icipe

African Insect Science for Food and Health

Desmodium intercropping eliminates striga threat and improves food security in Africa

Scientists at the International Centre of Insect Physiology and Ecology (*icipe*) in Kenya, in collaboration with colleagues at Rothamsted Research in the UK, have discovered that intercropping cereals with a perennial forage crop, desmodium, effectively eliminates the most significant constraint to cereal production in sub-Saharan Africa, the parasitic weed striga.

Striga (*Striga hermonthica* and *S. asiatica*) greatly reduces the productivity of maize, sorghum, millet, rice and tef by attaching itself to the roots of the crop and robbing it of nutrients. An individual striga plant produces many thousands of tiny seeds that can remain viable in the soil for 15–20 years.

Scientists at *icipe* have been working since 1998 to develop and extend an approach to striga control that is appropriate to the needs and capacities of East African smallholders. They have focused on identifying companion crops containing chemicals that naturally suppress striga, as well as having other economic uses for farmers.

Their research led them to the discovery that desmodium, a leguminous plant valued for its qualities as a nutritious animal fodder, also has a unique capacity to suppress striga growth and reduce the seed bank in the soil. Planting rows of desmodium between rows of cereal crops can effectively reverse declining crop yields by controlling striga and improving soil fertility, at the same time as providing farmers with a year-round supply of fodder.

Thanks to *icipe*'s ongoing collaboration with farmers, non-governmental organizations (NGOs) and national extension programmes, more than 75,000 mixed smallholder farmers in Ethiopia, Kenya, Tanzania and Uganda now control striga through desmodium intercropping. More work is needed to increase adoption levels and widen the spread of the management system to different cropping systems and agro-ecological conditions. This demands both the development of a strong commercial seed system for desmodium, and continued research on the efficacy of recently identified drought-resistant African desmodium species and their mechanism of striga suppression.

Above: Mary Atemo's farm in Kenya's Vihiga district used to be dominated by striga, and she was scarcely able to produce any grain at all.

Below: Since Mary started intercropping with desmodium, her 20 x 10 m plot has been free of the weed and she has been able to produce 135 kg of maize from it – equivalent to 3.31 tonnes per hectare. "We have enough food," she says, "for our good health."

Building on a lucky discovery

Across eastern Africa, millions of smallholder farmers cultivate cereal crops each year, growing maize, sorghum, millet, rice and tef for their own consumption and for sale. But the productivity of these crops – and the livelihoods and food security of the farmers who depend on them – is increasingly threatened by the spread of striga across the region.

The discovery that desmodium has the capacity to control striga was made by a team of scientists who were not even looking for strategies to manage the weed. Instead, Dr Zeyaur Khan, the agricultural scientist who leads the team at *icipe*, was aiming to develop a way of controlling an insect pest, the stemborer, which is also responsible for severe damage to cereal crops across Africa.

Striga: a parasitic menace

Present in more than a million hectares of cereal fields in eastern Africa, striga has been estimated to threaten the food security of 100 million people in the region. Across sub-Saharan Africa, it causes up to US$1 billion worth of damage to crops each year.

Striga plants produce thousands of tiny seeds that remain dormant in the soil, staying viable for up to 20 years. When a cereal crop is planted, its roots release chemicals that stimulate the germination of the striga seeds. But instead of growing their own roots to draw nutrients from the soil, striga plants develop a radicle – an embryonic root – that attaches itself to the crop roots. The striga plant then goes on to rob the crop plant of nourishment and water and inject it with phytotoxins, leaving the crop stunted and wilted.

Striga thrives on continuously cropped soils with low fertility, and its effects are most severe on crops that are already stressed, and where soil moisture is low and soil temperature high. These are conditions that are increasingly associated with the resource-poor smallholder farmers who are worst affected by the weed.

