substantial crop, irrigation is stopped, or at least interrupted long enough to impose quiescence leading to flower initiation.

Among the various climatic factors, temperature, rainfall and humidity have a greater bearing on mango production than irrigation and soils. Furthermore, the production of high quality mango fruit does not depend so much on elevation but on the range of temperatures available. The two important considerations for mango cultivation are a dry period at the time of flowering-in Kenya mainly during the months of August to October-and sufficient heat during the time of fruit ripening. For optimum growth and productivity, 20-26°C is believed to be ideal. Temperatures exceeding 40°C may, especially in hot/dry areas, lead to sunburn of fruits and stunting of tree growth. Although not very impressive, mango trees of selected cultivars like Sabre and Peach have been observed at elevations of up to about 1900 m. However, for more successful crops areas below 1200 m should be considered.

The amount of rainfall in a given locality is not as important as its intensity and distribution. Rainfall of 500-1000 mm at the right time of the year is sufficient for successful cultivation. However, the mango cannot do well in areas which experience frequent rains or very high humidity during the flowering period. Such conditions are not conducive to good fruit set and they increase the incidence of serious diseases like powdery mildew and anthracnose. Anthracnose can be a major problem as the same organism occurs on avocado, coffee and papaya. Powdery mildew is quite common when low temperatures accompany high humidity

Since the mango is a long-lived perennial, the planting distance usually depends to a large extent on the vigour of the cultivar/rootstock and on the environment. Most orchards (either solely mango or a few trees on small farms) are planted too densely and trees are forced to grow upright and tall. Overcrowding results in the production of fewer fruits which are apt to be poorly coloured and infected with diseases. Tall trees also present a harvesting problem and create difficulties during spraying and pruning. Normally, grafted trees are spaced at 8 x 10 m or 10 x 12 m, though at the coast seedlings require 12 x 14 m. Intercrops of short-lived fruit trees such as papaya or annual crops could be used for better utilization of land in widely spaced young plantations.

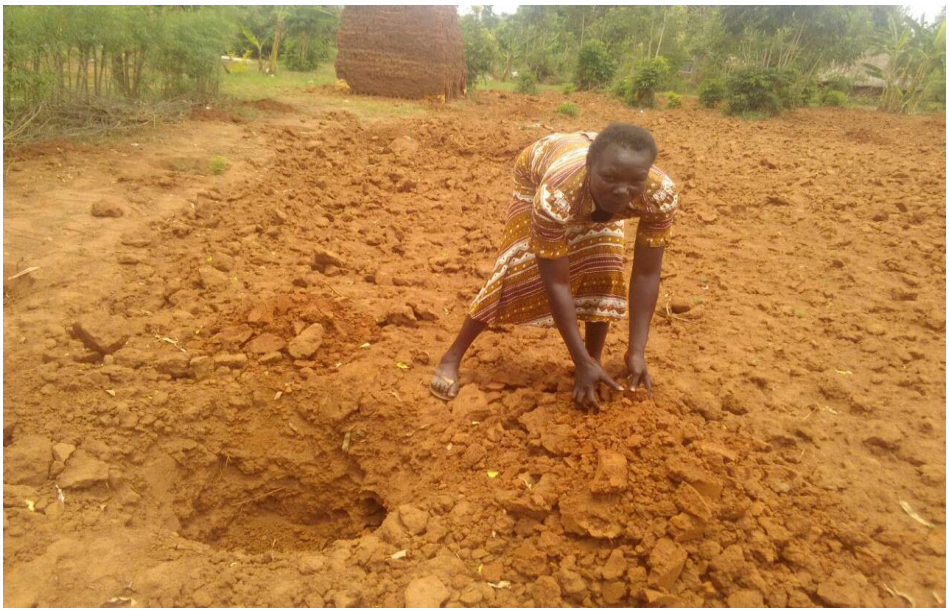


Figure 2: Farmers prepares land for orchard establishment in Funyula-Busia County

Maintenance

Mango plants should develop into strong well-shaped trees within the first 4 years and do not require pruning unless there are excessive branches or the shape is unusual. Depending on the cultivar and growth pattern selective pruning of branches may be required to encourage growth of lateral branches and to ensure development of good tree architecture for future fruit bearing. Any branches on the trunk lower than one metre from the ground should be cut. In later years, pruning is done mainly to remove diseased and/or dry branches or those touching the ground or crowding others.

Grafted trees tend to flower from the first year, and the formation of fruit on year-old mango trees is nothing exceptional. Flowering at this early stage and especially early bearing weakens young trees and often damages them severely. Therefore early flowering has to be avoided by removing the inflorescences; only from the third or fourth year should trees be allowed to bear fruits. A general criterion regarding mango nutrition is that care must be taken not to over-fertilize thereby promoting vegetative vigour at the expense of flowering and fruit set. This is particularly true for nitrogen application since trees are subject to fertilizer burn. Correct fertilizer requirements can only be determined by means of leaf and soil analyses taken in different agroclimatic regions. With trees in fruit, proper timing is critical and it is recommended that fertilizer be applied just after harvesting, during the rains.

In general, a tree at full bearing age (7 years and older) needs about 1.5 to 2.5 kg of Calcium Ammonium Nitrate (CAN) (26%); 2.25 kg superphosphate and 0.75-1.5 kg potassium chloride per year, or the equivalent inputs from manure or compost for small-scale farmers. These

quantities can be supplied either at one time or may be split into two doses administered with a two-month interval between them. Orchards should be kept clean, especially under the canopy of the trees where the fertilizer is spread uniformly in a circular belt around the drip line. This is the zone where the most absorption roots are located.

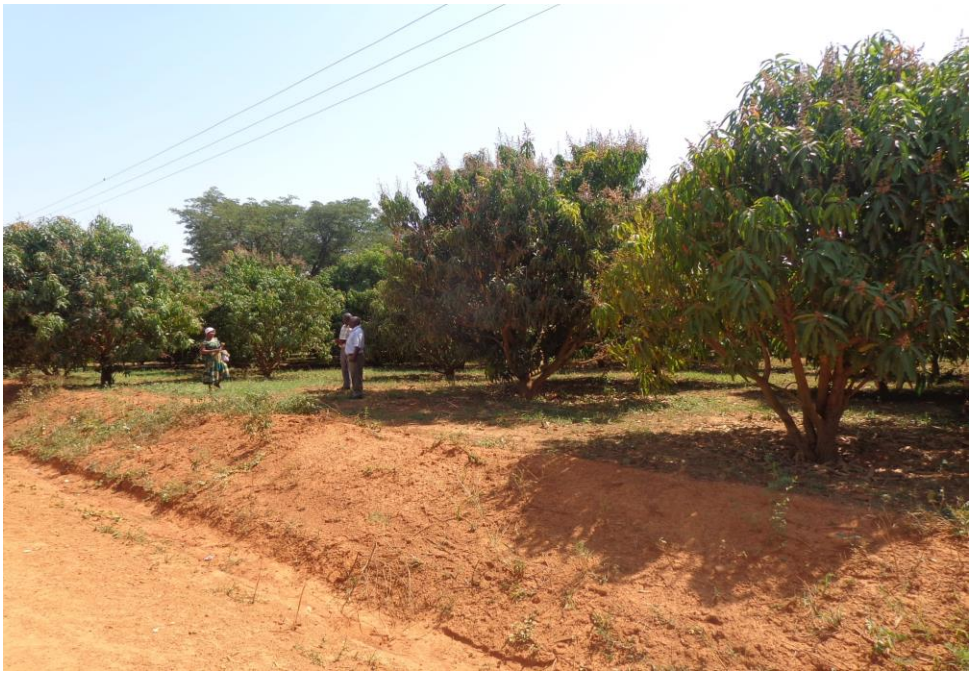
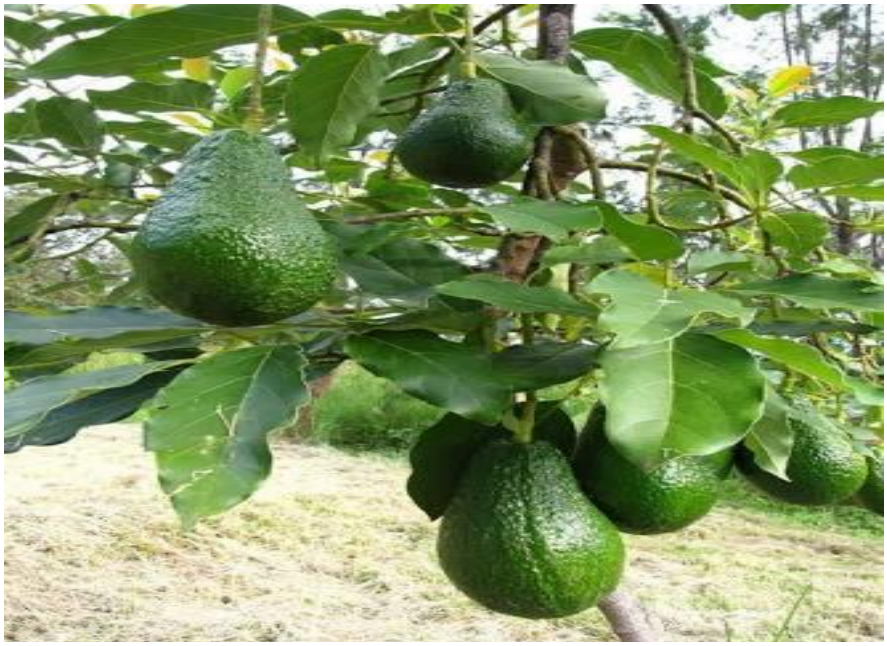


