OPPORTUNITIES FOR TREE IMPROVEMENT

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1.0 INTRODUCTION

Forest biodiversity refers to the wealth of life in a forest and has an intrinsic value globally and nationally. These values may be genetic, ecological, social, economic, cultural, recreational, aesthetic and educational in nature. Generally, biodiversity may be considered at three levels: the number of ecosystems with their interacting species and ecological processes; the number of species; and the genetic variability within a species.

In Kenya, although closed canopy forests cover only 2% of Kenya`s land area, they harbour a disproportionally large percentage of the nations biodiversity: 50% of woody plants, 40% of large mammals, 30% of birds and 35% of butterflies. These different life forms exist in a delicate, intricate and closely interwoven web. A decline in biodiversity and/or loss of a species results in a reduction of future stock and an imbalance of the closely interwoven web of forest life. It is therefore essential that forest biodiversity be conserved in its entirely from the ecosystem to the gene level. Such conservation would ensure that a representative sample of ecosystems and species are maintained, and that biodiversity and variation within a species is not diminished.

The current rapid increase in population has resulted in an increase in demand for forest products and competition for forest land by other land uses especially agriculture and settlement. Because of this, there has been an alarming decrease in forest cover, environmental degradation and loss of biodiversity. One of the strategies that has been developed to combat deforestation is establishment of woodlots on farms and large scale plantations of fast growing species. However, the success of such a programme depends largely on use of tree improvement techniques.

The main objectives of a tree improvement programme is to maximise returns and improve quality of forest products. To fulfil this objective, both genetic improvement and silvicultural techniques have to be used. These techniques include the use of genetically improved seed; use of high quality planting stock (vigorous, healthy seedlings); and proper management of plantations (adequate site preparation, suitable planting techniques, and adequate tending). This paper summarises the genetic techniques used in tree improvement and highlights how genetic variation found in natural stands, plantations and woodlots may be used for the production of genetically improved seed.

2.0 GENETIC IMPROVEMENT OF FORESTS

2.1 Natural variation

Tree genetic improvement involves the selection and control of parentage. It is concerned with how trees vary and how this variation can be used to improve productivity.

Variation (differences) in nature among trees within a species may be caused by:

(a) their genetic differences;

(b) the different environments in which the trees are growing in; and

(c) the interactions between the tree's genotype (genetic constitution) and the environment in which it is growing in.

Among the three causes of variation, genetic variation is the most important as it consists of the heritable quality of a tree.

Genetic variation is a necessity in an improvement programme and it is essential to maintain and increase it. Most tree species contain high variation for many economically important characteristics such as stem straightness, wood specific gravity and resistance to drought and pests. Continued development in a tree improvement programme is not possible if genetic variation is not maintained.

Genetic variation can be manipulated to obtain good gains in many tree characteristics that are under strong genetic control. The challenge to the tree improver is to determine the magnitude and kind of genetic variance present in the natural or unimproved populations of a tree species. Natural stands are of utmost importance as they provide material from which selection of desirable individuals may be made. For this reason, conservation of natural stands is essential for success of a tree improvement programme.

Variation among trees caused by environmental differences cannot be used in a breeding programme as they are not heritable and are often not predictable. However, environmental variation is the basis of silvicultural activities as some characteristics such as those related to growth, form and quality are under strong environmental influence. Some environmental factors that influence tree growth can be controlled and manipulated. These include stocking levels by varying spacing, tree-to-tree competition through thinning, nutrient deficiencies through fertilization and soil texture by sub-soiling. Although environmental variables that influence growth such as rainfall and temperature cannot be manipulated, tolerant strains that are well adapted to certain conditions such as dry areas may be developed.

For maximum progress in a tree improvement programme to be made, genotype-environment interaction must be determined. This refers to the change in the performance ranking of trees of a given genetic constitution when grown in different environments. Therefore performance in one environment should not be extrapolated to other environments as they may perform differently. Testing in various environments should first be done before large scale planting is undertaken.

