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Strategies for control of cereal stemborers and striga weed in maize-based farming systems in eastern africa involving 'push-pull' and allelopathic tactics, respectively

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Abstract The lepidopteran stemborers and parasitic striga weeds cause major yield losses in subsistence maize production throughout sub-Saharan Africa. A habitat management strategy for minimizing damage due to stemborers and striga weed has been developed in maize-based farming systems for small- and medium-scale African farmers. For stemborers, this strategy involves use of trap crops to attract stemborer colonization away from the cereal plants (pull) and intercrops to repel the pests (push). The two most successful trap crop plants Napier grass, *Pennisetum purpureum*, and Sudan grass, *Sorghum vulgare sudanensis*, attracted greater oviposition by stemborers, than cultivated maize. The intercrops giving maximum repellent effect were molasses grass, *Melinis minutiflora* and a legume species, silverleaf, *Desmodium uncinatum*. 'Push-pull' trials, using the trap crops and repellent plants, reduced stemborer attack and increased levels of parasitism of borers on protected plants, resulting in significant increases in maize yield. The trap crop and intercrop plants also provide valuable forage for cattle, often reared in association with subsistence cereal production. The plant chemistry responsible for stemborer control involves release of attractant semiochemicals from the trap plants and repellent semiochemicals from the intercrops. With *M. minutiflora*, certain chemicals repellent to ovipositing adults also increased parasitism of stemborers. Intercropping maize with *D. uncinatum* not only reduced stemborer colonization on maize but also reduced parasitization of maize by *Striga hermonthica*, which has been shown to be due to a novel allelopathic effect of the root exudates of the intercrop. There has been considerable take-up of the habitat management system by farmers in eastern Africa and more than 1,500 farmers in different agro-ecologies in western Kenya and eastern Uganda have adopted this technology.

Keywords: Stemborers, striga trapcrops weed, yield

Introduction

Maize and sorghum are the principal food and cash crops for millions of the poorest people in the predominantly mixed crop-livestock farming systems of eastern and southern Africa. Stemborers [*Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) and *Busseola fusca* Fuller (Lepidoptera: Noctuidae)] and striga weeds [(*Striga hermonthica* and *Striga asiatica* (Scrophulariaceae)] are two major biotic constraints to increased maize production in eastern Africa.

At least four species of stem borers infest maize and sorghum crops in the region, causing reported yield losses of 20-40% of potential output. Stemborers are difficult to control, largely because of the cryptic and nocturnal habits of the adult moths and the protection provided by the stem of the host crop for immature stages (Ampofo, 1986; Seshu Reddy and Sum, 1992). The main method of stemborer control, which is recommended to farmers by the Ministry of Agriculture, is use of chemical pesticides. However, chemical control of stemborers is uneconomical and impractical to many resource-poor, small-scale farmers.

Parasitic weeds in the genus *Striga* threaten the lives of over 100 million people in Africa and infest 40 percent of arable land in the savanna region, causing an estimated annual loss of $7 to $13 billion (M'boob, 1989; Musselman et al., 1991; Lagoke et al., 1991). Infestations by *Striga* spp. have resulted in the abandonment of much arable land by farmers in Africa. The problem is more widespread and serious in areas where both soil fertility and rainfall are low. Unfortunately, African women must engage themselves in weeding out striga, which is a time-consuming and labour-intensive activity. Recommended control methods to reduce striga infestation include heavy applications of nitrogen fertiliser, crop rotation, use of trap crops and chemicals to stimulate suicidal seed germination, hoeing and hand pulling, herbicide application and the use of resistant or tolerant crop varieties (Berner et al., 1995). All these methods, including the most widely practised hoe weeding, are seriously limited by the reluctance of farmers to accept them, for both biological and socio-economic reasons (Lagoke et al., 1991).

Therefore, reducing the losses caused by stemborers and striga through improved management strategies could significantly increase maize production, and result in better nutrition and purchasing power for many maize and sorghum producers. No single method of control has so far provided a solution to both the stemborer and striga problems (Berner et al., 1995). To put stemborer and striga control within the reach of African farmers, simple and relatively inexpensive measures need to be developed and tailored to the diversity of African farming systems (Lagoke et al. 1991). A sustainable solution would be an integrated approach that simultaneously addresses both of these major problems.

