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Review on *Striga* Weed Management

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ABSTRACT- *Striga*is a major constraint affecting sorghum, maize, other cereal crops, sugar cane and legume crop production in sub-Saharan Africa. *Striga* may result in a complete crop loss under the worst of conditions. Prodigious seed production, prolonged viability of the seeds and the subterranean nature of the early stages of parasitism make the control of the parasite by conventional methods difficult if not impossible. The increasing incidence of *Striga* has been attributed to poor soil fertility and structure, low soil moisture, intensification of land use through continuous cultivation and expansion of cereal production. Many potentially successful approaches developed to control this weed include using resistant/tolerant varieties, sowing clean seeds that are not contaminated with *Striga*seeds, rotating cereal hosts with trap crops that induce abortive germination of *Striga* seeds, intercropping, applying organic and inorganic soil amendments such as fertilizer or manure, fumigating soil with ethylene, applying post-emergence herbicides, push-pull technology and using biological control agents. Based on some studies, the interaction of tied-ridging with N fertilizer and resistant varieties; cereal-legume intercropping and its interaction with N fertilizer revealed the low *Striga* infestation. No single management option has been found effective across locations and time. Hence, an integrated *Striga* management approach, currently, offers the best possibility for reducing impact at the farm level.

Key Words- Intercropping, Integrated pest management, Fertilizer, Management options, *Striga*

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INTRODUCTION

Agriculture remains the main source of food and provides the primary source of livelihood for 36% of the world's total workforce [1]. In Asia and the Pacific, 40 to 50% of the workforce derives its livelihood from agriculture, while in sub-Saharan Africa (SSA) two-thirds of the working population still make their living from agriculture.

In Ethiopia, about 85% of the population depends on agriculture out of which over 90% still rely on rain-fed agriculture for their livelihood [2].

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The majority of the population in the Arid and Semi-arid areas depend on agriculture and pastoralism for subsistence. These activities face many constraints due to predominance of erratic rainfall patterns, torrential rainfall which is majority lost to run-off, high rate of evapotranspiration further reducing yields, weeds growing more vigorously than cultivated crops and competing for scarce reserves of moisture, low organic matter levels and highly variable responses to fertilizers [3].

Among the major pests of agricultural crops, weeds alone caused severe yield losses ranging from as low as 10% to as high as 98% of total crop failure in the dry land regions. It should be emphasized that yield losses caused by weeds could vary from crop to crop and from region to region for the same crops, in response to many factors that include: weed pressure, availability of weed control technology, cost of weed control and the level of management practices [4].

From the parasitic weeds, *Striga* sp. are fairly wide spread in semi-arid region's crops, including certain legumes, maize, pearl millet, sorghum, other cereal crops and sugar cane production. Small holder farmers are the most affected by the *Striga* problem because they have limited ways and means of controlling it. The increasing incidence of *Striga* has been attributed to poor soil fertility and structure, moisture stress, intensification of land use through continuous cultivation and an expansion of cereal production [5,6]. Most *Striga* infested areas are characterized by agricultural production systems exhibiting low productivity.

Distribution and Host Range of *Striga*

Striga has been given the common name of "witchweed" because it attaches itself to the roots of the host plant thus depriving it (the host) of water and nutrients. *Striga* spp. (witch weeds) belongs to the family *Orobanchaceae* [7]. Economically important *Striga* species are reported from more than 50 countries, especially from East and West Africa and Asia [8]. *S. hermonthica* is common throughout northern tropical Africa and extends from Ethiopia and Sudan to West Africa. It also extends from the western Arabian region southwards into Angola and Namibia [6]. *S. asiatica* has a wider distribution and is found throughout semi-arid areas of tropical and subtropical Africa, Asia and Australia [6]. Nigeria, Sudan, Ethiopia, Mali and Burkina Faso are heavily affected countries in Africa [9].

