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The impact of *Desmodium* spp. and cutting regimes on the agronomic and economic performance of *Desmodium*–maize intercropping system in western Kenya

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ABSTRACT

Low soil fertility, stemborers (particularly, *Chilo partellus*) and *Striga* weeds (*Striga hermonthica* and *Striga asiatica*) are major limitations to production of maize in western Kenya. The "Push–Pull" technology ("PPT") has been described as an appropriate innovative technology capable of addressing these constraints. The technology involves intercropping maize with *Desmodium* and planting Napier grass (*Pennisetum purpureum*) around the intercrop, but in the current study a modified PPT was used and Napier grass was not included. Field trials were conducted in two locations in western Kenya during 4 subsequent seasons to test the hypothesis that maize yield, the degree of *Striga* suppression and economic benefits of intercropping maize with *Desmodium* are affected by: (i) the related biomass production by different *Desmodium* species and (ii) the cutting regime of the *Desmodium*. Maize was intercropped with *Desmodium uncinatum* (Jacq.) DC, cv Silverleaf or *Desmodium intortum* (Mill.) Urb. cv Greenleaf, and treatments with sole maize (with and without urea) were included for comparison. To eliminate phosphorus (P) deficiency, all treatments received basal P. The first two *Desmodium* cutting events were fixed at land preparation i.e. at the start of every season, and 4 weeks later, following the recommended practice, while the third cutting was varied and conducted at 9, 12 or 18 weeks after planting maize. Maize yield in the *Desmodium*–maize intercropping system was only higher than sole maize without urea from the third season. This implies that when P is not limiting inclusion of *Desmodium* spp. into the maize cropping system would provide a substitute for inorganic N fertilizers to enhance crop growth and yield after *Desmodium* becomes well established. Cumulative maize grain yield over the four seasons with the *D. intortum* and *D. uncinatum* intercrops were 6.3 and 7.0, and 10.9 and 11.6 t ha^{-1} in Busia and Siaya, respectively, and significantly higher than or comparable to a maize monocrop (5.8 and 11.8 t ha^{-1}). Average net benefits from *Desmodium* intercropping over the four seasons were increased by 1290 and 918$ ha^{-1} relative to the maize monocrop in Busia and Siaya, respectively. Biomass yields were significantly higher for *D. intortum* than for *D. uncinatum*. Varying the time of the third *Desmodium* cutting had little effect on *Desmodium* biomass yields or maize grain yields in Busia, while in Siaya, *D. intortum* biomass yields were highest when cut at 12 weeks after planting. In the *Desmodium* intercropping systems, *Striga* counts were reduced by 95% in Busia and by 65–90% in Siaya with higher reductions when *Desmodium* was cut at 18 weeks after planting. In summary, the use of PPT provides robust and high economic benefits to smallholder farmers in western Kenya. The use of *D. uncinatum* with the third cutting at 18 weeks after planting is recommended, but can be modified according to the need for fodder without much effect on maize yield or revenue.

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1. Introduction

Maize (*Zea mays* L.) is an important cereal crop for most of sub-Saharan Africa (Pingali, 2001). Previous studies in western Kenya have shown that low soil fertility (Okalebo et al., 2006), African witchweed (*Striga* spp.), lepidopteran stemborers (*Chilo partellus* Swinhoe) and unreliable rainfall are major causes of low maize yields (De Groote et al., 2010; Odendo et al., 2001). Soil nutrient mining and the resultant soil fertility decline occur in most areas in Kenya, as observed by the negative N, P and K balance at the farm level (Smaling et al., 1997). These nutrient deficits are reflected in the overall low (<1 t ha^{-1}) and declining maize yields (Okalebo et al., 2006). However, survey in Siaya county has shown that yield increases from 0.5–0.7 to 1.4–1.6 t ha^{-1} can be achieved in western Kenya when improved maize varieties are used and fertilizers are applied (Odendo et al., 2001). The *Striga*-prone area forms a band around Lake Victoria in Western and Nyanza provinces of Kenya (De Groote et al., 2008). *Striga hermonthica* is estimated to infest about 200,000 ha of land and causes crop yield losses varying between 5% and 100% (Hassan et al., 1994; Parker and Riches, 1993). Stemborers occur in all major agro-ecological zones of Kenya and cause average crop losses of 13.5% countrywide and 16.6% in the Moist Mid-Altitude zone (De Groote et al., 2010).

Over the last two decades, research has provided a sound knowledge base on cropping systems, and crop and land management practices that increase food production while repressing the *Striga* spp. (Kanampiu et al., 2003). These practices consist of the use of one or several components, including the use of herbicide resistant/tolerant maize varieties (i.e. imazapyr resistant (IR) and Kakamega *Striga* Tolerant Population (KSTP)), rotation or intercropping with legumes that trigger suicidal *Striga* germination, application of fertilizer and organic inputs, irrigation and hand pulling (Kanampiu et al., 2003; Khan et al., 2002). Options for replenishing soil fertility and improving crop productivity in western Kenya include the use of mineral fertilizers, organic inputs (or their combination), phosphate rock, short duration fallows, N-fixing grain and forage legumes (Dahlin and Stenberg, 2010; Jama et al., 1997; Kifuko et al., 2007; Ndung'u et al., 2006; Ojiem et al., 2007; Okalebo et al., 2006). In some areas, the adoption of the proposed technologies has been high and positive impact has been reported; but in other areas adoption has been slow and uneven due to various socio-economic and environmental factors (Gachengo et al., 2004; Murage et al., 2011; Okalebo et al., 2006). To improve crop productivity in western Kenya, there is, therefore, need to practice integrated soil fertility management (ISFM) approaches (Vanlauwe et al., 2010); but given that pests significantly reduce cereal production in this region, ISFM can only be effective when used in combination with integrated pest management (IPM) approaches that reduce pest infestation and result in introduction of minimal toxic substances into the environment.

