Decades of Dedication:

towards enhancing food security and environmental sustainability in Africa

Over the past 20 years, thousands of small-scale farmers in eastern Africa have seen a dramatic turnaround in their lives. Where once they battled with poverty and hunger, they are now able to feed their families and invest in the future of their farms. They no longer live on the edge of society, but have become community leaders, and their children are healthy and assured of a good education. Their success is based on adopting a revolutionary approach to farming known as 'push–pull', which was pioneered by Dr Zeyaur R. Khan.

Dr Khan, a distinguished international professional entomologist, has dedicated more than 30 years of his career to advancing the science and practice of entomology by studying and applying chemical ecology, insect behaviour, and plant–plant and insect–plant interactions. His aim has always been to improve agricultural productivity as a means to combat poverty and food insecurity in Africa and beyond. His work in developing push–pull technology is a wonderful example demonstrating that creativity and innovation in agricultural sciences can provide practical solutions for the real problems of poor smallholders by removing constraints to their farming, leading to better food security and sustainable livelihoods.

Global opinion is now united in the belief that efforts to improve Africa's agricultural productivity must be based on approaches that are more environmentally sustainable and people-centred than the technologies that fuelled the Asian Green Revolution. Push–pull fits the bill perfectly: it is a holistic approach to pest and soil management; it teaches farmers how to become food-secure and build a livelihood on just a small piece of land, without demanding seasonal inputs that are beyond their resources; in protecting and enhancing soil fertility it lays the foundation for sustainable productivity gains; and it prepares farmers for the future by giving them the knowledge and tools they need to adapt their farming systems to the challenges of climate change.

"PUSH-PULL IS A PERFECT EXAMPLE OF A LOW COST, LOW INPUT PRODUCTION SYSTEM PROVIDING A PATHWAY TO AN EVERGREEN REVOLUTION WITHOUT CAUSING ENVIRONMENTAL AND SOCIAL HARM. THE TECHNOLOGY ENSURES BOTH SOIL HEALTH AND CROP SECURITY, AND CAN BE ADAPTED TO DIFFERENT GROWING CONDITIONS SO IT CAN ALSO BENEFIT FARMERS BEYOND AFRICA."

PROF. M. S. SWAMINATHAN
FOUNDER OF INDIA'S GREEN REVOLUTION

> "PUSH–PULL IS A BEAUTIFUL, BASIC SCIENCE THAT IS ALSO FULLY APPLIED AND IS BEING SUCCESSFULLY EXTENDED AND IMPLEMENTED BY SUBSISTENCE FARMERS… EVERY ELEMENT OF THE PUSH–PULL SYSTEM HAS BEEN CRAFTED TO MAXIMIZE THE OVERALL BENEFIT TO SMALLHOLDERS."
>
> **DR JAMES R. MILLER**
> DISTINGUISHED PROFESSOR OF ENTOMOLOGY
> MICHIGAN STATE UNIVERSITY, USA

Application of knowledge

Dr Khan first became interested in insects when doing his undergraduate studies in zoology. "Entomology was my favourite subject," he says. "I learned it from my father, who was basically a zoologist but worked on the endocrine system of insects, raising silk moths and cockroaches in our house in Bihar, India."

After completing his BSc in zoology, Dr Khan went on to do his Masters and PhD in agricultural entomology at the Indian Agricultural Research Institute in New Delhi. "I wanted to explore the application of insect science to agriculture, so even then I was looking at how insects interact with plants," he explains. This work laid the foundations for his subsequent research posts at the International Rice Research Institute, University of Wisconsin, Kansas State University and the International Centre of Insect Ecology and Physiology (*icipe*).

