Sustainable Agriculture Research; Vol. 2, No. 2; 2013
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

Striga Infestation in Kenya: Status, Distribution and Management Options

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Received: August 13, 2012 Accepted: September 28, 2012 Online Published: January 10, 2013

doi: 10.5539/sar.v2n2p99 URL: http://dx.doi.org/10.5539/sar.v2n2p99

Abstract

Striga spp. is considered to be the greatest biological constraint to food production in sub-Saharan Africa, a more serious problem than insects, birds and plant diseases. They are among the most specialized root-parasitic plants inflicting serious injury to their host depriving them water, minerals and photosynthate. The greatest diversity of *Striga* spp. occurs in grassland. However, *Striga hermonthica* mainly occurs in farmland infecting grasses. The parasite devastating effect is accomplished prior to its emergence from the soil. It may cause yield losses in cereals ranging from 15% under favourable conditions to 100% where several stress factors are involved, thereby affecting the livelihood of millions of resource-poor farmers. Piecemeal approach to address one aspect of *Striga* problem at a time has been a setback in technology transfer to producers. Future *Striga* control programs should not be conducted separately, but should rather be conducted in an integrated approach that combines research talents of various institutions. This will facilitate collaborative research and achieve qualitative interaction between stakeholders, which can easily produce reliable technologies that are practical and available to farmers. *Striga* being a pervasive pest, time is of essence in controlling it. There is an urgent need for the establishment of policies to promote, implement, and ensure a long-term sustainable *Striga* control program.

Keywords: control options, genetic diversity, occurrence, *S. hermonthica,* Kenya

1. Introduction

Striga, commonly known as witchweed, is the most economically important parasitic weed seed plant in the world. It is a genus of 28 species of parasitic plants that occur naturally in parts of Africa, Asia and Australia. The genus is now classified in the family of Orobanchaceae although earlier authors placed it in Scrophulariaceae (Gethi et al., 2005). Even though most *Striga* spp. do not affect agricultural production, some have devastating effects on crops particularly those planted by subsistence farmers (Mohamed et al., 2001; Westerman et al., 2007). The major agricultural *Striga* species are *Striga hermonthica* (Del.) Benth and *S. asiatica* (L.) Kuntze infecting cereals (maize, sorghum, millet and upland rice), and *S. gesneriodes* (willd.) Vatke legumes (cowpea) and tobacco. Other species such as *S. forbesii* (Benth.) and *S. aspera* (Willd.) Benth have been reported to have sporadic effects on cereal crops in their limited locations (Parker, 2009). Crops such as wheat (Ejeta, 2007) and napier grass (Atera & Itoh, unpublished data, 2012) previously unaffected by *Striga* are now showing serious infestation in Sahel.

Striga hermonthica problem has been in existence as early as 1936 in the fields of farmers within Lake Victoria Basin, western Kenya (Watt, 1936; Khan et al., 2006). During the last 20-30 years, it has attained devastating proportions due to cereal mono-cropping (Oswald, 2005). The parasite is reported to be infecting about 217,000 ha in Kenya, causing annual crop loss of US $53 million (Woomer & Savala, 2009). These losses largely depend on *Striga* density, host species and genotype, land use system, soil nutritional status and rainfall patterns (Atera et al., 2012a). The most affected are the poor subsistence farmers, who are not aware of the threat that *Striga* poses to their land quality and food security as the weed continues to increase its soil seed bank and spreading to new areas.

A survey conducted in the Sudan savannah zone of Ghana showed that an average number of 9,384 seeds m^{-2} was found in the Land that had been returned to cultivation after fallow. However, some fields had seeds in excess of 14,900 seeds m^{-2} (Abunyewa & Padi, 2003). Van Delft et al. (1997) reported that a single *Striga* plant can produce up 4,827 seeds, excluding an approximate similar amount of seeds present in maturing capsules in western Kenya. They estimated the average number of seeds produced per mature *Striga* seed capsule to be 1,188. According to Woomer and Savala (2009), *Striga* has infected farmer's fields in western Kenya with an average of 161 million seeds per ha resulting in three parasitic stems per maize plant. Other studies in the region showed that *Striga* density was at least 14 plants per m^2 (MacOpiyo et al., 2010). These results imply that only a few *Striga* plants are required to make cereal production unsustainable in this region.

