a yield basis alone, 46106/27 can be described as tolerant. Any variety which sustains a 70% loss would in most circumstances be described as highly susceptible.

Our results call for further experimentation in the field, including studies of the vector in ecologically diverse zones. If the concept of control by relatively simple cultural practices is proved satisfactory, then a reappraisal of breeding objectives might possibly be called for.

Doughty, L. R. *East African Agriculture and Forestry Research Organization Annual Report, 1958.* 48–55.

Synonymy in Sweet Potato Virus Diseases

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The literature pertaining to virus or viruslike diseases of sweet potatoes suggests that there are only two diseases definitely caused by viruses: sweet potato mosaic, with many synonyms, and sweet potato internal cork. The other viruslike diseases are either caused by mycoplasma, mites, or are physiological in nature.

Martyn (1968, 1971) and Smith (1972) listed seven virus diseases of sweet potatoes: (1) feathery mottle; (2) internal cork; (3) mosaic virus A; (4) mosaic virus B; (5) russet crack; (6) yellow dwarf; and (7) witches' broom. My observations suggest that there is no difference between mosaic virus A and B.

Sheffield (1957) distinguishes the two diseases on the basis of severity. Virus A is a mild disease transmitted by *Myzus persicae* and not by white flies. Virus B, a severe disease, is transmitted to sweet potato by the white fly *Bemisia tabaci* and not by aphids or mechanical means. I have frequently transmitted mechanically the severe disease to sweet potato. The aphid *Myzus persicae* is almost invariably associated with the severe disease in the field and has also frequently transmitted the disease from affected to healthy sweet potato vines in the greenhouse. The sweet potato feathery mottle disease as described by Doolittle and Harter (1945) is very similar to the sweet potato mosaic syndrome described by Sheffield (1957).

To help clarify the situation, I have reviewed all the available literature on sweet potato virus and viruslike diseases to establish the identities of the diseases. The results of this extensive literature survey have been summarized in Table 1.

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Discussion

A total of 21 virus or viruslike diseases have been reported from various parts of the world. One of the commonest virus diseases of sweet potatoes is mosaic, with symptoms typical of this group of diseases, it has been observed wherever sweet potatoes are grown extensively (Rosen 1920; Hansford 1944; Adsuar 1955; Yoshii 1960). In East Africa the mosaic syndrome has been referred to as mosaic virus A and mosaic virus B (Sheffield 1957). The syndrome is associated with virus particles of flexuous rods of 761, 767, or 844 nm (Nome 1974; Nome et al. 1974) or 850–900 nm (Hollings et al. 1970).

Descriptions of the diseases referred to as mottle leaf (Strydom and Hyman 1965), leaf spot (Martin 1970), ringspot, vein clearing, and leaf pucker (Loebenstein and Harpaz 1960) are identical with descriptions of foliar symptoms of mosaic. These diseases are also transmitted by aphids or white fly. The diseases referred to as rosette (Noble 1935; Steyaert 1946), curly top and yellow dwarf (Hildebrand 1958a,b) are manifestations of severe symptoms of mosaic and their descriptions are identical with those of sweet potato mosaic virus B. Hence it appears that there are 10 names referring to the same disease, namely mosaic, described by different authors on different varieties in different parts of the world. The disease known as celery mosaic (Welman

Table 1. Notes on virus and viruslike diseases of sweet potato.

Disease	Symptoms and modifying factors	Transmission	Causal agent	Distribution	Importance	Control
Mosaic	Vein clearing, vein banding, leaf distortion, small leaves sometimes wrinkled; short internodes and rosetting; may cause necrosis in tubers; symptom expression varies with temperature and cultivar	*Myzus persicae*, *Bemisia tabaci*. Grafting, mechanically, vegetative propagation. Not seed transmitted.	Virus(es) several strains. Flexuous rods 761, 767 or 850-890 nm. Serological characteristics not reported	USA, Puerto Rico Venezuela, Uganda Kenya, Tanzania, Malawi South Africa, Zaire Nigeria, ? Ghana ?Australia	Very severe in East and Central Africa and in Southern USA as well as South Africa and ? Australia	Virus-free planting material; heat therapy possible at 110°F; control with resistant cultivars possible; spraying against vectors did not reduce incidence in Uganda
Celery mosaic	Same as above; apparently a disease of celery transferred artificially to sweet potatoes	*Aphis gossypii*	Virus presumed	Cuba, Florida (USA)	Not specified	Not specified
Mottle leaf	Yellow spots on foliage	White fly: *Trialeurodes abutilonea*	Virus presumed	USA, South Africa	Severe in combination with "yellow dwarf" in South Africa	Not specified
Leaf spot	Small yellow spots almost like above but smaller	Not specified	Virus presumed	USA	Not specified	Not specified
Ring spot	Conspicuous chlorotic spots plus stunting; symptom expression varies between cultivars	*Myzus persicae* but not *Bemisia tabaci*; also transmitted mechanically	Virus particles of unspecified size; some particles similar to feathery mottle virus but differ from cucumber mosaic	USA, Israel	Not specified	Not specified
Vein clearing	Similar to mosaic especially as found in East Africa; symptoms masked by heat	Grafting; *Bemisia tabaci* but not mechanically	Virus presumed	USA, Ghana, Israel	Very severe losses in Israel and Ghana	Not specified
Leaf pucker	Leaf mottle, vein clearing, leaf wrinkling, folding and reduction in size; develops better in cool weather	Grafting but not aphids nor whitefly	Virus presumed	Israel, Philippines	Minor loss	Not specified
Rosette	Stunting and proliferation of branches from leaf axils	Not specified	Virus suspected	Australia, Zaire	Destructive in both areas	Not specified