One promising integrated approach that accommodates the principles of ISFM and IPM is the "Push–Pull" technology (PPT) that uses a mixture of behavior-modifying stimuli to manipulate the distribution and abundance of insects. This strategy was established in 1987 as an approach for integrated pest management for control of *Helicoverpa* in cotton crops in Australia. In Kenya, the International Centre of Insect Physiology and Ecology (*icipe*) and partners developed PPT for control of stemborers and *Striga* weed. The technology involves intercropping maize with a stemborer moth-repelling legume, *Desmodium uncinatum* (Jacq.) DC., and planting Napier grass (*Pennisetum purpureum* (L.) Schumach.) around the intercrop, which attracts and traps the stemborer moths (Khan et al., 2000). However, in western Kenya, farmers have adapted the technology differently based on the available resources, land availability and farming systems. Thus, in the instances where land is limiting, soil fertility is of greater concern and stemborer is not a problem, Napier grass is left out (Farmers, pers comm.). In addition to the N-fixing capacity of *Desmodium* spp., chemicals released by its roots induce abortive germination of *Striga*, providing a measure of control of this noxious weed (Khan et al., 2002; Midega et al., 2010). Nitrogen fixed by the intercrops may be available to the associated cereal crop in the current growing season through direct N transfer (He et al., 2003) or as a residual N for the benefit of the succeeding cereal crops (Baijukya et al., 2006).

Napier grass and *Desmodium* are nutritious fodder/forage crops. *Desmodium* also offers a good cover to the soil that leads to improved soil moisture content and organic matter, and reduced weeds. In integrated crop–livestock systems, lack of quality feed and low dry matter intake are major constraints (Omore et al., 1996), and so *Desmodium* spp. can provide a highly nutritious fodder supplement. However, farmers may require fodder at different times during the season. But, subjecting *Desmodium* to different cutting regimes could have an impact on crop yields through effects on N fixation, transfer and mineralization, as well as changes in competition for light and nutrients between maize and *Desmodium*. Cutting leys has been shown to increase senescence and turnover of nodules and roots (Jarvis and MacDuff, 1989), and has also been shown to reduce root biomass compared with intact plants (Dahlin and Stenberg, 2010). The PPT has been demonstrated to be effective in controlling stemborers and *Striga* weed with concomitant maize yield increases under farmers' conditions in western Kenya (Khan et al., 2001, 2008a,b), but the effects of the *Desmodium* cutting regime on the performance of the system are not yet fully understood. Also, despite the relatively well-documented role of *D. uncinatum* in controlling cereal pests and increasing maize yields (De Groote et al., 2010; Khan et al., 2006) in western Kenya, little information exists on the more than 300 other *Desmodium* spp. with diverse morphological characteristics. Other *Desmodium* spp., including *Desmodium pringlei*, *Desmodium sandwicense* and *Desmodium intortum*, have shown similar effects as *D. uncinatum* on *Striga* suppression within the "Push–Pull" method (Khan et al., 2007a,b), but unlike *D. uncinatum*, they have not been tested widely in the farmers' fields. *Desmodium* species adapt differently to different environments, which also affects their production potential. Research shows that the quantity of N_2 fixed by the legume in a cereal–legume system depends on the species morphology and the effectiveness of N_2-fixing bacteria (Ofori and Stern, 1987). It is, therefore, of interest to evaluate the performance of PPT using a *Desmodium* species with a higher biomass yield potential such as *D. intortum* (Luck, 1972).

The objectives of this study were therefore to: (i) assess maize grain and *Desmodium* fodder yield in a *Desmodium*–maize intercropping system using two *Desmodium* spp.—*D. uncinatum* and *D. intortum*); (ii) assess how varying the *Desmodium* cutting regime impacts on maize production and *Striga* incidence and (iii) determine the economic viability of the different *Desmodium* spp. and cutting regimes.

2. Materials and methods

2.1. Study area

The study was conducted in western Kenya for two years (2009 and 2010). The area is densely populated with about 360 inhabitants km^{-2} (De Groote et al., 2008) and a large proportion of poor people (Central Bureau of Statistics, 2003). Most households predominantly grow maize on small land holdings and obtain average yields of about 1 t ha^{-1} (Odendo et al., 2001). The main cash crops are cotton and sugarcane, but horticulture and dairy farming are becoming increasingly important as cash income sources (De Groote et al., 2010). The experiments were installed in two fields