Control of stem borers and striga in African cereals: a low input push-pull approach with rapidly expanding impact

Z R KHAN[1], J A PICKETT[2], M L HAMILTON[2], A HASSANALI[1], A M HOOPER[2], S P KUATE[1], C A O MIDEGA[1], J PITTCHAR[1] and B TORTO[1]

[1] *The International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi, Kenya*
[2] *Rothamsted Research, Harpenden, Hertfordshire, AL5 2JQ, UK*

Summary

A system which comprises intercropping between rows of maize with plants that repel stem borers and attract natural enemies, and which also dramatically reduce the level of striga infestation, combined with a surrounding crop of plants that trap out pests, has been developed for use by resource-poor farmers in sub-Saharan Africa. The intercrop and trap crops provide forage for cattle and goats. The technology is called "push-pull". It is knowledge-intensive and there are lessons to be learned in its dissemination to resource-poor farming communities. However, where these have been practised, the take-up and continued use is very high. There are alternative technologies for stem borer and striga control, but these are not compatible with subsistence farming economics, are not sustainable in the long term and could lead to increased acreages for the farms involved, with subsequent displacement of rural communities. The push-pull technology raises the farming level above subsistence by improving cereal yields and by providing animal forage, and the evidence also suggests that it does so whilst stabilising a high density rural population.

Key words: push-pull, intercropping, stem borer, striga, molasses grass, desmodium

Introduction

In sub-Saharan Africa (SSA) maize is a major crop, covering over 25 million ha, and is particularly important in resource-poor farming regions which represent a majority of the rural populations experiencing greatest poverty. Approximately 15% of this crop is lost through lepidopterous stem-boring insects, where the larvae cause extensive foliar and stem damage. In addition, over 6 million ha, *ca* 24% of the crop, is infested by the parasitic weed striga (*Striga hermonthica*). There are many options for control of striga (e.g. Vanlauwe *et al*., 2008), few of which have a real impact at the practical level and, of those approaches, most involve delivery through hybrid seed and modern herbicides. Use of fertilisers can obviate some of the yield loss caused by striga and irrigation can also help. However, purchasing seed (especially high value hybrid seed), herbicides, fertilisers and energy inputs necessary for irrigation are not options for most farmers because of their inability to pay, and even unwillingness to pay where erratic weather conditions prevent the guarantee of a crop being harvested. Farmers in these regions widely practise companion cropping, particularly intercropping ("kilimo cha mchanganyiko" in kiSwahili, a widespread East African language). In a collaboration led by the International Centre of Insect Physiology and Ecology (*icipe*) based in Kenya, originally with funding from the Gatsby Charitable Foundation and now predominantly by the Kilimo Trust, a system of exploiting both intercropping and trap cropping, the “push-pull” approach (in kiSwahili, “vuta sukuma”, or “pull-push”), has been developed to deliver stem borer and striga control in a way not only acceptable but highly beneficial to resource-poor farmers.

Besides the delivery of crop protection and weed control, both the intercrop and trap crops represent a valuable source of forage for both cattle and goats, particularly for smallholder milk production. Although this approach began initially in Kenya, with some regions now practising push-pull almost to saturation, the approach is rapidly expanding in other countries, including Uganda and Tanzania. In terms of overall coverage, the number of farms involved so far (25,000+) is small compared to those potentially able to benefit. However, the fact that some regions where the project has been most active have taken up push-pull so extensively indicates its wider potential and the need for understanding how such a knowledge-intensive approach, accommodating the currently resource-poor bulk of SSA farming, can be extended. Not only does this approach fit with current circumstances, but the rapid improvements in small farm economy are such that the rural community is stabilised and do not result in farms becoming larger at the expense of smallholders who would thereby be displaced from the land. The need to retain, but improve, smallholder farming was explained in detail in a speech by Dr. Akinwumi Adesina, Vice President, Alliance for a Green Revolution in Africa (AGRA), on 17th June 2009 at Science Forum 2009, Wageningen, The Netherlands, “Taking Advantage of Science and Partnerships To Unlock Growth in Africa’s Breadbaskets” (Adesina, 2009).

