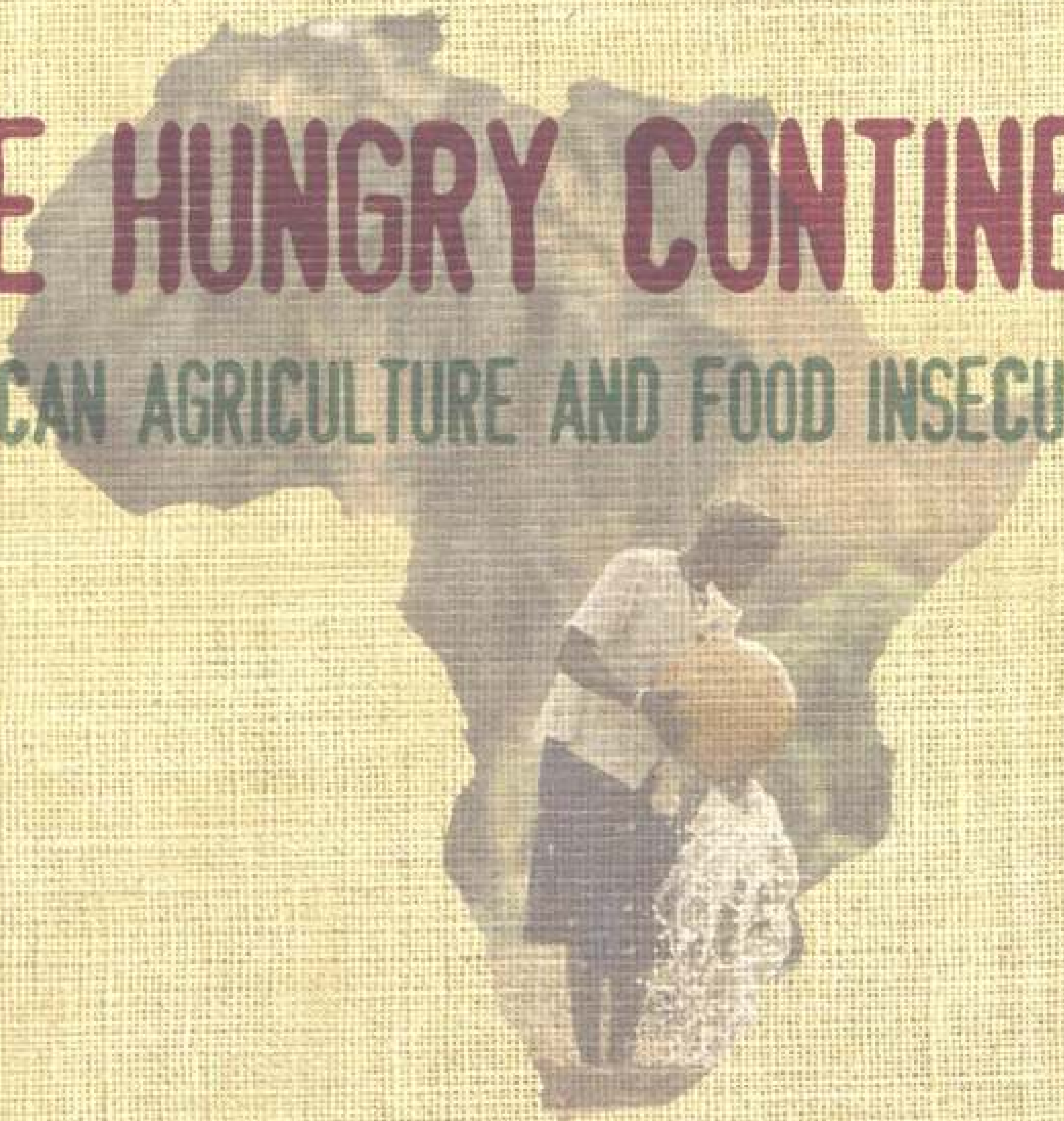
THE HUNGRY CONTINENT

AFRICAN AGRICULTURE AND FOOD INSECURITY



THE HOWARD G.
BUFFETT
FOUNDATION

10. Biological Pest Control: Push-Pull in East Africa

LOCATION: KENYA

A highly successful, ecologically based pest- and weed-management system was implemented in resource-poor smallholder maize systems in Kenya between 1999 and 2004. Combining researcher- and farmer-managed trials in ten districts, a single "push-pull" strategy significantly reduced reliance on pesticides, helped control pests for more than 1,500 participating farmers and increased maize yields by an average of 17 to 25 percent.[1]

