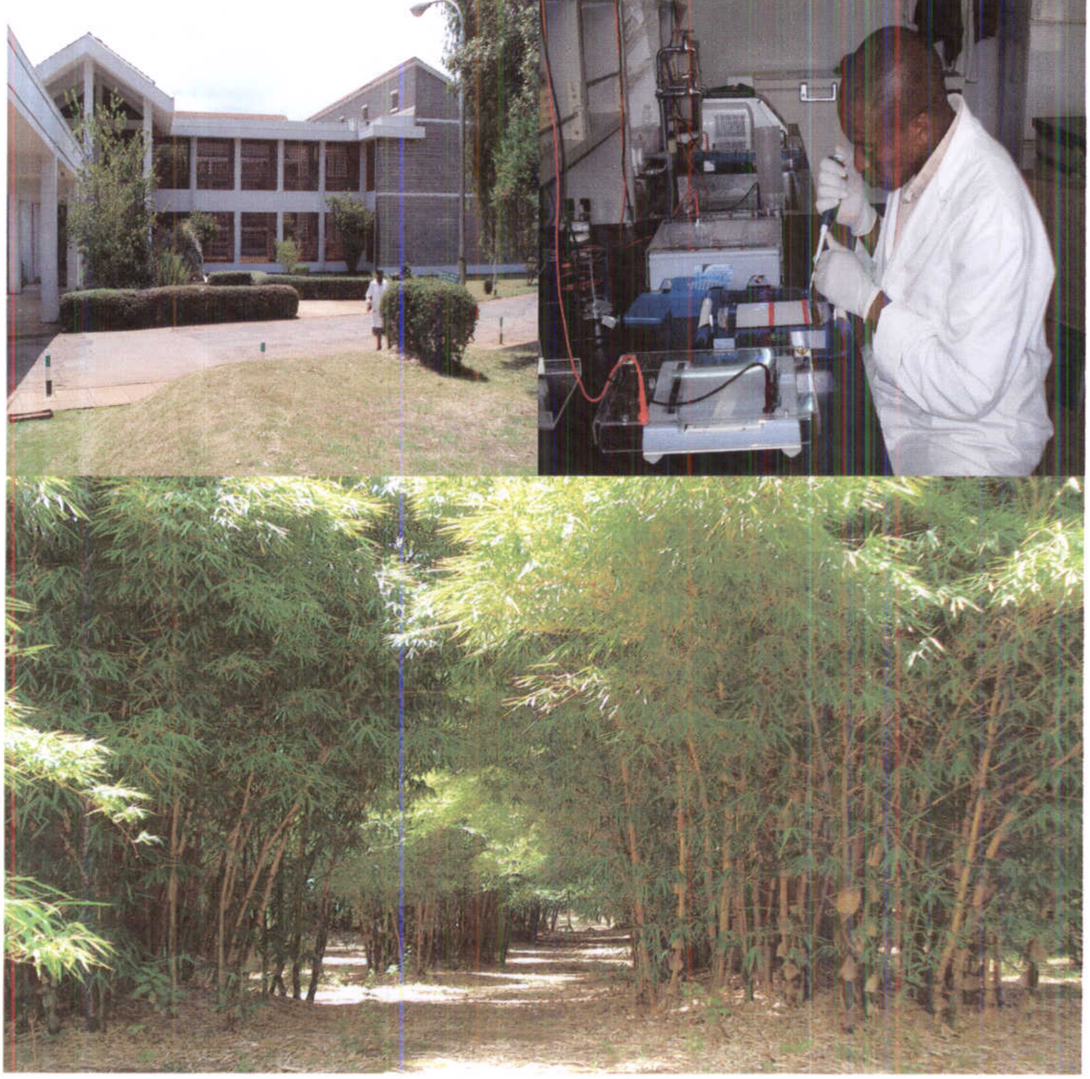
KENYA FORESTRY RESEARCH INSTITUTE



MUGUGA REGIONAL RESEARCH CENTRE

ANNUAL REPORT

JULY 2009 - JUNE 2010

PREFACE

Muguga Regional Research Centre (MRRC) is one of the 6 Research Centers of the Kenya Forestry Research Institute (KEFRI). The Centre is situated in Kikuyu Division, Kabete District, Central Province at Longitude 36° 34" East and latitude 1° 11" South. It is located about 25 km north west of Nairobi city and two kilometers off the Nairobi-Naivasha-Nakuru highway.

The centre's pivotal roles are:

- Identifying problems with users of research findings
- Planning and implementing research projects
- Providing linkages between headquarters and stakeholders
- Dissemination of research finds and technology transfer

During the year the Centre had 18 research scientists supported by 56 technical and 62 support staff making a total of 136.

The centre has mandate to undertake research and development activities in the highlands east of the Rift valley. Though based at Muguga, it has sub-centre at Nyeri. There are large number of scientists coordinated by the centre but with activities in other parts of the country. As a result this report presents both regional and other research activities accomplished from July 2009 – June 2010 within the country. The results are presented according to the achievements made by the centre under different research activities in natural forests, plantation forestry and dryland forestry.

A significant portion of the activities includes problem diagnosis, development of technologies and experimentation. A close working relationship was maintained through several community based organizations (CBOs), KFS field staff and NGO's.

We thank the Director (KEFRI) and the Government of Kenya for facilitating the centre in meeting its research obligations in the region and support to other activities nationally. Special thanks go to Mr. Bernard Kamondo for editing this report.

We encourage you to get in touch for further information especially in areas of possible collaboration and technology transfer in forestry related activities.

Finally I take this opportunity to thank all staff for their efforts during the past year. With more effort we are capable of improving the standard of research.

Ely J.M. Mwanza
Centre Director

1.0 STUDIES IN PLANTATION FORESTRY

1.1 INFESTATION OF EUCALYPTUS TREES BY *LEPTOCYBE INVASA* IN KENYA

Otieno B. O and Mutitu K.E

Introduction

Eucalypts have been grown for about one hundred years in Kenya, and the species are highly favoured for production of poles, fuelwood and timber. They grow rapidly, are easy to cultivate and adapt to a wide range of growing conditions (Turnbull, 2000). Kenya has had several pest problems including current infestation of the Eucalyptus by *Leptocybe invasa* Fisher & La Salle, sp. n (Hymenoptera: Eulophidae).

Leptocybe invasa is a small (1.5 mm) wasp that belongs to the gall-forming hymenopterans and it is know locally as Blue Gum Chalcid (BGC). Its origin is believed to be Australia, the native country of Eucalyptus species

According to Mutitu *et al*, (2007b), *L. invasa* was first recorded in Kenya in November 2002 in western region. The pest spread from the border districts of Kenya and Uganda. By May 2004, the pest had spread to districts like Busia, Vihiga, Kisumu, Nyando, Butere–Mumias, Bungoma and Teso. The pest attacks mostly the young seedlings in nursery and field saplings of up to five years old. There was need to study the BGC damage relationship with the possible associated factors altitude, agro-ecological zones, topography, host species etc. which would contribute to the development and implementation of management strategies. The objective of the study was to determine the factors responsible for infestation, damage incidence and severity patterns in Kenya for development and implementation of sustainable management strategies against *L. invasa.*

Materials and methods

This study was conducted in 20 districts of Kenya, belonging to five Regions/provinces from December 2005 to March 2010. Eucalyptus stands with less than five year-old trees were selected not only because BGC is known to severely infest young tress but also for ease of accessibility to tree crowns during damage assessment (Mendel *et al.*, 2004). Each Eucalyptus stand was divided into three blocks. In each block a plot of 20 trees was randomly established. The BGC population was estimated from the number of pest individuals found on a tree. The severity of damage induced was estimated from a whole tree canopy and was scored on a four-point scale based on the gall density.
The data was analyzed using ANOVA and correlation in General statistical package, (Genstat release 10.2). A damage index (DI) was calculated from the mean damage severity (MDS) and damage incidence (DIP) data collected per sample plot using formula modified from Hooda *et al*, (1992). Comparisons were made of the DIs and adult populations of *L. invasa* between the different altitudes, species and years and months.

Results

Population and damage was observed to vary significantly ($p<0.01$) in the different regions of the country with Western having the highest populations of adult insects as well as the damage levels. There were no flying adult insects observed in the Rift valley and Coastal regions though minor damage was observed on the trees. Significant variations ($p<0.01$) were observed in the population and damage among the various Eucalyptus germplasm planted at the coastal region. The highest damage incidence was recorded in the Hybrid variety GC 14, while the least attacked germplasm at the coast of Kenya was the GC 785 clonal variety. The Population and damage was observed to oscillate in different months of the year with an increase population of adults being followed by an increase in the damage index. The populations of the adult *L. invasa* as well as the proportion of infested trees in the samples plots have been increasing since the year 2006. The Damage index on Eucalyptus trees was observed to significantly reduce ($p<0.001$) as the altitude increased.

Discussion

Western region has been shown to have higher population of adult *L. invasa* closely followed by Nyanza. The high population translated into comparatively higher damage index than most of the other regions. This is due to the fact that initial infestation occurred was reported in Western region (Mutitu *et. al.*, 2007b) and the pest is slowly moving into the other regions either by human activity or using its highly developed flight capability to infest neighboring Eucalyptus plantations.

There was variation in damage caused to different Eucalyptus germplasm with GC14 having the highest damage index. This shows that this material is highly susceptible as it is also in the findings of Nyeko *et al.* (2010). Plots of *E. urophylla* which has been shown by Nyeko *et. al.* (2010) to be not damaged had the highest population of adults. Field observations have shown oviposition marks on *E. urophylla* indicating that the material could be attractive for ovipositioning but does not support the development of the larvae hence no galls on the plants.

Oscillations of the population and damage through out the year could indicate several overlapping generations of the insect in a year as Mendel *et. al.* (2004) also observed all development stages of the insect during the warm seasons in Israel. The highest damage occurs in April preceding highest adult population in May and June. In April there is production of new growth by the Eucalyptus trees as a result of the wet conditions in March and April, which avails more soft tissue suitable for attack by the pest.

The increase in insect population is a result of continued planting of Eucalyptus trees providing more young hosts as Mutitu *et. al.* (2007a) indicated that farmers were still willing to plant more Eucalyptus due to the enormous uses of the tree. The increase in flying *L. invasa* adult population translates to the observed increase in the proportion of trees that are damaged.
There is negative correlation between damage to *E. grandis* and altitude especially after 1000m above sea level with no damage recorded beyond 2000m above sea level. Mendel *et. al.* (2004) noted that populations of *L. invasa* thrive under wide range of temperatures including winter temperatures and therefore the observed negative correlation with altitude might not necessarily be due to differences in temperature but could be due to the fact that initial infestation occurred at slightly lower altitudes of Westen province.

Conclusion and Recommendations

- Species, season, proximity to introduction point, time after insect introduction and altitude have been identified as some of the factors influencing the infestation and damage of Eucalyptus by *L. invasa*. Its however important to monitor the higher altitudes for infestation of the widely planted and susceptible *E. grandis*.
- The pest is threatening Eucalyptus growing in the country and management through biological control needs to be initiated at in the highly infested Western region.
- The new plantations established with the long rains in March need to be protected by application of systemic insecticides at transplanting to minimize the high damage experienced in April.

Acknowledgements

We appreciate the financial support of KEFRI, AFORNET and NCST that enabled us to conduct the studies. The support we received from the farmers whose plots were used as data collection points during the study was of great importance to us and the invaluable support of KEFRI colleagues and tireless spirit of Entomology staff during data collection.

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1.2 HYBRIDIZATION OF EUCALYPTUS SPECIES

Kariuki J.G.

Introduction

A hybrid is a cross between two or more discrete genetic sources. A hybrid can be inter-specific (between two species) or between two different provenances or even genotypes. It usually has characteristics intermediate between the parents. Hybrids are appealing because of the potential they may hold to produce genotypes with special combinations of properties that may either increase the value of the genetic resource or final product e.g. specific timber properties, disease resistance or they may be developed to increase the growth potential of the genotype e.g. greater vigour on specific sites compared to pure species.

Hybridization gives the opportunity to combine characteristics, which cannot be easily, be obtained in pure species. Examples of successful hybrids are the *E. grandis* x *E. urophyla* cross produced at Aracruz in Brazil that showed greater coppicing ability and resistance to Diaporthe stem canker than would be obtained by selection of E. grandis alone. In South Africa, a cross of *Pinus ellioti* x *P. Caribaea* grows extremely well in most pine growing areas of Zululand, Natal and Mpulanga. The hybrid combines favourable vigour form and wood properties from both parental species and yield a high proportion of good quality timber.

Materials and methods

Initially, pollination was carried out at Turbo, in three different stands and subsequently at Muguga. Pollen was obtained from Gede and Kitui and Muguga. The species used for pollination were *Eucalyptus grandis*, *E. urophyla*, *E. tereticornis* and *E. camaldulensis*. The trees were selected in superior stands at above-mentioned locations. Materials used for pollination included; silica gel, hand gloves, toothpicks, storage bags, hand sprayer.

One-Stop Pollination was used, starting with identification of ready unopened flowers often yellow in colour, for pollen collection. These were collected as whole umbels that were stored in bags containing silica gel to hasten drying. Drying was necessary for the anthers to release pollen. Ready flowers from the female parent were emasculated and sprayed with water using a hand spray, to remove any pollen and avoid contamination. In addition, clonal hedges for use in hybridization were established at Muguga nursery.

Results and discussions

Germination of Eucalyptus hybrid seedlings

The seedlings were raised from seeds collected from hybridization in the previous year. The seedlings in Table 1 were germinated in a growth chamber in the Tree Improvement laboratory at Muguga. Germination was recorded at an average of 80%. The seed were also germinated at The Kenya Forestry Seed Centre glasshouse for use in raising clonal seedlings of the hybrids (Plate 1)

Table 1: Seedlings of Eucalyptus hybrids raised at KEFRI Hq glasshouse

Hybrid	Code	No. of seedlings
E. grandis x *E. camaldulensis*	GC	100
E. grandis x *E. Tereticornis*	GT	85
E. grandis x *E. urophyla*	GU	80

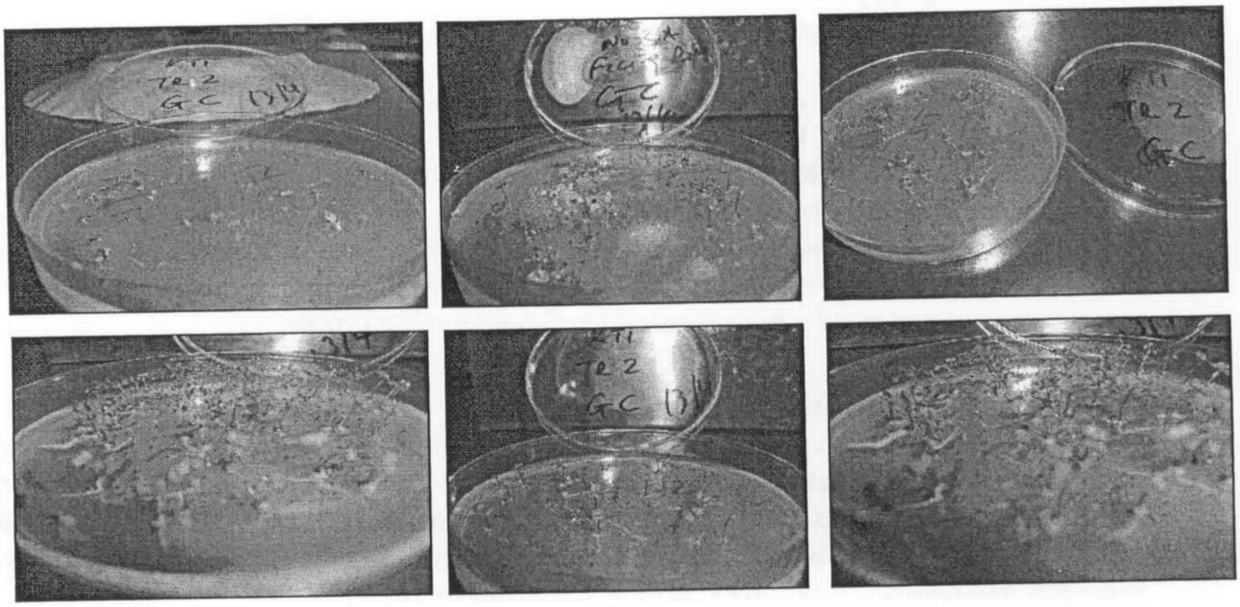

Plate 1. Germination of seeds of Eucalyptus hybrids

Planting and establishment of hybrid seedlings

Seedlings produced as described above were planted at Muguga in a hedge for testing and also for future production of the seedlings through cuttings, a method preferred for propagation of clones. The seedlings will subsequently be assessed and those with poor recombination as evidenced by slow growth will be culed while those with good growth will be retained and converted into a hedge for production of seedlings

Conclusions and recommendations

Hybrid seeds and seedlings were produced successfully mainly from pollination carried out at Muguga, Kitui and from past Turbo pollinations. The length of time taken from hybridization varied among the three sites. It took about 3 months to produce hybrid seeds in Turbo and Kitui compared to 4 months in Muguga. This could be attributed to colder conditions at Muguga compared to Turbo and Kitui. Germination tests were carried out in the glasshouse at Muguga to assess the viability of the hybrid seed. Hybrid seed of *E grandis* x *E. camaldulensis*, *E. Grandis* x *E. Urophyla* and *E grandis* x *E. tereticornis* were germinated.

Eucalypt hybrid breeding was initiated in Kenya in 2007 and is expected to be an integral part in the Eucalyptus breeding strategy. By 2007, the technique for pollination had been successfully refined and seeds produced successful in germination. However some key questions such as the mature growth performance of the hybrids on various sites; other economically important characteristics of the hybrids, such as the wood properties of these hybrids; and the ability to mass-produce the hybrids for commercial deployment will be evaluated in the long-term. Since three batches of hybrids have been produced, their growth will be assessed in the coming year and concurrently mass propagation of unculled hedges carried out.

1.3 ACQUISITION OF PLANT BREEDERS RIGHTS FOR *EUCALYPTUS GRANDIS* VARIETIES

Kariuki J. G.

Introduction

Eucalyptus grandis improvement has been going on in Kenya since 1990s through adoption of selection breeding strategies. These strategies have lead to an increase in production of *E. grandis* from $20m^3$/ha/yr to $70m^3$/ha/yr for some regions in the highlands of Kenya. Although production has doubled over time, the law has not protected the superior varieties by conferring Intellectual Property Rights of Plant breeders. KEFRI has developed several varieties from superior germplasm of *E. grandis* which will be protected by patenting through the Kenya Plant Health Inspectorate Services (KEPHIS). The process of registration will be done in phases, using draft guidelines for testing of Eucalypts in accordance to the International Union for the Protection of New Varieties of Plants (UPOV) (2006). The guidelines for testing state that Eucalypts testing should take at least three years. Characteristics for assessment include growth, form, and other tests of consistent distinctiveness displayed by the new varieties such as flower and leaf colour, etc.

Materials and Methods

Field experimental plot

Eight *E. grandis*: KEG1, KEG2, KEG3, KEG4, KEG5, KEG6, KEG7 and KEG8 varieties (Table 1) were selected from a pool of superior varieties developed in KEFRI over time KGC (Kenya grandis control) was used as a control for the experiment it also performs comparably well. Seed was collected from each of the varieties for propagation in the nursery. 300 seedlings were produced for each of the varieties that were established in two sites- Muguga and Turbo over the long rains in April 2007.

Table 1. *Eucalyptus grandis* varieties for registration with KEPHIS

Name of *E. grandis* variety	Number raised
KEG1	250
KEG2	475
KEG3	480
KEG4	480
KEG5	490
KEG6	490
KEG7	490
KEG8	380

Experimental Design and Layout

Ten treatments each were used for both sites (Muguga and Turbo), which were inclusive of the two controls (KSC and KGC). Each treatment had 25 seedlings and there were 4 replicates in each experiment. 2 guard rows were also included. An escapement of 2.5 m x 2.5 m was used. Assessment was carried out at 15, 27 and 38 months age for diameter and height.

A summary of the experimental design was:

- 8 treatments (KEG1-KEG8) and 2 controls (KGC and KSC)
- 25 trees per treatment
- 4 blocks
- 2 guard rows (*Eucalyptus grandis*)

Genetic fingerprinting

Eight *E. grandis* (KEG1, KEG2, KEG3, KEG4, KEG5, KEG6, KEG7 and KEG 8 lines) were selected from a pool of superior lines developed in KEFRI over time. One hundred (100) seedlings were produced for each line and were established in Muguga over the long rains in April 2007. Three trees were sampled per line. Three *E saligna* and 3 *E grandis* controls were included. Quality DNA was isolated using CTAB method.

Results

Progress of acquisition of plant breeder's rights (PBR) for *Eucalyptus grandis* through KEPHIS

KEPHIS do not have regulations for PBR on *Eucalyptus* species and these will need to be developed with KEFRI, following Draft guidelines developed by the International Union for the Protection of New Varieties of Plants (UPOV) that governs plant protection. KEFRI and KEPHIS officers will do this over time. According to proposed guidelines, the minimum duration of tests should normally be three years. Fees paid to KEPHIS for each variety before and during the registration process is as follows: Application for grant of PBR ($ 200); Application of protective direction ($ 40); Grant of protective direction certificate ($ 120); For technical evaluation of a variety ($ 600). The first three payments were done by KEFRI in the 2007/8 financial year, awaiting adoption and harmonization of guidelines for regulating *E. grandis* in Kenya and also awaiting gazettement of the varieties in the Kenya gazette, after which KEPHIS will proceed with the tests. Technical evaluation fees will be paid after the gazettement and adoption of the guidelines. KEFRI has however been advised to continue carrying out assessment of the trial, pending start of the process.

Growth of Eucalyptus varieties.

At two years and two months age, there was notable variation in growth of the Eucalyptus varieties, with individual tree height growth ranging from 5.4 to 11.2 m. However, the mean variety height growth ranged from 8.9m for KEG7 to 9.5 m for KEG 8. For diameter, individual tree growth ranged from 5.0 cm to 12.0 cm, with a variety mean ranging from 8.9cm to 9.4cm for KEG 5 and KEG 8 respectively (Figure 1 and 2).

