COLLABORATIVE CROP RESEARCH PROGRAM
THE McKNIGHT FOUNDATION

icipe
African Insect Science for Food and Health

Solving Napier Stunt Disease to save the smallholder dairy sector in East Africa – a success story

The International Centre of Insect Physiology and Ecology (*icipe*) in Kenya, working with national partners in East Africa and Rothamsted Research (UK), and funded by the McKnight Foundation (USA), has found varieties of Napier grass that are resistant to Napier Stunt Disease (NSD).

> *"Napier Stunt Disease interferes with animal fodder, soil erosion control, incomes and rural employment."*
>
> Boniface Aono

Napier grass is the most important fodder crop in smallholder dairy production systems in East Africa. It is a vital component of the intensive crop–livestock management system which sustains the livelihoods of dairy smallholders.

Since the late 1990s, Napier grass has been hit by the increasingly rapid spread of a disease which stunts its growth, often killing the plant. NSD is a considerable and growing threat to livelihoods and the future of the smallholder dairy sector.

In 2000, *icipe* and Rothamsted Research scientists Professors Zeyaur Khan, John Pickett and Lester Wadhams observed for the first time a stunting disease in Napier grass in Teso, western Kenya. They had a special interest in Napier grass as pioneers of push–pull technology, a cereal crop protection system in which it is planted as a trap plant to attract insect pests. Concerned about the threat posed not only to increased uptake of push–pull but also to the smallholder dairy sector, they began to track the spread of the disease.

By 2002, they observed that the stunting was spreading rapidly in the region, affecting about a quarter of Napier grass. In response, they initiated research into the causes and transmission of NSD, in order to develop a sustainable disease management approach. The team's labours bore fruit in 2013 when two NSD-resistant cultivars passed on-farm trials, and participating farmers were given the go-ahead to multiply them for wider distribution.

But ongoing work is still needed to develop an integrated management system, including the introduction of resistant cultivars, building farmers' knowledge about how NSD spreads, the proper disposal of diseased plants, the potential role of other grasses as reservoirs of NSD, and diversification of fodder sources.

Continuing scientific research is also essential to deepen understanding of the biology and epidemiology of the disease, particularly its potential to spread to food crops.

Above: Boniface Aono contrasts healthy and infected Napier grass plants on his farm in Kisumu, Kenya.

Below: Dr Khan shows EU Ambassador Lodewijk Briët the insect vector of NSD at the *icipe* field station at Mbita Point, where it was first identified by his team of scientists.

Napier grass at the heart of intensified smallholder dairy production

East Africa has a long tradition of mixed smallholder farming, combining the production of crops and livestock on the same farm. In the last thirty years, several contextual changes have driven the adaptation and intensification of this traditional livelihood system.

- **Population increase** has led to more land being used for cultivation, at the expense of grazing land.
- **Fragmentation of farm land** is widespread, as existing family holdings are split for inheritance by the next generation.
- **Liberalization of the dairy sector** in 1992 allowed smallholder farmers to produce, process and market their own milk for the first time.
- **Improved breeds of dairy livestock** have been introduced through both widespread government and non-governmental organization (NGO) programmes, and private enterprise. While improved cows and goats produce more milk, they also demand more fodder, and must be stall-fed to protect them from diseases.

These drivers of change have resulted in a steady increase in the number of improved and cross-breed dairy cattle and goats kept in zero-grazing units on small farms, and rising demand for cultivated fodder to provide an alternative to purchased animal feeds. Napier grass – high-yielding and easy to manage and propagate – is the fodder crop most commonly grown to meet this demand. It is also widely planted for environmental protection, stabilizing soil and acting as a windbreak.

Pascal and Ruth Otieno's experience of intensifying their dairy production is typical of many. They have been push–pull farmers since 2006, and they received a Friesian dairy cow from the NGO Heifer International when their fodder production rose. Pascal says that the most visible impact of intensifying his milk and fodder production has been to increase the family's cash income.

