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Review Article

Sweet Potato, A Research Neglected Important Food Crop, Regarding Virus Research and Propagation Systems: A Review

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Abstract

Although sweet potatoes are ranked seventh in global food production the research input is less than one third when compared with research input in potatoes in general. Thus, research in overcoming virus diseases was so far not able to overcome the Sweetpotato virus diseases causing severe reduction in yields in African countries. This review aimed at creating more awareness of carrying out researches in Sweetpotato virus and propagation systems mainly in African countries. The main virus diseases are described as well as selection and breeding efforts, both by conventional and genetic engineering approaches. Operations of pilot plants supplying farmers with virus tested planting material were suggested.

Keywords: Sweet potatoes; Virus diseases; African countries

Introduction

Sweetpotato (Ipomoea batatas) is ranked seventh in global food crop production, yielding c~ 131 million tons [1]. They are the third most important root crop after potato, which is the fourth most important food crop, with an annual production of about 300 million tons. Both crops are vegetative propagated and therefore virus diseases can become a major constrain. However, the number of scientific items on potato viruses was 3.6 times higher than those on sweet potato viruses, about 926000 on potatoes compared with 257000 papers on sweet potato. The number of scientific items on propagation of potatoes was about 489000, while on sweet potatoes, according to Google, it was 139000.

Sweet potatoes are grown on about 8.1 million hectares, yielding c~ 131 million tons, with an average yield of about 15 ton/ha [1]. They are mainly grown in developing countries, which account for over 95% of world output. The cultivated area of sweet potato in China, about 3.7 million ha, accounted for 70% of the total area of sweet potato cultivation in the world. China produces about 80 million tons, circa 46% of the total world production. Vietnam is the second largest producer. Sweetpotato is a 'poor man's crop', with most of the production done on a small or subsistence level. Sweetpotato produces more biomass and nutrients per hectare than any other food crop in the world. Thus, for example, across East Africa's semiarid, densely populated plains, thousands of villages depend on sweet potato for food security (If these data and information are from a referenced work, kindly cite it here and include the full reference in the reference section).

Sweet potatoes are grown for both the leaves, which are used as greens, and the tubers, for a high carbohydrate and beta-carotene source. Yields differ greatly in different areas or even fields in the same location. Thus, the average yield in African countries is about 4.7 tons/ha, with yields of 9.1, 4.5, 1.9 and 2.9 ton/ha in Kenya, Uganda, Sierra Leone and Nigeria, respectively. The yields in Asia are significantly higher, averaging 20.0 tons/ha. China, Japan, Korea and Israel have the highest yields with about 22.0, 21.7, 15.6 and 33.3 tons/ha, respectively. In South America the average yield is 12.3 tons/ha, with Argentina, Peru and Uruguay in the lead with 14, 16.8 and 10.9 tons/ha, respectively. For comparison, the average yield in the US is 22.8 tons/ha [1].

These differences in yields are mainly due to variation in quality of the propagation material. Sweet potatoes are vegetative propagated from vines, root slips (sprouts) or tubers, and farmers in African and other countries often take vines for propagation from their own fields year after year. Thus, if virus diseases are present in the field they will inevitable were transmitted with the propagation material to the newly planted field, resulting in a decreased yield. Often these fields are infected with several viruses, thereby compounding the effect on yields. In countries were care is taken to provide virus-tested planting material as, amongst others in the US and Israel, yields increase markedly, up to seven times and more. However, with potatoes most countries have reliable systems to provide farmers with high-grade "seed" potatoes [2].

Viruses of Sweetpotato

Viruses of sweet potato have been well characterized, though this is only a first necessary step in their control. Sweet Potato Feathery Mottle Virus Genus Potyvirus (SPFMV); is the most common sweet potato virus worldwide. In Africa, SPFMV causes a severe Sweet Potato Virus Disease (SPVD) in a complex infection with the whitefly-transmitted Sweet Potato Chlorotic Stunt Virus Genus Crinivirus (SPCSV) [Syn. Sweet potato sunken vein Genus Crinivirus (SPSVV)]. Most sweet potato cultivars infected by SPFMV alone show only mild circular spots on their leaves or light green patterns along veins. However, when infected together with the whitefly-transmitted SPCSV stunting of the plants, feathery vein clearing and yellowing of

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the plants are observed. In controlled experiments SPFMV-infection alone did not reduce yields compared to virus-free controls, while the complex infection with SPCSV reduced yields by 50% or more SPFMV is transmitted in a nonpersistent manner by aphids, including Aphis gossypii, Myzus persicae, A. craccivora and Lipaphis erysimi. SPFMV can be diagnosed by Enzyme-Linked Immunosorbent Assay (ELISA), and antisera are commercially available. However, ELISA reliably detects SPFMV only in leaves with symptoms.