Figure 3: Well established mango farm in Funyula-Busia County

Production and utilization

A mango tree yields 200 to 1200 fruits annually depending on the variety and age. Mango fruits are marketed locally or exported earning an average of Ksh. 2,000 to 12,000 per tree per year. The tree is used mainly for fruit production but provides other services and products including soil conservation, shade, charcoal, firewood, timber, carvings, furniture, herbal medicine and fodder.

3.2 Production and utilization of Avocado tree (Persea americana)



Introduction

Avocado comes from the family Lauraceae; it is native plant to Southern Mexico and Central America. Mexico is the largest avocado producer, accounting for 25% of the world production, followed by Chile with 8.5% (FAO, 2013). In 2011, world avocado production reached 4.4 million tons, increasing about 20% from 2007 to 2011. Avocado farming in Kenya presents a good opportunity not only for farmers, but a growing population of youths to venture into. The most common variety is the Hass avocado. Kenyan markets both domestic and export is growing but limited by the production capacity of the current farmers. Kenya produces an estimated 115,000 metric tons of avocado annually, 70% of which is grown by small-scale farmers. Some years back, most of the avocados were sold in local markets, but this has drastically changed

today, where three quarters of the avocado fruit grown is exported to other countries such as Russia, Hong Kong, Singapore, Belgium, Germany, Netherlands, France, Spain, Iran, Libya, and Egypt among others.

Most of the Kenyan avocado farmers are found in Muranga, Nyeri, Kiambu, Kisii, Meru and Mt Kenya regions. Leading exporters include Mt. Kenya Avocado Farms (FAO 2003). Initiatives by the Kenyan government have been a boost to Kenyan avocado industry to fully comply with global standards and regulations. Bodies like KEPHIS (Kenya Plant Health Inspectorate Service) are actively involved in monitoring as well as educating farmers and exporters. Increased investment by county government also plays an important role in boosting farmers who struggled with low prices from brokers. Today in Kenya more and more farmers are compelled to start growing improved avocado trees, which will triple the countries production rates for exportation.

Ecological requirements

Avocado does well in altitudes between 1000m to 2000m. The fruit is generally bigger in cool areas as compared to warm areas. The optimum temperature is 20 to 24 degrees celcius. Although avocados are fairly resistant to drought, well-distributed rainfall of between 1000-1200mm is adequate for proper crop development (Ofosu-Budu,2003). Irrigation is essential where rainfall is not adequate. Although an avocado tree cannot tolerate wet soil, it needs at least 25 mm of water every week during periods of insufficient rainfall such as in eastern Kenya. Too much rain during flowering leads to shedding of flowers resulting in significant reduction in production. Fungal diseases also normally become problematic in very wet weather.

Avocado is sensitive to strong winds, which may lead to breakage of branches or flowers and fruits drop and whole trees may even be uprooted. Hot dry winds may cause desiccation of flower buds or abrasions. Avocado needs plenty of light, 2,000 hours of sunshine a year are sufficient. Intense radiation causes scorching of leaves and fruits.

An avocado tree can grow successfully in a variety of soil types and in soil with acidic or alkaline pH levels, but the tree requires soil that has good drainage. Avocados are more sensitive to water-logging than citrus hence soils should be well-drained. Poorly drained soils are associated with the presence of the Phytophthora fungi, which causes root or stem end rot. Suitable soils are medium sandy loams with a pH range of 5.5 to 6.5.

Propagation

Avocados can be grown from seeds or from seedlings. Seeds should be pre-treated with hot water not exceeding 50 C. Grafting improves the variety by increasing its resistance to diseases, improving yield and increasing its adaptability to different soils. The planting material should be inspected by relevant personnel to ensure they are free from diseases.

Establishment

Before establishment, land preparation is required. In case of newly cleared land, it is advisable to plant an annual crop a year before growing avocados, in order to achieve a good tillage of the cleared land. If there are strong winds, it is necessary to ensure the wind-breakers such as hedges are in place. It is also advisable to plant the trees in straight lines to facilitate crop husbandry and harvesting. In Kenya, the rectangular pattern of planting is preferred for avocados, as it eases movement of machinery in between rows as well as other activities such as inspection, thinning, and pruning. Tree spacing depends on several factors such as soil fertility and climatic conditions. Spacing may range from 6m by 7m to 8m by 10m. (Hofshi, R. 1999). The planting holes should be around 60 cm to 70 cm. Soli testing is advised before establishing avocado plantations. At planting about two buckets of farmyard manure is properly mixed with top soil together with 250gm of double superphosphate fertilizer, and a certified insecticide to fill the planting holes. Planting should be done after the onset of rains when rainwater has properly penetrated the soil. When filling up the holes, it is important not to damage the roots. Newly planted avocado trees or seeds should be irrigated preferably until the first shoots appear. Young plants should be tied to sticks to support them.

Management

Thinning, Pruning and weed control

Thinning involves removing some of the already formed fruits in order reduce competition for nutrients, therefore ensuring high-quality fruits. Too many fruits will result to small sized fruits. Pruning starts at the planting stage where roots that are too long and do not fit in the planting hole are reduced in size. During the early stages of growth, trees are trained in order to maintain a good framework. Pruning is also normally done before flowering and upon completion of harvesting. The general guideline is that the tree canopy height should be 70% of row width. (Whiley, A.W. 2002). This allows light to penetrate. Pruning improves yield and provides a superior tree structure. Weed control reduces competition for nutrients and water. Some of the methods for weed control are mechanical cultivation, cover cropping, and mulching.

Pests and Diseases control

The most efficient and economical method of pest and disease control is prevention. These preventive measures include weed control, proper selection of planting material, maintaining optimum plant density and proper fertilizer application.

In Kenya, avocado production is not considerably affected by pests and rarely will pest control require a chemical application. However, some of the major pests attacking avocados include

- False codling moth which is a brownish, night-flying moth.
- Thrips-These are small insects of up to 14 mm in length which are found in avocado agricultural ecosystems.
- Scale insects.

Fungal diseases may also affect avocados and therefore need to be checked. They include;

- Root rot. Also known as *Phytophthora cinnamomi*, it is mostly found in areas with poorly drained soils and flood prone areas. Some of the preventive measures include fungal and hot water treatment of seeds and grafting on phytophthora resistant rootstock. There are two chemicals registered to combat this disease i.e. Ridomil, active ingredient Metalaxyl, is a granular formulation which is applied in the soil, and works by killing the pathogen. Aliette, the second chemical is applied onto the leaves.
- Anthracnose. It's also called *Colletotrichum gloeosporioides*. It attacks the fruits, forming dry, dark brown sports. It mostly attacks mature fruits. It is controlled using copper based fungicides as well as spraying with chemicals such as Benomyl, Mancozeb, Metiram, Propineb, Thiabendazole or Triforine.
- Cercospora fruit spot or *Pseudocercospora purpurea* also affects the fruits leaving small, light yellow spots which eventually turn to a brownish color on leaves and fruits. It's controlled using similar methods to Anthracnose.
- Scab. It attacks fruits, twigs, and leaves. Lesions emerge as little dark spots a little raised and are oval or elongated. It's controlled using similar methods to Anthracnose.

Pollination

An avocado tree needs to cross-pollinate with another variety for optimal fruit set. Although avocado flowers have both male and female flower parts, each part functions at a different time during the day. The trees are grouped into Type A and Type B, depending on the time of day their male and female flower parts are reproductively viable. Planting Type A tree and Type B tree increases successful pollination if enough insect pollinators, such as bees, are present.

