Meeting the Phytosanitary Requirements in Tree Germplasm Exchange in East Africa: Awareness on Importance, Challenges and Opportunities of Tree Seed Health among Stakeholders

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Abstract

Globally, over 90% of tree species are propagated through seed and raised as seedlings. Other propagation materials include cuttings, wildings, grafts, tissue culture and air-layering. Since seed is the main source of planting material and medium of tree germplasm exchange, it is also the major source of disease and pest introduction in new localities worldwide. Seed microflora usually comprises of fungi, bacteria and to lesser extent viruses, and can be external or internally seed borne. Some tree nurseries have reported over 80% losses to seed related diseases.

There has been an increase in tree diseases and pest incidences affecting the main plantation and agroforestry tree species in Kenya. Most pathogens are transmitted through seeds and cuttings while endophytes are transmitted through healthy looking host materials. For example, four major diseases and pests of eucalypts are reported to be on the increase within Africa. Their invasions are closely related to the continuous importation of *Eucalyptus* clones which have been traced to South Africa, Latin America and Australia. The future of local landraces of eucalypts are therefore unpredictable unless suitable biocontrol agents are introduced soon. In similar circumstances, the *Dothistroma* needle blight has almost stopped the growth of *Pinus radiata* in East Africa. The latent pathogen group; Botrosphaeriaceae is reported to be spreading fast on the popular *Grevillea robusta* and other tree species in Kenya.

Tree germplasm production and exchange unlike the food crops faces phytosanitary challenges that include inadequate sources of high genetic quality, low seed production due to unpredictable flowering patterns, uncontrolled movement of live germplasm and forest products, inadequate enforcement of the relevant legislations on tree seed trade, inadequate formal quarantine standards especially for indigenous tree seeds and inability to trace the origin of seeds within E.Africa. In addition, inadequate tree seed testing facilities and poor formal distribution networks of forestry seed contributes significantly to the challenges in undertaking phytosanitary measures. Efforts and investments should therefore be made to ensure that stakeholders access high quality tree germplasm to guarantee sustainability of our forest resources. This paper

therefore aims to create awareness on the status, challenges and opportunities that exist to ensure that phytosanitary measures are instituted for clean germplasm exchange.

Key words: Tree germplasm, exchange, pathogen and pest introductions, phytosanitary challenges, clean germplasm exchange

Introduction

The production, improvement, conservation and research on tree germplasm are major flagship projects at the Kenya Forestry Research Institute (KEFRI). The main goal of the institute is to meet the increasing demand of high quality germplasm for plantation and on-farm tree species locally, regionally and internationally. It is important to note that there has been a gradual decline in tree seed production in the last ten years (KEFRI Seed Report unpublished). This has been attributed to unpredictable flowering patterns due to changing climatic patterns resulting in reduction in seed production.

Over 90% of the tree species are propagated through seed which are raised as seedlings. Other types of propagation include grafts, cuttings and tissue culture to a lesser extent. In order to meet the increasing demand for high quality seed sources, KEFRI started to establish seed sources from 2010. To date the Institute has established and maintained approximately 1200 hectares of seed sources out of which 230 hectares comprise the highly demanded tree species for plantations and agroforestry that include; *Cupressus lusitanica, Pinus patula, Eucalyptus grandis, E. urophylla, E. camaldulensis, Grevillea robusta, Tectona grandis, Vitex keniensis, Casuarina equisetifolia, C. jughuniana, Markhamia lutea, Gmelina arborea, Melia volkensii, Acacia tortilis, Terminalia brownii, T. spinosa, T. Kilimandcharisca*, and Pine hybrids. The Institute is currently establishing seed sources for the endangered *such as Osyris lanceolata* among others.

Forest germplasm is complex and consists of two types; orthodox and non-orthodox or recalcitrant seeds. Examples of recalcitrant seeds include *Azadirachta indica, Vitex keniensis, Warbugia ugandensis, Prunus africana* among others. Orthodox seeds can be maintained for a long duration without deterioration under ambient conditions while recalcitrant seeds have short duration viability and are easily attacked by fungal diseases due to their pulpy nature. Forest tree seeds vary greatly in size, shape and texture.

Seed is the main medium of germplasm exchange worldwide. Therefore it is also the main means of disease and pest introduction in new localities worldwide resulting in non-native pest and disease invasion (Liebhold *et al.,* 2012). This paper explores the context phytosanitary challenges facing exchange of forest /tree germplasm and the efforts being put in place to mitigate some of the challenges and the way forward to ensure exchange of healthy tree germplasm in Kenya.