Management of stemborers and striga weed involving 'push-pull' and allelopathic tactics. Several national and international agricultural research centres continue to devote increasingly scarce resources towards the development of technologies intended to increase farm production through stemborer and striga management but with little impact (ECAMAW 1998). In contrast, with the funding from the Gatsby Charitable Foundation, the International Centre of Insect Physiology and Ecology (ICIPE) (www.icipe.org) and collaborative partners have developed alternative strategies for stemborer and striga management using technologies appropriate to resource poor farmers and hence have shown a high adoption rate and spontaneous technology transfer by farmers, resulting in significant impact on food security by increased farm production in the region (www.push-pull.net).

The R&D work, undertaken as a joint collaborative effort with the Kenya Agricultural Research Institute (KARI), the Ministry of Agriculture and Rural Development (Kenya), and the Rothamsted Research in UK), is based on novel strategies that combine a 'push-pull' tactic for controlling stemborers, on one hand, and *in situ* suppression and elimination of striga, on the other, in maize-based farming systems (Khan et al. 2000; 2001; 2002). The 'push-pull' tactic involves trapping stemborers on highly susceptible trap plants (pull) whilst driving them away from the maize crop using repellent inter-crops (push). The striga control tactic is based on the use of inter-crops that act through a combination of mechanisms, including abortive germination of seeds that fail to develop and attach on the host (Tsanuo et al. 2003). Plants, which repel stemborers as well as inhibit and eliminate striga, have also been identified. These strategies undertake a holistic approach to understanding and utilizing chemical ecology and agro-biodiversity for stemborer and striga management (Khan et al. 2002).

Although 'push-pull' strategy for controlling insect pests was originally described by Pyke et al. (1987) to control *Heliothis* sp. in cotton, the strategy used an attractant trap crop and a chemical feeding deterrent. Later, Miller and Cowles (1990) devised the term 'stimulo-deterrent diversion' strategy for 'push-pull' and used the system for protection of onions from the onion fly. They proposed to attract gravid females to onion culls and to protect the main crop with a combination of a feeding deterrent and a toxin. However, in both cases no consideration to natural enemies was given and a chemical deterrent or toxin was used to repel or kill the pest. The present 'push-pull' strategy does not use any chemical deterrents or toxins, but uses repellent plants to deter the pest from the main crop. The trap plants, used in the present push-pull strategy, have inherent ability of not allowing development of trapped stemborers (Khan et al. 2000). The strategy also attempts to exploit the natural enemies in the farming system (Khan et al. 1997 a, b).

Plants that have been identified as effective in 'push-pull' tactics include Napier grass (*Pennisetum purpureum)*, Sudan grass (*Sorghum vulgare sudanense)*, molasses grass (*Melinis minutiflora)*, silver leaf desmodium (*Desmodium uncinatum*) and greenleaf desmodium (*Desmodium intortum*). Napier grass and Sudan grass have shown potential for use as trap plants, whereas molasses grass and silverleaf desmodium repel ovipositing stemborers. Molasses grass, when intercropped with maize, not only reduced infestation of the maize by stemborers, but also increased stemborer parasitism by a natural enemy, *Cotesia sesamiae* (Khan et al. 1997b). In addition, *Desmodium*, when intercropped with maize, suppresses and eliminates striga (Khan et al. 2002). All four plants are of economic importance to farmers in eastern Africa as livestock fodder and have shown great potential in stemborer and striga management in farmer participatory on-farm trials. These innovations have found ready acceptance among the small-scale and medium-scale farmers in Kenya (Table 1).

Benefits of 'push-pull' strategies. The habitat management strategies based on the 'push-pull' and striga suppression-elimination tactics, conducted in seven districts in Kenya and 3 districts in Uganda, have helped more than 1,500 participating farmers to increase their maize yields by an average of 20% in areas where only stemborers are present and by more than 50% in areas where both stemborers and striga are problems (Table 2).