Curly top	As above	Not specified	Virus suspected	Australia	Destructive	Not specified
Feathery mottle	Random bright yellow spots or streaks; vein clearing and banding; leaf yellowing, distortion, stunting; some aspects similar to East African "virus A"; also shown to consist of three components: yellow dwarf, internal cork and leaf spot; symptoms more apparent in shade; cultivars react differently	Grafting; mechanical; *Myzus persicae* (non-persistent), *Aphis gossypii, Aphis apii, Microsiphum solanifolii, T. abutilonea*	Virus; flexuous rods of 800-844 nm; sub-strains suspected	USA, Japan New Guinea, ? Ghana	Potentially destructive	Control with resistant varieties possible
Russet crack	Leaf symptoms same as mosaic and feathery mottle; roots with superficial longitudinal cracks which may become corky; symptoms masked by temperature; cultivars react differently	Grafting; *Myzus persicae* and *A. gossypii*	Virus; flexuous rods of 800 and 876 nm seen; cross protection with feathery mottle	USA, Tonga Australia, New Zealand	Reduces market quality and yield	Not specified
Internal cork	Dark brown to black necrotic spots in tuber flesh starting as collapsed cells; development of phellogen around spots progressively producing cork; also sunken corky lesions on surface of tuber; cork may develop following mechanical injury; on foliage vein clearing, banding, green mottle, purple spots, bronzing, and necrotic streaks; three strains: severe, moderate, and mild. Heat enhances symptoms; warmer soil increases severity	Mechanical; *Myzus persicae, Aphis gossypii, Macrosiphum solanifolii,* grafting; vegetative propagation	Virus; viral RNA detected and polyhedral particles of 450-475A° seen	USA, Tonga New Zealand, ? Uganda	Yield unaffected but market value drastically reduced; flavour not affected; greatest effect in storage at high temperature	Spraying against vectors; storage at 55-60°F; resistant lines developed; tissue culture potential
Mottle necrosis	As for internal cork; apparently renamed internal cork	Not specified	*Pythium* sp., boron deficiency	USA	Severely reduces market value	Application of boron failed to control disease

Table 1. Notes on virus and viruslike diseases of sweet potato (concluded).

Disease	Symptoms and modifying factors	Transmission	Causal agent	Distribution	Importance	Control
Internal root necrosis	Brown necrotic streaks in tuber; not affected by storage at 75°F	Grafting failed	Physiological	New Zealand	Not specified	Not specified
Little leaf	Small narrow distorted yellow leaves; stunting; some necrotic streaks; rosette effect similar to Ishukubyo	Grafting; *Halticus tibialis*. Believed soil-borne	Mycoplasma-like bodies seen; virus suspected	Tonga, New Zealand Papua New Guinea	Severe in Papua New Guinea	Tetracycline; heat therapy 45-65°F; resistant clones; roguing ineffective
Witches' broom	As for little leaf	Grafting *Nesophrasyne ryukyuensis*; not by aphids, other leaf hoppers or seed	? Virus; mycoplasma-like bodies seen 200-250 um in phloem	Japan, Taiwan, Korea Java, Tonga, New Zealand	Very severe on Ryukyu Islands	Tetracycline; terramycin, hot water 45-60°F; resistant clones developed
Dwarf or ishukubyo	Dwarfing; proliferation of shoot from axils; small yellow leaves; stem produces little or no latex	Not specified	? virus; disease apparently same as Witches' broom	Ryukyu, Japan	Severe on Ryukyu Islands	Not specified, but see witches' broom
Yellow dwarf	Stunting, reduced leaf size and similar to East African mosaic disease "virus B"	Grafting; *Trialeurodes abutilonea* adults only	Virus suspected	USA, Israel New Zealand, South Africa	Very severe in parts of USA	Heat therapy, water at 38°C
Hard-core	Hard regions of tuber, inedible after cooking; condition increases with cold, reduces with heat	Not specified	Conflicting views: virus particles seen, flexuous rods 700 nm in roots and leaves; physiological	USA	Reduce cooking quality	Not specified
Erinose	Little to extreme hairiness of vines and leaves, leaf size reduced, plants stunted, necrosis of terminal buds; swelling of affected vines; varies with weather	Spider mite *Aceria* sp. Not transmitted by grafting	Not known with certainty. Mites suspected more than virus.	Uganda, Kenya Tanzania, Zaire and Rwanda	Affected vines produce few tubers.	Spraying with azobenzene
Bitter root	Roots bitter to taste either raw or cooked. Sometimes there are swellings on bitter roots possibly induced by insects. No external leaf symptoms.	Not known	Not known	Teso, Lango, West Nile and North Kigezi districts of Uganda.	Affected tubers too bitter for eating. Yield apparently not affected	Not known

