FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

INTERNATIONAL BOARD FOR
PLANT GENETIC RESOURCES

FAO/IBPGR TECHNICAL GUIDELINES
FOR THE
SAFE MOVEMENT OF SUGARCANE GERMPLASM

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**THE INTERNATIONAL SOCIETY
OF SUGAR CANE TECHNOLOGISTS**

INTRODUCTION

Collecting, conservation and utilization of plant genetic resources and their global distribution are essential components of international crop improvement programmes.

Inevitably, the movement of germplasm involves a risk of accidentally introducing plant quarantine pests* along with the host plant material; in particular, pathogens that are often symptomless, such as viruses, pose a special risk. In order to minimize this risk, effective testing (indexing) procedures are required to ensure that distributed material is free of pests that are of quarantine concern.

The ever-increasing volume of germplasm exchanged internationally, coupled with recent rapid advances in biotechnology, has created a pressing need for crop-specific overviews of the existing knowledge in all disciplines relating to the phytosanitary safety of germplasm transfer. This has prompted FAO and IBPGR to launch a collaborative programme for the safe and expeditious movement of germplasm, reflecting the complementarity of their mandates with regard to the safe movement of germplasm. FAO, as the depository of the International Plant Protection Convention of 1951, has a long-standing mandate to assist its member governments to strengthen their Plant Quarantine Services, while IBPGR's mandate - *inter alia* - is to further the collecting, conservation and use of the genetic diversity of useful plants for the benefit of people throughout the world.

The aim of the joint FAO/IBPGR programme is to generate a series of crop-specific technical guidelines that provide relevant information on disease indexing and other procedures that will help to ensure phytosanitary safety when germplasm is moved internationally.

The technical guidelines are produced by meetings of panels of experts on the crop concerned, who have been selected in consultation with the relevant specialized institutions and research centres. The experts contribute to the elaboration of the guidelines in their private capacity and do not represent the organizations to which they belong. FAO, IBPGR and the contributing experts cannot be held responsible for any failures resulting from the application of the present guidelines. By their nature, they reflect the consensus of the crop specialists who attended the meeting, based on the best scientific knowledge available at the time of the meeting. The experts that have contributed to this document are listed after this introduction.

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* The word 'pest' is used in this document as it is defined in the International Plant Protection Convention. It encompasses all harmful biotic agents ranging from viroids to weeds.

The technical guidelines are written in a short, direct, sometimes 'telegraphic' style, in order to keep the volume of the document to a minimum and to facilitate updating. The guidelines are divided into two parts: The first part makes recommendations on how best to move sugarcane germplasm and is divided into general recommendations and technical recommendations. Institutions recovering and maintaining healthy sugarcane germplasm and institutions that act as intermediate quarantine, and a few selected references are listed at the end of this first part. The second part gives descriptions of the most important pests that could be of quarantine concern.

The information given on a particular pest does not pretend to be exhaustive but concentrates on those aspects that are most relevant to quarantine. To minimize the number of cited references, the recent volume, 'Diseases of sugarcane: Major Diseases' edited by Ricaud *et al.* (1989) was taken as the primary bibliographic source. Consequently, cited references are limited to those of major significance or to those that do not occur in the bibliography of the corresponding chapter in the book mentioned above.

The present guidelines were developed at a meeting held in Réduit, Mauritius, from 29 to 31 July 1991. The meeting was hosted by the Mauritius Sugar Industry Research Institute and organized in collaboration with the International Society of Sugar Cane Technologists (ISSCT).

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GENERAL RECOMMENDATIONS

- Importation must be planned well in advance to allow the requested clone to be planted in a nursery whenever possible.
- Under no circumstances should germplasm be moved as rooted plant material except as *in vitro* plantlets.
- When available, accessions or cultivars should be obtained from a pathogen-tested *in vitro* collection. Otherwise, material should be obtained from the lowest risk area possible.
- All material should undergo the therapy and indexing procedures described in the following pages.

TECHNICAL RECOMMENDATIONS

A. Movement of setts

- Setts should, whenever possible, be obtained from a nursery established from setts that have undergone a cold soak in running water for 48 h followed by hot-water treatment (5O°C for 150-180 min).
- For each clone, at least two setts with 3 buds without insect damage should be collected from healthy looking plants.
- Knives or secateurs should be disinfected with ethanol (70%) or other suitable disinfectant.
- Setts should be thoroughly washed with soapy water using a brush.
- Leaf sheath material should be removed with a disinfected scalpel and setts should be inspected for punctures caused by insects.
- Setts should be given a short hot-water treatment at 50°C for 30 min, and dipped in an appropriate fungicide.

- Clones should be labelled directly on each sett.
- The whole sett should be dipped in low melting point paraffin wax.
- A label with the designation of each clone should be packed with the setts.
- Setts should be wrapped in dry paper and suitably packed.
- The material should be dispatched using the most expeditious transportation method.
- The consignment should be accompanied, on the outside of the parcel, by the necessary documentation (import permit, phytosanitary certificate, etc.) and by a statement indicating the treatments given to the setts in addition to those appearing on the phytosanitary certificate.
- Upon receipt, the parcel should be opened in containment and thoroughly inspected. If live insects are observed, the material should be fumigated or destroyed. In the case of insect damage being observed, a short hot-water treatment can be given again.
- Both ends of the setts and any tissue affected by rots should be cut off, and the waste material safely disposed of after autoclaving or by incineration.
- Setts should be planted in sterilized potting medium in an insect-free containment facility, and regularly inspected for two growth cycles.
- The containment facility should be treated with acaricide and insecticide as required.
- At the end of the first growth cycle, the material should be indexed for virus, virus-like and prokaryote diseases using the methods recommended in this publication.
- The material should then be ratooned and the canes from the first growth cycle should be destroyed.
- At the end of the second growth cycle, setts should be taken from the regrowth and should be soaked in cold water for 48 h, followed by a hot-water treatment at 50°C for 150-180 min.

- Alternatively, the canes from the first growth cycle can be cut into setts which should be soaked in cold water for 48 h followed by a hot-water treatment at 50°C for 150-180 min. These setts should be replanted in sterilized potting medium in an insect-free containment facility. At the end of this second growth cycle, a second cold and hot-water treatment may be given. It is advisable to retain the ratoon of the first cycle for observation for three months before destroying it.

- Setts can then be planted in the open, preferably in isolation, and inspected regularly for one crop cycle.

- All packing material, discarded plant material and used potting medium should be sterilized and/or destroyed.

