ONGOING AND PROPOSED FUTURE RESEARCH IN INDUSTRIAL FOREST PLANTATIONS IN KENYA

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SUMMARY

Several research activities have been going on in industrial forest plantations and some achievements have been made in some areas. Appropriate seed collection, extraction and storage techniques have been developed. Seed stands and orchards have been established for several plantation species for seed production. Plus trees of *Cupressus lusitanica* and *Pinus patula* have been selected. Selection and vegetative propagation of *P.radiata trees* resistant to *Dothistroma pini* is going on. A total of 67 trees of *C.lusitanica* resistant to cypress aphid have been selected. Eight months old seedlings have no advantage over 5 months old ones after planting. Good seedling establishment have been obtained after burning logging debris and slashing weeds. A 2.5 X 2.5m spacing of trees have been found to be economically superior. Research has also been carried out on pests and diseases especially *Armillaria* root disease, diseases of seeds and seedlings and cypress aphid. A parasitoid *Pauesia juniperorum* has been introduced to control cypress aphid but has not established. Strength values of the main structural timbers has been established and are in use. Spacing have been shown to have no significant effect on wood quality. A technology for production of laminated wood products have been developed and adopted. *P.caribaea* has been found to produce higher amounts of resin than *P.ellioti*. Several *Eucalyptus* spp have been found to be suitable for production of commercial medicinal and essential oils. Other ongoing research work and achievements have been outlined in the paper. Future directions in industrial plantation research are also proposed.

1.0 INTRODUCTION

Industrial forest plantations in Kenya play a major role in the country's economic growth. They are the major source of wood for the primary and secondary wood based industries. They are also the source of woodfuel, poles and non-wood products such as resin and essential oils and are important in protection of water catchments. However, industrial plantations have mainly been grown as monocultures composed of a few exotic species particularly *Pinus patula*, *Cupressus lusitanica*, *Eucalyptus saligna* and *E. grandis*.

Forestry research has played a major role in plantation forestry development. The main objective of research in industrial forest plantations is to increase productivity per unit area in order to meet the demand for wood. High productivity of forests may be achieved through supplying high quality propagation (seed and vegetative) material, applying appropriate nursery and plantation management techniques and efficient utilization of trees.

Research has mainly concentrated on: improving the quality of seed both physiologically and genetically; development of appropriate nursery and plantation management practices; and efficient utilization of forest products. Furthermore, with monocultures, the chances of disease and pest attacks are increased and therefore an integrated pest management program has been initiated. In recognition of the importance of communities in forestry management, socioeconomic issues are being addressed. Under each of these research areas, specific problems have been identified

and research has been directed to solve these problems. This paper highlights the ongoing research activities and achievements made in the last ten years.

2.0 SEED

High quality seed is the bedrock of successful plantation forestry. To effectively collect the seed, research on flowering, fruit setting, seed maturity and timing of seed collection has been undertaken and results documented (Albrecht 1993). Furthermore, appropriate seed collection , extraction, cleaning and storage techniques have been developed. To date, all seed is tested for germination potential, maturity and weight to guarantee that only seed of high quality is supplied. The genetic quality of the seed is ensured by exploiting only designated sources following rules of seed collection for industrial development (Albrecht 1993).

To date, seed has been collected from selected and established seed sources and supplied for plantation development. In the last decade, approximately 1000 kg of *Pinus patula,* 2000 kg of *Cupressus lusitanica,* and 300 kg of *Eucalyptus* spp have been supplied. These seeds should produce at least 35,000 ha of pine, 40,000 ha of cypress and 28,000 ha of eucalyptus plantations.

Although several research issues on seed have been addressed, reports from Forest Department (FD) nurseries indicate that there is inadequate germination leading to deficient seedling production. Germination tests have therefore been initiated at KEFRI and FD nurseries to verify seedling production from the seeds supplied. The work is being done collaboratively between KEFRI and FD and has been completed in Kiambu District. These tests have confirmed the poor germination of seeds in FD nurseries. The generally low germination was attributed to poor nursery techniques and managerial problems which need to be addressed. Similar tests are planned for other districts.