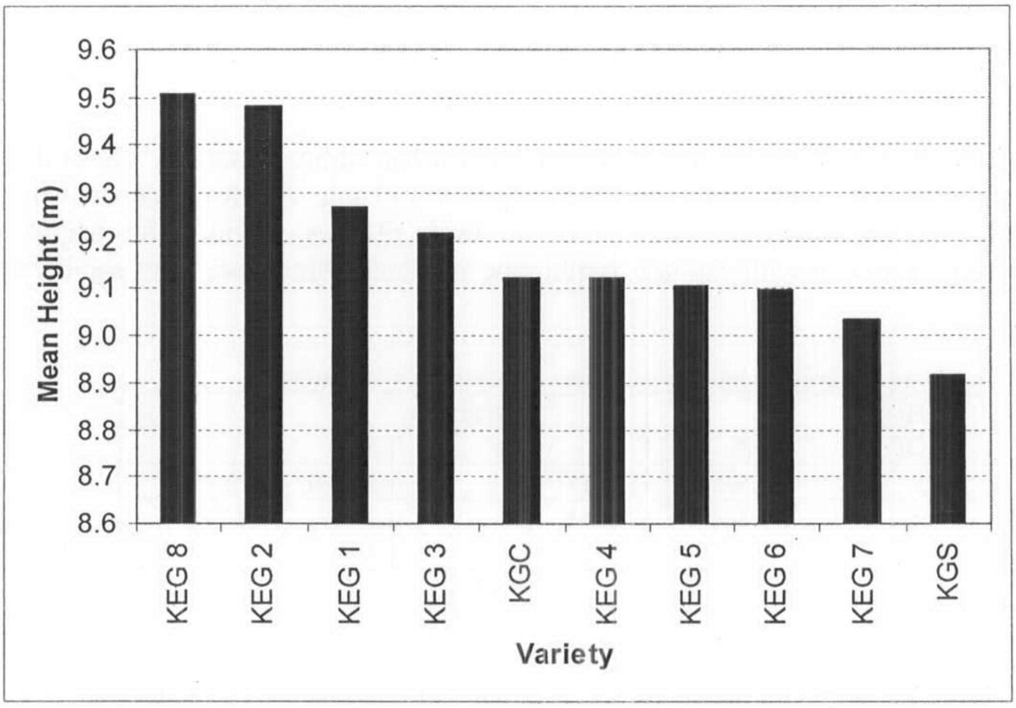

Figure 1. Mean height growth of varieties of *Eucalyptus grandis* at Muguga at 38 months

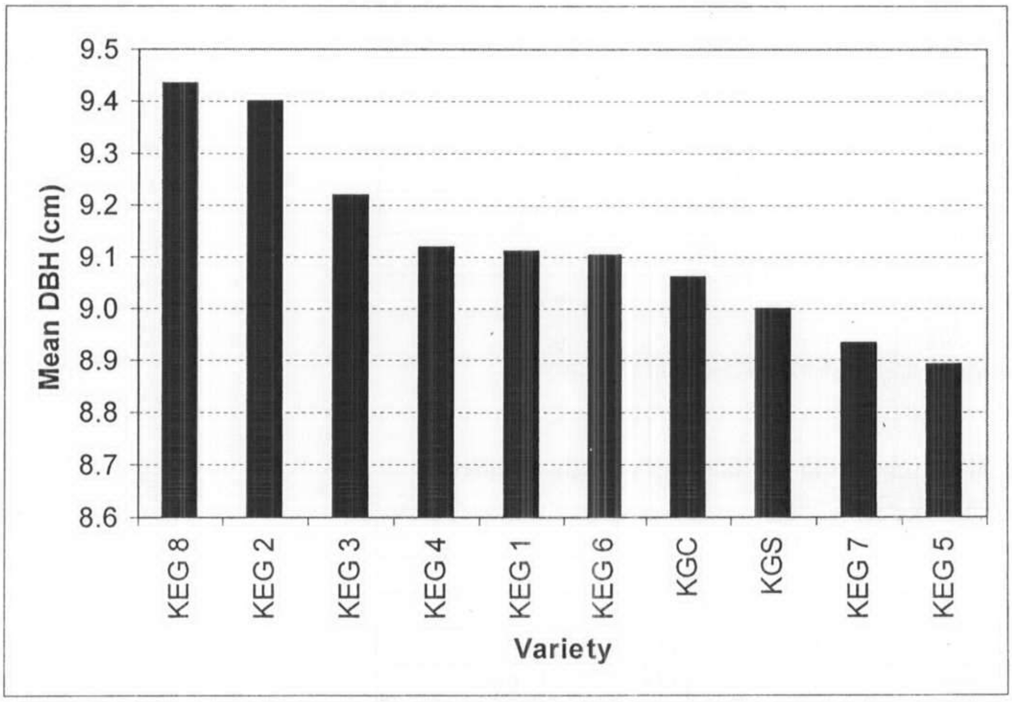

Figure 2. Mean diameter growth of varieties of *Eucalyptus grandis* at Muguga at 38 months

The results show that height and diameter growth had almost doubled. These differences were tested and found to statistically significant ($p<0.05$) (Table 2). However, not all varieties were different, with mean separation for the two traits (Tables 3 and 4 for height and diameter respectively), showing with varieties (within the same subset) that were not significantly different.

Table 2. Analysis of variance among varieties of Eucalyptus at Muguga

	Height			Diameter		
Source	Df	MS	F	df	MS	F
Block	3	7.528	20.311**	3	24.691	23.124**
Variety	9	1.884	5.083**	9	2.382	2.231*
Residual	720	0.371		706	1.068	
Total	733			719		

Table 3. Mean separation for height growth of varieties of *E. grandis* at age 38 months

	N	Subset	
Variety		1	2
KGS	13	9.92	
KEG 7	75	9.04	
KEG 6	84	9.10	
KEG 5	77	9.11	
KEG 4	64	9.12	
KGC	72	9.12	
KEG 3	62	9.22	9.22
KEG 1	126	9.27	9.27
KEG 2	67		9.48
KEG 8	93		9.51

Varieties within one subset are not significantly different ($p>0.05$)

Table 4. Mean separation for diameter growth of varieties of *E. grandis* at 38 months

	N	Subset		
Variety		1	2	3
KEG 5	65	8.89		
KEG 7	75	8.94	8.94	
KGS	13	9.00	9.00	9.00
KGC	72	9.06	9.06	9.06
KEG 6	84	9.10	9.10	9.10
KEG 1	124	9.11	9.11	9.11
KEG 4	64	9.12	9.12	9.12
KEG 3	62	9.22	9.22	9.22
KEG 2	67		9.40	9.40
KEG 8	93			9.43

Varieties within one subset are not significantly different ($p>0.05$)

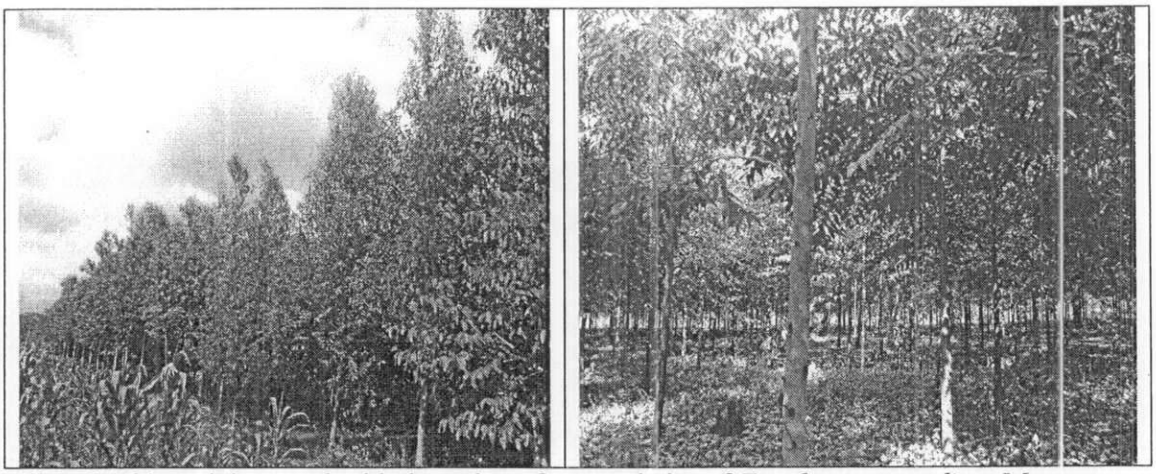

Plate 1. Thirty eight-month old plantation of test varieties of *Eucalyptus grandis* at Mugunga

Genetic fingerprinting of superior *E. grandis* superior lines

To protect any variety, it is important to genetically fingerprint (using DNA) the variety for identification. The varieties of the species were fingerprinted using Microsatellite markers . A clear procedure for DNA isolation (CTAB) from *E grandis* trees was determined. Quality DNA was isolated and stored at 4^0C. DNA quality was tested using RAPD KFP 8 probe but no distinct band was realised DNA was well amplified (see plate 3).

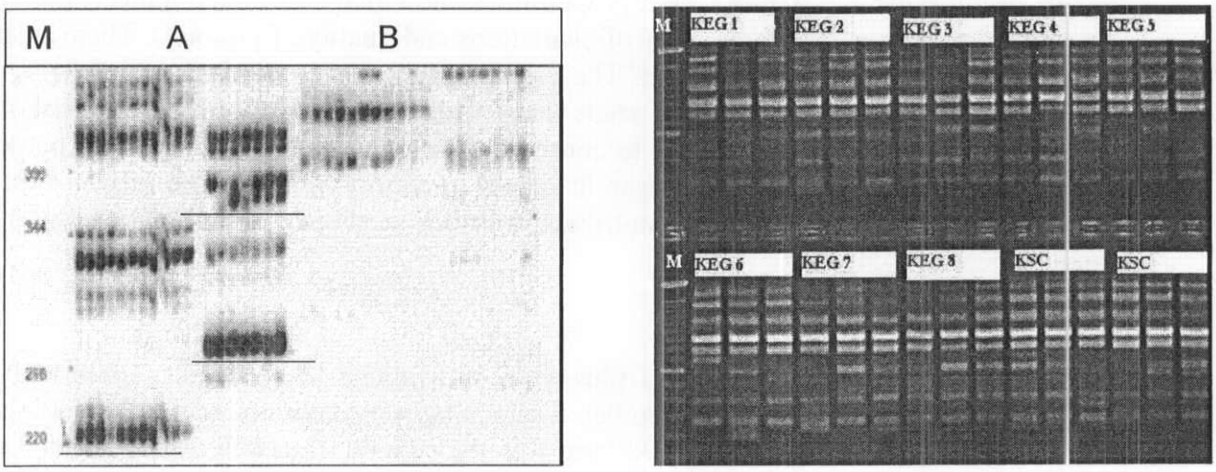

Plate 3: Amplified DNA for the *E. grandis* varieties

References

UPOV Code (2006): EUCAL (genus code) EUCALYPTUS (Sub-genus *Symphyomyrtus)* (Sections Transversaria, Maidenaria, Exsertaria) Draft Guidelines for the conduct of tests for distinctness, uniformity and stability.

1.4 GRAFTING AND ESTABLISHMENT OF CLONAL SEED ORCHARD OF CYPRESS AT MUGUGA

Kariuki J. G. and Mucheke W.

Introduction

Cupressus lusitanica was introduced in Kenya in 1905 and has since become an important industrial and plantation crop. *C. lusitanica* is an evergreen tree, 35 m high, with a dense, conical crown and is found in seasonally moist to permanently moist climates, with annual precipitation typically between 1000 and 1500 mm and a dry season lasting not more than 2-3 months. It is used for firewood, timber, construction wood and pulpwood, furniture, poles, posts, shade or shelter.

Intensive genetic improvement of the *Cupressus lusitanica* in Kenya was started in the early 1961. The strategy involved selection of plus trees through systematic searches in all plantations of the species in Kenya that were over 10 years of age. All the selected plus trees were cloned and planted at the Muguga tree bank/seed orchard.

Results of other genetic improvement programmes show that substantial gains can be obtained in selection of plus trees for productivity of plantations and quality of products. There is still need for quality cypress seed for afforestation. The established orchards have over time aged, been wind thrown and produce lesser amount of seeds. There is therefore need for establishment of additional orchards to increase seed output and to conserve the clonal materials. The main purpose of seed orchard establishment is to meet the gap in supply of quality seed. The objective of establishment of the clonal seed orchards is to contribute to meeting supply of quality seeds for plantation establishment in Kenya.

Methodology

Scions were collected from selected plus trees in Muguga in November 2008 and labeled by corresponding tree and plantation number. The scions were then taken to the nursery for grafting on the same day. The grafting method used was the side cleft, usually recommended for grafting of *C. lusitanica*.

Pots for the rootstock were labeled in concurrence with the tree number from which the scions were collected. The grafts were put in polythene sleeves, which were secured with sisal twine at the bottom. Water was added at the bottom of the sleeve before tying the top with sisal twine and the grafts put in a glasshouse. The grafts were raised in the

glasshouse for 3 months, hardened and planted in the field. The first phase of the seed orchard was established in 2008 and subsequently in 2009 and 2010.

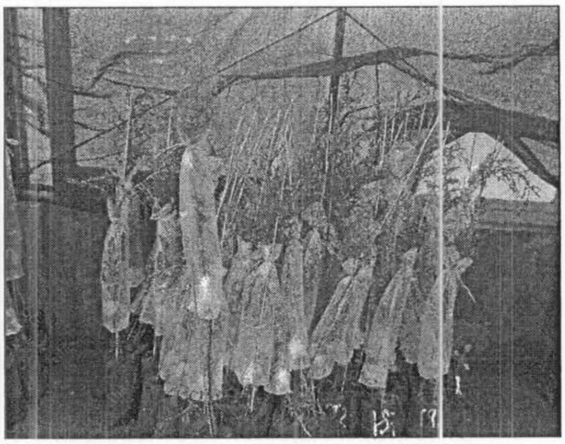

Plate 1: Grafted cypress in glasshouse at Muguga

Results

Scions from 18 plus trees were grafted, with 100 grafts for 5 plus trees while the rest had 50 scions. A total of 1150 grafts were done. Survival rate of grafts from different plus trees ranged from 3 to 74 % (Table 1).

Table 1: Graft survival rate for *Cupressus lusitanica*

No.	Plus Tree number	Number grafted	Number Surviving	% Survival
1	206	50	19	38
2	T 71	100	18	18
3	U 5	50	18	36
4	U 3	50	15	30
5	152	50	37	74
6	U 9	50	2	4
7	151	50	11	22
8	197	100	11	11
9	198	100	5	6
10	213	50	11	22
11	194	50	9	18
12	199	50	24	22
13	150	50	15	58
14	188	50	21	42
15	183	100	3	3
16	180	100	3	3
17	186	50	9	18
18	192	50	18	36
	Total	**1150**	249	21.80%

Successful grafts of *C. lusitanica* were planted at Malale area in Muguga, about 20 km North-East of Nairobi at an altitude of 2100 m above sea level. The site has deep, fertile volcanic loam soils and receives a mean annual rainfall of 988 mm. The design of the orchard was randomised, such that the same ramet was planted at least 4 planting spaces away from each other. A total of 1 hectare was designated for the orchard with a spacing of 4x4 metres (625/hectare). About one-third of the area designated for the orchard was planted in 2009. In April 2010, the remaining slots within the orchard were be filled up using the grafts raised in 2009.

Discussion and Conclusions

The overall grafting success for Cypress was average. Since the grafts used were physiologically from mature trees, it is expected that this will reduce the length of time required to produce seeds. The clonal seed orchards represent a more advanced step, since the genetic worth of the trees has been verified by progeny tests. It is recommended that the grafting be repeated again to fill empty slots in the cypress orchard, with the following measures taken into consideration:

1.5 EVALUATION OF IMAXI® (IMIDACLOPRID) AS A FOREST TERMITICIDE IN KENYA

Otieno B.O and Mutitu K.E

Introduction

Termites cause serious damage to crops, forest trees, wooden buildings and pastures in many regions of the tropics. Trees under conditions of stress are generally more susceptible (Gitonga, 1992). All the growth stages of trees are attacked with young exotic species being the most susceptible (Harris, 1971). Termite damage to seedlings and crops includes debarking of roots and stems; cutting off at ground level and hallowing out from within the root and stem system, resulting to death of the plant (Amadalo, 1992).

Resistance development against chemicals, when continually used, is rampant in insects and due to this other pesticides available in Kenya for control of other insect pests in crops with potential for control of termites need to be tested to provide farmers with alternatives to Fipronil.
Imidacloprid is considered by the World Health Organization to be moderately toxic and works by interfering with the transmission of stimuli in the insect nervous system. Specifically, it causes a blockage in a type of neuronal pathway (nicotinergic) that is more abundant in insects than in warm-blooded animals (making the chemical selectively more toxic to insects than warm-blooded animals).
The main objective was to test the efficacy of Imaxi® (Imidachloprid) to increase the number of registered termiticides for use in the afforestation programmes in Kenya to deal with development of termite resistance

Materials and methods

Field trials were set up on-farm in Western and Eastern provinces of Kenya, in Busia and Kibwezi respectively, which are known to be termite prone areas.
Eucalyptus grandis and *Grevillea robusta* were planted for Busia trial while *E. camaldulensis* and *G. robusta* were planted at Kibwezi.

The experiment was set up in a randomized complete block design with treatments comprising control, Reagent 3G (Fipronil) as standard, Imaxi upper (4ml/l), Imaxi standard (2ml/l) and Imaxi lower (1ml/l). One litre of the Imaxi concentrates, one litre of water as control and 33g of Regent 3G was applied to the planting holes just after the seedlings were planted out. The trees were assessed every season and data collected included: termite attack, chalcid attack height and root collar diameter. The attack of the chalcid (Leptocybe invasa), which is also a pest of Eucalypts, was assessed in Busia by subjecting the tree canopy to a four-point scale. Analysis of Variance (ANOVA) was used to compare the mortality of trees exposed to the various treatments while Probit analysis used to determine the effective doses in generalized linear model.

Results

The mortality of trees in non-treated plots was as high as 81% in *G. robusta* and 76% in *E. grandis* in Kibwezi and Busia respectively (Table 1 and 2).

Table 1. Cumulative percentage mortality of trees in plots with different concentrations of Imaxi and standard in Busia

Species	*Treatment*	*Age of trees post planting (months)*					
		2	**5**	**11**	**14**	**26**	**33**
E. grandis	Control	25.4	47.6	61.9	74.6	88.9	96.8
	Std	9.5	12.7	19.0	22.2	22.2	36.5
	4ml	2.4	2.4	2.4	7.1	49.2	50.8
	2ml	0.0	0.0	4.8	14.3	55.6	58.7
	1ml	9.5	12.7	17.5	27.0	57.1	60.3
G. robusta	Control	4.8	22.2	58.7	61.9	76.2	76.2
	Std	0.0	19.0	44.4	50.8	77.8	77.8
	4ml	1.6	1.6	1.6	3.2	9.5	15.9
	2ml	1.6	1.6	1.6	4.8	20.6	22.2
	1ml	0.0	0.0	0.0	9.5	39.7	39.7
S.e.d =11.9							

Table 2. Cumulative Percentage mortality of trees in plots with different concentrations of Imaxi and standard in Kibwezi

		Age of trees post planting (months)					
Species	*Treatment*	4	6	10	13	20	28
E. camaldulensis	Control	37.0	42.6	46.3	48.1	48.1	51.9
	Std	0.0	7.4	11.1	16.7	18.5	25.9
	4ml	0.0	0.0	0.0	0.0	3.7	11.1
	2ml	1.9	1.9	1.9	1.9	1.9	7.5
	1ml	0.0	0.0	5.6	5.6	9.3	27.8
	3ml	0.0	0.0	0.0	0.0	0.0	11.1
G. robusta	Control	0.0	40.7	70.4	75.9	77.8	81.5
	Std	13.0	14.8	18.5	20.4	22.2	35.2
	4ml	14.8	13.0	13.0	14.8.	20.4?	40.7?
	2ml	1.9	1.9	3.7	5.6	11.1	24.1
	1ml	9.3	9.3	14.8	16.7	20.4	31.5
	3ml	0.0	0.0	0.0	0.0	7.4	13.0
Sed =11.9							

There were significant differences, in tree mortality due to termite attack, in different species, treatments. There was observed interaction in termite attack between the tree species and the pesticide levels (Table 3).

Table 3. Anova table

Change	d.f	s.s.	m.s.	v.r.	F pr.
+Species	2	7771.3	3885.7	15.28	<.001
+Treatment	5	99273.9	19854.8	78.07	<.001
+ species. Treatment	9	13045.3	1449.5	5.70	<.001

The probit analysis gave different concentrations for different species while the sites have almost same concentration. The concentrations needed for different trees vary with the tree species to be treated with *E. camaldulensis* requiring the lowest concentration (Table 4).

Table 4. Calculated concentrations of Imaxi (ml/l) necessary for control of termites in plantations of exotic species in different regions at year 3.

Trial site	Tree species		
	E. Camaldulensis	*E. grandis*	*G. robusta*
Kibwezi	0.45	-	0.8
Busia	-	3.4	0.8

The mortality of trees due to termites starts to reduce by the 13th month, i.e. about 1year Increased concentrations of imaxi applied to plots led to reduced mortality of trees throught time except *E. camaldulensis* in Kibwezi.

The chalcid damage indices of control plots were observed to be significantly higher than that of chemical treated plots (p=0.002).

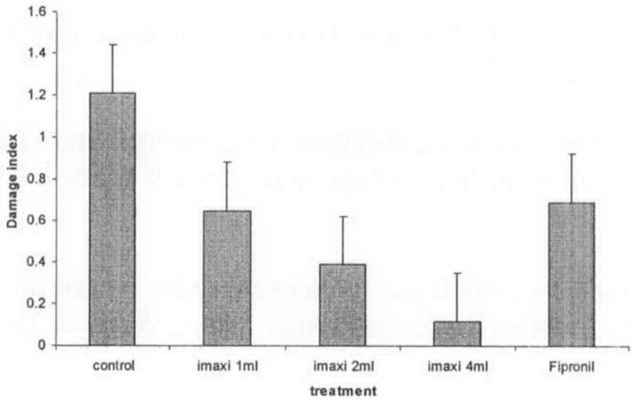

Figure 1. *Leptocybe invasa* damage indices of *E. grandis* plots with different treatments in Busia.

Discussions

The observed mortality in the non-treated plots corroborate with other findings in which termites have been found to cause a lot of damage to seedlings. The observed trees mortality was due to ring-barking and root debarking by termites and most attack of this form have been reported in other regions to occur in young eucalyptus plantations, and has been thought to be related to the lack of alternative food sources for the termites during the early establishment period of the plantation. Mortality of *G. robusta* was found to be high in Kibwezi than in Busia, which could be due to the fact that Kibwezi is drier compared to Busia (Adoyo et al , 1997; Braunn 1977). Mortality due to termites in *G. robusta* was found to be lower than in *E. grandis* in Busia while it was higher than *E. camaldulensis* in Kibwezi, which shows that different species have different levels of susceptibility to termites attack. There was significantly lower termites damage in Imaxi (imidacloprid) exposed trees compared to the rest of the treatments, indicating that Imaxi have better protection capability on trees. The concentrations or application rate of Imaxi varies with the tree species being planted. Imaxi was also observed to help in reducing the damage on Eucalyptus caused by *Leptocybe invasa,* gum Chalcid. This makes it more suitable since its application is able to provide several benefits.