The host range is almost wide and, besides the cultivated cereals, it attacks, many of the wild grasses. The traditional crops in the African savanna attacked by the parasite are sorghum (*Sorghum bicolor* L., maize (*Zea mays* L.), pearl millet (*Pennisetum glaucum* L.), and sugarcane (*Saccharum officinarum* L.) and rice (*Oriza sativa* L.) [10].

Striga Biology

Striga plants have green opposite leaves, bright irregular flowers with corolla tube slightly bent at the middle. The flowers are pink, red, white or yellow. There is a considerable variation in flower color. The plant is characterized by herbaceous habit, small seeds and parasitism. The seeds of *S. hermonthica* are extremely small, about 0.2 X 0.3mm, weighing about 0.7 μg. They are generally dispersed by water, wind, cattle, and man .The number of seeds per capsule ranges from 700–1800 depending on the species. The seeds can remain viable in the field for as long as 14-20 years .The minimal length of the life cycle of the parasite, from germination to seed production comprises an average of 4 months [10].

Since *Striga* is a parasitic weed the seedlings cannot sustain themselves on their own resources for a particular long after germination. Therefore, they need to find a host root shortly after germination and the germination needs to be perfectly timed with the presence of a host root. Exogenous germination stimulants called strigolactones are produced by the host's root and also by some non-host (usually referred to as trap crops) roots (*Gossypium* sp.). They are plant hormones, which inhibit shoot branching [11] but also signals to seeds of parasitic weeds such as *Striga* to start germinate. Strigolactones are also involved in other physiological processes such as abiotic response and the regulation of the plant structure is also regulated by strigolactones. Strigol, a synthetic compound belonging to the strigolactones was first isolated from cotton (*Gossypium* sp.) and is used as a germination trigger for *Striga* [12]. When the seed have been germinated the seedling can live for 3 to 7 days without a host. After that it will die if it is not attached to a root and there has been able to create a parasitic link to that particular root. The seedling finds its way to the host root by chemical signals and then creates a xylem-to-xylem connection between the seedling and the root. However, the seedlings cannot be at a greater distance from the root than 2 to 3 mm to find its way there. When the seedlings have attached to the root it grows underground for 4–7 weeks before they emerge and are actually seen in the field. One plant can host many *Striga* plants and *Striga* affects the plant mostly before its emergence. The symptoms are however hard to distinguish from symptoms caused by drought, lack of nutrients and other diseases [10].

Subsequent to germination, which occurs in close proximity of the host roots, a haustorium (organ of attachment and a physiological bridge between the host and the parasite) is produced on the perception of a host-derived chemical signal [13]. Haustorium initiation, which represents the switch from the vegetative to the parasitic mode of life, occurs on or near the host. The haustorium attaches, penetrates the host root and establishes connection with the host xylem. Following attachment, the parasite remains subterranean for six to eight weeks [13]. During this period, the parasite is completely dependent on its host and is most damaging. Generally, the below ground and above ground development of *Striga* is shown in the life cycle of *Striga* (Fig. 1).

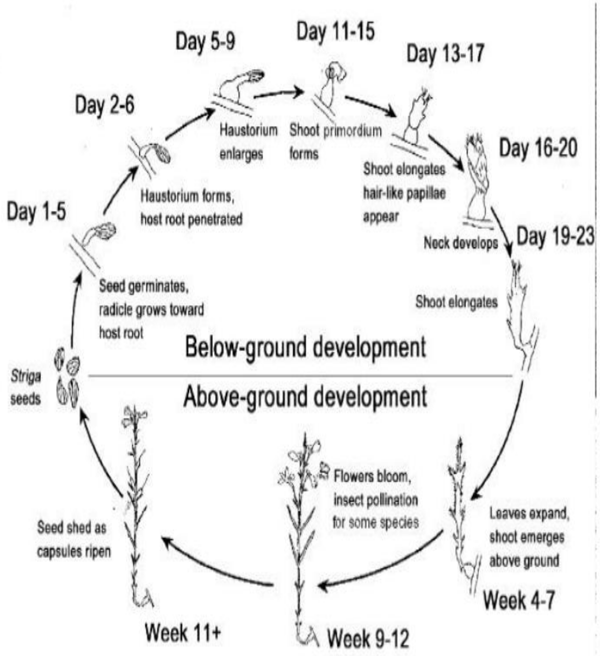

Fig 1 : General life cycle of *Striga* species

Source: *Striga* Research Methods [14].