East Africa appears as a hotspot for evolution and diversification of SPFMV [3].

Virions are filamentous; not enveloped; usually flexuous; with a modal length; of 830-850 nm. The genome consists of single stranded linear RNA, with a Poly (A) region. Though SPFMV alone generally causes only minor damage, its control is imperative as in combination with other viruses its effect on plant growth and yields may become substantial.

Sweetpotato Chlorotic Stunt Virus Genus Crinivirus (SPCSV). {Possible synonym: Sweetpotato sunken vein virus (SPSVV)}. Infection of sweet potato by SPSVV alone produced on cv. Georgia Jet mild symptoms consisting of slight yellowing of veins, with some sunken secondary veins on the upper sides of the leaves. Effects on yields by SPSVV or SPCSV alone are minor or but in complex infection with SPFMV or other viruses yield losses of 50% and more are observed [4]. SPCSV and/or SPSVV are transmitted by the whitefly Bemisia tabaci biotype B, Trialeurodes abutilonea, and B. afer [5,6]. In a semi persistent manner, requiring at least one hour for acquisition and infection feeding. The virus is best being diagnosed on a pair of sweet potato plants- one healthy, the other infected by SPFMV. On the healthy plants hardly any symptoms will become apparent, while (if carrying SPFMV) severe symptoms of SPVD will appear. Diagnosing SPSVV (or probably also SPCSV) by PCR can be erratic as the virus is not distributed evenly in the plant.

Sweet Potato Virus Disease (SPVD) is caused by the interaction of SPFMV and SPCSV/SPSVV. Characteristic symptoms of the disease include vein clearing, chlorosis and stunting. The disease was described by Schaefers and [7] in Nigeria and is the most important virus (complex) disease in East Africa, where sweet potato is often the main food staple [8]. The disease was described in Israel by [9], the USA [10] and Spain [11]. It can cause losses over 50%, especially in Uganda and Kenya.

Sweet Potato Mild Mottle Virus Genus Ipomovirus, (SPMMV). Synonym: sweet potato B virus [12]. SPMMV has so far been reported inter alia from West- and South Africa, Indonesia, China, Philippines, India, New Zealand, and Egypt.

SPMMV can cause leaf mottling, stunting and loss of yields. The virus is transmitted semipersistently by B. tabaci, by grafting and by mechanical inoculation. Virions are flexuous rod shaped particles, 800–950 nm in length, containing 5% RNA and 95% protein. The genome consists of single stranded RNA. A synergism was observed in sweet potato doubly infected by SPMMV and SPCSV (but not by SPFMV)

Cucumber Mosaic Virus Genus Cucumovirus (CMV) is one of the most widespread plant viruses, recorded in more than 190 species, belonging to more than 40 families [13]. CMV has been isolated from I. setifera [14] and [15] succeeded in transmitting CMV by mechanical inoculation to I. nil, I. purpurea, I. lacunosa, and I. trichocarpa but not to I. batatas cv. Puerto Rico [16]. Failed in transmitting CMV to healthy sweet potato plants. However, sweet potatoes carrying the whitefly-transmitted SPSVV can easily be infected by CMV by aphid, mechanical or graft inoculations [16] found that CMV was able to infect sweet potatoes without the assistance of SPCSV. It appears that CMV strains are nonspecific for infection in sweet potato. CMV isolated from cucumber [16] were able to infect sweet potato plants assisted by SPSVV or not, respectively. In some fields in Israel during the 80es heavy infections together with SPFMV and SPSVV caused severe yellowing and stunting. Later, when farmers used certified planting material such symptoms were hardly found. Apparently, the presence of another virus (SPSVV) facilitates replication or translocation of some CMV strains in sweet potato.

It may be that there is a gene silencing mechanism that inhibits replication of such CMV strains in healthy sweet potato and is suppressed by SPSVV, allowing CMV to replicate and/or move in the sweet potato plant.

It is interesting to note that although CMV occurs worldwide, in sweet potato it has been reported so far only from Israel, Japan, New Zealand [17], Spain, West Africa and Egypt [18]. CMV was not found in Kenya [19] and Tanzania [20] even though SPCSV is very widespread SPCSV strains do not support infection of sweet potatoes with CMV, while SPSVV is needed to infect sweet potatoes with CMV. Other sweet potato virus diseases could be found in the study of [21].