Conclusion and recommendations

- Termite attack is a serious threat to exotic species establishment in Kenya and this necessitates use of pesticide for their management
- Threat of attack is high in *Eucalyptus grandis*, *E. caldulensis* and *G. robusta* trees in the first year of their establishment
- Imaxi shows good results and has additional benefit of managing *Leptocybe invasa.*
- Imaxi should be registered for use in termite management during establishment of tree plantations.

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1.6 *CINARA CUPRESSIVORA* AND ITS NATURAL ENEMIES IN THE CYPRESS PLANTATIONS OF KENYA

Otieno B.O, Njenga F. and Mutitu K

Introduction

Kenya has large area of industrial forest plantations of *Cupressus lusitanica* (planted on about 86,000 ha) out of this, about 5,153 ha was infested by the aphid to variable damage levels ranging from slight to severe (Mwangi, 2002). *Cinara cupressivora* (Watson and Vogtlin) (Homoptera: Aphididae) a pest of the eucalyptus trees was first recorded in Kenya in 1990 and had spread to all cypress growing regions of the country within one year (Owuor, 1991). By 1990, Kenya had about 86,000 ha of industrial Cypress forest plantations of which about 5,153 ha were infested by the aphid to variable damage levels ranging from slight to severe (Mwangi, 2002).

Cinara cupressivora (Homoptera: Aphidae) are brownish soft-bodied insects, often with a grey waxy coating. They are about 2.4 mm long. Adults are winged or wingless. They often occur with several young (nymph), which they produce rapidly. They are commonly seen in colonies along the twigs of infested trees.

Monitoring the populations of the cypress aphid and the biocontrol agent has been on since 1998 with an objective of establishing the effect of parasitoid, *Pauesia juniperorum* on the population trends of cypress aphid (*Cinara cupressivora*) and its damage to trees. Since *C. cupressivora* and its its introduced biocontrol agent *P. juniperorum* seems to have started synchronizing, its still important to monitor the population of tha aphid. Traping method was introduced alongside the Host tree assesment method.

Materials and Methods

The study was carried out from 1999 to 2009 in 20 permanent sample plots each comprising 900 trees, established within young cypress plantations. Data collection was carried out in the plots with open canopy and when the canopy had closed, other plots were established in nearby young plantations. One hundred (100) sample plants were randomly selected from the plots and one twig randomly selected from the trees. Data was collected from the 40cm tip of the branches, on the counts of aphids, number of mummies of *P. juniperorum* (both emerged and un-emerged mummies) and counts of other natural enemies while the canopy damage was scored on the whole plant.

The tree canopy damage by aphids was categorised on a scale of 1-4, based on browning of canopy observed. The method was modifiesd from Day *et al*., (1993).

Data analysis

Aphid population was log transformed while the counts of mummies of *P. juniperorum* was square root transformed to meet assumptions of variance homogeneity (Sokal & Rohlf, 1995), although untransformed data are presented in the figures for ease of interpretation.

The populations of the aphid was compared in various locations and related to that of the other natural enemies The data was analyzed using Analysis of Variance (ANOVA) and correlation in General statistical package, (Genstat release 10.2). A damage index (DI) was calculated from the mean damage severity (MDS) and damage incidence (DIP) per sample plot using formula modified from Hooda *et al*. (1992). ANOVA was used to compare the DIs and aphid populations between the locations, years and months.

Results

The dynamics of *C. cupresivora* and *P. juniperorun*

There was a significant reduction in the aphid population densities between the year 1999 and 2009 ($p<0.01$) (Fig. 1). The population of *C. cupresivora* varied significantly in the different cypress growing regions ($p=0.01$) with Londiani and Mount Kenya regions having higher populations than Muguga and Turbo regions. Significant interactions were also found between parasitoid (*P. juniperorum*) populations in different regions and the years ($p < 0.01$).

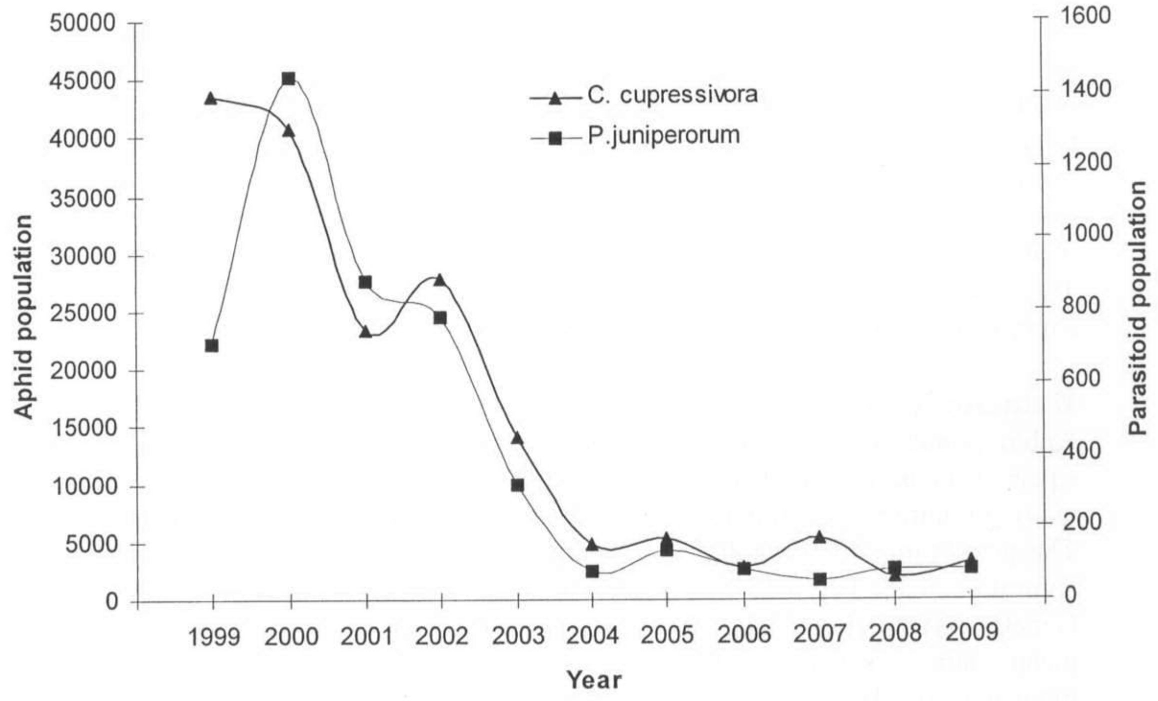

Figure 1: Population trends of *C. cupresivora* and *P. juniperorum* over the years in Kenya

Aphid damage to cypress trees

The damage inflicted on the cypress trees by the aphid varied significantly among the different tree growing regions ($p < 0.01$) and years ($p < 0.01$).

Influence of weather on aphid and parasitoid populations

There was a positive correlation between the aphid population and the mean daily temperature ($p= 0.027$) but not with rainfall and Relative humidity. A positive correlation between the population of *P.juniperorum* and the mean monthly Rainfall ($p= 0.013$) was established. There was a significant monthly variation of aphids over the years ($P < 0.01$), with the aphids being least abundant during the months when there was high rainfall (Figure 2).

Aphid and other natural enemies

Other natural enemies observed on aphid infested trees included spiders, syrphids, coccinelids, and lacewings. A Significant positive correlation was found between the numbers of aphids and a number of natural enemies. The highest correlation value was observed between the cypress aphid and its specialized parasitoid. The presence of lacewings was negatively correlated with the aphid population.

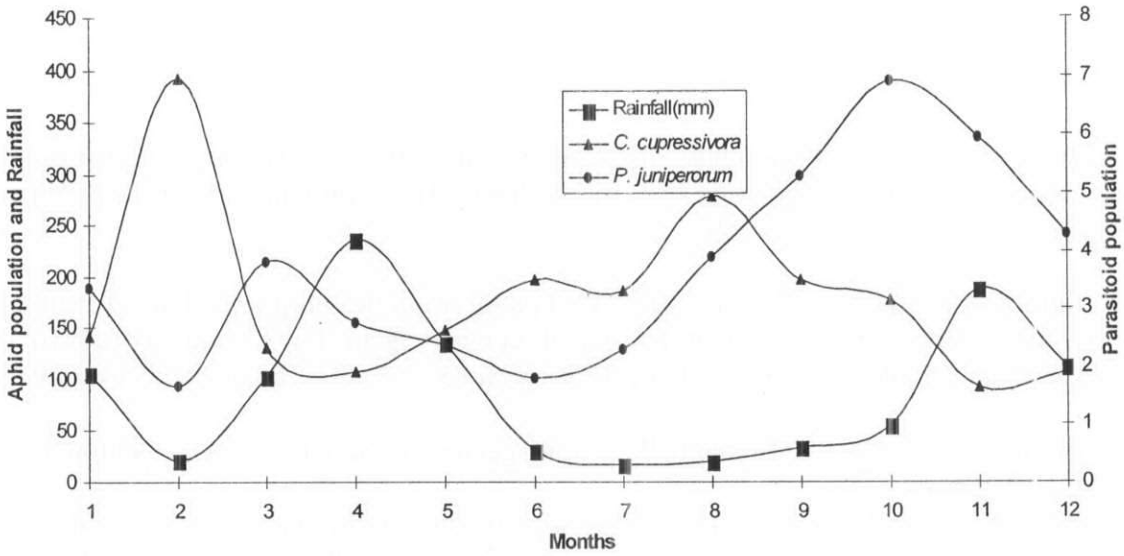

Figure 2: Annual population cycle of *C. cupressivora,* and P. *juniperorum* in Muguga, Kenya

Discussion

The peak population of P. *juniperorum* mummies lagged behind the peak population of aphids indicating that the parasitoid responded to the increase in aphid population by increasing in numbers and subsequently reducing the aphid population. Kairo and Murphy (2005) found that the aphid population thrived very well at temperature ranging between 20° – 25° C; this partly explains the rapid build up of infestations and subsequent damage to cypress trees in equatorial Africa. They also found that temperature influenced longevity, development time and the fecundity, all of which influenced the intrinsic rate of increase. Most species of predators and parasitoids have a significant functional response to aphid density and tend to aggregate in aphid patches thereby creating favorable situation for intra and inter specific encounters. Generalist predators such as coccinelids, spiders, syrphids and lacewings commonly engage in intra-guild predation feeding not only on other predators but also on parasitoid.

Conclusion and way forward

There seems to be synchronization between the aphid population and their parasitoids such that higher population levels of the parasitoids resulted in a decrease in the number of aphids.
The frequency of monitoring the aphid needs to be reduced since the biological control programme is working.

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1.7 PESTS AND DISEASES DIAGNOSIS, ADVISORY SERVICE AND DATABASE

Mwangi L.M and Otieno B.O

Introduction

The diagnosis and advisory service on pests and diseases in forestry is considered as an important activity provided to the public by KEFRI'S IPM section. It is intended to provide information on management of pests and diseases of trees where they are encountered.

Materials and methods

The Monitoring of pests and diseases continued in the financial year 2009/2010 as part of the activities within the entomology and pathology sections of KEFRI. Specimens were sent from the field using the technical order No. 40. In addition visits were made to areas where problems were reported. Specimens were also collected during the visits. Identification of insects and isolation and identification of fungi was carried out in laboratories at Muguga

On arrival, the specimens were recorded on specially designed forms to record all the details pertaining to them e.g. origin, species, type of specimen and date received. The materials were then diagnosed by:

(i) Direct observation of symptoms to detail the possible disease. Direct observation of materials is done under the microscope.

(ii) Damp chambered using plastic containers and filter papers soaked in water to allow the fungi to grow.

(iii) Plated on 2% malt extract agar media in Petri dishes. The media supports the growth of fungi. Visits were made to the pests infested areas and samples collected for identification at the KEFRI laboratory using the Insect Reference Collection.

The insect damage and diseases encountered in the year under review are highlighted in Table 1 and 2 respectively.

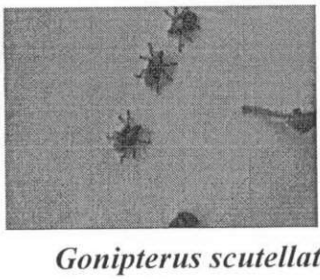
Table 1. Insect damage reported for year 2009 – 2010

Host/Source	Cause/Insect	Location	Remarks/Advice
Eucalyptus globules	Psyllids (homoptera: psyllidae)	Kinale	All management options can be applied i.e. biological, chemical, cultural or legislative, but advised not to apply any management option since the psyllids are not a threat to Eucalyptus even when the population are abundant.
Eucalyptus clones	*Thaumastocoris peregrimus*	Kiserian (Kajiando)	The specimen taken to Kenya National Museums for identification. Later identified as *Thaumastocoris peregrinus.*
Structural wood	Termites	Limuru	Advised to apply Termidor (fipronil)
Eucalyptus grandis	BGC	Kakuzi (Thika)	?
Mixed species of Eucalyptus clones	*Gonipterus scutellatus* (Eucalyptus snout beetles)	Naivasha	*Gonipterus scutellatus* is controlled biologically by a parasitoid *Anaphes nitens.* It is also advisable to seek professional advice on the right species to plant per-site.
Ornamental trees (*Duranta ripens*)	White flies	Kenya School of monetary studies (Nairobi)	Sticky traps taken to the site and trapped insects taken back to the lab for further action.
Eucalyptus clones	1. *Thaumastocoris peregrinus* 2. *Gonipterus scutellatus*	Kajiando	Advised to apply Imidachloprid in case of Thaumastocoriss sp. For *G. scutellatus,* the farmer advised to be patient for a biological agent (*Anaphes nitens*) to take effect.
Eucalyptus clones	1. *Gonipterus scutellatus* 2. BGC	Thika	A verbal advice given on Gonipterus damage and management and a bronchure on BGC given. A report from Pathology and soil labs was also to be sent to the farmer as technicians collected some samples from those labs.
Eucalyptus spp	BGC	Marigat	Advised to observe hygiene inside the farm by slashing tall grass. Plant only suitable materials recommended for the region.

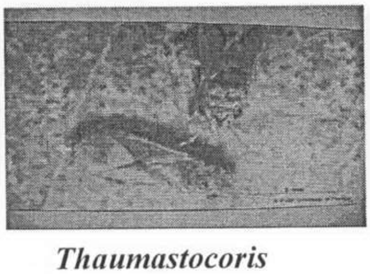
The major pests encountered were. *Gonipterus scutellatus* and Blue gum chalcid (BGC). However a new pest of Eucalyptus *Thaumastocoris peregrinus* was found in Kajiando. The resurgence of *Gonipterus scutellatus* is a major concern since a biological control was introduced many years ago.

Table 2. Diseases encountered in year 2009/2010

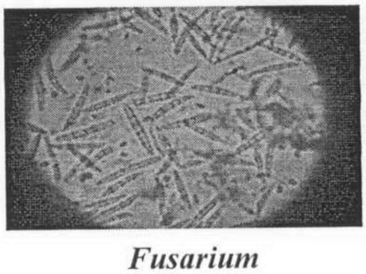
TYPE OF SPECIMEN	**SYMPTOMS**	**FUNGUS ISOLATED**	**LOCATION**	**REMARKS**
Eucalyptus sp.	Die back	*Pestalotia, Epicoccum, Botryosphaeria*	Kamachuzi	None
Prunus Africana	Leaf spots	*Alternaria, Epicoccum*	KEFRI HQS	Sprayed with Ridomil
Cypress	Wilt	*Fusarium*	Utum Singh (Brar farm)	Destroy affected plants
Pinus	Wilt	*Fusarium, Phomopsis*	Utum Singh (Brar farm)	"
G. robusta	Die back, Blight	*Fusarium, Pestalotia, Alternaria, Epicoccum, Botryosphaeria*	KEFRI HQS	Need more investigation
Kei apple	Death	*Fusarium, Alternaria*	Ridgeways Nairobi	"
GC 522	Wilt, Dieback	*Fusarium*, Bacteria	Karirana Tea Factory	Uparoot affected tree
Jatropha curcas	Stem rot	*Botryosphaeria*	Magarini	Remove trees
Jatropha curcas	Stem rot	*Fusarium*	Mpeketoni	cut back
Jatropha curcas	Stem rot	*Alternaria fusarium*	KARI Experimental plots	"
Cupressus lucitanica	Browning of needles	*Pestalotia, Monochaetia, Fusarium, Nectria*	Kamae Forest Station	Discard plants
Melia olkensii	Wilt Root rot	*Fusarium*	Kiambere	Discard plants



Gonipterus scutellatus



Thaumastocoris



Fusarium

The fungus *Fusarium* was the most encountered pathogen on many species of trees causing stem rot, root rot and wilts. It was found on upcoming species of interest such as *Jatropha curcas* and *Osyris lanceolata*.

Conclusion and way forward

Although less number of pests and diseases were encountered, there are some that need attention such as. ***Gonipterus** scutellatus, Thaumastocoris peregrinus and Fusarium.* This is because of the frequency of occurrence and the new pest *Thaumastocoris peregrinus*.. The database was also updated with more entries. The missing information on diseases was also added to the database. These will be put on CDs once the link programme is developed.

1.8 MODELLING RECRUITMENT OF SEEDLINGS OF COMMON PLANTATION AND FARM TREE SPECIES FOR IMPROVEMENT OF FOREST COVER IN CENTRAL KENYA

Oeba V O.

Introduction

Seedling recruitment has been studied widely in natural vegetations and to some extent on forest plantations when assessing the forest structure and regeneration (Farwig et al., 2009; Prior et al., 2009; Keyes et al., 2009 and Astrup et al., 2008). In this sense a seedling recruit has been defined as a propagule that has been germinated and is able to survive without maternal resources (Ribbens et al., 1994). Rammig et al. (2006) examined the speed of tree regeneration using spatially explicit simulation model which incorporated the interaction between the changing herb layer and growth and showed that seed availability, seedling survival and presence of advance regeneration were key processes of successful reforestation. The recruitment of tree species depended on vegetation types and advances of tree regeneration. Models have been revised to take into account predictability of tree recruits when assessing potentials of forest regeneration. Independent tree models for non-gap class have shown that recruitment is usually modeled at the stand level where the number of recruits per species is represented as a function of stand variables such as basal area, density, species proportion and site characterization (Porte and Bartelink, 2002).

In this study we focused Senior Clerical Officer on entry of new seedlings into a forest system as distributed by Kenya Forestry Service (KFS), Kenya Forestry Research Institute (KEFRI) and established tree nurseries taking into account different stages ranging from entry into a seed bank to transplanting. This was likened to birth processes in stochastic sense following the Markov chains that are oftened used to model the dynamics of various populations. This approach was motivated by the culture of tree planting in Central Kenya by various environmental conservation organizations and groups as well as the introduction of eucalyptus hybrid clones by Tree Biotechnology Project (TBP). However little efforts have been laid down to define clear methods on how to undertake regular analysis of information trends, modelling and forecasting to develop knowledge for accurate planning and informed decision on tree growing. Therefore the objective of this paper was to model and predict the recruitment of seedlings of common plantation and farm tree species for improvement of forest cover in Central Kenya using time series analysis and mixed model procedures.

Materials and Methods

Sampling design and data collection

Stratified and simple random sampling techniques were used to select tree nurseries for verification of secondary data in each Central region counties. Secondary data on exotic and indigenous tree species seedlings distributed from 1990 to 2006 was obtained from the KFS head office of Central Conservancy, registered tree nurseries and KEFRI. Records on the number of tree nurseries and area planted were obtained from the KFS head office of Central Conservancy. The monthly data on eucalyptus hybrid clones seedling distributed to Central Kenya from 2001 to 2007 was obtained from Tree Biotechnology Project (TBP), Karura.

Data analysis

The entry of seedlings into forestry system is what we referred to recruitment process, which was likened to birth process in stochastic sense following the Markov chains. Time reversal of Markov chain was used to estimate the distribution of time series models for forecasting the seedling recruitment on farm and gazzetted forests within Central highlands conservancy. In particular, class of time series models used was Autoregressive Integrated Moving –Average models (ARIMA). These models are designed for the analysis of series of observations taken at regular intervals such as hourly or yearly and could describe the behaviour of a single series or relate one series to others (Digby et al., 1989). The autoregressive (AR) model used was of the form

$$X_t = \delta + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \dots + \phi_p X_{t-p} + A_t \quad \text{..............................3.1}$$

where X_t is the time series, A_t is white noise, and

$$\delta = (1 - \sum_{i=1}^{p} \phi_i)\mu$$

with μ denoting the process mean whereas p is the order of the AR model.

The differences on the number of seedlings recruited of the commonly grown plantation tree species across the years among the sites and species were determined using mixed modelling approach The data was captured in Ms excel 2007 and analyzed using Genstat V12 and Gretl statistical software.

Results and discussions

Trends of seedling recruitment of various tree species

Overall there was a trend of the total number of seedlings recruited since 1990 to 2006 both exotic and indigenous tree species among farmers and gazzeted forests for re-forestation and afforestation programmes (Figure 1). There was high peak in 1993 and 2003 with yearly variation across the data period.

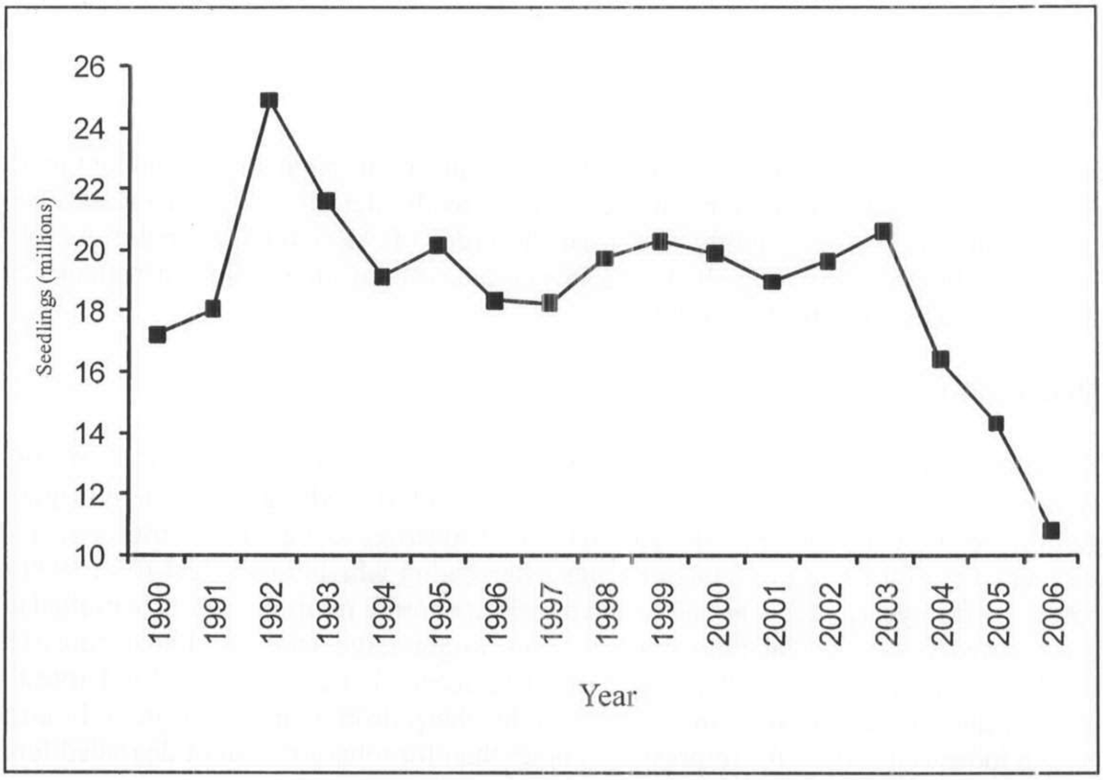


Figure 1: Seedling recruitments to gazzetted forests and farmers' field in Central Kenya from 1990 to 2006

The ARIMA model with one Autoregressive parameter (ARp), one order of differencing and moving average significantly ($p<0.05$) fitted the data better than other two models (Table 1). This was based on the Akaike information criterion (AIC) for model selection.