B. Movement of *in vitro* material

The safest and preferred method for inter-country germplasm transfer is as *in vitro* cultures. *In vitro* techniques are effective in eliminating most fungal and bacterial diseases, and may currently be the only option to eliminate the diseases of unknown etiology listed in the section 'Other diseases'. The following procedures should be implemented:

- Collecting tools should be disinfected between each accession.

- Setts should be taken from plants that are as healthy as possible, and preferably from a nursery.

- Setts should be given a cold soak for 48 h in running water, followed by a hot-water treatment at 50°C for 150-180 min.

- Setts should be germinated in an incubator at 40°C, planted in sterilized soil under containment and grown for 4 to 6 months.

- Shoot-tip cultures are carried out as follows:

    - Take a stalk piece of about 15 cm long, including the youngest buds.

    - Remove the outer leaf sheath and rub the bundle for a few minutes with 70% ethanol.

- In a laminar flow hood, dip the bundle in 90% ethanol and flame it.
- Open the leaf sheaths and excise the apical bud and 2 or 3 stem sections containing the youngest lateral buds.
- Place the buds on culture medium (see page 12) in Petri dishes.
- Place Petri dishes in a growth chamber at 25°C with a photoperiod of 12 h and a light intensity of $50 \mu Em^{-2}s^{-1}$.
- When the buds produce roots (after 3 to 8 weeks) transfer the buds to 200 x 20 mm test tubes where they will produce tillers.

- Callus culture must be avoided because of the risk of giving rise to variants.
- For the movement of *in vitro* cultures, neither antibiotics nor charcoal should be added to the medium.
- Clear plastic culture vessels should be used and the agar concentration should be increased to help protect the plantlets during transit.
- Material should be dispatched by the most efficient transport method and be protected from extremes of temperature.
  - Upon receipt, material should be visually inspected for microbial or any other obvious contamination, and contaminated tubes should be destroyed.
- Material should be established in sterilized potting medium in an insect-free containment facility and kept under observation for one full growth cycle.
- Material should be indexed for virus and virus-like diseases as described below. If found to be infected it should be destroyed, or undergo therapy if a reliable therapy is available and be re-tested for freedom from pathogens.
- Material that has tested negative and shown no disease symptoms during the whole growth cycle should, prior to release, be given a cold soak for 48 h followed by a hot-water treatment at 50°C for 150-180 min.

C. Movement of true seed

Little research has been reported on the disease risks associated with the movement of true seed of sugarcane. However, past experience indicates that the risk is negligible. Although no diseases are known to be transmitted through the caryopsis of the sugarcane fruit, a few fungi have been reported to be present in the remnants of florets and glumes in fuzz (Byther & Steiner, 1972). Therefore seed must not be moved internationally unless properly cleaned.

The following procedures should be implemented:

- Seed should be de-fuzzed using the method described by Heinz (1987).
- Following de-fuzzing, the clean caryopses should be given a dry seed dressing with a broad spectrum fungicide.
- Details of all treatments applied should be recorded on the phytosanitary certificate accompanying the seed.
- Upon arrival, the seed should be inspected visually. If there are any signs of insects the material should be fumigated or destroyed. If found to be clean, the seed should be sown in sterilized potting medium in an insect-free containment facility, and the seedlings kept under observation for at least three months.
- After three months in close containment, healthy seedlings may be transferred to the field in an area isolated from commercial sugarcane fields. They should be observed for one full growth cycle before being released.

D. Collecting germplasm

- Setts must be taken only from stools which show no visual symptoms of systemic diseases.
- Setts should be free of insects and insect damage, particularly with regard to borers, although the stools may be infested in part.
- Cutting implements should be sterilized between accessions using ethanol (70%) or another suitable disinfectant, both when collecting in the field and when preparing setts.

- Setts should be dipped or dusted with both a broad-spectrum fungicide and a suitable insecticide.

- Prior to packing, it is advisable to dip at least the cut ends in low melting point paraffin wax.

- Setts should be clearly marked and wrapped in paper (newspaper is quite suitable) and labelled inside and on the outside of the package. A duplicate collecting sheet or description of the clone should also be included inside the package.

- Drying-out of the setts may occur during prolonged transport from remote locations. A ventilated plastic bag may be used to prevent desiccation, but this practice may cause other problems due to high humidity or overheating.

- On receipt at the quarantine station, a short hot-water treatment (50°C for 30 min) should be given. Even if considerable root and shoot growth have occurred, this can be carried out safely. Alternatively, if fumigation has to be carried out, a non-phytotoxic fumigant gas is advisable, as methyl bromide may affect the viability of emerging shoots.

Selected references

Byther, R.S. & Steiner, G.W. 1972. Four seedling diseases in Hawaii: Causal agents, control, and a selective medium for isolation. *Phytopathology* **62**:120-124.

Heinz, D.J. 1987. *Sugarcane Improvement Through Breeding.* Elsevier, Amsterdam.

Ricaud, C., Egan, B.T., Gillaspie, A.G., Jr. & Hughes, C.G. eds. 1989. *Diseases of Sugarcane: Major Diseases.* Elsevier, Amsterdam.

IN VITRO CULTURE MEDIA

Basal medium

Murashige and Skoog's (1962) mineral solution (macro and micro-nutrients):

Macro-elements

NH_4NO_3	1650	mg/l
KNO_3	1900	mg/l
$CaCl_2.2H_2O$	440	mg/l
KH_2PO_4	170	mg/l
$MgSO_4.7H_2O$	370	mg/l

Micro-elements

H_3BO_3	6.2	mg/l
$MnSO_4.4H_2O$	22.3	mg/l
$ZnSO_4.7H_2O$	8.6	mg/l
KI	0.83	mg/l
$Na_2MoO_2.2H_2O$	0.25	mg/l
$CuSO_4.5H_2O$	0.025	mg/l
$CoCl_2.6H_2O$	0.025	mg/l

Fuji's vitamins

Glycine	2	mg/l
Nicotinic acid	5	mg/l
Pyridoxine	5	mg/l
Thiamine	1	mg/l
Inositol	100	mg/l

Fe EDTA	41	mg/l
Sucrose	30	g/l
Agar	8	g/l
Activated charcoal	2	g/l

The basal medium is slightly modified according to the purpose:

- First culture: add 3.5 g/l charcoal.
- For multiplication: increase sucrose to 50 g/l.
- For storage or shipping: decrease sucrose to 20 g/l.

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DESCRIPTIONS OF PESTS

Virus and virus-like diseases

1. Chlorotic streak

Cause
Unknown.

