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 grass is the most important fodder crop in smallholder dairy production systems in East Africa. It is a vital component in 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, 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 was 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. Twelve additional grasses previously studied for their forage value are being tested for their resistance to NSD. They are still in the screen-house and lab stages before they can be tested on farm.

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.

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

Professor Khan shows former European Union 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 STUNT DISEASE INTERFERES WITH ANIMAL FODDER, SOIL EROSION CONTROL, INCOMES AND RURAL EMPLOYMENT."
>
> **BONIFACE AONO**
> FARMER, KISUMU WEST, KENYA

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. Since the 1980s, 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 farmland** is widespread, as existing family holdings are split for inheritance by the next generation.
- **Liberalisation 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 on a wide scale through government and non-governmental organisation (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, stabilising 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

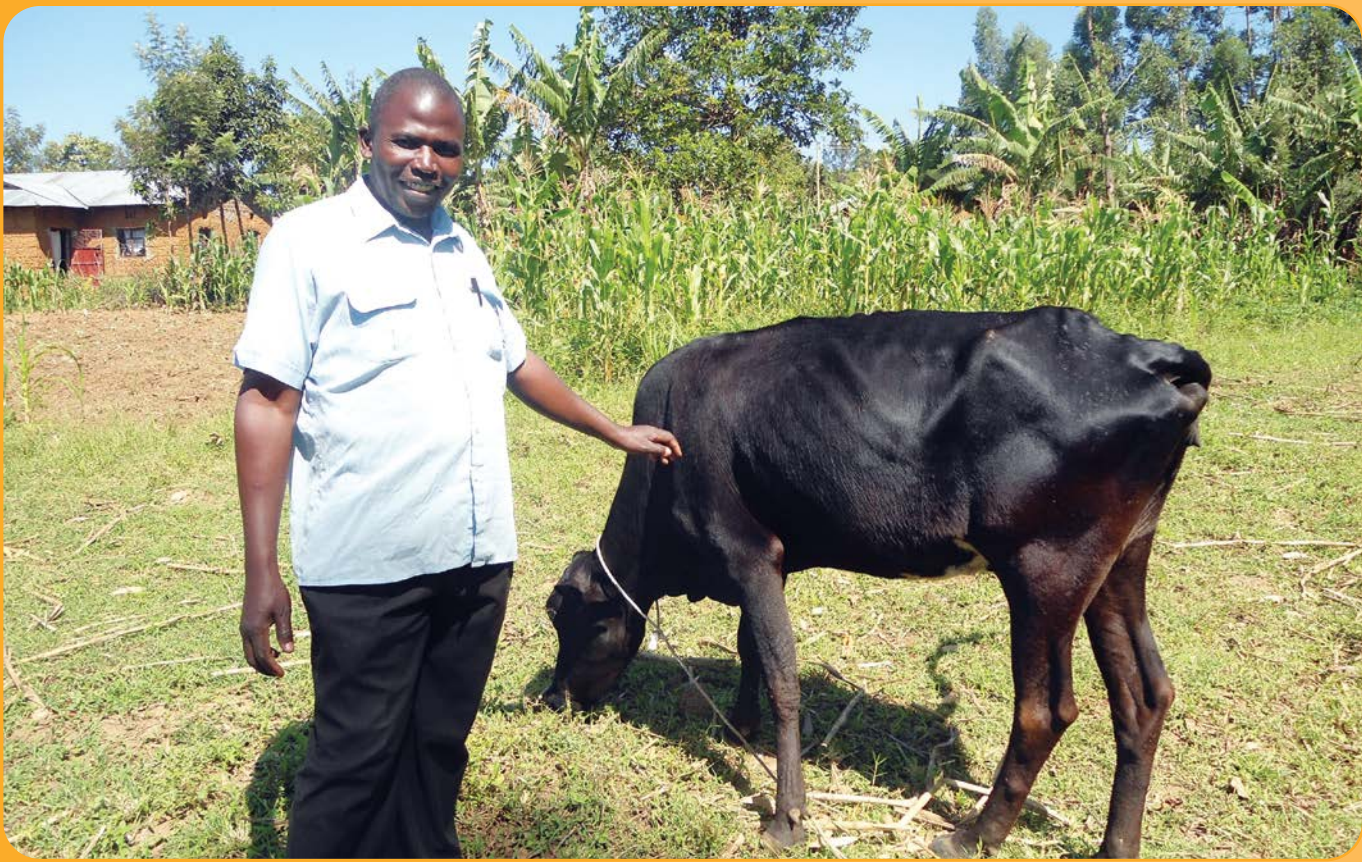
Whether grown in a single stand or as a border crop, Napier grass has become an integral part of the improved livelihoods that can result from intensive smallholder dairy production. For many farmers, milk production improves household income, helps meet the costs of educating children and provides much-needed 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 seemingly 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.

Ruth Otieno milks her 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 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.

Napier stunt disease makes agricultural intensification riskier for farmers



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, due to relying on inadequate pasture.