Economic importance of *Striga*

Although there are more than 35 species, only three species are recognized as economically important [15]. *S. hermonthica* (Del.) Benth and *S. asiatica* (L.) Kuntze are the two most widespread and the most economically significant species that parasitize on sorghum (*Sorghum bicolor* L. Moench), pearl millet (*Pennisetumglaucum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.), whereas *S. gesnerioides* (Willd.) Vatke attacks crops such as cowpea (*Vignaunguiculata* L. Walp.) and peanut (*Arachishypogaea* L.) [16]. Of these species *Striga hermonthica* is the most serious biotic problem to cereal production [10]. *S. hermonthica* is a debilitating root parasite. It causes damage in two ways, first by competition for carbon and nutrients and second through physiological interactions, and metabolic processes the bulk of which is unknown [17].

The effect of *Striga* damage to crops is a reduction in yield. The extent of yield loss is related to the incidence and severity of attack, the host's susceptibility to *Striga*, environmental factors (edaphic and climatic) and the management level at which the crop is produced [18]. Its effects on crops range from stunted growth, through wilting, yellowing, and scorching of leaves, to lowered yields and death of many affected plants. A report by [9] indicated that annual sorghum losses attributed to *Striga* in SSA are estimated at 22–27% and specifically at 25% in Ethiopia, 35% in Nigeria, and 40% in Mali. In terms of monetary value, the annual cereal losses due to *Striga* are estimated at US$7 billion in SSA. In Ethiopia, Mali and Nigeria, the annual losses are estimated at US$75 million, US$87million and US$1.2 billion respectively [9]. In Sudan, more than 500,000 hectares under rain fed cultivation are heavily infested by *Striga*, which commonly results in yield losses of 70–100% and thus severe *Striga* infestation can result in complete crop failure [10].

Management and control options of *Striga*

De Groote *et al.* [19] opined that *Striga* is a particular problem in areas with low moisture and where soil fertility is being eroded through increased population pressure, decreased use of fallow and minimal use of organic or inorganic fertilizer. Most importantly, it mostly affects the livelihoods of poor subsistence farmers in cereal-based agricultural systems in Africa. Prodigious seed production, prolonged viability of the seeds and the subterranean nature of the early stages of parasitism make the control of the parasite by conventional methods difficult if not impossible [10]. Several measures have been tried and adopted for control of *Striga*. Many potentially successful approaches developed to control this weed include using resistant/tolerant varieties, sowing clean seeds that are not contaminated with *Striga* seeds, rotating cereal hosts with trap crops that induce abortive germination of *Striga* seeds, intercropping, applying organic and inorganic soil amendments such as fertilizer or manure fumigating soil with ethylene, hoeing and hand pulling of emerged *Striga*, applying post emergence herbicides, push-pull technology and using biological control agents [10]. Generally, the approaches can be grouped in to four independent *Striga* control options, namely cultural, chemical, genetic, and biological.

Cultural management practices

Effective control of *Striga* has been difficult to achieve through conventional hand or mechanical weeding as the parasite exerts its greatest damage bewitching the crop before its emergence above ground, and providing evidence for host plant infection. Many of the traditional control methods, including crop rotation, soil fertility, trap and catch cropping, intercropping, hand-pulling and fertilization is still in vogue [10]. Still these practices are not adopted by farmers. Because they are perceived by poor farmers as unaffordable or uneconomical, labor intensive, impractical, or not congruent with their other farm operations. A lot of studies have been reported mainly on the effect of intercropping and fertilizer against *Striga* as follows:

Intercropping practice on *Striga* management

Weed control is an important aspect in intercropping because chemical control is difficult once the crops have emerged. A study by [20] showed that intercropping maize with legumes considerably reduced weed density in the intercrop compared with maize pure stand due to decrease in the available light for weeds in the maize-legume intercrops, which led to a reduction of weed density and weed dry matter yield compared with sole crops. Similarly, [21] demonstrated that intercropping maize or sorghum with the fodder leguminous *Desmodium uncinatum* (Jacq.) DC. and *D. intortum* (Mill.) Urb, significantly reduced *S. hermonthica* infestation and increased grain yield. Similar studies in Kenya indicate that intercropping with cowpeas between the rows of maize significantly reduced *Striga* numbers when compared to within the maize rows [22]. Moreover, finger millet (*Eleusinecoracana*) intercropped with green leaf desmodium (*Desmodium intortum*) reduced *Striga hermonthica* counts in the intercrops than in the monocrops [23]. Fasil *et al.* [24] also reported related findings on sorghum-cowpea intercropping where *Striga* emergence was lower under intercrops than sole crops. Generally, various studies have shown that intercropping cereals, mainly with legumes such as cowpea (*Vignaunguiculata*), peanut (*Arachis hypogaea*) and green gram (*Vigna radiate*) can reduce the number of *Striga* plants [25]. Potentially, they might be acting as trap crops, stimulating suicidal *Striga* germination or the microclimate under the crop canopy may be altered and interfere with *Striga* germination and development [26]. It was also hypothesized that nitrogen fixed by the legumes might interact with *Striga* growth, as increasing the amount of available nitrogen can reduce *Striga* densities [27].

Fertilizer application on *Striga* management

As *Striga* is more favor in less fertile soil, a system that would improve soil fertility to increase yield as well as reduce *Striga* infestation will be also of double advantage. Good soil management practices involving the use of crop residues and organic manure have been effective control measure against *Striga*. Vogt *et al.* [28] observed that *Striga* infestation decreased with increasing organic matter of the soil and that organic matter, content seemed to be the most important factor which preserved the soil fertility. Since soil microbial biomass flourishes best in a medium rich in organic matter, organic or inorganic soil amendments may increase soil suppressiveness to *Striga* spp. and also improve soil conditions to increase yield of subsequent cereal. Different research findings were reported by authors. According to Hess and Ejeta [29], 55–82% reduction in number and weight of *S. hermonthica* recorded due to application of N using urea in Niger. [30]. Also reported that N fertilizers altered assimilate partitioning in favour of the ear and increased maize grain yield and reduced *Striga* count by 64%. Similarly, the study of Kamara *et al.* [31], conducted in North east, Nigeria showed a reduction in *Striga* infestation and damage by the application of N fertilizer on maize varieties. *Striga* infestation was significantly reduced at 120 kg N ha^{-1} in the early variety and 60 and 120 kg N ha^{-1} in late varieties [32] noted that, the nitrogenous compound fertilizer which contains urea considerably suppressed germination of *S. hermonthica* when applied during conditioning.

The germination of *S. hermonthica* seed is associated with the secretion of germination stimulants by host plants. The secretion ultimately depends upon the nutrient status of the soil [33]. It has been demonstrated that under N and P deficiency, host plants secrete high amounts of germination stimulants into the rhizosphere, while the supply of sufficient N and P reduces this secretion [34,35]. Research studies showed that the effect of N was less pronounced than the effect of P on strigolactones secretion. As DAP fertilizer contains 18% N and 46% P_2O_5, high availability of P in DAP might lead to less production of strigolactones. However, direct suppressing effect of N on *Striga* sp. cannot be neglected [36].

