International Scholars Journals

Advances in Agriculture and Agricultural Sciences ISSN 2381-3911 Vol. 4 (11), pp. 001-006, November, 2018. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Potential application of *Hyptis spicigera* for biological control of *Striga hermonthica* infestation

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Accepted 13 February, 2018

Food situation has remained insecure and unpredictable in sub-Saharan Africa leading to high levels of cyclic famine and poverty. This has been exacerbated by perennial pest problems, which cause substantial pre- and post- harvest food grain losses. Production of cereal crops is threatened by *Striga hermonthica* weed known to infest an estimated 46000 ha of land in the traditional food producing areas in western and coastal Kenya. It is against this background that this study was designed to evaluate the efficacy of *Hyptis spicigera*–maize cropping systems on *S. hermonthica* infestation and maize grain yield and, generate a recommendation compatible with the target farmer dormains. Results showed that *Striga* counts were significantly (P < 0.05) reduced where maize was following fallow with *H. spicigera*. This was most effective in reducing *S. hermonthica* incidence and increased maize yield from 2.2 to 3.4 T/Ha. Intercropping maize and *H. spicigera* in the same plot at the same time negatively affected maize growth resulting in reduced maize yields. Indications were that root cuttings of *H. spicigera* stimulated *Striga* seed germination while their stubble (stem and leaves) reduced *Striga* seed bank in the soil. *Striga* seed bank analysis showed that *Striga* seed depletion increased with increase in *Hyptis* bushes with critical *Hyptis* seeding rate of 3 kg/Ha for maximum reduction in *Striga* seed bank. The findings of this study have implications for plant protection against *S. hermonthica* and improvement of cereal crop production in *Striga*-prone environments.

Key words: *Striga* Incidence, seeding rates, cropping systems, maize yield.

INTRODUCTION

Production of maize (*Zea mays*), sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), rice (*Oryza sativa,* L.) and sugar cane in Sub- Saharan Africa and Asia is threatened by *Striga* weed infestation. *Striga hermon-thica*, (Del) Benth, infests an estimated 46000 ha of land in the traditional food producing areas in western and coastal Kenya resulting in total failure or halving of crop yields. *Striga* spp. is an obligate hemiparasitic angio-sperm, which attaches to roots of a wide range of tropical cereals depriving them of water, soluble mineral salts and metabolites. The host often shows drought symptoms, resulting in total yield loss (Press et al., 1990).

The life cycle of *Striga spp.* is composed of five stages: germination, haustoria initiation, penetration of host tissue, physiological compatibility and parasite growth and maturation. Apart from normal seed germination requirements, *Striga* spp. requires a chemical stimulant for germination to occur and a second chemical signal to initiate haustorium, which connects *Striga* roots to its host for resource acquisition (Siame et al., 1993; Chidley and Drennan, 1987; Musselman, 1980). The fact that germi-nation stimulants are also found in non-host plants sug-gests that induction of germination in absence of a host root can be used to reduce *Striga* populations via suicidal germination (Rugutt, 1990). Although trap plants release chemicals that stimulate *Striga* seed germination they do not produce haustorial initiation signals, nor are they attacked by the parasite (Eplee, 1992).

Current *Striga* control measures include chemical con-trol, rotation with trap crop, soil fertility amendments, hand pulling, and intercropping (Kabambe et al., 2008).

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Search for resistant crop varieties is underway and promising. Most of these measures do not offer complete control and may require several seasons for substantial *Striga* reduction. An integrated approach to *Striga* control is considered most feasible for low input production of most developing countries. Such an approach would incorporate tolerant genotypes, agronomic practices to delay or reduce emergence, minimize seed return to soil, avoid maximum damage to the soil, and general enhancement of crop growth (Kabambe et al., 2008). It is therefore important to look for options that will help reduce witch weed pressure and enable good crop yields.

