Enhancing resistance to coffee wilt disease in Uganda – the conventional way

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Today, much emphasis is placed on the prospects of using genetically modified (GM) crops to withstand pests and diseases or other environmental pressures such as water stress, and to modify them so that they withstand herbicide treatment that kills weeds. Yet we should not overlook the great strides in overcoming pests and diseases that continue to be made with conventional plant breeding. In recent years, the story of breeding for resistance to coffee wilt disease (CWD) is an important reminder that conventional plant breeding still has a place in the armamentarium of the modern plant breeder.

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over the last decades.[2] This has been based on a process of genetic inheritance through back-crossing and selection for features such as faster growth, higher yields, pest and disease resistance or consumer quality, and has dramatically changed domesticated plant species compared to their wild relatives.

Conventional breeding using genetic inheritance was first discovered by Gregor Mendel in 1865 following experiments with crossing peas, where he provided the first evidence of hereditary segregation and independent assortment.[2,3] According to Manshardt,[4] conventional breeding is better suited for improving many traits simultaneously, or improving traits controlled by many genes, or traits for which the controlling gene has not been identified. The advantage of this breeding is that it is relatively inexpensive, technically simple and free of necessary government regulation. However, it is estimated that with conventional breeding it takes about 7–10 years (or even longer) to complete and/or release a variety of an annual cultivar such as corn, wheat or soybeans.[2] For tree crops such as coffee, it takes much longer – up to 30 years.[5] For this reason, genetic engineering might be applied as a choice to circumvent the shortcomings of sexual reproduction.[4]

The importance of coffee in Uganda

More than 1.3 million Ugandan households derive their livelihoods directly from coffee,[6] the majority of them being rural smallholder farmers. Coffee contributes about 20 per cent of Uganda's foreign currency earnings and about 64 per cent of earnings from traditional export crops alone.[7]

Uganda relies on two types of coffee, Robusta (*Coffea canephora* Pierre) and Arabica (*Coffea arabica* Linnaeus), of which Robusta accounts for 80–85 per cent of the exports by volume and 65–80 per cent of total earnings. However, Uganda has a higher competitive advantage for Robusta coffee production due

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to the fact that the country's general altitude is higher (more than 1,000 metres above sea level) than that of most countries where the crop is grown, thus conferring exceptionally high consumer quality. The devastation of Robusta coffee by coffee wilt disease (CWD) caused by the fungus, *Fusarium xylarioides* Steyaert, during the last two decades (1990s to late 2000s) led to losses of up to 45 per cent and greatly undermined government efforts to increase coffee production from 3.15 million bags in 2001/2 to 12 million bags by 2007/8.[8]

The coffee wilt disease menace

By 2002, CWD had affected at least 90 per cent of Robusta coffee farms and destroyed more than 45 per cent of Robusta coffee trees all over the country.[8,9] The overall effect was a significant reduction in export volumes, from 4.2 million 60-kilo bags of green coffee beans exported in 1996[10] to 2.0 million bags in 2006.[9] This implies that Uganda could have lost about 50 per cent of the revenue expected from coffee exports as a result of the disease itself or related factors such as farmers' abandonment of coffee production as an enterprise.[11]

Many rural smallholder Robusta coffee farmers were left in abject poverty due to losses in coffee, leading them to change their lifestyles and reduce expenditure on their education, health and food consumption as well as social welfare. As a result, 27 per cent of households liquidated their assets, including land, communication equipment (radios and television), bicycles and large livestock such as cattle, and opted to invest in non-crop farming enterprises to meet household needs such as food, medical expenses or burial arrangements. New

ventures included starting poultry farms and purchasing motor bikes to launch transportation businesses.[11]

Coffee-wilt disease also undermined previous research efforts that had developed six high-yielding and good-quality Robusta coffee varieties, popularly known as clonal coffee.[12] However, these varieties may have been inadvertently selected for higher yields without considering their susceptibility to CWD, as the disease had not been reported as a serious impediment to coffee production in the country.

Efforts to manage coffee-wilt disease

The role of research

The Coffee Research Centre (COREC), based at Mukono under the National Agricultural Research Organisation (NARO), played a leading role in correct diagnosis of CWD and in educating farmers to identify early symptoms and then manage the disease.[8,13] Through research, it was established that infected plant parts such as stems, branches, leaves, roots, coffee husks and infected seedlings were the primary sources of new infection and spreading of the disease to new sites.[8,14] It was also found that the pathogen did not survive for more than two years in infected dead plant parts and soil under field conditions. Besides infected plant parts, the disease was also found to spread through contaminated soil, running water and contaminated tools. Genetic studies of the isolates of the pathogen from different parts of the country confirmed that *F. xylarioides* from Uganda belonged to one strain which exclusively affects Robusta coffee.[15,16,17] All this information was utilised in the formulation and

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dissemination of cultural management strategies for controlling the disease.