Napier Stunt Disease threatens livelihoods

Whether grown in a single stand or as a border crop, Napier grass has become an integral part of the improved livelihoods that can result from intensive smallholder dairy production. For many farmers, milk production improves household income, helps meet the costs of educating children and provides much-needed dietary protein. Zero-grazing units facilitate the collection and processing of farmyard manure to improve soil fertility.

But these development gains have been eroded since the inexorable spread of NSD. Milk production has dropped, and instead of gaining income from milk sales, many farmers are forced to find cash to buy the fodder needed by their improved cattle. Some have had no choice but to sell their animals.

Napier grass is cut and fed to stall-reared or tethered dairy animals, goats as well as cattle. Kenya has the largest smallholder dairy sector in sub-Saharan Africa.

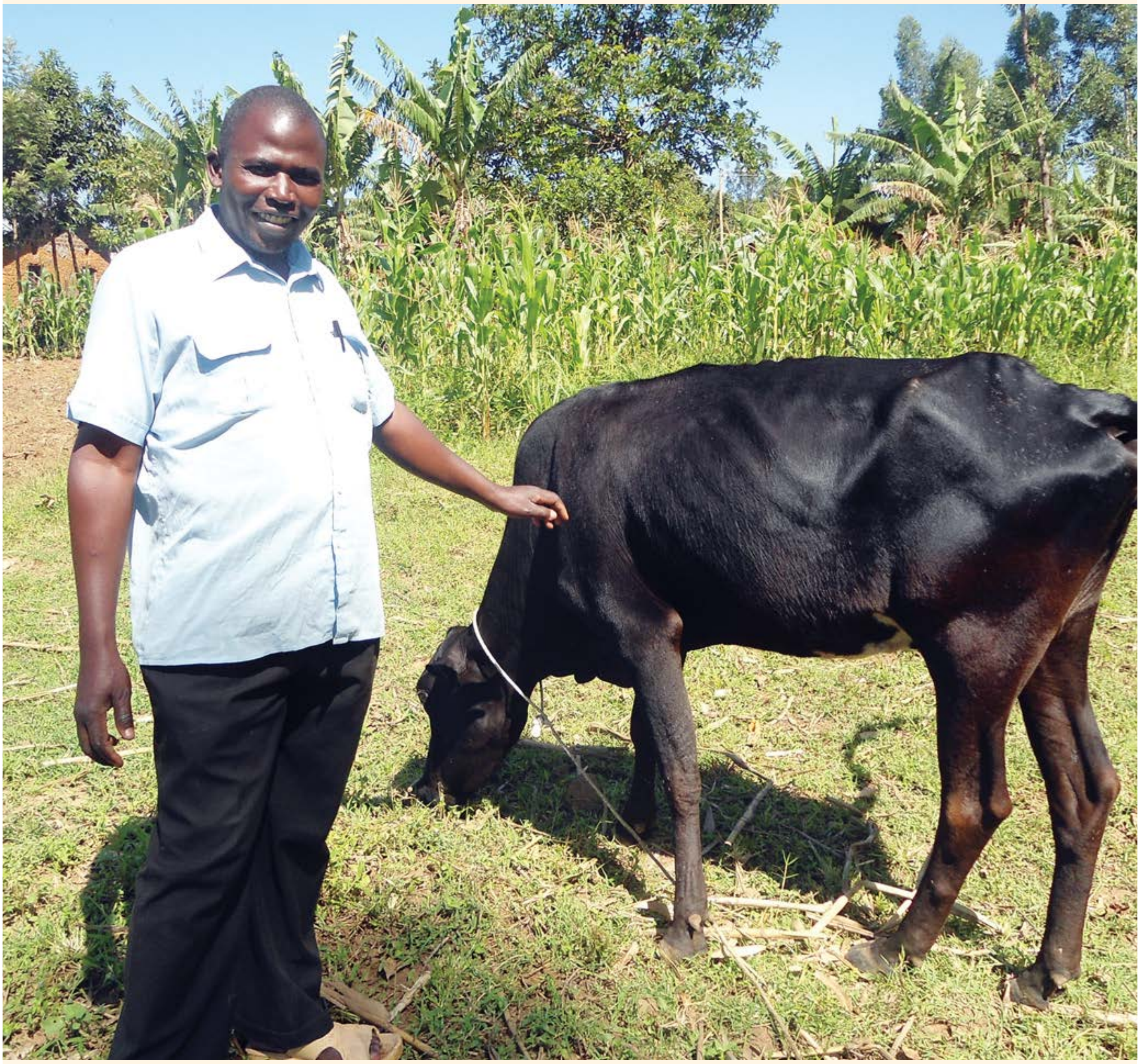
Ruth Otieno milks the Friesian dairy cow which gives 20 litres every day. Most of this is sold to pay school fees for the family's six children.

