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Community phytosanitation to manage cassava brown streak disease

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ABSTRACT

Cassava viruses are the major biotic constraint to cassava production in Africa. Community-wide action to manage them has not been attempted since a successful cassava mosaic disease control programme in the 1930s/40 s in Uganda. A pilot initiative to investigate the effectiveness of community phytosanitation for managing cassava brown streak disease (CBSD) was implemented from 2013 to 2016 in two communities in coastal (Mkuranga) and north-western (Chato) Tanzania. CBSD incidence in local varieties at the outset was > 90%, which was typical of severely affected regions of Tanzania. Following sensitization and monitoring by locally-recruited taskforces, there was effective community-wide compliance with the initial requirement to replace local CBSD-infected material with newly-introduced disease-free planting material of improved varieties. The transition was also supported by the free provision of additional seed sources, including maize, sweet potato, beans and cowpeas. Progress of the initiative was followed in randomly-selected monitoring fields in each of the two locations. Community phytosanitation in both target areas produced an area-wide reduction in CBSD incidence, which was sustained over the duration of the programme. In Chato, maximum CBSD incidence was 39.1% in the third season, in comparison with an incidence of > 60% after a single season in a control community where disease-free planting material was introduced in the absence of community phytosanitation. Kriging and geospatial analysis demonstrated that inoculum pressure, which was a function of vector abundance and the number of CBSD-infected plants surrounding monitored fields, was a strong determinant of the pattern of CBSD development in monitored fields. In the first year, farmers achieved yield increases with the new varieties relative to the local variety baseline of 94% in Chato (north-west) and 124% in Mkuranga (coast). Yield benefits of the new material were retained up to the final season in each location. The new variety (*Mkombozi*) introduced under community phytosanitation conditions in Chato yielded 86% more than the same variety from the same source planted in the no-phytosanitation control location. Although there was an 81% reduction in CBSD incidence in the new variety *Kiroba* introduced under community phytosanitation compared to control conditions in Mkuranga, there was no concomitant yield increase. Variety *Kiroba* is known to be tolerant to the effects of CBSD, and tuberous roots of infected plants are frequently asymptomatic. Community phytosanitation has the potential to deliver area-wide and sustained reductions in the incidence of CBSD, which also provide significant productivity gains for growers, particularly where introduced varieties do not have high levels of resistant/tolerance to CBSD. The approach should therefore be considered as a potential component for integrated cassava virus management programmes, particularly where new cassava plantations are being established in areas severely affected by CBSD.

1. Introduction

Cassava brown streak disease (CBSD) is one of the most important constraints to the production of cassava in Africa. Its continental significance has increased since the early part of the 21st century as new outbreaks were reported from the Great Lakes region of East and Central Africa (Alicai et al., 2007; Legg et al., 2011). Because of these new epidemics, concern has been raised about the potential for further westwards spread towards the major production zones of West-Central and West Africa (Legg et al., 2014a). Significantly, Nigeria is currently

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the world's largest producer of cassava (FAOSTAT, 2017), and if CBSD was to spread there, its effects on cassava production could have a global impact.

Cassava brown streak disease is caused by two species of cassava brown streak ipomovirus (CBSI) (Family *Potyviridae*: Genus *Ipomovirus*): *Cassava brown streak virus* (CBSV) and *Ugandan cassava brown streak virus* (UCBSV) (Mbanzibwa et al., 2009). These are spread through stem cuttings when infected plants are used as a source of planting material, and they are also spread in a semi-persistent manner by the whitefly vector, *Bemisia tabaci* (Genn.) (Maruthi et al., 2005; Jeremiah, 2012). For many years, following the first report of CBSD in Tanzania (Storey, 1936), the geographical distribution of the disease was confined to coastal East Africa and the shores of Lake Malawi (Nichols, 1950). Recent epidemics reported from the Great Lakes region from 2004 onwards have been linked with the occurrence of super-abundant populations of the whitefly vector in these regions (Legg et al., 2011, 2014b, 2015). This change in the vector dynamics was considered to be the key factor in the earlier development and spread of the severe pandemic of cassava mosaic disease (CMD) (Otim-Nape et al., 1997), caused by cassava mosaic begomoviruses (CMBs), which are also transmitted by *B. tabaci* (Chant, 1958; Dubern, 1994). Although *B. tabaci* genotypes occurring on cassava may also colonize other host plants (Sseruwagi et al., 2006), their abundance on these hosts is so low as to render them insignificant in the epidemiology of the CBSIs and CMBs. Additionally, cassava is the only commonly-occurring host of the CBSIs. One alternative host is recognized in the published literature (*Manihot glaziovii* Muell.-Arg.) (Mbanzibwa et al., 2011), but this occurs infrequently in most areas of cassava cultivation.

