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Review Article

Witch Weeds (Striga spp.) Dissemination and Infestation in Ethiopian: Review Article

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Abstract

The endemic parasitic witch weeds (Striga spp.), which are found throughout sub-Saharan Africa, including Ethiopia, are progressively expanding their geographic range and degree of infection, which is significantly decreasing crop productivity. They are currently regarded as a widespread blight. The fight for economic expansion and food security is weakened by the Striga issue. Countries where Striga was only beginning to spread 25 years ago are now seeing significant annual losses in agricultural productivity. The projected yearly loss of sorghum in SSA due to Striga is 22–27%, and in Ethiopia, it is 25%. In SSA, Striga causes an annual loss of $7 billion in grains, of which $75 million is Ethiopia's portion. A significant biotic limitation and substantial danger to the production of food for subsistence in Ethiopia is Striga. The predominant species is Striga hermonthica, which is most severe in severely degraded regions of the country's north, northwest, and east, including Tigray, Wollo, Gonder, Gojjem, North Shewa, and Eastern Hararghe. Because of its wide geographic distribution and devastating effects on millions of people's livelihoods, Striga is quickly growing into a pandemic of significant proportions in the nation. Diverse sorghum germplasm may be found in Ethiopia, where there is also a chance to create Striga-resistant cultivars.

Keywords

Striga, Varieties, Resistance, Tolerance, Infestation, Dissemination

1. Introduction

In sub-Saharan Africa, witch weeds (Striga spp.) are endemic parasitic weeds that are gradually expanding their geographic range and degree of infestation, which significantly lowers crop productivity. It is one of the main biotic factors limiting the production of sorghum (Sorghum bicolor (L.) Moench) in a number of sub-Saharan African countries, including Ethiopia. In addition to maize, rice, and millet, the parasite also targets these crops [1]. According to [2] the study of, Striga may result in yield reductions of 20–80% [4]. A Striga infestation may cause a small percentage reduction in output and, in certain situations, total crop failure [9]. Sorghum yield losses ranging from 65 to 100% have been seen in Ethiopia and Sudan [1].

The most economical and successful control strategy for Striga is thought to involve the use of resistant genotypes [3, 4]. Finding adequate sources of Striga, however, is one of the biggest obstacles to breeding resistant strains of Striga and determining a workable, long-term solution for managing Striga in sorghum. Over 100 million people's livelihoods are under serious risk in sub-Saharan Africa as a result of the projected $7 billion annual yield loss caused by Striga alone [2].

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In the areas of northern and eastern Ethiopia that grow cereals, Striga is a serious issue [5]. According to surveys conducted in Ethiopia's northwest and northeast, Striga, which attacks finger millet, sorghum, and maize, is still a significant issue [6]. Thus, this overview aims to assess areas of infestation and spread in Ethiopia.

Constraints of Sorghum Productions

Millions of Ethiopian peasant farmers rely on the cultivation of sorghum for their livelihoods. But at only two tons per hectare, its production is poor [7]. Several biotic and abiotic stressors are blamed for this. Striga, low soil fertility (nutrient inadequacy), drought, stem borers, and shoot flies are among the variables that reduce yield [7]. While there is a considerable loss of grain as a result of these restrictions, the amount of loss differs from area to area. Striga is a significant productivity barrier in the majority of Ethiopia's sorghum-producing regions. Due to allelopathy, competition for nutrients, and a restriction on the sorghum plants' ability to express their full genetic potential, the weed reduces crop output. According to [7, 8], Striga and low soil fertility (nutrient inadequacy) are the two main problems limiting sorghum productivity in eastern Africa, including Ethiopia. As a result, Striga is the main obstacle to sorghum growth, followed by low soil fertility and drought, according to recent research done in the northwestern regions of Ethiopia, which is part of the country's sorghum-growing belt.