Napier Stunt Disease makes agricultural intensification riskier for farmers

When George Kane and other members of his Farmer Field School group first noticed diseased Napier grass on their plots in 2007, they had no idea what caused it. Some tried adding more manure to the soil or rotating the crop, while others uprooted the diseased grass and began again with new plant material. But no method proved effective and the disease spread steadily.

NSD struck at a crucial time on George's farm. He had decided that the carrying capacity of his one acre smallholding meant that he was better suited to a single, productive stall-fed dairy animal than his three local-breed grazing cattle. He sold his local cattle and replaced them with a Friesian cross-breed. His gamble will pay off only if a viable solution to NSD is found, assuring him of enough fodder to adequately feed his cow.

> *"Milk is gold, but its production is affected by NSD. More than 90 percent of Napier grass in Bungoma district is affected."*
>
> George Kane



Milk sales are the main source of income for George's family of eight. Since NSD spread across his farm, his cross-breed cow does not get enough to eat and is rapidly losing weight.

Dr Khan and fellow agricultural entomologist Dr Charles Midega supervise the extraction of DNA from plants to detect NSD in the *icipe* laboratory at the Thomas Odihambo Campus, Mbita.

Evolving research on Napier Stunt Disease

Having observed the rapid spread of the stunting disease in 2002, the *icipe* team set out to learn more about the problem. This was achieved over several years of multidisciplinary research to uncover the complex biological, chemical and ecological interactions between plants, insects, bacteria and people, which would shed light on the origins and spread of the disease.

The *icipe* team first contacted Rothamsted plant pathologist Dr Phil Jones. He recommended inviting his colleague Dr Latunde-dada Akiwunmi to collect Napier cuttings and culture them in a laboratory at *icipe* in Nairobi, in order to identify the disease. Dr Akiwunmi discovered that it was caused by bacteria. Further DNA analysis by Dr Jones identified phytoplasma, a tiny parasitic bacteria, as the culprit. Phytoplasma are known to cause around 200 plant diseases, often spread by insects that feed on plant sap.

The *icipe* scientists turned to finding out whether any insects were spreading the NSD phytoplasma. They collected live samples of 20 different species of sap-sucking insects associated with Napier grass and reared them in cages, feeding them on diseased Napier grass to acquire the phytosplasma. When the insects laid eggs on the diseased grass, the emerging nymphs acquired phytoplasma in the same way. After 30 days, healthy Napier plants were introduced and exposed to the insects and nymphs for 60 days. Samples of surviving insects and plants were then tested for phytoplasma. This process led to the identification of a common leafhopper as the insect vector of the disease.

Carrying out this kind of study demands the DNA analysis of many thousands of plant and insect samples, to detect the presence of the disease. Early in the research, screening for phytoplasma was carried out using a Polymerase Chain Reaction machine. But this method is laborious, costly and technically demanding. During their research on NSD, the *icipe* team has used a new simpler phytoplasma diagnostic tool, Loop Mediated Isothermal Amplification of DNA (LAMP), which makes screening for NSD cheaper and faster.

Phytoplasma transmission experiments like this one led to the identification of the insect vector of NSD.

FACTS ABOUT NAPIER STUNT DISEASE

What is Napier grass?