One of the recommended options is the use of trap-crops either in sole stands to decrease the *Striga* seed bank in the soil or as intercrops in maize to reduce attachment to the host and suppress emerged *Striga* plants. Three pasture legumes, *Mucuna gigantica*, *Stylosanthes guyanensis* and *Desmodium* spp. have been shown to be better *Striga* germination stimulant producers than maize and are potential trap crops (Ndung'u et al., 2000). In Integrated *Striga* Management (ISM) strategy called 'Push-Pull', a highly attractive trap plants like napier grass (pull) are planted around the crop stand which is intercropped with repellant (push) plant like *Desmodium* spp. The 'push-pull' strategy gave up to 15 - 20% increase in maize yield. Although soil shading and additional nitrogen contributed to reduced *Striga* infestation, allelopathic mechanisms associated with *D. uncinatum* was a major factor. Root exudates of *D. uncinatum* contain isoflavanones that stimulate germination of *Striga* and related constituents that inhibit lateral root growth (Tesso et al., 2006). Another successful ISM strategy was that maize or sorghum was intercropped with cowpea, and *Hyptis suaveolens* extracts was used to effectively control cow pea pod borer (*Maruca testulalis*) (Gbehounou, 2007).

Earlier studies have shown that *Hyptis* spp. Possesses exudates that stimulate *Striga* germination but not haustorium attachment (Onek et al., 2003). This explains why indigenous Acholi people of southern Sudan use *Hyptis* spp. as traditional trap crop for reducing *Striga* infestation in their farmlands. The same plant has been used to control grain storage insect pests such as *Tribolium* and *Sitophilus* spp. (Pendleton, 2007). This trap crop can form a valuable part of an ISM strategy for western Kenya since *Hyptis spicigera*, is a common herb within Lake Victoria basin, an area equally under *Striga* infestation (Githinji and Kokwaro, 1994). The major challenge is to develop a technological package that will help peasant farmers to effectively control *Striga hermonthica* infestation within a sustainable farming system by use of *H. spicigera*. Such a system would deplete the *S. hermonthica* seed bank in the soil. The objectives of this study were to evaluate the efficacy of *H. spicigera*–maize cropping systems on *Striga hermonthica* infestation and to establish appropriate cropping system and seeding rate for maximum *Striga* reduction and maize yields in infested fields.

MATERIALS AND METHODS

Experimental sites

In March 2006, four farmers' fields with history of *Striga* infestation were selected in Lambwe Division, Suba District and Oyugis Division Rachuonyo District, both in Western Kenya. During the 2006 long rains, the selected farmers' fields indicated initial high *Striga* infestation and therefore were appropriate for use as experimental sites. Each field site was measuring 150 x 150 m which was then subdivided into three blocks measuring 150 by 50 m. Each block was subdivided into plots measuring 6 x 4 m to take care of various treatments and replications. The first block was used for cropping system trials, while the second block was for *Hyptis* seeding rate trials and the third block was used for *Hyptis* seed multiplication.

Collection and preparation of *H. spicigera*

The initial seeds of *H. spicigera* were provided by Dr. L. A. Onek and multiplied at Kibos Field Station, Kisumu. *Hyptis* seeds were planted in pure stand and grown to maturity. After three months the bushes were harvested, dried and threshed to release clean seeds. The seeds were stored in bags for use in field experiments.

Field experiments

Effect of cropping systems on *striga* infestation and maize yield

The first block contained treatments for crop rotation trials only as follows: Maize following fallow with *Hyptis*; maize following weedy fallow; and maize following maize. The second block was designed for intercropping trials with the following treatments: Interrow with *Hyptis*; Intrarow with *Hyptis*; Samehill with *Hyptis*; and maize alone as control. After preparing plots in each block in April 2006, *Striga*-susceptible maize variety H511 was planted at a spacing of 75 x 30 cm at a rate of 1 maize seed per hole and about 5 *Hyptis* seeds per hole. Fertilizer was applied at a rate of 36 kg N ha^{-1} in the form of Diammonium Phosphate (18:46:0) such that each hole received 4.5 g of the compound fertilizer. The fertilizer was thoroughly mixed with soil before sowing maize seeds. Two maize seeds were sown per hill and grown to maturity. Stem borer and shoot-fly were controlled by application of Bullock and Furadan respectively at first weeding. The number of *Striga* plants emerging from each plot as well as maize growth and yield parameters were recorded on weekly basis from 7 to 12 weeks after planting (WAP). The data obtained was then subjected to statistical analysis.