Fungal attacks in seedbeds also lower germination of seeds. Work to determine the major fungal pathogens associated with tree seeds and on devising appropriate control measures has been in progress. Studies have concentrated on isolation and identification of fungi attacking *Eucalyptus spp, Juniperus procera* and *P. patula* seeds. Several fungi have been found associated with seeds of these species e.g Aspergillus spp, *Fusarium* spp and *Penicillium* spp. Use of chemicals and pretreatment methods are being tested for control of the fungi. To date, Thiram, Captan and Fernisan D are some of the chemicals found to effectively inhibit fungal growth.

For proper timing of seed collection and distribution, experiments have been undertaken to evaluate the influence of temperature on the viability of seeds over time.

Results show that *Pinus patula* is sensitive to temperatures above 30oC and germination decreases within the first year, from a range of 65 - 70% to below 50%.

Vitex keniensis, C. lusitanica and *Eucalyptus* spp seed maintain their viability even when stored at room temperature. All are amenable to conservation through storage in extreme cold regimes of -30 ^{0}C.

3.0 TREE IMPROVEMENT

3.1 Improvement progamme

Among the activities undertaken in order to supply high quality seeds is the recruitment of improved seed sources through selection and establishment of seed stands. Currently, seed stands have been established of *P. patula* (317.7 ha), *C. lusitanica* (63.5 ha), *Eucalyptus* spp (9.0) and *V. keniensis* (509.1 ha). The amount of seeds collected from these seed stands is enough to meet the FD annual requirements for quality seeds.

To further increase the genetic quality of seeds, "plus" trees have been selected that show phenotypically superior and desirable characteristics such as fast growth rates, resistance to diseases and pests, good form, good branching habits and high wood quality. To date, 146 *C. lusitanica* and 75 *P. patula* "plus" trees have been selected and used for establishing clonal seed orchards for supplying genetically high quality seeds. Currently, there are 12.3 ha. of *C. lusitanica* and 13.6 ha. of *P. patula* seed orchards. In addition, a tree bank consisting of all "plus" trees has been established for conservation purposes and for studies on phenology and control pollination.

The success of an intensive tree improvement program depends on the genetic quality of the parent ("plus") trees. Progeny trials have therefore been established to assess the genetic worth of selected "plus" trees; determine the inheritability of desirable traits, and calculate genetic gain. Results from progeny trials of *C. lusitanica, E grandis* and *P.*
patula have revealed poor and superior progenies . Parent trees of the poor progenies have been removed from seed orchards to further improve the genetic quality of seeds obtained. Heritabilities of desirable characteristics such as height, volume, and diameter growth have also been shown to be high (Chagala and Kariuki 1996). Furthermore, results have revealed that trees raised using seed from seed orchard have 30% more volume than those raised from general collections (Kariuki and Chagala 1996). In addition, progenies of *E. grandis* "plus" trees selected in Australia were 57% taller than those from general seed collection (Oballa 1989).

3.2 Breeding for resistance to dothistroma blight

P. radiata is the most popular species for the pulp and paper industry but suffers devastating attack by *Dothistroma pinii* that causes dothistroma blight. A breeding program has therefore been initiated to breed varieties resistant to *D. pinii* with the aim of reintroducing *P. radiata* as a plantation species . Ongoing work in collaboration with PanAfrican Paper Mills Company (PPM) includes selection of resistant trees, establishment of seed orchards and progeny trials, introduction of germplasm from other countries, and establishment of pilot plantations. Techniques

for vegetative propagation of juvenile and mature trees using cuttings and by grafts are being developed.

A total of 128 resistant trees of *P. radiata* have been selected. These have been used to establish 19.7 ha of seed orchards, and progeny trials established at Timboroa and Kaptagat. Preliminary results from progeny trials at three years of age reveal that different progenies respond differently to attack by *D. pinii* ranging from light to severe. Progenies of New Zealand plus trees (265-875 and GF17) and those of local resistant trees (KRS-1) are significantly taller and more resistant than the others. This work is continuing.

Techniques for rooting of cuttings from juvenile material have been developed, and rooting can now be done with a 70% success. These cuttings may be used for establishing plantations in case of seed shortage. Furthermore, new germplasm from Australia and New Zealand has been introduced to broaden the genetic base of *P. radiata*. This will reduce the chances of pest attacks, and also provide a broad base of material from which to make new selections.