CHALLENGE:

Maize and sorghum are the primary staple crops for millions of the poorest people in eastern and southern Africa. Stem borers, the parasitic *Striga* weed, and low soil fertility are the main constraints to grain production in Kenya and other parts of sub-Saharan Africa.[2] Seventeen species of stem borers have been found to infest maize throughout Africa, significantly limiting yield potential. Though impact varies by region, crop cultivar and farming practices, stem borer losses in eastern Africa average 20 to 40 percent, reaching as high as 80 percent in some areas. *Striga's* impact on yield can be even greater, with 30 to 100-percent losses recorded in many areas. *Striga* losses are often exacerbated by low soil fertility, a problem prevalent in East Africa. When the two pests occur together, farmers frequently lose their entire grain crop.[3]

Chemical pesticides have proven largely ineffective[4] in controlling stem borers; they are also prohibitively expensive and potentially harmful to human health, soil, water quality and biodiversity. In addition, these inorganic compounds kill the stem borer's natural enemies.[5] Traditional practices—burning unharvested biomass or wild host species—are not recommended because they also impact beneficial insects.

Economic losses from stem borers and *Striga* weeds amount to about $7 billion annually, primarily affecting resource-poor and subsistence farmers. Research suggests that preventing stem borer and *Striga* weed crop losses and improving soil fertility in eastern Africa could increase cereal harvests to feed an estimated 27 million people.[6]

Kenya currently ranks 128 out of 169 countries on the Human Development Index[7]. Agriculture is an important economic activity, employing approximately 75 percent of Kenya's labor force. Its contribution to GDP is currently estimated at 21.4 percent.[8] Due to extreme climate variability, Kenya endures repeated environmental disasters—both droughts and floods—that result in periodic rationing of electricity and water, reduced agricultural output, low rates of economic growth and widespread food insecurity for millions of people. In 2010 Kenya faced significant staple crop deficits at 40 percent of normal production; the price of maize rose to 70 to 80 percent above the long-term average, creating financial hardship and food insecurity in many communities. In some areas, reported acute malnutrition rates are more than 20 percent. Food insecurity remains especially high among vulnerable groups in marginal agricultural districts.[9]

RESPONSE:

Researchers from the Rothamsted Research Station (UK) and the International Center of Insect Physiology and Ecology (ICIPE) have worked in East Africa for the last 15 years on an effective ecologically based pest-management solution for stem borers and *Striga*. Their research produced the successful "push-pull" intercropping technology, which manages pests, increases animal forage and enhances soil quality and fertility.[10] From initial experimental trials to on-farm experimentation and, finally, to widespread implementation, the push-pull selective intercropping strategy has yielded consistently positive results.[11]

The push-pull system manages pests through a stimulo-deterrent chemical ecology strategy that encourages biological control by natural enemies and reduces stem borer reproductive success. Through selective intercropping with important fodder species and wild grass relatives, maize fields are environmentally modified: Stem borers are simultaneously repelled—or pushed—from the system by one or more plants and are attracted to—or pulled—toward "decoy" plants, protecting the crop from infestation.[12] Intercropping maize with additional plants known to both repel stem borers and attract natural enemies (parasitoids)[13] can further decrease stem borer densities by appreciably enhancing parasitism rates.

An extensive selection process has identified multiple plant species for Kenyan push-pull systems. Attractant plants such as Napier grass (*Pennisetum purpureum*) and Sudan grass (*Sorghum vulgare*) are highly effective trap crops serving to "pull" stem borers away from the maize crop. Molasses grass (*Melinis minutiflora*) successfully repels (i.e. "pushes") stem borers away from the maize crop while significantly enhancing parasitism rates by parasitoid wasps, thus increasing pest mortality and reducing crop losses.[14]

Researchers have used similar ecological strategies to develop biological, non-chemical practices to control the invasive *Striga* weed in the same smallholder maize systems. Two leguminous plants, *Desmodium uncinatum* and *Desmodium intortum*, produce root exudates that work together to limit *Striga*'s reproductive success.[15]