The purpose of this paper, therefore, is to examine the incidence of *Striga hermonthica* in Kenya and research achievements on its control. Some of the concepts in this paper will be drawn from our research of seven years in *Striga* infestation and occurrence, and cereal production in western Kenya. Agricultural production and costraints that limit its productivity will be assessed. A review on genetic diversity of *S. hermonthica* and its related species will be highlighted. Finally, the achievements of research on *Striga* control options available for farmers and their potential applicability will be discussed.

2. Agriculture and Distribution of *Striga* in Kenya

2.1 Land Use

The agricultural sector in sub-Saharan Africa is the key source of food, incomes, employment, and more often, foreign exchange. In Kenya, agriculture is an important economic activity and accounts for approximately 26% of GDP (Gok, 2010). It is a major contributor to foreign exchange earnings; even though less than 8% of the land is used for crop production. The land suitable for cultivation is about 20%, of which only 12% receive adequate rainfall for agricultural production and about 8% is regarded as medium potential land. The rest of the land is arid and semiarid. Farming in Kenya is carried out by small scale holders with limited technology who own not more than two hectares. These small farm production, operated by about three million farming families, account for 75% of total production in Kenya (Gitau et al., 2009). It is estimated that about 80% of the workforce in the country is engaged in agriculture/food processing.

2.2 Crop Production

The major food crops grown in Kenya are maize, sorghum, sweet potatoes, wheat, rice, beans, finger millet and cassava (Taylor, 2009; Atera et al., 2012b). According to FAO (2006), cereal yield in SSA increased by only 29% between 1961 and 2005 compared to 177% in Asia and 144% in Latin America. On the other hand however, in the same period the population grew by 216% in the SSA (United Nations Population Division, 2007). The implication of this statistics is that production of cereals in SSA has to be increased to feed the growing population. In Kenya, cereal consumption was approximately 3.9 million tonnes (Ministry of Agriculture, 2010) while the production was 2.9 million tonnes in 2009 (Table 1). A preliminary forecast by FAO showed that Kenya needs to import 2.3 million tonnes of cereals to bridge a production deficit over 2011/12 cropping season. Cereals play a central role for food supply but its production has lagged behind. The production capacity of the country's food systems has not kept pace with the surging demand for food. The low yield recorded in the country is due to constraints of nutrient depletion, loss of organic matter and drought. Production of cereals is also negatively influenced by incidence of pests and diseases such as bird damage, leaf blight and the parasitic weed *Striga*.

2.3 Food Security

Food security situation in Kenya has deteriorated significantly under the umbrella of business-as-usual scenario which calls for anything short of a revolution. The food shortage trends have to be reversed by all means through appropriate agricultural technologies including replenishing soil fertility, use of certified seeds, utilizing Good Agricultural Practices (GAPs), reducing weed soil seed banks, disease and pest pressures (Bruce, 2010). Emphasis should not only be laid on technology transfer, but also on policies that will achieve sustainable productive growth and reduce food insecurity. It is absolutely essential that any interventions to increase crop production must be focused on the farmers. In addition, farmers should be empowered to participate as equal partners in development of new technologies that will fit into their farming systems. *Striga* weed undermines the struggle to attain food security, and so its control must be addressed by all means.

In Kenya, food security means maize (*Zea mays* L.) production. It is regarded as a source of food in the entire nation and produced by almost every farmer. In addition, some farmers consider it as a source of income. Maize is life to some communities in Kenya because of its famous use to prepare the stable dish "*ugali*". Unfortunately, the area which is considered to be the grain basket of the country is heavily infested by *Striga* (Figure 1), reducing yields of farmers' dependence by 30-100% (Bruce, 2010).

Table 1. Cereal production and consumption in Kenya in 2009

Crop	Area under crop cover (ha)	Production (tons)	Consumption (tons)
Maize	1,885,071	2,442,823	3,240,000
Wheat	131,594	219,301	96,480
Rice	21,829	42,202	410,000
Sorghum	173,172	94,555	81,000
Finger millet	104,576	56,417	40,000

Source: Ministry of Agriculture, Kenya, 2010.