Table 1: Model selection for forecasting seedling recruitment in Central Kenya based on Akaike criterion and log-likelihood ratio

ARIMA model with	Parameters coefficient	s.e	Z	p-value	Log-likelihood ratio	Akaike criterion
AR only	0.676	0.226	2.999	0.003	-39.54	85.08
AR and MA	0.417	0.561	0.743	0.458	-39.25	86.50
	0.383	0.620	0.619	0.536		
AR, Difference and MA	0.673	0.326	2.062	0.039	37.21	82.49
	-1.000	0.196	-5.106	<0.001		

Forecasting the number of seedling recruited using the estimated parameters for five years there was some increasing trend where the forecasted values from 1990 to 2006 were within the trend of the data (Figure 3). This was further evidenced with autocorrelation and partial correlation coefficients functions (ACF and PACF) at various time lags. The results showed that most coefficients were near zero, indicating that seedling recruitment was at random and fitting of the ARIMA model with specified parameters was correctly identified. Also the results based on partial correlation coefficients suitably identified the order of AR model the point at which the PACF essentially became zero. The 95% confidence intervals of the coefficient parameters were within estimated range for both ACF and PACF.

Discussion

The uptake of seedling by various sectors plays a critical role in improvement of forest/tree cover in any country. Therefore the overall decreasing trend of seedling recruitment (Figure 1) painted a gloomy scenario in reference to the status of forest/tree cover in Central Kenya. This may be associated with the ban on industrial forests harvesting which took effect from 1999 implying that before the ban year, trees that had reached their economic rotations were clearfelled and replanting was carried out in sustainable manner. This might have lead to almost consistence trend of seedling recruitment till 1999. Trees that had reached their maturity for harvesting and were delayed due to the ban may further explain the sharp drop as indicated in 2006 implying limited area in industrial forests for reforestation other than for rehabilitation of degraded forest areas.

Forecasting of seedling recruitment using ARIMA model based on different parameters indicated a slight increase from 2007 to 2011 demonstrating the power of time series analysis in projecting the likely scenario of seedling recruitment for improvement of tree cover. The techniques of time series analysis have been commonly applied in sales, weather stations, economic forecasting, budgetary analysis, census, stock market, yield projections, inventory studies, monitoring industrial processes or tracking corporate business metrics. It usually requires more data points taken over time at equally spaced interval in order to identify autocorrelation, trend and seasonal variation. This forms a critical component when modelling time series data following autoregressive order, differencing and moving averages in order to correctly forecast the most likely scenario in the future. Therefore the limited data points in this study led to minimal use of time series analysis for forecasting on seedling recruitment for only five years (2007-2011). This implied that with availability of data taken at equal interval, modelling of time series analysis data would be very instrumental on tracking the status of forest/tree cover in Central Kenya among other areas of the country.

In conclusion, the uptake and high preference of exotic tree species such as *Cupressus lusitanica*, *Pinus patula*, eucalyptus hyribd clones and *Grivellea robusta* for reforestation and afforestation programmes would continue to positively improve the tree cover within the Central Kenya region. However, more efforts are needed on improving collection of quality seeds and other methods of propagation of indigenous tree species as they will be instrumental in forest rehabilitation and long life on farmers' field. The successful application of time series analysis models in forestry data indicated further strength of such modelling technique in other science fields. However for adequate forecasting of seedling recruitment using time series analysis models in aid of decision making and monitoring of tree cover changes, more data taken at regular interval to correctly predict such tree recruitment trends will be needed.

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1.9 MODELLING DETERMINANTS OF TREE RETENTION ON FARM FOR IMPROVEMENT OF FOREST COVER IN KENYA

Oeba V.O.

Introduction

Farm forestry has proved to be an important enterprise for small and large-scale farmers in low, medium and high potential areas worldwide. Studies have shown that various factors influence the farmer's decision to plant trees on farm. For instance secure land tenure was found to be significantly associated with tree-planting or agro-forestry practices as renters were found to be less likely to adopt medium or long term conservation practices (Moser et al. 2009; Arbuckle Jr et al. 2009). Some farmers plant trees as a lifestyle change, especially the older ones as compared to the younger ones who do it as part of career change by combining an off farm job or business enterprise with farming to meet the family demand for increased income. This increases pressure on farmers who still have farms to manage and workloads invariably become too much to handle, hence singling out forestry which is not labour intensive and can free more time for work off the farm and for the family (Valdivia and Poulos 2009; Teagasc Agriculture and Food Development Authority (TAFDA) 2007).

Kenya which has been internationally considered to be a low cover forest country envisions achieving 10% forest cover over the next decade through: promotion of farm forestry; intensification of dry lands forest management; encouragement of private sector engagement in industrial plantations and involvement of communities in forest management and conservation. A number of strategies geared towards attainment of this percentage have been documented in

government blue prints. For instance the Ministry of Youth Affairs and Sports (MOYAS) has developed an ambitious programme of trees for job where the youths are engaged in tree planting and nurturing of trees for pay with a main aim of creating employment and conserving the environment (Government of the Republic of Kenya 2008). Kenya Forestry Service (KFS) produced and distributed over 65 million seedlings during 2008/2009 financial year to support tree planting on farmlands and drylands (KFS 2009).

However the decision to plant trees on farmer's land can be difficult and vary from farmer to farmer. This can pose serious challenge on Kenya's ambitious tree planting programme on farmlands for attaining 10% forest cover. In addition, Kenya's vision 2030 blue print (Government of the Republic of Kenya 2008) on sector reform for environment, water and sanitation 2008-2012 identified lack of incentives for farmers and communities to invest in tree crops and non-wood forest products. Therefore understanding the characteristics and behaviour of landowners who may be interested in the various agro-forestry practices will form a strong foundation on approaches that may be used in improving forest cover. This study addressed determinants of the lifetime value of the farmer willing to retain trees on farm for improvement of forest cover in Kenya.

Materials and Methods

Study areas

This study was carried at Kiambu-Lari, Kiambu-Kikuyu, Nyeri South and Nyeri North of Central highlands conservancy.

Sampling of farm households and data collection

A sampling frame was designed in all study areas where a list of farmers who planted over one hundred trees or at least a quarter an acre under woodlot or plantations was drawn. Farmers were then stratified according to land sizes, tree planting densities and species diversity varying from intense boundary planting, woodlots to a plantation. To quantify the area under trees for cases of boundary planting conversions were done to assume uniform area under trees, which was equated as either a woodlot or a plantation of 0.5 ha. In each stratum, simple random sampling was used to select farm-household respondents and proportional allocation of questionnaires was used in each of the stratified category. Sampling techniques used ensured that selected farm households were uniformly distributed across the study sites resulting to 209 respondents of which 48, 79, 48 and 34 were from Nyeri South, Nyeri North, Kiambu-Lari and Kiambu-Kikuyu respectively. The data collected mainly composed of household and farm characteristics. The enumerators were trained and pre-testing was done to ensure consistency, reliability and validity of the instrument.

Data analysis and model applications

Variables from households and farm characteristics were assessed to capture relevant information from farmers. It was hypothesized that the likelihood of the farmer willing to retain trees on farm would be influenced by a number of explanatory factors. To explore the association between likelihood and explanatory variables Chi-square was used. Non-parametric tests, namely; Mann-Whitney U and Kruskal-Wallis H were used to compare mean rank differences between and among explanatory variables of lifetime value of the farmer willing to retain trees, respectively. In order to examine the probability and extent at which the farmer was willing to retain trees on farm, a dummy variable was created categorizing farmers as not likely, less likely and most likely to retain trees on farm. This was a depended variable regressed against the independent or explanatory variables. The binary logistic (not likely/likely) and multinomial logistic regression model were used and a comparison was drawn among the models.

Results

Descriptive statistics and non-parametric tests of tree retention determinants

Study sites and household determinants

Study sites were significantly associated (χ^2 = 13.49, d.f = 6; p=0.036 for j=3 and χ^2 = 7.685, d.f = 3; p=0.05 for j=2) with the likelihood of the farmer willing to retain trees on farm. Nyeri North followed by Kiambu-Lari had high proportion of farmers who were most likely to retain trees on farm as compared to those from Kiambu-Kikuyu and Nyeri South. This was significantly different (χ^2 = 9.60, d.f = 3; p=0.022 for j=3 and χ^2 = 7.648, d.f = 3; p=0.054 for j=2) based on Kruskall Wallis H test. However there were no significant differences (p>0.05) on likelihood of tree retention between Kiambu-Kikuyu and Nyeri South (Table 1).

There were significant associations (χ^2 = 7.631, d.f = 2; p=0.022 for j=3) and differences (Mann Whitney U test: Z = -2.20, p=0.028 for j=3 and Z =-1.54, p=0.028 for j=2) between gender of the household head and farmers' tree retention. Male-headed households were most likely to retain trees on farm as compared to female-headed households. Similarly, there were significant association (χ^2 = 3.570, d.f = 1; p=0.059 for j=2) and differences (Mann Whitney U; Z = -1.83, p=0.067 for j=3 and Z =-1.89, p=0.059 for j=2) between main occupation and farmer's willingness to retain trees. Those that were in formal full time employment had high proportion as compared to full time farmers. Also there were significant associations (χ^2 = 8.020, d.f = 3; p=0.046 for j=2) and differences (Kruskall Wallis H test: χ^2 = 7.979, d.f = 3; p=0.046 for j=2) between education levels of the respondents and farmers' likelihood of retaining trees on farm. Those who had attained post secondary and primary education had high proportion as compared to those who had no academic qualification. On the other hand, marital status was not significantly associated (χ^2 = 2.451, d.f = 2; p=0.281 for j=2 or 3) and difference (Mann Whitney U; Z = -1.26, p=0.206 for j=3 and Z =-0.88, p=0.377 for j=2) with farmer's lifetime value to retain trees (Table 1).

Consequently, of the sampled farmers 59%, 31% and 10% owned their land through inheritance from their parents, purchase and given by the community/government, respectively. However no significant association (χ^2 = 4.609, d.f = 4; p=0.333 for j=3 and χ^2 = 0.554, d.f = 2; p=0.758 for j=2) and differences (Kruskall Wallis H test: χ^2 = 0.117, d.f = 2; p=0.943) were found between type of land ownership and farmers' tree retention (Table 1). Land size significantly influenced ($F_{2, 201}$= 5.930; p=0.003) farmers' likelihood of tree retention where those who were most likely to retain trees had an average of 4.7 ha with a maximum of 71 ha as compared to less likely whose average land size was 1.6 ha and a maximum of 6 ha. Those that who were not likely to retain trees on farm had an average land size of 1 ha with a maximum of 2.8 ha. Exotic tree species *Eucalyptus* spp, *Cupressus lusitanica* and *Grivellea robusta* were the most planted as compared to the indigenous ones which was dominated by *Olea Africana* followed by *Prunus africana* and *Croton megalocarpus*. Farmers who were motivated in tree planting for environmental conservation and improving sources of livelihood were mostly likely to retain trees on farm. This was significantly associated ($\chi^2 = 10.453$, d.f = 2; p=0.005) and different (Mann Whitney U: Z = -2.114, p=0.034) among farmers categories.

Table 1. Study sites, household and land ownership determinants associated with likelihood of farmers' tree retention in Central Kenya.

		j=3					j=2			
		Not likely	Less likely	Most likely	Mean rank	Total (n)	Not liley	Likely	Mean rank	Total (n)
Determinants	Categories	%	%	%	μ	n	%	%	μ	n
Site	Kiambu-Lari	19	35	46	104	48	46	54	100	48
	Kiambu-Kikuyu	38	21	41	90	34	59	41	95	34
	Nyeri-South	32	27	40	93	47	60	40	95	47
	Nyeri North	15	23	62	118	79	38	62	117	79
Gender	Male	19	28	53	104	161	47	53	103	161
	Female	39	21	40	83	199	61	40	89	38
Main occupation	Full time farmer	25	28	47	98	174	53	47	98	174
	Formal job	15	19	68	119	14	33	68	118	27
Education level	None	30	35	35	83	23	65	35	83	23
	Primary	22	24	54	102	79	46	54	103	79
	Secondary	22	32	46	96	69	54	46	95	69
	Post secondary	18	11	71	117	28	29	71	120	28
Marital status	Married	22	26	52	103	187	48	52	102	187
	Not married	40	20	40	85	15	61	40	90	15
Land ownership	Inherited	21	30	49	-	120	51	49	-	120
	Bought	28	17	55	-	60	45	55	-	60
	Donated	30	20	50	-	20	50	50	-	20

Tree management and marketability determinants

Most of the farmers interviewed (84%, n=165) lacked any technical skills in tree management as compared to 16% (n=32) who had acquired such skills. These included nursery establishment, thinning, pollarding, short rotation coppice, fertilizer application, tree harvesting, forest economics and management of tree competition with agricultural crops among others. However, there was a significant association ($\chi^2 = 3.748$, d.f = 1; p=0.053 for j=2 or 3) on skills acquisition and farmer's likelihood of tree retention on farm. Majority (66%) of those who had got the technical skills were most likely to retain trees on farm as compared to those who had not obtained the same skills. This was again significantly associated (χ^2 = 3.698, d.f = 1; p=0.054) with their decision in growing trees based on the technical skills acquired (Table 2).

Labour involved on tree management was not found to be intense and costly by the majority (74%, n=130) as compared to 26% (n=45) who stated that it was intense and labour costly. This was significantly associated (χ^2 = 7.567, d.f = 2; p=0.023) with farmer's tree retention on farm. Also 94% (n=187) of the respondents did not receive forest extension services as compared to 6% (n=12) who did. This was not significantly associated (χ^2 = 3.824, d.f = 2; p=0.148) with farmer's tree retention on farm, although a majority (78%, n=7) of those who had received extension services, were most likely to retain trees on farm as well as those who not received (48%, n=88) extension services. Seeking for authority from Kenya Forestry Service was significantly associated (χ^2 = 5.883, d.f = 2; p=0.053 for j=3 and χ^2 = 4.123, d.f = 1; p=0.042 for j=2) with the likelihood of farmer retaining trees on farm. Overall, 69% (n=103) sought for permit to harvest trees as compared to 41% (n=72) who did not. Consequently there was a significant association (χ^2 = 7.318, d.f = 2; p=0.026 for j=3) between respondents who found such regulations necessary on tree farming and likelihood of retaining trees retention on farm (Table 2).

Comparatively, no significant association (χ^2 = 4.315, d.f = 2; p=0.116 for j=2 or 3) between existence of village forest association and level of likelihood of farmer retaining trees. Thirty five percent (n=61) of the respondents stated that there were village forest associations in comparison with 65% (n=115) of none. Similarly there was no strong significant association between marketing problems and farmer's likelihood (χ^2 = 4.630, d.f = 2; p=0.099) of tree retention on farm. Also 79% (n=124) did not experience any marketing problems of their tree produce as compared to 21% (n=33; Table 2).

Table 2. Tree management and marketability determinants of influencing farmer's tree retention on farm in Central Kenya.

		j=3				j=2		
		Not likely	Less likely	Most likely	Total (n)	Not likely	Likely	Total (n)
Determinants	Categories	%	%	%	n	%	%	n
Technical skills	yes	14	21	66	29	34	66	29
	no	26	28	46	163	54	46	163
Use of skills	yes	14	7	79	28	21	79	28
	no	26	19	55	31	45	55	31
Labour and cost	yes	9	28	63	43	37	63	43
	no	30	24	46	127	54	46	127
Extension services	yes	0	22	79	9	22	78	9
	no	25	27	48	183	52	48	183
Harvesting permission	yes	18	26	57	97	43	57	97

		j=3				j=2		
		Not likely	Less likely	Most likely	Total (n)	Not likely	Likely	Total (n)
Determinants	Categories	%	%	%	n	%	%	n
	no	32	27	41	71	59	41	71
Harvesting regulation	yes	16	29	55	76	45	55	76
	no	35	20	45	75	55	45	75
Village forest associations	yes	16	35	49	57	51	49	57
	no	27	22	51	112	49	51	112
Membership	yes	23	31	46	35	54	46	35
	no	25	26	49	148	51	49	148
Ready market	yes	21	25	54	109	46	54	109
	no	36	21	42	33	58	42	33
Marketing problems	yes	10	29	61	31	39	61	31
	no	28	25	47	117	53	47	117

Determinants of tree retention using binary and multinomial logistic regression models

Both binary and multinomial logistic regression following stepwise method of fitting variables showed study site, monthly income, land size, extension services, labour and cost involved in tree management and harvesting permission from KFS as significant determinants influencing the likelihood of the farmer willing to retain trees on farm. Also in logistic regression model, major occupation, education level and acquisition of technical skills were significant determinants of the lifetime value of the farmer's tree retention. Similarly, multinomial logistic regression identified gender of the household head, age, reasons motivating farmers to plant trees, harvesting regulation and existence of village forest association were significant determinants influencing the farmers' tree retention (Table 3).

Table 3. Likelihood ratio tests and model classification of tree retention determinants using binary and multinomial logistic regression

	Intercept		-2 log likelihood		Chi-square ratio test		d.f		p-value		% model classification	
Determinants	Logt	Mult	Logt	Mult	Logt	Mult	Logt	Mult	Logt	Mult	Logt	Mult
Site	0.00	32.0	281	45.1	7.75	13.1	3	6	0.05	0.04	59	50
Gender HH	0.03	17.8	273	24.8	2.4	6.9	1	2	0.12	0.03	55	51
Occupation	-0.01	16.9	275	20.6	3.63	3.67	1	2	0.06	0.16	55	50
Age	0.07	86.4	262	238	0.01	152	1	126	0.93	0.06	52	67

Education	0.07	30.4	267	40.0	8.22	9.56	3	6	0.04	0.14	58	52
Marital status	0.04	16.4	279	18.7	0.79	2.26	1	2	0.38	0.32	53	51
NMH	0.09	89	275	85	0.51	1.52	1	2	0.47	0.47	53	52
Income	0.13	64.2	220	168	13	104	1	80	0.00	0.00	60	53
Land tenure	0.04	29.4	276	43.9	0.55	14.5	2	10	0.76	0.15	52	51
Land size	0.02	72.4	231	130	52	57.9	1	6	0.00	0.00	68	68
Tree use	-0.08	24.1	240	27.3	2.12	3.18	2	4	0.35	0.53	55	48
Motivation	0.10	17.5	225	27.5	1.63	10.0	1	2	0.20	0.01	56	52
Technical skills	-0.04	17.0	262	21.1	3.79	4.08	1	2	0.05	0.13	56	49
Skill effect	0.69	12.6	71.8	16.6	3.78	3.94	1	2	0.05	0.14	66	66
Labour & cost	0.00	17.1	232	25.8	3.80	8.67	1	2	0.05	0.01	57	50
Extension services	-0.02	13	263	18.8	3.19	5.72	1	2	0.07	0.06	53	50
Harvest permission	0.00	18.1	229	23.9	4.14	5.87	1	2	0.04	0.05	58	50
Harvesting regulation	0.01	17.5	208	25	1.49	7.45	1	2	0.22	0.02	55	50
Forest associations	0.01	17.8	234	22.1	0.05	4.35	1	2	0.83	0.11	51	50
Membership	-0.06	17.6	253	18.1	0.15	0.47	1	2	0.70	0.79	51	49
Ready market	0.06	16.8	195	19.8	1.39	3.03	1	2	0.24	0.22	55	51
Marketing problems	0.00	16.4	203	21.7	2.01	5.36	1	2	0.16	0.07	55	50

* Logt = Logistic regression values; Mult = Multinomial logistic regression values; HH = Household head; NMH= number of members in the household

Discussion

The application of binary and multinomial logistic regression underscored the significance of using methodology in data analysis. The discrepancy that was observed between the two models may be explained by random occurrence of small sample sizes in multinomial and binary variable as well as the power of the statistical test based on uncorrelated variables. This was well demonstrated when the non-parametric tests were carried out of which the p-value for main occupation notably decreased from 0.166 on checking for significant associations to 0.067 on inferential tests, showing an increasing source of evidence that main occupation was a significant factor associated with tree retention among the group of farmers. Consequently, the p-value of education level considerably decreased from 0.171 to 0.111, showing further an inherent evidence of education level on influencing farmer's tree retention. Nyeri North which had relatively high land sizes may explain high level of tree retention on farm. Other studies have shown that land is a significant factor influencing community's decision to plant trees on large scale. Farmers with small-scale land holdings opted for agricultural rather than forest plantations, as they needed immediate cash flow hence shorter rotations of crops cultivated. One percent increase in land under outright ownership, there was a 7.6% in the probability that farmers will establish forest plantations (Zhang and Owiredu 2007; Siregar et al. 2007).

Conclusion

The application of descriptive statistics and non-parametric test significantly helped modelling of hypothesized determinants of LTV of the farmer's tree retention on farm. The use of binary and multinomial logistic regression models proved to be useful tools and advances the methodology of analyzing such survey data. The household, farm attributes, tree management and marketability characteristics were instrumental determinants that influenced the farmer's decision on tree retention on farm. Therefore the findings of this study will be very instrumental in assisting the government of Kenya while undertaking forestry reforms for improvement of forest cover to 10% in the next decade by taking into account of these findings. Further studies on development of models in relation of tree retention on farms will form instrumental tools for decision making.

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2.0 STUDIES IN NATURAL FORESTRY

2.1 USE OF VIABLE INCENTIVE MEASURES FOR SUSTAINABLE FOREST RESOURCE CONSERVATION AMONGST COMMUNITIES LIVING ADJACENT TO ARABUKO SOKOKE FOREST

Kiptot E., Luvanda, A and B. Owuor

Introduction

Forests are a source of livelihoods to about 3 million people living adjacent to them, also support a wide range of biodiversity (Mogaka et al., 2001). Rural livelihoods are characterized by extreme uncertainty and seasonality. When households are poor and livelihoods insecure, maintaining natural woodlands/forests for their indirect, option and existence values is a luxury which many farmers cannot afford. For poor people who live adjacent to forests, the returns from cutting trees for timber or clearing for agricultural land is often more attractive, because of the benefits that accrue directly to the individual (Wiggins, et al. 2004). Existence of the forest denies communities living next to the forest the opportunity to use the forest for other purposes i.e. timber, since it is considered illegal to cut trees for timber. To motivate the forest adjacent communities to conserve the forest, there is need to provide them with incentives.