Effect of *H. spicigera* seeding rates on *Striga* infestation and maize yield

A conventional seeding rate for similarly small seeds was used as a guide for determining the optimum seeding rate for *H. spicigera.* The seeding rate for sesame and finger millet ranges between 5.5 to 9.0 kg/Ha by broadcasting or drilling. On this basis, plots measuring 3.0 by 2.5 m were made to have 11 rows 30 cm apart. There were seven treatments and four replicates: 0, 1.0, 3.0, 5.0, 7.0, 9.0 and 11.0 kg/Ha. During planting, Hyptis seeds was mixed with fine sand in the ratio of 1:3 and drilled in each row, then covered with thin layer of soil (Plates 1c and 1d). Diammonium Phosphate (18:46:0) fertilizer was applied at rate of 60 kg P_2O_5/Ha . The *Hyptis* plants were grown to maturity and then harvested. The *Striga* seed bank analysis was done by soil elutriation method at Kibos *Striga* research facility. The data obtained was then subjected to statistical analysis.

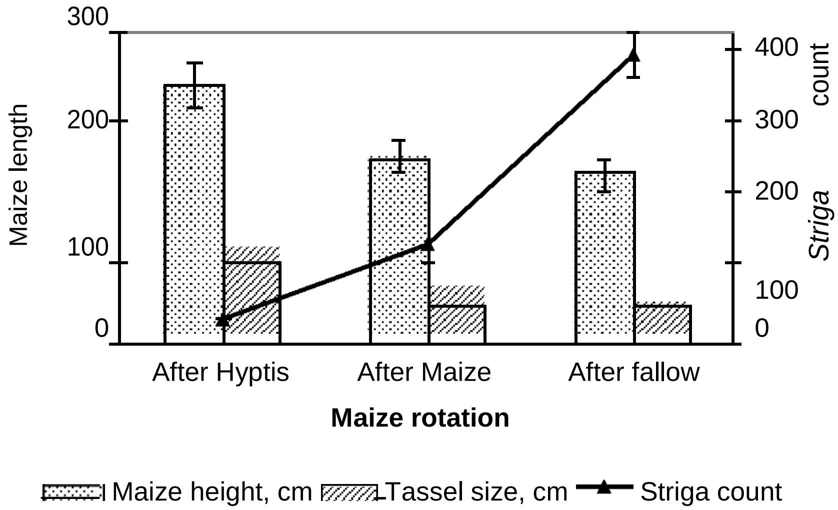

Figure 1. The effect of *Hyptis* on *Striga* incidence and maize growth under crop rotation.

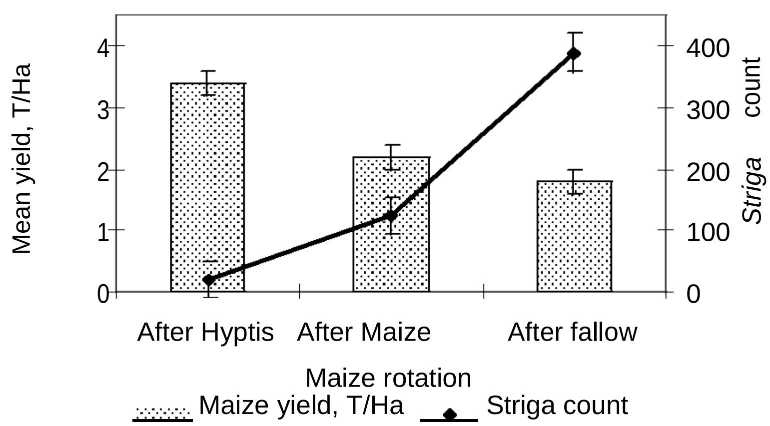

Figure 2. The effect of *Hyptis spicigera* on *Striga* incidence and maize yield under crop rotation.