Dr Khan with Lord Sainsbury of Turville, founder of the Gatsby Charitable Foundation

> "I HAVE STRUGGLED, BUT PUSH–PULL HAS IMPROVED MY LIFE. I SELL MAIZE, I SELL MILK, I PAY SCHOOL FEES – AND EVEN AFTER THAT I HAVE ENOUGH FOR THE FAMILY TO EAT."
>
> **ANNETTE TAAKA**
> FARMER, BUSIA, UGANDA

In 1993, Dr Khan moved to Mbita Point in rural western Kenya, where he has lived for 27 years, to lead *icipe*'s work on stemborers, a major pest of maize. The then *icipe* Director, Professor Thomas Odhiambo, challenged him to find out where the stemborers go when the maize is harvested and how they come back when a new crop is planted. This simple question set Dr Khan on a path that eventually led to many thousands of farmers incorporating a sustainable habitat management strategy – push–pull – for pest control into their agricultural systems.

Having successfully secured funding from the Gatsby Charitable Foundation, and established a partnership with scientists at Rothamsted Research (UK) which remained strong two and a half decades later, Dr Khan began to examine the relationships between wild and cultivated grasses and stemborers. "This was the time," he says,

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What is 'push–pull'?

Disabled farmer Jairus Ounza has built a successful enterprise selling meat from rabbits and chickens fed on desmodium from his push–pull plot

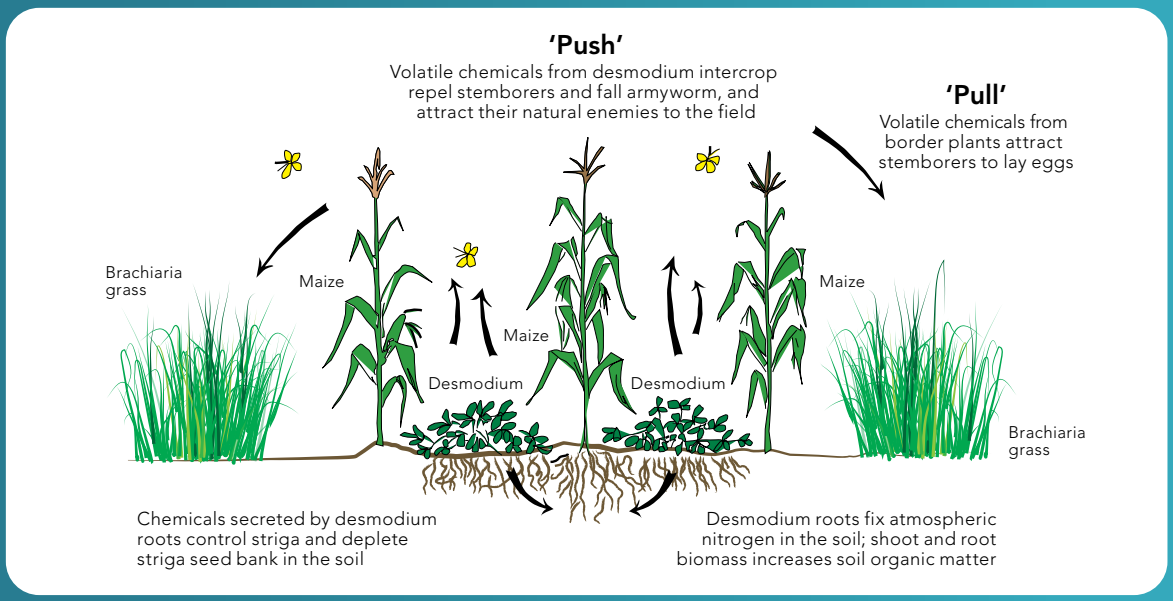
Stemborer (above left) and striga (above right) are major constraints to cereal production in sub-Saharan Africa

Push–pull is a novel cropping system that integrates pest, weed and soil management with sustainable yield increases in cereal-based farming systems. It controls cereal stemborer pests by attracting them to trap plants like Napier grass, which prevent the pests completing their life cycle (the 'pull'). At the same time, a repellent intercrop (the forage legume silverleaf, Desmodium uncinatum) drives the pests away from the crop (the 'push'). Chemicals released by the intercrop roots also control the parasitic weed Striga hermonthica by inducing abortive germination, providing very effective control of this noxious weed. The companion plants provide high-value animal fodder, which farmers can sell or feed to stall-fed dairy animals. The intercrop plants also help to improve soil health by enhancing fertility and preventing degradation.