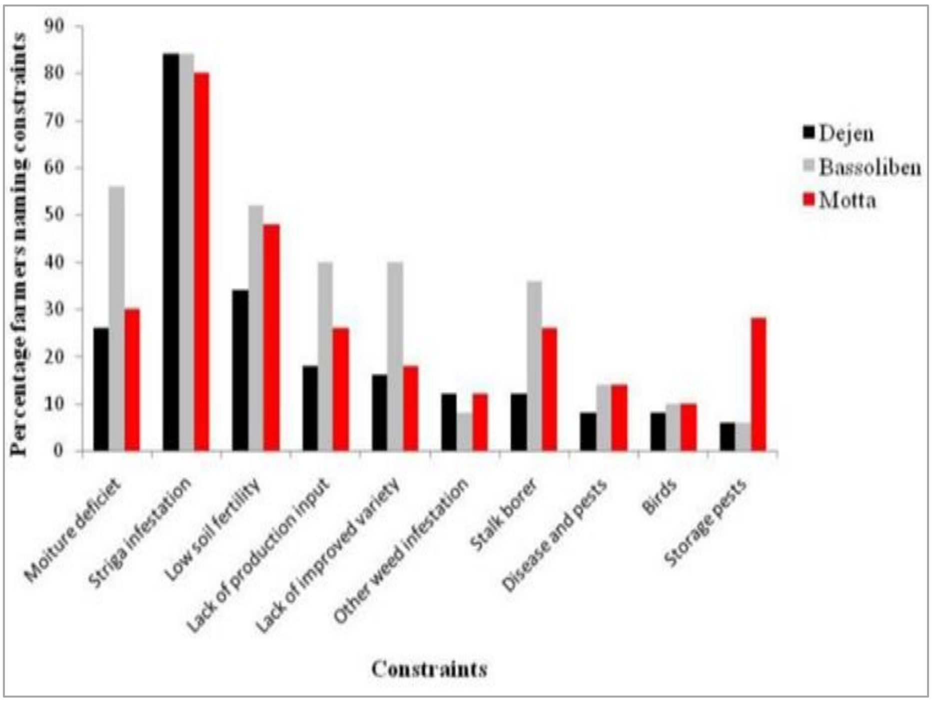

Figure 1. *Major Sorghum production constraints Source: [13].*

2. Witch Weeds (Striga spp.)

The family Orobanchaceae (formerly: Scrophulariaceae) includes the genus Striga. Cereal crops in this genus include maize (Zea mays L.), sorghum [(Sorghum bicolor (L.)Moench)], pearl millet (Pennisetum glaucum L. R. Br. or P. americanum [L.] K. Schum), and rice (Oryza glaberrima Steudel and O. sativa L.) [10]. In Africa, it also parasitizes a variety of wild grass types. Striga comprises around 50 species, some of which have an impact on the production of grains and legumes in Asia and sub-Saharan Africa [11, 12].

Among all plant parasites that feed on roots, the Striga species are some of the most specialized [11]. According to [14], Striga is an emerging plant that combines the life modes of a hemiparasite and a holo-parasite at the seedling stage. *Striga hermonthica*, *Striga asiatica*, *Striga aspera*, Striga forbesi, and Striga gesnerioides are among the parasitic species that are particularly significant economically in Africa as crop parasites [14].

One of the main production barriers to the development of sorghum, millet, rice, and maize in Africa's arid land zones is Striga hermonthica (Del.) Benth (Scrophulariacae) [1]. It is a concern in Ethiopia's areas of subsistence agriculture as well. Due to decades of ongoing deforestation and crop monoculture, the region's naturally low soil fertility, frequent droughts, and general degradation of its natural resources all contribute to the situation. Food output has decreased in numerous nations as a result of the increased spread of Striga [5].

In most places, Striga weed is blamed for losses that vary from 30 to 100% [1]. These losses are frequently made worse by infertile soil. Long-term fallow land, crop rotation, and intercropping were popular techniques used in traditional African farming to control Striga infection to a manageable level. When the infestation is severe, this parasitic weed is known to produce projected yield losses ranging from 40 to 100%. This is particularly true in the northern, northwestern, and eastern regions of the country where sorghum farming is the most advantageous option for farmers.

