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 Sub-Saharan 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 organisations (NGOs) and national extension programmes, more than 236,000 mixed smallholder farmers in Sub-Saharan Africa 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-tolerant African desmodium species and their mechanism of striga suppression.

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

Since Mary started intercropping with desmodium, her two 20 x 15 m plots have been free of the weed and she has been able to produce 315 kg of maize from them – equivalent to 5.25 tonnes per hectare. "We have enough food," she says, "for our good health."

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.

Building on a lucky discovery

Across Sub-Saharan 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, Professor Zeyaur Khan, the agricultural scientist who leads the team at *icipe*, was aiming to develop a way of controlling insect pests, stemborers, which are also responsible for severe damage to cereal crops across Africa.

In 1993, Khan's team and their partners at Rothamsted Research began working to develop 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.

"DESMODIUM IS A UNIQUE PLANT, AND IT HAS HELPED REPAIR MY FARM. THE **STRIGA IS UNDER CONTROL.**"

RHODA ABONG'O
MAIZE FARMER, RACHUONYO, KENYA

A visit to Mbita Point by the then 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 there was also no striga.

This lucky discovery triggered a sequence of experiments and trials that 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 disseminated 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 withstand 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 non-native greenleaf (*D. intortum*) to include in a second, climate-smart version of push–pull.

Striga: a parasitic menace

Present in more than a million hectares of cereal fields in eastern Africa alone, 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$ 2.4 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 conditions 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 fertiliser, 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.

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

Red-flowered *Striga asiatica* is the main striga species in southern Africa.

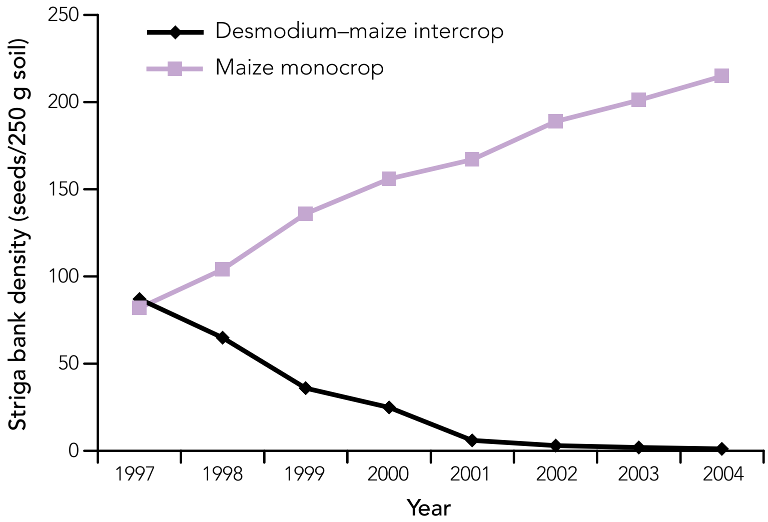
The carpet of purple flowers of ***Striga hermonthica*** in this Kenyan maize field shows how an infestation of the weed can dominate and devastate a cereal crop.

Effective in the longer term

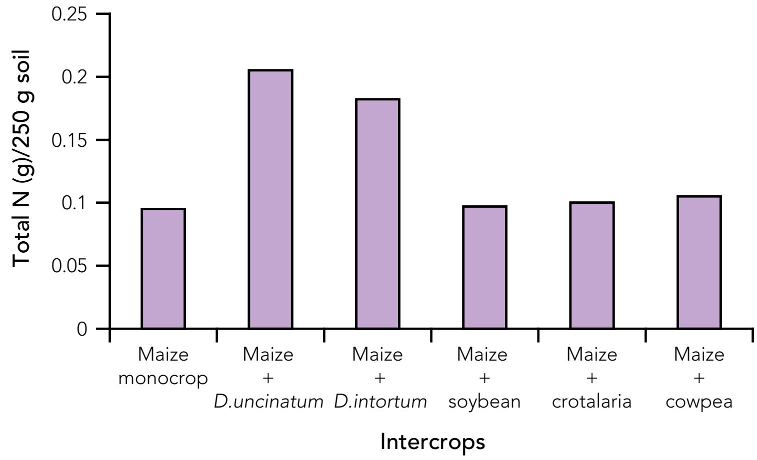
Having confirmed the allelopathic effect and suicidal germination (see box, page 4), the research team established several field trials and monitored them over time to see if desmodium continues to control striga in the long term. One of these involved periodically examining the number of striga seeds 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 such as fertiliser 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 seven 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 continued for 38 growing seasons, and clearly show that neither intercropping with cowpea, groundnut or green gram nor applying heavy doses of nitrogen fertiliser 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.

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

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 sterilised 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 sterilised soil only. Comparisons could then be made between maize plants irrigated by desmodium root exudates, 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 characterise 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.

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

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 November 2019, more than 236,000 farmers – of whom 52% are women – were using either silverleaf or greenleaf desmodium to control striga across Sub-Saharan Africa.

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."

"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 Odula.

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.

Better fodder, healthier animals

Integrating the production of crops and livestock is a traditional practice in this region. Providing milk, meat, manure and draught 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 Nyakomote 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 four improved breed zero-grazing dairy cows, their milk yield has improved by 50%. Studies have also confirmed that farmers who do not own livestock also adopt desmodium-based technology, and 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 Nyakomote, pictured in his zero-grazing unit in Tanzania's Tarime District.

John Otiep was given a baler box by the International Livestock Research Institute (ILRI) and now bales his desmodium at harvest. A bale of brachiaria sells for KSh 350 at the market, while brachiaria–desmodium hay will fetch KSh 400 (US$ 4).