Desmodium is a perennial legume that exerts its allelopathic[16] effect on *Striga* even when maize is out of season. When intercropped with Napier grass, the two plants control two of Africa's most detrimental maize pests and also prevent soil erosion, fix nitrogen, enhance soil organic matter, conserve soil moisture and increase quantity and diversity of beneficial arthropods. The push-pull intercropping systems serve as models for creating more productive and ecologically sustainable subsistence maize systems for eastern and southern Africa.[17]

RESULTS:[18]

- In 1997, push-pull polycultures showed significantly higher rates of biological control (via enhanced parasitism)[19] in several multi-year comparative experimental trials. In the study, maize monocultures showed parasitism rates of 4.8 percent and 0.5 percent for *C. partellus*, and *B. fusca*, respectively. The push-pull systems had parasitism rates of 6.17 percent and 18.9 percent for *C. partellus*, and *B. fusca larvae*, respectively.[20] In 1999, on-farm maize trials in Kenya's low-yielding Suba district yielded only 1.8 t/ha in control plots compared to 4 t/ha in push-pull plots.
- In the same year, trials on maize crops in Kenya's high-yielding Trans-Nzoia district yielded 4 to 5

t/ha in control plots compared to 6 to 7 t/ha in push-pull plots.

- In 2001, the push-pull system helped control pests for more than 1,500 participating farmers and increase maize yields by an average of 17 percent in Trans-Nzoia and 25 percent in the Suba district.

- In a similar 2000-2003 study in seven Kenyan districts and three Ugandan districts, habitat management strategies based on the push-pull system helped more than 1,500 participating farmers increase maize yields by an average of 20 percent in areas with only stem borers; yields were increased by more than 50 percent in areas with both stem borers and *Striga* weed infestations.

- The push-pull and *Striga*-suppression elimination tactics have contributed to increased livestock production of both milk and meat by providing more fodder and different crop residues, especially on small farms. In the Suba district, for example, where more than 250 farmers have adopted push-pull systems, the number of improved dairy cattle has increased from four in 1997 to 350 in 2002.

- A recent study by the University of Haifa in Israel, on the impact of push-pull technology on soil quality showed the abundance and diversity of beneficial soil arthropods were significantly higher in push-pull plots compared to maize monocultures.

- The habitat management strategies are a promising method for gender empowerment, providing women with income through the sale of farm grain surpluses, fodder and *Desmodium* seed.

- A seven-year (1998-2004) agronomic and cost-benefit study in six western Kenyan districts showed that push-pull technology consistently delivered significantly higher maize-grain yields when compared to maize–bean intercrops and maize monoculture systems. The push-pull system yields ranged from a low of 1.9 t/ha in Suba district to a high of 6.3 t/ha in the Kisii district. In comparison, yields in the maize–bean intercrop ranged from a low of 0.9 t/ha in Suba district to a high of 3.9 t/ha in Trans-Nzoia districts. Maize monocultures were low yielding—between 1.0 t/ha in Suba and Busia districts to 3.9 t/ha in Trans-Nzoia districts. Higher yields are recorded in push-pull systems despite a reduction in the area of land allocated to maize due to the intercropping of selected grasses and legumes.[21]

- In the same seven-year study, a cost-benefit analysis showed that with the exception of one district, the push-pull systems outperformed bean and maize monoculture systems economically in the first year[22] despite higher initial variable and labor costs.[23] In calculating total labor and non-labor costs, total variable costs and total revenues for each farm and cropping system, the total gross benefits in US $/ha were significantly higher for farms using push-pull systems than for farms using maize–bean intercrop and maize mono-crop systems in *all* years and in *all* districts studied.[24]