Push-pull planting material

Surveys were made using a wide range of locally available cereals, grasses and legumes to establish which could act as repellents for stem borer moths laying eggs on cereals, particularly maize. The most powerfully repellent plant, molasses grass (*Melinis minutiflora*), was also shown to attract parasitic wasps that attack the stem borers, particularly at the larval stage (Khan *et al*., 1997). For trap crops, two cattle forage grasses attractive to stem borers were identified: Sudan grass, *Sorghum sudanensis*, and Napier grass, *Pennisetum purpureum*. The latter was also found to destroy stem borer larvae at their later instars (Khan & Pickett, 2004). Initially, farmers were offered the “pull” component, i.e. trap crops, and then intercropping with molasses grass; take-up was rapid and the two treatments were soon combined to give the full push-pull system. In extensive discussions with farmers, legumes to replace the molasses grass intercrop were requested, because the farmers were already practising intercropping with edible legumes. Although the edible beans and most of the forage legumes were unsuitable for stem borer control, species in one genus, *Desmodium*, e.g. *D. uncinatum*, silverleaf desmodium, and *D. intortum*, greenleaf desmodium, were good in this respect, but required one-to-one planting with rows of maize, whereas molasses grass gave highly effective results at a planting of one-to-four.

In areas around the shore of Victoria Lake in Kenya, there is a high prevalence of the parasitic weed *Striga hermonthica* and it was soon observed that desmodium was also providing dramatic striga control, with spectacular reduction of flowering striga, increased growth of the cereal crop (initially maize) and impressive improvements in yields. This intercrop was therefore recommended for striga-infested regions, whereas molasses grass can be used where there are only problems of stem borer attack.

We now understand part of the mechanisms by which stem borers are controlled and parasitic wasps attracted, and also the allelopathic chemistry produced by the desmodium plant which controls striga (Guchu *et al*., 2007; Hassanali *et al*., 2008; Hamilton *et al*., in press). However, although, for striga control, the chemistry is rapidly being elucidated, the insect mechanisms are still being studied, in collaboration with Julie Scholes and Kay Titcomb at the University of Sheffield and Malcolm Press at the University of Birmingham. Push-pull gives excellent results not only in maize but also in sorghum, *Sorghum bicolor*, and pearl and finger millet

(*Pennisetum glaucum*, *Eleusine coracana*), and even in upland, i.e. non-irrigated, rice (*Oryza sativa*).

Technology transfer to resource-poor farmers

Take-up of the push-pull technology is shown in Fig. 1 and some results from on-farm evaluation are given in Fig. 2. The economics are impressive for these farming situations (Fig. 3), as are the benefits realised by farmers (Fig. 4) (Khan *et al*. 2008a, 2008b). Dissemination has employed a variety of approaches and the most effective, including the use of farmer teachers, have been analysed (Amudavi *et al*., 2009).

Future science for push-pull

Although push-pull technologies are up and running and the dissemination process is working well, although needing vastly more resources to make these technologies available to all the farmers who could benefit, there is a continued and, indeed, growing need to service the technology and to devise new approaches to its exploitation. It is essential that traits conferring the push-pull effect against stem borers and the allelopathic control of striga by desmodium are maintained as seed is multiplied (molasses grass and desmodium) and planting material is made available (Napier grass and desmodium). Thus, it is essential to understand the underlying mechanisms and to use the science base to troubleshoot where problems occur. With regard to the latter, for example, Napier grass used in the push-pull system, and also as a monocrop for cattle forage on large stockholding farms, is experiencing wide infection by a phytoplasma causing Napier stunt. The science base from this project has been rapidly used to identify the vector, a planthopper, *Recilia banda* (Cicadellidae) (Obura *et al*. 2009), which is facilitating a programme for selecting resistance in this species of grass. Farmers are now also able to interplant edible beans in the push-pull system, either with maize in the same hole or between maize plants within a row, without compromising the effectiveness of the desmodium-based technology (Khan *et al*., 2009).