The type of crossing system in a species has a major effect on variation pattern. An outcrossing breeding system maintains a high degree of genetic variation while related matings reduce genetic diversity and vigour. Related mating may be within the same tree, among trees raised from cuttings of the same tree (ramets) or among related trees. Relatedness is common among natural forest stands.

For a successful tree improvement programme, the short term need of obtaining immediate gains and the long term need to provide a broad genetic base essential for continued progress over many generations must be considered. Therefore both high gains and conservation must be taken into account.

2.2 Categories of variation

Apart from variation among species, categories of variation within a species can be broadly grouped into geographic sources (provenances), sites within provenances, stands within sites, individual trees in a stand and within individual trees.

Genetic differences among provenances are often large especially for characteristics related to adaptability. These provenances may also show large differences among sites within the provenance. Although such differences among are usually due to environmental influence rather than genetic, they should still be taken into account particularly when sampling natural populations.

Sometimes stands of trees within a site may differ. These are of little importance as they are also often due to environmental influence. However care should be taken as these differences could be due to human activity particularly selective logging and should not be ignored.

Tree differences within a stand is a major type of genetic variation that is used in selection and breeding programmes. Most characteristics of economic importance have a large amount of individual tree variability. On the other hand, variability within a tree occurs only for some characteristics and are of little significance in most cases.

Generally, among the various categories of variation described above, provenance and tree-to-tree differences form the bulk of genetic variation found within a species in a natural stand, and account for approximately 90% of the total variation. Good gains can be achieved from use of provenance and tree-to-tree variation.

3.0 PRODUCTION OF GENETICALLY IMPROVED SEEDS

There are various sources of seeds, the use of which depends on the economic importance of the species, availability of seeds, availability of resources and the stage in tree improvement programme of the species. There are four sources of seeds which can be used to improve yield and they vary in the amount of genetic gain obtained. These sources are: individual trees, good stands, seed stands and seed orchards.

3.1 Single trees

Seeds may be collected from phenotypically superior single trees in a stand (i.e. trees that look superior). In natural stands, these individuals have an advantage as they are usually well adapted to the area. This is also the case for exotic species that have been grown in an area for a long time, as a land race that is well adapted to the plantation site usually develops. Although gain from such seed collection is limited due to pollination by unselected male plants and seed collection is time consuming, the gain obtained in terms of wood quality, adaptability, disease resistance and other characteristics may be quite high. Not more than 5 to 10 trees per hectare should be collected as this minimises relatedness and maintains desirable genetic quality.

3.2 Good stands

In this case, seeds are collected from the best stands in a plantation or a natural stand. The gain obtained is similar to that obtained for individual tree collection, but it has an advantage over single tree collection as seeds are cheaper to obtain since time taken in walking from tree to tree is minimised. However, collection of seeds from a few good stands will yield seedlots with a high degree of relatedness than seeds collected from individual trees growing in many different sites.

3.3 Seed stands

These are stands with superior phenotypic characteristics. They may be established in a natural stand or a plantation with a high frequency of superior individuals and managed purely as a seed stand. The difference between a seed stand and a good stand is that seed stands are selected and managed for seed production, while good stands are not managed.

The points to consider while selecting a seed stand are: the stand should contain a large number of good individuals as this implies that the good qualities are genetic and will be passed on to the seedlings; trees should be mature but not too old to allow for collection of seeds over many years; there should be selection and removal of undesirable/inferior individuals to allow for pollination among good trees only; thinning of the stand should be done to avoid crown competition; and the seed stand should be isolated from pollen contamination to avoid pollination from inferior individuals. Proper records of the seed stand such as location, seed origin, year planted/established and silvicultural operations undertaken such as thinning must also be kept.

The area of a seed stand should not be too large to minimize undesirable pollination, but should not be too small to minimise related mating. A minimum of 4 hectares is practical.