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Cultural control recommendations

Once research had established the mode of transmission of CWD, farmers were massively sensitised and advised to uproot and burn infected coffee trees *in situ*[8,9,13] when the first signs of infection were detected. They were also encouraged not to use farm tools that had been used in infected farms. Together with other stakeholders, coffee scientists went into overdrive to train farmers in Robusta growing areas through farmer-field schools, coffee production campaigns and training of trainers on cultural methods of CWD management.

Under this arrangement, extension officers and more than 40,000 farmer trainers were informed through participatory research, using farmer field schools in all Robusta coffee growing districts.[8,13,18] This had a multiplier effect, as trained farmers were able to train others by hosting farmer field days with other coffee farmers at their farms, guided by researchers and extension officers. In addition, this was amplified by dissemination of training materials under a regional project funded mainly by the Common Fund for Commodities and the government of Uganda, in the form of brochures and posters prepared in different languages – including English, Luganda, Lusoga and Runyakitara – for extension workers, farmers, primary and secondary schools as well as higher institutions/universities where agriculture is taught. The farmer field schools attracted other players such as non-governmental organisations, who in addition multiplied and distributed clean and disease-free coffee planting materials. Furthermore, it was emphasised that organic manures (applied at

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20 kilos per tree), mulching and the application of herbicides such as glyphosate (Round-up) rather than using machetes ("slashers") for controlling weeds in coffee plantations could, if significantly adopted, reduce the rate of disease infection and spread.

Management interventions also included massive replanting of disease-free clonal coffee seedlings by the Uganda Coffee Development Authority and information dissemination through coffee production campaigns involving other partners.[8] Over time, coffee production and exports started to improve, rising from the earlier figure of 2.0 million bags to reach 2.73 and 3.15 million bags of green coffee beans by 2011 and 2012 respectively.[6] It has been estimated that if losses due to CWD had been avoided, Uganda would currently be exporting more than 5 million bags of green coffee beans worth above US $600 million per annum.

Despite the fact that disease management played a vital role in containing CWD, it was still considered to be a short-term measure: permanent solutions had to be sought. Developing CWD-resistant varieties was therefore deemed the most cost-effective and sustainable option.

Development of resistant varieties

The use of resistant varieties is considered to be the most appropriate, cost-effective and sustainable method of controlling CWD in Uganda. However, it is important that this is done without compromising yield, quality and resistance to other diseases. Since CWD first appeared in Uganda in 1993, the resistance

of the available commercial varieties (Robusta and Arabica) had to be ascertained and new varieties developed.[1,16]

The search for Robusta coffee varieties resistant to CWD was initiated at COREC in 2001. This involved screening all coffee germplasm from naturally infected fields and following artificial inoculations in the screen house. In this regard, Arabica coffee was found to be totally resistant to the *F. xylarioides* strain in Uganda but Robusta coffee was significantly susceptible.[1,16]

Using this approach, seven CWD-resistant Robusta clones were identified and released for further multiplication and dissemination to farmers, while more than 1,500 resistant clones were identified through large-scale screening of germplasm using artificial inoculations in the screen house at Kituza;[1] these continue acting as a gene pool for further selection of more multi-lines. The 1,500 clones identified through artificial inoculations were planted in mother gardens at COREC, Kituza, and thereafter were cloned and planted in CWD-infested field trials for further evaluation for other diseases, tree stature and cup and bean qualities. Multiplication of the seven released lines has been going on, using both cloned rooted cuttings and tissue culture, and a number of mother gardens have been established in many parts of the country in order to involve other stakeholders and make the plants available to more farmers. However, the process of generating sufficient planting materials for all farmers in the country will take a long time, as this will involve supplying plants to more than 500,000 households involved in coffee cultivation. It

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has been estimated by the government that Uganda will need more than 200 million plants to rejuvenate its intended production capacity.

The process of generating sufficient CWD-resistant planting materials for the affected households is still a big challenge and will require concerted efforts involving both the public and private sector. To bridge this gap, COREC and UCDA initiated a partnership with the private sector, using one of the most vibrant local laboratories[19] to generate at least 2 million planting materials through tissue culture. In addition, the capacity of private nursery operators as well as the COREC tissue culture laboratory was enhanced for the generation of planting materials by vegetative propagation through rooted nodal cuttings. More planting materials have already been supplied to about 100 private nursery operators distributed throughout the major Robusta coffee-producing regions of the country. Other nursery operators are also being identified to receive plants and be trained to further multiply the planting materials through cloned rooted cuttings.

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