When George Kane and other members of his farmer field school first noticed diseased Napier grass on their plots in 2007, they had no idea what was causing it. Some tried adding more manure to the soil or rotating the crop, while others uprooted the diseased grass and began again with new planting material. But no method proved effective and the disease continued to spread.

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 cow than his three local-breed grazing cattle. He sold his local cattle and replaced them with a Friesian cross-breed. He now has about quarter of an acre of Napier grass 'South Africa', and buys supplementary feed from his neighbours who grow Napier but have no livestock.

> “MILK IS GOLD, BUT ITS PRODUCTION IS AFFECTED BY NSD. **MORE THAN 90% OF NAPIER GRASS** … IS AFFECTED.
>
> **GEORGE KANE**
> FARMER, BUNGOMA COUNTY, KENYA

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

Evolving research on Napier stunt disease

Having observed the rapid spread of NSD 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 among plants, insects, bacteria and people which 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 NSD was caused by bacteria. Further DNA analysis by Dr Jones identified a phytoplasma, a tiny parasitic bacterium, 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 species of sap-sucking insects associated with Napier grass and reared them in cages, feeding them on diseased Napier grass to acquire the phytoplasma. 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 requires 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 (PCR) 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.

Napier stunt disease: the facts

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

In 'conventional' push–pull technology, Napier grass is used as a trap plant to attract insect pests.

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

What is Napier grass?

Napier grass (*Pennisetum purpureum*) is a high-yielding fodder grass that 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.

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 recognised by severe stunting and yellowing, and a profuse growth of shrivelled, unhealthy new plant shoots. Often the whole stand is affected, and dies. NSD also attacks other fodder grasses including Bermuda grass (*Cynodon dactylon*) and Jaragua (*Hyparrhenia rufa*).

What causes it?

NSD is caused by a specialised bacterium called a 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.

How is it transmitted?

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

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

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

For over 35 years, Aloice Ouma (now deceased) 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, Jimmy Pittchar and his team of social scientists from *icipe* 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% since the arrival of NSD.

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 began to search 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 initial funding from the McKnight Foundation to develop a sustainable management strategy for the 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 50 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 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 the negative effects of NSD. As well as providing farmers with reliable productivity, these varieties will help control the spread of the disease to non-resistant but less attractive varieties. In addition, an alternative fodder grass, brachiaria 'Mulato II' was identified as being resistant to NSD. Brachiaria is used as a drought-tolerant trap crop in climate-smart push–pull technology.

Brachiaria 'Mulato II', a drought-tolerant fodder grass that is also resistant to NSD. It is widely used in climate-smart push–pull.

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 Bungoma Umbrella Farmer Field School Network. The Network teaches groups of farmers about the technology and how it works, and supports them in implementing it.

Peter is one of the experienced farmer field school leaders and peer educators recruited by *icipe* to disseminate push–pull technology. It was to this group 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 ongoing research, he used his training in making participatory videos to film parts of his visit. This footage became part of a short film used to train other farmers on the causes and management of NSD.

Opportunities and challenges in extending stunt-resistant Napier grass

In Kakamega County, 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. Subsequently, David has distributed NSD-resistant Napier to over 250 farmers.

Sadly, the fate of Elizabeth's trial crop was not 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.

During 'random' farmer surveys carried out in western Kenya and eastern Uganda, *icipe* collected Napier grass materials the farmers had used and presumed, in their own experience, to be resistant to NSD. Several splits of each material were collected from the farmers, with notes on physical characteristics, duration of use by the farmer and location. After rigorous disease-transmission tests in the laboratory and under field conditions, an additional three cultivars were identified to have good resistance: 'Phanice', 'Tundwe' and 'Wanga'. These are currently undergoing resistance-stability testing with farmers in western Kenya before they can be officially released.

Rampant NSD left David Omurumba so disillusioned that he uprooted his entire Napier grass crop in 2012. Thankfully, the 'South Africa' (in the background), 'Ouma 2', 'Phanice' and 'Wanga' varieties that were field-tested on his farm and that he now multiplies are helping end the severe shortage of fodder in Kakamega County.

Ongoing research is essential

The identification of the phytoplasma, *Maiestas banda*, and 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 need for continued sensitisation on proper field hygiene practices, and to fingerprint the resistant varieties to avoid any future mixture with susceptible varieties. *icipe* has collected 29 more resistant cultivars to provide options for farmers in different areas and with different preferences as part of an integrated management approach for the disease in East Africa; these cultivars are still in the screen-house and lab stages of trials and are yet to be tested on farm.

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

To avert this risk, research is being conducted 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 that are susceptible to infection with NSD, but also those that may host the leafhopper and the phytoplasma without developing the disease, becoming a source of infection for valuable crops.

icipe scientists will continue working on these challenges in research and extension – in partnership with the farmers who face a daily struggle with crop pests and diseases. Together, they will ensure that the research agenda focuses specifically on farmers' real needs.

COLLABORATIVE CROP RESEARCH PROGRAM

THE McKNIGHT FOUNDATION

Participants in on-farm trials of 'Ouma 2' and 'South Africa' 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).

Diseased and healthy specimens of Bermuda grass (*Cynodon dactylon*, left) and jaragua (*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.

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