There are several recommended methods for striga control, including the application of nitrogen fertilizer, herbicides, chemical germination stimulants and resistant or tolerant crop cultivars. Each of these solutions demands the annual or bi-annual purchase of expensive external inputs. This means that for many smallholders, digging and pulling the weed – a labour-intensive and largely ineffective task, given that by the time striga emerges from the ground it has already damaged the crop – is the only striga control mechanism to which they have access.

The carpet of purple striga flowers in this Kenyan maize field shows how an infestation of the weed can dominate and devastate a cereal crop.

Striga attaches itself to the roots of its host, drawing out nutrients and moisture and injecting phytotoxins into the plant.

> *"Desmodium is a unique plant, and it has helped repair my farm. The striga is under control."*
>
> Rhoda Abong'o

In 1993, Khan's team and their partners at Rothamsted Research began working towards the development of a sustainable habitat management system for stemborer control that involved growing a repellent plant to push the insect away from the crop, and a trap plant to attract and kill it. An early version of what has become known as the 'push–pull' system, which used an intercrop of molasses grass (*Melinis minutiflora*), was developed at *icipe*'s field research station at Mbita Point, Kenya, and was proven to be successful at controlling stemborers.

A visit to Mbita Point by the Suba District Agricultural Officer changed the future course of the push–pull research. Khan recalls that, on observing the prototype demonstration plot, the officer remarked, "Your technology will only be accepted by the farmers if it can also give the solution to striga." Although Khan initially replied, "No! We are an insect centre, we don't work on striga," the conversation prompted him to search more widely for an alternative 'push' crop for the system which could also control striga.

It was already known that some plants in the legume family could repel stemborers, and that others had some effect on striga. Coming across the seed of a legume which he had never worked with before in a Nairobi seed shop led Khan to purchase a kilo of silverleaf desmodium (*Desmodium uncinatum)*, which he included in the stemborer trials at Mbita. Much to his surprise, he observed that not only was the stemborer population reduced where the desmodium was planted, but also that there was no striga.

Rhoda Abong'o stands in her maize plot in Rachuonyo, Kenya where – thanks to a greenleaf desmodium intercrop – there is no striga, and a good crop of healthy maize.

This lucky discovery triggered a sequence of experiments and trials which confirmed beyond doubt that silverleaf desmodium was highly effective at controlling striga. This led to it being included in the version of the push–pull system that was first extended to farmers in 1998. At the same time, a painstaking process of ongoing research eventually began to reveal the exact mechanisms by which desmodium suppresses the weed.

Since 2009, many farmers have reported that silverleaf desmodium cannot always stand the high temperatures and long dry seasons that are becoming increasingly common in the region. In response, the team tested a number of drought-tolerant desmodium species, and found several that possessed the same striga-suppressing qualities as silverleaf. Although this included three native African varieties – *Desmodium ramosissimum*, *D. repandum* and *D. incanum* – none had commercially available seed, so the team selected a non-native variety, greenleaf (*D. intortum*), to include in a second, climate-smart version of push–pull.

Desmodium's unique mechanism for suppressing striga

The *icipe* scientists, together with their partners at Rothamsted Research, established a series of experiments to find out how desmodium suppresses striga. In a drip experiment at Mbita Point, they planted maize in pots in sterilized soil, to which 3,000 striga seeds were added. Desmodium was also planted in pots, which were placed on a shelf above some of the maize plants. The desmodium was irrigated with distilled water, which then flowed into the maize pots placed below. The remaining maize plants were irrigated with distilled water passed through a pot of sterilized soil only. Comparisons could then be made between maize plants irrigated by desmodium root eluates, and those irrigated without.

The drip experiment confirmed that desmodium was controlling striga, and provided the foundation for several years of chemical research to isolate and characterize the compounds responsible and understand their roles.