Having chlorophyll-containing leaves, Striga is an obligatory hemiparasitic weed that requires a host plant to complete its life cycle. However, it is not dependent on its host for its metabolic needs [15]. After emerging, Striga still benefits from its host despite the green leaves [15]. Parasitism, decreased photosynthesis, and increased photosynthate partitioning to host plant roots are the causes of Striga damage. By attaching itself to the roots of the host plant, it depletes the crop plant's supply of water, nutrients, amino acids, and carbon assimilations [15]. When a crop is infected with Striga, its levels of abscisic acid rise while those of cytokinins and giberellic acid fall.

Striga causes its host's biomass allocation to change and negatively impacts photosynthesis by upsetting the balance of plant growth regulators in the host. The roots receive a greater amount of biomass than the stem. Striga also decreases water use efficiency [16] and has a significant impact on the host plant's water economy due to its high transpiration rates, which increases the crop's susceptibility to drought.

Origin and Domestication of Striga

Eleven of the more than 40 species in the genus Striga are thought to be parasites on crops. It is believed that Striga originated in Africa. Plant species origin is typically shown by the frequency and degree of genetic diversity of a species in a given geographic location where more forms develop and specialized relationships are noted. The highest diversification of both the parasite population and the two crops that Striga readily infests, sorghum and pearl millet, is found in the wide tropical savannah that lies between the Nubian hills of Sudan and the Semien Mountains of Ethiopia. Both pearl millet and sorghum are known to have originated in this region, and it's possible that these two species still reside there of Striga affecting cereals, namely *Striga hermonthica*, and *Striga asiatica*.

It's possible that *Striga gesnerioides*, a species that has evolved specifically to serve as a pest of legume crops, started in western Africa. Presently, Striga may be found in nearly every part of sub-Saharan Africa, with the exception of places with excessive rainfall or high elevations where temperatures may be too low for the parasite to flourish. Striga is particularly severe in barren, nutrient-depleted soils with low levels of organic matter. The species with the widest geographic range is S. hermonthica. It is the species that damage crops the most because of its high plant size and compulsive out-crossing tendency. Much of sub-Saharan Africa is home to S. hermonthica, with western, central, and eastern Africa having the highest incidence. It is also present in portions of the Arabian Peninsula's southwest region, which is located on the other side of the Red Sea. The largest range of S. asiatica is found in eastern and southern Africa. Along with the US and Australia, it is also found in Asia, mainly in southern India.

Globally, Africa, the Arabian Peninsula, the Indian subcontinent, and the United States are among the regions where *Striga gesnerioides* is found. The legume crops that are farmed extensively in western Africa particularly cowpeas are the most severely impacted economically by this species. Because *Striga gesnerioides* and *Striga asiatica* are self-fertile, there is apparent genetic variety seen in both parasitic specialization and various morph types. When compared to the obligatorily out-crossing *Striga hermonthica*, they seem to be far less variable.

3. Dispersal of Striga and Infestation in Ethiopia

A significant biotic limitation and substantial danger to the production of food for subsistence in Ethiopia is striga. Previous records state that the weed is indigenous to the nation. Only seven of the approximately 12 striga species thought to exist in the nation have been officially recognized. Striga aspera on maize; Striga asiatica on sorghum and maize; Striga gesnerioides on sweet potatoes; *Striga forbesi* and Striga pinatifida on wild vegetation are the following, in order of significance: Striga hermonthica on sorghum, maize, millet, and other cereal such as tef.

Striga hermonthica is the predominant species, according to Fasil and Parker. It is most severe in severely degraded areas of the country's north, northwestern, and east, including Tigray, Wollo, Gonder, Gojjem, North Shewa, and Eastern Hararghe (Figure 2). Given its widespread distribution, Ethiopian scientists believe that striga poses a greater threat to the nation than it does to the other SSA nations.