Symptoms
Foliar yellowish to creamy-white streaks with wavy and irregular margins. These streaks may be quite short or run the full length of the leaf, and are often fragmented, at least in the younger leaves. Discoloured vascular bundles similar to those of ratoon stunting disease, but redder in colour, occur at the nodes. Affected Plants of susceptible varieties show heavily streaked tops and necrosis. After ratooning, the young shoots will be heavily streaked, wilted and abnormally stiff, and usually die.

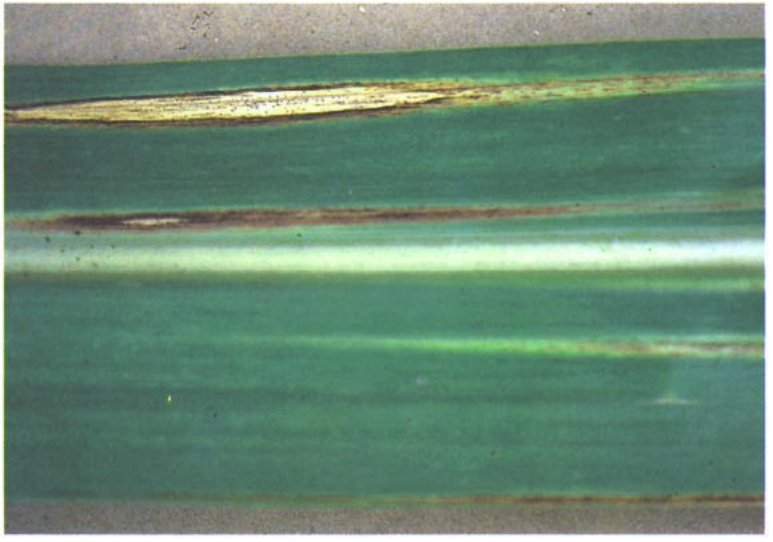

Fig. 1. Leaf symptoms of chlorotic streak disease. (Dr. J.I. Victoria, Cenicaña, Cali Valle)

Natural host range
Saccharum officinarum, S. robustum, S. spontaneum, S. edule, S. barberi/sinense and intergeneric, *Saccharum* hybrids. Symptoms have also been observed in *Pennisetum purpireum, Panicum maximum, Erianthus arundinaceus, E. maximus, Arundo donax, Paspalum paniculatum* and *Coix lachryma-jobi.*

Geographical distribution
Argentina, Australia, Brazil, Cambodia, China, Colombia, Côte d'Ivoire, Cuba, Dominican Republic, Fiji, Grenada, Guadeloupe, Guyana, Honduras, Indonesia, Jamaica, Madagascar, Mali, Martinique, Mauritius, Mozambique, Nicaragua, Panama, Philippines, Réunion, Samoa, South Africa, St. Lucia, Surinam, Taiwan, Thailand, Trinidad, Turkey, USA (Hawaii; Puerto Rico; continental), and Venezuela (Egan, 1989). Papua New Guinea (Egan, 1991).

Transmission
Readily transmitted by planting diseased setts. Transmission from diseased to healthy plants occurs through the root system, generally under wet conditions.

Therapy
Hot-water treatment of setts at 50°C for 30 min.

Indexing
Unnecessary as therapy is 100% effective.

References
Egan, B.T. 1989. Chlorotic streak. pp. 247-262. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr., & C.G. Hughes. Elsevier, Amsterdam.

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2. Fiji disease

Cause
Fiji disease phytoreovirus (FDV). Double-shelled icosahedral particles of 65-70 nm diameter, which easily break down to form subviral particles.

Symptoms
Typical symptoms are creamy white to green galls on the undersurface of the leaf blade and midrib, and the leaf sheath. They occur longitudinally on the larger vascular bundles, and may vary from just visible to many centimeters long. The galls are commonly 50 mm long, 2-3 mm wide and 1-2 mm high. Diseased plants are stunted, with a fan-like appearance due to stiff, shortened, distorted leaves which are usually dark green in colour. The growing point is killed, and a witches' broom-like effect may occur on mature stalks of certain cultivars. There is no recovery of diseased plants, which become severely stunted on ratooning and eventually die.

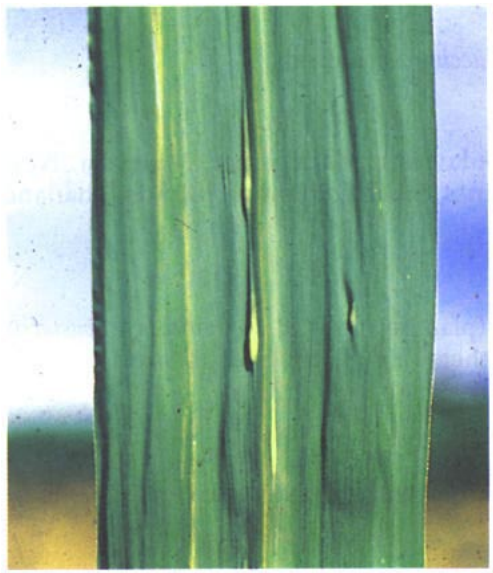

Fig. 2. Fiji disease - leaf showing typical galls on midrib and leaf blade. (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Fig. 3. Fiji disease - distorted and greatly reduced leaves in spindle at advanced state of disease development. (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Fig. 4. Fiji disease - small very stunted stools of a susceptible variety, some of them are dead. (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Natural host range
Only reported from *Saccharum* spp. or *Saccharum* hybrids.

Geographical distribution
Australia, Fiji, Indonesia (Irian Jaya; Sulawesi), Madagascar, Malaysia, New Caledonia, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand and Vanuatu.

Transmission
By cuttings, and by several *Perkinsiella* spp. (planthoppers). *P. saccharicida, P. vastatrix* and *P. vitiensis* are known vectors but others (e.g., *P. lalokinensis)* are suspected in Papua New Guinea.

Particle morphology
FDV particles are nearly spherical (icosahedral, with protrusions at the 12 vertices), about 70 nm in diameter.

Therapy
No efficient therapy has been reported.

Indexing
FDV particles are difficult to detect by electron microscopy except in and near gall tissue as concentrations are extremely low elsewhere. Serological techniques are being developed, but are not sufficiently sensitive yet (1991) for use in asymptomatic plants. As the latent period for symptom expression is known to be up to 8 months under certain conditions, the usual observations of suspect plants must be continued for at least one year.

Reference
Egan, B.T., Ryan, C.C. & Francki, R.I.B. 1989. Fiji disease. pp. 263-287. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr. & C.G. Hughes. Elsevier, Amsterdam.