3.3 Breeding for resistance to cypress aphid

A resistance breeding program has also been initiated for *C. lusitanica* which is the most widely grown plantation species in Kenya. The main objective is to develop varieties resistant to *Cinara* spp. A which has in the recent past devastated cypress plantations. Ongoing activities in collaboration with International Institute for Biological Control (IIBC) and Tanzania Forestry Research Institute (TAFORI) include selection of trees resistant to cypress aphid; assessment of aphid damage in experimental plots of *C. lusitanica* and related species; and establishment of seed orchards and progeny trials.

A total of 67 resistant trees of *C. lusitanica* have been selected, seeds collected and progeny trials established. Growth and aphid damage assessment shows that the trees selected from Tanzania were more resistant than those from Kenya and Uganda (Obiri *et al.* 1994). This suggests that new germplasm should be introduced from Tanzania for use in further trials, and for use as seed sources for resistant material. *C. lusitanica* has also been shown to be the most susceptible species in the family Cupressaceae, while *C. torulosa* is among the most resistant (Obiri 1994). This information will be used for selecting alternative species and designing inter- and intra- specific hybridization studies for developing resistant varieties.

3.4 Species diversification

With the current devastating disease and pest attacks on the major plantation species, it is essential that alternative species be identified that may replace the existing ones. Ongoing work in collaboration with Oxford Forestry Institute (OFI) includes introduction of germplasm from other countries; and establishment of species and provenance trials.

High yielding species such as *Pinus maximinoi*, *P. canariensis P. pseudostrobus* , *E. regnans* and *P. patula* var. *tecumuminii* have been found to perform significantly better than *P. patula* in growth rate. However, other desirable characteristics especially those of wood quality and disease resistance are yet to be ascertained before these species/provenances are recommended to replace existing species. Provenances of *Casuarina equisetifolia* from Malaysia, Thailand and Benin were also found to be significantly more superior than the Kenyan land races (Kimondo 1996). In addition, various provenances of *E. urophylla* with outstanding performance have been selected for further improvement (Kiriinya and Kimondo 1997).

3.5 Genetic variation studies

Knowledge of genetic variation of a species is essential in a tree improvement progamme. Therefore, studies on determination of genetic variation of *P. patula*, *C. lusitanica* and *V. keniensis* using biochemical analysis have been initiated. Ongoing activities include collection of seed from *P. patula* and *C. lusitanica* plantations, seed orchards, seed stands, and from trees on farmlands. Laboratory analysis is underway. Results obtained will be used as a basis for broadening the genetic base of these species

4.0 NURSERY AND PLANTATION MANAGEMENT

4.1 Nursery management

Raising of seedlings has become a major activity even among the rural communities. To facilitate sound seedling husbandry, KEFRI has embarked on nursery research to shorten the nursery period with the main aim of reducing overall cost. Results obtained six months after planting indicate that seedlings planted at eight months have no advantage over those of five months.

In the nursery, seedling survival may be reduced by various diseases resulting from fungal attack. Knowledge and control of these diseases is therefore important in the production of healthy seedlings. Research aimed at determining the major diseases of seedlings, their causal agents, pathogenicity and control measures is underway in selected nurseries in Kiambu District, Londiani and Turbo areas. Some of the most common fungi identified are *Phyllosticta ragatensis* on *V. keniensis*, *Botrytis cinerea* on *C. lusitanica* and Powdery mildews (*Oidium eucalyptii*) on *E. saligna*. It has been found that occurrence of diseases is closely related to prolonged wetness of leaves, and that severe infection results in dieback and defoliation. However, spraying with benlate fungicide reduces disease incidence.

4.2 Plantation management

Silvicultural practices have experienced numerous changes that continue to influence the day to day management of forest plantations. This has necessititated initiation of various research activities. In view of the escalating labour costs, one main activity has

been to determine species site preparation requirements. The aim is to identify the basic minimum initial and subsequent site preparation activities that must be undertaken to ensure both high survival and fast growth of seedlings. Preliminary results in Molo and Turbo indicate that burning of logging debris just before the rains, and immediate planting on the onset of the rains followed by slashing the competing weeds twice a year ensures good establishment. However, slashing must be done at the ground level to minimize the sprouting of weed stumps. Pitting should be of the right size (30 cm diameter and 30 cm depth). This has been observed to optimize the growing period of the newly established seedlings before the start of the dry season.