2.4 Origin and Occurrence of Striga

It is believed that *Striga hermonthica* and *S. asiatica* originated in the Nubian hills of Sudan and Semien mountains of Ethiopia. These areas are also known to be the origin of sorghum and pearl millet which are readily infected by the witchweed (Ejeta, 2007). *S. gesnerioides* may have originated in West Africa. Over the years, *Striga* has spread to other parts of sub-Saharan Africa through the activities of man.

There are nine (9) *Striga* species found in Kenya (Table 2). Among them, *S. hermonthica* is considered to be the most dangerous and common particularly in the densely populated regions of Nyanza and Western Provinces of Kenya (Figure 2) (Dogget, 1965; MacOpiyo et al., 2010). *S. asiatica* is predominantly found in the coastal region infecting upland rice (Gethi et al., 2005) and exists sporadically in Isiolo, Busia and Naivasha (Mohamed et al., 2001). The species that is adapted as a pest of legume crops, *S. gesneriodes*, has a wide geographical distribution in Kenya compared to the other species. It occurs as far as Kilifi (Coastal province of Kenya) spreading to Homa hills (Nyanza province, western Kenya) infecting cow pea.

2.5 Economic Importance of Striga

Striga infestation causes a loss of 30-50% to Africa's agricultural economy on 40% of its arable land (Amudavi et al., 2007; Hearne, 2009). A survey conducted in 30 communities in Borno state, northern Nigeria, indicated that farmers' rated *Striga* infestation as the leading priority constraint together with low soil fertility to crop production (Dugje et al., 2006). Similar surveys (Weber et al., 1995; Kim et al., 1997) showed *S. hermonthica* as a serious problem in Guinea savanna of Nigeria and yield losses ranged from 10 to 100%. In western Kenya, a survey of 83 farms revealed that 73% of the farms are infected with *S. hermonthica* (Woomer & Savala, 2009). The average yield loss due to *Striga* is 1.15, 1.10 and 0.99 tons per hectare for maize, sorghum and millet, respectively (MacOpiyo et al., 2010). However, the damage can reach as high as 2.8 tons per ha in maize and sorghum in some locations with high *Striga* densities (Andersson & Halvarsson, 2011). The loss represents 12.3% of the 2.4 million metric tonnes of maize that Kenya produces annually. This translates to about 39.6 kg of maize loss per capita, amounting to about 20% of a typical person's annual food requirement. Clearly, this shows the consequences of *Striga* infections are severe rendering small scale farmers helpless and often bewildered. It requires innovative and focused actions to assist them to reclaim health of their soil to overcome this agricultural scourge.

Figure 1. *S. hermonthica* infection in Busia, western Kenya: (A) Maize–groundnut intercrop with heavy infestation; (B) Reduction of yield in maize under *Striga* infestation

Table 2. *Striga* spp. distribution and occurrence in Kenya

Striga species	Host plants	Occurrence area
S. asiatica	Maize, rice, sorghum, pearl millet, finger millet, sugar cane, wild grasses	Kilifi, Isiolo, Mathews range, Alupe, Daka Chom, Kiunga
S. bilabiata	Wild grasses	Naivasha, Chyulu hills, Rumbia, Kahawa, Mathews range
S. elegans	Wild grasses	Nairobi, Loitokitok, Laikiapia, Rumuruti
S. forbesii	Sorghum, rice, maize, sugar cane	Narok, Mara plains, Kipini, Chyulu hills, Uasin Gishu plateau, Trans Nzoia
S.gesnerioides	Cow pea	Kilifi, Buna, Homa hills, Rongo, Nairobi, Naivasha
S. hermonthica	Maize, rice, sorghum, pearl millet, finger millet, sugar cane, wild grasses	Alupe, Churaimbo, Miwani, Bungoma, Kendu, Migori, Kuria, Nyamira, Siaya, Homabay
S. latericea	Sugar cane, wild grasses	Samburu, Mariakani, Kwale, Voi, Machakos, Sultan Hamud, Kilifi, Mwea
S. lutea	Wild grasses	Kwale, Shimba hills, Embu, Chyulu hills
S. pubiflora	Sugar cane, wild grasses	Kwale, Shimba hills, Voi

Source: Mohamed et al., 2001; Gethi et al., 2005; Khan et al., 2007; De Groote et al., 2008; Authors' own observations.