3. Mosaic

Cause
Sugarcane mosaic (SCMV), sorghum mosaic (SmMV) and maize dwarf mosaic (MDMV) potyviruses, approximately 750 nm long. These viruses were formerly regarded as members of a complex of strains of SCMV, but have been recently classified as distinct viruses. A fourth virus, Johnson grass mosaic potyvirus (TGMV), infects sugarcane less readily.

Symptoms

Light green or chlorotic mosaic of varying intensity and pattern depending on virus, sugarcane variety, temperature and growing conditions. General dwarfing of shoots and stools. External necrosis and colour variation can occur on the rind but are not common on commercial hybrids. Internal stalk necrosis is sometimes observed. Latent infection may occur.

Fig. 5. Different intensity of mosaic symptoms on variety NCo376. (Dr. R.A. Bailey, South African Sugar Association, Mount Edgecombe)

Natural host range

Besides *Saccharum* spp., the host range is wide, affecting numerous species of wild and cultivated Gramineae, including maize.

Geographical distribution

Worldwide, but has not been reported from several sugarcane producing countries, including Mauritius and Guyana.

Transmission

Transmitted by several species of aphids, through infected setts, and by mechanical inoculation.

Therapy
Thermotherapy followed by meristem-tip culture can be used to eliminate SCMV in quarantine.

Indexing
Can be readily done by ELISA. Mechanical inoculation of indicator sugarcane clones such as CP31-294, CP31-588, CP29-291 and Co281, *Sorghum bicolor* cv. Rio, and inbred sorghum lines such as SA8735 and PI35038, can also be used for indexing and for differentiation of the various viruses causing mosaic.

References
Gillaspie, A.G., Jr., Mock, R.G. & Hearon, S.S. 1984. Status of identification of sugarcane mosaic virus strains worldwide. *Maize Virus Dis. Newsl.* **1**:30-32.

Koike, H. & Gillaspie, A.G., Jr. 1989. Mosaic. pp. 301-322. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr. & C.G. Hughes. Elsevier, Amsterdam.

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Shukla, D.D., Tosic, M., Jilka, J., Ford, R.E., Toler, R.W. & Langham, M.A.C. 1989. Taxonomy of potyviruses infecting maize, sorghum and sugarcane in Australia and the United States as determined by reactivities of polyclonal antibodies directed towards virus-specific N-termini of coat proteins. *Phytopathology* **79**(2):223-229.

Tosic, M., Ford, R.E., Shukla, D.D. & Jilka, J. 1990. Differentiation of sugarcane, maize dwarf, Johnsongrass and sorghum mosaic viruses based on reactions of oat and some sorghum cultivars. *Plant Dis.* **74**(8):549-552.

4. Ramu stunt

Cause
Unknown, but a virus is suspected.

Symptoms
Numerous pale green to light yellow-green streaks with wavy margins, which may arise from the leaf base, along the midrib or within the leaf blade. They may extend from several millimeters up to the full length of the leaf, vary in width from 2 to 5 mm or more; be continuous or frequently interrupted, and in some varieties have almost a beaded appearance or striations. Symptoms vary considerably between varieties. The leaves are stiff, shortened and senesce prematurely,

giving the stools a very trashy appearance. Plant growth is greatly reduced. Plants arising from infected setts or after ratooning of diseased stools produce many yellowish shoots, and remain stunted; death follows, usually within a year.

Fig. 6. Different symptoms of Ramu stunt - typical broad leaf striping (left) and strong symptoms in the spindle area. (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Fig. 7. Ramu stunt - stunted yellow stools in young ratoon crop. (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Natural host range
Symptoms typical of Ramu stunt in commercial sugarcane have been seen on *Saccharum officinarum* chewing canes at Ramu village; on an *S. robustum* wild cane beside the Lae-Madang Road; and on intergeneric hybrid near Kainantu, Highlands Province. Not known from other species.

Geographical distribution
Papua New Guinea (Morobe and Highlands Provinces) (Egan, 1991).

Transmission
The planthopper, *Eumetopina flavipes,* has transmitted the disease in preliminary tests, but this requires further confirmation. The disease is spread readily in infected sett material, but limited experiments with mechanical transmission have been unsuccessful.

Therapy
No information is available.

Indexing
Plants should be observed for at least one full year. No definitive information is available on latent period for symptom express-ion, but it is thought to be variable, up to several months

References
Egan, B.T. 1991. Notes on sugarcane diseases in Papua New Guinea. *ISSCT Tech. Newsl.* No. 91/3.

Walker, J.M., Egan, B.T. & Eastwood, D. 1987. Ramu stunt, an important new sugarcane disease in Papua New Guinea. *Trop. Pest Mgmt.* **33**(4):347-349.

5. Red leaf mottle

Cause
Peanut clump furovirus (PCV). Rod shaped particles, 250-300 x 20 nm.

Symptoms
Symptoms appear in the form of small chlorotic spots in narrow to broad bands along the midrib of well developed leaves. The spots later turn red, and the leaves then develop a red mottling on a wide area of the lamina. On a few varieties, long stripes appelar on the younger leaves, of either elliptic shape or herringbone-patterned bands across the lamina.

Fig. 8. Red leaf mottle - small chlorotic spots in broad bands (Dr. Th. Erwin, CIRAD, Montpellier)

Natural host range
Besides *Saccharum* spp., peanut *(Arachis hypogaea)* and sorghum (Dollet *et al.*, 1975) are known to be infected.

Geographical distribution
The disease is present on sugarcane in the north of Senegal and in the south of Burkina Faso.

Transmission
The virus is sett-transmitted. Plants of healthy seed cane can become infected when planted in soil where diseased cane was previously grown. The peanut clump virus is transmitted in peanut and sorghum by the fungus *Polymyxa graminis* (Thouvenel & Fauquet, 1981).

Therapy
PCV survives normal hot-water treatment.

Indexing
The virus is detected by serological methods, particularly microplate and dot-blot ELISA. Mechanical transmission is easy to *Chenopodium amaranticolor,* resulting in local necrosis, and to *Nicotiana benthamiana,* giving mosaic-type symptoms (Baudin & Chatenet, 1988).

References
Baudin, P. & Chatenet, M. 1988. Détection sérologique du PCV, isolat canne á sucre, agent de la marbrure rouge des feuilles. *L'Agronomie Tropicale* **43**:228-235.

Dollet, M., Fauquet, C. & Thouvenel, J.C. 1976. *Sorghum arundinacearum* a natural host for peanut clump virus in Upper Volta. *Plant. Dis. Reptr* **6 0**:1076-1080.

Thouvenel, J.C. & Fauquet, C. 1981. Further properties of peanut clump virus and studies on its natural transmission. *Ann. appl. Biol.* **9 7**:99-107.