Incentives are specific inducements designed and implemented to influence or motivate people to act in a certain way. In the context of forest conservation, economic incentives are concerned with making it more worthwhile in financial and livelihood terms for communities to maintain rather than to degrade forest resources in the course of their economic activities. Incentives respond both to local needs, circumstances and economic activities and to the broader market policy and institutional failures which make communities unwilling or economically unable to conserve nature in the course of their economic activity (Emerton, un-dated).

The Kenya Forest Service currently uses penalties and disincentives to discourage forest degradation. However this has not helped and therefore alternative approaches such as the use of incentives need to be used. The Forests Act, (2005) currently provides incentives in the form of; limited grazing, collection of dead wood for fuel wood, mushrooms, medicinal plants etc but communities do not consider these to be good enough. In addition, the Act also provides for the formation of CFAs to manage sections of forests but there are no proper guidelines for their implementation and how benefits are going to be shared (GoK, 2005). The purpose of this study, therefore, was to propose an alternative approach of forest conservation through the use of acceptable and tangible incentive measures.

Specific objectives

1. Undertake a literature review to document the use of incentive measures in Kenya and other parts of the world.

2. Understand current forest policy and legislation to identify if there are any incentive measures and how they help/or do not help in promoting forest conservation
3. Document the dynamics of livelihood strategies among adjacent forest communities, which will provide background information required for designing incentive packages.
4. Propose incentive measures that are socially, culturally and economically sound.

Research Methods

Study site

The study was in Araboke-Sokoke forest at the Coast. It covers 420 square km close to the Indian Ocean in Kilifi and Malindi Districts about 110 km north of Mombasa.

Research design

The work was divided into two parts. The first part was a literature review to document experiences on the use of incentive measures in forest conservation and understand the current forest policy current forest policy and legislation to identify if there are any incentive measures and how they help/or do not help in promoting forest conservation. The second part involved carrying out a survey to get background information on community livelihoods which will form the overriding focus of the design and implementation of economic incentives for community conservation, identifying interactions between livelihoods and natural forests. Primary data was gathered through group discussions, household surveys and key informant interviews. Arabuko Sokoke forest was selected for this study given that to a certain extent incentives measures have been applied as a tool for conservation.

Results

Review of forest law and policy

There are various sections in the Forest Act 2005 and Draft Forest Policy 2009 that gives incentives for conservation. i.e. empowering local communities to manage forest through associations that are now recognized in the law.

Demographic information of the farmers interviewed

The respondents living around the forest were mainly from the Giriama tribe (89%), with a minority Kambas (3%), Taita (3%), Chonyi (3%), Luyha (1%) and Chonyi (1%). There were from three districts namely; Malindi , Ganze and Ki lifi.

Incentive measures taken up by the community living around Arabuko Sokoke Forest

Table 1 lists the oncentive measures in use at Arabuko Sokoke forest

Table 1: Incentive measures taken up by the respondents

Activity	Frequency (n=70)	% of respondents
Butterfly farming	37	53
Mushroom	4	6
Silk farming	11	15.7
Firewood	9	13
Seedling production	44	63

Agroforestry	43	62
Beekeeping	33	47
Herbal medicine	8	11
Poles/posts	1	1.4
Aloe vera	15	21
Ecotourism	5	7.1
Fishing	2	2.8

Challenges facing conservation of Arabuko Sokoke Forest

- High incidences of poverty
- Weak law enforcement mechanism
- Human wildlife conflict
- Operationalization of (Partiipatory Forest Management) PFM has been very slow- Management Plans have taken too long to be approved by Director KFS
- Un-productive land resource
- Have been using traditional hives which are prone to infestation by wildlife and other pests.
- Some of the enterprises are seasonal in scope and income
- Aloe vera project did not take off due to lack of capacity in value addition and marketing
- Community expectations very high and hence have become demoralised
- No clear policy about benefit sharing
- Lack of ready markets for the products eg Aloe vera
- Lack of skills in value addition
- Lack of incentives to community patrol men
- Poaching of bush meat
- Unreliable market for the seedlings

How different incentives have impacted on conservation and local livelihoods

- Butterfly farming and bee keeping have improved the livelihoods of forest adjacent communities
- Currently there are 1,070 individuals living around the forest from 54 villages. Out of which 800 are engaged in butterfly farming and 4, 996 individual are involved in beekeeping.
- Some farmers have abused the fuel-wood permit. Instead of collecting fuel wood for home use, they are doing it for commercial purposes although it has not affected the conservation of the forest. Forest patrols have been intensified.
- Community awareness on conservation has been raised
- The demand for honey is high, while the market for butterfly pupae has been problematic. 80% of the honey is sold in the hotel industry while butterfly pupae are sold in Europe.
- High level of butterfly habitat disturbance has led to scarcity of some species. Scarcity is also related to seasonality.
- Good relationship between wardens, locals and foresters has been cultivated

Recommendations on other incentives that can be introduced to boost conservation of Arabuko Sokoke Forest

1. Revenue sharing: Modalities need to be put in place after research has been done to establish how much revenue is generated; how much funds are injected to manage the forest; What percentage should go to the communities and at what level should communities be involved in management of the forest.

2. Conservation of rare species in the forest and when the populations exceed the carrying capacity, communities can be allowed to undertake culling of the edible species
3. Expanding Ecotourism facilities in the forest: Bring in big investors who will in turn provide employment to local communities
4. Raring of Guinea fowls on farm to reduce the incidence of illegal hunting in the forest

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2.2 THE STATUS OF THE KEFRI NATURAL FOREST GATWIKIRA BLOCK

Giathi G., Gachathi N. and Njehu J.

Introduction

The forest is made up of two blocks; Gachuthi (30 ha) and Gatwikira (13ha). They lie about two kilometers apart, however, they were a part of a continuous forest running all the way from Nairobi, Ngong to the Kikuyu escarpment. Both blocks are covered by remnant of a semi-deciduous dry forest type. In its pristine undisturbed condition it forms a closed canopy forest. The upper canopy usually consists of *Olea europaea ssp. africana, Calondendrum capense, Warburgia ugandensis, Zanthoxylum usambarense, Cassiporea molasana, Ekerbagia rueppeliana, Croton megalocarpus* and *Juniperus procera.* Other species of this forest include *Ehretia cymosa, Albizia* *gummifera, Dovyalis abyssinica, Acokanthera schimperi, Euclea divinorum* among others and the shade tolerance *Teclea* species that mainly forms the under storey layer.

As with major of the other indigenous forests in Kenya, this forest has undergone both legal and illegal exploitation. Any kind of exploitation was banned from late 1970s, however, illegal exploitation by the neighbouring communities for various products continues unabated. These include wood poaching for fuel wood and construction materials, livestock grazing and harvesting of non-wood forest products such roots and tree barks for medical purposes. This has created open spaces within the forest and especially along the common boundary with the settled area. Illegal uprooting of wildlings for private nurseries has been reported. How all these activities have

affected the status of this forest in terms of composition, structure and regeneration is the subject of this investigation. The local community through a series of sensitization meetings has come to value the importance of this forest in their life in provision of various goods and services. They are therefore interested in its conservation and rehabilitation. The objective of the present study is to understand the status of the Gatwikira forest block to guide on possible interventions to promote its conservation and rehabilitation.

Overall Objective

To conserve and rehabilitate KEFRI natural forest at Muguga

Specific Objectives

To determine the status (composition and regeneration) of this forest
To determine the species needed for rehabilitating the forest and to acquire them.
To initiate and manage the rehabilitation process.

Methodologies

This forest borders an all weather earth road serving also as a border between the KEFRI forest estate and the settlement. Sample plots for data collection were marked along a series of transects running from the forest edge (Near the settled area) toward the interior of the forest. The point of marking the first transect was chosen at random and the subsequent transects were marked running parallel to it. From the first transect, the subsequent transects were systematically marked at 100m interval until the whole forest block was covered.

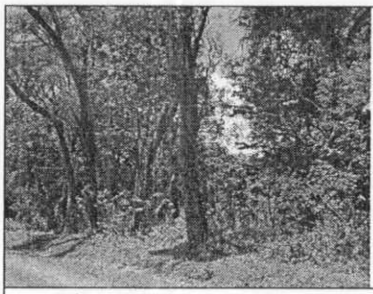

Plate1.Border between forest and settlement marked by a road

Plots measuring 20 m x 20 m were marked along each transect. The starting point of the first plot in each transect was picked randomly from 1 to 15m from the forest- settled area borderline. From this plot, the successive plots were marked at an interval of 20 m. In each of these plots, one corner was then picked at random and a subplot measuring 5 m x 5m marked and within it another sub-plot of 2 m x 2 m was randomly marked.

The larger 20 m x 20 m plots were used to sample trees and cut-stumps. All trees above 5 cm over bark diameter at breast height (dbh) were recorded by species, dbh, and height. All cut stumps were recorded including the cross sectional diameters of each cut-stumps at the point of cut and at the ground level. These were to give an indication of the dbh of the harvested trees. Also, the species and coppicing potential of each stump were noted. The coppicing potential was indicated by the presence or absence of coppices. Saplings and shrubs data was collected from the 5 m x 5m subplots. Sapling was taken as that tree with at least 1.0 m tall to dbh of 5 cm or less. The diameter (dbh) and height of sapling were taken and species identified. Seedlings and the ground vegetation cover data was sampled from the 2 m x 2m subplots. Any tree that was less than 1.0 m tall was classified as a seedling. It was recorded by species and height.

Results

The stocking level of the mature trees and shrubs was 437 stems ha^{-1} and with a basal area of $17.2m^2\ ha^{-1}$. They consisted of forty different trees and shrubs species from 21 families. Among the tree species, fours were exotics including *Eucalyptus globules, E. grandis, E. paniculata* and *E. saligna.* These were grown in a small plantation within the larger Gatwikira block. Within this plantation colonization by indigenous forest trees species especially *Teclea simplicifolia* and *Warburgia ugandensis* from the surrounding area was taking place. The most prominent indigenous trees of this forest were the *Warburgia ugandensis, Schrebera alata, Calodendrum capense Croton megalocarpus* and *Olea europaea ssp. africana.* Minor trees species included the *Trimeria grandifolia, Mystroxylon aethiopicum, Dovyalis abyssinica* and *Zanthoxylum usambarense* among others. Among the shrubs *Acokanthera oppositifolia, Clausena anisata, Dombeya burgessiae, Erythrococca bongensis, Grewia similes, Hibiscus spp* and *Solanum indicum* were the most important

The population of sapling was 127 ha^{-1}; consisting of 64 individuals from twelve species of shrubs and 63 from fourteen species of trees. The seedling population was $65ha^{-1}$ only and comprised of twelve species of tree and shrubs. In block were Sixteen out of the forty trees and shrubs species in this forest had neither sapling nor seedling. These included *Ekebergia capensis, Dracaena steudneri, Dovyalis abyssinica, Albizia gummifera, Diospyros abyssinica, Cussonia holstii* and *Calodendrum capense* among others. They therefore face danger of local decline and extinction. They should be included as the priority enrichment plant species to be planted in the cleared gaps within the forest and along the forest edges.

The ground vegetation cover consisted of seven species of grasses, 27 herbs, 10 climbers and 10 shrubs. Bare ground with no vegetation was about 40 % of the total ground surface area and quite a large proportion of this was under the areas with a closed forest canopy. Such areas should not be planted.

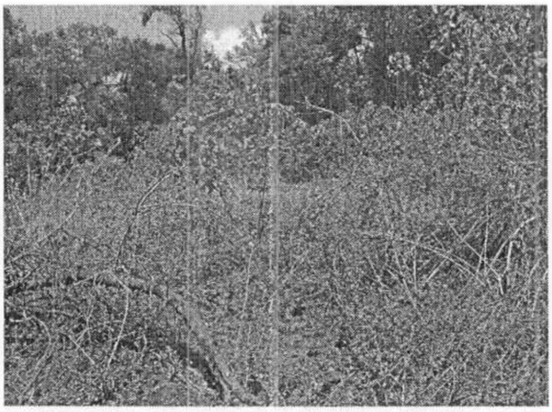

Plate 2. Cleared site inside the forest

The total number of cut stumps was $92ha^{-1}$ from 23 different trees and shrubs species. This was about a fifth of the standing stock. About 75 % of the stumps were sprouting/coppicing. Among the species with high potentials of coppicing included *Vangueria madagascariensis, Teclea simplicifolia* and *Erythrococca bongensis*. This mode of regeneration will aid in the overall recovery of the degraded forest sections. Other species such as *Fagaropsis angolensis O. europaea ssp. africana* and *Schrebera alata* were not coppicing. Their rate of decline through wood poaching may be higher than those species with high potentials of coppicing from cut stumps.

The way forward

- Seeds of the priority species for rehabilitation should be acquired from the Kenya Forestry Seed Center (KFSC) and others bought from seed merchants and where possible collection would be done within this forest or other similar forest.
- Seedlings should be raised from the seeds acquired.
- Purchase seedlings of the species that would not be possible to raise in the nursery
- To initiate and manage the rehabilitation process through planting and the subsequent spot weeding and beating up.

2.3 EASTERN AFRICA BAMBOO PROJECT

Sigu Gordon

Introduction

During the reporting period, the project worked with farmers groups and stakeholders in different regions and sites namely in Kakamega, Kisumu, Olenguruone, Kinale, Kamae, Kiambaa, Nairobi and it's environ. This report is therefore focusing on the achievements of the project's objectives and how these achievements reflect on the overall success of the project in Kinale, Kamae and Kiambaa.

Materials and Methods

In this report, the following methodologies were used to gather the information.

- Reviewing project documents including Mid-term review recommendations, annual reports, Steering Committee meeting reports etc.
- Group discussions, observation and individual interviews

- Field visits in Kinale/Kamae, Kiambaa and Nairobi.

Results and Discussion

Kinale Kamae bamboo project

The group was started in 2006 with a total membership of 40, of whom 8 are women. This group has done very well in both propagation and product making. A number of the members currently have mature bamboo plantations averaging 1-3 acres of land.

Figure 1: A bamboo plantation planted by a member of the Kinale Kamae group in 2006

Most of these bamboo plantations were planted in 2006 when the project was introduced to members. The members have therefore demonstrated to the rest of the community that bamboo species mature fairly fast and can be a source of quick income for improving livelihoods.

Bamboo products making

Most members trained in products making from this group have established workshops at their family level and generally work with their family members in bamboo products making. Those who have established workshops in their homes reckons that there is good market to sell finished products but only when the products are hawked in churches, Agricultural Shows, open days, political rallies or any other big gathering that attracts large crowds.

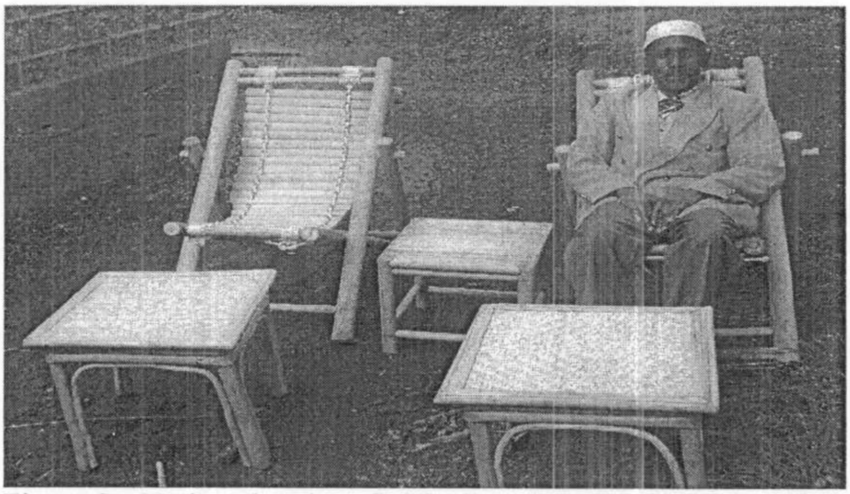

Figure 2: Various bamboo finished products made by one of those trained by the project in 2009 in Kinale Kamae.

Bamboo and Tree Company (Private sector)

This is a private sector initiative in bamboo nursery development, being done with technical support from project. It has since grown to about 100,000 seedlings of 12 major species of bamboo. Currently employs 7 people who are undertaking propagation work in the premise's 10 green houses. The bamboo seedlings are raised and sold in polythene bags of different sizes, with seedlings raised in the small bags and big bags sold at KES 250 and KES 1,000 respectively

The premise has also been used by KEFRI as a trial and research ground particularly for new germplasm received from other East African Bamboo Project partners particularly from Ethiopia and Belgium.

Kiambaa bamboo group

This group settled in Kiambaa in central province of Kenya in 1982, having arrived from Zimbabwe. The group originally came to Kenya as missionaries but had skills in working with bamboo for weaving various items including; flower baskets, fruit baskets, chairs, trays, lantern hangers and clothe hangers, of various designs.

The demands for their finished products have ever been rising particularly in markets in Nairobi and its environs. Members of this group have since 1982 relied on bamboo raw materials from those selling them in central markets situated in Nairobi.

The project has been working with this group and has helped them modify and work on new design that fetch them good returns for a better income to improve their livelihood. KEFRI has also helped this group in getting bamboo culms from their trial plots at the KEFRI headquarters

The group reckons that the demand to supply finished products to Curio shops, super markets and individual traders in Nairobi has been overwhelming. However there are short supplies of mature bamboo culms that can be used to make durable products, which are appealing to their clients. In this regard, the group has been linked to the Kinale, Kamae members who have mature plantation of bamboo.

Strengths of the Project Design

Initial trainings given to all the group members used simple training materials and hand outs, backed with sketches, graphics, and drawings. The tools to which the groups were introduced

were equally simple. Some of the innovative group members have even crafted their own tools which have proved to be effective in processing bamboo products.
The project also trained group member on making good use of locally available wastes materials in raising seedling. These included sugar and salt used packets, polythene papers and plastic containers.

Figure 3: Recycled materials used in the nursery

The project strategy of involving key stakeholders in the forestry sector and private sector in implementation process is an assurance of sustainability of the project activities.

Impacts of the Eastern Africa Bamboo Project

- The project has greatly contributed to the creation of awareness of the importance of bamboo as alternatives to wood in making products and in environmental conservation.
- The project has also demonstrated to the government of Kenya the potential of bamboo in wealth creation and in providing alternative employment opportunities to the citizenry of the country and help in alleviating poverty in both urban and rural areas.
- The country is currently adopting planting of different species including some indigenous and exotic species. KEFRI has been handy in providing back-up information on what species to plant where, their field performance and suitability for various uses.

Recommendations

- The potential of bamboo in alleviating poverty, creating sustainable employments and in water catchment restoration and rehabilitation has been demonstrated.
- The project needs to put in place a monitoring plan to be able to quantify and document changes in social and economic well-being, resulting from the project activities for communities and other stakeholders.

Conclusion

The project has demonstrated the potential of bamboo in creating sustainable employment in both rural and urban marginalized areas. Its fast growth rate and ability to grow in a mixed stand with woody tree species makes it ideal in rehabilitating and conserving water catchment areas in the country. Bamboo development and further research can provide an important window in boosting Kenyan industrial development particularly in cottage industries. In order to realize this potential, the momentum already created by the project needs to sustained.

2.4 IMPACT OF INSTITUTIONS AND INCENTIVES ON FORESTS AND WOODLAND RESOURCES (IFRI/IFLEA) THE CASE OF ARABUKO-SOKOKE

Obonyo Emily

Background information

The Arabuko Sokoke forest is found along the Coastal strip of Kilifi and Malindi districts. It is claimed to be among the last remnant indigenous forests in Kenya; the largest and most intact coastal forest in East Africa, and still the largest remnant of the forests that once dominated Kenya's coastal fringe. One of the objectives of the study was to identify the main institutional actors/players and their roles in the management of the forest.

Highlight of results

The main oorganizations involved in conservation and management efforts include a joint team by the Kenya Forest Service, Kenya Wildlife Service and Kenya Forest Research Institute who joined to launch the Arabuko-Sokoke Forest Management Team (ASFMT). This group has a goal of promoting conservation and at the same time sustainable utilization. Other organizations include A Rocha Kenya (ARK) which is mainly involved in Environmental Education; Wildlife Clubs of Kenya (WCK) through its Educational Officers trains and helps school children and communities to initiate Wildlife and tree planting activities; Bird Life International, Nature Kenya, Government parastatals including NMK; Private organizations and local CBO's.