By understanding the underlying biochemistry and associated plant molecular genetics from which is derived the allelopathic control of striga, edible beans will be bred or genetically modified to provide this trait in their roots without affecting the quality of the beans for human consumption. The type of defence provided to maize and other cereals by molasses grass is already present vestigially in cereals, but this could be bred or genetically engineered into these crops so that they would more rapidly mount this type of defence on initial attack, even on oviposition by the pests. All these traits could be provided so that farmers could gather their own seed after initial establishment of crop and push-pull plants with appropriate traits.

Conclusions

Provided that the technologies fit in with aspects of current farmer practice in this “kilimo cha mchanganyiko”, and assuming that there is an appropriate scientific input, these new and sustainable technologies can be developed even for the poorest farming communities. These technologies can then be used to raise living standards above subsistence levels whilst, at the same time, stabilising dense rural populations. Eventually, farmers may coalesce into larger enterprises and the rural population density may become lower in favour of urban conurbations, but this should occur by choice rather than by the economically enforced displacement of rural poor to which Akinwumi Adesina referred (Adesina, 2009).

Acknowledgements

This work was funded by the Gatsby Charitable Foundation (UK), Kilimo Trust (East Africa) and the Biovision Foundation (Switzerland). Rothamsted Research receives grant-aided support from the Biotechnology and Biological Sciences Research Council (BBSRC) and was funded through the BBSRC/DFID SARID initiative. The authors also acknowledge the assistance provided by *icipe* field staff, Ministry of Agriculture extension staff, and the farmers.

References

Adesina A. 2009. Speech "Taking Advantage of Science and Partnerships To Unlock Growth in Africa's Breadbaskets", Science Forum, 17 June 2009, Wageningen, The Netherlands.

Amudavi D M, Khan Z R, Wanyama J M, Midega C A O, Pittchar J, Nyangau I M, Hassanali A, Pickett J A. 2009. Assessment of technical efficiency of farmer teachers in the uptake and dissemination of push-pull technology in Western Kenya. *Crop Protection* **28**:987-996.

Guchu S M, Yenesew A, Tsanuo M K, Gikonyo N K, Pickett J A, Hooper A M, Hassanali A. 2007. *C*-methylated and *C*-prenylated isoflavonoids from root extract of *Desmodium uncinatum*. *Phytochemistry* **68**:646-651.

Hamilton M L, Caulfield J C, Pickett J A, Hooper A M. 2009. *C*-Glucosylflavonoid biosynthesis from 2-hydroxynaringenin by Desmodium uncinatum (Jacq.) (Fabaceae). *Tetrahedron Letters* (in press).

Hassanali A, Herren H, Khan Z R, Pickett J A, Woodcock C M. 2008. Integrated pest management: the push-pull approach for controlling insect pests and weeds of cereals, and its potential for other agricultural systems including animal husbandry. *Philosophical Transactions of the Royal Society London B* **363**:611-621.

Khan Z R, Ampong-Nyarko K, Chiliswa P, Hassanali A, Kimani S, Lwande W, Overholt W A, Pickett J A, Smart L E, Wadhams L J, Woodcock C M. 1997. Intercropping increases parasitism of pests. *Nature* **388**:631-632.

Khan Z R, Pickett, J A. 2004. 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*, pp. 155-164. Eds G Gurr, S Wratten and M Altieri. Australia: CSIRO Publishing.

Khan Z R, Midega C A O, Amudavi D M, Hassanali A, Pickett J A. 2008a. 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**:224-233.

Khan Z R, Amudavi D M, Midega C A O, Wanyama J M, Pickett J A. 2008b. Farmers' perceptions of a 'push-pull' technology for control of cereal stemborers and *Striga* weed in western Kenya. *Crop Protection* **27:**976-987.

Khan Z R, Midega C A O, Wanyama J M, Amudavi D M, Hassanali A, Pittchar J, Pickett J A. 2009. Integration of edible beans (*Phaseolus vulgaris* L.) into the push–pull technology developed for stemborer and *Striga* control in maize-based cropping systems. *Crop Protection* **28**:997-1006.