RESULTS

Effect of cropping systems on *Striga* infestation and maize yield

The field experiments showed significant ($P < 0.05$) reduction in *Striga* incidence whenever maize followed *H. spicigera* in a rotation sequence. Maize following both weedy fallow plots and continuous maize had higher *Striga* counts (389.25 and 124.25 respectively) compared to plots where maize followed *Hyptis* in a rotation which had 20.25 *Striga* shoots. Maize grain yield (T/Ha) was 1.79 and 2.18 respectively in plots where maize followed fallow and where maize followed maize. Maize yield increased to 3.40 T/Ha in plots where maize followed *Hyptis* bushes (Figure 2). A higher yield realized was due to reduced *S. hermonthica* infestation and increased crop nutrient uptake leading to improved plant growth (Figures 1 and 2). Any intercropping maize with *Hyptis* did not give significant low *Striga* counts. Samehill intercrop had lowest yield and lowest maize height.

Effect of *H. spicigera* seeding rates on *Striga* infestation and maize yield

In both field sites, Oyugis and Lambwe, there was decrease in *Striga* seed bank with increase in *Hyptis* seeding rates (Figures 4 - 6). The decrease was significant in plots treated with 3 kg/Ha of *Hyptis* seeds, beyond which the decrease was not significant. This shows that the 3 kg/Ha is the critical *Hyptis* seeding rate for maximum reduction in *Striga* seed bank. Complete depletion of *Striga* seed bank requires at least three seasons of growing *Hyptis*

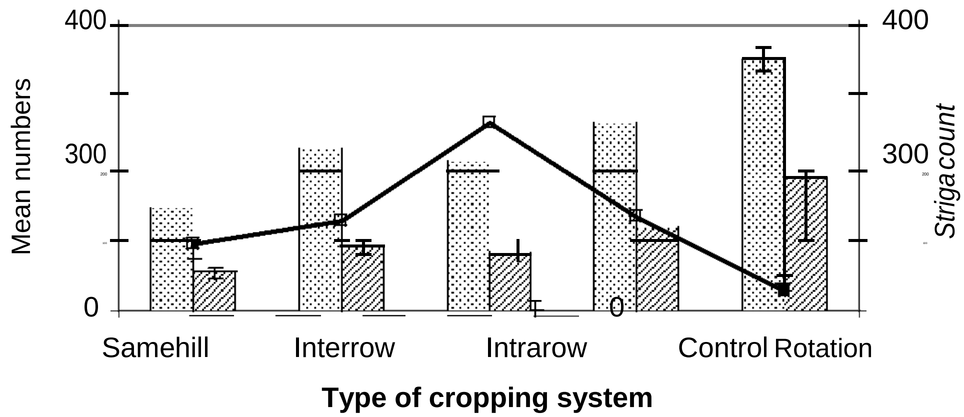

Figure 3. The effect of *Hyptis* bushes on *Striga* incidence and maize yield parameters under crop systems.

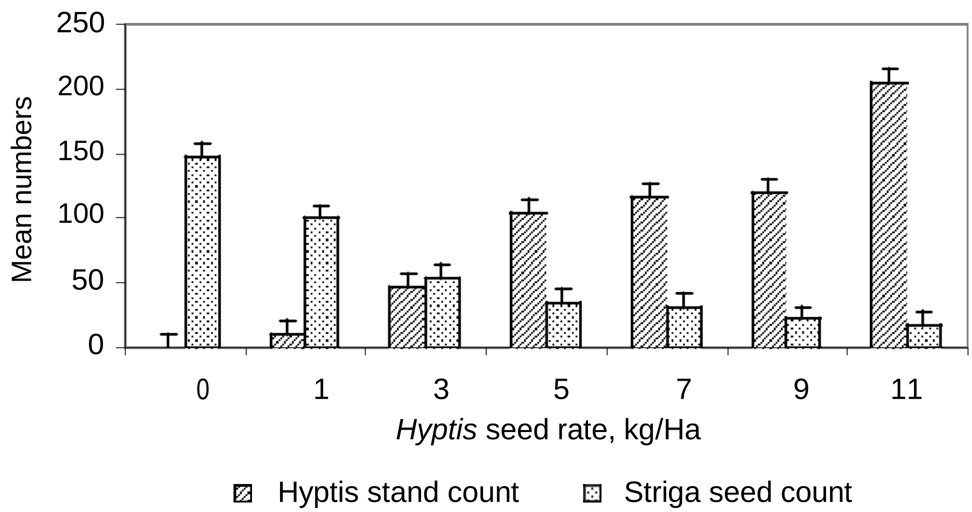

Figure 4. The effect of *Hyptis* seeding rate on *Striga* seed bank at Oyugis farmer's fields.

bushes. This is because only a fraction of *Striga* seeds are stimulated to germinate in presence of any biostimulant.