Silvicultural treatments of established plantations are an important management activity. The main silvicultural treatments (intensity and frequency of thinning and pruning) of plantations in Kenya are labour intensive, and were adopted from S Africa during the introduction of the species. At that time, schedules for local conditions had not been developed. However, the economics of raising a plantation and the quality of the end products are of great concern to the consumers. As a result, research has been initiated to determine the timing of thinning based on various different initial spacing and the appropriate pruning regimes. Preliminary results confirm that based on the current thinning and pruning schedules, the 2.5 x 2.5 m spacing adopted for cypress plantation establishment is economically superior to other regimes.

To address socioeconomic issues in plantation management, modalities for community participation in establishment and management of these plantations are being addressed. Local communities are thus currently participating in studies on establishment and tending techniques.

4.3 Microorganisms of economic importance

Mycorrhiza are microorganisms that play an important role in increasing growth, yield and survival of plantation species. Research has been initiated to determine the nature and extent of mycorrhiza association on exotic trees. Field surveys for ectomycorrhiza fungi associated with pines and eucalyptus are underway, together with glasshouse synthesis studies involving inoculation of seedlings with specific mycorrhiza fungi. This would enable selection of effective fungi for inoculation in nurseries.

From the surveys, several ectomycorrhiza fungi such as *Suillus* spp, *Cortinarius* spp. *Thelephora terrestris, Rhizopogon luteolus,* and *Hebeloma* spp were predominant in nurseries at Kinale and Uplands where pines are raised; while *Pisolithus tinctorius* and *Scleroderma* were found associated with eucalyptus species at the coast. Studies have also shown that inoculation with these mycorrhizal fungi can improve tree growth. Synthesis of mycorrhiza under glasshouse conditions has also been successful.

On the other hand, *Armillaria* spp. adversely affect the survival, growth and yield of both indigenous and exotic tree species. Research has been initiated to determine the species of armillaria present in commercial plantations and assess the damage caused. Results have revealed that *Armillaria* spp are present in some major commercial plantations all over the country. The main species affected are *P. patula, C.*

lusitanica, Eucalyptus spp and *V. keniensis.* Two major species, *A. heimii* and *A. mellea* subsp *africana* were found to be present in these plantations above 1500m.a.s.l and where rainfall is abundant. Damage due to the disease was found to be substantial (up to 12%) in some plantations.

4.4 Pest management

Biological control is an important aspect of an integrated pest management program for cypress aphid. An exotic parasitoid to *Cinara* spp. *A, Pauesia juniperorum* has been introduced but has not established todate. For the impact of both the exotic parasitoid and indigenous natural enemies to be determined, permanent sample plots have been established in representative cypress growing areas for monitoring aphid populations.

Results have revealed that for the past three years, aphid damage levels have been constant or declining. However, there are still pockets of high populations and severe damage in plantations which coincide with hot dry whether. Local arthropods which contribute to the suppression of aphid population have been noted, although none of them are specific to the aphid. There is therefore need to continue with the importation program of the exotic parastoid until it is established. It is proposed to import the same from Malawi instead of Europe as the climate of the former is closer to that of Kenya and could improve chances of establishment.

Cypress aphid has also had some effect on growth and yield of the cypress plantations. To evaluate the extent of this effect and possible future consequences in timber supply, 36 permanent sample plots established in the cypress growing areas have been used. Preliminary results indicate that mortality resulting from cypress aphid infestation is about 1% in young plantations (< 15 years old) and 5% in older plantations (15 years and above). There has been no marked loss in growth in young plantations (Muchiri 1996).

5.0 WOOD AND NON-WOOD FOREST PRODUCTS

A number of research and development activities directed towards the promotion and extension of efficient utilization of wood and non-wood forest products are being undertaken. These studies could be broadly grouped into three categories: wood properties and quality; development of efficient and low wood processing methods, and exploration of the potential for commercial exploitation of industrial non-wood forest products.