Harvesting and yield

Avocados flowers at around October and are mature for picking between June to September. It is important to know how to identify the correct harvesting period because avocados are harvested raw and ripen off the tree. A few fruits are harvested and kept in favourable conditions to ripen. If the fruits ripen evenly, they can be considered to have matured. Careful picking of similar fruits from the trees can then commence.

The yield depends on several factors such as proper pest and disease control, plant density, and soil fertility among others. Generally, the average yield of Hass avocados in Kenya is 87 780 fruits per hectare. There is great potential for avocado production in Kenya, especially for export. Some regions especially the central region and the rift valley region have impressive climatic conditions for the production of this fruit. The biggest challenge, however, remains lack of understanding among some farmers on the pesticides minimum residual levels (MRL) guidelines by the European market. Without this crucial information, there is a danger of farmers producing fruits only for them to be rejected by the export companies. Every effort should be made to

sensitize the farmers about these guidelines to ensure the highest export quality of Hass avocado is produced in Kenya.

Utilization

Avocados have amazing health benefits supported by scientific research. The fruit grants the following benefits;

- Avocado fruit contains fat soluble vitamins which are less common in other fruits
- Avocado pulp contains variable oil content, potassium and unsaturated fatty acids (Nakasone and Paul, 1998)
- They are high in protein and mineral content, compared to animal protein.
- Avocados are an essential source of good cholesterol.
- They are used in cosmetics, for example, in the manufacture of facial and hair oil.
- Economically, they are a good source of income for farmers besides earning foreign currency for the country especially Hass avocados.

Avocado growing is largely a permanent investment and, therefore, there is need for careful planning before venturing into it. In Kenya, avocado is mainly cultivated by both large-scale growers and small scale farmers.

Storage

- Avocadoes can me stored at room temperature until they are fully ripe. It generally takes anywhere from four to seven days for a hard avocado to fully ripen. To speed up the ripening process, avocadoes are put in a brown paper bag-placing an apple in the bag will help hurry things along even more. This will usually cut down the ripening time to 1 to 3 days.
- If they are fully ripen and are to be used later, they should be placed in the fridge in a plastic bag. There they will usually keep well for another three to five days.
- To keep cut up avocadoes from turning brown, they are wrapped tightly in plastic wrap before refrigerating –sprinkling a small amount of lemon or lime juice onto the exposed avocado flesh will also help prevent discoloration.
- Avocado can also be stashed into a freezer, avocados freeze well, with just a little bit of extra preparation. To freeze: wash, peel and then puree the avocados. Add to the ½ tablespoon of lemon juice for every avocado used to prevent browning. Place the puree in covered airtight containers or heavy-duty freezer bags and use within six months for best quality.

3.3 Production and utilization of pawpaw

Introduction

Pawpaw is one of the most economically important fruit tree in the Caricaceae Family produced mainly in areas located in tropics and sub-tropics countries (CRFG, 1998). The pawpaw is believed to be native to southern Mexico and neighbouring Central America but it is now present in every tropical and subtropical countries of the world. The fruit was rapidly propagated in the tropics, most likely due to the abundant and highly viable seeds. The crop has adapted quite well to tropical areas with fertile soils and abundant rainfall. Brazil is the main producer and trader of pawpaw in the world, though new producers have appeared in the international market trade increases. With the development of better cultivation and post-harvest technologies, pawpaw is becoming a new star in the world's tropical fruit market. In general, pawpaw crops have shown a continuous and stable growth and importers are confident of the future of this market. The key for a successful prospect for pawpaw lies on development of new varieties, better crop handling and post-harvest technologies. (Medinillla, 2000).

Figure 4: Pawpaw plants well arranged in rows

Figure 5: Ripe Pawpaw fruit

Growth habit

Pawpaws are well adapted to many soil types but mostly require a light and well-drained soil with high organic matter. Pawpaws do not tolerate flooding even for short duration hence are easily killed by excess moisture. The soil need to be moist in hot weather and dry in cold weather. Pawpaws do not tolerate salty water or soil (CRFG, 1998). They also like to be as free from wind as possible, although this is not as critical as their need for sun. Pawpaw can be grown successfully in shade, but the fruit is rarely sweet. They are best planted in mounds or against the foundation of a building where water can be controlled (CRFG, 1998). They are therefore recommended in regions with well distribution rainfall throughout the year without flash floods, water-logging and strong winds (Agrolink, 2002).

Although pawpaws do best in light, porous soils rich in organic matter, they can also grow in scarified limestone, marl, or various other soils of optimum pH range of between 5.5 and 6.7 under adequate care. No herbicides should be used due to the little woodiness of the pawpaw tree stem which may end up damaged. Weeding should be performed manually or mechanically-aided and superficially since deep soil disturbances can damage the root system. It is advisable to use black polyethylene film on the surface to avoid weed growth (Infoagro, 2002).

Propagation

Papaya is propagated through seeds. Although pawpaw may be planted directly in the orchard, considerable savings can be made on seeds and labour, by using transplanted seedlings raised in the nursery. Seedlings should be raised from seeds extracted from ripe pawpaw fruit produced by controlled pollination to ensure the quality and uniformity of the plantings. The seeds are first scrubbed lightly with sand to remove the gelatinous covering, the slurry of sand is then mixed with water; the bad seeds and gelatinous covering of the seed will then float. The floating seeds and the gelatinous covering are then removed. The good seeds are then spread out in the shade to air dry. The air-dried seeds can then be sown in trays, polybags or any container which has rich moist topsoil and watered every other day. The seedlings will be ready for transplanting when they are 20 cm high.

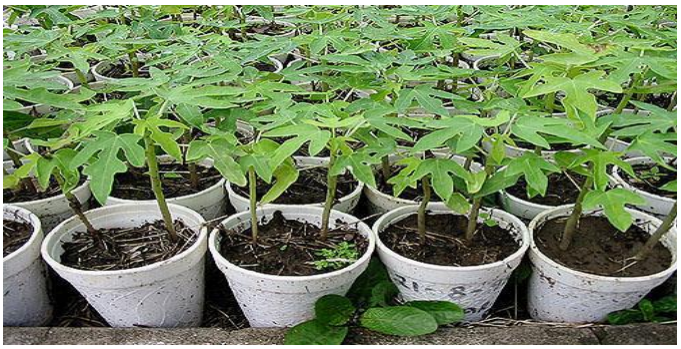


Figure 6: Well established Pawpaw seedlings in the nursery ready for transplanting

Establishment

Transplanting site should be on a well-drained soil with loamy sand mostly preferred. However, pawpaw can tolerate a wide range of soils provided it is not waterlogged. Plough and harrow the transplanting site and plant the seedlings in holes of 15 cm —20 cm deep and 2 x 2 m spacing in rows or corridors of 4 m to allow movement of equipment. The spacing can be increased if papaya is inter-cropped with coconut and other crops. Since there are no reliable characteristics to distinguish male, female and hermaphrodite plants until they bear flowers, 2-3 plants are recommended to be planted and be allowed to grow on each hill until flowering. When the flowers appear and the sex determined, males and undesirable plants are removed to maintain one male plant per 25-100 female plants as pollinator or only vigorous hermaphrodite of female plants are maintained. An elevated plot along row can be made to facilitate proper irrigation and drainage. Organic fertilizer and manure should be spread and incorporated in the soil during land preparation.

Transplanting should be done when the rains have stabilized i.e. transplant during the rainy or cloudy days to assure good plant start. After transplanting, one should make sure the plants get adequate water every 2-3 days until they are well established. The pawpaws should be watered regularly especially when the climate is hot or dry to prevent growth retardation, flower abortion and dropping of young fruits. Weekly watering is advisable during dry months. Too much watering should be avoided to prevent fungal infection. One should ensure that the soil is well aerated from time to time through shallow cultivation; this is to avoid root rot.

General sanitation should be exercised. Clean fields minimize spread of pests and diseases. Regularly remove diseased, senescent and dried leaves. These areas provide good habitat and unnecessary source of pests and diseases. Blown-down and diseased trees should be cut down and carried away from the field. Diseased leaves and fruits should be removed and buried or burned.

Fertilization

Plant nutrition should constantly be monitored and fertilizer applied on time. The best fertilizer is the organic compost mixed with the soil during land preparation. This should be augmented with chemical fertilizers high in potash and contain trace mineral elements. Boron is one critical element that needs to be always present as it is needed for flower fertilization and fruit development. 20-40 grams Boron is adequate for each plant.

