Push–pull to control fall armyworm

Native of the Americas, fall armyworm (FAW; *Spodoptera frugiperda*) is the caterpillar (larva) of a moth. It is an invasive pest that was accidently introduced to parts of Africa and has spread rapidly across the continent. The good news is that push–pull maize fields are largely protected from this pest by their repellent ('push') properties.

First recorded in Africa in western Cameroon in late 2015, accidental introductions are believed to be behind the first outbreaks – in central and western Africa (Benin, Nigeria and Togo, and São Tomé and Príncipe) in early 2016. The species then spread rapidly in late 2016 and through 2017 to almost every Sub-Saharan country with suitable climate and habitat (today, it is only absent from Djibouti, Equatorial Guinea and Lesotho).

FAW has a widely varied diet, having been recorded feeding on at least 100 plant species from 42 families; however, in tropical Africa it is primarily a pest of maize. Its invasion of Africa is attributed to its strong migratory tendencies: in North America, it spreads north from areas where it is a year-round resident in subtropical southern states as far as southern Canada during the warm summer months – an annual migration of over 2,000 kilometres.

The female moth lays eggs on maize leaves in masses of 50–300, typically producing 1,500 eggs in her lifetime and potentially in excess of 2,000. Caterpillars generally emerge three to five days after egg-laying and the name 'armyworm' comes from the fact that the first-instar caterpillars (hatchlings) move *en masse* eating leaves. However, the second- and third-instar caterpillars are often cannibalistic, resulting in only one or two larvae reaching the whorl or heart by the time they are fourth-instar caterpillars.

FAW is not a stemborer, but rather eats the leaves, heart, tassels and cobs of the maize, giving the plants a rather tattered appearance. No stage of FAW can hibernate, which is why the species is restricted in terms of residency to the tropics and subtropics. This also explains its appearance on seedling maize – in contrast with typical African maize stemborers, which have seasonal life cycles and do not attack seedlings.

Maize field devastated by fall armyworm, Mbita sub-county, Homa Bay County, Kenya.

An unwelcome arrival

Although not totally unexpected by scientists (quarantine interceptions of FAW had been increasing in Europe on imports of vegetables and live plants from the Americas), the arrival of FAW in Africa is disastrous news for farmers. FAW devastates the crops it attacks, and in Africa it shows a strong preference for maize.

Farmer Lawrence Odek of Sigulu village, Homa Bay County, western Kenya, says: "Fall armyworm is very dangerous … its arrival and spread was very abrupt and seemingly continuous. … Fall armyworm eats the heart of maize and the cobs. [My neighbours] lost whole crops." This was especially the case in the long

Fall armyworm caterpillar on maize cob.

rainy season of 2019. Not many miles away, 64-year-old farmer Mary Rabilo notes that many fields in the vicinity of her farm have suffered 100% maize crop loss every season from the second season of 2017 through to the first season of 2019.

On seeing the levels of devastation, many farmers began to panic and they tried everything they could think of to control the pest. One popular choice was Omo (washing powder), either alone as powder or paste, or mixed with chilli pepper. Hidaya Mahmoud of Isbania village, Migori County, western Kenya, even tried kerosene – "it was an emergency; I would try anything," she said. Other control measures included wood ash, manual removal and destruction of the larvae, and insecticides. None of these are very effective, in part because the young larvae are very small, becoming buried deep within the maize whorl and therefore protected from the application of external agents, and in part because of the sheer numbers of individuals infesting each field. A number of insecticides in particular are known to be ineffective against this pest, and the situation is no different in Africa.

Fall armyworm moth: the scales rub off quickly, leaving a nondescript brown moth (Robert Webster / xpda.com / CC-BY-SA-4.0).

Fall armyworm in the 'whorl' or heart of the maize showing destruction caused.

Some good news for Kenyan push–pull farmers – in their own words

Push–pull farmers are faring much better than their neighbours in the face of the FAW onslaught. "My neighbour's land without push–pull was much infested," says Nactical Kutayi of Vihiga District, "but there were none in my push–pull."