Seed Pathology

Microflora affecting seeds are mostly fungi, bacteria and to lesser extent, viruses. Seed infections can be (i) Internally seed borne where pathogen attacks the seed coat, endosperm and embryo, (ii) Externally seed borne where pathogens are externally carried over on seeds and or (iii) Surface contaminants where fungal fruit bodies or spores occur on the surface of seeds.

Seed infections result in (i) Poor germination from the effects of fungi that cause pre and post emergent damping off, (ii) Weak seedlings or reduced seedling growth vigour, (iii) Seed rots, leaf diseases such as spots, blights shoot tip deaths and sometimes whole seedling deaths which are reported to account to >80 % losses in tree nurseries (iv) Loss in market value of seeds and (v) Production of toxic chemicals that are harmful to humans and animals. Seed-borne micro-organisms include pathogens causing plant disease in the field and also during storage.

Trends in forest pathogens in Kenya

Tree diseases have been on the increase in Kenya.. The first major disease reported in Kenya are exotic pathogen, *Dothistroma pini* needle blight which had a catastrophic effect on *Pinus radiata* in East Africa (*Odera and Arap Sang, 1980)* and slowed down its plantingfrom the 1970s till now. Intensified research however shows that there may be some tolerant *P. radiata* genotypes in Timboroa, Kenya which could be exploited for plantation establishment (Mbinga, 2002).

Other introduced tree diseases include *Armillaria heimii* Pegler [*Armillariella elegans* (R. Heim) J.B. Taylor, J.E. Hawkins & McLaren; [*Clitocybe elegans* R. Heim., which causes root rots on many species of both broadleaves and conifers. It causes economic damage on *Pinus patula*. Another Armillaria species, *Armillaria mellea* (Vahl) P. Kumm., [*Agaricus melleus* Vahl; or *Agaricus sulphureus* Weinm.;] also causes root rot disease on many species of plants in Kenya.

Endophytes are also transmitted through seeds. For example an emerging group of pathogens falling in the Botryosphaeriaceae are spreading fast in Kenya. The Botryosphaeriaceae have been identified as important pathogens on the popular agroforestry tree species-*Grevillea robusta.* It is also widespread in multipurpose tree species that include *Melia volkensii, Senna siamea* and *Azadirachta indica* (Njuguna *et al.,* 2011; Njuguna, 2011). The Botrosphaeriaceae have also been proved to be seed-borne and also pathogenic on Montane Forest species; *Prunus africana* (Gure, 2005).

Likewise various diseases comprising of the Botryosphaeriaceae and the closely related Teratosphaeriaceae are reported to be on the increase on the genus *Eucalyptus* within Africa. Recent studies clearly indicate that in Kenya, these fungal pathogens are closely related to the importation of *Eucalyptus* clones and can be phylogenetically traced to fungi affecting the genus in South Africa, Latin America and Australia (Machua *et al.*, 2016).

Trends in forest pests in Kenya

Forest pests have also had catastrophic effects in Kenya since the 1960s. It is reported that most of the forest pests in Kenya have been accidentally introduced in Kenya with severe impacts to forest plantations (FAO, 2005). For example, *Cinara pinivora* Wilson, an aphid attacking *Pinus* species is not a native. It was introduced into Kenya and it is a threat to pine plantations in Kenya (Maina, 2005). The aphid attacks pine seedlings causing defoliation and mortality of affected plants. The good news is that the pest can be kept under control by insect predators belonging to Coccinellidae, Syrphidae, Chrysophidae, Staphilidae, Dermaptera and some Heteroptera (Penteado, 1995). Another non-native pest to several species of *Pinus* is the *Eulachnus rileyi* Williams [*Lachnus rileyi* Williams] commonly known as the pine needle aphid. Heavy infestation causes leaf fall and stunted growth of seedlings.

The genus *Cuppressus* has been attacked by an exotic forest pest is *Cinara cupressivora* Watson & Voegtlin, belonging to the order Hemiptera: Aphididae, commonly known as giant cypress aphid or cypress aphid. The aphid is known to attack conifers including, *Cupressus* spp.; *Juniperus* spp.; *Thuja* spp.; among others. The pest was first identified in Malawi in 1986 and quickly spread within East and southern Africa causing significant damage of dieback and total tree death. It arrived in Kenya in 1990 (Ciesla, 1991). However biological control agent *Pauesia juniperorum* was introduced in Kenya and has since significantly controlled the cypress aphid (Day *et al.*, 2003)., The most affected species was *Cupressus macrocarpa* and *Cupressus lusitanica.* Non-native pests of economic importance have been reported on Eucalyptus species in Kenya as shown in Table 1.