Management

Weed control

Weeding is very necessary for papaya since weeds can reduce productivity of a plant by 25%. Weeding helps sanitize the immediate environment of the plant from insect pests that climb the

trunk like ants carrying aphids. Weeding also reduces weeds which compete for plant food nutrients in the soil. Weeds also act as host and vector or carrier of pests and plant diseases.
One should clean an area of one meter radius around the base of the plant. Herbicides should be as much as possible since they kill microorganism in the soil that helps enhance decomposition of organic wastes into fertilizer and plant food. Tall weeds in between the rows should be slashed or be harrowed to keep them down. The cleanliness of the field should be maintained at all times.

Propping

Propping is necessary to support the growing plants, especially during the fruiting stage. Wooden poles or bamboo are the most common propping materials. Propping should only be done on leaning plants. First, direction the plant is leaning is observed and then the stem is wrapped or cushioned the point of the plant where the poles are tied to avoid hurting the plant since wounded stems may induce stem rot.

Pest and disease management

Oriental fruit fly is a major pest of papaya that deposits their eggs on mature fruits. In case of infestation, fruits should be harvested at the mature green stage and disposed properly to avoid spread of pest.
Army and Cut-worm: The larva feeds on young and mature leaves of the host plants, making large holes on the leaves. Control involves spraying the leaves and stems after emergence every two weeks
Grubs (Japanese Beetle). As the larvae grow older, they become voracious and feed on the roots. Control involves drenching the soil at the base of the stem and applying organic fertilizer with herbal pesticide property.
Scale insects: These are round, oval pear shaped flattened scales of various colors on trunks or fruits. Controlled by spraying Lime sulfur 1 tbs per gallon water.
Red spider mites: Are tiny 8 legged yellow, dark green or reddish spiders on the underside of foliage. They prefer to feed on very young plant tissues. They can transmit viral disease. Heavily infested parts (branches and leaves) should be pruned and buried or burned. Controlled by spraying with herbal insecticide or Lime sulfur and by ensuring that seedlings are clean without infestation or diseases during planting
Mites and aphids: They suck plant sap and may transmit virus diseases. Control includes removal of alternate host, ants and allows natural predators and enemies in the plantation or spraying herbal insecticide and lime sulfur underneath the leaves.
White flies: Are minute winged insects. Control involves spraying with Malathion and Lime sulfur. Herbal pesticide will also drive away the insect pest.
Nematodes: They cause damage to papaya roots. Planting marigold or spreading organic fertilizer will greatly help suppress nematode infestation.

Damping-off: This infects both the seedlings and the mature plants. Cultivating the soil to aerate with good drainage will reduce this fungal disease. It is also important to allow sunlight to penetrate the soil surface to dry-off the fungus.
Anthracnose: They infect the fruits during ripening. They appear as circular spots on the fruit. Spraying herbal fungicides at weekly interval before harvest is an effective control. Hot water treatment similar to mango (dip in 45*C for 20 minutes or 52*C for 10 minutes. 58*C for 30 seconds) reduce or eliminate decay.
Papaya ring-spot virus: It initially appears as oil streaks on stem and petioles and as it progresses, mottling of leaves become evident. Severely infected plants do not flower or they die young. To control, plant is isolated, removed and burned. Also use tolerant varieties.
Ants: They're small to large in size, yellow, red brown or black in colour, winged or wingless and live in colonies. Controlled by regular hand weeding and cultivation at the base of the plant to disturb foraging ants and nests. Maintain a weed free area at the base of each plant, the diameter of which is the same as the plant canopy.
Mealybugs: Are flattened oval insects (1-4 mm long). They can transmit a viral disease known as leaf drop. Control the presence of ants that spread mealy bugs and other minute insects. Spray herbal pesticide.
Aphids: These are tiny lice-like insects with colour ranging from pink yellow, brown to black. They can transmit a viral disease known as rosette. Control is by spraying weekly with Lime sulfur 1 tbs. per gallon water.
Phytophthora: This is the rotting of the roots, fruit and stem. Can also include seedling damping-off, root rot, trunk cankers and fruit rots. Prevention is by removal of infected plants and fruits from the field and dispose them properly by burying or burning.
Viral diseases

- Rosetting – Shortening of the internodes.
- Chlorosis – Weakening of the green color of the leaves.
- Yellowing – Chlorosis and dominance of yellow color of the leaves.
- Mosaic – Pale green, yellow or chlorotic areas sharply bordered by small vines of the leaves that are often angular in appearance.
- Mottle – Discoloured areas of various round shapes, often diffusely bordered.
- Leaf spots – Single or concentric rings of chlorotic or necrotic areas to large irregular patches of the leaves.
- Vein clearing – Vein appearances of the leaves are translucent rather than chlorotic or yellow.
- Papaya leaf curl – Crinkling and curving of leaves with margins rolled down and inward.

Prevention

- Control all insects that are virus carriers like aphids, white fly, leafhopper, mealy bug, thrips and mites or insects that produce viral disease.
- Use herbal insecticides for control of the virus carriers.

- Remove weeds and other plants which are virus alternate host.
- Rouge and bury or burn infected plants to destroy the virus source.
- Disinfect all tools and equipment being used to cut any part of the plant after each use in every plant. Use 3% formalin / aniline solution.
- Spray Lime sulfur one a week for 4 consecutive weeks and once a month thereafter.

Harvest and post-harvest handling

The appearance of yellow colour traces on the green fruit is an indication of maturity and ready for harvest. The papaya fruit is harvested when 25% or ¼ of the fruit is ripen. Pawpaws are harvested manually depending on the size and age of the tree, using specialized tools, knives or by hand. When harvesting, one should hold the fruit, twist until it snaps or cut peduncle with a shape knife. The fruit should never be dropped to the ground. Fruits should be delivered to the packinghouse of cannery 2-4 hours from harvest. Heavily bruised, damaged, diseased, over-ripe, or old fruits are rejects. Harvesting schedule should be at least twice a week, this is to minimize incidences of over ripe fruits. After harvesting, the fruits are treated by dipping them in hot water (45 ^{0}C for 20 minutes, 52 ^{0}C for 10 minutes or 58 ^{0}C for 1 minute). The fruits are then air dried and wrapped in clean paper and then placed in wooden or hard plastic fruit crates. Harvested fruits should never be exposed to direct sunlight.

Fruit storage and ripening

Recommended storage temperature for pawpaw is 10 ° C. Ripe pawpaw should be refrigerated to slow down the ripening process. Place ripe, whole fruit in a plastic bag in the refrigerator, and it should last about a week (About, 2002). The fruit ripening is probably regulated by naturally produced ethylene similar to apple, tomato and banana. Furthermore, storage at 4 ° C for 4 weeks or more seems to delay ripening until removal to room temperature. Among those treatments designed to accelerate the ripening process of fruit, the treatments commonly used include exposure to ethylene, acetylene ethephon (2-chloroethylphosphonic acid).

Utilization

This includes the economic and social impact of the Pawpaw crop:

- Toothache relief - the inner bark is used for this in Samoa.
- Amebicide - latex and seeds used in Central America to kill *Entamoeba histolytica* which causes dysentery and liver abceses.
- Cosmetics: Pawpaw fruit pulp is the basic component of many facial creams, salves, and shampoos. Pawpaw is beneficial for skin care and repair since it contains vitamin A which accelerates the formation of new cells, it also contains vitamin C which is an anti-oxidant, and builds capillary strength, improved smoothness, softness, and resiliency. Pawpaw reduces the signs of premature aging and eliminates dead skin cells. Pawpaw tea

and fruit contains an enzyme that dissolves surface cell debris making it a great facial peel. Beta-carotene, protects the skin and provides elasticity.

- Papain - is one of two proteolytic enzymes (the other is chymopapain) found in pawpaw latex. Papain is used during surgical procedures to dissolve ruptured spinal discs; it is referred to as "nature's scalpel" because it preferentially degrades dead tissue.
- Latex is extracted on a commercial scale in East Africa and Sri Lanka. The green fruit are "tapped" by making incisions on the fruit surface in the morning, and catching the latex in a container hanging beneath. The latex is dried, ground into powder, and packed in tin containers
- Papain is also one of popular meat tenderizer. Green pawpaw can be rubbed onto a piece of meat, cooked with it, crushed leaves can be wrapped around meat, or a commercial tenderizer preparation sprinkled on the surface. Beef cattle are sometimes injected with papain a half an hour before slaughter to tenderize them.
- Processing into food stuffs: Pawpaw pulp is perfectly suited for conversion to juices or to be had by itself or with cream as a superb dessert. It can also be used in puddings, bakery fillings, and fruit meals for children, flavours for food industry, and also to make the delicious ice cream and yoghurt. Ripe pawpaw may be frozen whole or peeled, sliced and packed in sugar (1 part sugar to 10 parts pawpaw by weight) and quick-frozen in moisture-proof containers.