Increased maize yields accompanied by the following additional features of the technology have contributed in no small part to the high farmer adoption rates:

- **Food Security**. The contribution of 'push-pull' strategies to food security cannot be over-emphasized. Intercropping or mixed cropping of maize, grasses and fodder legumes has enabled farmers in Kenya to increase crop yields and thus improved food security and benefit-cost-ratio (Table 3). This feature of the technology is suitable to mixed farming conditions, which are prevalent in eastern Africa. In recent years, the contribution of 'push-pull' strategies to human nutrition could be particularly important in most of the farming systems in eastern and southern Africa. The striga and stemborer menace has seriously and negatively affected sorghum farming in arid and semi-arid areas to the extent that farmers in those areas cannot produce adequate food for themselves. Therefore, ICIPE and its partners are developing similar 'push-pull' system for sorghum farmers (Table 4). Please see photographs at http://www.push-pull.net/sorghum_pp.htm

- **Dairy and Livestock Production.** The 'push-pull' and striga suppression-elimination tactics have contributed significantly to increased livestock production (milk and meat) by providing more fodder and different crop residues, especially on small farms where competition for land is quite high. For example, the Suba District of Kenya, a milk-deficit region on the shores of Lake Victoria, produces only 7 million liters of milk, far short of the estimated annual demand of 13 million liters, and has mostly indigenous livestock (zebu). In this district, a major constraint to keeping improved dairy cattle for milk production is the unstable availability and seasonality of feed, often of low quality. The habitat management strategy, adopted by more than 350 farmers in this district, has facilitated efforts by agricultural authorities to promote livestock production and improve milk supply there by integrating crop and fodder production and more and quality feed available for cattle. Through the combined effort, the number of improved dairy cattle in the district has increased from 4 in 1997when on-farm trials with this project were initiated, to more than 400 in December 2002. With this rate of growth in numbers of improved dairy cattle in the district, based almost entirely on the increased availability of forage from the Habitat Management strategy, it is expected that Suba will be self-sufficient in milk production by the year 2010.

- **Soil Conservation and Fertility.** Soil erosion and low fertility are very common problems in eastern Africa. The habitat management strategy has placed some of the existing practices to address these problems in a multi-functional context. For example, the cultivation of Napier grass for livestock fodder and soil conservation, now assumes an additional rationale as a trap plant for stem-borer management. Similarly, desmodium, a nitrogen-fixing legume, already grown for improving soil fertility (Fig.1) and for quality fodder, is also an effective striga suppressant.

- **Enhancing Biodiversity**. The innovation is contributing to the promotion and conservation of biodiversity. The habitat management approach embodies maintenance of species diversity. A recent study with the University of Haifa, Israel has demonstrated that the numbers of beneficial soil arthropods in maize-desmodium fields were significantly higher than the numbers in maize monocrop (Table 5). The destruction of biodiversity is linked to the expansion of crop monoculture at the expense of diverse vegetation. Similarly, in a field trial conducted in 2001, both diversity and population of natural enemies on maize in a 'push-pull' system was significantly more than on maize monocrop (Fig. 2)

- **Protecting Fragile Environments.** Existing evidence indicates that higher crop yields and improved livestock production, resulting from habitat management strategies, has the potential of supporting many rural households under existing socio-economic and agro-ecological conditions. Thus, there will be less pressure for human migration to environments designated for protection. Moreover, farmers using such strategies have less motivation to use of pesticides (Table 1).

- **Income generation and Gender empowerment.** The habitat management strategies have shown promise of not only significantly enhancing farm incomes but also gender empowerment through the sale of farm grain surpluses, fodder and desmodium seed (Table 6). In addition to targeting women farmer-groups, improved rural productivity and quality of life is expected to impact youth groups in the rural areas and help to stem rural-urban migration.

Conclusion

The 'push-pull' approach described here will expand into Kenya, Uganda, Tanzania and Ethiopia for stemborer and striga control. A pilot programme has been initiated in southern Africa, addressing stemborer control in the arid and semi-arid areas of the Northern Province of South Africa. However, each region has, in addition to varying climatic conditions and use of alternative cultivars, some differences in crops that must be taken into account. Whereas maize is the main crop in the farming systems in Kenya and Uganda, sorghum, pearl millet and maize are planted in southern Africa. Pest management options in this region are affected by low rainfall, the limited extent to which cattle are kept