Management efforts for both CBSD and CMD have mainly focused on the development of resistant varieties (Dixon et al., 2003; Kawuki et al., 2016). CMD-resistant varieties have been bred using conventional approaches, and these varieties are widely distributed through the cassava-growing regions of Africa (Manyong et al., 2000). By contrast, there has been less success with efforts to identify, introgress and disseminate sources of resistance to CBSD.

Phytosanitary measures have also been widely advocated for CMD and CBSD control. At farm-level, the removal of infected plants (roguing) and selection of healthy stems for replanting have frequently been recommended by research and extension agencies (Hillocks and Jennings, 2003). Recent studies, however, have highlighted important contrasts in the epidemiologies of the two virus groups causing these diseases. Persistently-transmitted CMBs are retained by the whitefly vector for much longer periods than CBSIs, allowing for longer distance spread (Dubern, 1994; Legg et al., 2011; Jeremiah, 2012). In addition, the symptoms of CBSD are much less readily recognized than those of CMD, since CMD is typically most severe on young leaves at the top of the plant, whilst CBSD symptoms are most commonly expressed on lower leaves, do not distort the leaf shape, and may readily be confused with other conditions such as mineral deficiency or leaf senescence (Nichols, 1950). Limited progress in developing CBSD resistance, the relative difficulty of recognizing CBSD symptoms in infected plants, and inefficiency of long-distance spread of CBSIs by the whitefly vector, together mean that there is an urgent need to control the disease through the implementation of a 'clean seed' programme. Systems for the production of healthy planting material have been initiated in several countries of East Africa worst affected by CBSD (IITA, 2014). These aim to 'prime' the system with virus-indexed plantlets produced and multiplied through tissue culture. This approach is combined with pre-basic field production of planting material in isolated locations within production zones, and a rigorous and formalized mechanism for inspecting and certifying seed production sites at pre-basic, basic and certified levels. Pre-basic cassava 'seed' (= planting material) is the highest quality 'seed', produced by breeders of the national research system. Basic 'seed' is produced by private seed companies or large farmers who receive pre-basic 'seed', multiply it and sell to certified 'seed' producers, who are large or medium-scale farmers. Cassava 'seed' at each of these levels is required to be inspected by national seed inspection authorities prior to being sold or distributed through formal seed dissemination programmes. As stocks of certified planting material at the various levels have become more readily available, questions have arisen about the best model through which to introduce certified planting material to village communities. Theoretically, since CBSIs spread poorly over distance, there should be a significant benefit to growers in reducing area-wide inoculum levels if they introduce healthy planting material as a group. In addition, the benefit of this approach should be greatly enhanced if existing sources of inoculum are removed prior to the introduction of clean planting material of the new variety. There is a precedent for community-level action of this type. In the 1930 and 1940s, epidemics of CMD had a devastating impact on cassava production through large parts of Uganda. This was addressed by a colonial government programme which enforced the removal of existing fields that were infected, and provided for their replacement with disease-free stocks of planting material with higher levels of CMD resistance (Jameson, 1964). The effort proved effective, and CMD was subsequently considered to be a disease of only moderate importance until the devastating epidemic that affected virtually all cassava-growing regions of the country in the 1980s and 1990s (Otim-Nape et al., 1997). There have been no subsequent efforts anywhere where CMD occurs in Africa or Asia to apply community-wide phytosanitation measures. This is partly a consequence of the relative success achieved in breeding for resistance, but also the difficulty of implementing such a programme under the less authoritarian community governance conditions of post-independence Africa. The contrasting characteristics of CBSD's symptomatology and epidemiology, however, provided an opportunity to test a new community-level phytosanitation initiative which was the first of its kind for CBSD and the first for any cassava disease since the 1940s. The objective of this study was to determine if selected communities in regions affected by CBSD would be able to co-operate in applying phytosanitation to manage CBSD. More specifically, the study aimed to determine whether collective action involving groups of neighbouring cassava producers jointly applying phytosanitation measures would deliver improved disease management and yield outcomes in comparison with control communities in which material from the same source was introduced to single dispersed individuals who did not apply phytosanitary controls. The study was conducted between 2013 and 2016 in two communities in Tanzania, one in the north-west of the country next to Lake Victoria, and the second in the eastern coastal zone of the country. It was anticipated that if the results obtained were favourable, the approach might be scaled out more widely for community management of CBSD in all affected parts of East and Central Africa.

2. Materials and methods

2.1. Study location

Four communities were initially targeted for the piloting of community phytosanitation in Tanzania. Two of these were in the Lake (Victoria) Zone of the north-west (in Muleba and Chato Districts) and two in the eastern Coast Zone (in Kisarawe and Mkuranga Districts). Following preliminary interactions with all communities, the programme determined to complete the initiative in one location per Zone: Chato in the Lake Zone and Mkuranga in the Coast Zone. These two locations were selected based on the importance of the cassava crop to the communities and the relative severity of CBSD. Mkuranga District is in the Coast Region, immediately to the south of the metropolitan Region of Dar es Salaam. Chato District is in Geita Region, on the shores of the south-west corner of Lake Victoria (Fig. 1).