The chemicals exuded from the desmodium roots have two different effects on striga:

- In common with many other plants in the legume family, the phytochemicals exuded from desmodium roots stimulate the germination of striga seed. In desmodium, the responsible exudates are isoflavanones.
- Other phytochemicals in the desmodium root exudate interfere with the subsequent development of striga, inhibiting the growth of the radicle and thereby preventing successful parasitism.

The combination of these two effects is called allelopathy. Allelopathic action results in what is known as 'suicidal germination' of striga.

Because desmodium is perennial, these chemical mechanisms not only undermine the growth of the weed in the short term, but also cause the gradual and continual removal of the striga seed bank in the soil.

Using a desmodium intercrop to control striga is one of very few examples of practical allelopathy at work as a weed management strategy.

Dr Zeyaur Khan (left) explaining the drip experiment on the allelochemical basis of striga control by desmodium to *icipe*'s Director General Dr Segenet Kelemu.

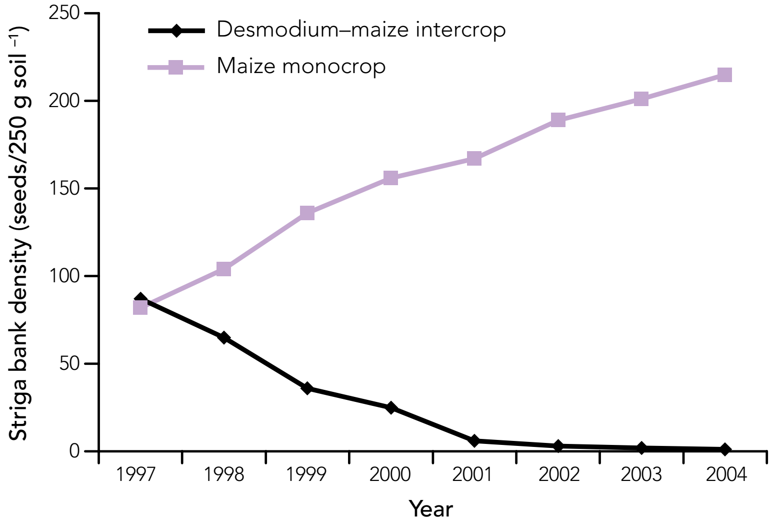
Prof. John Pickett (left) and Dr Tony Hooper with the high-performance liquid chromatography equipment at Rothamsted Research which they used to elucidate the structure of the compounds in desmodium root exudates which produce the allelopathic effect..

Effective in the longer term

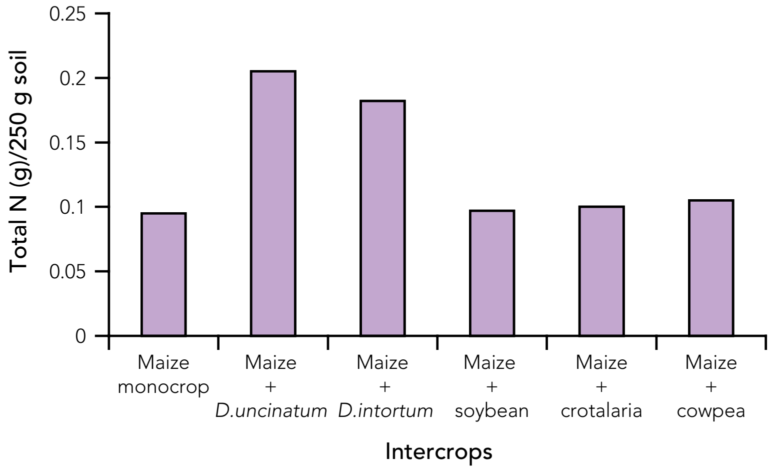
Having confirmed the allelopathic effect and suicidal germination, the research team established several field trials and monitored them over time to see if desmodium continues to control striga in the long-term. One of these involved periodically examining the number of striga seeds in the soil of two plots, one with a desmodium–maize intercrop and the other with a maize monocrop.