Table 1. Examples of non-native forest pests on Eucalyptus sp. in Kenya

Pest	Arrival and Status	Remarks
Glycaspis brimblecombei Moore (Eucalyptus red lerp gum psyllid)	October 2014 from South Africa and is spreading fast. The wind is a major agent in spread.	No action yet
Thamaustocoris peregrinus Carpintero et Dellape (Eucalyptus Winter Bronze bug)	Identified in Nov. 2009) widespread and spreads fast via weed.	Biological control is available (Mutitu *et al*., 2013)
Leptocybe invasa Fisher & La Salle (Blue Gum Chalcid)	Widespread in East Africa. It is known to have moved from Kisumu to Malindi in a day by road.	Biological control is available (Nyeko, 2010)

Pest	Arrival and Status	Remarks
Gonipterus sculletus Gyllenhal (Eucalyptus snout beetle)	Identified in 1926, widespread on Eucalyptus clones. It is reported that a wrong parasitoid (*Anafe nitens*) was released in 1930s hence the constant re-emergence.	Biological control?

In addition, the growth of *Leucaena leucocephala* a promising agroforestry tree species in Kenya was seriously hampered by the introduction of the pest *Heteropsylla cubana* Crawford [*Heteropsylla incisa*, (Sulc.)], commonly known as *Leucaena* psyllid. The pest also attacks *Albizia* spp.; *Mimosa* spp.; *Samanea saman*. The pest was reported in Kenya in 1992 (Reynolds and Bimbuzi, 1992).

Phytosanitary Challenges Affecting Tree Germplasm Exchange

According to Article V.2a of the IPPC (1997): *"Inspection and other related activities leading to issuance of phytosanitary certificates shall be carried out only by or under the authority of an official of national plant protection organization. The issuance of phytosanitary certificates shall be carried out by public officers who are technically qualified and duly authorized by the official national plant protection organization to act on its behalf and under its control with such knowledge and information available to those officers that the authorities of importing contracting parties may accept the phytosanitary certificates with confidence as dependable documents."* (See also ISPM Pub. No. 7: *Export certification system*). In Kenya, Phytosanitary certificates are issued by the Kenya Plant Health Inspectorate Service (KEPHIS).

The Seeds and Plant Varieties Act, CAP 326, Revised Edition 2012 [1991] further requires that all plant and animal products designated for export or import undergo specific tests to ensure that they meet the required phytosanitary standards for safety and to reduce risks of exporting or importing materials that may be detrimental or injurious to humans, animals and the environment. However in most cases materials are moved or exchanged between institutions and individuals without following the laid down procedures and regulations. Following is a summary of the phytosanitary challenges that face exchange of tree germplasm or reproductive material in Kenya.

a) Difficult to control movement of forest resources and forest products within and across countries

Movement of forest resources follow movement of human. Humans easily move from one area to another in search of livelihoods and settlement. In the process they move with everything including products such as timber, fuel wood, packaging materials, poles and posts through (i) Road networks that include road, rail, human, animal transport, (ii) Water transport through

containerised shipments and package materials, (iii) Air transport and other means of transport. These movements are difficult to control because people do not declare what they carry for fear of losing them through confiscation by authorities. The porosity of our borders makes it even harder to control germplasm exchange. People living along the borders easly move materials without control. The border entry points to any country within East Africa further aid the exchange of uninspected materials through laxity and lack of requisite human and non-human skills.

b) Difficulties in control movement of live materials within and between countries

Most stakeholders /farmers do exchange all types of planting materials easily that include among others; seeds, cuttings and seedlings. These have been moved even across borders for afforestation programmes and projects. The most common and fast means of movement is "farmer to farmer" exchange between localities and even across borders. It has been observed that; the quality and health status of such materials is usually is not guaranteed. Liebhold *et al.,* (2012) reported that live plant imports introduce live pests and diseases into new regions and are the major pathways for the primary introductions of forest pests and pathogen invasions.. Further the study showed that continuous imports of reproductive materials may also introduce more virulent and or additional genotypes of a pathogen or pest thus altering its diversity and genetics.