Napier grass (*Pennisetum purpureum*) is a high-yielding fodder grass which tolerates frequent cutting. These qualities make it the most important fodder grass in East Africa. It is grown by the majority of the region's smallholder dairy and cereal farmers.

Healthy Napier grass for sale at Luanda market, near Maseno, Kenya.

In push–pull technology, adopted by more than 70,000 of the region's farmers, Napier grass is used as a trap plant to attract insect pests.

What is Napier Stunt Disease?

NSD is a disease that affects Napier grass. Its symptoms are visible in the re-growth that happens after the grass has been cut or grazed. Affected plants are recognized by severe stunting and yellowing, and a profuse growth of shrivelled, unhealthy new plant shoots. Often the whole stool is affected, and dies. NSD also attacks other fodder grasses such as *Cynodon dactylon* and *Hyparrhenia rufa*.

What causes it?

NSD is caused by a specialized bacteria called phytoplasma, which stops the grass from taking up the nutrients it needs to grow. The phytoplasma that causes NSD is a member of a phytoplasma group, 16SrXI, already known to cause stunting in rice and Bermuda grass.

A specimen of stunted Napier grass, showing yellowing and biomass loss.

How is it transmitted?

The phytoplasma are carried from plant to plant by the leafhopper *Maiestas banda* Kramer, which draws its food from the part of the Napier grass which is infected by phytoplasma. High population densities of *Maiestas banda* Kramer on field sites in western Kenya confirmed the identification of the leafhopper as the principal insect vector for NSD.

The phytoplasma are also spread through the common practice of propagating split Napier grass roots for multiplication.

Maiestas banda Kramer, a tiny leafhopper, spreads the disease from plant to plant.

For over 35 years, Aloice Ouma preserved a Napier grass variety on his farm in Busia, Kenya. He shared it with *icipe* to use in their research. It turned out to be phytoplasma-resistant, and now bears his name – Ouma 2.

Searching for an integrated management solution

In 2008, social scientists from the *icipe* team interviewed farmers to find out more about their perceptions of NSD and its effects on their livelihoods. They surveyed a random sample of 150 farmers in western Kenya.

- 87% were aware of the disease and its rapid spread, but none knew what caused it or had a strategy for managing it.
- The majority did not produce enough Napier grass or other fodder on their farm to feed their livestock.
- Milk production had gone down by an average of 65%.

Although the news that NSD was caused by a phytoplasma and carried by a leafhopper began to spread to farmers through *icipe* scientists and field technicians, it was clear that an NSD management strategy was urgently needed. The *icipe* team turned to searching for varieties of Napier grass that would resist the disease.

But this search had to be undertaken with extreme caution. There are different mechanisms of resistance to disease. Some plants and varieties can host the phytoplasma but not develop symptoms of the disease, while others escape infection because they are unattractive to the leafhopper. Introducing a variety with high resistance to the leafhopper would risk forcing the insect to seek new hosts, possibly spreading the disease to previously unaffected plants, including food crops.

The team obtained funding from the McKnight Foundation to develop a sustainable management strategy for control of NSD. This included identifying Napier varieties with a low level of resistance to the leafhopper but a high level of durable resistance to the phytoplasma. With support from the International Livestock Research Institute (ILRI), *icipe* scientists collected germplasm – parent planting material – of fifty Napier grass cultivars and obtained 70 new accessions from the Kenya Agricultural Research Institute (KARI). In addition, hundreds of varieties were collected from farmers' fields. All of these were screened over a two-year period. The team also screened several alternative fodder grasses for their resistance to NSD.

This process led to the selection of three resistant varieties with slightly different resistance mechanisms. These were cultivated for two years at *icipe*'s Mbita Point field station to test the durability of their resistance, before being subjected to on-farm trials in 2013. Two varieties, Ouma 2 and South Africa, are particularly attractive to *Maiestas banda* but resistant to its negative effects. As well as providing farmers with reliable productivity, these varieties will also help control the spread of the disease to non-resistant but less attractive varieties. In addition, an alternate fodder grass, *Brachiaria* cv Mulato II was also identified as resistant to NSD. *Brachiaria* is used as a drought-tolerant trap crop in climate-smart push–pull technology.