Other long-term trials tested the efficacy of desmodium intercropping for striga control against a range of other leguminous intercrops, as well as other common anti-striga treatments like fertilizer application and mulching with maize leaves and stalks. The results confirmed that in the long-term, desmodium is more effective at eliminating the weed than all these alternative approaches.

Data from these trials also confirmed that both silverleaf and greenleaf desmodium are more effective at fixing nitrogen than other common leguminous intercrops.



Over a period of eight years, a desmodium–maize intercrop was found to reduce the density of striga seed in the soil to virtually nothing.



The amount of nitrogen fixed by greenleaf and silverleaf desmodium means that they have a strong positive effect on soil fertility.

These field trials at Mbita Point have now continued for 22 growing seasons, and clearly show that neither intercropping with cowpea, groundnut or green gram nor applying heavy doses of nitrogen fertilizer provide an effective long-term solution to striga infestation. None of these approaches share the allelopathic effect that is the scientific basis of the efficacy of desmodium intercropping for striga control.

The benefits of desmodium intercropping for mixed smallholder farmers

Having confirmed that desmodium intercrops are an effective method of managing striga, the *icipe* team began collaborating with farmers' groups, NGOs and national research and extension programmes to promote desmodium intercropping.

Extension efforts began in 1998, running parallel to the ongoing research at Mbita Point. The team used a knowledge-intensive, farmer-centred approach, with a network of fieldworkers in western Kenya teaching small groups of male and female farmers about desmodium intercropping and the underlying biological and ecological relationships that make it work. Gradually, the practice crossed the borders into Tanzania and Uganda, and in 2013 farmers from Ethiopia visited Kenya to learn about desmodium intercropping and how to apply it on their own farms. By December 2013, more than 75,000 farmers – of whom 51 percent are women – were using either silverleaf or greenleaf desmodium to control striga across the region.

This widespread acceptance of the approach owes much to its congruence with the region's existing farming systems. Most farmers were already familiar with the agricultural practice of intercropping cereals and legumes, giving them confidence in using a new intercrop plant. Edible beans, traditionally intercropped with cereals to provide an additional source of protein to the harvest, can be incorporated into the system without compromising the efficacy of desmodium's control of striga. Furthermore, farmers' existing integration of crops and livestock also meant that they could immediately see the economic value of growing a protein-rich fodder. Their experiences reveal an interlinked set of positive outcomes that result from using desmodium intercropping to control striga.

Shafi Shehsheruf (second from right) was part of a group of Ethiopian farmers who visited Kenya in 2013 to find out more about desmodium intercropping. "There is a lot of striga in my place," says Shafi, "and through this trip I found that desmodium is the solution. I saw everything being done by Kenyan farmers and I want to implement this in my farm."

More grain, improved food security

Smallholder farmers in eastern Africa usually cultivate a range of food crops – cereals, roots, vegetables and fruit – for both domestic consumption and sale. But their definition of food security is usually framed around grain, the staple food. A farm family will say they are food secure if they can grow enough maize, sorghum, millet or tef to feed themselves from one cropping season to the next. The single greatest benefit of desmodium intercropping is that, by eliminating the threat of striga, it increases cereal production and thereby improves food security.

Valentine Odula is 63 years old and his household in Uganda's Tororo district is home to 21 people. Before 2011, the maize on his nine acres of land was "completely damaged by striga," and he "hardly harvested anything." Since taking up desmodium intercropping, Valentine, like many other adopters, has been able to harvest healthy crops of maize which have transformed the food security of his household.


"I used to buy cereals to feed my family, since I could not get enough from my farm. I am now happy because today I feed us all with maize from my desmodium intercrop plot without extra purchase," says Valentine.

Better fodder, healthier animals

Integrating the production of crops and livestock is a traditional practice in this region. Providing milk, meat, manure and draft power, livestock are also a form of savings and income. Adding a desmodium intercrop into the farming system means providing nutritious food for these animals, reducing the need to find grazing, improving animal health and increasing productivity. Dairy animals – cows and goats – are especially important, as there is always a high demand for milk in the market.