Seed stands have an advantage of providing a quick and reliable source of seeds which are superior due to removal of inferior trees and which result in pollination by phenotypically superior trees. However, they have the disadvantage that trees in the stand may be closely related and this may result in low yields.

Seed stands may be introduced into a tree improvement programme as an interim source of seeds before production from seed orchards become available. They are also important for those species where an intensive tree improvement programme is not desirable.

Seed stands are not directly linked to the establishment of seed orchards, which are advanced sources of improved planting material. The gain obtained from the use of seed stands is lower than that obtained from a seed orchard, but higher than that from non-selected sources such as single trees and good stands.

3.4 Seed orchards

Seed orchards are advanced sources of planting material. They are only established for those species of economic importance as their establishment and management is time consuming and expensive. For a species to warrant intensive tree improvement, it should cover at least 400ha.

The stages of establishment of a seed orchard follow those of an intensive tree improvement programme. Generally, it involves plus (superior) tree selection, establishment of seed orchards and genetic/progeny testing.

3.4.1 Plus tree selection and genetic tests

In order to undertake plus (superior) tree selection, the best provenance for a particular site and/or large scale planting of the desirable provenance has to be done first to provide enough material for selection. This is then followed by selection of plus trees from the plantations. Plus tree selection exploits the variation found among individual trees. These trees are selected on the basis of their phenotype (i.e their appearance) and then used in establishing seed orchards. The selection of plus trees is more rigorous than that for the other three sources of seeds (single trees, good stands and seed stands) as the best tree is selected from many hectares. In comparison, several trees are selected in one hectare for the other seed sources.

Plus tree selection constitutes an essential part of tree improvement as it aims at obtaining significant amounts of gain quickly and inexpensively, while at the same time maintaining a broad genetic base to ensure future gains. By selecting individuals which are superior in certain desirable characteristics and by grouping them in a seed orchard to reproduce in the next generation, there should be a better average performance of trees raised using material from the seed orchard.

To increase the genetic quality of seed orchards, progeny tests have to be done to test the genetic worth of plus trees. This is because plus trees are selected based on their phenotype (appearance), and it is not possible to determine whether their good qualities are due to environmental influence (i.e. the tree could be growing on fertile soil) or its genetic constitution. Progeny tests are done by collecting seeds from each plus tree, raising seedlings and growing them in a uniform environment to eliminate environmental effects. The performance of seedlings from each plus tree is then analysed. Those plus trees whose offspring perform poorly are then removed from the already established seed orchard leaving only those plus trees whose offspring show good performance. Removal of these undesirable plus trees improves the genetic quality of seed orchards tremendously.

Another important genetic test is for estimation of genetic gains. In this test, seeds are collected from improved and unimproved material, grown in a uniform environment and the performance of the seedlings analysed to ascertain the superiority of the improved material. If performance of improved material is lower than that of the unimproved material, the improvement programme is not worthwhile and should be terminated.
Genetic tests are also undertaken to determine the degree at which a desirable character is heritable. Breeding for a character that is not highly heritable would not be worthwhile as gains obtained would be low, while high gains may be made for those characteristics that are highly heritable. For example, in breeding for timber, some of the desirable

characteristics is small branches and straight stems. High gains may be obtained by selecting trees with these characteristics as they are highly heritable.

3.4.2 Seed orchard establishment

The purpose of establishing seed orchards is to produce large quantities of genetically improved seed. They are established using selected plus trees and are planted concurrently with progeny tests. Seed orchard establishment is an important step in a tree improvement programme as it ensures future availability of genetically improved material.

Seed orchards represent a more advanced step to other seed sources (seed stands, single trees, good stands) since the genetic worth of trees used in their establishment is verified through genetic testing. As they are established using only selected plus trees, in practice, they should yield the best planting material as they provide for the mating of superior individuals. Their management is purely for seed production.

The size and longevity of a seed orchard is determined by the seed demand and the expected seed production from the orchard both of which may be estimated. A minimum of 15-25 clones or families are required to ensure a sufficient genetic base and to limit selfing.