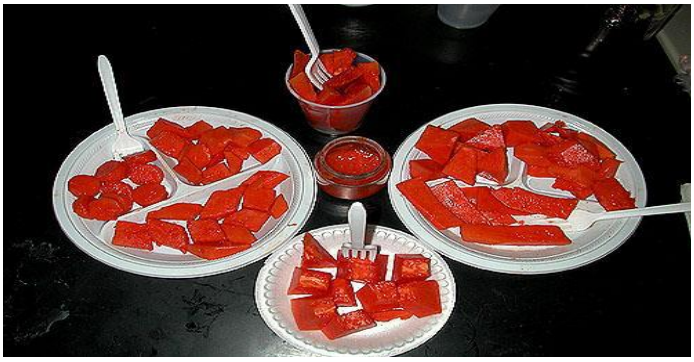


Figure 1: Pudding from pawpaw

4.0 PRODUCTION AND UTILIZATION OF KEY FODDER TREES

Introduction

Fodder legumes have a number of advantages; they are readily available on the farm and can be used for other purposes; being perennial plants, fodder trees are not susceptible to sudden climatic changes and continue to produce high quality fodder even during droughts when grasses and other annual forages are dry and long gone (Paudel and Tiwari, 1992). Moreover, their fast growth enables them to produce large quantities of biomass, which can be used not only for animal feeding but also as mulch in cropping systems. They are also used to control soil erosion (Sibanda 1993). When intercropped with food crops, fodder legumes do not compete with food crops for nutrients as their deep root system enables them to tap nutrients from the deeper soil layers, which are generally not available for shallow rooted food crops. They also improve soil fertility by fixing atmospheric nitrogen and have other symbiotic relationships, which enhances uptake of minerals such as phosphorus by plants (Topps, 1992). In the dry season, fodder trees also provide shade to animals and protect them from the hot and dry weather conditions. They are also used as a source of firewood, provide timber for construction and fencing, and function as a hedge around the fields. A number of these trees bare fruits, which are used as a source of food for humans. Others have pharmacological properties and have been used to treat a number of ailments at village level.

However, care should be practiced in feeding livestock with fodder. The main limitation to effective utilization of fodder legumes as feed for ruminants is the high content of tannins and other anti-nutrients such as saponins, cyanogens, mimosine, coumarins, etc which limit nutrient utilization (Makkar,1993). These compounds are also known to have other detrimental effects, which may range from reduced animal performance to neurological effects and increased animal mortality rates. The toxic effects of these compounds depend on their concentration in a fodder species and level of intake of the fodder. The most widely occurring anti-nutrient in plants is a group of polyphenolic compounds commonly called as tannins. Tannins limit animal performance by suppressing intake and digestibility of forages (Meissner and Paulsmeier 1995). They bind feed proteins and enzymes to form feed protein-tannin complexes, which are resistant to both rumen microbial and enzymatic degradation. They also lower enzyme activity (Aufrere et al 1995). These compounds also enhance the loss of endogenous proteins, which affect overall nitrogen metabolism in the animal. It may also be noted that at lower levels (2-4%) of tannins, these could have beneficial effects on ruminant animals ~ suppress bloat in ruminants and reduce excess degradation of high quality protein in the rumen. This helps in increasing the amount of rumen undegradable protein, which is finally made available to the host animal for supplying essential amino acids. However, iIt must be emphasised that the purpose of pointing out the potential toxic effects of these compounds is to be aware of their presence rather than to discourage the use of fodder legumes by ruminant animals. These compounds will be diluted in the main feed and will rarely exhibit their toxic effects since fodder legumes are generally not

used as a sole feed for ruminant animals. It is also important to note that a number of ruminant animals, particularly sheep and goats have capability to adapt slowly to most anti-nutrients.

In order to minimise the detrimental effects of tannins and phenolic compounds in fodder legumes, several suggestions have been put forward, some of which can be applied in the traditional smallholder areas. Among these are the post-harvest processing techniques such as sun-drying and wilting of forages before they are fed to animals. Conservation of fodder into bags or ensiling them in silo pits with other feed resources has also proved beneficial in minimising the detrimental effects of tree fodder legumes. Another approach for enhancing the use of fodder legumes is through mixing of fodder with other feed resources such as crop residues. This helps to dilute the overall concentration of tanniniferous compounds in the diets thereby minimizing their effects. The other potential way may be to harvest the legumes and feed to animals in the stall in a controlled manner.

4.1 Common Agroforestry-Fodder Production Models

According to Calub and Lasco (1999) a number of fodder production systems designed to produce sufficient foliage for livestock feeding particularly during the dry season were evaluated and a lot of research is still being conducted with several others being refined. These production systems include various types of agroforestry-silvopastoral systems, where trees, animals and pastures are deliberately combined to obtain benefits and services. The integration of these components can vary both in time and in space. Some of the common models are as follows:

Fodder bank systems

Trees are planted as close as 1m x 1m and are cut regularly to induce maximum herbage production. The cut herbage is usually carried to animal feeding stalls, sometimes sheep or goats are brought to the plots and allowed to forage on the cut branches of naturally-growing fodder. The system is called fodder bank, which provides reserve fodder when it is in short supply, usually in the dry season.

Protein bank

This is a type of fodder bank which intentionally chooses trees, shrubs legumes with high protein-containing leaf biomass. Commonly used species include *Leucaena leucocephala*, *Gliricidia sepium*,

Three-strata forage system

This is another type of fodder bank; it involves the planting of forages, shrubs and trees to form three canopy layers or strata in a unit of land. Pasture grasses, vines and herbs occupy the lower strata; shrubs occupy the middle strata and trees occupy the upper strata. The combination of grasses and trees can ensure year-round supply of fodder.

Live fence or boundary systems

Single or double rows of fodder trees are planted along farm boundaries. The trees have the dual purpose of providing fodder and serving as live fence posts. If intended to enclose animals, the trees are usually planted densely, as in hedges, to prevent animals from getting out. In some parts of Africa, thorny species are planted as thick hedges to prevent livestock from straying into crop plots and also to fence them off from wild animals.

Hedgerow intercropping systems

Fodder trees, mostly leguminous are planted as hedges in single, double or triple rows. The spaces in between hedgerows are planted with pasture grasses. As in fodder banks, herbage may be cut and carried to animal feeding stalls. The more common practice is to let the animals forage on the cut tree branches and pasture grasses.

Tree plantation and animal grazing systems

The understory of tree plantations is utilized as grazing area for cattle, sheep and goats. The plantation may be of forest trees, fruit trees, coconuts, oil palms or rubber. The livestock are allowed to graze freely on improved pasture grasses planted under trees

Indigenous cut-and-carry systems

As the name implies, the fodder is cut and carried to animal stalls. Farmers have long been practicing this system. Indigenous legumes such as *Ficus*, Acacia, *Leucaena*, *Gliricidia and Albizia* are the most preferred fodder tree species.

4.2 Trees suitable for fodder

Not all types of trees and shrubs can be used for fodder production. When farmers select trees for fodder production they should look for several characteristics: Leaves and pods should have a high nutritive value, which means that they contain a lot of protein. Trees should produce many leaves and regrow easily after frequent pruning. Edible parts of the tree should not contain (too much) toxins. Tree leaves need to have a high palatability, which means that the animals like to eat them and can digest them well. Trees must preferably be tolerant to drought, pests and diseases. Trees should not compete too much with other crops. For example, good fodder trees should form deep roots in order to avoid competition with shallow rooted crops for water.

4.3 Harvesting techniques of fodder trees

The following techniques can be used when harvesting leaves from the fodder trees:

1. Pruning and lopping: These are methods in which the side branches of a tree are cut. Pruning is different from lopping in that the branches are cut from the base. Lopping is not always done starting from the lower part, but can be done more haphazardly.

2. Pollarding: If all branches and the crown of a tree are cut off but the whole stem is left (about 2 meter), this is known as pollarding.
3. Coppicing: Many species of trees and shrubs have the ability to resprout after the whole tree has been cut. If this ability is used for regeneration of the tree the practice is known as coppicing.

4.4 Pruning regimes of fodder trees

First pruning is carried out when the thickness (diameter) of the stem at 50 cm above the ground level is 8-10 cm. The altitude, soil fertility, rainfall and the type of tree determine how fast the tree grows and thus the period in which the stem reaches the required thickness .For fast growing trees the required diameter will in general be reached within one year.

