Disease-resistant GM cassava in Uganda and Kenya during a pandemic

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The emerging pandemic of cassava brown streak disease (CBSD) presents a threat to cassava production in East Africa. Genetic modification (GM) of cassava for resistance to CBSD under field conditions was demonstrated in Uganda and Kenya between 2009 and 2012. The study described here was undertaken to determine if investment in GM cassava for delivery of CBSD-resistant varieties to smallholder farmers would be economically sound.

In 2014, smallholder cassava farmers and wholesalers in western Kenya and in northern, eastern and central Uganda were interviewed to evaluate their knowledge and acceptance of GM cassava. Interviewees were assessed for their awareness of the major constraints facing cassava production and their willingness to grow and sell GM varieties modified for resistance to CBSD. Information gathered was used to determine the potential adoption rates and economic benefits of deploying GM cassava to combat the rapidly increasing spread and impact of CBSD in East Africa. If deployed by 2025, the net benefit of the CBSD-resistant varieties is estimated at US$ 436 million in western Kenya and US$ 790 million in Uganda over a 35-year period. This indicates that the research

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Originating from Latin America, the tuberous root crop cassava is now central to maintaining food security across much of tropical Africa. Cassava has been subject to a succession of pandemics, including cassava mealy bug and virulent forms of the two virus diseases, cassava mosaic disease (CMD) and CBSD. Indeed, virus diseases are presently estimated to cause annual losses of almost a third of the total crop.[1] CMD causes malformation of the leaves and reduced storage root yields, while CBSD induces serious necrosis of the edible roots, rendering the crop unfit for sale or consumption.

Over the last 15 years the incidence and severity of CBSD has increased, spreading beyond its traditional area of distribution in coastal East Africa to appear in Uganda and western Kenya. It is now spreading quickly through Central and Southern Africa to reach pandemic proportions. Delivery of robust, disease-resistant varieties to help cassava farmers secure their crop against the effects of CBSD is paramount but has proved to be difficult. Traditional breeding methods have been limited in their ability to tackle the disease due to lack of genetic resistance to the causal viruses in existing cassava varieties.

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Engineering virus resistance

The Virus Resistant Cassava for Africa (VIRCA) project was initiated in 2006. Its objective is to improve smallholder livelihoods by delivering CMD- and CBSD-resistant cassava varieties to farmers in Uganda and Kenya.[2] VIRCA is

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a collaborative public-sector project involving the Donald Danforth Plant Science Center (DDPSC), USA; the National Crop Resources Research Institute (NaCRRI), Uganda; the Kenyan Agricultural Livestock Research Organization (KALRO), Kenya; and the International Institute for Tropical Agriculture (IITA), Nigeria. VIRCA is employing GM technologies to develop cassava with robust resistance to both CMD and CBSD. The GM varieties are not expected to require high input levels of fertilisers or other agrochemicals and will fit into existing smallholder cassava farming systems in a manner identical to non-GM cassava. As a not-for-profit project, no premium cost for the technology will be passed to the farmer.

GM approaches to crop improvement have different objectives when applied by the public and private sectors. The private sector must operate within trait, commodity and market contexts that ensure profit at least to repay the investment in research, development and distribution costs. This often requires exclusive rights over the improved varieties, unless royalty-free rights are granted for humanitarian reasons. The public sector, in contrast, can deliver royalty-free planting materials to farmers, and focus on crops, traits and regions where no direct economic returns exist. The latter case is prevalent in Sub-Saharan Africa, especially for subsistence and semi-subsistence staple crops like cassava. Strategically targeted investment of public funds to benefit smallholder farming systems is essential, however, if the desired social and economic returns are to be realised. The present study was undertaken to evaluate if a GM approach can prove economically viable in smallholder agriculture in Africa. The virus-resistant GM cassava under development by the VIRCA project was used as a case study for this assessment.