The organizations are interlinked through collaboration, information sharing, funding and others. The circles represent the different stakeholders involved in the use and management of the Arabuko Sokoke forest. The size of the circle depicts the role the stakeholder plays in the management of the forest; therefore, the bigger the circle, the bigger the role played by the particular stakeholder. The distance of the circle from the forest also indicates the strength of the stakeholder in decision making on forest management. From the diagram, the KEFRI, KFS, KWS and the NMK are the organizations with the strongest power on management decisions of the forest, followed by the local community through various community based organization. NGOs are next in line followed by private entities. Although the Provincial Administration and other governmental bodies and departments are involved, their role is not profound or direct. The ASFADA is the umbrella body consisting of most of the CBOs around Arabuko Sokoke Forest (fig 1)

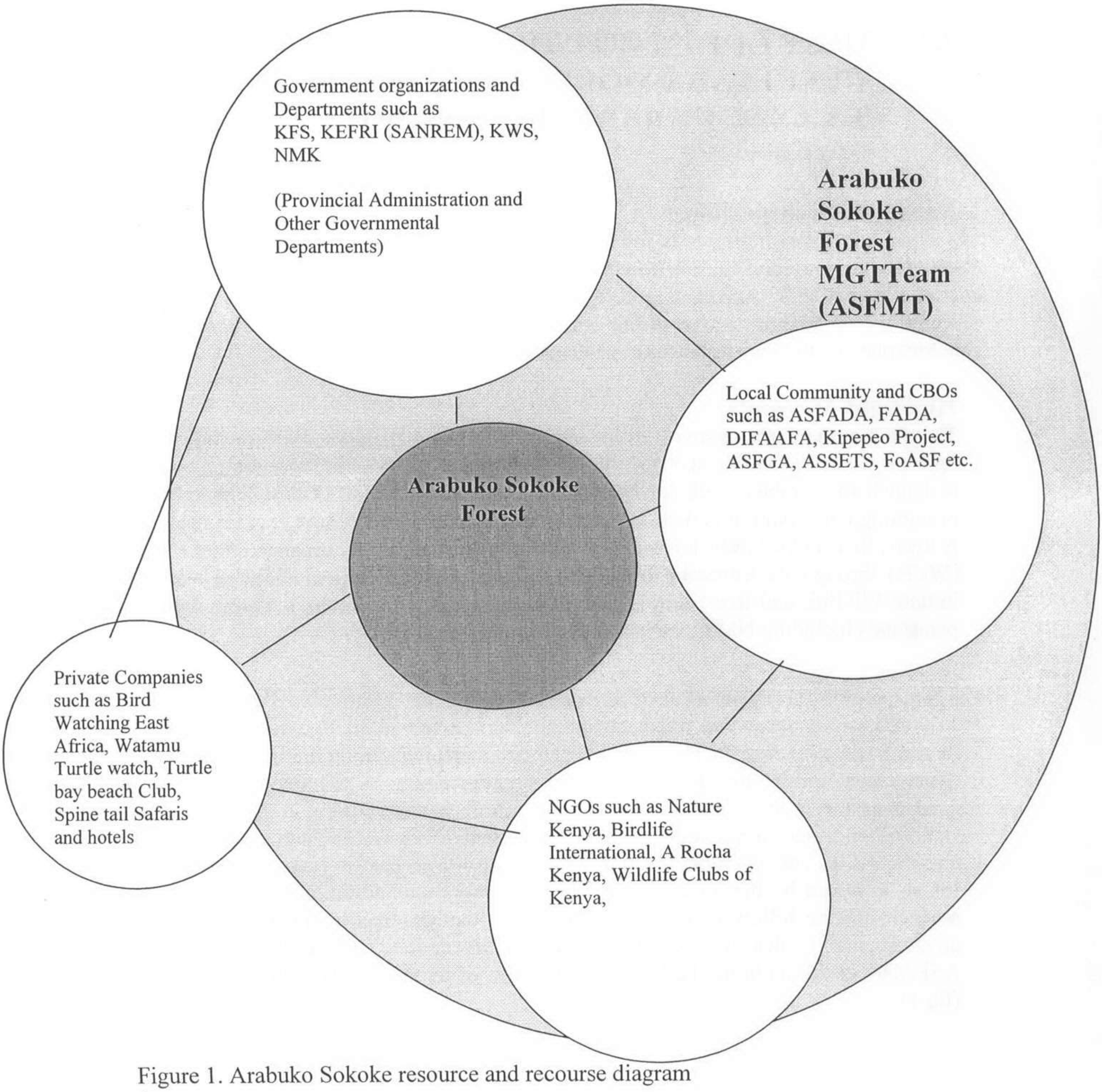

Figure 1. Arabuko Sokoke resource and recourse diagram

Acronyms

KFS- Kenya Forest Service
KEFRI- Kenya Forestry Research Institute
KWS- Kenya Wildlife Service
SANREM- Sustainable Agriculture and Natural Resource Management
NMK- National Museums of Kenya
CBOs- Community Based Organizations
NGOs- Non Governmental Organizations
ASFADA- Arabuko Sokoke Forest Dwellers Association
DIFAFA- Dida Forest Adjacent Forest Association
FADA-Forest Adjacent Dwellers Association
ASSETS- Arabuko Sokoke Schools and Ecotourism Scheme
ASFGA- Arabuko Sokoke Forest Guides Association
FoASF- Friends of Arabuko Sokoke
ASFMT- Arabuko Sokoke Forest Management Team

2.4.2 GOT RAMOGI SACRED FOREST: VALUE OF CULTURE IN FOREST CONSERVATION

Obonyo Emily

Introduction

Got Ramogi sacred forest is located in Got Ramogi Sub- location, Central Yimbo Location, Usigu Division, Bondo District on the Northeastern shores of Lake Victoria. The forest covers an area of 283 hectares. The present forest is now a secondary forest due to the harvesting over the years by the people living in the area. The County Council of Bondo holds the Forest in trust. However, the Kenya Forestry Research Institute (KEFRI) and Forest Department (FD) have for a long time managed it. There are however plans to gazzete the forest.

The objectives of the visit to Ramogi Hill forest was to assess the resilience of the culture and to identify the main drivers of institutional change that were likely to lead to institutional entropy. The collection of social data was done through Participatory Rural Appraisal (PRA) methods such as historical profiling, and focus group discussions with members of the community and interviews with key informants.

Results highlights

The settlement in Ramogi is composed of four clans namely, Owil, Minyejra, Dimo and Kisodhi who are descendants of Ramogi who is believed to be the father of the Luo community in Kenya. The area has six historical landmarks which are sacred to the community

Main drivers of change

The condition of the forest has generally remained the same though there has been an increase in the harvesting of poles and posts. Members of the community still acquire fuel wood, poles and posts and grass from the forest that is not within the sacred sites although there have been few instances of harvesting in the sacred zones without permission.

Poverty was identified as the main driver of change. The future of the forest with regard to the rising demand for fuelwood which is used for sale to alleviate the living standards has got to be secured. With the current demand for fuelwood, the condition of the forest is bound to deteriorate. This can be prevented by promoting drought resistant tree species in the area for provision of fuelwood and construction materials. There is also need to develop more water projects that can assist in irrigation and probably reduce the

dependence on fuelwood from the forest for cash. This would encourage the local residents to establish tree nurseries and in turn establish their own woodlots and even plant vegetables that have a ready market in the nearby fishing towns. The team observed that the community has made efforts of bringing water closer to them by building dams. The government and well wishers should encourage these efforts and fund them where possible.

The demand for fuel wood has also seen to initial cases of harvesting near the sacred grounds. The changes in marketing structures and the demand for more economic empowerment may lead to changes in institutional arrangements so that cultural beliefs and practices may be disregarded in favour of economic benefits.

The community members should work towards finalizing the Got Ramogi Cultural Resource Centre, which will earn them income as a source of tourist attraction. The local herbalists should also join hands to help preserve the knowledge they have by establishing records on the different plant species in the forest and their uses.

3.0 STUDIES IN DRYLAND FORESTRY

3.1 ENHANCEMENT OF SEED PRODUCTION AND SEED GERMINATION OF *OSYRIS LANCEOLATA*

Kamondo B., Otieno B.O. and Osore C.

Introduction

Osyris lanceolata (trade name East African Sandalwood) in the family Santalaceae is an evergreen shrub to small tree growing up to a height of 6 meters. The species has a relatively wide ecological distribution occurring in Eastern and Southern Africa. In Kenya, it grows in Coast, Eastern, Rift valley, Nyanza, Central and Western provinces. The species is normally found in rocky sites and along margins of dry forests, evergreen bushland, grassland, and thickets at altitude of 900 – 2550 m above sea level.

The species has captured the limelight due to its overexploitation to meet the international demand for its perfumery and medicinal products. The tree is locally endangered which threatens not only the survival of the species, but also the sustainability of the trade in the species products. The protection of the natural populations of the species will be helped by putting in place a domestication program where cultivation and harvesting of the species on-farm will ease the pressure on the natural populations. As the species is not a plantation species, little is known about its silviculture. In appreciating this fact, Kenya Forestry Research Institute (KEFRI) embarked on research on propagation of *O. lanceolata* in support of envisaged domestication program. Tree propagation through seeds is the most preferred option for mass propagation. Ongoing research work in KEFRI improved Osyris seed germination. However, the duration of germination which was close to two months remained long predisposing the seed to predation when in the soil. Granted that *Osyris lanceolata* seeds poorly, the process of floatation through useful in removing empty seeds and therefore enhancing seed quality was found to drastically reduce the amount of available seeds. A beetle that was observed to be associated with *O. lanceolata* fruits in the field was suspected to be predating on the embryo (resulting in empty seeds) as probing spots were observed on fruits (Kamondo *et al.*, 2007, Machua *et al*, 2008). Experiments were therefore initiated with an objective of enhancing seed quality, seed germination and reducing the length it takes for seed to germinate

Materials and methods

Promotion of seed quality through control of insects suspected to predate on seed embryo

Fruits in all stages of maturity were collected periodically and observed for bug puncture *Dismegistus sanguineus*, then dissected to observe viability status (presence of germ), presence of fly larvae, or damage and colour of the endosperm. Attempts were made to control the insect populations as a means of promoting quality and quantity of seeds. Two pesticides namely Imidachloprid and chloropyrifos with systemic and contact insecticidal mode of actions respectively were used. The experiment was controlled through use of water in place of the pesticides. Female trees were identified in a population in Kitui and 3 groups of 5 trees each separated by reasonable distance selected. The soil around the base of trees was drenched with 3 litres of constituted concentrate of the imidachloprid (500EC) while the Chloropyrifos (200SL) was sprayed onto the osyris plant canopy according to recommended application rates. The frequency of application was every two months in accordance with the manufacturer's prescription. Five replicates of treated plots were selected, treated and seeds collected for assessment. Seeds were collected every 2 months and subjected to the same handling and tests as those collected for assessing the viability of probed fruits.

Seed germination experiments

Ripe fruits indicated by bright orange colour were picked by hand from population in Wii village Kitui district. The fruits were subjected to floatation (Smith *et al.,* 2003) as a means of separating fruits with full viable seeds from those with empty seeds. Any floating fruits were discarded while those that sunk were depulped manually by gently rubbing the seeds between hands. The cleaned seeds were subjected to another floatation procedure to further raise the proportion of full viable seeds in the seedlot. Any floating seeds were discarded. The seeds that sunk were drained, spread and air dried for 3 days on a suspended coffee wire tray layered with mosquito net wire under shade. The seeds were packed in airtight plastic bottles and transported to the laboratory.

An experiment was set up to test the effect of dry heat and nipping when combined. Dry heat treatment involved placing of seeds in a petri dish and putting them in an oven at a constant temperature 40 °C for durations of 1, 2, 3, 4, and 5 hours. Nipping was done by holding a seed with a forceps and removing using a scalpel blade a small part of the seed coat until the endosperm was exposed As a control, intact seeds were also subjected to the same dry heat treatments. Seed germination test was carried out on sand in a glasshouse in a Complete Block Design with 3 blocks. Fifty seeds were sown for each treatment in each block. Observations were done daily to record the first germination. Seed were considered to have germinated when it had at least 1 cm protrusion from the sand. After initial germination, seed germination was recorded daily.

Results and discussion

Promotion of seed quality through control of insects suspected to predate on seed embryo

There was a positive correlation between *D. sanguineus* probing damage and; absence of germs in fruits of Osyris, the probing and discolouration and presence of fly. There was no difference in the viability between the fruits from chemical treated trees and the water-treated ones (p=0.065). High proportions of *D. sanguineus* probed fruits were observed to be those with the brown and variegated colours (Table 1). These also had low viability.

Table 1. Insect damage in Osyris fruits at different maturity stages.

	Fruit colour					
	Brown	Green	Orange	Red	Variegated	Yellow
%Probed	94	34	49	29	83	66
% with Germ present	5	64	64	85	9	19

The seeds probed by *D. sanguineus* mostly ended up with a discolouration of the endocarp and no visible germ. The absence of germ, an indicator of the loss of viability, could be due to sucking of the sap in the green fruit by the insect while the discolouration could be due to the insect either introducing a fungal pathogen or weakening the fruits making them susceptible to a latent fungus in the plant.

The variegated fruits had green and orange colours on the fruits and were also distorted in shape due to the probing action of the insect. The brown and the variegated fruits had the least number of seeds with the germ while the red fruits had the highest observed viability. The damage of *D. sanguineus* appears to occur at the green stage of the fruits with damaged fruits getting distorted and finally turning brown. The non-damaged fruits mature to yellow and finally to red fruits, which are mostly viable.

Granted that there was no significance difference in the viability between the fruits from chemical treated trees and the water-treated ones, and that chemical use is also expensive an economic considerations need to be made to decide whether their use is necessary.

Seed germination experiment

Germination capacity was derived from the counts of germinated seeds as a percentage of the total number of seeds sown. The germination pattern was analyzed through graphical presentation. The significance of seed pre-sowing treatments means was tested by factorial analysis on the transformed arcsin square root of germination percentages. The pattern of germination over the duration of the experiment is presented in figure 1.

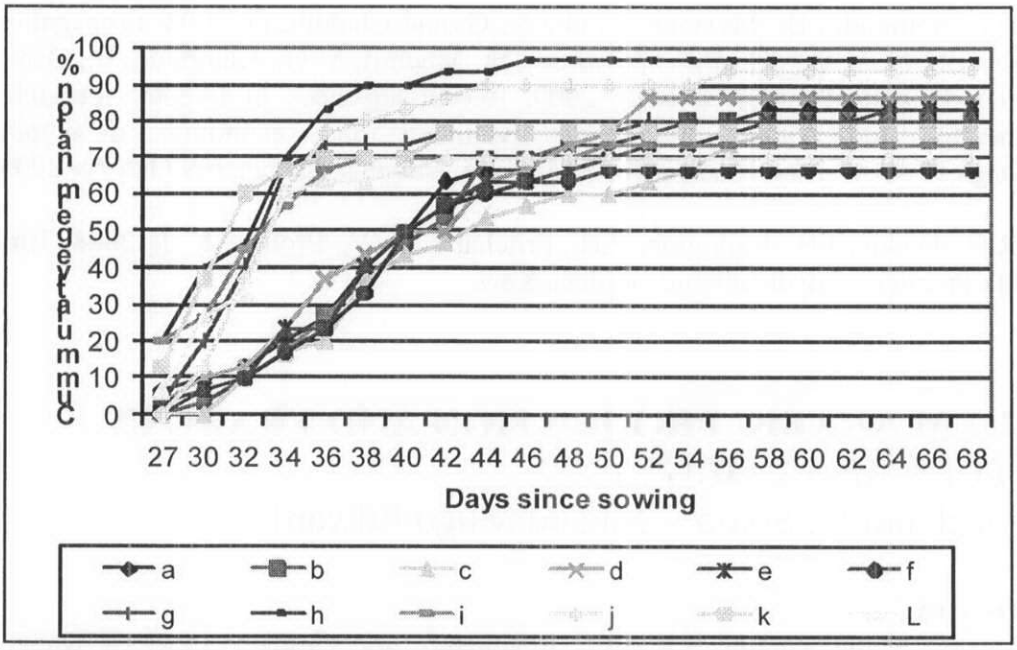

Figure 1: Germination trends of Osryis subjected to nipping (group of curves with higher germination) and dry heat treatments (group of curves with lower germination)

The germination curves separated in two groups up to about day 45 into the germination period with nipped seeds generally having higher germination. However on testing for significance the treatments did not significantly affect the final germination capacity. However, the treatment had significant effect on mean germination time and germination value.

Recommendations

The insect, *D. sanguineus* appears to be responsible for loss of viability in fruits of *Osyris lanceolata.* Use of chloropyrifos and imidachloprid does not appear to increase the proportion of seeds that are viable in the field. Red fruits have least insect attack and should be picked for more viable seeds. The seasonality of insect attack need to be investigated to determine the best time for fruit harvesting that ends with most viable seeds. The fungi associated with the fruits of *O. lanceolata* need to be investigated and documented for their management.

Osyris seed should be subjected to flotation before and after depulping and sinkers used in raising seedlings. To hasten germination and avoid seed losses through predation and fungal attack, seed should be nipped before sowing.

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3.2 GUM ARABIC PRODUCTION AND TRADE IN TURKANA COUNTY

Gachathi F., Somo Abdi and Mugo Edward

Introduction

The majority of the Turkana County's inhabitants are Turkana, most of whom are pastoralists. They practice a mixed economy based on animal husbandry which include cattle, camels, goats, sheep and donkeys, growing of sorghum and collecting of wild fruits. Their lifestyle is largely determined by the needs of their animals. Ecological conditions, which are both diverse and unpredictable, force them to exploit natural resources in a highly versatile way. Gum arabic is among these natural resources and could be an appropriate option to livelihood diversification in Turkana. The purpose of this study was to map out areas of gum arabic production in Turkana and understand how it is marketed.

Gum Arabic producing areas

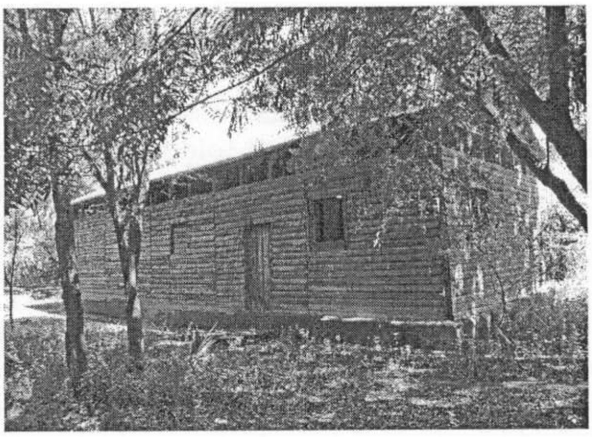
Eighteen areas in Turkana County were recognized as the main gum arabic producers with well-established collection Centres. These areas can be grouped into four broad Regions: South, comprising Kaakongu, Kaalem ngorok, Lokichar, Kasuroi and Nakukulas; West, Lorengkipi, Namorupus and Lokiriama; North West, Latea and Kalobeyei; North, Kaeris, Mlimatatu, Kaleng, Kaikor, Kakelae, Sasame, Kachoda and Lokitaung (Fig. 1). In an effort to get gum arabic from as close to the source as possible, all areas except two, which were inaccessible (Nakukulas and Latea) were visited. The GPS readings and elevations were recorded (Table 1). A common feature of these areas is that they are hilly and rocky. The gum arabic producing species was *Acacia senegal* var. *kerensis* often growing together with *A. reficiens*.

Trade of gum Arabic in Turkana

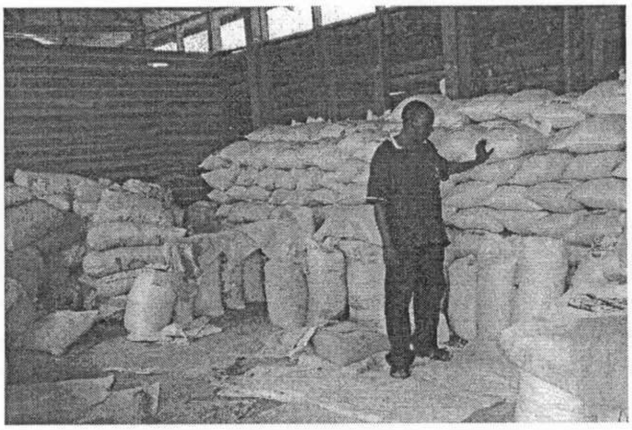
In Turkana, gum arabic were collected by men, women and even children. Organized gum collector groups were found in Kaakongu and Kasuroi. The gum was sold to local traders in trading centers. These traders were mostly of the Somali community who kept shops, some in very remote areas. Two modes of sale were commonly used; barter, which involved exchange of gums for foodstuff (sugar, maize flour, rice, beans, tea leaves, salt) or related needs (beads, tobacco, human or livestock medicines) and cash. Collectors who opted for cash were paid between Ksh 30 and Ksh 40 per kilogramme. The traders after buying about 5-10 bags or when transport was available delivered the gums to Lodwar where they sold it to Slade stores. Traders were paid 70 shillings per kilogramme. Here gums were properly cleaned, sorted and packed into 50 kg bags which are labelled. The store maintains six regular workers and hires extra labour at the pick of the season. According to the lady in-charge of Slade stores, gum arabic was transported to Nairobi when every 10 tones were ready.

Table 1. Main gum arabic producing areas in Turkana County

Region	**No.**	**Area/Centre**	**GPS Readings**		**Elevation**
			Northing	**Easting**	**Metres**
SOUTH	1.	Kaakongu	02^0 01.635’	035^0 31.596’	737
	2.	Kaalem ngorok	02^0 08.043’	035^0 29.816’	744
	3.	Lokichar	02^0 22.586’	035^0 38.684’	778
	4.	Kasuroi	02^0 28.604’	035^0 39.339’	754
	5.	Nakukulas			
WEST	6.	Lorengkipi	02^0 34.385’	034^0 59.488’	885
	7.	Namorupus	02^0 50.409’	035^0 02.159’	744
	8.	Lokiriama	02^0 45.489’	034^0 52.692’	889
NORTH W.	9.	Letea			
	10	Kalobeyei	03^0 45.050’	034^0 37.392’	651
NORTH	11	Kaeris	03^0 59.226’	035^0 28.806’	688
	12	Mlimatatu	04^0 08.366’	035^0 28.040’	673
	13	Kaleng	04^0 22.204’	035^0 33.972’	605
	14	Kaikor	04^0 31.273’	035^0 25.275’	593
	15	Kakelae	04^0 31.343’	035^0 35.732’	525
	16	Sasame	04^0 29.029’	035^0 44.709’	553
	17	Kachoda	04^0 19.315’	035^0 40.686’	574
	18	Lokitaung	04^0 16.102’	035^0 45.181’	736



Store for cleaned and packed gum



Slade's gum arabic stores in Lodwar

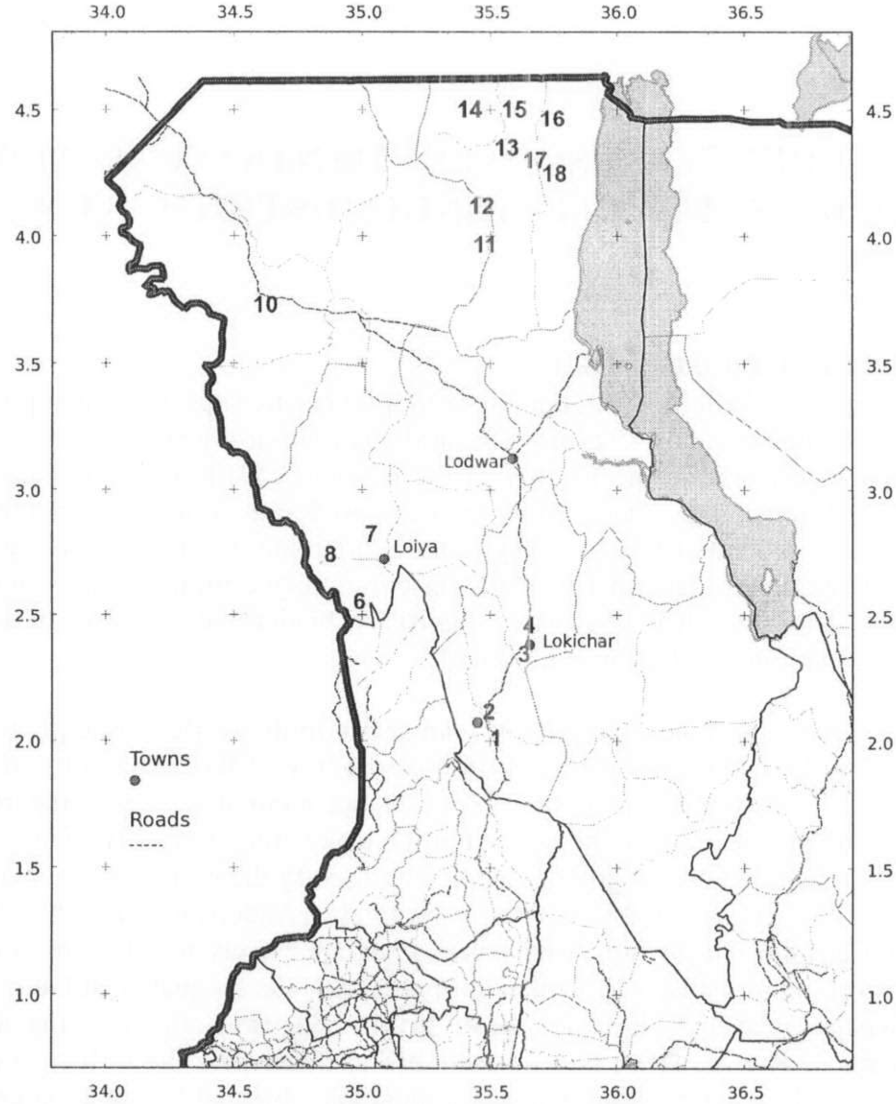


Fig. 1. Main gum arabic producing areas in Turkana district

1 Kaakongu	7 Namorupus	13 Kaleng
2 Kaalem ngorok	8 Lokiriama	14 Kaikor
3 Lokichar	9 Letea*	15 Kakelae
4 Kasuroi	10 Kalobeyei	16 Sasame
5 Nakukulas*	11 Kaeris	17 Kachoda
6 Lorengkipi	12 Mlimatatu	18 Lokitaung

* No grid reference

3.3 INFLUENCE OF SOIL ELEMENTS ON QUALITY OF GUM ARABIC IN BARINGO DISTRICT, KENYA

Lelon J.K

Background and Justification

Acacia senegal (L.) Willd is a leguminous multipurpose tree species which produces gum arabic exudate during the dry season in the arid and semi-arid lands of Kenya. It plays an important role in restoring the fertility of the degraded soils through biological nitrogen fixation in dryland farming systems. Gum arabic is produced in form of nodules or tear in arid and semi-arid lands (ASAL) ecosystem. Gum arabic is a natural polysaccharide of high-molecular weight that consists mainly calcium, magnesium, and potassium salts and some mineral elements. It is used as an emulsifier, binder and stabilizer in the food and pharmaceutical industries (Lelon et al. 2010).

