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Cumulative effects and economic benefits of intercropping maize with food legumes on *Striga hermonthica* infestation

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ABSTRACT

The parasitic weed *Striga hermonthica*, commonly known as striga, is a major biotic constraint to maize production in sub-Saharan Africa (SSA) where it causes serious food insecurity and poverty in smallholder farming communities. We previously discovered an effective control method for it involving intercropping cereals with fodder legumes in the genus Desmodium, commonly known as desmodium. The objectives of the current study were to evaluate cumulative effects of intercropping maize with the commonly grown food legumes on striga infestation, and to establish any economic benefits of the same. Treatments comprised maize plots planted in monocrop stands or intercropped with five different food legume species or desmodium. Intercropping maize with desmodium gave the most consistent and significant suppression of striga. Out of the food legume intercrops, only crotalaria, groundnut and greengram intercrops had significantly lower striga counts and only in some of the cropping seasons. Grain yields were consistently and significantly higher with desmodium intercrop, although they were also increased with food legume intercrops compared to maize monocrop, thus confirming superiority of intercropping with legumes over maize monocrop. Although production costs in terms of total labor and variable costs were significantly higher for the intercrops than for the maize monocrop, total revenue and net benefits were significantly higher in the former, especially for desmodium. The desmodium intercrop gave the highest economic benefits followed by crotalaria and greengram intercrops. These results confirmed the effectiveness of desmodium in suppressing striga and improving yields and economic returns to smallholder farmers. They also showed that it is profitable to invest in food legume intercrop systems, especially the crotalaria and greengram systems, and indicate that intensifying maize cropping systems through integration of these food legumes in combination with other approaches can contribute to an integrated management of striga and provide a more sustainable and profitable productive system to smallholder farmers.

1. Introduction

The parasitic weed *Striga hermonthica* Benth. (Orobanchaceae), commonly known as striga, is an increasingly important constraint to cereal production in sub-Saharan Africa (SSA), where it is estimated to affect cereal crops on over 21 million ha (Sauerborn, 1991; Gressel et al., 2004). This is partly because of the intensification of cereal-based systems in the region in response to the rising demographic pressures that has led to an increase in the area under continuous cereal mono-cropping and reduced the traditional fallow period that used to keep pressure of most weeds, including striga, at tolerable levels (Franke et al., 2006). Maize (*Zea mays* L.), the main staple and cash crop for millions of subsistence farmers in SSA, is one of the cereals most affected by striga, with most of the varieties grown in the region being susceptible to the weed (Kim et al., 1985). Infestation by striga can cause severe yield losses of up to 100% depending on the level of susceptibility of the specific host genotype (Berner et al., 1995). These losses are estimated to be more than US$7 billion in SSA annually (Berner et al., 1995) and affect livelihoods of approximately 100 million people (Kanampiu et al., 2002). Striga infestation is more severe in agricultural systems where there is poor soil fertility and low inputs of fertilizer (Sauerborn, 1991; Debra et al., 1998), making it a serious problem for the resource-poor subsistence farmers in the region (Gurney et al., 2006). However, effective control of the parasite remains elusive due to low uptake of control approaches, the parasite's high reproductive ability and longevity of its seeds, combined with a complicated mode of parasitism that occurs below ground.

Striga is an obligate hemi-parasite whose lifecycle is intimately linked with its host from which it derives moisture, photosynthates

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and minerals (Tenebe and Kamara, 2002) via a complex interchange of signals (Scholes and Press, 2008). Initiation of the host–parasite relationship takes place below ground where root exudates released by the host plant stimulate the germination of striga seeds. The seeds then produce a radicle and ultimately a haustorium to penetrate the root of their host (Van Ast and Bastiaans, 2006). Losses to crops are therefore caused by competition for these resources between host and parasites, and by phytotoxic substances released by the parasite that affect crop growth shortly after attachment of the parasite to the host plant even at low levels of infestation (Press et al., 2001). Striga is a highly prolific parasite, with estimates of 5000 to 85,000 seeds being produced by one single reproductive plant (Webb and Smith, 1996). These seeds can remain viable in the soil for over 10 years (Bebawi et al., 1984), which together with the complicated mode of parasitism makes control of striga difficult (Oswald, 2005). Consequently farmers often abandon fields under high striga infestation (Kroschel, 1999).

For effective control of striga use of an approach that provides a single mode of action may not be satisfactory and relevant to the wide diversity of biophysical and socio-economic environments in which farmers work (Franke et al., 2006). Additionally, the weed's genetic plasticity may allow it to adapt to individual control measures. There is therefore a need for an integrated control strategy that is flexible and robust enough to suit farmers' environments and practices (Debra et al., 1998). Furthermore, it should be low-cost to put it within the reach of smallholder farmers (Reda et al., 2005). Prevention of new seed production, reduction of the soil seedbank of infested fields, prevention of spread from an infested to non-infested soil and improvement of soil fertility are desirable objectives in an integrated striga management approach. Although a number of approaches have been developed in an attempt to address the objectives above, the rate of uptake by smallholder farmers has been limited due to a combination of both biological and socio-economic reasons (Oswald, 2005).