DISCUSSION

Chemicals with allelopathic potential are present (commonly in conjugated form) in almost all plants and in many tissues, like leaves, stems, flowers, fruits, seeds and roots. Under specific conditions, these chemicals are released into the environment (atmosphere or rhizosphere) by means of volatilization, leaching, decompose-tion of residues, and root exudation (Chou, 1990), in ample quantities and long persistence to affect a neighboring or successional plant. These processes are also affected by environmental complex, and are not easy to single them out (Einhellig, 1987). *H. spicigera* (Family Labiatae) contain *Striga* germination stimulants but is a non-host (Onek et al., 2003).

The results from *Hyptis*-maize cropping systems trials showed that *H. spicigera* have the potential to reduce damage by *S. hermonthica* in *Striga*-susceptible maize cultivar H511. *H. spicigera* may be changing maize root exudation patterns leading to reduced *S. hermonthica* emergence. Another likely mechanism by which *H. spicigera* could decrease *S. hermonthica* seed bank in the soil is through suicidal germination since *H. spicigera* is a non-host stimulant. The low yields and poor maize development observed in all intercropping systems is due to competition for nutrients between maize and *Hyptis* and therefore behaved as a weed. The high *Striga* incidence could be explained by germination resulting from stimulation by both maize and *Hyptis*.

Maize yield obtained in maize following *Hyptis* rotation represents 55% increase from continuous sole maize. These results compare very well with other studies where 28% yield increase was obtained after 1 year's rotation where maize followed soybean, cowpea or groundnut

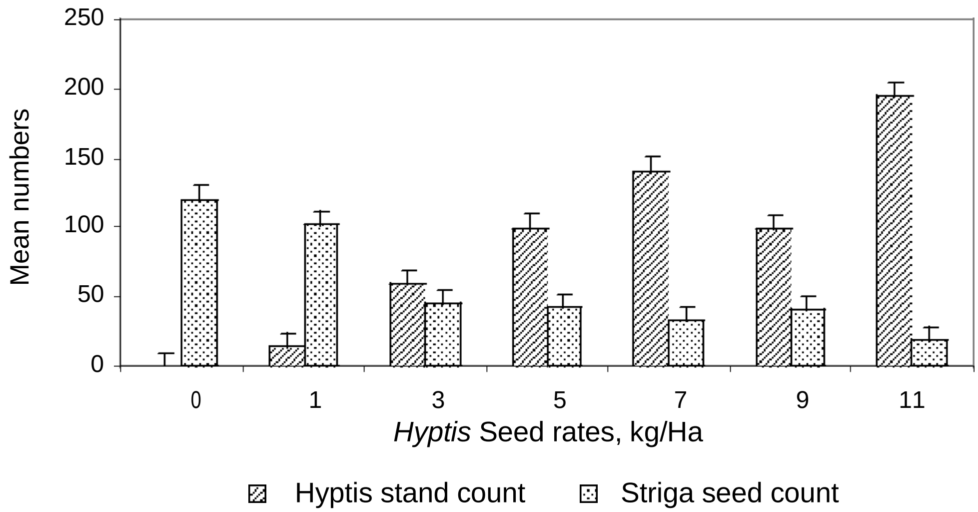

Figure 5. The effect of *Hyptis* seeding rate on *Striga* seed bank at Lambwe farmer's field.