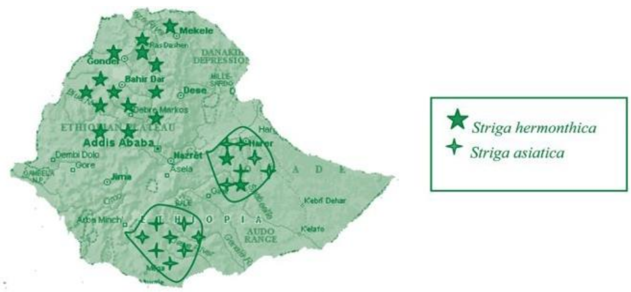

Figure 2. Distribution of two major striga species in Ethiopia Sources: [5].

3.1. Ideal Environment

In semi-arid tropical regions, Striga typically favors infertile soils found in open grasslands and savannahs. Their seeds stay latent until it rains since they are accustomed to hot, dry weather. S. asiatica has been documented from a variety of climate zones, including mild temperate regions (usually where it is dry or at least seasonally dry) and seasonally dry tropics and subtropics, while likely being most suited to dry, tropical environments. While S. Gesnerioides has naturalized in Florida, which is subtropical and occasionally moist, S. Hermonthica and S. Hermonthica both favor hot, arid, or semi-arid climates [17]. The parasite poses the greatest threat to agricultural systems that have short or no fallow seasons, low levels of soil fertility, and little use of fertilizers, herbicides, better seeds, and modern management practices [18].

Csurhes [17] reported that temperatures ranging from 25 to 35 ℃ are necessary for Striga seeds to germinate. According to [10], 35 ℃ is the ideal temperature for S. hermonthica and *Striga asiatica* germination. Unlike many other Striga species, *Striga asiatica* can withstand colder temperatures, which is why it has thrived in temperate climates outside of its natural habitat. The seeds of this plant can be stored at -7 ℃ without losing their viability. When the average daily temperature is 22 ℃, plants reach maturity. This species may be able to increase its host range and geographic range due to the flexibility of its environment. As [14] reported that S. hermonthica can withstand temperatures ranging from 40/30 ℃ to 25/15 ℃ during the day and night.

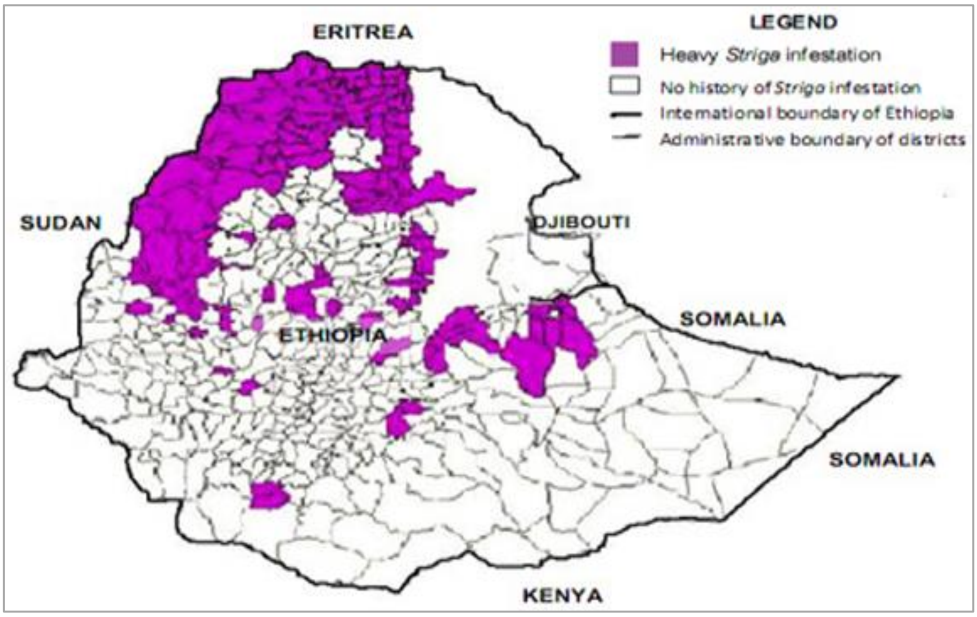

Figure 3. *Historically known areas with heavy Striga infestation in Ethiopia Source: [19].*