Desmodium is particularly useful for zero-grazing dairy animals, allowing farmers like Emmanuel Nyakomothe to cut and carry protein-rich fodder from their own land, where the plant is also serving to improve soil fertility and crop productivity. Now that Emmanuel includes desmodium in the daily food ration for his two improved breed zero-grazing dairy cows, their milk yield has improved by 50 percent. Studies have also confirmed that owning livestock does not influence preference for the desmodium-based technology, as farmers who do not have animals sell desmodium to their neighbours, either as fresh feed or hay.


"I urge farmers with dairy cattle to try desmodium for producing more milk," says Emmanuel Nyakomothe, pictured in his zero grazing unit in Tanzania's Tarime district.

“An excess of desmodium in the farm means more money in the family,” says Mary Onyango. This bale of desmodium hay will fetch KSh 250 (US$ 2.95) at market.

Ugandan farmer Simon Omalla intercrops desmodium with maize and sorghum. “Desmodium has really improved the soil fertility in my farm,” he says. “It also acts as a cover crop, controlling soil erosion and adding moisture. My maize and sorghum yields have both gone high!”

“Greenleaf desmodium is hardy in any harsh climate, but it controls striga and fixes nitrogen just like the silverleaf,” says Herin Odera, pictured feeding greenleaf to her zero-grazing improved dairy goats.

Income diversification

Selling agricultural surplus is an important means of acquiring the income that is needed for education, healthcare and clothing. By improving milk and maize production, desmodium increases the potential that there will be surplus to sell. But it is also valuable in its own right, with market demand being particularly high during the dry season when other fodder is scarce.

For Kenyan farmer Mary Onyango, the sale of goats’ milk has become central to her household economy. She began intercropping with desmodium in 2011 and now she is able to sell 2.5 litres of goats’ milk daily for around KSh 240 (US$ 2.80), money which she sets aside for school fees for her seven children. The increased crop productivity she has witnessed since including desmodium on her farm means that she can now also sell surplus maize and beans, as well as desmodium hay.

Fertile soil, sustainable production

Desmodium improves crop yields not only by controlling striga, but also by improving soil fertility. As well as fixing nitrogen, the long, trailing vines of this low-growing plant also conserve soil moisture, prevent erosion by wind and rain, and contribute organic matter to the soil. Furthermore, the livestock which eat desmodium are usually tethered or stall-fed, facilitating the easy collection of farmyard manure, which can be composted and returned to the soil to further boost fertility.

Simon Omalla started intercropping desmodium with the maize and sorghum on his farm in Uganda’s Tororo district in 2008, and witnessed an increase in soil fertility as the striga diminished. He keeps four local cows and nine local goats under a semi-zero grazing regime, composting their manure and using it to further boost soil fertility on his maize fields.

Climate change adaptation

Herin Odera was an early adopter of desmodium intercropping, planting her first silverleaf intercrop plot in 1999. Her farm is in the Lambwe Valley, a drought-prone area of Kenya in which long, dry spells are becoming more common. When the rains failed in 2010, her silverleaf desmodium was badly affected. In 2012, she obtained greenleaf desmodium seed and planted a second desmodium intercrop plot. A greater diversity of fodder crops on her farm has made her dairy goat enterprise far more resilient in the context of climatic changes.

Diversified cropping, greater resilience

Growing more than one staple crop on the same farm is a strategy that has long been used by farmers in this region as an insurance strategy against one or other crop failing. So an important strength of desmodium intercropping is that it controls striga in several cereal crops. Although at present the majority of adopters use the practice in maize cultivation, some also use it to keep their sorghum crops free of striga. Many of the region's farmers are now able to increase the diversity and resilience of their farming systems by planting desmodium intercrop plots of both crops.