Kenya has emerged as a new supplier of gum arabic in the world market, but the country does not meet the competitiveness and adequate supply of the commodity to the market (FAO, 1995). Kenya's gum is not able to attract premium prices compared with the Sudan gum in the world market because of problems relating to quality (FAO, 1990). The international specifications of gum arabic quality specify the optical rotation and nitrogen content as -26^0 to -34^0 and 0.26 - 0.39%, respectively, (Anderson *et al.* 1990, 1991). The quality of Kenyan gum has not been investigated adequately to allow its improvement. Research work on influence of chemical properties of soils on quality of Gum arabic from *Acacia senegal* varieties has not been given adequate attention under dry land environments of Kenya. There is need therefore to investigate the influence of chemical properties of soils in relation to quality of gum arabic obtained from the natural stands of *Acacia senegal* varieties between and within sites under the ASAL conditions of Marigat division, Baringo district.

Objectives

The objectives of this study were to determine the soil chemical properties in relation to chemical properties of gum arabic from *A. senegal* varieties and factors that influence quality in the four study sites and compare the physicochemical characteristics of the gum arabic of the area with international specifications.

Materials and Methods

Study area

The study sites were Solit (ST), Kimorok (KK), Kapkun (KN) and Maoi (MI), in Marigat division, Baringo district. Selection of sites was based on survey of high stand density, occurrence and wide distribution of *A. senegal* and its varieties. The size of the plots in Solit and Kapkun with high stand of *A. senegal* var. *senegal* and other closely related species was 0.5 and 1.0 ha, while 0.8 and 1.0 ha for Kimorok and Maoi with high stand density of *A. senegal* var. *kerensis* and other closely related species.

Soil and gum arabic analysis

Methods for determination of nitrogen content and trace elements in soils and gum arabic samples were done to according to the methods of Anderson and Ingram (1993 and Okalebo *et al.* (2002).

Data analysis

Statistical analysis of data was carried out using SPSS for windows Release 8.0.0 (1997) and Microsoft Excel (2003) computer software. The statistical method used was Analysis of Variance (ANOVA) using Generalized Linear Models Procedure (GLM).

Results and Discussion

The international specifications of quality parameters of gum arabic are given in Table 1.

Table 1: International Specifications of Quality parameters of Gum Arabic

Source of Gum arabic: Kordofan gum belt region, Sudan Ref: FAO (1990)			
Species: *Acacia senegal* var. *senegal* and its varieties			
Moisture content (105^0C)	13	-	15 %
Ash content (550^0C)	2	-	4 %
Volatile matter (105^0C)	51	-	65 %
Internal energy (850^0C)	30	-	39 %
Optical rotation	-26^0	-	34^0
Nitrogen content	0.26	-	0.39 %
Cationic compositions of total ash content (550^0C)			
Copper	Iron	Manganese	Zinc
52 – 66 ppm	730 – 2490 ppm	69 – 117 ppm	45 – 111 ppm

The international specifications state that quality parameters of gum arabic must conform to certain chemical specifications and these must be adhered to by both the producers and processing enterprises. The parameters are meant to identify and characterize the toxicological risks and hazards and provide the assurance that gums have not come from other tree species. To maintain and sustain high gum quality in the world market. Correlations between soil chemical properties and gum composition in relation to sites and varieties are used to reveal the variety of *Acacia senegal* that produce better quality of gum arabic. The correlations between soil nitrogen, available micronutrients (copper, iron, manganese and zinc) of soils and gum arabic compositions are presented in Table 2.

Table 2 Correlations between soil and gum chemical properties

	Soil N	Soil Cu	Soil Fe	soil Mn	Soil Zn	Gum N	GumCu	Gum Fe	Gum Mn	GumZ
Soil N	1	-0.079	-0.017	0.037	**- .390****	**-0.244***	0.13	0.166	0.232	**0.465****
	.	0.519	0.89	0.761	0.001	0.044	0.288	0.174	0.056	0
Soil Cu	-0.079	1	**0.286***	**0.333****	-0.18	-0.009	0.23	0.084	0.04	**0.286***
	0.519	.	0.017	0.005	0.138	0.942	0.057	0.494	0.744	0.017
Soil Fe	-0.017	**0.286***	1	**0.721****	-0.143	-0.018	0.18	-0.133	**0.321****	0.036
	0.89	0.017	.	0	0.242	0.882	0.139	0.276	0.007	0.769
Soil Mn	0.037	**0.333****	**0.721****	1	-0.231	0.059	0.011	-0.038	0.117	0.06
	0.761	0.005	0	.	0.056	0.63	0.928	0.756		0.624
Soil Zn	**- 0.390****	-0.18	-0.143	-0.231	1	-0.06	**0.289***	-0.167	0.091	0.108
	0.001	0.138	0.242	0.056	.	0.623	0.016	0.17	0.456	0.379
Gum N	**- 0.244***	-0.009	-0.018	0.059	-0.06	1	-0.204	0.082	**- 0.379****	-0.225
	0.044	0.942	0.882	0.63	0.623	.	0.093	0.504	0.001	0.063
Gum Cu	0.13	0.23	0.18	0.011	**0.289***	-0.204	1	0.072	**0.243***	**0.506****
	0.288	0.057	0.139	0.928	0.016	0.093	.	0.555	0.044	0
Gum Fe	0.166	0.084	-0.133	-0.038	-0.167	0.082	0.072	1	**- 0.447****	0.192
	0.174	0.494	0.276	0.756	0.17	0.504	0.555	.	0	0.114
Gum Mn	0.232	0.04	**0.321****	0.117	0.091	**-.379****	**0.243***	**- 0.447****	1	0.213
	0.056	0.744	0.007	0.339	0.456	0.001	0.044	0	.	0.079
Gum Zn	**0.465****	**0.286***	0.036	0.06	0.108	-0.225	**0.506****	0.192	0.213	1
	0	0.017	0.769	0.624	0.379	0.063	0	0.114	0.079	.
N	69	69	69	69	69	69	69	69	69	69

Footnote:

N = 69
r = Pearson correlation
P value = Sig. (2-tailed)
** = Correlation is significant at the 0.01 level (2-tailed).
* = Correlation is significant at the 0.05 level (2-tailed).

(a) Nitrogen

Acacia senegal variety *senegal* in Solit and Kapkun had negative correlation between soil nitrogen and gum nitrogen at r = -0.28 ($P < 0.05$). This was attributed to high level of SOM (1.97%) that increased the availability of nitrogen (0.3%) in the soils. Soil nitrogen was highly correlated to gum zinc with r = 0.47 ($P < 0.01$, Table 1). The positive correlation showed interaction between nitrogen and zinc as a result of high levels of nitrogen that reduced the availability zinc uptake by *Acacia senegal* varieties from the soils.

(b) Copper

The correlation between soil copper and gum copper on *Acacia senegal* variety *senegal* in Solit and Kapkun was r = 0.088 (P <0.05). The positive correlation between soil copper and gum copper was due to high levels of calcium (17.33 cmol (+)/ kg) that accumulated on the soil surface which reduced the availability copper uptake by *Acacia senegal* variety *senegal*. The correlation between soil copper and gum zinc was r = 0.29 (P <0.05; Table 1). This was attributed to high levels of Zn (7.64 ppm) that reduced the availability copper uptake from the soils. Gum copper was highly correlated to gum zinc with r = 0.51 (P <0.01). This may be attributed to high levels of phosphorus that accumulated on the soil surface which reduced the availability zinc uptake by *Acacia senegal* varieties from the soils.

(c) Iron

The correlation between soil iron and gum iron on *Acacia senegal* variety *senegal* in Solit and Kapkun had positive correlation (r = 0.09) which showed interaction between soil iron and gum iron composition. This was as a result of the effect of high level of calcium that inhibited concentrations of iron (151.21 and 250.05 ppm) that reduced the availability iron uptake from the soils. Soil iron was highly correlated to gum manganese with r = 0.32 (P <0.01). This was attributed to high levels of manganese (383.23 ppm) that reduced the availability iron uptake from the soils. Gum iron was highly correlated to gum manganese with r = -0.45 (P <0.01). This was as a result of high levels of copper (1.67 ppm) that reduced the availability iron uptake from the soils.

(d) Manganese

The correlation between soil manganese and gum manganese in Solit and Kapkun was r = -0.08 (P <0.05). The negative correlation in Solit showed interaction between manganese and manganese in gum composition because the effect of high level of calcium that inhibited concentrations of manganese (263.03 ppm) that reduced the availability manganese uptake from the soil. In Kapkun, available manganese (343.90 ppm) was high because of acidic sandy clay soils (pH 5.96).

(e) Zinc

In Solit and Kapkun, negative correlations between soil zinc and gum zinc was r = -0.15 (P <0.05). The negative correlation in Kapkun indicated interaction between soil zinc and gum zinc because of high level of phosphorus (13.91 ppm). Solit had high soil pH and calcium (pH 7.05 and 17.33 cmol/ (+)/ kg) that may have reduced the availability zinc uptake by *Acacia senegal* variety *senegal* from the soils. Soil zinc was significantly correlated at to gum copper (r = 0.29, P <0.05), because of high levels of iron and manganese (287.20 ppm Fe and 383.23 ppm Mn) which competed with copper ions and reduced its availability in the soil solutions.

Conclusions

The soil chemical properties (nitrogen, copper, iron, manganese and zinc) showed strong correlations with gum arabic compositions (gum nitrogen, copper, iron, manganese and zinc) which proved the effect of soil conditions as factors influencing quality parameters of gum arabic.

The quality of gum arabic parameters depend on the variety, the soil conditions and availability of the nutrient uptake, difference in varieties of *Acacia senegal* and soil types in the study sites.

The quality of gum arabic from *Acacia senegal* variety *senegal* and *Acacia senegal* variety *kerensis* had average nitrogen (0.28% - 0.34%), and levels of iron, manganese and zinc were similar to gum quality parameters (nitrogen content of 0.26 - 0.39%) of international specifications.

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3.4 MANAGEMENT OF INVASIVE SPECIES: THE EXAMPLE OF PROSOPIS SPECIES

By Choge Simon

Introduction

Two donor supported projects on management and utilization of Prosopis were initiated during the period under review. The first one was a collaborative project between KEFRI and KARI supported by ASARECA. It focuses on the early warning and contingency plans for resource management during crisis in pastoral and agro pastoral areas of East and Central Africa. It also addresses the human conflicts and natural disasters within the Greater horn of Africa and the implications of resource sharing, examples of which is Prosopis feeds that remain one of the critical resources in ASALs.

The second related project deals with local utilization of prosopis leaves and pods for feeding livestock during drought as a mitigation measure, and is supported by the Ministry of Livestock Development in collaboration with KEFRI and the University of Nairobi. Various project activities were successfully carried out during the reporting period and are therefore reported here.

Objectives

Broad objective

The long-term goal of the projects dealing with management of invasive species is to bring the invasions under complete control in Kenya, particularly *Prosopis juliflora* tree species.

Specific objectives

The specific objectives were are as follows;

(a) To conduct a learning tour to South America and India to document the technologies being used to manage, control, process and utilize prosopis tree resources
(b) To establish linkages with other countries and institutions with a view to synergize efforts towards management and utilization of the species
(c) To document the crisis types and their associated indicators, coping mechanisms and the mitigation measures within the ASALs of Kenya
(d) To facilitate the affected communities to collect, process and to use Prosopis feed resources as a mitigation strategy for drought

Methods

Learning trips to Argentina, Peru and India
Members of the delegation were drawn from the Ministry of Livestock, the University of Nairobi and KEFRI.

Linkages with other countries and institutions to symergize efforts on management of Prosopis
During the learning tour, institutions dealing with management and utilization of Prosopis were identified; letters of intent to undertake joint collaborative approaches on management were also signed between the representatives of the respective institutions.

Documentation of crisis types and their associated indicators, coping mechanisms and the mitigation measures within the ASALs of Kenya
This activity was carried out by hosting community workshops in three representative districts of Baringo, Tana River and Taveta using two representative communities in each case. In Bura, the communities selected were the Orma (purely pastoral living within the plains) and the Malakote/Wailuana (semi pastoral, living along the riverine areas of River Tana). Twenty (20) members of each community were selected and assembled for one day workshop. In Baringo, Njemps and Tugen were selected while in Taveta, the Wataveta were selected.

Facilitation of the communities affected by Prosopis invasions to collect, process and to use Prosopis feed resources as a mitigation strategy for drought
Viable community groups were identified in Taveta, Baringo and Tana River and given milling machines to process Prosopis pods

Results

Learning trips to Argentina, Peru and India

(a) Use of Prosopis pods as a raw material for manufacture of livestock feeds and human food are growing industry in Argentina, Peru and India. Much research is being carried to improve the processing as demanded by the growing local and export market base for the products

(b) Private Public Partnership have been initiated to commercialize the processing technologies for Prosopis products in each of the countries

(c) Improvement of Prosopis characteristics through grafting and breeding are on-going in each of the countries because Prosopis is largely considered as a crop. Several Prosopis species are being tested by research institutions, including those that have no thorns and with very sweet pods.

(d) Marketing of the feeds are has also successfully began by private companies working closely with national research institutions in each of the countries

(a) Making of human food from Prosopis is also a growing programme in all the countries visited. The human food units have been created in many institutions, and they have successfully made Coffee substitute from Prosopis as well as a number of other foods such as cakes and biscuits, all now being sold on shelves in the supermarkets. In India for example, the local communities eat fresh leaves and fruits of Prosopis cineraria and it are a very delicious meal in many dry areas of India. Prosopis cineraria is an indigenous tree to India. CAZRI has manufactured a machine that is able to separate all parts of a pod particularly when being used for human food.

(b) Use of Prosopis for production of electricity is an established industry in India. Because of this, the Government of India has sanctioned the planting of Prosopis in dry areas and desert parts to supply the biomass to electricity producing industries in the country. This is a new policy that has just been implemented in India

(c) Use of Prosopis for furniture industry is also an established industry in Argentina and India. Prosopis wood is mainly used in the manufacture of chairs, coffee tables and many other articles of high value for household and company use in each of the countries and also for export

Linkages with other countries and institutions to symergize efforts on of management Prosopis

Letters of intent to undertake joint research were signed with 14 different institutions in all the 3 countries visited. KEFRI's management is in the process of formalizing these agreements through the Minstry of Forestry and Wildlife.

Documentation of crisis types and their associated indicators, coping mechanisms and the mitigation measures within the ASALs of Kenya

Most communities prioritized drought as the most serious environmental crisis faced. Its wide-ranging effects are felt across board in all livelihoods, gender and economic mainstays. They indicated that majority of them depend on livestock and livestock products as the main economic livelihood as well as crop production in certain cases. On the communication pathways, mobile phone is preferred in among all the communities as well as across the three sets of participants i.e. community representatives, technical staff, and Policy makers. The communities cited their inability to process Prosopis pods due to lack of machinery and training to do so.

Facilitation of the communities affected by Prosopis invasions to collect, process and to use Prosopis feed resources as a mitigation strategy for drought

In response to the problems documented from the communities covered, theprojectsfacilitated the purchasing and delivery of milling machines to the identified groups to be shared by the members and other community members.

Conclusion

Experiences documented from Argentina, Peru and India show that Prosopis is now considered as a commercial tree crop. Targeted research towards its improvement through breeding, grafting hence cultivation of improved germplasm is a high priority activity in these countries. Our research and development programmes will therefore borrow very heavily from these experiences in the near future.

3.5 GENETIC DIVERSITY AND POPULATION STRUCTURE OF *ACACIA SENEGAL* (L) WILLD. IN KENYA USING RAPD MARKERS.

Machua J., Omondi. S. and Odee David

Introduction

Acacia senegal(L.) Willd. is a deciduous shrub of medium sized multipurpose agroforestry species that belongs to the subfamily Mimosoideae and classified in the subgenus *Aculeiferum,* which accommodates all African *Acacia* species lacking spinescent stipules (2001). It is commonly found in arid and semi-arid zones, mostly in the tropical and sub-tropical regions of sub-Saharan Africa and extends to Indian sub-continent. The species has four varieties namely; var. *senegal*, var. *kerensis*, var. *rostrata* and var. *leiorhachis* (Brenan 1983). Three varieties, *kerensis*, *senegal* and *leiorhachis* are found in Kenya sometime together or closely distributed, with *kerensis* being widely distributed and the commercial gum arabic producer (Fagg & Allison 2004).

Acacia senegal is known to produce gum arabic, a commodity of international trade widely used in food, pharmaceuticals, cosmetic products and lithographic ink companies (motlagh *et al.* 2006). The species also provide ecological implications for households in asals of Africa by restoring soil fertility and conserving environment (fagg & allison 2004). Variety *senegal* is known to produce higher quality gum arabic compared to other varieties, while *kerensis* produces gum with higher viscosity and protein content making it less valuable. the two varieties are found in Kenya sometimes together or closely distributed hence higher possibility of cross-pollination and exchange of genetic information. The species have shown several phenotypic variations but it is not yet known whether they represent response to habitat variations in an otherwise normal population or genetic differences (Brenan 1983; Fagg & Allison 2004). No sufficient information is available on how much genetic information is exchanging between the *A. senegal* populations in Kenya, despite its biological, social and economic importance. Such information is crucial for devising strategies to sustainably utilize the genetic resource. Furthermore, knowledge of within and between population differentiations will help to develop efficient sampling strategies. The central aim of the present study was to characterize and understand the genetic diversity among the natural populations of *A. senegal* in Kenya using RAPD markers. The specific objectives were: 1) To study the genetic diversity within and among populations, 2) To detect the underlying population differentiation and structure among the populations.

Materials and methods

Population sampling

Two hundred and ninety individual from 11 natural populations of *Acacia senegal* in Kenya were sampled for this study. Between 20-30 adult trees were sampled per population at a distance of between 150-600 m apart depending on the size of the population and distribution of trees within the population. A minimum distance of 150 m between individual trees was used to avoid the risk of selecting closely related individuals. The leaves were dried on silica gel and stored at -20°C until DNA extraction.

Table 1: Geographic locations and descriptions of the study sites (populations)

Population	Code	Longitude	Latitude	Alt (m)	T (°C)	RF (mm)	N
Ngarendare	NN	0°33′39.9″	37°20′45.3″	972	27	580	30
Daaba	D	0°32′00.2″	37°45′39.9″	941	28	325	30
Archers Post	AP	0°39′52.7″	37°38′47.0″	810	29	550	30
Serolipi	SE	1°09′05.8″	37°35′51.9″	763	32	500	30
Kargi	KI	2°38′35.8″	37°27′34.7″	454	35	450	30
Merille	ME	1°31′40.8″	37°45′23.7″	627	36	650	30
Ngurunit	Ng	1°43′17.0″	37°17′24.3″	760	34	700	30
Lokichar	LO	2°21′57.2″	35°38′24.5″	786	38	225	20
Lokitaung	LOK	4°23′48.5″	35°31′40.5″	606	36	200	20
Kakuma	KA	3°45′26.1″	34°39′59.5″	670	38	240	20
Marigat	MA	0°28′20.4″	35°55′10.6″	1243	28	1250	30

*n, number of tree sampled per population; Alt, altitude; T, temperature; RF, rainfall

DNA extraction and PCR amplification

Total genomic DNA was isolated from the leaves following a modified CTAB protocol and quantification performed through comparison with low DNA mass ladder (Invitrogen) in ethidium bromide-stained 1% agarose gels. A total of 40 arbitrary primers were screened for RAPD amplification. Ten of the RAPD primers were found to show clear and analysable bands. Polymerase chain reaction (PCR) amplification was carried out in a 25µl reaction volume containing 1XPCR buffer (10 mM Tris-HCL pH 8.3, 50 mM KCl, 1.5 mM $MgCl_2$), 200mM each of dNTPs, 20 µM of primer, 0.5 units of Taq polymerase (Invitrogen) and 25 ng DNA template.

PCR amplification was performed in a TECHNE TC - 412 Thermal Cycler (UK), with an initial denaturation at 94.5 °C for 5 min., followed by 40 cycles. Each cycle consisted of denaturation at 94 °C for 45 s, primer annealing at 37 °C for 1 min, and extension at 72 °C for 2 min with a final extension at 72 °C for 5 min. PCR products were separated on 1.5 % agarose gel in 0.5 X TBE (Tris–Borate EDTA) buffer and stained in ethidium bromide (10mg/ml). The sizes of the amplified fragments were determined using a 100-bp DNA ladder (Invitrogen) run along the sides of the amplified products. The amplified products were visualized under ultraviolet light and photographed with gel documentation system (Gel LOGIC 200 imaging system-Kodak MI SE)

Data analysis

To assess molecular variation, Shanon's diversity index was used. Nei's unbiased genetic distance (*D*) was determined using POPGENE 1.32 software. The Nei's genetic distance matrix was used to generate the phylogenetic tree using unweighted pair group arithmetic average method (UPGMA) method in MEGA software (Tamura *et al.*, 2007). Analysis of molecular variance (AMOVA) was performed using GenAlEx 6.4 software (Peakall and Smouse, 2006).