A number of legumes, commonly grown as intercrops in cereal-based cropping systems in SSA, have been implicated in the control of striga (Carson, 1989; Carsky et al., 1994; Khan et al., 2000, 2002; Tenebe and Kamara, 2002; Khan et al., 2006a,b). Indeed one of the most successful approaches for control of striga involves intercropping cereals with forage legumes in the genus *Desmodium*, commonly known as desmodium, in smallholder farmers' fields in eastern Africa (Khan et al., 2008a). This followed a serendipitous discovery during the development of a 'push-pull' strategy for control of stemborer pests in maize in Kenya involving systematic investigation of companion crops (Khan et al., 2000) where plots intercropped with silverleaf, *Desmodium uncinatum* (Jacq.), were observed to have significantly reduced emergence of striga. On the other hand, intercropping with food legumes has yielded mixed results, and therefore the objectives of the current study were to evaluate cumulative effects of intercropping maize with the most commonly grown food legumes in SSA on striga infestation, and to establish any economic benefits of the same. This would enable us to understand and exploit any potential role of food legumes in an integrated striga management approach for smallholder farmers, particularly in areas where livestock is not a major component of farming systems and where desmodium may not appeal to farmers in different socio-economic strata.

2. Materials and methods

2.1. Study site

These studies were conducted at the International Centre of Insect Physiology and Ecology (*icipe*), Thomas Odhiambo Campus, Mbita Point (0°25′ S, 34°12′ E), on the eastern shores of Lake Victoria in western Kenya, where striga is a serious limitation to maize cultivation (Khan et al., 2006a), and infests about 246,000 ha under maize (De Groote et al., 2008). The study was conducted between 2005 and 2012 during the long (March–August) and short (October–January) rainy seasons, covering a total of 16 cropping seasons. The Campus receives approximately 900 mm of rainfall per annum, with a mean annual temperature of 27 °C, and is located at an altitude of approximately 1200 m above sea level.

2.2. Plot layout and data collection

Plots measuring 5 by 6 m each were laid out in a completely randomized design in four replications following methodologies of Khan et al. (2007), and were separated by a 2-m buffer space. In each plot a striga-susceptible maize variety (a Western Seed Company Hybrid, WH505) was intercropped with one of six different species of legumes: cowpea [*Vigna unguiculata* (L.) Walp.] (Var. ICV2), crotalaria (*Crotalaria ochroleuca* G. Don), greengram [*Vigna radiata* (L.) Wilczek] (Var. Local), groundnut (*Arachis hypogaea* L.) (Var. Homabay), Greenleaf desmodium [*Desmodium intortum* (Mill.) Urb.] and beans (*Phaseolus vulgaris* L.) (Var. Local 'Nyayo') (all Fabaceae). Maize was planted at 75 cm between and 30 cm within rows, while food legumes were planted between the rows of maize. Desmodium on the other hand was planted through a drilling system in furrows between the rows of maize. A plot of monocrop maize was included as control. Two weeks after germination, maize plants were thinned to one plant per hill as is often the practice (Khan et al., 2006a). Desmodium, being a perennial legume was planted only once, at the beginning of the study, and was cut back at the beginning of subsequent cropping seasons while the other legumes were planted together with maize at the beginning of every cropping season. Phosphorus, in form of di-ammonium phosphate (DAP), was applied in each plot at planting at the rate of 60 kg/ha. Nitrogen was applied after thinning of maize, in form of calcium ammonium nitrate (CAN), at the rate of 60 kg/ha. Plots were kept weed free by hand-weeding, except for striga throughout the growing season. During the 8th, 10th and 12th weeks after maize emergence, 60 maize plants were randomly sampled in each treatment plot and the number of emerged striga counted from within a radius of 15 cm of each plant. At physiological maturity of both crops, height of each of 60 randomly selected maize plants was measured in each plot. All the maize plants and food legumes in each experimental plot were harvested and grain yields converted into tons per hectare after drying to 12% moisture content level. Maize stover and desmodium forage, two important fodder sources for the smallholder farmers in SSA, were dried to 18% moisture content and similarly weighed and each converted into tons per hectare. Additionally, yield advantage obtainable by growing maize in an intercrop set-up over a monocrop system was determined through partial land equivalent ratio (PLER), which was calculated using the formula below (Dariush et al., 2006).

$$\text{PLER} = \sum \frac{Y_{\text{mi}}}{Y_{\text{mm}}} \quad (1)$$

where Y_{mi} is the yield of maize in the intercrop, and Y_{mm} is the yield of maize in the monocrop.

2.3. Economic analyses

To evaluate any economic benefits of intercropping maize with the legumes, analyses were conducted during the long and short rainy season of 2005 and long rainy season of 2006. This was conducted using methodologies adapted from Khan et al. (2008b), where total labor costs (TLC), total non-labor costs (TNLC), total