"Sometimes they [FAW] come," says Timothy Okoba Chilamba, also of Vihiga District, "but not very strong."

"They attacked the whole farm, but not such serious impact on push–pull," says Lawrence Odek.

"Fall armyworm is not a big challenge in push–pull," says Judith Owomo of Siaya County.

"We had fall armyworm invasion in 2017," says George Manialo of Sikata A village, Bungoma County, "but push–pull protects 80% and we have food security."

"In the invasion there was a big difference: non-push–pull fields were infested, but in the push–pull I found fall armyworms dead on the desmodium," says Allan Metho of Kisumu West. "I used my smartphone to photograph the armyworm and post it on Facebook. Dickens [Nyagol, technician] of *icipe* was the first to respond and tell me what it was."

"The infestation of push–pull was minimal and the maize survived and recovered," says Mary Rabilo.

"I had signs of fall armyworm, but no reduction in maize yield," says Mary Achieng Opany, Siaya County. "Some maize in non-push–pull plots close to the push–pull was also not infested." Conversely, her

Sophia Muita Chacha examines FAW damage in her non-push–pull maize plot in Kibranga village, Migori County, western Kenya.

neighbour Peter Ochieng Wambi reported that "an adjacent plot was infested."

"The first season that fall armyworm arrived, it infested my young maize in push–pull, but the maize still out-yielded my neighbours'," says Jane Anyango of Busia County. "That was the only time I had armyworm problem in push–pull."

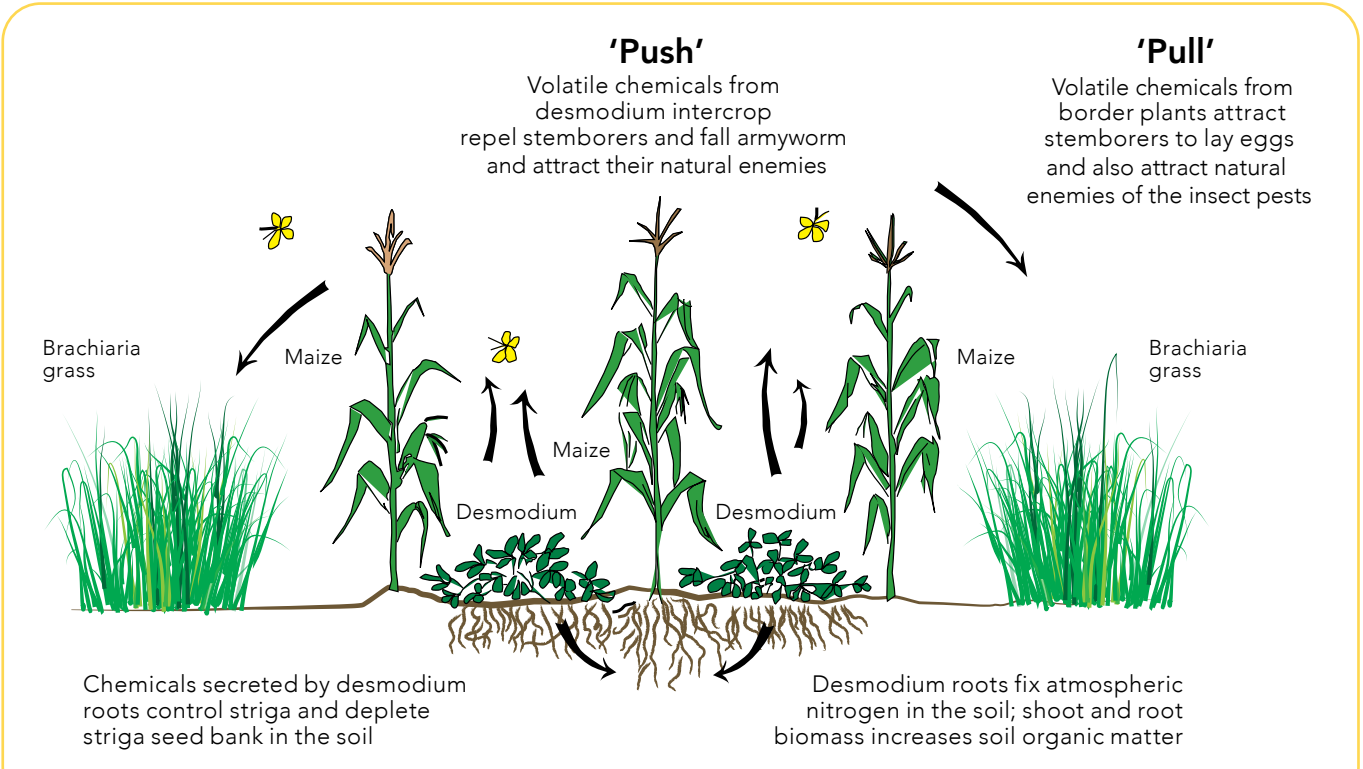
Husband-and-wife team Mendo Murimi Simeon and Jackline Boke of Komosoko village, Migori County, said that their "fields were still eaten" by FAW when the "Napier and desmodium were just established. In the second season," when the grass and legume were more established, "push–pull did better than other fields."