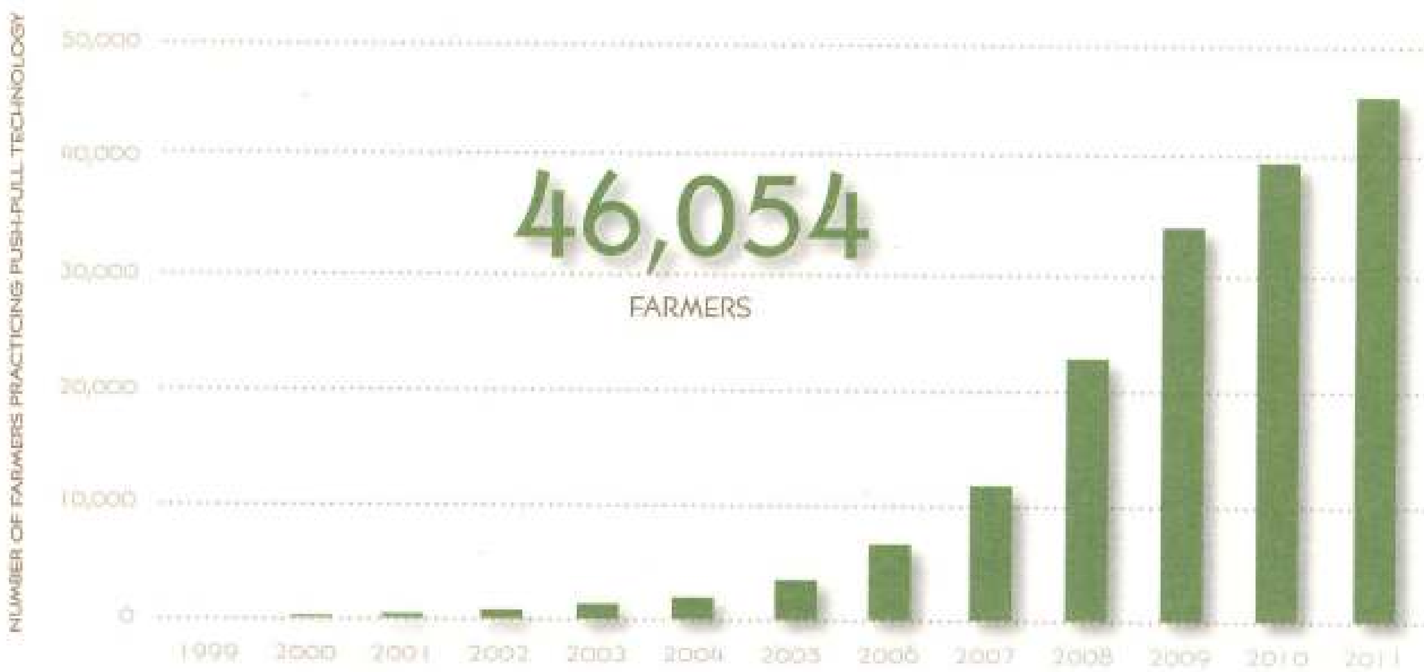
Push-pull systems have been widely adopted within the communities where farmer-managed trials were carried out, particularly in the Trans-Nzoia and Suba districts.

- As of 2011, more than 46,000 smallholder farmers in East Africa have adopted the push-pull systems.

Their maize yields have increased from an average of 1.0 t/ha to 3.5 t/ha without the use of chemical insecticides and with minimal external inputs.

Push-pull is one of the most successful examples of conservation biological control,[25] and the research methodology and findings hold great promise for maize-growing regions throughout eastern and southern Africa. In addition to enhancing yields, the strategy increased small livestock production, conserved soil resources, controlled important weeds, enhanced functional biodiversity and increased incomes and women's empowerment.[26] Push-pull is an appropriate technology for poor farmers in East Africa because it is based on locally available renewable inputs and can thus be easily integrated into traditional poly-culture cropping systems. On a larger scale, principles of push-pull can be applied to low-input and organic agriculture systems world-wide.[27]

ADOPTION OF PUSH-PULL TECHNOLOGY IN EAST AFRICA, 1999-2011



Source: ICIPE, http://www.push-pull.net/adoption.shtml

COLLABORATING PARTNERS:

International Centre of Insect Physiology and Ecology (ICIPE); Rothamsted Research Station, Hertfordshire, United Kingdom; Kenya Agricultural Research Institute; Ministry of Agriculture, Kenya; Gatsby Charitable Foundation, UK; and Biotechnology and Biological Sciences Research Council of the UK

ENDNOTES:

1 Z.R. Khan "Combined control of *Striga hermonthica* and stemborers by maize-*Desmodium* spp. Intercrops," *Crop Protection* 25, no. 9 (2006): 989–95.