Infestations of witchweed are common throughout portions of Africa, especially Ethiopia. A Striga infestation may cause a small percentage reduction in output and, in certain situations, total crop failure. According to [1], heavily infested farms frequently experience losses of 65–100% in nations like Ethiopia and Sudan. Ethiopia's north is heavily infested, especially the majority of Tigrai and sections of Amhara, East Hararghe, Somalia, and the western Gambela region. Ethiopia is classified as a strongly infested country at the African level (Figure 3).

3.2. Effect and Loss Due to Striga

Striga infestation typically results in a large decline in yield, often approaching 65% in strongly infested fields. Striga infestations frequently cause significant yield losses. According to [20], on vulnerable sorghum cultivars at high levels of Striga infestation, grain production losses of up to 100% are probable. According to [1], losses of 65–100% are typical in extensively infested fields in places like Ethiopia and Sudan; nevertheless, the total loss might happen when Striga infection is exacerbated by drought. Farmers have either abandoned their property or shifted to other less important crops in certain locations where the attack is so severe that they are unable to grow sorghum anymore [5].

It is commonly known that parasitic weeds significantly reduce crop productivity throughout most of Africa. However, except for the few studies that are still frequently mentioned, there hasn't been any hard evidence on the level of spread, yield losses, influence on the economy, or welfare of countries or consumers. Despite their roughness, these estimates have proven helpful in examining the national and regional impact of parasitic weeds; nonetheless, there are certain limitations when extrapolating these figures to the impact on the continent.

Striga generally results in average yield losses that are estimated to be at or above 50%. There have been estimates of between 30 and 50 million hectares of severe to moderate Striga infection overall. However, estimates of the amount of agricultural damage in a given nation or area on the African continent differ based on the crop cultivar, level of infestation, and prevailing cultural traditions. Although a lot of spread has happened since these preliminary approximations were made, no fresh numbers have surfaced. The parasite Striga is spreading at an alarming rate in eastern Africa, where the infection is at its worst and frequently causes crop failure in any given crop season.

***Table 1**. Degree of Striga infection on crops.*

Striga species	Crops						
	Maize	Sorghum	Rice	Pearl millet	Finger millet	Cowpea	Sugarcane
Striga hermonthica	xxx	xxx	xx	xxx	xxx	-	Xx
Striga angustifolia	-	xx	-	-	-	-	Xx
Striga asiatica	xxx	xxx	xx	xx	xx	-	X
Striga forbesii	x	x	x	-	-	-	X
Striga aspera	xx	x	xx	-	x	-	X
Striga gesnerioides	-	-	-	-	-	xxx	-
Striga latericea	-	-	-	-	-	-	X
Striga pubiflora	-	-	-	-	-	-	X

Note: xxx-Serious infection, xx-Moderate infection, x-Less infection, No infection Sources: [5]

4. Ethiopia's Sorghum Genetic Diversity and Prospects

The genus Sorghum comprises five subgenus or sections: Eu-Sorghum, Chaetosorghum, Heterosorghum, Para-Sorghum, and Stiposorghum. Of these, Eu-Sorghum encompasses all sorghum races and varieties, wild and weedy cousins [21]. In addition, [22] identified ten intermediate races (guinea-bicolor, guinea-caudatum, guinea-kafir, guinea durra, caudatum-bicolor, kafir-bicolor, durra-bicolor, kafir-caudatum, kafir-durra, and durra-caudatum) that resulted from natural intercrossing among basic races. These races are all identifiable based on the morphology of their spikelets and panicles, which can be traced back to their respective environments and the nomadic peoples who initially cultivated them [23]. The racial groups known as durra, in Ethiopia and India, kafir, south of the equator in Africa, caudatum, throughout Central Africa, and guinea, which predominates in West Africa, are all extensively spread throughout Africa and Asia [22].