Resistance to Viruses

The best way to overcome virus diseases is by breeding resistant varieties. Effort has been made both to select and breed resistant cultivars by conventional approaches or by genetic engineering. Conventional breeding has some limitations due to biological nature of the crop [22,23]. Genetic improvement of sweet potato has been challenging due to their heterozygous genetic constitution, polyploidy, self-incompatibility and cross-incompatibility [24,25]. Sweet potato is hexaploid (2n = 6x = 90) [26], and the large number of chromosomes may result in meiotic irregularity. Sexual compatibility barriers associated with the hexaploidy nature restricts hybridization within the species [27]. Using graft inoculations in a study in Uganda high levels of resistance to SPVD were observed in the cultivar Munyeera, while cultivars New Kawogo and Polyster were considered resistant and moderately resistant, respectively [28]. Similar results were observed under natural field infection. It seems therefore that additional work on various landraces may yield answers to SPVD.

Mwanga et al. [25] hypothesized that resistance to SPCSV and SPFMV is conditioned by two separate recessive genes inherited in a hexasomic or tetradisomic manner. Subsequent molecular marker studies yielded two genetic markers associated with resistance to SPCSV and SPFMV. The authors suggested that additional genes may be associated with resistance to these two viruses.

Emphasis in developing resistance to SPVD has largely focused on resistance to SPFMV, an important component of S PVD [29,30]. This resistance breaks down in co- or multi-infections with SPCSV and SPMMV.

Nevertheless, the amount of breeding and selection work on sweet potatoes is much less than that on potato and a marked increase of work in this field, especially on resistance to SPCSV, would be beneficial.

Attempts to Obtain Spvd Resistant Plants by Genetic Engineering

Several attempts were made to develop resistance to SPVD. Thus, Nyaboga et al. [31] got some protection against SPVD in plants that were transformed with SPFMV-derived genes.

With financial assistance from United States Agency for International Development (USAID)/Agricultural Biotechnology Support Project (ABSP), a collaborative research project between Kenya Agricultural Research Institute (KARI) and Monsanto was launched in 1991 to develop engineered virus resistant sweet potato. However, the resistance that was observed under experimental conditions in USA broke down in East Africa possibly because the transgene was not from a locally prevalent SPFMV strain or because the transgenes still carried a small amount of virus, or because the plants became infected with SPCSV. For these reasons, the commonly encountered mixed virus infections in the field and the genetic variability of sweet potato viruses pose an important challenge that needs to be addressed prior to achieving sustainable virus resistance [32].

A landrace of sweet potato variety 'Huachano', shown to be resistant to SPFMV, was genetically engineered for resistance to SPCSV [33]. The transgene was designed to express an SPCSV-homologous transcript that forms a double-stranded structure and hence efficiently primed virus-specific resistance. Many transgenic lines accumulated only low concentrations of SPCSV following infection and no symptoms developed. These results show that sweet potato can be protected against the disease caused by SPCSV using PDR. However, the low concentration of SPCSV in the transgenic plants was still sufficient to break down the natural high levels of resistance to SPFMV in the cultivar 'Huachano'. Apparently, immunity to SPCSV appears to be required for prevention of the SPVD symptoms.

Additional and concentrated efforts using landraces with certain degrees of resistance to SPCSV in combination with building up this resistance by genetic engineering may lead to overcome the sweet potato virus disease.

Providing Virus-Tested Propagation Material

At present the best way to control virus diseases in sweet potato is to supply the grower with virus-indexed propagation material. Such programs are operating in Israel and in the Shandong province of China [34]. The majority of sweet potato producers in the US utilize virus-tested tissue culture technology and use certified virus-tested foundation seed [35]. In Israel, as a result of planting virus-tested material, yields increased at least by 100%, while in China increases ranged between 22–92%. The payoff to the farmer has been high and in Israel use of certified material is common practice, while in China the use of pathogen-free material is being extended. In African countries such programs are operating only on a limited scale, because sweet potatoes are grown mainly as a food security crop, and not as a commercial one.

Conclusion and Recommendation

It is advisable that several pilot projects for providing growers with virus indexed propagation material should be established in 2-3 African countries. These projects should prepare mother plants from meristems, test them for viruses (mainly SPFMV and SPCSV), keep them in insect free greenhouse, or in insect protected screen houses and distribute them to growers who will increase them and plant from them their field. Farmers will plant the next season fields only from the scheme and not from their own fields. Pursuing this scheme rigorously should increase yield significantly.

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