Results

Out of 40 RAPD primers screened, 10 produced clear and reproducible fragments and yielded a total of 360 scorable fragments of 200 – 1450 base pairs (bp). Individual primers generated between 22 – 36 bands with a mean of 29 bands per primer. Of the 360 bands, 301 (83 %) were polymorphic across the 2900 trees. The diversity observed was very high with the mean percentage polymorphism at 70.80 % but ranging from 62-85% per population. The higher number of polymorphic loci (85%) was exhibited at Ngurunit while the lowest (62%) at Lokichar population. Other diversity indices used to describe variations includes; mean number of observed alleles (A) which ranged from 1.8-2.6, gene diversity (H) ranged from 0.173-.0386 and Shannon information index (I) ranged from 0.235-0.411. Analysis of molecular variance (AMOVA) found most of the genetic variation residing within the populations (91%) rather than among the populations (9%) (Table 2).

Table 2: Analysis of molecular variance (AMOVA) of 11 populations of *Acacia senegal*

Source of variation	DF	SS	MS	Est. Var.	%Mol var.
Among populations	10	167.103	16.710	0.453	9%
Within populations	289	1268.467	4.389	4.389	91%
Total	299	1435.570		4.842	100%

DF, degrees of freedom; SS, sum of square; MS, mean square, Est.Var., estimated variance; % Mol.

Var., percentage molecular variance

The UPGMA cluster analysis based on Nei's genetic distance identified two main groups by clustering Daaba, Lokichar, Merille; Marigat, Lokitaung and Kakuma populations together with a sub-cluster of Daaba, Lokichar and Merille on one side and another having Marigat, Lokitaung and Kakuma; a second group consisting of, Ngurunit, Ngarendare, Archerspost, Kargi and Serolipi populations with a sub-cluster of Ngarendare and Serolipi in one group, ArchersPost and Kargi in another group leaving Ngurunit isolated as shown in the figure bellow.

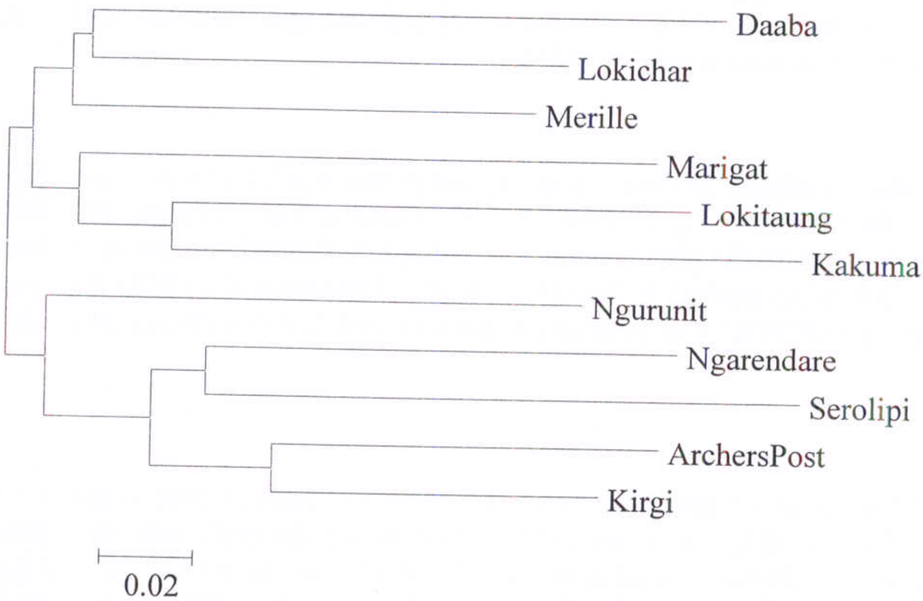

Figure 1: Unrooted UPGMA dendrogram of pairwise genetic distances between 11 populations of *Acacia Senegal* in Kenya.

Discussion and conclusion

The RAPD analysis of the 11 populations discovered high levels of genetic diversity, with a total of 48 alleles and mean number of alleles per locus per population ranging from 4.4 to 5.3. The diversity discovered are similar to those reported in other studies (Chiveu *et al.*, 2008), but much higher than those reported for this species using isoenzyme technique (Chevallier and Borgel, 1998). The diversity observed may be maintained by sufficient gene flow among the populations facilitated by efficient pollen movements. It has been reported by White *et al.* (1999) that increased pollen movement counteract the negative effects proposed for habitat destruction and fragmentation. Similar findings were reported for the dry forest tree *Enterolobium cyclocarpium*. The results also agree with the predictions of Hamrick and Godt (1996), that tropical plant species, on average, maintain high levels of variation within populations than among populations. This same pattern was observed in populations of *Acacia melanoxylon*.

The higher genetic diversity realized suggests that the studied populations are amenable to *in-situ* genetic conservation. Genetic structure of the species was characterized by greater genetic variability within populations rather than among populations. This is an indication of the out-crossing characteristics of *Acacia* species and efficient gene flow among the populations. For the establishment of a breeding program, or seed orchard, populations of *A. senegal* can be identified which have high levels of genetic diversity so that as much variation as possible can be captured in the base population.

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3.6 TISSUE CULTURE OF SANDALWOOD (OSYRIS IANCEOLATA)

Machua Joseph and Nyingi James

Introduction

Domestication of *Osyris lanceolata* (Sandalwood) has been hampered by low seed production, poor germination that at times can take upto a year (Mwangingo *et al*, 2006) and high variability between individual trees. Seeds are available in small quantities and there is unreliable supply. Alternative means of propagation were therefore being developed to complement the seeds. Vegetative propagation through cutting has not yet yielded optimal success and therefore this study was conducted to initiate experiment on tissue culture to complement other propagation techniques

Materials and methods

Several *in vitro* trials of Osyris were set up in the laboratory to determine growth hormone concentrations that could stimulate direct organogenesis. These experiments contained basal nutrient medium based on Murashige and Skoog (MS), (1962) at varying levels of auxins and cytokinins. The growth hormones were formulated in order to induce direct organogenesis, organogenesis via callus and shoot multiplication.

Explants were harvested from young seedlings in the glasshouse and put in a glass jar containing distilled water in which 2-3 drops of Tween® 20 had been added (under Lamina flow clean bench). The jar was swirled gently for 15minutes and explants washed with running tap water for 10 minutes. The shoots were trimmed to a length of 1cm and leaves to squares of 1cm dimensions and then cultured on MS nutrient media supplemented with a cytokinin Dichlorophenoacetic acid (2, 4-D) to induce callus. A second stage media was formulated to induce somatic embryos from the callus. Whole and split seeds were treated as above. Shoot multiplication media was formulated with MS nutrient media supplemented with a cytokinin 6-benzylamino-purine (BAP). Nodal explants were harvested from young seedlings as above and trimmed to one node of 1cm and then cultured on MS nutrient media.

Results and discussions

Callus indication

Osyris lanceolata calli were induced from both nodal explants and seeds (Plates 1 and 2 respectively) in the first stage media. No callus emerged from leaf discs. Somatic embryos did not emerged in the second stage media after 8 weeks.

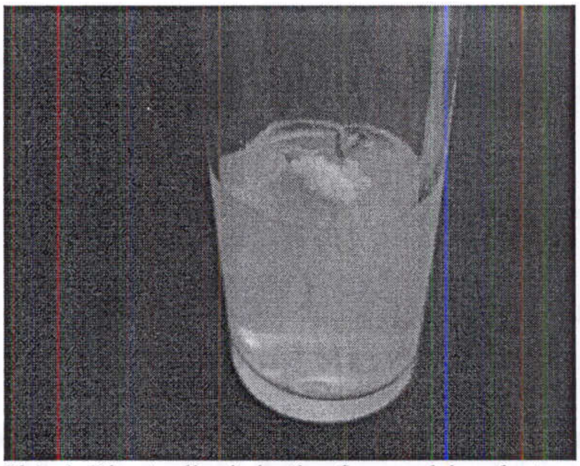

Plate 1. Direct callus induction from nodal explants

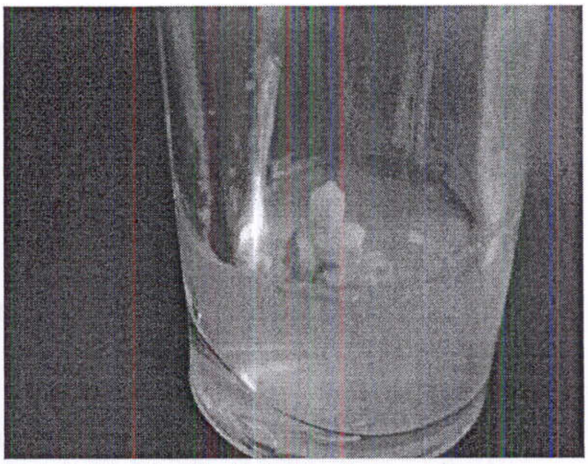

Plate 2. Direct callus induction from seeds

Shoot multiplication

Osyris lanceolata nodal explants resulted in 1:10 shoot multiplication ratio when incubated in IBA (Plates 3 and 4).

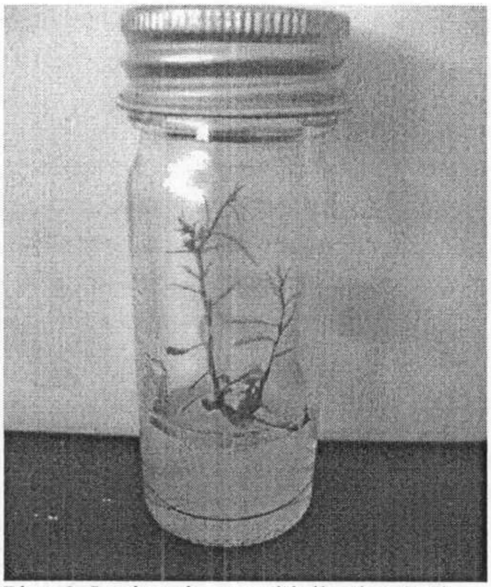

Plate 3. In vitro shoot multiplication (1:2)

Plate 4. In vitro shoot multiplication (>1:7)

Conclusions

Preliminary results indicated that *Osyris lanceolata* is amenable to tissue culture and clonal multiplication can be achieved *in vitro*. These results indicate that a protocol has now been established for *in vitro* shoot multiplication of Sandalwood (*Osyris lanceolata)* from nodal explants and future studies can now focus on rooting either *in vitro* or *ex vitro* in the nursery

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3.7 RELATIONSHIPS BETWEEN *ACACIA SENEGAL* TREES AND SOIL MICROBIAL COMMUNITIES

Machua J., Kimiti J. and Odee D.

Introduction

In year 2010 an assessment of natural rhizobia populations in soils from various sites continued according to Odee et al., (2003). Three *Acacia senegal* varieties were used to trap the indigenous rhizobia in a glasshouse experiment as shown in table 1.

Arbuscular Mycorrhiza assessment

An assessment of indigenous arbuscular mycorrhiza was carried out by trapping the *Glomoromycota* species from various soils using three acacia Senegal varieties; *Senegal, kerensis and* leoirachis according to Machua, (2005). Assessment was carried out on the number of spores and results are shown in Table 2.

Results and discussion

All the sites evaluated revealed a high variation in their indigenous Rhizobia inoculum potential. The three *Acacia senegal* varieties also exhibited wide variation and prevalence in nodulation under different soils. *Acacia Senegal* variety *leoirachis* trapped the highest number of Rhizobia in Kimalel soil followed by variety Senegal in the same soil (Table 1). On the contrary, variety *senegal* and *kerensis* could not trap any Rhizobia from Daaba soil in spite of *kerensis* being the dominant variety growing at Daaba. However, all the varieties were able to trap some Rhizobia from the all the other sites.

The three *Acacia senegal* varieties trapped indigenous Glomeromycota spores from various *Acacia senegal* sites (Table 2). *Acacia Senegal* variety *Senegal* trapped the highest number of mycorrhiza spores followed by variety *Kerensis.* Ngarendare site had the highest mycorrhiza spore inoculum while Solit had the least. Four Glomeromycota families namely; Scuteloporaceae, Acaulosporaceae, Glomeraceae and Gisgasporaceae were found in all *Acacia Senegal* sites with exception with the exception of Gisgasporaceae, which was missing in both Rimoi and Solit. Overall, the family Glomeraceae trapped the highest number of spores followed by Scutelosporaceae while Gigasporaceae trapped the least.

Table 1: Indigenous population of rhizobia in soils collected from nine sites with natural populations of the three *Acacia senegal* varieties.

		Acacia Senegal **varieties**		
		Senegal	***kerensis***	***leiorachis***
Site	**Rimoi**	1.95×10	4.3×10	4.58×10^2
	Kulamawe	5.4	6.1	1.06×10^2
	Kajiado	2.65×10	1.14×10	2.73×10^2
	Ntumburi	1.04×10^2	1.95×10	5.35×10
	Solit	1.82×10	1.69×10	2.13×10^2
	Namanga	1.56×10	7.3	7.3
	Kimalel	5.59×10^2	1.63×10^2	5.94×10^3
	Ngare Ndare	8.4	3.0×10	1.18×10
	Daaba			1.1

Table 2. ***Glomeromycota spores in various*** **Acacia senegal** ***sites in Kenya***

Site	Variety	Scuteloporaceae	Acaulosporaceae	Gisgasporaceae	Glomeraceae	Total spores
Kimalel						
	Senegal	21	12	2	43	78
	Kerensis	15	6	0	44	65
	Leiorachis	10	11	0	28	49
						192
Solit	Senegal	24	12	0	9	45
	Kerensis	17	8	0	3	28
	Leiorachis	12	9	0	3	24
						97
Kajiado	Senegal	32	24	10	60	126
	Kerensis	28	30	10	45	113
	Leiorachis	31	18	8	44	101
						340
Rimoi	Senegal	18	8	0	51	77
	Kerensis	16	10	0	53	79
	Leiorachis	8	3	0	28	39
						195
Kulamawe	Senegal	46	40	3	102	191
	Kerensis	35	41	0	76	152
	Leiorachis	39	28	3	76	146
						489
Ntumburi						
	Senegal	29	7	0	13	49
	Kerensis	11	3	3	14	31
	Leiorachis	16	3	0	11	30
						110
Ngarendare	Senegal	67	18	3	204	292
	Kerensis	53	24	0	182	259
	Leiorachis	52	34	3	155	244
						795
Daaba	Senegal	13	10	5	33	61
	Kerensis	11	12	0	19	42
	Leiorachis	11	8	3	24	46
						149
	Total	**615**	**379**	**53**	**1320**	**2367**

Conclusion

These results indicate that *Acacia Senegal* varieties are promiscuous in nodulation and will nodulate with Rhizobia form foreign soils. However, more studies on actual nitrogen fixation using 15^N natural abundance are recommended to establish the effectiveness of the nodulation. This study reveals the level of mycorrhiza diversity in *Acacia Senegal* sites. It has been shown that Glomeraceae and Scutelosporaceae are the most dominant arbuscular mycorrhiza in *Acacia Senegal* sites. These results indicate that the two Glomeromycota families (Glomeraceae and Scutelosporaceae) could be used to further develop an inoculum for *Acacia Senegal* varieties.

On-going and planned activities

A 1Ha *Acacia senegal* spacement trial plantation with mixed varieties of senegal and kerensis established in 1997 at Tiva in Kitui was loaned to Acaciagum project for microbial, physiology and genetic studies. Microbial assessment of rhizobia and mycorrhiza on this site are ongoing.

A new 1 Ha site was also established in November 2010 with various provenances. Site characterization in this site is ongoing. Measurements of soil physicochemical and microbiological parameters (pH, EC, organic C, total N, available N, total P, mineral P, available P, arbuscular mycorrhizal fungi) on this site is in progress.

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Machua, J. M. (2005) A molecular approach to monitor persistence and spread of arbuscular mycorrhizal inoculants in *Calliandra calothyrsus* (Meisn.) MSc. thesis

4.0 STAFF

4.1 RESEARCH SCIENTISTS

Name	Qualification	Designation	Research Area
Ely J.M. Mwanza	BEd Sc., M For Sc.	Chief Research Officer (Centre Director)	Forest Pathology
Linus Mwangi	Bsc. Msc	Principal Research Officer	Forest Pathology
Francis Gachathi	Bsc. Msc.	Principal Research Officer	Plant Taxonomy
Jane Njuguna	Bsc. Msc.	Principal Research Officer	Forest Pathology
Joram Kagombe	Bsc. For, Msc.	Principal Research Officer	Socio-economics
Simon Choge	Bsc. For, Msc.	Principal Research Officer	Dryland Silviculture
Eston Mutitu	Bsc. Msc.	Principal Research Officer	Entomology
Gordon Sigu	Bsc. For, Msc.	Principal Research Officer	Forest Ecology
Tom Omenda	Bsc. MSc.	Principal Research Officer	Forest Ecology
Jacinta Kimiti	Bsc. MSc., PhD	Senior Research Officer	Soil Science
Evelyn Kiptot	Bsc. For, Msc., PhD	Senior Research Officer	Agroforestry
Bernard Kamondo	Bsc. For, Msc.	Senior Research Officer	Seed Science
Joseph Lelon	Bsc. MSc., PhD	Senior Research Officer	Soil Science
Jesse Lugadiru	Bsc. For,	Research Officer I	Forest Extension
Emily Obonyo	Bsc. M.Phil	Research Officer I	Sociology
Joseph Machua	Bsc. Msc.	Senior Research Officer	Tree Biotechnology
Beryn Otieno	Bsc. Msc	Research Officer 1	Entomology
Michael Gathura	Bsc.	Research Officer ll	Forest Silviculture
Stephen Omondi	Bsc	Assistant Research Officer	Tree Breeding
Jane Njehu	Bsc.	Assistant Research Officer	Plant Taxonomy
Anne Wekesa	BSc	Assistant Research Officer	Tre Biotechnlogy

4.2 FORESTERS

Name	Designation
William Mucheke	Senior Forester
Nicholas Riako	Forester II

4.3 TECHNICAL STAFF

Name	Designation
Luke A Gibera	Senior Technologist
Simon N. Wakaba	Senior Technologist
George N. Mbuthia	Technologist I
John G. Mungai	Senior Technologist
Emmanuel Makatiani	Technologist I
Thomas O. Nyairo	Technologist I
Peter K. Kungu	Technologist I
Francis N. Mwaura	Technologist II
Margaret N. Kuria	Technologist II
Mary Gathara	Technologist II
Mwangi wa Gathura	Technologist II
James Kamau Nyingi	Technologist II
James M. Gitu	Technologist II
John O. Obango	Technologist II
Jane Njehu	Technologist II
Beatrice Ndakwe	Technologist II
Shadrack O. Aluoch	Technologist II
Eliud Waweru	Snr. Lab. Technician

Name	Designation
Jared Ogembo	Technolost ll
Lucy M. Kagunyu	Snr. Lab. Technician
Gorret J. Kigen	Snr. Lab. Technician
Mary W. Mwangi	Snr. Lab. Technician
George A. Omollo	Technician II
Ruth W. Njuguna	Senior Lab.Technician
Beth W. Ngugi	Technician II
John K. Nganga	Technician II
Peter M. Kamau	Technician II
Paul Kibera	Technician II
Grace Njeri Ngigi	Technician II
Patrick K. Maina	Technician II
Samuel Kamonde	Technician II
Samuel Wakori Kubai	Technician II
John O. Ochieng	Technologist l
Emily C. Yobterik	Senior Lab.Technician
George Opondo	Senior Lab.Technician
Anne M. Kamau	Senior Lab.Technician

4.5 ADMINISTRATION AND FINANCE

Name	Designation
Omoro Nyamamba	Accounts Assistant
Peter I. Njoroge	Assistant Administrator/Accounts
Rhodah I. Gibera	Personal Secretary I
Joyce Chege	Senior Copy Typist
Miriam Mwai	Senior Copy Typist
Alice Muroki	Senior Copy Typist
Jane N. Mwangi	Senior Copy Typist
Margaret Kimondo	Copy Typist
Anne Wachira	Copy Typist
Rahab Nderitu	Copy Typist
Jossy J. Wekesa	Senior Clerical Officer
Hannah W. Kariuki	Senior Clerical Officer
Christopher Chesire	Senior Clerical Officer
George Mmasi	Senior Clerical Officer
Malusi Makau	Clerical Officer
Enock Akali	Administrative Officer ll
Godtrick M. Kisingo	Senior Storeman ll
John Nyandiko	Senior Storeman

5.0 ALLOCATED GoK FUNDS FOR FINANCIAL YEAR 2009-2010

VOTE HEAD	PARTICULARS	AMOUNT
2210203	Postal Courier & Telegram Expenses	5,000
2210201	Telephone Exp., Telex and Mobilephone Services	-
2210300	Domestic Travel and Transport Costs	800,000
2210502	Printing & Publishing	300,000
2210503	Subscription to Newspapers and Magazines	50,000
2211004	Purchase of fungicides Insecticides & Sprays	60,000
2211005	Chemicals & Industrial Gases	550,000
2211008	Lab Materials, Supplies & Small Equipment	500,000
2211015	Food and Rations	50,000
2211016	Uniforms & Clothings	
2211023	Purchase of Supplies for Production	500,000
2211101	G.O.S. (Paper, Pencils & Small Office Equipment)	600,000
2211102	Supplies & Accessories for Computers & Printers	800,000
2211103	Sanitary & Cleaning Materials	150,000
2211201	Transport Operating Exp. – Fuel & Lubricants	1,600,000
2211301	Bank Charges & Commission	25,000
2211310	Contracted Professional Services – Others	
2220101	Maintenance of Motor Vehicles	2,800,000
2220201	Maintenance of Plant & Equipment	1,100,000
2220205	Maintenance of Buildings	250,000
2220210	Maintenance of Computer Software & Networks	150,000
2210504	Advert. Awareness & Publicity Campaign	1,200,000
2210505	Trade Shows & Exhibition	400,000
3111001	Purchase of Office Furniture	
3111002	Purchase of Computers, Printers & Other IT	170,000
3111004	Purchase of Exchange & Other Comm. Equip.	
3111107	Purchase of Lab Equipment	2,400,000
3110701	Purchase of Motor Vehicles	-
2211006	Purchase of Workshop Tools, Spares & Small Equipment	50,000
2211011	Purchase of Photographic & Audio Visual Materials	50,000
2211311	Contracted Technical Services	100,000
3111005	Purchase of Photocopiers & Other Office Equipment	100,000
TOTAL		**14,610,000**