3.4.3 Maximization of seed production

Knowledge of species' specific requirements especially reproductive biology is crucial for the proper matching of species and site for maximum production of fruits. The age at which trees produce their first crop varies according to the species, variety, environmental conditions and management.

Plants will often reproduce late if not at all if they grow or are grown on the periphery of their geographic distribution or under adverse growth conditions. Due to this, seed orchards should be established in the main portion of a species' geographic and ecological range. For exotics, a seed orchard should be established only once the flowering and fruiting have been successfully proven in the area. A site should be selected promotes seed production. A site with an average fertility is preferred to that with high fertility since the later might promote vegetative growth at the expense of reproduction. Poor soil fertility may be manipulated with the application of fertilizer, and a flat or slightly undulating area is preferred since such an area is generally uniform in soil structure and fertility. Other management requirements include accessibility, protection and isolation from pollen contamination.

Physiological maturity may be hastened if the trees are grown under favourable conditions. For those species with a late reproductive age, reproduction may be hastened by using cuttings or grafts as these vegetative materials tend to retain their physiological age and consequently flower at an earlier age than plants raised from seeds. The position on the tree where cuttings are taken often influences the flowering habits.

Physiologically good growth conditions generally promote good flowers and an ample flowering is a precondition for abundant seed production. Good flowering and fruiting also require good soil and climate, excess light, effective pollination and reduced crown and root competition.

Internal factors within the plant also influence flowering and seed production. These are: accumulation of nutrients in the tree; a brief physiological stress period during flower initiation; effective pollination; and an optimum level of flower promoting hormone. Spacing should be large (at least 10m) to avoid crown and root competition.

Some of these factors are site specific and must be taken into account when locating a site for a seed orchard. Others can be manipulated through proper management practices.

3.4.4 Vegetative propagation

Vegetative propagation is an important tool in a tree improvement programme. For seeds, although the female parent may be known, the male parent is often unknown and a female plant may be pollinated by trees with inferior characteristics. On the other hand, vegetative material is identical to the plant from which it is collected from.

Vegetative material may be used in establishing seed orchards, propagation of special breeding material such as hybrids and other desirable individuals, conservation of genetic resources and genetic testing. Although use of vegetative material results in uniformity and higher gain than that from seedlings, it has several disadvantages which include poor rooting, high cost of production and propagation is not often possible from old tree. There are also risks such as low adaptation to environmental conditions, pests and diseases due to uniformity and restricted variation which affects later selection and gain.

3.4.5 Other activities

Other activities enhance productivity and conservation include:

(a) establishment of a tree bank, where all plus trees are grown for conservation and breeding purposes;

(b) control pollination to generate variation;

(c) conservation of genetic resources both *in-* and *ex-situ*; and

(d) Distribution of genetically improved propagation material (seeds, seedlings and cuttings) which form the final links to the end user and ensures a steady supply of improved material.

4.0 CONCLUDING REMARKS

With the rapid increase in demand for forest products, conservation of biodiversity is a necessity as it ensures continued genetic variation for future selection of desirable characteristics. The only way to conserve the remaining forest genetic resources is by sustainable forest management through strategies such as establishment of plantations and woodlots of fast growing species and also use of various techniques for the management of natural forests. Intensification of simple tree improvement techniques by use of the variation occurring in nature can result in success of afforestation programmes, and sustainable management of forests and other natural resources.

REFERENCES

FAO 1993. Production of Genetically Improved Planting Materials for Afforestation Programmes. Proceedings of a Workshop 18-25 June 1993, Caimbatore, India.

UNDP/FAO 1993. Selection of plus Trees. Field Manual No. 2RAS/91/004

UNDP/FAO 1993. Seed Stands: Guidelines on Establishment and Management Practices. Field Manual No. 3RAS/9/004.

Zobel, B. And Talbert, J 1984. Applied Tree Improvement. John Wiley and Sons Publishers. 505P.