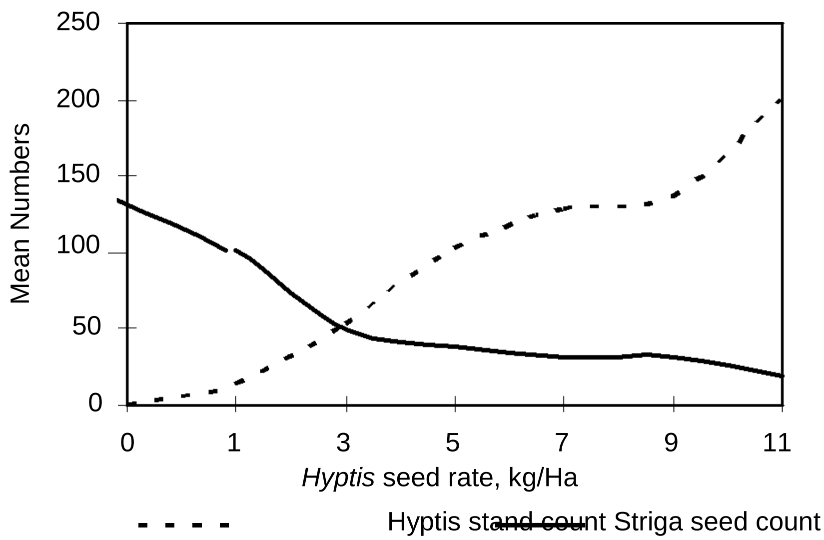

Figure 6. The relation between *Hyptis* population and *Striga* seed bank in farmer's field.

and 56% increase after two years (Kureh et al., 2006). Earlier studies by Odongo and others gave (2001) recommended *Striga* –tolerant maize KSTP94 which gave between 3.5 - 4.4 T/Ha grain yield where H512 gave only 2.0 T/Ha, but this has been matched by use of *Hyptis*-maize rotation which gave 3.5 T/Ha. According to Manyong and others (2007), the average yield increase (T/Ha) of maize under different *Striga* control technologies are: IR maize (2.25); *Striga*-resistant maize with legume (2.23); *Striga*-resistant maize without legume (2.25); Intercropping with legumes followed by *Desmodium*/cassava (1.65); and Maize-*Desmodium* strip-cropping (Push-pull) (0.83). Comparatively, *Hyptis* -maize rotation was capable of increasing maize yield by 1.4 T/Ha.

These results are in agreement with other studies of intercropping maize with legumes such as cowpea, groundnut, field bean and bambara nut, soybean (Musambasi et al., 2002; Kureh et al., 2000) and fodder legumes such as *M. gigantica, S. guyanensis and Desmodium* spp. (Ndungu et al., 2000) which are also *Striga* trap crops. Most researchers strongly recommend intergrated approaches in which use of pre-emergence herbicide, fertilizer, improved seed variety as well as sequence rotation with legumes, and intercropping with trap crops to reduce *Striga* seeds in the soil and improve fertility (Kabambe et al., 2008). Technical feasibility and socio- economic acceptability of some of the integrated *Striga* control packages (ISCOPA) at farmers' level have been confirmed (Aliyu et al., 2004).

Conclusion

Sequence rotation with *H. spicigera* was most effective in reducing *Striga hermonthica* incidence especially where maize followed *H. spicigera*. However, intercropping maize and *H. spicigera* indicated negative effects on maize growth and development, leading to lower yields. While the roots of both *H. spicigera* and maize were shown to stimulate *Striga* seed germination, the stubble (stem and leaves) also had a positive effect in the reduction of *Striga* seed bank in the soil. The observations reported here not only have implications for plant protection against *S. hermonthica* but also for management of the soil ecosystem since *Hyptis* litter as humus could also increase soil fertility, soil aeration and its bushes and mulch would control soil erosion.

The success of this new *Striga* control method requires an integrated approach and a collective involvement of the whole farming community. These findings show very strong extension potential. Up-scaling of the practice and large scale demonstration to involve more farmers should be carried out during the expansion phase to confirm the practicability, adoptability and sustainability of the new technology, as well as to validate findings by follow-up trials. Cost-benefit analysis for one farming year will also add value to the new technology. This involves assessing costs of input versus output, as well as comparing existing *Striga* control technologies with this new one. Finally, processing of the new technology for national performance trials (NPT) needs to be done.

ACKNOWLEDGEMENTS

Funding was provided by African Institute for Capacity Development, AICAD, to whom we are grateful. Our thanks are also due to, Egerton University, NALEP Extension Officers, farmer teachers and colleagues.

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