Nelson Oyoko and his wife of Vihiga County, Kenya intercrop desmodium with maize and sorghum to control striga, stemborers and fall armyworm. "Desmodium has improved my soil fertility. It acts as a cover crop controlling soil erosion and conserving moisture. My maize and sorghum yields have really improved."

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.

Kenyan farmer Samuel Sana is a great believer in both farm and income diversification. He began intercropping with desmodium in about 2000, when striga was a major problem on his farm; now he no longer has striga. The maize from one of his plots goes to the school he helped establish. He sells honey from his 13 beehives, four fifths of his bean crop as seed, fruit from his 18 grafted mango trees, calves and milk, and he has a contract from United States Agency for International Development (USAID) to grow large numbers of tree seedlings.

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.

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

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 in 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 insurance 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 two decades ago by crossing African and Asian rice species. While NERICA varieties are high-yielding and drought tolerant, they are also susceptible to striga. Although several NERICA varieties have been released and adopted, the spread of NERICA among smallholders in eastern Africa has been slow, 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 maize and sorghum in Kenya's Siaya County. 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." She has been happy to share the 'good news' about push–pull and desmodium with at least 20 other farmers.

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 Sub-Saharan Africa.

Desmodium ramosissimum, shown on the right controlling striga in a plot of sorghum, is even more drought tolerant than greenleaf, and it flowers and sets seed in equatorial and tropical climates.

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* engaged 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 grown 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. Despite *icipe*'s work with local seed companies to establish farmer-based commercial production of desmodium seed, contract seed production faltered. Today, two commercial companies (Alexis Business Limited, Rwanda, and Mukushi Seed Company, Zimbabwe) and community-based organisations in eastern and southern Africa produce desmodium seed. In addition, the Ethiopia Institute of Agricultural Research (EIAR), Institut de l'Environnement et Recherches Agricoles (Burkina Faso) and Institut des Sciences Agronomiques du Burundi (ISABU) also produce seed.

A problem for farmers, however, is that commercial seed is expensive. It would be better for them – and ultimately the spread of desmodium – if they could produce their own seed. While silverleaf desmodium will seed in eastern African farmers' fields, greenleaf does not flower in equatorial or tropical climates. Thus, the search was on for species of desmodium that would fulfil the role of greenleaf (in push–pull and combatting striga) while flowering and seeding in farmers' fields.

icipe has identified two species of desmodium that are native to Africa, or at least recorded on the continent for a long time: *D. incanum* and *D. ramosissimum*. These two species have the added advantage of being even more drought tolerant than greenleaf – potentially future-proofing push–pull and striga control.

"With the introduction of third-generation push–pull, including these 'new' desmodium species, we are trying to create a highly flexible system," says Professor Khan. "Farmers will have four desmodiums to choose from depending on their circumstances. Where recurrent drought is not yet a perennial problem, silverleaf is ideal – it does the job and seeds readily." Where farmers do have access to seed or other planting material (e.g. vines) and where drought spells are not yet too long, greenleaf is still a good choice. The two 'original' species have a yield advantage over the new ones, which may be a consideration for farmers who want to produce a lot of high-quality fodder for their animals or for sale.

Where drought is becoming particularly bad or planting material simply isn't available, the 'new' species will be the desmodiums of choice.

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

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.

On-farm desmodium seed production in Masvingo District, Zimbabwe.

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." Partnerships among research and development organisations in striga-afflicted areas is the best way of achieving this. *icipe* participated in the Integrated Striga Management in Africa project (ISMA), funded by Bill & Melinda Gates Foundation and led by the International Institute of Tropical Agriculture in Nigeria. *icipe* and the national agricultural research systems of Ethiopia, Kenya and Tanzania work together on the EU-funded Integrated Biological Control and Applied Research Program (IBCARP), which is testing 'new' species of demodium for striga suppression and adaptability in various agro-ecosystems.

Meanwhile, Food for the Hungry International has integrated the push–pull system in its agro-ecology programme, to promote desmodium production for striga control across five countries, and Send A Cow International has integrated it in its sustainable organic agriculture programmes to promote desmodium production for striga control and fodder.

Other partnerships are needed, including more work with private sector seed companies to improve the supply of desmodium seed, to develop its marketing and distribution networks, and to extend it to varieties and species that are not yet commercially available.

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 such as 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.

A delegation from the European Union and project Steering Committee visited push–pull farmers in Rwanda in September 2018 to assess the implementation of climate-smart push-pull.

Dr Fasil Reda, former head 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 Ethiopian Government's portfolio as one of its top-priority technologies for striga control."

Acknowledgements

Thanks to Bill & Melinda Gates Foundation (through the ISMA Project), the Biovision Foundation (Switzerland), the Department for International Development (UK), the European Union, the Kilimo Trust, the Gatsby Charitable Foundation (UK), Norwegian Agency for Development Cooperation (Norad), McKnight Foundation and the Rockefeller Foundation, which have all funded various aspects of the research and dissemination of desmodium intercropping. *icipe* also thanks its core donors (SDC, Sida, the Kenyan Government, the Ethiopian Government) and all other donors and partners who have helped in development and dissemination of push–pull technology (http://www.icipe.org/donors-and-partners).

UKaid from the British people · European Union · biovision · Norad · icipe@50 1970–2020 Insects for Life

ISBN (print) 978-9966-063-40-3 ISBN (PDF) 978-9966-063-41-0

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

***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