3. Genetic Diversity of *Striga* strains

The relatedness of species is commonly assessed by morphological characters. However, reliable closeness of parental species has been evaluated according to the level of successful hybridization and fertility of the resultant progeny (Murray et al., 1993). Based on their morphological similarities, it has been suggested that *Striga* species have formed complex groups (Aigbokhan et al., 2000). Some of these species such as *S. hermonthica* and *S. aspera* are found in the same locality, parasitizing the same cereal crops and wild grasses, sharing insect pollinators and can be intercrossed to produce seeds. Mohamed et al. (2007) proposed that there are several factors that have contributed to genetic diversity in *Striga*: (a) persistent seed bank of several generations of populations; (b) hybridization; (c) broad geographic distribution; (d) long distance dispersal and (e) locally adapted host races. Among these factors geographical distribution appears to play the greatest role in determining genetic differences in the species (Aigbokhan et al., 2000).

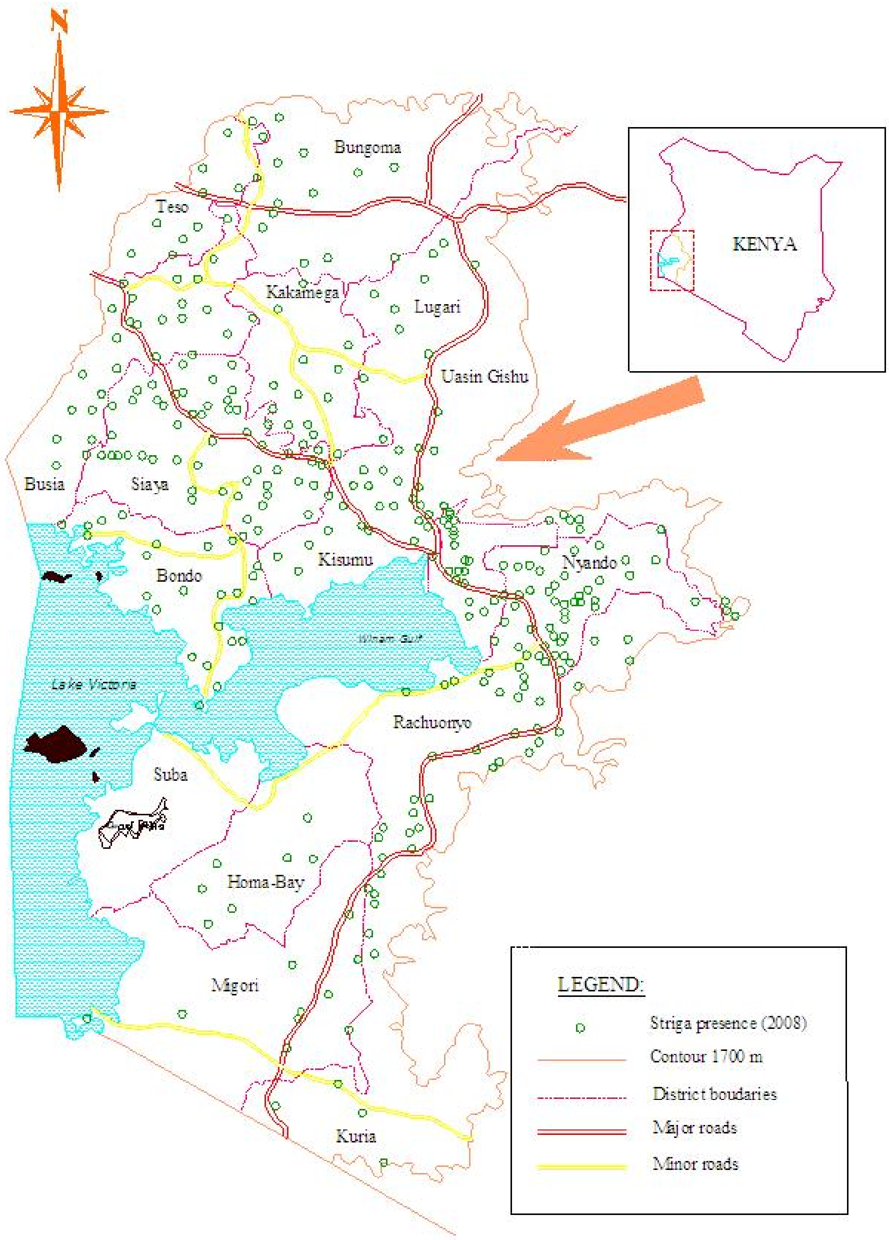

Figure 2. Part of western Kenya map showing *Striga hermonthica* infections (De Groote et al., 2008; Authors' own observations)

Considering the wide range of distribution of *Striga* spp., limited studies on genetic diversity have been conducted in Kenya (Gethi et al., 2005). However, recent molecular advancements have provided the necessary tools that can be used in *Striga* diversity studies. These include polymerase chain reaction (PCR) and randomly amplified polymorphic (RAPD) which offer better characterization due to their high level of polymorphism compared to other markers such as morphological markers. Studies conducted on genetic diversity on *S. hermonthica* from Mali, Kenya and Nigeria showed high levels of variation existing between and within populations (Koyama, 2000). However, Gethi et al. (2005) reported that there is 90% similarity in *S. hermonthica* population collected from Kenya. He has argued that there seems to be substantial gene flow between *Striga* populations leading to low differentiation and seed dispersal has been basically through contaminated seeds.