Obura E, Midega C A O, Masiga D, Pickett J A, Hassan M, Koji S, Khan Z R. 2009. *Recilia banda* Kramer (Hemiptera: Cicadellidae), a vector of Napier stunt phytoplasma in Kenya. *Naturwissenschaften* **96**:1169-1176.

Vanlauwe B, Kanampiu F, Odhiambo G D, De Groote H De, Wadhams L J, Khan Z R. 2008. Integrated management of *Striga hermonthica*, stemborers and declining soil fertility in western Kenya. *Field Crops Research* **107**:102-115.

Figure legends:

Fig. 1. Numbers of farmers adopting the push-pull strategy in Western Kenya. Total number of farmers: 2004 = 2,100; 2005 = 3,300; 2006 = 6,415; 2007 = 10,952; 2008 = 16,197 (2009 = 19,119).

Fig. 2. On-farm evaluation of push-pull technology (n=420).

Fig. 3. Economics of the push-pull system.

Fig. 4. Benefits realized by farmers following adoption of the push-pull technology in various districts in Kenya.

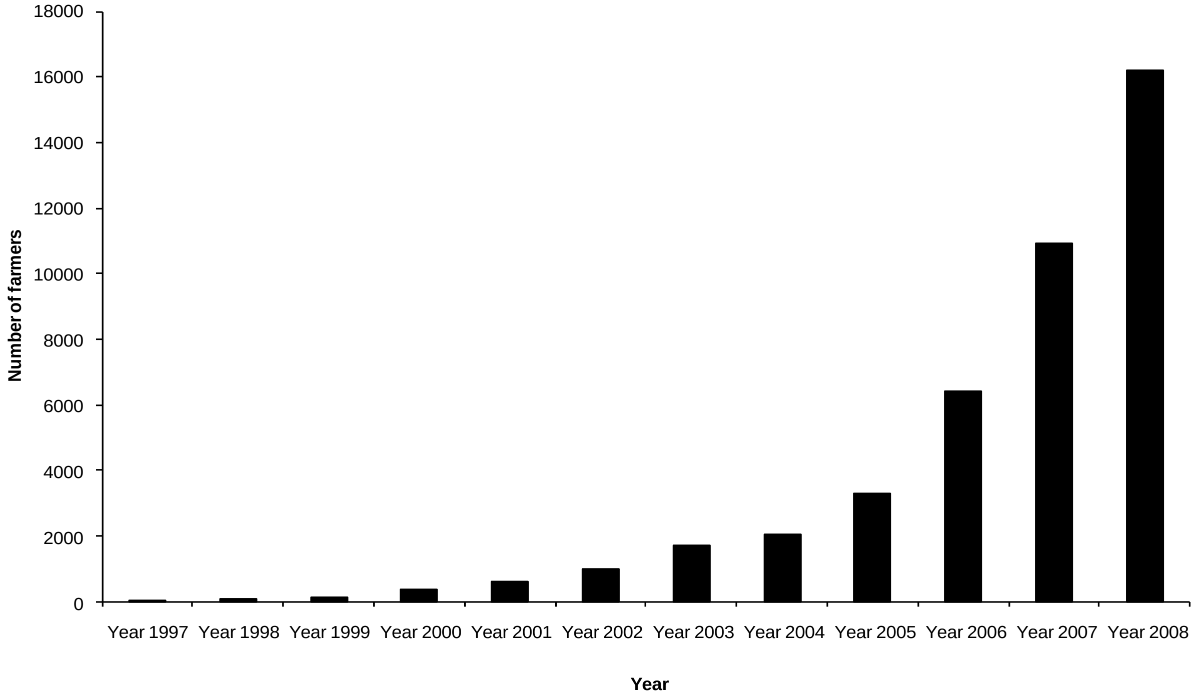
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Number of farmers
Year 1997
Year 1998
Year 1999
Year 2000
Year 2001
Year 2002
Year 2003
Year 2004
Year 2005
Year 2006
Year 2007
Year 2008
Year