The technology improves gender equity, diversifies farmers' income sources, and is appropriate and economic as it is based on locally available plants, not expensive external seasonal inputs. As such, it fits well with traditional mixed cropping systems in Africa. To date it has been adopted by about 236,000 smallholder farmers in sub-Saharan Africa whose cereal yields have tripled on average.

Recently, with funding from the European Union, Dr Khan and his team have adapted the conventional push–pull system to drier and hotter conditions linked to climate change by identifying and incorporating a drought-tolerant trap plant and a repellent intercrop. This 'climate-smart' push–pull responds directly to the rising uncertainties in Africa's rain-fed agriculture (due to the continent's vulnerability to climate change), and addresses the major constraints faced by smallholder cereal–livestock farmers in such harsh environments.

See www.push-pull.net for more information. ■



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Dr Khan and Mary Atemo, a disabled farmer from Vihiga, Kenya

"when I found out that some of the 500 grass species we surveyed – including Napier – were highly attractive for stemborer egg-laying, but the larvae did not develop to adult stage. That was a very big achievement, because finding a grass that is highly attractive to the insect but doesn't support its development is what makes a good trap plant to help farmers reduce their pest population."

The idea of using trap plants in pest management – the 'pull' element of push–pull – was not new. But the challenge that faced Dr Khan was how to translate his discovery into a practice that farmers would be prepared to use. "At this point," he reflects, "I did not have much experience of engaging directly with farmers. But I thought, if I am going forward with something, I must have feedback." So Dr Khan's first discussions with farmers about which of the stemborer trap grasses would be most useful to them laid the foundations for nearly two and a half decades of farmer involvement in the development and adaptation of push–pull.

The discovery and selection of Napier grass (Pennisetum purpureum) as a suitable stemborer trap plant was followed by more scientific research to identify a suitable repellent plant. This resulted in the first version of a push–pull system, where one row of stemborer-repellent Molasses grass (*Melinis minutiflora*) was planted for every ten rows of maize, with the plot surrounded by a border of Napier grass.

This pioneering push–pull system was quite popular in Kenya's Trans-Nzoia district, where it dealt effectively with the stemborer problem. "But," Dr Khan recalls, "when we introduced the technology to Western and Nyanza provinces, farmers planted maize, and although we were able to control the stemborers, the parasitic striga weed had already killed the plants."

> "THE PUSH–PULL TECHNOLOGY IS TRULY CHANGING THE LIVES OF WOMEN FARMERS, PARTICULARLY THE VULNERABLE."
>
> **AGATHA ANSELMO MURUGAHU**
> FARMER, TARIME DISTRICT, TANZANIA

Building on his knowledge that some legumes produced 'push' chemicals, in the back of his mind he was also aware that legume–cereal rotations had been able to reduce striga in some locations. By chance, in a Nairobi seed shop, Dr Khan saw desmodium on the shelf. "I didn't know it," he recalls, "and I asked the shopkeeper what it was. He said it was a fodder legume used by dairy farmers in zero-grazing systems. So I bought a kilo of seed, out of curiosity, and planted it between the maize rows. We found that, not only was the stemborer population reduced where the desmodium was planted, but also there was no striga weed. I said maybe it is a coincidence, so we planted again and we came up with the same results."