6. Streak

Cause
The sugarcane strain of maize streak geminivirus (MSV). Isometric particles, 20 nm in diameter, occurring in pairs (which are 20 x 30 nm in size).

Symptoms
Narrow, elongated but relatively short (1 mm to 20 mm or more) translucent spots and streaks in a fine, broken linear pattern on leaves. The streaks, usually 1-2 mm wide, occur more typically on younger leaves. Infected plants may be stunted.

Natural host range
Besides on *Saccharum* spp., the sugarcane strain of MSV occurs in Mauritius on *Cenchrus echinatus,* a graminaceous weed. No wild grass hosts of this strain are known from Africa. The maize strain of MSV may occasionally infect sugarcane.

Geographical distribution
Benin, Cape Verde, Côte d'Ivoire, Egypt, India, Kenya, Madeira, Malawi, Mauritius, Mozambique, Pakistan, Réunion, South Africa, Sudan, Uganda, Zaire and Zimbabwe.

Transmission
By infected setts and by *Cicadulina* spp. (Cicadellia leafhoppers).

Fig. 9. Streaks and translucent spots caused by maize streak geminivirus. (Dr., R.A. Bailey, South African Sugar Association, Mount Edgecombe)

Therapy

Cannot be eliminated from setts by conventional means.

Indexing

Can be detected serologically by ELISA and ISEM using antisera prepared from either maize or sugarcane strains of MSV.

Reference

Bock,. K.R. & Bailey, R.A. 1989. Streak. pp. 323-332. In: *Diseases of Sugarcane: Major Diseases.* Eds: C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr., & C.G. Hughes. Elsevier, Amsterdam.

Other viruses of sugarcane

1. Sugarcane bacilliform badnavirus (SCBV)

Symptoms

In most cases there are no foliar symptoms, but SCBV infection is associated with prominent chlorotic flecking in some noble sugarcane clones. In mixed infections with SCMV the symptoms of SCMV are accentuated.

Natural host range

Occurs in noble canes *(Saccharum officinarum),* some older commercial hybrids, and a few commercial hybrids-of more recent origin. It also occurs in *Musa* spp., *Sorghum halepense, Rottboellia cochinchinensis* and *Brachiaria extensa.*

Geographical distribution

Probably distributed worldwide wherever sugarcane is grown.

Transmission

Transmitted through infected setts, by the pink sugarcane mealy bug, *Saccharicoccus sacchari* and by the grey sugarcane mealybug *Dysmicoccus boninsis.* Seed transmission has not been demonstrated experimentally, but several other plant badnaviruses are seed- and pollen-transmitted at high levels (60-90%).

Particle morphology

Non-enveloped bacilliform particles, 30 x 120-150 nm in size, containing double-stranded DNA.

Therapy

None. SCBV survives normal hot-water treatments.

Indexing

SCBV can be reliably indexed by ELISA and ISEM.

References

Autrey, L.J.C., Saumtally, S., Dookun, A. & Boolell, S. 1990. Occurrence of sugarcane bacilliform virus in Mauritius. *Proc. S. Afr. Sugar Technol. Ass.* **64**:34-39.

Lockhart, B.E.L. & Autrey, L.J.C. 1988. Occurrence in sugarcane of a bacilliform virus related serologically to banana streak virus. *Plant Dis.* **72**:230-233.

Cornstock. J.C. & Lockhart, B.E.L. 1990. Widespread occurrence of sugarcane bacilliform virus in U.S. sugarcane germplasm collections. *Plant Dis.* **74**:530.

2. Sugarcane clostero-like virus (= sugarcane mild mosaic virus)

Symptoms
No distinctive foliar symptoms.

Natural host range
Occurs in noble canes *(Saccharum officinarum)* and commercial hybrids. Also infects Sorghum *(Sorghum bicolor),* Johnson grass *(S. halepense)* and rice *(Oryza sativa),* but there are no reports of natural infection of these species.

Geographical distribution
Malawi, Mauritius and USA (Florida).

Transmission
Transmitted through infected setts and by the pink sugarcane mealy bug, *Saccharicoccus sacchari.* There is no evidence for seed transmission.

Particle morphology
Flexuous threadlike particles, 1400-1600 x 12 nm.

Therapy
No information.

Indexing
Can be reliably indexed by ISEM, and to a certain extent by ELISA.

References
Autrey, L.J.C, Boolell, S. & Lockhart, B.E.L. 1991. Occurrence of sugarcane clostero-like virus in Mauritius. In: Sugar Cane, No. 6, p. 9. *ISSCT Third Sugar Cane Pathology Workshop.* November/December 1991. (Abstr.)

Lockhart, B.E.L., Autrey, L.J.C. & Comstock, J.C. 1992. Partial purification and serology of sugarcane mild mosaic virus, a mealybug-transmitted clostero-like virus. *Phytopathology,* **82:** 691-695.

Prokaryotic diseases

1. Grassy and white leaf diseases

Cause

Non-cultivable mollicutes (formerly referred to as ‘mycoplasma-like organisms’).

Fig. 10. Grassy shoot and white leaf disease - stunted stalks and side shoots. (Dr. A.S. Patil, Dept. of Sugar Cane Pathology, Pune)

Symptoms

Grassy shoot disease (GSD): Diagnostic symptoms include stunting, excessive tillering and side shoots from the bottom to the top of stalks. Leaves may be reduced in size with a soft texture. Cream or white stripes parallel to the vascular bundles occur, and may coalesce, resulting in total leaf chlorosis.

White leaf disease (WLD): The main symptoms consist of chlorotic leaves especially in the spindle portion and the tillers. Single, white or cream stripes parallel to the midrib are present in the early stage, later extending to the entire length of the leaf. Mottling may occur as dots, streaks or patches of green on a white background. Svmptoms may be masked at low temperature but reappear as the temperature rises.

Fig. 11. Grassy shoot and white leaf disease - chlorotic leaves in the spindle. (Dr. J.C. Comstock, USDA-ARS Sugarcane Field Station, Canal Point)

Natural host range

Besides *Saccharum* spp., GSD is found in *Sorghum bicolor* and *Pennisetum purpureum,* and WLD is found in *Brachiaria subquadripara, Dactyloctenium aegyptium, Chloris barbata* and *Sporobolus fertilis.*

Geographical distribution

GSD is reported from Bangladesh, India, Malaysia, Nepal, Pakistan and Sri Lanka. WLD is reported from Taiwan and Thailand.