1934, 1935) is apparently a disease of celery which was transmitted artificially to sweet potato.

The other common disease is feathery mottle (Doolittle and Harter 1945). A comparison of the photographs showing the symptoms of this disease (Doolittle and Harter 1945) and Sheffield's (1957) photographs of the mosaic diseases of sweet potatoes in East Africa, shows clearly that the symptoms of the two diseases are identical. The virus particles identified in both diseases also appear very similar (Nome et al. 1974; Hollings et al. 1970) and both diseases are masked by high temperature. Further, Alconero (1971) and Nome et al. (1974) have shown that the feathery mottle disease is the same as russet crack. Hence it appears that the mosaic diseases mentioned earlier, feathery mottle and russet crack, are one and the same disease, or are very closely related manifestations of a mosaic syndrome.

The internal cork virus disease, however, appears to be a distinct disease unrelated to mosaics both in symptom expression and etiology. The most characteristic symptom of the disease is the development of cork in the tubers (Nusbaum 1946a,b) which is associated with polyhedral virus particles (Salama et al. 1966). A disease which in early literature (Harter 1925; Harter and Whitney 1929) was described as mottle necrosis was apparently the same and was renamed "internal cork virus" disease when its etiology became known.

Little leaf (van Velsen 1967), witches' broom (Murayama 1966), and ishuku-byo (Summers 1951) are all transmitted by leaf hoppers and are associated with mycoplasma-like bodies (Lawson et al. 1970; Kahn et al. 1972). They can be cured with antibiotics (So 1973) and are therefore not virus diseases.

Hardcore seems to be a disease of uncertain etiology. Daines et al. (1974) have conducted experiments on it and concluded that it was related to chilling during the process of curing the tubers. When the tubers were cured at a temperature of 27 °C the disease did not develop. But Harmond et al. (1974) noticed flexuous virus rod particles 700 nm long in roots and leaves affected by hardcore. These workers do not specify whether or not the material they used contained a latent virus infection.

Another disease affecting tubers is internal root necrosis (Nielsen and Harrow 1966). It causes lesions of a lighter colour than internal cork, is not affected by temperature, and is not graft transmissible. Therefore it is probably a physiological condition.

Erinose of sweet potatoes (Sheffield 1954), a common disease in East Africa, causes extreme hairiness to vines and leaves of sweet potatoes and may lead to heavy losses in yield. It is associated with spider mites (*Aceria* sp.), and Sheffield failed to transmit it by grafting. Affected vines recovered from the disease when they were fumigated with azobenzene. Hence available evidence suggests that the disease is caused by mites sensu stricto.

There is a disease in Uganda known as "bitter root" which makes the tubers unpalatable. The disease has not been investigated sufficiently and its etiology is therefore unknown.

Conclusion

From the evidence, it appears that there are two distinct virus diseases of sweet potatoes: (1) sweet potato mosaic covering all diseases with mosaic symptoms as well as feathery mottle and russet crack; these diseases are associated with virus particles consisting of flexuous rods 760–900 nm; and (2) internal cork characterized by tubers containing necrotic regions surrounded by phellem. The foliar symptoms may be of a mosaic type but the disease is associated with polyhedral virus particles. There is no conclusive evidence that hardcore disease is caused by either a virus or a physiological disorder.

Other viruslike diseases are caused by: mycoplasma-like bodies; mites; physiological disorders; genetics (as in the case of bitter root).

Information on sweet potato virus diseases has been derived largely from symptomatology of sweet potato and other hosts, and from the mode of transmission. Only to a limited extent has this knowledge been based on electronmicroscopy or serology. There is a need for more electronmicroscopic and serological studies of sweet potato viruses to verify the identity of each and to better understand the relationships between the diseases.

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