After the first pruning, the following prunings or loppings should not be done too regular, otherwise the yields per pruning and the life span of the tree will be reduced. The farmer should experiment to experience how a tree copes with a certain pruning frequency. The intervals may be longer or shorter depending on the climate, rainfall, soil fertility and altitude. In general, avoid cutting trees too often or at a low height at the beginning, during and immediately after the wet season. Too much pruning of trees during these periods exposes them to a high chance of disease attack. It is wise to let the trees grow and save the leaves for the dry season.

In dry areas, it is useful to allow the stem to reach more than 10 cm in diameter before pruning or allowing browsing by livestock. The main root is then supposed to have grown deep enough to reach the lower water table, thus allowing the tree to get enough water during the dry season. There-after, pruning should not exceed 2-3 cuts per year to be sure that the strength of the tree is not lost. In areas with long dry seasons, water shortage can lead to the loss of fodder material, unless cutting times are chosen wisely. If the aim is to maximize the yield of fodder at the height of the dry season, experiments have shown that the final wet season cut should be made six months earlier. Pruning tools: Secateurs or pruning clippers is the recommended tool for pruning or lopping the trees. Much damage can be done because of bad pruning techniques such as pruning with a machete. When the branches are cut at the base with a sharp machete, a large gash is left. This causes a ‘dieback’ and has a negative effect on the regrowth of the tree. If the farmer has only a machete for pruning, the cut should be upward (from the underside up) not downward.

Pruning regime of Calliandra

The first pruning after planting is done at about 12 months. Then it can be cut 3-5 times a year down to a height of about 80-100 cm. Cutting can be done more frequently during the rains. Calliandra growth slows considerably when it is cold, so it is best to leave more time between prunings at this time. Calliandra coppices well and it is recommended cutting the tree right back to 30 cm after 3-4 years, allowing it to shoot. Cutting Calliandra six months before the dry season gives maximum yield during that season. The trees have a life span of about 10-20 years.

Pruning regime of Gliricidia

Early seedling growth is slow but once established, growth is fast (up to 3 meter per year). The first pruning after planting is done at about 9 months. The tree tolerates lopping, coppicing and regular browsing well. Gliricidia can be pruned 3-4 times per year at a height of 30-150 cm. Pruning will stimulate leaf production.

Pruning regime of Leucaena

It should be cut 75-100 cm above the ground every 2-4 months after the first pruning (9 months after planting). Leucaena is a vigorous coppicer and responds well to pollarding. Coppiced stems sprout 5-15 branches, depending on the diameter of the cut surface, and 1-4 stems dominate after a year of regrowth. Leucaena can produce well for 10 to 20 years or even up to 35 years.

Pruning regime of Sesbania

The first pruning after planting is done at about 12 months. Then pruning 3-5 times per year at a height of 50-100 cm above the ground is recommended. Coppicing below 50 cm will reduce yields, strength and life span of the trees. *Sesbania sesban* has a short life span. It may start dying even after two years from time of establishment. Varieties as *Sesbania grandiflora*, may live for more than 20 years. This variety however, may not do well in highlands.

4.5 Feeding of fodder-trees to the animals

The part of the trees fed to livestock is usually leaves, but pods, seeds and small twigs may also be fed. In general, the animals like fodder tree leaves, though they may have to get used to some species.

Browsing or 'cut-and-carry': Fodder tree leaves can be browsed or 'cut-and carried' to stall-fed (zero-grazed) animals. Browsing is possible but it should be done in a rotational manner. This means that the trees are browsed for a couple of days and left for six or more weeks to recover. Overgrazing should be avoided otherwise fodder trees will die. The cut-and-carry system is recommended even though it involves a lot of work. For most tree species, the fodder leaves should be fed to the animals within an hour of harvesting. Pruning, coppicing and pollarding is common in the sub-humid zones. In the medium and dry zone browsing is much more common.

Mixture of napier-grass and fodder trees: Napier-grass can be fed as much as the animal can eat. In addition to napier-grass, fresh fodder tree leaves can be fed in limited quantities.

When to feed fodder trees: If there is plenty of fodder trees available at the farm the leaves can be fed to the animal throughout the year in limited quantities. If there are a limited number of trees, it is recommended to feed a dairy cow, dairy goat and sheep the month before and the

month after giving birth. Oxen should be fed one or two months before and during the period of land preparation.

Example of a fodder tree diet for dairy cows: To the napier-grass diet of a crossbred dairy cow 8 kg of fresh fodder tree leaves can be added. This mixture provides for body maintenance and production of 10 liter of milk or more, depending on the type (genetic potential) of the cow and the quality of napier-grass. If 2½ kg maize germ is added to this mixture, on a daily basis, it will maximize the benefit from the use of fodder tree leaves. When this ration is fed to the crossbred cow in its early lactation, it might produce about 15 litre of milk per day (depending on genotype and management conditions).

Calliandra: It's digestibility declines quickly once it is cut and should therefore be fed to the animals within an hour of harvesting. It improves the quality of milk; it becomes more concentrated and increases the butterfat content, producing a thick cream layer at the top after boiling. They also said that their cows preferred the foliage over protein concentrates because of its palatability (taste).

Gliricidia: Farmers sometimes complain that animals do not like Gliricidia leaves. This is because of the strong odor, which occurs when the leaves are crushed. Wilting or drying for 24 hours between cutting and feeding appears to reduce the odor of the leaves. It has been reported that animals, which first refused Gliricidia became used to it in a few days, after which it was readily consumed.

Leucaena: Cows with a high Leucaena diet may produce tainted milk. This can be avoided by keeping them away from the leaves for two hours before milking. Pasteurization also removes the taint.

Sesbania: The leaves and tender branches of Sesbania have a high digestibility. The species may become a weed and sometimes attracts soil nematodes, which also attack other crops.

Maximum quantities of fodder to be fed:

For all animals, the advice is to feed small quantities and increase the amount fed over time to quantities recommended as mentioned below:

Calliandra: There is no side effect known of using Calliandra in low quantities. It contains however tannin, which can reduce digestibility. To avoid this, leaves should be fed immediately after cutting. Feed a maximum of 3-4 kg for heifers and 8-9 kg for dairy cows per day. Sheep and goats can eat a mixture containing fodder tree leaves up to 50% of their ration.

Gliricidia: It is normally recommended, when feeding cattle, goats and sheep, to use fresh Gliricidia leaves at levels of 10-30% of the ration weight, with either grass or other roughages.

Leucaena: This tree contains a toxin called 'mimosine', which is harmful when consumed in large quantities. Overfeeding with leaves, young twigs and pods may lead to hair loss, low weight gains, low birth weight and infertility. Quantities to be fed to the animals are recommended as follows: sheep and goats 30-50% and cattle 10-30% of the total amount of feed consumed daily.

Sesbania: This fodder tree is only harmful when fed to livestock in excess. It contains 'saponin', a poison, which when consumed in excess, may cause bloat. To avoid the adverse effect of overfeeding with Sesbania, the amount included in the diet should not exceed 30% of the total daily amount of feed consumed by the animal.

4.6 Production and utilization of Calliandra calothyrsus

Introduction

The tree can only be used by farmers in the humid and sub-humid zone with a minimum annual rainfall of 700 mm. It grows well on a wide range of soil types but prefers light textured, slightly acidic soils. It can tolerate infertile and compacted or poorly aerated soils but does not tolerate waterlogged and alkaline soils. *Calliandra* is affected by a few pests only but is often attacked by ants. The seed pretreatment procedure is to immerse in hot water, allow cooling and soaking for 12-24 hours.

Propagation

Seeds are planted in nurseries, either bare-rooted or in polythene pots, and then transplanted on farm three months later at the onset of the rains. Others plant seed directly in their fields. An evaluation of bare-rooted Calliandra seedlings in western Kenya reported 34% higher survival rates than direct seeding but the cost per surviving seedling was 24% higher, due to nursery labor costs (Swinkels 1994). Bare-rooted seedlings cost less to produce than potted seedlings but are more susceptible to drought after transplanting. The choice among alternative techniques depends on the species involved, the available resources and farmers' skills.

Yield

Calliandra yields 1.5 kg dry matter per tree per year on farms in central Kenya, grown in hedges pruned at 0.6 m to 1 m height, five times per year. In Zimbabwe, where many farmers plant in pure stands, calliandra yields range from 2.5 to 5.6 tons/ ha/year.