Face-to-face evaluations were undertaken by interviewing approximately 450 cassava farmers and 60 wholesalers using structured questionnaires designed to determine their perceptions of the major constraints facing cassava production and marketing. Participants were also surveyed for their knowledge of biotechnology, to establish where they obtained such information, and whether this would influence their adoption of GM cassava varieties improved for resistance to CMD and CBSD. Data collected allowed statistical analysis for preference of different traits across a range of farm households and market conditions. This information was used to evaluate how such preferences would be met with the cassava varieties being targeted for genetic modification. It is rare for *ex-ante* impact studies – based on forecasts before the event rather than actual results – to include an *ex-ante* evaluation of adoption in this manner. This was achieved using a market research method termed conjoint analysis, which allows detailed assessment of the different valued attributes and traits within a crop product such as cassava. Variation in demand for these traits was assessed across households to determine which characteristics influenced demand for the GM varieties. The adoption potential was in turn used to determine the potential economic impact of deploying the virus-resistant GM cassava.

Deciding which cultivars to genetically modify is critical

A number of critical decisions have to be made in the development and deployment of GM cassava varieties. Deciding which cultivars to genetically modify is critical. Smallholder farmers cultivate many different cassava varieties within the same agro-

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economic region, sometimes even within the same fields. Choice of cultivar for genetic modification has a number of dimensions, including adaptive range, cultivation and cropping characteristics, in addition to consumer traits such as cooking and eating qualities. These affect the ease and rate of adoption of cassava varieties, the geographic scale of uptake and, in turn, the potential economic benefits gained from deployment of a GM variety. The VIRCA project chose to modify two varieties – TME204 and Ebwanateraka – which have a history of cultivation by farmers in Uganda and western Kenya, and both of which possess consumption traits preferred by consumers. The initial trait focus was genetic modification for resistance to CBSD within cultivar TME204. TME204 possesses inherent resistance to CMD but is highly susceptible to CBSD. The present study of the potential impact of the VIRCA varieties comes midway through the development of the TME204 variety with GM resistance to CBSD, clearly demonstrated under regulated field trials in the two countries.

Principal findings

The survey of smallholder farmers and cassava retailers in 2014 highlighted differences between western Kenya and Uganda. In western Kenya farmers prefer fast-maturing CBSD- and CMD-resistant cassava varieties, whereas in Uganda farmers prefer high-yielding CBSD- and CMD-resistant varieties. The threat of virus disease was clearly recognised as a major concern among farmers in both countries, with CBSD tolerance being the most valued trait attribute in both locations. In western Kenya, a sweet taste and good flour significantly influence farmers when selecting a cultivar. A sweet taste is also preferred in Uganda, as well as short cooking time. These preferences are compatible with the trait attributes of the two varieties considered for genetic modification in the VIRCA project.

Both varieties were selected because they were popular among farmers before the CBSD pandemic. They both yield well (potentially more than 30 tonnes per hectare) and mature in a relatively short time (9–12 months). Both cultivars are recognised as excellent, with a sweet taste, soft texture and good flour quality. Analysis of the data collected from farmer surveys therefore confirmed the selection of these two cultivars as good targets for genetic modification with virus resistance.

For relatively low-income farmers with limited education, a surprisingly high percentage indicated an awareness of biotechnology. Approximately 50 per cent of the farmers surveyed in western Kenya and 58 per cent of farmers in Uganda responded as such. Importantly, this awareness of biotechnology resulted in over 90 per cent of farmers in both countries indicating willingness to grow the GM virus-resistant varieties, with the GM trait not negatively affecting the potential willingness of farmers to adopt them. In Kenya, farmer information on biotechnology was found to come primarily from other farmers, the Ministry of Agriculture and the Kenya Agricultural and Livestock Research Organization (KALRO). These government organisations would be expected to provide practical and accurate information on the GM varieties, especially as they would also be responsible for the initial multiplication and deployment processes. In Uganda, reliance is principally on other

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farmers, radio or non-governmental organisations (NGOs) for information on biotechnology, though with NGOs there is some potential for confused or contradictory messages on this topic. The need to manage information flow in Uganda associated with the multiplication and deployment of the GM varieties is therefore an important outcome of this study.