Figure 1

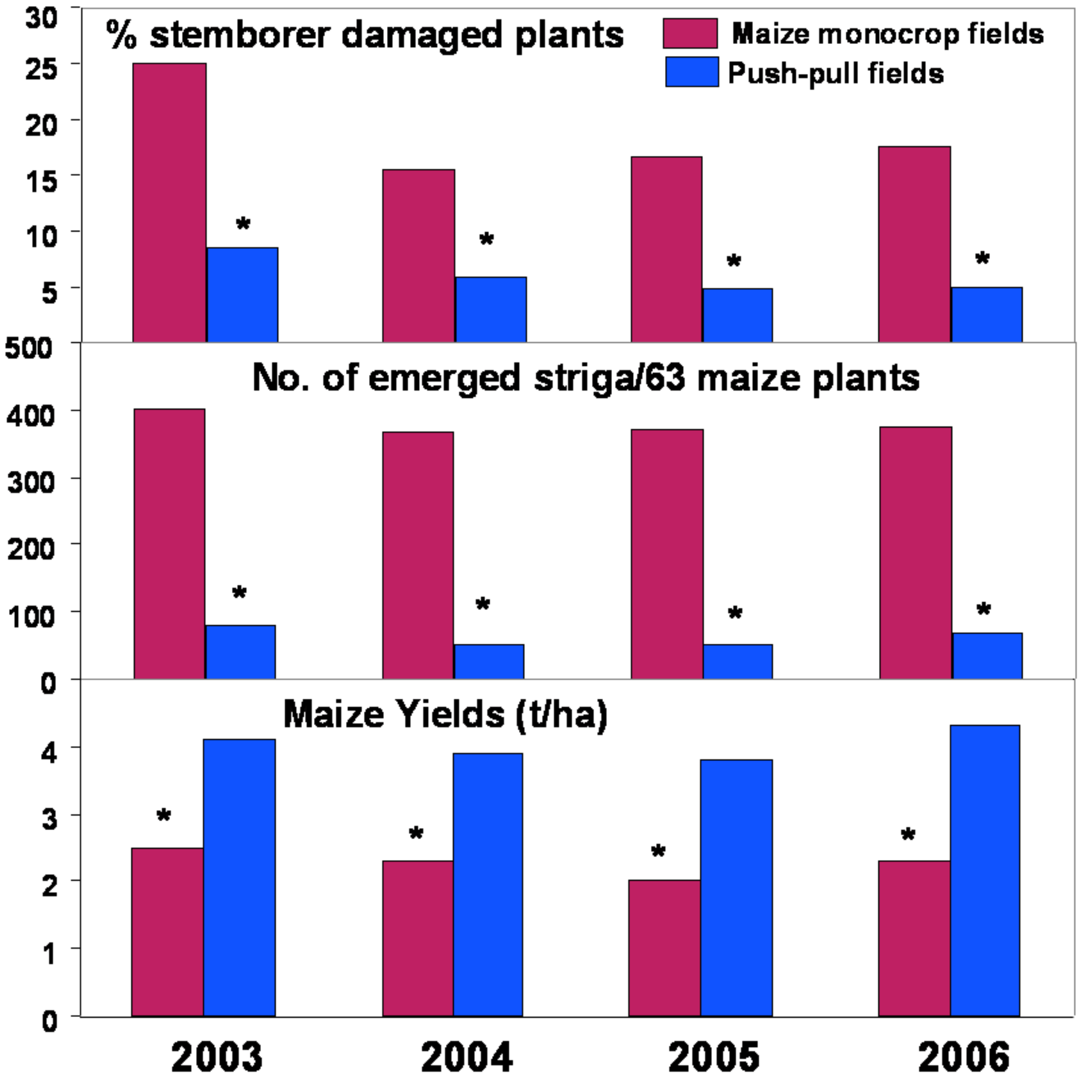
% stemborer damaged plants
Maize monocrop fields
Push-pull fields
No. of emerged striga/63 maize plants
Maize Yields (t/ha)
2003
2004
2005
2006