c) Uncontrolled tree seed trade

Tree seed trade within East Africa is largely uncontrolled. There are inadequate legislations on tree seed trade. Most E.African countries use agricultural regulations and Kenya is no exception. Agricultural regulations still lack standards for control of health issues regarding tree seeds, more so for many indigenous species The trade is also riddled with huge variations in prices of forestry seed even of the same species in different areas within the same country. High quality tree seed sources are also inaccessible to a greater majority of stakeholders due to poor distribution channels of forestry seed. For example the Forestry Seed Centre (KFSC) is located at Muguga which is far from many stakeholders. In addition packaging of forestry seed is poor within the country due to the complex nature of forest germplasm, and that limits their distribution too.. The current ban on sale of polythene for packing is a draw-back to the newly designed packaging materials. It will take a while to design and test new packaging materials.

d) Inadequate traceability to source of forest germplasm

Although some sources have been selected and georeferenced, many seed sources do not have the required documentation on the origin of the seed. This causes traceability problem hence lowering pricing of seed.

e) Inadequate resources to support production, storage and exchange of high quality forest germplasm

Forest germplasm production and conservation is largely supported by funds from the exchequer which are not adequate to support all the required processes . The current annual allocation is Ksh 10,000,000 against a requirement of Kshs 75,000,000. There is also shortage of trained personnel in tree seed collection, processing, testing and certification. There are also inadequate storage facilities to meet national demand.

Mitigating the phytosanitary challenges faced in forest germplasm exchange

The Kenya Forestry Research Institute has initiated some measures to mitigate some of the challenges. These include;

a) Production of high quality tree germplasm

KEFRI produces on average 10 tons of tree seeds comprising of about eighty tree species which meets about 40% of national tree seed demand. Demand for tree seeds is expected to increase from the demands of the newly launched National Forests Programme (NFP) 2016-2030 whose major focus is expansion of commercial forestry and rehabilitation programmes. In some cases, KEFRI also imports reproductive materials (mainly seeds) of selected tree germplasm for mainly for research trials. The institute also produces forest reproductive materials that include grafts, cuttings, marcots among others for research purposes. Production and conservation of high quality tree germplasm involves selection of mother trees of identified tree species which meet specific characteristics among them free of pests and diseases. It also involves developing protocols to raise planting materials of difficult to propagate indigenous tree species that include *Terminalia brownii, Tectona grandis, Melia volkensii, Gmelina arborea, Markhamia lutea, Osyris lanceolata, Ocotea usambarensis, Maesopsis eminii* and *Terminalia spinosa* among others.

b) Amendment of the Seeds and Plant Varieties Act 2012 to include Tree Seed Regulations

The institute is the process of proposing an amendment to the Seeds and Plant Varieties Act 2012 to include Tree Seed Regulations. The amendment will guide and facilitate the production, conservation and trade in forest germplasm. It will also provide for guidelines on formation of a National Tree Seed Advisory Committee (NTSAC), registration of tree seed sources and tree seed merchants, tree seed inspection, collection, processing, sampling, testing, tree seed importation and exportation, packaging, labelling and sealing, validity certification and quality declaration and offences and penalties for breaking the rules stipulated under each section.

c) Ensuring tree seed traceability to source

The institute has made significant efforts towards ensuring that tree seeds going out of KEFRI can be traced to the source. KEFRI represents Kenya in the OECD Forest Seed and Plant Scheme as the Chair of the Tree Seed traceability committee. The institute is also currently

working on registration and documentation of all information on available tree seed sources in the country. Though expensive, the activity is a priority to enable the institute to trade internationally and also for the seeds to attract better prices. Through compliance to the OECD regulations, the institute will ensure that establishment and management of tree seed sources meet international standards.

d) Building capacity of staff and stakeholders in forest/tree germplasm

Together with partners the institute will continue to build capacities of staff to carry out key activities such as collection, processing, testing and distribution of high quality germplasm. The institute is also building capacities of stakeholders in the above in addition to establishment, management of tree nurseries and tree resources. Sensitization campaigns on the importance of healthy materials and good forest management will be carried out countrywide through various media and fora.