Desmodium can also be used to control striga in crops of non-irrigated, upland rice, such as the New Rice for Africa (NERICA) varieties that were developed a decade ago by crossing Asian and African rice species. While NERICA varieties are high-yielding and drought tolerant, they are also susceptible to striga. Although NERICA is grown commercially in Tanzania and Uganda, it has not yet spread widely among smallholders in eastern Africa, partly because of this striga risk. Desmodium–NERICA intercropping therefore has considerable potential to improve the resilience of smallholder cereal farming by further increasing crop diversity in areas where rice is not commonly grown.

Mary Otuoma grows both sorghum and maize in Kenya's Bondo district. She is standing in front of her maize–silverleaf intercrop, and in the background is her sorghum–greenleaf intercrop. Thanks to the yield increases on these two small plots, Mary says, "I now have enough food."

Non-irrigated upland rice such as the NERICA pictured here is susceptible to striga infestation, but a desmodium intercrop controls the weed. This may help make NERICA more attractive to smallholder cereal farmers, and increase its uptake in eastern Africa.

Sowing the seeds of change – partnerships for desmodium intercropping

In contrast with other recommended striga control practices, desmodium has the advantage of being a perennial crop that, once established, can continue being productive for many years. Nevertheless, farmers who want to begin desmodium intercropping require either desmodium seeds or vines in their first season. As more and more farmers have become aware of the effects of desmodium on striga, demand for these inputs has risen.

When *icipe* first began extending desmodium intercropping to farmers, silverleaf seed was available commercially from the Kenya Seed Company (KSC). But the price of this seed, imported from Australia, was too high for many farmers to afford. To respond to this challenge, *icipe* began working in collaboration with the Kenya Agricultural Research Institute (KARI) to engage farmers in a seed multiplication project to test the farm conditions and management practices needed to establish desmodium bulking plots, and to harvest and process the resulting seed. Many farmers have gone on to grow seed in this way on a small scale, for their own use and for sharing with their neighbours. This has ensured a steady trickle of farmer-to-farmer spread.

Other farmers have extended the desmodium intercrops on their own farm or spread the technology to their neighbours by building on the discovery made by early adopters that new desmodium plants can be established by means of vegetative propagation. Under the right conditions, desmodium vines grow roots easily, meaning that the plant can be multiplied without the need for new seed if the farmer has an existing stock of plant material. Propagation techniques are now included in *icipe's* desmodium intercropping training, and this has also resulted in steady, local spread of the technology.

While local, farmer-to-farmer spread is a positive step, ensuring large-scale dissemination of desmodium intercropping demands partnerships with the private sector to increase the availability of seed on the open market. Since 2003, *icipe* has worked with local seed companies to establish farmer-based commercial production of desmodium seed. As a result, KSC now contracts farmers to grow seed for sale.

To produce seed commercially, KSC contract farmers must comply with a strict set of management practices. KSC supplies seeds and inputs to contract farmers, deducting the cost from the total amount it pays for the harvested and processed seed. In the long rainy season of 2013, KSC contracted a new cohort of farmers from 13 farmer field schools in Bungoma district to produce seed under their supervision, providing training on harvesting, fermenting,

Each season, John Mweta leaves some of his desmodium to set seed, which he collects to use on his farm and share with other members of his farmers' group in Tanzania's Tarime district.

Dr Zeyaur Khan (right) explaining desmodium vine propagation to Dr Bashir Jama, director of the Alliance for a Green Revolution in Africa's Soil Health programme, during a farm visit in Kenya's Vihiga district.

drying, shelling and winnowing seed. Peter Wafula, Chair of the Bungoma Umbrella Farmer Field School Network, whose family have been producing seed commercially since 2012, says that the contracting arrangement, "gives farmers the incentive to produce more seed, because of the assured market and better agronomic practices."