Figure 2

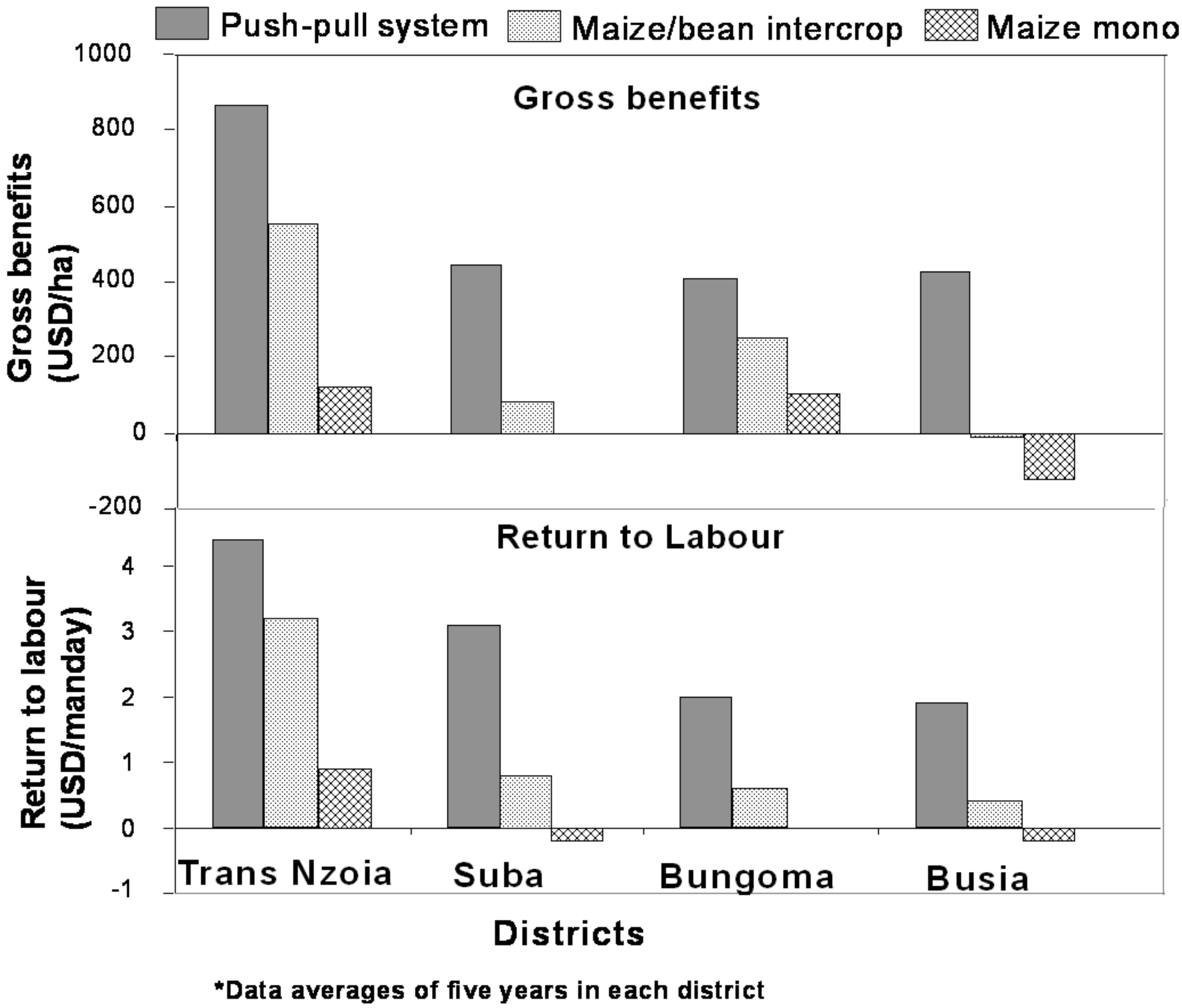
Push-pull system
Maize/bean intercrop
Maize mono
Gross benefits
Gross benefits (USD/ha)
1000
800
600
400
200
0
-200
Return to Labour
Return to labour (USD/manday)
4
3
2
1
0
-1
Trans Nzoia
Suba
Bungoma
Busia
Districts
*Data averages of five years in each district