5.1 Wood properties and quality

A total of four studies are being undertaken:

One of these is on the efficient use of plantation grown timbers for structural purposes. The overall objective is to establish strength properties of Kenyan grown cypress and pine species, to be used for deriving permissible design stresses, and for drafting a Kenyan standard code of practice for structural timber. To date, strength values of the

main structural timbers have been established and used by the Ministry of Public Works to prepare updated basic and grade stresses (Ng'ang'a 1992; Chikamai and Onchieku 1995). This has led to a reduction in the amount of timber used by about 40%.

Ongoing work in collaboration with Overseas Development Administration (ODA), FD, Ministry of Public Works and Kenya Bureau of Standards has four components: timber grading, full size structural testing, trussed rafter and development of a design code. Results from these studies will be applied to further reduce the amount of timber used.

Studies on the effect of spacing on wood quality of *P. patula* and *C. lusitanica* have also been undertaken using 30 year old tree samples from seven square spacings ranging from 1.8 to 6.1m. The main aim was to determine the most appropriate spacing for pines and cypress for sawlogs and pulpwood.

Results show that there is no significant effect of spacing on wood quality (specific gravity) of these species (Muga ***et al***. 1997). For merchantable sawlogs, spacing between 3.0 x 3.0m and 3.6 x 3.6m on a 25 year rotation without intermediate thinning was found to be the most appropriate, as these have the highest standing volume, greatest financial returns and produces wood with uniform properties (Muga ***et al***. 1997; Orondo and Muchiri 1996). However, there is need to determine the production cost and net financial returns before the final decision on appropriate spacing is made. Research on the effect of spacing on fibre lengths and strength properties is ongoing.

Wood quality analysis using samples from a eucalyptus species trial (*E. saligna*, *E. camaldulensis*, and *E. maculata*) established on vlei soils at Turbo, indicate that all the three species could be used for pulp and paper production (Muga and Githiomi, 1996). Nevertheless, there is need to determine the chemical and pulp properties of these species.

Properties of *Eucalyptus saligna* which influence its use as transmission poles have also been studied in collaboration with East African Tanning and Extraction Company (EATEC). The study aims at establishing the wood properties (heartwood/sapwood ratio, density variations, moisture content, strength properties and chemical penetration) in order to enhance more efficient utilization of the species for transmission poles. Samples were obtained from Nakuru, TransNzoia, Uasin Gishu and Baringo Districts. Results show that all the properties studied had significant differences between sites (Kagombe ***et al***, 1994). Poles from Nakuru have the highest density and strength properties (MOR = 79.3 Mpa), while those from Trans Nzoia have the least (MOR = 58.1 Mpa). The average chemical retention using cromated copper arsenate (CAA) is 13.1 kg/m^3 and 21.95 kg/m^3 for 30 and 60 minutes respectively (Kagombe ***et al***, 1994).

5.2 Development of efficient low cost methods for wood processing

Two research areas are being addressed: production of laminated wood products and low cost treatment of posts and poles.

For the study on the production of laminated wood products, the overall objective is to develop technologies for laminating different timber pieces to produce high quality products. Through selection and combination of timber, choice of adhesive, and good workmanship, unique high quality products have been developed. To date, the technology has been adopted by the prisons department and other wood based industries. A guide to production of fancy items has also been prepared (Chikamai *et al*. 1996).

Due to diminishing supply of cedar and other durable wood, research has been initiated to develop treatments for non durable posts and poles in order to prolong their service life. Simple, cheap but effective wood treatment technologies of dipping poles and posts using a combination of creosote and old engine oil has been developed, with low income communities as the main target group. The cost of treating a 1m pole using the whole pole method has been reduced from Ksh.15.00 to Ksh. 8.00 using controlled and less labour intensive conditions. Furthermore, the cost of treating a pole by the butt method now ranges from Ksh.5.00 to Kshs.10.00. Posts and poles treated through this method can be effectively used in fencing and construction (Njenga, 1990).