What's going on? What farmers think and what science has told us so far

Farmers have various explanations as to why push–pull is protecting their crops from FAW. These are all related to the basic concept of push–pull. Some mechanisms have been proven scientifically, while others are still being researched. For example, Charles Odhiambo Sawayi says that push–pull repels FAW and Mary Achieng Opany says that FAW "fears" desmodium; meanwhile Allan Metho and Margaret Anyango correctly suggest that desmodium odour repels FAW. Allan and Margaret also state that desmodium is toxic to FAW caterpillars.

In Homa Bay County, Kenya, Eunice Atieno Ong'ou found that Napier grass protected maize by hosting and killing the caterpillars (a 'suicidal' attraction to egg-laying moths, as the Napier proved an inappropriate host); however, this is neither a common nor widespread experience. Dan Olianga Abu Kachi of Kakamega County, Kenya, credits the Mulato II cultivar of brachiaria with protecting his cereals.

Dr Charles Midega, *icipe* senior scientist is investigating the detailed mechanisms by which the various push–pull components control FAW. "We are satisfied that desmodium is acting as much as a repellent to fall armyworm as it does to stemborers," says Professor Zeyaur Khan, principal scientist and lead researcher in push–pull at *icipe* for the past quarter of a century. "However, we have yet to find a grass species or cultivar that is as attractant to fall armyworm as Napier grass and brachiaria are to stemborers." Surveys have shown that push–pull effects 80–90% control of FAW in farmers' fields in Kenya, and 65–75% control in Uganda, according to Girma Hailu, Uganda country coordinator for *icipe*. Hailu has also observed – both on research station and on farms – that the arrival of FAW in non-push–pull fields has pushed stemborers (presumably by competition) onto sorghum as a secondary host.



How push–pull protects crops from fall armyworm.

Farmer David Ouro of Rachuonyo sub-county, Homa Bay County, Kenya, examines fall armyworm damage on his maize plants.

Raising awareness and monitoring the situation

With the invasion of Africa by FAW (and its even more recent arrival in China, India, Sri Lanka and parts of Southeast Asia), several major international agriculture organisations are actively gathering information, and supporting awareness and monitoring campaigns. These include CAB International, the Food and Agriculture Organization of the United Nations (FAO) and the United States Agency for International Development (USAID). Both FAO and USAID are promoting community-based systems for monitoring FAW and providing early warning to farmers of impending outbreaks, while in Kenya, *icipe* has been producing public service radio messages to raise awareness among farmers.