However, using F_{ST} standards value range (Wright, 1978) of 0.15 to 0.25 for highly differentiated population and 0.05 to 0.15 for moderately differentiated, Welsh and Mohamed (2011) showed that *S. hermonthica* samples collected from Ethiopia were genetically different and all populations were significantly different from each other. Nevertheless, he attributed Kenyan population similarity to a small area sampled covering only 0.5º latitude and less than 0.1º longitude. Other studies of *S. hermonthica* populations infesting cereal crops from several countries in western, eastern and central Africa using isozyme markers showed little genetic diversity to genetic diversity levels of up to 6.8% (Bharathalakshmi et al., 1990; Olivier et al., 1998).

More detailed analysis of genetic diversity in *S. hermonthica* population is required for understanding the parasite well for effective management. The parasite is said to have the ability to withstand a wide range of climatic conditions as well as to quickly adapting to different hosts and environments (Welsh & Mohamed, 2011). This makes it even more difficult to develop universally resistant host crops, and effort towards obtaining resistant cultivars may need to take the view that *Striga* species are diverse.

4. Research Achievements

Research on *Striga* control in Africa started from the 1940s onwards (Timson, 1945; Andrews, 1947) and, in the last 20 years these efforts have been increased and considerable resources have been invested in developing control options (Oswald, 2005; Woomer, 2004). Several organizations have been involved in conducting research in Kenya and developing *Striga* control mechanisms: International Maize and Wheat Improvement Centre (CIMMYT) (Odhiambo & Ransom, 1993); Badische Anilin- und Soda-Fabrik (BASF) a private chemical company; International Centre of Insect Physiology and Ecology (ICIPE) (Khan et al., 2008); International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) (Haussmann et al., 2001); Tropical Soil Biology and Fertility Program of the International Centre for Tropical Agriculture (TSBF-CIAT) (Vanlauwe et al., 2008); African Agricultural Technology Foundation (AATF) and International Institute of Tropical Agriculture (IITA) (Manyong et al., 2008). Other institutions from advanced countries mostly from Europe (The UK and The Netherlands), USA and Canada have also been involved in conducting research on *Striga* (Kim, 1996; Andersson & Halvarsson, 2011). These institutions have recommended control options to farmers in Kenya geared towards reducing infestation and damage. The options include: the use of resistant crop varieties, intercropping of cereals and legumes, crop rotation, use of trap crops that stimulate suicidal germination, and application of manure and nitrogen fertilizer. These options are summarized in Table 3 with factors in favor and against their adoption by farmers in Kenya.