The high and increasing cost of mineral fertilizers and low purchasing power of small scale farmers have necessitated investigating the efficacy of fertilizer application at low to very low levels. The use of very low doses of mineral fertilizers and their placement near the planting hole, a technology termed 'microdosing', have been shown to reduce application rates and thus cost of fertilizer per surface area, while still improving crop yields [37]. Microdosing of DAP may prove to be an efficient and cost effective option to reduce *S. hermonthica* damage in sorghum in SSA, particularly in combination with other control options, such as intercropping, use of organic fertilizer and hand pulling of *S. hermonthica* at flowering to achieve integrated *S. hermonthica* management [35].

Genetic resistance

Striga resistance is the ability of the host root to stimulate *Striga* germination but at the same time prevent attachment of the seedlings to its roots or to kill the seedlings when attached. The use of resistant crop cultivars is the most economically feasible and environmentally friendly means of *Striga* control. In East Africa, the most promising new approach to *Striga* control is the use of resistant cultivars (e.g. of sorghum). *Striga* resistant cultivars have been bred in a number of crops. However, cultivars with immunity to *Striga* have not been found in all host crops. The host/parasite relationship is governed by a series of steps involving stimulation of germination, haustorium initiation, penetration of the host root, connection to the host xylem and concurrent growth [38].

Many cereals are found to be naturally resistant to *Striga* e.g.; rice, sorghum and some genotypes of maize. A resistant plant stimulates germination of *Striga* but it does not allow it to attach to the root. Study in *Striga* infested areas revealed cultivation with resistant crops results in fewer *Striga* plants and higher crop yield than a non-resistant genotype of the cultivated plants would do [39].

Biological control

Biological control is generally defined as the deliberate use of living organisms to suppress, reduce or eradicate a pest population [40]. Means of biological control of weeds include herbivorous insects, microorganisms specially fungi, and smothering plants. The insects that attack *Striga* can be classified according to the site damaged into defoliators such as *Junonia* spp., gall forming as *Smicronyx* spp., shoot borers as *Apanteles* spp., miners as *Ophiomyia Strigalis*, inflorescence feeders as *Stenoptilodestaprobanes* and fruit feeders as *Eulocastra* sp. [41] . Twenty eight fungi and two bacteria were found to be associated with *Strigahermonthica* in Sudan. Among the fungi, only *Fusarium nygamai* and *Fusarium semitectum* var. *majus* showed potential to be used as bio-agents for the control of *Striga* [42].

Chemical control

Various chemicals including herbicides, fumigants (e.g, methyl bromide) and germination stimulants (e.g, ethylene) have been reported as means of control of *Striga* [43]. Herbicides like Imazapyr and pyrithiobac applied as seed dressing to maize were reported to give efficient control of the parasite [44] . The excellent control capacity of the herbicides is most likely due to their relatively long persistence in the rhizosphere. Furthermore, multi-location testing showed that this herbicide provided excellent early season control of both *S. asiatica* and *S. hermonthica* and could increase yield 3 to 4-fold in heavy infested fields [44].

Emerged *Striga* plants can be successfully killed with common herbicides. However, much damage is done by the fully parasitic young plants before emergence, so such herbicide treatments do not necessarily reduce yield losses. The main strategy for control is accordingly to reduce the seed bank of *Striga* in the soil by stimulating the seeds to germinate in the absence of host plants [45]. This can be achieved by:

1) Planting a *Poaceous* trap crop (susceptible cereal or grass) which is plugged in a few weeks after sowing before the weeds mature and set seed;

2) Sowing crops, which stimulate germination, but are not parasitized, for several seasons (e.g. sunflower, groundnut, soybean);

3) Treating the soil with ethylene which simulates the chemical substances which exude from host roots and stimulate germination.