Brachiaria cv Mulato II, a drought-tolerant fodder grass, is resistant to NSD. It is widely used in climate-smart push–pull technology in eastern Africa.

Building on the foundations of farmer participation

Bungoma farmer Peter Waboya remembers the moment in 2008 when he first learned about the phytoplasma causing NSD from *icipe* field technicians. It was just one episode in his long relationship with *icipe*. He adopted push–pull in 2006 and has become a great champion of the technology, heading the Simana Push–Pull Farmer Field School. This teaches groups of farmers about the technology and how it works, and supports them in implementing it.

Peter is one of a network of experienced farmer leaders and peer educators that has been built up to disseminate push–pull technology. It was to this network that *icipe* turned for hosting on-farm trials of the new resistant varieties of Napier grass. The knowledge, skills and relationships already in place meant that these farmers were poised to multiply and share new plant material as soon as it had passed the necessary screening procedures.

When Peter was invited to Mbita Point to share his experiences of NSD and learn about on-going research, he used his training in making participatory videos to film parts of his visit. This footage became part of the short film he has made to train other farmers on the causes and management of NSD.

Opportunities and challenges in extending stunt-resistant Napier grass

In Butere district, Kenya, David Omurumba and his neighbour Elizabeth Atieno are members of the Waaminifu self-help group. Both hosted on-farm trials of the resistant Ouma 2 and South Africa Napier grass varieties. In September 2013, they got the go-ahead to multiply the plants for distribution to other farmers. The group gathered for a field day on David's farm, and all 26 members will plant push–pull and single stand Napier fodder using cane cuttings from the plot.

Sadly, the fate of Elizabeth's trial crop has not been so positive. Such is the desperation for fodder in this area that one night thieves came and harvested the lush new growth of Napier grass. This loss of vital plant material serves to demonstrate the severity of NSD's impact on rural livelihoods.

Rampant NSD left David Omurumba so disillusioned that he uprooted his entire Napier grass crop in 2012. He hopes that the South Africa (in the background) and Ouma 2 varieties that have been field-tested on his farm will end the severe shortage of fodder in Butere district.

On-going research is essential

The identification of the phytoplasma, *Maiestas banda* Kramer, and two NSD-resistant Napier grass varieties are important achievements, milestones on the road towards an effective and robust management strategy for the disease.

A priority now is to ensure that the widest possible extension of the resistant varieties is undertaken in the context of adequate training. There is a need to introduce proper hygiene practices, and to fingerprint the resistant varieties to avoid any future mixture with susceptible varieties.

But on-going research into NSD remains urgent. It is vital that strategies to reduce stunt in Napier grass must not cause the shift of the phytoplasma to other crops. Many cereal crops – maize, millet and rice – are in the grass family, potential hosts to *Maiestas banda* Kramer. Further analysis of NSD phytoplasma DNA in rice and millet has shown that it can indeed infect these important food crops.

Diseased and healthy specimens of *Cynodon dactylon* (left) and *Hyparrhenia rufa* (right) show clearly how NSD also affects other grasses. This means that the spread of the disease could lead to the infection of food crops in the *Poaceae* (*Gramineae*) family.

Participants in on-farm trials of South Africa and Ouma 2 host a visit from Dr Linnet Gohole (centre, with handbag), the Regional Representative of the McKnight Foundation, which funded the NSD research, and Dr Francis Muyeho of the Kenya Agricultural Research Institute (standing third from left).

The research needed to avert this risk is into the epidemiology of the disease in the context of the agro-ecosystems where it is found. This includes searching for wild grasses in the field which are susceptible to infection with NSD, but also those which may host the leafhopper and the phytoplasma without developing the disease, becoming a source of infection for valuable crops.

The team of scientists at *icipe* will continue working on these challenges in research and extension, in partnership with the farmers who face a daily struggle with the pests and diseases of their crops. Together, they will ensure that the focus of the research agenda is on farmers' real needs.

Acknowledgements

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