A farmer in East Africa needs about 500 calliandra trees to feed a dairy cow throughout the year at a rate of 2 kg dry matter per day. One kilogram of dried calliandra (24% crude protein and

digestibility of 60% when fed fresh) has about the same amount of digestible protein as 1 kg of dairy meal (16% crude protein and 80% digestibility). depending mainly on the amount of tree fodder fed; higher use led to higher returns [26].

Planting and management

Calliandra can be planted between upper-storey shrubs on farm boundaries, in hedges around homesteads, on contour bunds, and in lines between Napier grass. Seedlings are transplanted from the nursery (when they are 0.2m to 0.3m in height) and planted at a spacing of about 0.5m by 0.5m to 0.75m by 0.75m. More dense spacing of 0.3m between plants can be used in high potential areas. Use manure and water the seedlings adequately. Calliandra trees are cut back at a height of 2m to between 0.5m and 1m to improve foliage which is used as fodder for livestock.

Pests and disease control

Calliandra is fairly resistant to pests and diseases. However, some fungal pathogens like *Armillaria mellea* can cause root rot in cool and high altitude areas. Affected plants should be uprooted and burnt.

Harvesting

Fodder is ready for harvesting in about 9 – 12 months after planting depending on the region. It is possible to have 4 to 6 harvests per year. Use a *panga* or secateurs (pruning scissors). Letting animals eat the leaves or young branches directly is not recommended as they may destroy the plants. Leaves and young branches should be cut when they are about 3 feet. After about 12 years, you should replace the plants with new ones. One disadvantage of this shrub is that it does not produce large amount of seeds. Farmers who wish to collect seeds should do so very carefully since the seeds are naturally dispersed far away from the tree as the pods split suddenly.

Feeding animals

One kilogramme of dry calliandra has the same amount of digestible protein as about 1 kg of dairy meal. On a fresh weight basis, 3 kg of calliandra is equivalent to about 1 kg of dairy meal and the effects of calliandra and dairy meal have been found to be supplementary, suggesting that the two feeds are nutritionally interchangeable. A farmer would need about 500 shrubs to feed a dairy cow throughout the year at a rate of 2 kg dry matter (6 kg fresh material) a day. Because it has high levels of tannin (a bitter substance), calliandra should only be fed to ruminants like cows, goats and sheep. It is therefore not easily digested by non-ruminants like pigs, rabbits and chickens.

Other uses

Apart from feeding dairy animals, calliandra is useful in improving the soil nutrient levels and is useful for the reforestation of bare areas that are prone to soil erosion. Calliandra wood is also

good for fuel as it grows quickly, burns well and can be used to produce charcoal. The poles can also be used in supporting climbing beans. In addition, the leaves can be used for mulching and as green manure for other crops since it adds nitrogen to the soil. Its flowers provide nectar for bees, and the honey produced is said to be of good quality.

4.7 Production and utilization of Leucaena leucocephala

Introduction

This tree is found from lowlands up to 2100 meter. *Leucaena leucocephala* is one of the most widely used species in alley cropping, where it is planted in hedges along contours at intervals of 3–10 m with crops in between. It is planted in an agroforestry system with sorghum. Sorghum yields can be high even in poor rainfall conditions. It requires an annual rainfall of 650-1500 mm, but can be found in drier and wetter regions. The species is not suited to acid soils or to waterlogged conditions. *Leucaena leucocephala* is a popular fodder species but it is sometimes attacked by a pest called 'Leucaena psyllid' (*Heteropsylla cubana*). Other species like *Leucaena diversifolia*, *Leucaena esculenta* and *Leucaena pallida* show some degree of tolerance for this pest. Seed pretreatment involves soaking in hot water for 2 minutes. Leucaena grows well in areas where rainfall is between 1 200 and 2 000 mm. It does not like soils that retain too much water, so it grows best in well drained soils that are preferably alkaline. It does not like acid soils. Areas with about 1 500 mm of rain, four months of dry season and alkaline soils are the best for growing Leucaena. Leucaena as a legume is able to transform the nitrogen gas existing in the air into nitrogen compounds that can be used by the plant itself; therefore it grows well without fertilization in soils that are poor in nitrogen. This change of nitrogen gas to nitrogen compounds is known as nitrogen fixation; it is done by bacteria called rhizobia that live on the roots of Leucaena.

Propagation

Leucaena seeds are very hard, so they must be treated before planting. Boil water: pour it on the Leucaena seeds, using three times the amount of water to the amount of seeds, and stir the seeds for about five minutes: then pour the hot water away, and add cold water to cool down the seeds. Drain out the cold water and plant the seeds immediately. If you cannot plant immediately, dry the seeds and store them for later planting. When you plant Leucaena for the first time in your field, the rhizobia may not be present, so you have to inoculate the seeds with the rhizobia. To do this, you rub the rhizobia on the seeds so that when they germinate, the rhizobia on the roots can then fix nitrogen.

4.8 Production and utilization of Sesbania sesban

Introduction

This tree tolerates waterlogged and poor soils. It has been successfully grown in arid areas with only 500 mm annual rainfall, but it prefers a rainfall up to 2000 mm. Yields are lower when the soil is more acid. *Sesbania sesban* and *S. grandiflora* have a high nutritive value but they do not withstand intensive cutting. Because both species produce a lot of seeds and are easily established by direct seeding of untreated seeds, resowing after harvesting might be better than allowing it to regrow. In this regard they could be sown on fallow land, to improve soil fertility.

5.0 PRODUCTION AND UTILIZATION OF KEY BIOENERGY TREES

5.1 Production and Utilization of Grevillea robusta

Description

Grevillea robusta is a semi-deciduous exotic tree species attaining a height of 20 m or more with a straight trunk, angular branches and oval leafy crown. The bark is dark grey, rough and vertically grooved. The leaves are generally long, pale green on upper side and silver grey on the underside. The fruits are dark brown capsule about 1 cm, with a slender beak.

Propagation methods

Grevillea is propagated through seed, wildlings and cuttings. However, Grevillea seed is difficult to collect as it is easily dispersed by wind. No pretreatment of seed is required. There are averagely 83,000 seeds/kg.

Establishment and management

The tree grows well on neutral to acidic loam or light sandy soils but does not tolerate waterlogging or heavy clays. The species does well at an altitude of 200 to 2000 m.a.s.l. and a mean annual rainfall of 500 to 1700 mm. In Coast region, 18,648 ha is classified as area of high capability. The tree is preferred for boundary planting at single or double line (s) spacing of 5.0 x 5.0 m. Pollarding, lopping and pruning should be carried out repeatedly during early growth to yield straight bole and to regulate shading and competition with adjacent crops.

Production and utilization

It is estimated that one mature tree at rotation age of 15 to 20 years can produce timber and fuelwood worth Ksh. 25,000. Grevillea is used for timber, plywood, paneling, fuelwood, charcoal, furniture and fencing. It is also used as bee forage, ornamental, shelterbelts, shade trees, mulch and for soil conservation.

5.2 Production and Utilization of Cupressus lusitanica

Description

Cupressus lusitanica is an evergreen exotic tree species attaining a height of 35 m with a straight trunk, generally conical but irregular in shape with branches that hang down. The bark is red-brown with vertical grooves, grey with age. Leaves are dull blue-green, scale -like with pointed tips and 2 to5 mm long.

Growth conditions

Cupressus lusitanica grows best at an altitude of 1000 to 4000 m.a.s.l. with average rainfall of 1000 to 2500 mm per annum. It flourishes in deep, moist, well drained, fertile loam soil with neutral to slightly acidic pH.

Propagation methods

The tree is propagated from seed and grafting. There are 215,000 seeds/kg and pre-sowing treatment is not necessary.

Establishment and Management

Cypress is a fast growing tree. The recommended spacing is 3.0 x 3.0 m. Weeding is absolutely necessary during the first year for good establishment. Pruning is done in years 3, 6, 9 and 13 after establishment. Thinning is necessary. It produces poles after 10 years and general purpose timber after 20 years. The species is not good for inter-cropping.

Production and utilization

At rotation age of 20 years, a standing tree is estimated to be worth Ksh. 6,000. Conversion into timber would fetch Ksh. 30,000 at farm gate. The main use of the tree is timber production. Other uses include; veneer, pulp and paper, poles, posts, fuelwood, wind breaks and live fence.