Peter Waboya is a member of the 32-farmer-strong Bungoma County Farmer Field School. He is also coordinator for 248 farmer field schools in the region. FAO is funding a FAW community-based early warning system in western Kenya via 11 of those farmer field schools (one in each sub-county). In a project whose partners include the Ministry of Agriculture, *icipe*, seed companies, chemical companies, and basically "any stakeholder who cares", FAW is monitored via field-based pheromone traps. The pheromones used are the 'calling cards' emitted by the female moths to attract a mate, thus it is only the male moths that are actively trapped and killed. However, numbers trapped give a clear indication of moth movements and warn of impending outbreaks.

The farmer field schools are teaching their members how to control FAW through integrated pest management (IPM) measures, including farming practices such as early planting and seed selection. The Bungoma County Farmer Field School also hosts demonstration plots showing the impacts of FAW on maize in push–pull fields, fields where larvae are hand-picked, fields sprayed with insecticide, and those that

Fall armyworm on dry maize cob.

Peter Waboya (right) of Bungoma County Farmer Field School with a pheromone trap used to monitor fall armyworm, and farmer Patrick Wepukhulu Waboya with one night's catch at the height of an outbreak.

are treated with botanicals (products obtained from plants used to repel or kill pests). When comparing these options, it is evident that push–pull gives the best level of control.

USAID is similarly funding a community-based monitoring project in five districts of Uganda, which covers awareness, monitoring and reporting. The project includes training of national trainers (extensionists and researchers), stakeholder collaboration, and training of local community focal persons. The latter includes monitoring, use of mobile phones and alerting farmers, and squashing eggs and larvae to control FAW in small family-farm fields.

Elsewhere, some farmers are keen to spread the good news about push–pull's benefits in the face of FAW, whether or not they are official peer farmer trainers. For example, Shadrack Akhura has established a demonstration plot on his farm in Kakamega County, Kenya, to teach push–pull to other farmers. "This small Push–pull plot [about 10 m × 10 m], receives no fertiliser and no chemicals, but yields almost one 90 kg bag of maize," he says.

Integrated pest management: going deeper into and beyond the 'basic' push–pull

Girma Hailu reports that research on intercropping edible legumes with maize in Uganda gives 25–30% reduction in FAW compared with monocropped maize. "This is proposed as an additional optional IPM component," he says, "especially where desmodium seed and planting materials are not available." Availability of seed and planting material of desmodium is an ongoing issue for the spread of push–pull across the continent. "We are also studying early planting of desmodium or edible legumes to see whether they will protect maize from early infestation," he continues.

Sarah Awuor, assistant coordinator of community-based organisation Sigomere Organic Agriculture Program (SOAP), says: "where we have several push–pull farmers close together, we don't see any fall armyworm." The area in question comprises 18 smallholder farms occupying about 8,000 square metres (0.8 ha or about 2 acres), which have 3,200 square metres of push–pull maize forming a perimeter and large monocropped

"I introduced push–pull because of fall armyworm and striga"

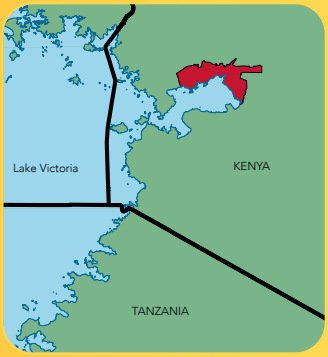
Name:
Dan Ochieng

Location:
Kisumu County, Kenya

Age:
42, farmer

Farm:
Quarter of an acre of maize and vegetables

Household size:
9 – Dan, his wife and seven children



Dan was experiencing serious infestations of FAW and striga in his maize fields, when another farmer introduced him to push–pull. Dan established his first push–pull maize plot in 2018. In the second season of 2018, the push–pull plot had no striga flowers and less FAW damage than the rest of his farm. At his wife's behest, he expanded the push–pull and in 2019 his farm suffered zero attacks from either FAW or striga.

"Before push–pull, I was getting less than 50 kg of maize from my farm," says Dan. "Now I am getting three bags from the two push–pull plots." These bags are the standard 90 kg sacks used for grain in Kenya, so Dan is getting 270 kg of maize per season.