Transmission

Both GSD and WLD are sett transmitted. WLD is transmitted by the leafhopper *Matsumuratettix hiroglyphicus*. There is an unconfirmed report of transmission of GSD by a leafhopper in India. Previous reports of transmission of GSD by aphids are believed to be errors.

Therapy

GSD: Moist hot air treatment at 54°C for 4 h.
WLD: Hot-water treatment at 54°C for 50 min.

Indexing

Examination of ultrathin sections by electron microscopy. These organisms occur in phloem tissue.

Reference

Rishi, N. & Chen, C.T. 1989. Grassy shoot and white leaf diseases. pp. 289-300. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr., & C.G. Hughes. Elsevier, Amsterdam.

2. Gumming

Cause

Xanthomonas campestris pv. *vasculorum* (Cobb) Dye
Synonym: *Xanthomonas vasculorum* (Cobb) Dowson

Symptoms

The foliar phase of the disease is marked by yellow stripes starting from tips of leaves and progressing inwards along lateral veins, at an angle to the midrib; the stripes becoming necrotic towards the tips of the leaves. In a susceptible variety, the stripes elongate gradually, finally penetrating the leaf sheath and the stalk to initiate the systemic phase of the disease. The external symptoms associated with this phase are partial or total chlorosis of leaves. Internal symptoms include discolouration of vessels at nodes and internodes, gum pockets, especially at nodes but also in the internodal tissue and even in the growing point. If the growing point is affected, the plant dies. A yellow, gummy substance may be exuded from cut stalks or between the sheaths and young leaves still unroiled in the spindle. Other symptoms associated with the disease are leaf and shoot deformation, red striping of the leaves, and ‘knife cut’ lesions.

Fig. 12. Typical symptoms of gumming disease: leaf stripes (top left), chlorosis (top right), internal gum pockets (bottom left), and gum exudation (bottom right). (Dr. J.C. Autrey, Mauritius Sugar Industry Research, Réduit

Natural host range

Besides *Saccharum* spp., maize, palms *(Dictyosperma album*, *Roystonea regia* and *Areca catechu)* broom bamboo *(Thysanolaena maxima)* and Guatemala grass *(Tripsacum fasciculatum*, syn. *T. laxum).*

Geographical distribution
Argentina, Belize, Brazil, Colombia, Cuba, Dominica, Dominican Republic, Fiji, Ghana, Guadeloupe, India, Madeira, Madagascar, Malawi, Martinique, Mauritius, Mozambique, Panama, USA (Puerto Rico), Réunion, South Africa, St. Kitts & Nevis, Swaziland, and Zimbabwe.
It has been eradicated from Australia (Anon., 1975).

Transmission
The disease is transmitted under natural conditions when friction between leaves causes wounds through which the bacterial pathogen can enter into the 1eaves. Disease dispersal is by setts, wind-blown rain, and cutting implements.

Therapy
No effective therapy available.

Indexing
Indirect immunofluorescence; isolation of bacterium.

References
Anon. 1975. *75 Years of Scientific Progress.* p. 29. Bureau of Sugar Experiment Stations, Australia.

Ricaud, C. & Autrey, L.J.C. 1989. Gumming disease. pp. 21-38. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr. & C.G. Hughes. Elsevier, Amsterdam.

3. Leaf scald

Cause
Xanthomonas albilineans (Ashby) Dowson.

Symptoms
Latent infection is a characteristic of this disease and so the symptoms may not appear in quarantine. Symptoms in the chronic phase may include fine white or reddish pencil-lines, 1-2 mm wide, which diffuse to form yellow or white leaf stripes (up to 10 mm wide); leaf chlorosis on young plants; development of side shoots on mature plants; inward curling of leaves; leaf scalding; and reddish discolouration of vascular bundles at nodes or at base of side-shoots. In the acute phase, sudden plant death occurs.

Fig. 13. Late state of leaf scald disease with side shoots developed. (Dr. J.C. Comstock, USDA-ARS Sugarcane Field Station, Canal Point)

Natural host range

Besides *Saccharum* spp., *Brachiaria piligera, Imperata cylindrica, Paspalum conjugatum, P. dilatatum, Panicum maximum, Pennisetum purpureum, Rottboellia cochinchinensis* (Ricaud & Ryan, 1989). *Zea mays* (Autrey *et al.*, 1991).

Geographical distribution

Argentina, Australia, Barbados, Benin, Brazil, Burkina Faso, Cameroon, China, Cuba, Fiji, Ghana, Grenada, Guadeloupe, Guyana, India, Indonesia, Jamaica, Japan, Kenya, Madagascar, Malawi, Martinique, Mauritius, Morocco, Mozambique, Myanmar, Nicaragua, Nigeria, Panama, Philippines, Reunion, South Africa, St. Kitts & Nevis, St. Lucia, Sri Lanka, Surinam, Swaziland, Taiwan, Tanzania, Thailand, Trinidad, Uruguay, USA (Puerto Rico; Hawaii; continental), Venezuela, and Zimbabwe (Ricaud & Ryan, 1989). Pakistan (Akhtar, Malik & Aslam, 1988). Papua New Guinea (Magarey, 1989).

Transmission

Disease dispersal is by infected setts. The pathogen can be spread aerially (Autrey *et al.*, 1991) and by cutting instruments. Other methods of transmission are suspected.

Therapy

Cold soak treatment of setts (24-48 h soak in running water at 18-25°C), followed by hot-water treatment for 3 h at 50°C.

Indexing

Pathogen can be detected by serological techniques (ELISA; immunofluorescence) and isolation (Davis, Dean & Warmuth, 1991).

References

Akhtar, M.A., Malik, K.B. & Aslam, M. 1988. Sugarcane leaf scald *(Xanthomonas albilineans)* in Pakistan. *Trop. Agric.* (Trinidad) **65**:281-282.

Autrey, L.J.C., Saumtally, S., Dookun, A., Sullivan, S. & Dhayan, S. 1991. Aerial transmission of the leaf scald pathogen, *Xanthomonas albilineans* (Ashby) Dawson. In: *Sugar Cane* No. 6, p. 4. ISSCT Third Sugarcane Pathology Workshop. November/December 1991 (Abstr.).

Davis, M.J., Dean, J.L. & Warmuth, C.J. 1991. Detection of *Xanthomonas albilineans* in sugarcane stalks (Abstr.). *Phytopathology* **81**:1223.

Magarey, R.C. 1989. First record of leaf scald disease in Papua New Guinea. *ISSCT Tech. Newsl.* No. 89/2.

Ricaud, C. & Ryan, C.C. 1989. Leaf scald. pp. 39-58. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr., & C.G. Hughes. Elsevier, Amsterdam.