Figure 3

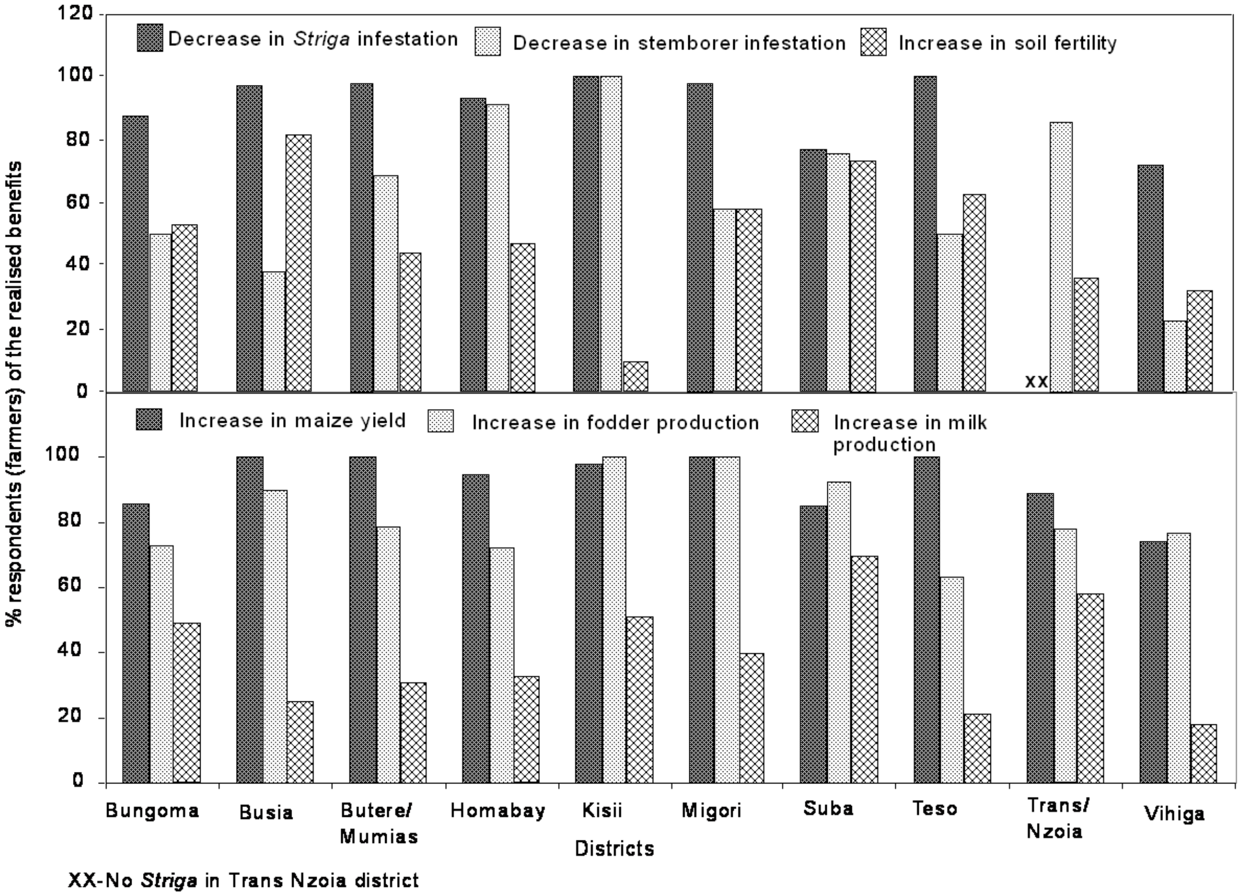
Decrease in *Striga* infestation
Decrease in stemborer infestation
Increase in soil fertility
Increase in maize yield
Increase in fodder production
Increase in milk production
% respondents (farmers) of the realised benefits
120
100
80
60
40
20
0
XX
Bungoma
Busia
Butere/ Mumias
Homabay
Kisii
Migori
Suba
Teso
Trans/ Nzoia
Vihiga
Districts
XX-No *Striga* in Trans Nzoia district

Figure 4