Integrated *Striga* management

No single management option has been found effective across locations and time. An integrated *Striga* management approach, currently, offers the best possibility for reducing impact at the farm level. Many reports on *Striga* management suggested the combined use of cultural agronomic practices, herbicides, host plant resistance, fertilization, trap cropping, germination stimulants and biological control [46]. Control is most effective if a range of practices are combined into a program of integrated *Striga* control (ISC) that can provide sustainable control over a wide range of biophysical and socio-economic environments [31,47]. Franke *et al.* [47] found that ISC that combined rotation of *Striga* resistant maize, trap crops and fertilizer application reduced the *Striga* soil seed bank by 46% and increased crop productivity by 88% while [48] showed that these practices reduced *Striga* infestation and damage on farmers' fields and increased productivity by more than 20%. Likewise, a report by [31] showed that applying N fertilizer may not be feasible as a stand-alone solution to managing purple witch weed in cereals because of the high cost of fertilizer, but the combined use of N fertilizer and *Striga* tolerant/resistant maize and sorghum varieties has shown promise in the west African Savanas. Furthermore, an experiment conducted in Niger State on two varieties of maize (Jo-98 and local) intercropped with soya bean and nut at three levels of N application (0, 50 and 100 kg N ha^{-1}) showed highly significant (P= 0.01) effect on the severity of *Striga* infestation [49]. Accordingly, resistant variety Jo-98 showed less severity of *Striga* and its interaction with N ground

fertilizer at 100 kg ha^{-1} as well as its intercropping decreased *Striga* infestation as compared to local (susceptible) (Table 1).

An integrated management approach, if properly designed, using a combination of suitable control measures, has the potential to provide a lasting solution to *Striga* problems. Babiker [10] reported that soil fertility and soil moisture management should be an integral part of any *Striga* control strategy. A similar study conducted by Temam [50] pointed out that species of *Striga* were controlled by using the resistant variety, fertilizer and tied ridges on farms of eastern Ethiopia, which had long been abandoned due to *Striga* infestation. According to Table 2, species of *Striga* were controlled by using the resistant variety, fertilizer and tied ridges on farms; whereas, the local cultivar had severe infestations where the average yield of the resistant variety was 1718 kg ha^{-1} as against only 216 kg ha^{-1} from the local variety. The *Striga*-infested local varieties died, failed to produce a head or had very small heads. Gebisa and Gressel [51] also added that treatment combination that included resistant variety, fertilizer and tied ridge gave significantly higher yield followed by one that combined local variety with fertilizer and tied ridging in North wollo at Sirinka and Kobo sites.

Table 1: Effect of variety, intercropping, and nitrogen rate interaction on the severity of *Striga* infestation **(%)**

Intercropping/ Maize Variety	**Nitrogen rate (kgNha^{-1})**			
	0	**50**	**100**	**Mean**
Maize only (J0-98) – Resistant	62.2	39.2	9.4	36.9
Maize only (Local) –Susceptible	82.2	40.4	30.4	51.0
J0-98 + Soyabean	19.4	14.2	6.8	13.5
Local + Soyabean	50.1	20.8	10.8	27.2
J0-98 + groundnut	13.2	6.2	4.3	7.9
Local + Groundnut	45.2	19.3	7.6	24.0
N-rate mean	45.4	23.4	11.6	–

F-LSD (0.01) for comparing variety (V) means = 20.6; F-LSD (0.01) for comparing intercropping (I) means = 14.9; F-LSD (0.01) for comparing V x I interaction = 42.4

Source: Intercrops With Trap Crops, Nitrogen Fertilization for *Striga hermonthica* (Del.) Benth Control at Niger State [49].

Table 2: *Striga* count and sorghum yield as influenced by variety, fertilizer and tied ridge

Treatment	*Striga* count/m^2			Yield (kg/ha)		
	Babile	Fedis	Gursum	Babile	Fedis	Gursum
Improved variety with fertilizer and tied ridge	1	2	4	1467	1740	1947
Improved variety without fertilizer and tied ridge	2	3	5	1200	980	1244
Local variety with fertilizer and tied ridge	140	151	170	122	235	290
Local variety without fertilizer and tied ridge	266	181	288	98	148	130

Striga count against treatment and yield against treatment were significant at $p \leq 0.01$. *Striga* count against location and yield against location were not significant.

Source: Distribution of two *Striga* species and their relative impact on local and resistant sorghum cultivars in East Ethiopia [50].

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