As well as building this relationship with KSC, *icipe* has also worked closely with KARI's seed unit. For the last ten years, the unit has produced modest quantities of both silverleaf and greenleaf desmodium seed, which has been sold to both private companies and farmers for the multiplication of certified seed.

Despite these efforts to strengthen seed supply through several different channels, more work is needed, not least to begin commercial production of drought-tolerant native African desmodium varieties and expand the existing supply of greenleaf. With this in mind, *icipe* has recently begun to build relationships with two experienced international private sector seed companies, Grupo Papalotla (Mexico) and Tropical Seeds LLC (USA), which will contribute expertise for the commercialization of seed production, certification and demand-driven marketing.

Pauline Wafula holds a ball of desmodium seed harvested from her farm. Once this has been dried, threshed and winnowed, she will sell it to KSC for KSh 1000 (US$ 12)/kilo. "Desmodium seed bulking has become a big saviour for our family," she says.

Desmodium ramosissimum, shown on the right controlling striga in a plot of sorghum, is drought-tolerant, but seeds are not yet commercially available. By building new relationships with seed companies, *icipe* hopes that in the future, farmers will be able to include it in their desmodium intercrops.

Strong partnerships for science and extension: a future agenda for effective striga control

Desmodium intercropping is one of a range of strategies available to farmers for the control of striga. Attaining widespread, effective striga control, according to *icipe* social scientist Jimmy Pittchar, is a matter of "developing a host of methods, to give farmers options best suited to them, in both cost and environmental terms." Partnership between the range of research and development organizations working in striga-afflicted areas of Africa is the best way of achieving this. The *icipe* team contributes to this partnership approach through its participation in the Integrated Striga Management in Africa project (ISMA), funded by the Bill and Melinda Gates Foundation (BMGF) and led by the International Institute of Tropical Agriculture in Nigeria.

Other partnerships are needed to consolidate the advances already made in extending desmodium intercropping. These include more work with private sector seed companies to improve current supply of desmodium seed, to develop its marketing and distribution networks, to extend it to varieties that are not yet commercially available, and to ensure that commercial seed production delivers another source of income diversification for contract smallholder farmers.

Partnerships with smallholder farmers are the foundation of all *icipe's* efforts to develop and extend desmodium intercropping, and these will continue to be a key element of ensuring the wider spread of the practice to different geographical areas and other crops like upland rice and millet.

More scientific research is also needed, to further illuminate the mechanisms by which the African desmodium species suppress striga, to explore the possibility of selecting edible food legumes with similar biological traits, and to facilitate extension to areas where farmers do not keep livestock. Genetic studies of germination stimulants and post-germination inhibitors could also contribute to future biotechnological approaches to striga control.

Acknowledgements

Thanks to the Gatsby Charitable Foundation (UK), the Kilimo Trust, the European Union, the Department for International Development (UK), the Biovision Foundation, the Rockefeller Foundation and BMGF (through the ISMA Project) who have all funded various aspects of the research and dissemination of desmodium intercropping.

Dr Yilma Kebede of BMGF (left) and ISMA coordinator Dr Mel Oluoch visit a maize–desmodium intercrop at the KARI field station in Alupe, Kenya.

The participation of these Ugandan farmers in evaluating desmodium–rice intercrop trials illustrates the central importance of partnerships with farmers to *icipe's* research and extension activities.

Ethiopia is the latest country to join the desmodium intercrop revolution. Dr Fasil Reda of Ethiopia's Agricultural Transformation Agency – pictured on the left discussing the practice with Kenyan farmers – says that desmodium intercropping is, "now included in the government's portfolio as one of its top priority technologies for striga control."

icipe
African Insect Science for Food and Health

icipe—International Centre of Insect Physiology and Ecology
P.O. Box 30772-00100
Nairobi, Kenya
Tel: +254 (20) 8632000
Fax: +254 (20) 8632001/8632002
E-mail: icipe@icipe.org

Writing, design and layout by Green Ink (www.greenink.co.uk)