5.3 Industrial non-wood forest products

To address the potential of exploiting non-wood forest products for commercial purposes, research on oleoresin tapping from pines and production and utilization of eucalyptus oils is being carried out.
Pinus elliottii is the main source of oleoresin and is grown in only two districts in the country. This resource base for oleoresin is relatively small and unlikely to sustain the long term demand of Rosin Kenya Limited, a company that specializes in the manufacture of both distilled and fortified rosin and turpentine. There is need to develop technologies, and improve on resource management in order to increase the production of oleoresin. Diversification of the resource base by utilizing alternative sources of oleoresin from other pine species, notably *P. radiata* and *P. caribaea* is also recommended.

A study was carried out to examine the effect of diameter class and crown size, number of faces, face width and interval between streaks on the oleoresin yield in *P. elliottii;* and to determine the potential of *P. caribaea* for oleoresin production. Results show that trees with a diameter at breast height (DBH) of 30 cm or more produce significantly higher yields of oleoresin than those with a smaller DBH.

It has also been observed that more or wider faces per tree result in increased yield. However, for economical production and by applying sound techniques, two faces of 7 cm at a time are desirable. The study also confirms that *P. caribaea* gives higher yields than *P. elliottii.*(Chikamai, 1995).

Due to the high demand world-wide for medicinal eucalyptus oils and the fact that Kenya has vast plantations of eucalyptus, a study was initiated to promote the

production and utilization of essential oils for pharmaceutical purposes from *Eucalyptus* species grown in Kenya and to verify the resource availability.

The essential leaf oil of five eucalyptus species (*E. globulus, E. camaldulensis, E. macarthurii, E. maidenii* and *E. citriodora*) grown in Kenya were analyzed using Gas chromatography (GC) GC - Mass spectrophotometer (GC-MS). The results show that *E. globulus, E. maidenii* and *E. camaldulensis* are rich in 1,8 - cineole (>70%), and the principal components in *E. citriodora* and *E. macarthurii* are citronellal and geranyl acetate, respectively (>80%) (Asefa *et al.* 1997). The three medicinal oils exhibit adequate 1,8 - cineole content, but have no alpha - and Beta - phellandrenes. This indicates that oils from these eucalyptus species are suitable sources for production of commercial medicinal oils. *Eucalyptus macarthurii* and *E. citriodora* with their relatively high geranyl content are suitable for production of perfumery essential oils (Asefa *et al*, 1997).

6.0 CONSTRAINTS

Most of the research programmes in industrial plantations lack sufficient funding for operations. This results in allocation of funds to routine activities at the expense of research in novele areas. A case in point is seed research where seed collection and supply have priority over genetic improvement of the seed sources. Furthermore, most donors expect industries to support research in wood products, and do not commit funds to this area. However, wood based industries do not meet this expectation, and this creates a vacuum in funding leading to inadequate basic and applied research.

In most industrial plantations research programmes, field experiments are located in stations far removed from the researchers which makes it impossible for experiments to be closely monitored. It is thus inevitable to sometimes involve non-research personnel in the collection of data in the field. Whereas some of these people show great commitment to such tasks, there are others who do not observe the procedures as required and the data they collect is unreliable. More attention should also be paid to maintenance of the experiments as it can lead to loss of valuable germplasm especially in collaborative international trials and conservation stands.

Apart from financial and managerial issues, human interference is rampant throughout the duration of experiments, adversely affecting the results in the long run. Such interference usually begins during the establishment phase in cases where the shamba system is in force and continues where grazing is allowed in plantations. Selective cutting of good trees is also a practice which interferes with experiments as do fires in areas such as Turbo and Londiani. The excision of forest land for human settlement also interferes with research trials. As such, a legal framework for guiding community participation in forest management is required.

Non- human-related factors are sometimes responsible for poor performance of research trials. Wild animals in the forest, for instance, show preference for attacking certain tree species and resultant damage affects growth performance. This makes it

difficult to compare performance of different treatments in the affected areas. Considering that problems in industrial plantations are multi-faceted, then weak inter-institutional and disciplinary linkages are a major drawback to research.