Traders are often seen as gatekeepers for the potential acceptance of new and improved varieties, in effect anticipating consumer reaction. For cassava this is partly true given the large subsistence component of the crop, with on-farm consumption being the norm.

In western Kenya, about a third of wholesalers currently trade in the two cassava varieties (TME204 and Ebwanateraka) being targeted for GM virus resistance. The availability of these varieties was low when this study was performed. However, approximately 80 per cent of wholesalers responded that they would trade them if available. Some 70 per cent indicated that they would trade them as GM varieties and 80 per cent stated that they would sell them at a discounted price, with any discount expected to fall over time as consumers became more accustomed to the quality of the GM varieties.

In Uganda, there is little present market trade in the two varieties being targeted for GM disease resistance, at least in the larger wholesale markets for cassava. This is probably due to supply constraints resulting from the impact of CBSD, because traders knew of the varieties and responded that they would trade them if available. If the varieties were genetically modified, retailer responses indicated some reduction in the prospect of trading, but this was only about 10 per cent, with some increase in trading indicated if the GM varieties were to be sold at a 25 per cent discount. The strong implication generated by surveying wholesalers in both countries is that increased supplies of these varieties in the form of a GM product would be readily accepted by traders. Such increases in supply are expected as a result of the reliable yield gains generated by virus-resistant GM strains of TME204 and Ebwanateraka.

Benefits

The *ex-ante* analysis estimates of net benefits (i.e. net present value) for the release of the CBSD-resistant varieties are US$ 436 million in western Kenya and US$ 790 million in Uganda over a 35-year period, calculated using an adoption date in 2025. This produces an internal rate of return of around 50 per cent in both countries, a result comparable to rates of return found in other studies of agricultural biotechnology. For example, a recent meta-data analysis found that GM crops on average increased farmer yields by 22 per cent and farmer profits by 68 per cent.[3] In the present GM cassava study farmers are the principal beneficiaries, although consumer benefits are also significant. Such high rates of return can be expected when effective control measures are being deployed during a pandemic such as the current situation with CBSD.

Increased supplies of the target varieties in the form of a GM product would be readily accepted by traders

For the GM cassava varieties studied here, the costs are therefore small in relation to the potential economic benefits. High adoption rates, large yield gains and relatively low research and development (R&D) investment costs are key aspects of the strategy being implemented by the VIRCA project. All these

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factors support the large economic return of GM cassava as determined in this study.

The potential impact of the GM varieties being targeted by VIRCA is characterised by the relatively small initial deployment area of western Kenya and Uganda. Even so, these results provide strong support for the strategy of deploying virus-resistant GM cassava varieties. They also provide support for the development of additional GM cassava varieties that meet farmers' preferred characteristics within the wider East, Central and Southern African regions. Such products would increase the impact of the technology and bring the benefits of CBSD- and CMD-resistant material to a greater number of farmers. Experience gained in Uganda and western Kenya should also reduce the cost of developing and testing additional varieties, further increasing the net benefits of the GM approach to CBSD resistance.

Conclusions

The potential of biotechnology, especially GM crops, is often exaggerated. However, trait deployment through genetic modification can play a strategic role in agricultural R&D in Sub-Saharan Africa. The development of virus-resistant GM cassava varieties is a good example of the strategic use of the technology, especially if combined with critical design options that optimise the potential adoption and economic impact of the GM varieties.

This study validates the approach being pursued by the VIRCA programme in terms of both the adoption potential of these varieties and the expected economic returns on the investments in the programme. The economic benefits, which average US$ 35 million a year across the two countries, are large, based on a number of factors and design decisions, including: (1) the choice of preferred varieties for genetic modification that will lead to high adoption within the target regions; (2) successful resistance to CBSD during an evolving pandemic; and (3) R&D costs that are low in comparison to the potential benefits. The *ex-ante* impact analysis supports the extension of this approach to other countries and sub-regions being affected by CBSD.

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