2 Lepidopteran stem-borers, (larval insects) are ubiquitous pests that attack cereal crops throughout all growth stages. The larvae cause damage ranging from 20 to 80 percent loss of yield; *Striga* or "witchweed" are parasitic weeds that affect cereal crops (maize, sorghum, rice and sugarcane) in many parts of Africa. There are two common species in East Africa: *Striga hermonthica* and *Striga asiatica*. See: ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems." Z.R. Khan et al., "Exploiting chemical ecology and species diversity: stem borer and Striga control for maize and sorghum in Africa," *Pest Management Science* 56, no. 11 (2000): 957 – 962.

3 Ibid; Z.R. Khan et al., "Intercropping increases parasitism of pests," *Nature* 388 (1997): 631-632. Khan and Pickett, "The 'push-pull' strategy for stemborer management," ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems." D. Chikoye et al., eds., "Reducing Poverty through Improved Striga Control: Proceedings of the second Striga management stakeholders conference," International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, September 8–9, 2004.

4 Pesticides are ineffective because of the pest's cryptic and nocturnal behavior. Pesticides are not able to penetrate deep inside the plant stems where stem borer larvae reside. Further, the long-term viability of any insecticidal control (topically applied or plant produced through molecular techniques) is unlikely due to the development of genetic resistance. See: Khan and Pickett, "The 'push-pull' strategy for stemborer management." R.G. Van Driesche and T.S. Bellows, *Biological Control* (New York: Chapman and Hall, 1996).

5 The term "natural enemies" refers to insect predators or parasitoids that prey upon or otherwise inflict significant mortality on the pest species through parasitism (i.e. laying eggs in the eggs of the pest species). T.R. New, *Invertebrate Conservation and Agricultural Ecosystems* (Cambridge: Cambridge University Press, 2005). A. McLaughlin and P. Mineau, "The impact of agricultural practices on biodiversity," *Agriculture, Ecosystems & Environment* 55, no. 3 (1995): 201-212. J. Clay, *World Agriculture and the Environment: A Commodity-by-Commodity Guide to Impacts and Practices* (Washington: Island Press, 2004). P.A Matson, W. J. Parton, A. G. Power and M. J. Swift, "Agricultural intensification and ecosystem properties," *Science* 277 (1997): 504-509.

6 ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems." Z.R. Khan and J.A. Pickett, "The 'push-pull' strategy for stemborer management: a case study in exploiting biodiversity and chemical ecology," in *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*, eds.

7 Human Development Reports, International Human Development Indicators, http://hdr.undp.org/en/statistics/.

8 United States Central Intelligence Agency (CIA), The World Fact Book, https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html

9 UN Office for the Coordination of Humanitarian Affairs, http://ochaonline.un.org/OCHAHome/WhereWeWork/Kenya.aspx (accessed March 26, 2010); World Food Program, Kenya/East Africa, 2010, http://www.wfp.org/countries/kenya.

10 Khan et al., "Intercropping increases parasitism of pests," R. Kfir, W. A. Overholt, Z.R. Khan and A. Polaszek, "Biology and management of economically important cereal stem borers in Africa," *Annual Review of Entomology* 47 (2002): 701-31; http://www.push-pull.net/PDF%20files/Annual%20Reviews%20of%20Entomology.pdf.

11 Z.R. Khan and J.A. Pickett, "The 'push-pull' strategy for stemborer management: a case study in exploiting biodiversity and chemical ecology."

12 A.M. Shelton and F.R. Badenes-Perez, "Concepts and Applications of Trap Cropping In Pest Management," *Annual Review of Entomology* 51, no. 1 (2006): 285.

13 Parasitoid: An animal that feeds in or on another living animal, consuming all or most of its tissues and eventually killing it. See Biological Control: A Guide to Natural Enemies in North America, Cornell University, http://www.nysaes.cornell.edu/ent/biocontrol/.

14 Khan and Pickett, "The 'push-pull' strategy for stemborer management." ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems," D.A. Landis et al., "Habitat Management to Conserve Natural Enemies of Agricultural Pests in Agriculture," *Annual Review of Entomology* 45 (2000): 175-201. Z.R. Khan, D.G. James, C.A.O. Midega and J.A. Pickett, "Chemical ecology and conservation biological control," *Biological Control* 45, no. 2 (2008): 210-224.