Four races are present in Ethiopia: bicolor, caudatum, durra, and guinea, according to [23, 24]. In a different study conducted in Eastern Ethiopia, [25] identified five fundamental races: the normal durra race is found in the lowlands; intermediate altitudes are home to durra, durra-caudatum, and caudatum; and highlands are home to bicolor-caudatum, guinea-caudatum, and bicolor races.

One of the greatest collections of worldwide sorghum germplasm accessions in its gene bank is owned by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which has a global mandate for sorghum improvement research in the semi-arid tropics (SAT) [26]. With 36,774 accessions from 90 countries, including Ethiopia, it is a significant global germplasm collection repository. The collections now in existence account for over 80% of the crop's variability [27].

Ethiopia is a significant global source of germplasm for sorghum development initiatives. More than 10,000 native sorghum germplasm accessions were gathered from various sorghum-producing areas of the nation and then assessed by the Institute of Biodiversity Conservation and the Ethiopian Sorghum Improvement Program for several agronomic and taxonomic traits.

Sorghum is farmed in eight major agro-ecologies and twenty sub-agroecologies in Ethiopia, which together account for over 66% of the nation's total land area. The genetic variety of the crop in terms of grain color, quality, plant height, resilience to disease and pests, and adaptability to a wide range of temperature and moisture regimes is just as varied as the sorghum-producing settings. The sorghum development program can greatly benefit from such highly variable genetic resources [25].

Plant genetic resources are therefore a crucial component for maintaining and raising agricultural output. Concerns over the loss of genetic resources have led to a major focus on the collection and conservation of genetic variety of vital food crops, such as sorghum [28]. Furthermore, breeders have only used a small portion of the entire material that is available. Many domesticated agricultural plant species, including sorghum, barley, tef, chickpea, and coffee, have their genetic diversity concentrated in Ethiopia. These species are mostly found there in the form of locally adapted landraces and wild varieties that have evolved to withstand harsh environmental circumstances. Small-scale farmers' tiny fields are home to a large portion of this agricultural diversity, which has greatly contributed to the development, upkeep, and effective use of resources [28].

Since sorghum is an indigenous crop of Ethiopia, there is a great deal of variability in the nation. Ethiopia is the global repository for favorable genes of many different crops, including sorghum, for which it is the Vavilonian center of origin and variation. Ethiopian farmers cultivate a variety of mixed sorghum landraces on their fields for a range of regional uses. Ethiopia ranks first among nations that have contributed germplasm collections to the global collections of sorghum at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), indicating that Ethiopia is a rich source of sorghum landraces. Ethiopian sorghum germplasm has been highly contributing to global agriculture.

5. Striga Management Options

5.1. Soil Fertility

Striga thrives in less fertile soil, therefore a method that increases soil fertility would both boost yield and decrease Striga infestation a double benefit. Utilizing agricultural residues and organic manure as part of good soil management techniques has proven to be an effective way to prevent Striga. As the amount of organic matter in the soil increased, the prevalence of striga infestation dropped as well. This organic matter content appeared to be the primary component maintaining the fertility of the soil. Organic or inorganic soil amendments may boost soil suppressive to Striga spp. and also improve soil conditions to increase the yield of succeeding cereals since soil microbial biomass thrives better in a medium rich in organic matter.

5.2. Inter Cropping

According to several researches, intercropping cowpeas between maize rows considerably decreased the quantity of Striga when compared to within the rows. Furthermore, compared to monocrops, finger millet intercropped with green leaf desmodium decreased the number of Striga hermonthica in the intercrops [29]. Striga emergence was lower under intercrops than sole crops; according to related observations on sorghum cowpea intercropping that was also reported by Fasil R in 2005.