e) Seed research and technology

The institute continues to carry out research on tree seed technology. This includes generating technologies to improve collection, processing, storage and germination of tree seeds among others. The focus is on developing technologies for germination of indigenous tree species as well as to establish testing standards for key species with collaborators that include OECD members, KEPHIS, World Agroforestry Centre (ICRAF), Seed Trade Association of Kenya (STAK), Kenya Seed Company and many other stakeholders to enhance exchange of healthy forest germplasm. The institute is already carrying out research in collaboration with ICRAF to develop a germplasm health quality management system (GH-QMS) for all ICRAF nurseries and field genebanks by 2020. The project is currently focussing on developing standards for *Grevillea robusta, Moringa oleifera, Sclerocarya birrea, Adansonia digitata, Berchamia bicolor, Vangueria rotundata* among others.

f). Establishment of a Tree Seed Certification Unit

The proposed amendment to the Seeds and Plant Varieties Act 2012 also provides for the establishment of the Tree Seed certification Unit. The unit will offer tree seed testing services and also phytosanitary certificates for tree seeds. This will be the first of its kind in the region. Resources to establish the unit and other tree seed activities are being mobilized from various sources including the exchequer.

g) Monitoring of forest pests and diseases

Forest health is critical to the exchange of health tree/forest germplasm. The institute carries out research aimed at developing pest and disease diagnostic technologies in order to improve pest /disease management support systems and advisory services to stakeholders especially on priority tree species. A forest health monitoring system has been put in place in all eco-regions to improve early detection of forest pests and diseases. The health team also seeks to understand the

role of climate change on the emergence of "new" forest pests /diseases in order to devise appropriate management strategies.

Conclusions

From the foregoing it is clear that phytosanitary challenges to tree germplasm exchange require multi-stakeholder collaboration, establishment of partnerships and networks to ensure that stakeholders access high quality germplasm. Mobilization of resources is therefore key to facilitating and sustaining the mitigation activities outlined above.

References

Ciesla, W. M. (1991). Cypress Aphid: A new Threat to Africa's forests. *Unasylva* 167(42)

Day, R. K., Kairo, M.T.K., Abraham, Y.J., Kfir, R., Murphy, S.T. Mutitu, K.E., Chilima, C.Z. (2003). Biological control of homopteran pests of conifers in Africa. In Neuenschwander, P. Borgemeister, C., C. & Langewald, J., eds., *Biological control in IPM systems in Africa*. CAB International, PP 101-112.

FAO, (2005). Global review of forest pests and diseases. A thematic study prepared in the framework of the Global Forest Resources Assessment 2005: FAO Forestry Paper 156.

Gure, A., Slippers, B., Stenlid, J. (2005). Seed-borne Botryosphaeria spp. from native Prunus and Podocarpus trees in Ethiopia, with a description of the anamorph *Diplodia rosulata* sp. nov. *Mycol Res.* 2005 Sep; 109 (Pt 9):1005-14.

Liebhold, A.M., Brockerhoff, E.G., Garrett, L.J., Parke, J.L., Britton, K.O., *(*2012). Live plant imports: the major pathway for forest insect and pathogen invasions of the US. Frontiers in Ecology and the Environment 10*:* 135–143.

Machua, J., L. Jimu, J. Njuguna, M. J. Wingfield, E. Mwenje and J. Roux, (2016). First report of *Teratosphaeria gauchensis* causing stem canker of Eucalyptus in Kenya: Short Communication. *For. Path*. doi: 10.1111/efp.12264

Mbinga, J. M. E., (2002). Genetic Variation in *Pinus radiata* (D. Don) progenies at Timboroa, Kenya. MPhil Thesis, Moi Unoversity, Kenya.

Mutitu, E., J. G.B. P. Hurley, B. Slippers (2013). Biology and rearing of BC for *Thaumastocoris peregrinus*. J. Econ. Entomology 106(5):1979-1985.

National Forests Programme 2016-2030. Ministry of Environment Natural Resources

Njuguna, J., Barklund, P., Ihrmark, K. and Stenlid, J. (2011). A canker and dieback disease threatening the cultivation of *Grevillea robusta* on small scale farms in Kenya. African Journal of Agricultural Research Vol. 6(3) pp 748-756.

Njuguna, J. W. (2011). *Stem canker and dieback disease on Grevillea robusta Cunn ex R. Br.* distribution, causes and implications in agroforestry systems in Kenya, Uppsala: Sveriges lantbruksuniv., Acta Universitatis agriculturae Sueciae, 1652-6880 ; 2011:23 ISBN 978-91-576-7558-3. Doctoral thesis.