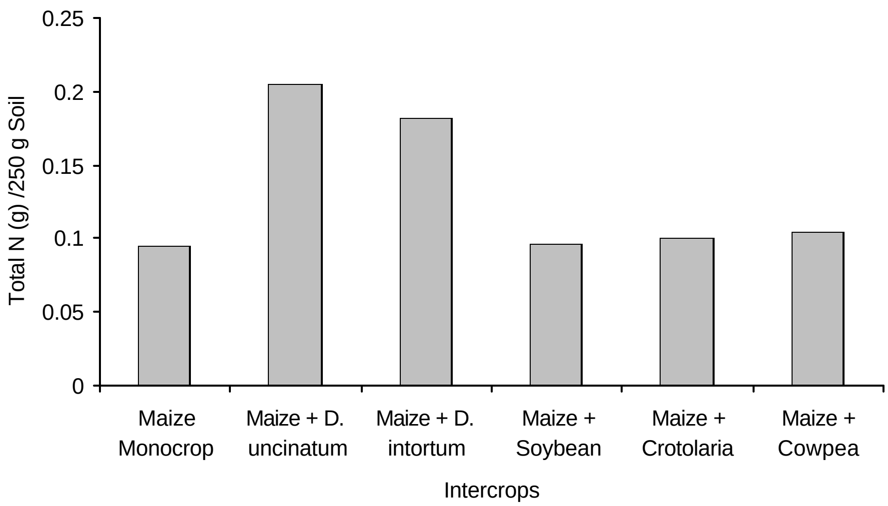
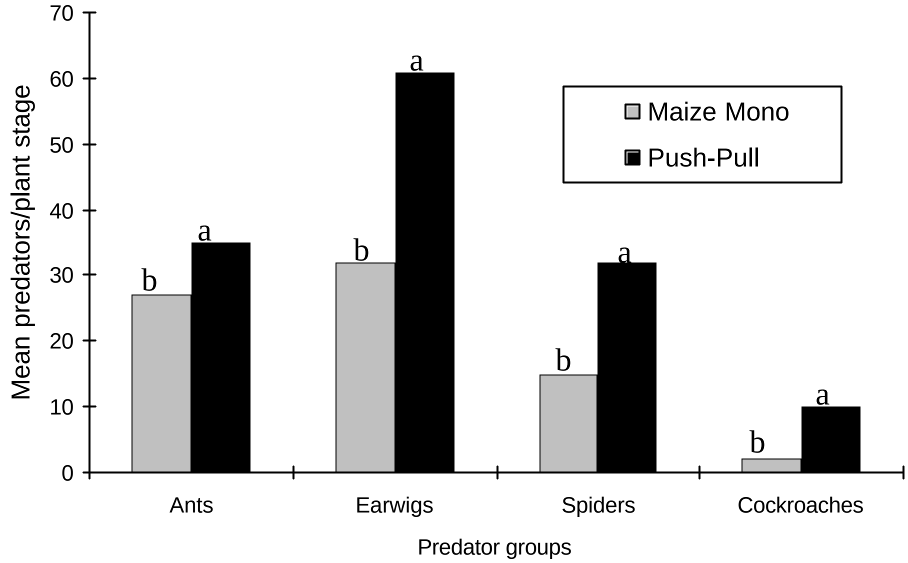


Figure 1. Total Nitrogen Fixed in Soil with Different Intercrops



Means followed by different letters are not significantly different (P<0.05)

Figure 2. Comparison of stemborer predators on maize plants in 'push-pull' and control fields (Lambwe, Kenya), 2001

and the fact that the cattle are largely free-grazing. However, wherever these approaches are developed for the specific needs of local farming practices and communities, it is essential that the scientific basis of the modified systems should be completely elucidated. Every effort will be made to ensure that technology transfer follows the incorporation of these practices into other regions of Africa.

The allelopathic mechanism was found to involve inhibition of development of haustoria of *S. hermonthica*. Work is ongoing to identify the compounds, released from the *D. uncinatum* roots, involved in suppression of the parasite. The sophisticated mode of action demonstrated here, when fully elucidated, may give more exploitable leads which are needed not only in subsistence agriculture but also to answer future world demands in agricultural production and in developing new approaches for molecular biology in *S. hermonthica*.

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