Intercropping cereals, primarily with legumes like cowpea, peanuts, and green gram, has generally been demonstrated in studies to decrease the amount of Striga plants. They may be serving as trap crops and obstructing the germination and growth of Striga [5].

5.3. Biological Control Methods

Because biological control is particularly appealing for controlling root parasite weeds in annual crops, conventional weed control methods are challenging to implement due to the intimate physiological interaction these weeds have with their host plants. Given that the bio-control agents are typically very aggressive, host-specific, easy to generate in large quantities, and diverse in terms of the number of isolates, biological control with microorganisms is currently emerging as a crucial part of the integrated management of Striga. Moreover, biological control techniques are typically inexpensive, self-sustaining, and free of unfavorable aftereffects. According to [19], managing Striga with bio-control agents is also significantly less hazardous and environmentally harmful than using chemical pesticides.

5.4. Host Plant Resistance

The capacity of the host root to promote Striga germination while simultaneously preventing or killing the seedlings upon attachment to its roots is known as striga resistance. The best environmentally and financially viable way to control Striga is to utilize resistant crop varieties. Using resistant cultivars, like sorghum, is the most promising new strategy for controlling Striga in East Africa. Many crops have had cultivars resistant to striga developed. Cultivars resistant to Striga, however, are not present in every host crop. eeA sequence of events including haustorium initiation, penetration of the host root, attachment to the host xylem, and germination stimulation control the host/parasite relationship [22].

Numerous cereals, including rice, sorghum, and certain genotypes of maize, have been discovered to be naturally resistant to Striga. Striga is encouraged to germinate by a resistant plant, but it is prevented from adhering to the root. Conversely, a genotype that is tolerant to Striga promotes germination and supports the same number of Striga plants as the sensitive genotype, but it yields more grain and exhibits fewer signs of damage. Research conducted in regions infested with Striga found that cultivating crops resistant to the disease produces fewer Striga plants and a higher crop yield than cultivating plants with a non-resistant genotype [20].

6. Achievements in Striga Control

Numerous strains of striga resistance were created in Ethiopia. When compared to control locations, the striga-resistant cultivars, such as Gobiye, Abshir, and Birhan, that the Sirinka Research Center releases for use in striga-infected fields in the Kobo and Sirinka areas exhibit a yield increase of around three times (25–34 q/ha). In the Kobo region alone, increased usage of the new kinds could result in significantly higher yields. An enhanced cultivar resistant to Striga, fertilizer delivery techniques, and appropriate crop management procedures were all part of the ISM plan.

7. Conclusion

In sub-Saharan Africa, witch weeds (Striga spp.) are endemic parasitic weeds that are gradually expanding their geographic range and degree of infestation, which significantly lowers crop productivity. Of all the plant parasites that feed on roots, the Striga species are some of the most specialized. Striga is a significant biotic limitation and a substantial danger to the production of food for subsistence in Ethiopia. The predominant species, Striga hermonthica, is most severe in severely degraded regions of the country's north, northwest, and east, including Tigray, Wollo, Gonder, Gojjem, North Shewa, and Eastern Harerghe. Because of its wide geographic distribution and devastating effects on millions of people's livelihoods, Striga is quickly growing into a pandemic of significant proportions in the nation.

Striga continues to be a serious obstacle for many other cereals in addition to sorghum. The projected yearly loss of sorghum in SSA due to striga is 22-27%, whereas in Ethiopia it is 25%. In SSA, Striga causes an annual loss of $7 billion in grains, of which $75 million is Ethiopia's portion. Ethiopia is a country with a great deal of variability when it comes to crops, and one of the world's main sources of beneficial crop genes is Ethiopian sorghum.

Ethiopia ranks first among nations that have contributed germplasm collections to the global sorghum collections at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), indicating that Ethiopia is a rich source of sorghum landraces. Ethiopian sorghum germplasm has been greatly contributing to global agriculture. In Ethiopia, sorghum cultivars resistant to striga can be developed.

Author Contributions

Temesgen Teressa is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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