Realising at once the importance of this discovery, Dr Khan reported it to the Gatsby Foundation, who immediately provided funds to further develop the technology and extend it to farmers as an effective way of controlling striga and stemborer. In 1998, the push–pull experimental field at Mbita Point was planted, the first of many demonstration plots, and work began in earnest to share push–pull with farmers and extension officers and learn more about how it actually worked. ■

> "THE PUSH–PULL TECHNOLOGY HAS INDEED CHANGED OUR LIVES AS FAR AS FOOD SECURITY IS CONCERNED."
>
> **PETER WABOYA**
> CHAIRMAN, BUNGOMA UMBRELLA FARMER FIELD SCHOOL NETWORK, KENYA

A sustainable and profitable option



Push–pull works equally well with sorghum as with maize (left), yielding fodder that can support livestock enterprises with goats (middle) or cows (right). Dairy animals fed on push–pull fodder increase their milk yields, which improves the diets of farm families and benefits their health.

Push–pull has proven highly popular with farmers in Ethiopia, Kenya, Tanzania and Uganda. Of 236,000 adopters, almost 138,000 have planted the 'climate-smart' push–pull. By making creative use of locally available plant species, the technology helps farmers to increase food production and raise farm incomes without the need to buy pesticides and chemical fertilizers. Farmers have doubled and, in striga-infested areas, more than tripled their maize yields, often with three-fold increases in milk production. The technology has allowed the most land-constrained farmers to achieve food security with as little as 0.25 ha plots. Early push–pull adopters have not only maintained these improved yields for over 21 years on their original plots, but also expanded their plots and farm activities extensively, demonstrating the sustainability and profitability of the technology.

Dr Khan's visionary approach has gone beyond the usual remit of a research scientist, fostering widespread adoption of a transformational technology in addition to developing a novel and sustainable agricultural system. With his high intellect and strong desire to address Africa's hunger and poverty, he has built an extensive network of partners to ensure the sustained dissemination and uptake of the technology among poor communities while mainstreaming this process in the partners' institutional mandates. This has created ownership of the technology among partners and communities and ensured a platform where farmers can provide feedback and seek assistance. It has also created an avenue for the diversification of livelihood approaches brought on board not only by the push–pull products but also by the partners' solutions. Dr Khan has thus demonstrated that science plays a crucial role in alleviating Africa's chronic hunger and poverty and that this is achievable through the sustainable exploitation of the continent's rich floral and faunal biodiversity, rather than through such unaffordable seasonal inputs as inorganic fertilizer and pesticides.

The technology has also created a pool of knowledgeable stakeholders in soil and pest management in the region. In total, 21 PhD, 21 MSc graduates and 15 World Food Prize interns have been trained. Additionally, at least 25,000 extension staff, 100,000 farmers and 50,000 opinion leaders have received formal push–pull tuition. In developing farmers' knowledge and skills, the technology fosters their confidence and ability to investigate and assess other technologies, raising farmers' status in the community at the same time as making them more adaptable and resilient.

An independent impact assessment report, conducted in Kenya and Uganda in 2009 by Inter-cooperation of

> "THOUSANDS OF PEOPLE IN OUR VILLAGE ARE FOOD-SECURE NOW BECAUSE OF THIS TECHNOLOGY, WHICH IS CHANGING OUR LIVES IN MANY WAYS. WE THINK MOST SMALL-SCALE FARMERS IN AFRICA CAN BENEFIT FROM THIS TECHNOLOGY. GOD WILLING, THIS MAY BE A GREEN REVOLUTION IN AFRICA."
>
> **NACTICAL KUTAYI**
> FACILITATOR, EPWOPI FARMER FIELD SCHOOL, EBUKANGA, KENYA

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Switzerland, confirms that push–pull is a significant factor in improving food security and livelihoods. This states that the impact is "impressive at both household and national levels". In total, 75% of 144 interviewed farmers achieved 300–400% increases in maize yields. Not only can these farmers feed their families throughout the year, but they also have surplus maize to sell. The study describes push–pull as "probably the single most effective and efficient low-cost technology for removing major constraints faced by the majority of smallholder farmers in the region, resulting in an overall and significant improvement in their food security and livelihoods".