7.0 PROPOSED FUTURE DIRECTIONS IN INDUSTRIAL PLANTATION RESEARCH

7.1 Seed

Seed quality should be safeguarded by selecting younger plantations of trees with superior desirable characteristics for seed collection. It is also recommended that seed be collected from plantations raised from seed supplied by the Kenya Forestry Seed Centre.

Relocate *P. patula* seed orchards to higher elevation and expand the acreage such that at least 50% of seed required is supplied from them.

More attention will be paid to the pests and diseases affecting various aspects of seed physiology.

7.2 Tree improvement

More plus trees will be selected and more seed orchards and progeny trials established for *P. patula, C. lusitanica* and *E.grandis*. This will be complimented by determining heritability of desirable characteristics and gains obtained.

The genetic base for exotic trees will be continuously expanded through introduction of new germplasm

Research on vegetative propagation techniques of plantation species should continue.

The breeding program for important indigenous and exotic species of outstanding quality will be intensified to diversify plantation species.

Genetic variation studies will continue on existing and proposed plantation species and information obtained will be the basis of making selections of new germplasm and for conservation purposes.

The characteristics of high yielding species currently shown to perform better than *P. patula* in growth rate will be ascertained before making recommendations on suitability for plantation species diversification.

Socio-economic issues pertaining to the production of high quality seed in a liberalized seed market will be addressed.

7.3 Nursery and plantation management

Resistance breeding programmes for Dothistroma blight in *P. radiata* and cypress aphid in *C. lusitanica* will be continued. The interaction of such breeding programmes with other aspects of integrated pest management that are planned or already in place will be studied with the overall objective of quantifying progress made in pest management.

Most silvicultural operations which are currently prescribed for plantations will be re-evaluated with an aim of minimizing labour inputs and maximizing yields.

Pests and diseases which attack trees in the nursery and plantation will continue to be identified and appropriate control measures will be developed.

Site preparation requirements will be studied so as to ensure high survival and good growth of seedlings after they are planted out in the field. In this respect, the nature and extent of association of mycorrhiza with exotic and indigenous trees will be determined. This will facilitate selection of effective fungi for inoculation in nurseries, geared towards inoculation with specific mycorrhiza where possible.

Mixed species and multiple-aged plantations will also be investigated as a strategy for pest management. To begin with, information will be gathered from existing trials of mixed species planting of *Juniperus procera* at Kabaru.

Growth and yield studies of various plantation species will continue in order to determine the optimal rotation age for various forest products. Bioeconomic models of various management regimes will be employed as tools for these studies.

Alternative species will be identified to replace those prone to animal damage in plantations. Cost effective control measures which minimize risks of attack of the susceptible trees will be developed. In collaboration with Kenya Wildlife Service and the Forest Department, the concept of multiple-use forestry will be addressed as it applies to the reduction of game damage in affected areas.

7.4 Wood and non-timber wood utilization.

Research on softwood furniture production will be undertaken to come up with designs, production technologies and finishes to make furniture manufactured from softwoods more attractive to the customers due to scarcity of hardwoods. Adequate cost evaluation, pricing and suitable marketing systems will be developed.

A study on the functional characteristics of wood adhesive and wood paints will be initiated. This will focus on the documentation of available information on wood adhesive and paints, evaluation of their performance on the available wood species for furniture manufacture and classification according to their performance.

An appraisal of the sawmill industry in Kenya will be undertaken. The current status of the industry will be reviewed and interventions desired for economic and efficient use of forestry resources in the industry ascertained.

Processing and wood properties of cypress and pine thinnings and plantation grown indigenous hardwoods will studied. The study will establish the physical, mechanical, and preservative properties, and efficient methods of processing these species for economic use.

Wood preservation studies will be carried out to establish the efficiency of various timber treatment methods in terms of penetration and retention of the preservatives in the treated wood and macro-distribution of the various preservative ingredients. In addition, research on efficient low cost methods of treatment will continue. Graveyard tests will be established to determine the durability of timber treated with various methods.

Studies on efficient harvesting methods will focus on the current harvesting methods with an objective to document equipment and tools used, their effectiveness and limitations, to determine cost and productivity in logging, and to propose modifications on tools/equipment used in harvesting to make them effective and productive.

Research aimed at providing information on alternative timber species for pulp and paper manufacture will be carried out.

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