Generally, it has been accepted that *Striga* control can be possible and sustainable if a wide range of individual technologies are combined into a program of integrated *Striga* control (ISC) to serve a range of bio-physical and socio-economic environments (Ellis-Jones et al., 2004; Douthwaite et al., 2007). In fact, Franke et al. (2006) reported that ISC approach reduced *Striga* seed bank by 46% and improved crop productivity by 88%. The major objective of ISC is to reduce *Striga* densities in the soil to avoid new plants emerging in the subsequent seasons. However, there is stand-off on the complexity of control options to be involved and farm management as well as the resources required for its implementation.

5. Conclusion

Striga infestation in Kenya has increased in size and severity despite the 70 years of support in research. Increased pressure on land, as a result of cereal production (particularly mono cropping) and reduction in the use of fallow, is responsible for the worsening situation. The control methods developed have not been adopted by farmers. The reasons for non-adoption are that the farmers doubt them (Khan et al., 2009; Atera, 2010) and they hear rumours that the methods do not work, and thus they are unwilling to test them. We strongly recommend that researchers and farmers should have an active linkage to technology transfer, as currently transfer of technology seems to be the limiting constraint. In our view, the technique of female sterility should be explored in *Striga* control in conjunction with intercropping with crop traps that stimulate suicidal germination. The technique will be based on gene introduction into *S. hermonthica* genome to cause female sterility while maintaining male fertility. On the other hand, intercropping as a farming system will readily be acceptable to farmers and able to fit into their farming requirements. The combination of these control options would increase yields and eliminate the need for alternative methods of eradicating the witchweed.

Table 3. Factors in favor and against *Striga* controls options recommended to Kenyan farmers

Strategy	Factors in favor of control options	Setbacks for control options	Ref.
Manual weeding	Reduction of *Striga* seed bank, easy to implement	Yield benefit is not immediate, labor intensive	11,12
Crop rotation	Increase soil fertility, reduction of *Striga* seed bank	Benefit accruement requires time, costly as per family food requirement	7,8,14
Hand pulling	Reduction of *Striga* seed bank if done before flowering, increase in yield	Inappropriate disposal increase seed bank	10,11,14
Allelopathic effect (Desmodium)	Reduction of *Striga* incidence, increase yield, provide livestock fed	Crop uneconomical to farmers without livestock	6,7,14
Push and pull	Provide livestock feed, reduction of *Striga* seed bank, control of stem borer, improvement of soil fertility	Costly to implement initially, benefit accruement requires time, trap crop used uneconomical	6,7
Fertilizer application	Increase in yield, improvement of soil fertility, reduction of *Striga* incidence	Costly to implement, labor intensive	12,13
Intercropping	Reduction of *Striga* seed bank, increase soil fertility, provide additional income	Labor intensive, trap crop used uneconomical	3,5,6
Seed dressing (herbicide)	Increase in yield, easy to implement, Reduction of *Striga* incidence	Purchase of seed every season is costly	1,4,10
Compost application	Increase in yield, easy to implement, reduction of *Striga* incidence, increase soil fertility	Increase pests, labor intensive	10,13
Resistant crops	Easy to implement, high crop yield	Purchase of seed every season is costly	7,10,14
Herbicide	Reduction of *Striga* seed bank	Unavailable to farmers, cost prohibitive	10,11
Transplanting	Reduction of *Striga* emergence, improvement of crop yield	Labor intensive	9

1-De Groote et al., 2008; 2-Gacheru & Rao 2001; 3-Kanampiu et al., 2002; 4-Kanampiu et al., 2003; 5-Khan et al., 2007; 6-Khan et al., 2008; 7-Manyong et al., 2008; 8-Oswald & Ransom, 2001; 9-Oswald et al., 2001;10-Oswald, 2005; 11-Ransom, 2000; 12-Ransom & Odhiambo, 1994; 13-Smaling et al., 1991; 14-Authors'own observations.

Acknowledgement

The authors are grateful to Mitsui Corporation (08-C-083), Japan, for financial support and Florence Nyaboke Onyancha of KOSFIP, Hombay, Kenya for editing this manuscript.

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