Push–pull is a perfect example of a low-cost, low-input production system, as envisaged by the World Food Prize Laureate and eminent agricultural scientist Dr M.S. Swaminathan regarding an evergreen revolution, or "productivity in perpetuity", to end global hunger and poverty while protecting environmental integrity. Dr Swaminathan agrees that the push–pull method will ensure both soil health and crop security. He says: "Such a method can be adapted to different growing conditions by the appropriate choice of crops." ■

"THIS RESEARCH HAS SIGNIFICANT IMPLICATIONS FOR OTHER PARTS OF THE WORLD, IN ADDITION TO AFRICA. PUSH–PULL FEATURES AS ONE OF THE CASES USED BY THE UK GOVERNMENT'S FORESIGHT FOOD AND FARMING FUTURES PROJECT, WHICH SEEKS TO IDENTIFY INNOVATIVE EXAMPLES OF SUSTAINABLE AFRICAN FARMING SYSTEMS AND TO USE THESE AS EXAMPLES TO CATALYSE SUBSTANTIAL DEVELOPMENT ACROSS THE AFRICAN CONTINENT AND BEYOND"

PROFESSOR JULES PRETTY
VICE-CHANCELLOR, UNIVERSITY OF ESSEX, UK

"I HAVE HAD TREMENDOUS SUPPORT FROM DR KHAN AND HIS STAFF AND THEY ARE VERY GOOD AT EXPLAINING THE TECHNOLOGY TO FARMERS AND DEALING WITH OUR PROBLEMS. I'D LOVE TO MAKE KOGELO A STRIGA-FREE VILLAGE; THEN WE COULD BRING MANY MORE PEOPLE HERE TO SEE JUST HOW EFFECTIVE PUSH–PULL IS AS A MEANS TO ERADICATE HUNGER AND POVERTY."

MAMA SARAH OBAMA
KENYAN FARMER AND GRANDMOTHER TO THE FORMER PRESIDENT OF THE USA

Explaining the science of plant–plant and insect–plant interaction to World Food Prize intern Anthony J. Wenndt

Climate-smart push–pull and the future

Still listening after 20 years: Dr Khan discusses push–pull with members of the Yenga Farmers Group

Push–pull continues to spread rapidly and achieve a positive, long-term impact on farmers' lives. Although initially Dr Khan had set a target of reaching one million households by end of 2020, due to several challenges this goal will be achieved by 2025. At present the technology has reached over 236,000 households in 16 countries. This will lift at least 10 million people out of hunger and poverty.

Part of the strategy towards this goal involves addressing the limitation that the silverleaf desmodium and Napier grass cannot tolerate long dry spells, and so allow expansion of push–pull into new areas with lower average rainfall. Supported by funding from the European Union, and working in partnership with the national agricultural research institutes of Ethiopia, Kenya and Tanzania, Dr Khan's research team began to search for drought-tolerant intercrop and border crop components for the system. They collected and screened a new set of potential species, which were tested at research stations as well as by farmers. This led to the development of 'climate-smart' push–pull, based on drought-tolerant greenleaf desmodium (Desmodium intortum) and Brachiaria grass (*Brachiaria* 'Mulato II'). Dissemination began in 2012 and farmers soon reported satisfaction with the quick-growing greenleaf, which, because it is fast to mature, deals effectively with striga in the first season. Brachiaria grass, which is easy to harvest and palatable for animals, has also proved a popular choice for women who prefer brachiaria over Napier grass.

Developing adaptable agricultural systems that are resilient to the risks and shocks of long-term climate variability is essential to maintaining food production into the future. Climate-smart agriculture also needs to protect and enhance natural resources and ecosystem services in ways that mitigate future climate change.

Push–pull contributes towards this outcome in several ways. It makes efficient use of land, labour, water and other agricultural inputs. As part of an integrated crop–livestock system, it fosters local nutrient cycling, whereby livestock benefit directly from quality fodder from push–pull and in return provide farmyard manure to fertilize the soil. Because it contains a legume, it adds nitrogen to the soil; because it reduces digging and adds organic matter to the soil, it enhances the capacity of the soil to hold water and sequester carbon. Finally, it improves the health of both crops and livestock, making them better able to withstand climate shocks and stresses.

