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Navigating the International Exchange of Plant Genetic Resources Amidst Biosecurity Challenges: Experiences of IITA in Africa

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International Exchange of Germplasm is Vital for the Sustainable Development of Global Agriculture and Conservation of Biodiversity

International exchange of genetic resources as botanic seeds, plants or plant parts suitable for propagation has played a crucial role in the growth of international and national genebanks; development of improved high-yielding nutrient-rich crop varieties resilient to pests, diseases, and abiotic stresses; international trade in planting materials; and even international research collaborations. The frequency of international exchange of germplasm is on rise due to the growing demands of global food systems, international research partnerships, and trade linkages. Studies on the origin and use of food crops indicated that 68.7% of national food supplies are derived from crops with a foreign origin and emphasize the importance of the inter- and intra-continental exchange of germplasm (Khoury *et al*., 2016). The 11 CGIAR genebanks with 730,000 accessions in 35 collections manage the world's largest and genetically most diverse collections, and have distributed ~380,000 samples to over 120 countries between 2012 and 2014 for their own research and also to meet the demands of national crop improvement programmes (CGIAR 2014; Galluzzi *et al*., 2015). The 11 CGIAR genebanks were also credited with the highest annual number of international germplasm exchanges, especially under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). National climate change adoption policies on broadening genetic diversity for resilient cropping systems and the prevention of biodiversity loss are also spurring germplasm exchanges. Landraces and wild germplasm are mainly exchanged by the genebanks; improved varieties and research material (training sets, international evaluation trials, pre-breeding populations, etc.) are mainly exchanged by the breeding programmes, and both the private and public sectors are involved in the distribution of plant propagative materials for commercial and non-commercial uses. Various mechanisms are in place to facilitate germplasm exchange between countries. Phytosanitary cleanliness is the key criterion for a decision on the export or import of germplasm.

Germplasm Exchange is a Risky Affair and Regulated through Quarantine Controls

Exchange of germplasm carries simultaneous risks of moving harmful pests and pathogens between geographies and introducing them in new territories where they were not known to exist (e.g., intercontinental spread of *Banana bunchy top virus*). High risk of biotic agents spreading through plant and plant-propagation materials was recognized in the nineteenth century as a consequence of damaging outbreaks caused by pests and pathogens introduced with the germplasm (Klinkowski, 1970). The Irish famine due to the epidemic of potato late blight (*Phytophthora infestans*) in the 1840s was a notable example of catastrophic damage by an introduced pathogen from South America. Sensing similar risks, quarantine measures were enacted in 1873 for the first time in Germany and the UK as a legal measure for the inspection of potato for Colorado potato tuber beetle imported from the USA. Quarantine measures were subsequently adapted by several countries and eventually by the mid-twentieth century they had been established as a global norm.

Quarantine procedures continue to evolve to prevent every possible biotic risk from consignments of propagative and non-propagative plant products. Despite comprehensive measures, pests and pathogens find their way into new territories (Waage *et al*., 2006) resulting in serious economic damage. For instance, introduced insects and pathogens in the USA were estimated to cause annual losses worth US$40 billion (Pimental *et al*., 2005). More recently, the introduction of *Maize chlorotic mottle virus* (MCMV) in Kenya

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resulted in the loss of production worth over US$188 million between 2012 and 2014 (de Groote *et al*., 2016). The MCMV subsequently spread to other countries in East Africa, establishing a major threat to maize in the African continent (Mahuku and Kumar, 2016). A few plausible reasons for the incursion of biotic agents despite quarantine controls could include insufficient capacity limiting rigorous phytosanitary controls, insufficient knowledge on biological risks, and biophysical factors that are beyond human control. An analysis of 1,300 known invasive pests and pathogens and the risks they pose to 124 countries has identified developing countries, especially those in sub-Saharan Africa, (SSA), as the most vulnerable because of weak capacities to prevent or manage biological threats (Paini *et al*., 2016). Stringent inspections by both exporting and importing parties could reduce the risk of biotic agents spreading along with the germplasm and compensate for weak controls along the distribution network.