4. Ratoon stunting disease

Cause

Clavibacter xyli subsp. *xyli* Davis *et al.* (a fastidious, xylem-limited bacterium).

Symptoms

Non-specific stunting, the extent of which depends on the susceptibility of the clone and also on growing conditions. Stunting is aggravated under conditions of water stress and in ratoon crops. A pink discolouration near the apical meristem of young shoots and short red, orange or brown marks at the nodes may be seen in some clones when stalks are split longitudinally, but are neither consistent nor diagnostic.

Fig. 14. Ratoon stunting disease - stunted shoot (top) compared to healthy shoot(bottom). (Dr. R.A. Bailey, South African Sugar Association, Mount Edgecombe)

Natural host range
Only reported from *Saccharum* spp.

Geographical distribution
Probably present wherever sugarcane is grown.

Transmission
By infected setts. It is easily transmitted mechanically from plant to plant, e.g., during harvesting (Gillaspie & Teakle, 1998). It can spread naturally through the soil (Autrey *et al.*, 1991; Bailey & Tough, 1991) and may persist for several months following eradication of infected crops (Bailey & Tough, 1991).

Therapy
Thermotherapy consisting of a soak in running water for 48 h followed by hot-water treatment (50°C for 150-180 min). However, some sensitive clones germinate poorly after thermotherapy.

Indexing
Immunofluorescence and phase contrast microscopy of xylem sap. It can also be detected by ELISA.

References

Autrey, L.J.C., Dookun, A., Saumtally, S., Dhayan, S. & Sullivan, S. 1991. Soil transmission of the ratoon stunting disease bacterium, *Clavibacter xyli* subsp. *xyli.* In: *Sugar Cane,* 6: pp. 5-6. ISSCT Third Sugarcane Pathology Workshop. November/December 1991. (Abstr.).

Bailey, R.A. & Tough, S.A. 1991. Mechanisms of infection of sugarcane by the ratoon stunting disease bacterium, *Clavibacter xyli* subsp. *xyli.* In: *Sugar Cane,* 6: p. 5. ISSCT Third Sugarcane Pathology Workshop. November/ December 1991. (Abstr.).

Gillaspie, A.G., Jr. & Teakle, D.S. 1989. Ratoon stunting disease. pp. 59-80. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr. & C.G. Hughes. Elsevier, Amsterdam.

Fungal diseases

1. Downy mildew

Cause

The usual pathogen is *Peronosclerospora sacchari* (T. Miyake) Shirai & K. Hara (syn. *Sclerospora sacchari),* but *P. philippinensis* and *P. spontanea* may also cause the disease.

Symptoms

Pale green to light yellow streaks occur in the leaves, generally 1-3 mm in width but much wider in susceptible varieties. These streaks are separated by normal green leaf tissue, vary greatly in length, and may occur across the whole leaf blade. The streaks are initially regular in outline, usually continuous. With age, the streaks change colour to darker yellow, then to a mottled red-brown and finally may become dark reddish. A fine white down, and large numbers of conidia are produced, mainly on the underside of the leaf, under conditions of 100% humidity, and this is the most useful diagnostic feature. Oospores may develop in autumn and winter, often in the leaves of abnormally long and thin stalks called jump-ups, and this results in leaf splitting or shredding symptoms. Diseased stools are stunted. Large numbers of small, thin shoots may be produced on ratooning, but few survive for long.

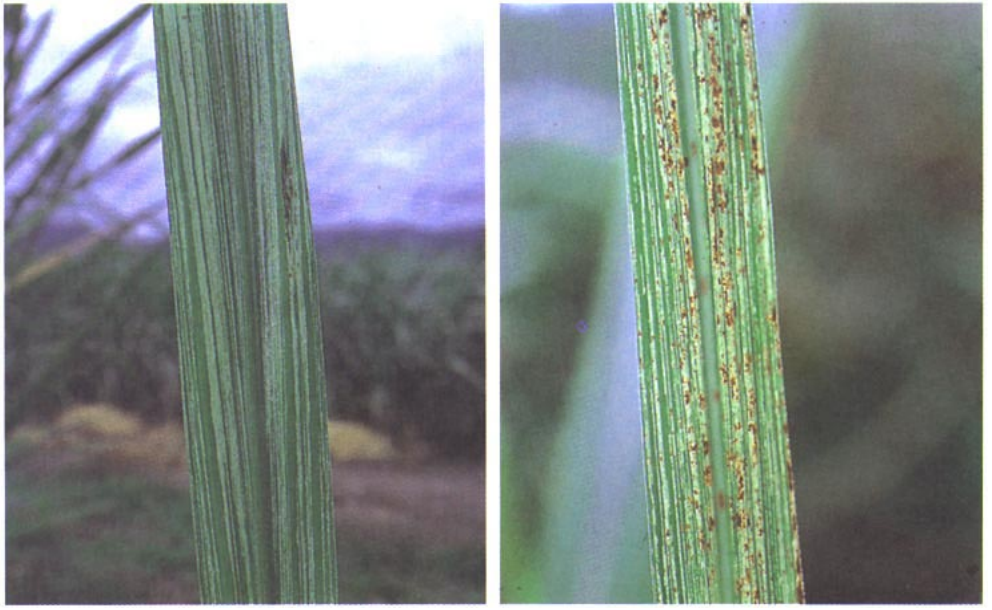

Fig. 15. Downy mildew - young leaf with downy mildew striping and white down on the leaf (left) and older leaf with red-brown discolourations in stripes (right). (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Natural host range

P. sacchari occurs on all species of *Saccharum*, while *P. spontanea* is known from *Saccharum spontaneum* but may also occur on sugarcane., *P. sacchari* and *P. philippinensis* have caused major epidemics in susceptible maize varieties. Natural infection has also been observed in gamagrass *(Tripsacum dactyloides)* and both cultivated and broomcorn forms of sorghum *(Sorghum bicolor)*.

Geographical distribution

Fiji, India, Indonesia, Japan, Papua New Guinea, Philippines, Taiwan, Thailand (Leu & Egan, 1989). The disease was eradicated from Australia in the 1960s (Egan, 1984).

Biology

Conidia require warm nights and 100% humidity for production, germination and survival. They are very short lived, and probably cannot remain airborne for distances greater than 500 m and still remain viable. The role of oospores is unknown, but transmission through contaminated soil is suspected. Downy mildew is spread readily by infected setts.