"I have two cows, which I now feed entirely from push–pull fodder – I used to have to ask my neighbours to allow me to graze the animals on their farms. After three seasons of push–pull, I have more peace, no worry: my animals are at home and safe. I have reduced weeding, and have time to cultivate vegetables. I trained my wife [in push–pull techniques and management], and it was she who encouraged me to expand into a second field. When one of my daughters started Form 1, I sold 40 kg of maize and some desmodium to pay the initial fees of 4,000 shillings a term. I also paid the registration fees of 700 shillings for each of the two children in primary school."

Current farm production is not enough for Dan's family's needs: "we are not yet food secure, but it is a definite step from where I was!" Dan plans to expand his vegetable plots and sell the produce to raise funds to lease or buy more land, and thereby expand his farm, aiming at family food security. ■

maize plots 'inside'. It appears that the dense cluster of push–pull plots is protecting non-push–pull fields within the same area. Programme staff credit the repellent properties of greenleaf desmodium for this protective effect. This is clearly an area in need of research. A current BBSRC project, in collaboration with Keele University, is investigating the underpinning science and has now identified repellent semiochemicals from greenleaf desmodium.

As Lillian Ouma of Busia District, Kenya, says, FAW is "here to stay", but the prospects for push–pull farmers seem much brighter than for those without push–pull. This is yet another incentive to expand the technology as wide and as fast as possible. ■

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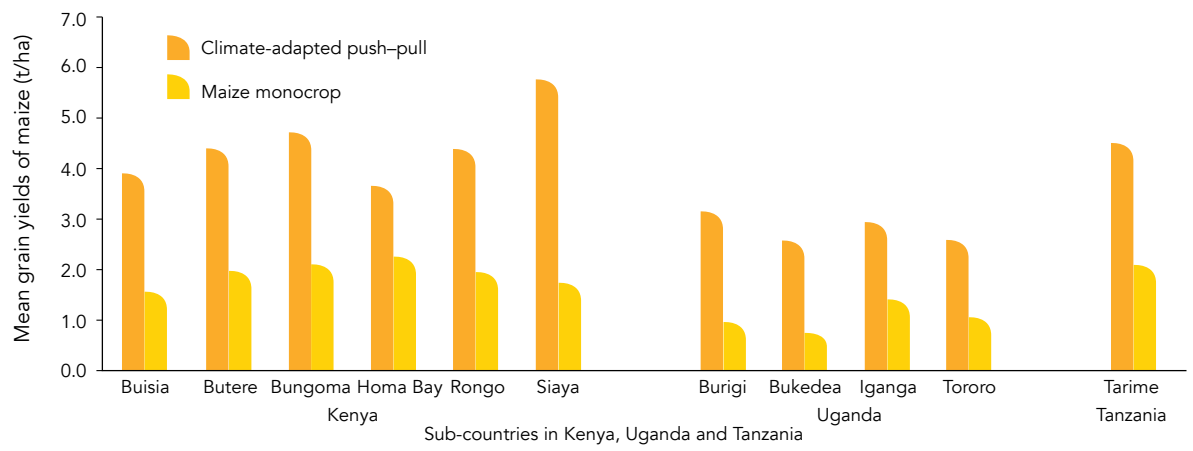

Maize yields in push–pull compared with monocropped maize (after Midega *et al.*, 2018, *Crop Protection* 105: 10–15).

"IF FELLOW FARMERS WOULD **FULLY ENGAGE AND PRACTISE PUSH–PULL,** SPRAYING WOULD NOT BE NECESSARY"

DAN OLIANGA ABU KACHI,
KAKAMEGA COUNTY, KENYA.

"JOIN THE PUSH–PULL TECHNOLOGY **TO AVOID SUCH LIKE ARMYWORMS** IN THE FARMS"

MAUREEN AMBUBI,
VIHIGA COUNTY, KENYA

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