15 One species of *Desmodium* stimulates germination of *Striga* seeds and others inhibit the growth of the plant after germination, and then it dies. This combination provides a novel means of reducing the *Striga* seed bank in the soil through efficient suicidal germination even in the presence of maize host plants. See ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems."

16 Allelopathy refers to the chemical inhibition of one species by another. The "inhibitory" chemical is released into the environment where it affects the development and growth of neighboring plants. See Cornell Science Inquiry Partnerships, Cornell University, http://csip.cornell.edu/Projects/CEIRP/AR/Allelopathy.htm.

17 Khan et al., "Exploiting chemical ecology and species diversity." ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems."

18 Khan and Pickett, "The 'push-pull' strategy for stemborer management." Z.R. Khan et al., "Economic performance of the 'push-pull' technology for stemborer and Striga control in smallholder farming systems in western Kenya," *Crop Protection* 27 (2008): 1084-1097. Zeyaur R. Khan et al., "On-farm evaluation of the 'push-pull' technology for the control of stemborers and Striga weed on maize in western Kenya," *Field Crops Research* 106, no. 3 (2008): 224-233. ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems." C.A.O. Midega, Z.R. Khan, J. Van Den Berg, C. Ogol, T.J. Bruce and J.A Pickett, "Non-target effects of the 'push–pull' habitat management strategy: Parasitoid activity and soil fauna abundance," *Crop Protection* 28, no. 12 (2009): 1045–1051.

19 High rates of parasitism by natural enemies are beneficial. High rates of parasitism = high rates of mortality of pests = decreased crop losses.

20 *Chilo. Partellus* (Pyralidae) and *Busseola fusca* (Noctuidae) are the two most important species of stem borer larvae infesting maize in East Africa.

21 Khan et al., "Economic performance of the 'push-pull' technology for stemborer and *Striga* control in smallholder farming systems in western Kenya." In all the districts, increased grain yield was realized from the first cropping year and was sustained throughout the study period; results of the study corroborate findings of previous studies on push-pull systems outperforming other maize intercrops or maize monocultures. In addition to control of stem borer and *Striga* weed, the ecological performance of push-pull systems are attributable in part to enhanced nitrogen fixation, soil organic matter deposition and water retention due to *Desmodium* inter-plantings.

22 Benefits of the push-pull system are consistently found to be more significant starting in the second cropping year.

23 When compared to maize monocultures, cost and labor are initially higher when establishing push-pull systems due to the expenses and labor of establishing the perennial grass intercropping species.

24 A complete annual quantitative breakdown can found on Tables 5-10 in Khan et al., "Economic performance of the 'push-pull' technology for stemborer and *Striga* control in smallholder farming systems in western Kenya." Findings from this study show that the use of push-pull is both agronomically and economically efficient at the farm level.

25 P. Barbosa, ed., *Conservation Biological Control* (London: Academic Press, 1998); M. Jonsson, S.D. Wratten, D.A. Landis and G.M. Gurr, "Recent advances in conservation biological control of arthropods by arthropods," *Biological Control* 45, no. 2 (2008):172-175; Biological control is defined as the reduction of pest populations by natural enemies (predators and parasitoids) of agricultural pests. See Biological Control: A Guide to Natural Enemies in North America, Cornell University, http://www.nysaes.cornell.edu/ent/biocontrol/.

26 Z.R. Khan and J.A. Pickett, "The 'push-pull' strategy for stemborer management: a case study in exploiting biodiversity and chemical ecology," G.M. Gurr, S.D. Wratten and M.A. Altieri (Ithaca: Cornell University Press, 2004), 155–164; International Centre of Insect Physiology and Ecology (ICIPE), "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems," http://www.push-pull.net/index.shtml.

27 S. Cook, Z.R. Khan and J.A. Pickett, "The Use of Push-Pull Strategies in Integrated Pest Management," *Annual Review of Entomology* 52 (2007): 375-400; ICIPE, "A Novel Conservation Agriculture Strategy for Integrated Pest and Soil Management in Cereal Farming Systems."