Fig. 16. Downy mildew - the 'jump-up' effect where odd stalks rapidly elongate. (Dr. B. Egan, Bureau of Sugar Experiment Stations, Indooroopilly)

Quarantine measures

- Hot-water treatment of setts at 50°C for 2 h eliminates the pathogen.
- Apical meristem culture is effective if preceded by hot-water treatment at 52°C for 10-20 min.
- Curative metalaxyl treatment at 1.25 g a.i./l will eliminate the pathogen in setts given a short dip.

References

Egan, B.T. 1984. Downy mildew disease and Australian cane varieties. *BSES Bull.* 5:17-18.

Leu, L.S. & Egan, B.T. 1989. Downy mildew. pp. 107-133. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr., & C.G. Hughes. Elsevier, Amsterdam.

2. Red rot

Cause

Glomerella tucumanensis (Speg.) Arx and Müller

Asexual stage: *Colletotrichum falcatum* Went

Synonym: *Physalospora tucumanensis* Speg.

Symptoms

Internal red discolouration of stalks, typically with white transverse bands. Sometimes these patches are so numerous that they give a mottled appearance to the tissues. A discolouration is also present on the rind, often at the nodes but also in the internodes. In the later stages, infected stalks become hollow and shrink longitudinally. Later symptoms may include yellowing, withering and drying of leaves, and finally death of the stalk, mortality of shoots, erratic regrowth of ratoons and rotting of setts. The fungus can infect leaves, causing red discolourations of the mid-rib and occasionally leaf spots on the lamina.

Natural host range

Besides *Saccharum* spp., *Leptochloa filiformis* and *Miscanthus* spp., sorghum and Johnson grass.

Fig. 17. Red rot - discolouration on the rind (left) and internal red discolouration of stalks (right). (Dr. AS. Patil, Dept. of Sugar Cane Pathology, Pune)

Geographical distribution
Worldwide.

Biology
The spores are partly windborne and infect shoots through wounds, bud scales, leaf scars, root primordia and stalk borer tunnels. The pathogen is also transmitted through diseased cuttings, rain splash, dew droplets and soil. Cool and dry conditions are conducive to infection. Asexual and sexual structures are produced on decaying canes and/or debris, and cause infection after planting.

Quarantine measures
- Moist hot air at 54ºC for 2 h, aerated steam treatment at 52ºC for 4 to 5 h, or hot air treatment at 54º for 8 h eliminate the pathogen from setts.

- The standard cold soak in running water for 48 h followed by hot-water treatment (50°C for 150-180 min) will also eliminate the pathogen from infected setts.

Reference
Singh, K. & Singh, R.P. 1989. Red rot. pp. 169-188. In: *Diseases* of *Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr. & C.G. Hughes. Elsevier, Amsterdam.

3. Smut

Cause
Ustilago scitaminea H. Sydow.

Symptoms
Whips formed from the terminal meristem or from lateral shoots of infected stalks, covered with black spores (teliospores). Infected shoots are slender and grass-like, with narrow, short laminae.

Natural host range
Besides *Saccharum* spp. and the related genera *Miscanthus* and *Sclerostachya, lmperata arundinacea* and *Erianthus saccharoides.*

Geographical distribution
Smut is cosmopolitan in distribution. The disease has not, however, been found in Australia, Ecuador, Fiji or Papua New Guinea.

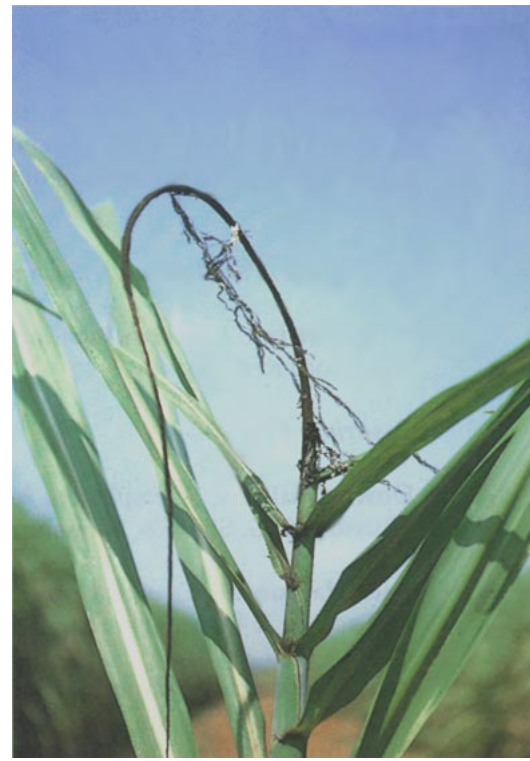

Fig. 18. Smut - whip covered-with black teliospores. (Dr. R.A. Bailey, South African Sugar Association, Mount Edgecombe)

Biology

Dispersed by windborne spores, which infect lateral buds of stalks. Such infection remains latent but develops in young shoots after germination, eventually producing the whip. Infection may also occur in soil subject to heavy aerial contamination. The fungus can survive up to several weeks in dry soil. Humid conditions reduce spore viability. Different-races of the fungus have been reported.

Quarantine measures

The standard cold soak in running water for 48 h followed by hot-water treatment (50°C for 150-180 min) will eradicate smut from infected setts.

Reference

Ferreira, S.A. & Comstock, J.C. 1989. Smut. pp. 211-229. In: *Diseases of Sugarcane: Major Diseases.* Eds. C. Ricaud, B.T. Egan, A.G. Gillaspie, Jr. & C.G. Hughes. Elsevier, Amsterdam.

Other diseases

- The following diseases can be transmitted in setts. However, it is most likely that the causal organisms will not survive the cold soak/ hot-water treatment recommended as a standard treatment in the Technical Recommendations of these Guidelines:

  - **Red stripe,** *Pseudomonas rubrilineans* (Lee *et al.)* Stapp.
  - **Mottle stripe,** *P. rubrisubalbicans* (Christopher and Edgerton) Krasil'nikov.
  - ***Fusarium* spp.**
  - **Downy mildew,** *Sclerophthora macrospora* (Sacc.) Thurum, C.G. Shaw & Narashiman.
  - **Bacterial mottle,** *Erwinia chrysanthemi* Burkholder, McFadden & Dimmock.
  - **Wilt,** *Cephalosporium sacchari* E. Butler.
  - **Pineapple disease,** *Ceratocystis paradoxa* (Dade) C. Moreau.

  The following diseases of unknown etiology and of extremely limited distribution are readily sett-transmitted and are not eliminated by the recommended cold soak/hot-water treatment:

  - **Striate mosaic**
  - **Spike**
  - **Sembur**
  - **Dwarf**

Arthropod pests

Any risks of introducing insects, such as stalk borers, mealy bugs and scales, are eliminated by the hot-water treatments.

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