MANGO SEEDLINGS DISTRIBUTED AND PLANTED IN SIAYA AND BUSIA COUNTIES

Table 1: List of farmers who received mango seedlings

NO	DATE	FARMER'S NAME	AREA PLANTED	MANGO VARIETY	Number of seedlings
1.	October 2017	Hendrick Anyango	Samia	Apple Mango	62
2.	October 2017	Washington Ndanyi	Samia	Apple Mango	124
3.	October 2017	Bernard Abwoga	Samia	Apple Mango	124
4.	October 2017	Shadrack Mukhula	Samia	Apple Mango	62
5.	October 2017	Vincent Awori	Samia	Apple Mango	17
7.	October 2017	Ankanory Mudenyo	Samia	Apple Mango	124
8.	October 2017	Christine Nekesa	Samia	Apple Mango	62
9.	October 2017	Jane Rose Narocho	Samia	Apple Mango	124
10.	October 2017	Mellen Ombongo	Samia	Apple Mango	62
11.	October 2017	Mary Achoka	Samia	Apple Mango	18
12.	October 2017	Patroba Manyuru	Samia	Apple Mango	22
13.	October 2017	Michael Ogana	Samia	Apple Mango	32
14.	October 2017	Hellen Obonyo	Samia	Apple Mango	22
15.	October 2017	Rosemary Obonyo	Sio port	Apple Mango	46
16.	October 2017	Edmond Osalo	Port Victoria	Apple Mango	62
17.	October 2017	Moses Omia	Sio Port	Apple Mango	28
18.	October 2017	Chrispinus Egesa	Sio Port	Apple Mango	62
19.	October 2017	Fransisca Oguba	Sio Port	Apple Mango	70
21.	October 2017	Peter Khadies	Sio Port	Apple Mango	62
22.	October 2017	Celestine Lwande	Bukiri	Apple Mango	62
23.	October 2017	Fredrick Juma	Busembe/Sio Port	Apple Mango	62
24.	October 2017	Fredrick Onyango	Busijo/Sio Port	Apple Mango	42
25.	October 2017	Musa Mohammed	Sio Port	Apple Mango	62
26.	October 2017	Mark Oganyo	ATC Siaya	Ngowe/Apple	200
27.	October 2017	Henry Odhiambo	ATC Busia	Ngowe/Apple	400
28.	October 2017	Catherine Mumo	Sio Port	Ngowe/Apple	140

CONCLUSION AND RECOMMENDATIONS

Fruit, fodder and bioenergy trees contribute to local household food and livelihood security. In Kenya, edible fruits and nuts from woodlands and forests contribute economic value to the forest though subsistence consumption and at times for sale. Fodder trees and shrub legumes play an important role as alternative feed during dry spells. Bioenergy trees provide readily available wood biomass and other forest products reducing forest degradation. Fruit, fodder and bioenergy trees come in handy in marginal areas where chances of total crop failure are high. There is a need to build capacity of local farmers on value chain of the key trees.

REFERENCES

About.com. 2002. homecooking. www.about.com/library/weekly.

Akinnifesi, F.K., Leakey, R.R.B., Ajayi, O.C., Sileshi, G., Tchoundjeu, Z., Matakala, P., Kwesiga, F.R. (2008) *Indigenous fruit trees in the tropics:domestication, utilization and commercialization*, CAB International, Wallingford, UK, in association with the World Agro-forestry Centre, Nairobi, Kenya.

Archbold, D.D., 2001. Grant 2001-35503-10775. University of Kentucky. Department of Horticulture. California Rare Fruit Growers, Inc. (CRFG)., 1998.Fruit Facts, Volume 1.

Aufrere,J.,Guerin,H.,Molenat,G.,Chenost,M.Hubert,D.,Gouy,J.,Critical review of chemical and enzymatic methods for the estimation of nutritive value in roughages. Proceedings of the satellite symposiums of the IV international symposium on the nutrition of herbivores, Montpellier, France,(1995).

Brufau, G. et al. (2008) Phytosterols: physiologic and metabolic aspects related to cholesterol-lowering properties. Nutrition Research, v.28, p.217-225.

Hofshi, R. 1999. High Density Avocado Planting - An Argument for Replanting Trees. Subtropical Fruit News 7(1): 9-13.

Keatinge, J.D.H., Waliyar, F., Jamnadass, R.H., Moustafa, A., Andrade, M., Drechsel, P., Hughes, J.A., Kadirvel, P., Luther, K. (2010) Relearning old lessons for the future of food – by bread alone no longer: diversifying diets with fruit and vegetables, *Crop Science*, vol 50, pp.S51–S62.

Le Houe´rou HN (1980): Browse in Africa, the Current State of Knowledge. ILCA;

Makkar,H.P.S.,"Antinutritional factors in food for livestock, Animal Production In developing Countries",(M.GILL,E.OWEN,G.E.POLLOTT,T.L.JLAWRENCE,Eds.)BritishSocietyofAnimal Production"OccasionalPublications No.16,(1993)69-85.7 5

Medinilla, A., 2000. El cultivo de la pawpaw maradol. Plantaciones Modernas. 5:2, 5-34.

Medlicott, A. P., Diaye, M. N. and Sigrist, J. M. M., 1990. Harvest maturity and concentration and exposure time to acetylene influence initiation of ripening in mangos. J. Amer. Soc. Hort. Sci. 115 (3): 426-428.

Meissner,H.H.,Paulsmeier,D.V.,Plant compositional constituents affecting between-plant and animal species prediction of forage intake,J.Anim.ScL,73(1995) 2447-2457.

Morton, J. F., 1987. Pawpaw. In: Fruits of warm climates. Miami, FL. p. 336–346. University of Cornell., 2000. Hort 400. Plant Propagation. Department of Floriculture & Ornamental Horticulture.

Nair PK. (1993) An Introduction to Agroforestry. Netherlands: Kluwer Academic Publishers; Sinclair FL. A general classification of agroforestry practice. Agroforestry Syst 1999;49:161-80
Nakasone, H.Y and R.E Paul 1998. Tropical fruits CAB International, Wallingford, UK, Pages 101

Ofosu –Budu 2003. Performance of citrus root stalks in the Forest zone of Ghana. Ghana J Hort, 3: 1-9

Paudel, K. C.,Tiwari, B.N., (1992)"Fodder and forage production", Sustainable livestock production in the mountain agro-ecosystem of Nepal,(J.B.ABINGTON Ed.),FAO Animal Production and Health PaperNo.105,Rome,Italy, 131 —154.

Ruel, M.T., Minot, N., Smith, L. (2005) *Patterns and determinants of fruit and vegetable consumption in sub-Saharan Africa: a multi-country comparison*, IFPRI (International Food Policy Research Institute), Washington DC.

Schreckenberg, K., Awono, A., Degrande, A., Mbosso, C., Ndoye, O., Tchoundjeu, Z. (2006) Domesticating indigenous fruit trees as a contribution to poverty reduction, *Forests, Trees and Livelihoods*, vol 16, pp.35–51.

Sibanda,S.,Cattle food resources and their use in communal lands ,J . Zimbabwe Soc.Anim.Prod.5(1993)37-42.

Swinkels R (1994) Cost comparison of two establishment methods of Calliandra on farms in western Kenya. In Agroforestry in the Highlands of Eastern Africa. Summary proceedings of AFRENA workshop. Edited by Atta-Krah K. ICRAF;:87-94.

Topps,J.H.,Potential composition and use of legume shrubs and trees as fodders for livestock in the tropics,J.Agric.Sci.Camb.118(1992)1-8.

UNSCN (2010) *6th Report on the world nutrition situation: Progress in nutrition*, United Nations System–Standing Committee on Nutrition, Geneva, Switzerland, http:// www.unscn.org/files/Publications/RWNS6/report/SCN_report.pdf, accessed July 2012.

Wambugu C, Place F, Franzel S(2011): Research, development and scaling up the adoption of fodder shrub innovations in East Africa. Int J Agric Sustain, 9:100-109.

Weinberger, K., Lumpkin, T. A (2005) Horticulture for poverty alleviation – the un-funded revolution, Working Paper No. 15, AVRDC (The World Vegetable Center), Shanhua, Taiwan.

Whiley, A.W. 2002. Chapter 10 - Crop Management. Whiley, A.W., B. Schaffer and B.N Wolstenholme (eds.) The Avocado: Botany, Production, and Uses. pp. 231-258.

WHO (World Health Organization) (2002) *The World Health Report 2002: Reducing Risks, Promoting Healthy Life*, http://www.who.int/whr/2002/en/, accessed July 2012.

WHO (World Health Organization) (2003) *Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation, Geneva, 28 January– 1 February 2002*, Technical Report Series 916, WHO/FAO, http://whqlibdoc.who.int/trs/who_ trs_916.pdf, accessed July 2012.