Push–pull is now being extended in Benin, Burkina Faso, Burundi, Congo (Republic of), Ethiopia, Ghana, Malawi, Mozambique, Rwanda, Senegal, Togo, Zambia and Zimbabwe. So the profile of the technology is rising far beyond push–pull's home territory of eastern Africa.

"I'd like to see it spread throughout Sub-Saharan Africa," says Dr Khan. "It is also adaptable to rice, millet and other crops, including vegetables, cotton and coffee, so it is going in many directions. One of my dreams is to have a smarter system in which the plants can defend themselves by identifying pest attack and informing neighbouring plants and natural enemies. The beauty of this science is that the companion and main-crop plants all have the potential to communicate with each other and with pests' natural enemies. So a better and smarter push–pull would be drought-resilient and labour-reducing, while producing enough food for the family even under the most adverse climatic conditions, and it could defend itself against pests. That would be perfection!"

Steven Wisecarver, former Country Director of US Peace Corps in Kenya and former USAID-Kenya Country Director, regards Dr. Khan as coming from the same mould as Norman Borlaug, the Nobel Peace Prize winner and World Food Prize founder. "Like Dr. Borlaug, he has devoted his life to the science of increasing food production for the benefit of the poorest of the world's poor. Push–pull technology will finally realize the dream of bringing the Green Revolution to the African farmer". ■

Dr. Khan explains the process of developing climate-smart push–pull to H.E. Lodewijk Briët, former EU Ambassador to Kenya, and Prof. Christian Borgemeister, former Director General of *icipe*, July 2013

Receiving the TWAS prize from the President of the People's Republic of China, Hu Jintao, in Tianjin, September 2012

Dr Zeyaur R. Khan has been working as the Principal Scientist and Programme Leader of the Habitat Management Programme at *icipe*. He is also *icipe*'s first Thomas Odhiambo Distinguished Research Fellow. He is a Fellow of the African Academy of Sciences (AAS), the Entomological Society of America (ESA) and the World Academy of Sciences (TWAS). He is Honorary Fellow of the Royal Entomological Society, London, UK. He is an adjunct Professor of Entomology at Cornell University, USA and was Extraordinary Professor at the North-West University in South Africa. In 2010, Dr. Khan was appointed as a council member of the International Congress of Entomology. In 2011, Dr Khan received The TWAS Prize in Agricultural Sciences. In 2010 he received the Nan-Yao Su Award for Innovation and Creativity in Entomology and the ESA Distinguished Scientist Award. In 2015 he received prestigious Louis Malassis International Scientific Prize for his outstanding career in agriculture. His work has been covered in Nature, Ecology Letters, Biology Letters, New Scientist, National Geographic and many other distinguished, high-impact journals and books. Over the past 25 years Dr Khan has raised research grants amounting to more than US$ 35 million for research and development of the push–pull technology.

"THROUGH DR KHAN'S ORIGINAL AND PRACTICAL THINKING AND THE INGENUITY OF PULLING TOGETHER MANY PIECES OF A LARGE BIOLOGICAL AND ECOLOGICAL PUZZLE, HE HAS DEVELOPED THE PUSH–PULL TECHNOLOGY, WHICH HAS SIGNIFICANTLY IMPACTED ON THE AVAILABILITY AND QUANTITY OF FOOD. ITS MANY ON- AND OFF-FARM BENEFITS ARE ALREADY MAKING A SIGNIFICANT CONTRIBUTION AND IT ULTIMATELY WILL BECOME THE CORNERSTONE OF SUSTAINABLE AGRICULTURE IN AFRICA."

DR HANS R. HERREN
PRESIDENT, MILLENNIUM INSTITUTE AND
LAUREATE WORLD FOOD PRIZE 1995

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