Germplasm Exchange from International Institute of Tropical Agriculture (IITA) is Vital for Ensuring Food Security in SSA

IITA in Nigeria is one of the CGIAR centers with an international genebank conserving germplasm of its six mandate crops: banana and plantain (*Musa* spp.), cassava, cowpea and wild *Vigna* species, maize, soybean, and yam. Since its establishment in 1967 the center has collected and conserved over 33,000 accessions of landraces and wild relatives representing global collections (cowpea and yam) as well as regional resources (cassava, maize, *Musa,* and soybean). The center also has a vibrant international breeding programme developing improved varieties of its six mandate crops. Both the genebank and the breeding programmes frequently exchange germplasm for research and other uses. Generally landraces and wild relatives are exchanged from the genebank; breeding programmes often exchange parental lines, pre-breeding populations, inter-specific hybrids, and inbred lines, and share international multilocational trials; seed system programmes acquire pest-free material for the bulk propagation of planting materials; germplasm or plant products are exchanged for research use. IITA conserves and distributes cowpea and *Vigna* spp., maize, and soybean as botanic seeds, germplasm of cassava, *Musa,* and yam as in vitro tissue culture plants or plant propagules such as stems, corms, or tubers.

The Germplasm Health Unit (GHU) of IITA Facilitates the Safe Exchange of Germplasm to End-Users

The majority of the IITA operations are in developing and less developed countries that lack adequate quarantine services to ensure the safe exchange of germplasm. Following the recommendations made in August 1993 during the Sixth International Plant Protection Congress in Montreal the CGIAR centers, including IITA, have established a dedicated GHU to ensure the exchange of germplasm that meets desired phytosanitary standards. The GHU facilitates the production, maintenance, and exchange of pest-free germplasm in accordance with the international requirements on plant protection advised by the FAO-International Plant Protection Convention (IPPC), the African Union Inter-African Phytosanitary Council (AU-IAPSC) and National Plant Protection Organizations (NPPOs). The Unit operates within the framework of the procedures for the introduction and export of germplasm established by the Government of the host country. For instance, all the exchange operations of IITA's activities in Nigeria are organized in accordance with the legislation of the Nigerian Agricultural Quarantine Service (NAQS).

GHU performs plant health indexing, seed treatment, and phytosanitation of clonal crop germplasm and ensures compliance with the national regulations on germplasm introductions and exports. GHU conducts research to develop technologies and strategies for improved phytosanitary cleaning of germplasm, better diagnostics for virus indexing, and efficient schemes for seed health inspection. GHU also participates in the surveillance schemes to generate baseline knowledge on pest and pathogen distribution in the target countries and this knowledge is used to establish inspection schemes.

GHU procedures are frequently updated in accordance with new knowledge on pest and pathogen occurrence in hosts and geographies. Increasing reports of new viruses, many of which were discovered based on the small RNA sequencing using NGS technologies (Roossinck *et al*., 2015) are posing new challenges to phytosanitary decision-making. The NGS-based discovery of viruses in some clonal crop germplasm considered to be virus-free is exposing the limitations of current procedures. New schemes are being developed to standardize the virus indexing of clonal crop germplasm using NGS-based methods for a high-level assurance of health status.

GHU adopts the most stringent standards to monitor germplasm imported to and exported from IITA. Germplasm of clonal crops is exchanged in the form of virus-indexed *in vitro* plants generated from meristem tip cultures subjected to thermo- or chemotherapy procedures. Certified in vitro plants are used for propagation under pest-free conditions (contained screen houses) to generate vegetative plant parts (mini-stem cuttings for cassava; mini-tubers for yam; corms for *Musa*) for distribution to countries/partners that cannot accept in vitro plants owing to a lack of facilities for propagation or post-flask management.

GHU annually facilitates germplasm exchange with 40 to 50 countries; the majority of them are in Africa. Maize is the germplasm most frequently exchanged, followed by cassava, cowpea and other *Vigna* species, soybean, and yam. *Musa* germplasm exchange is pacing since the development of a new decision scheme in 2015 for distributing *Musa* germplasm with integrated badnavirus genomes that were blocked from distribution. GHU proactively engages with stakeholders to appraise and understand the needs and possibilities for facilitating germplasm exchange within the permissible rules.

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