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Challenges and management of parasitic weeds in Ethiopia

Takele Negewo[1*]

Abstract

Background Unlike regular weeds, parasitic weeds parasitize their host crop for sustenance, and critically reduce growth and productivity of the host plants.

Main body The parasitic weeds or heterotrophic plants are conveniently divided into different groups; hemi/partial- or holo/total-parasites, facultative or obligate parasites, root or stem parasites and annual or perennial parasites. Out of about 4000 parasitic plant species, certain species under few plant families; (Orobancheaceae, Convolvulaceae, Loranthaceae and Viscaceae) are considered to be among the most serious agricultural pests of economic importance. They can incur up to 100% yield reduction on host crops depending on the levels of infestation, crop susceptibility and environmental conditions. Their dense occurrence strongly hampers host-crops cultivation. Ample management practices have been tried using many control methods, but so far no economical, feasible or universally dependable means in controlling any of the parasitic weed species. There is inadequate knowledge on parasitic weeds.

Conclusion This manuscript developed to provide information, knowledge and technology on biology, harmful effects and management of parasitic weeds all over the world particularly in Ethiopia.

Keywords Haustoria, Harmful effects, Heterotrophic plants, Host-crops, Parasitism

Background

Unlike regular weeds, parasitic weeds form protoplasmic connection with host plants and directly derive their nutrients, water and food. They have a haustorium, the morphological and physiological bridge between host and parasite that serve as conduit for materials that can move from the host into the parasite. Thus, the parasitic plants obtain growth resources directly from host plants. There are about 4000 flowering plant species having adapted to parasitize other plants. Certain parasitic plant species under Orobanchaceae, Convolvulaceae, Loranthaceae and Viscaceae families are considered as the most serious agricultural pests of economic importance grow on crop plants (Joel 2009; Simberloff and Rejmánek 2011).

Parasitic weeds or heterotrophic plants are conveniently divided into different groups; hemi/partial- or holo/total-parasites, facultative or obligate parasites, root or stem parasites and annual or perennial parasites. The hemi-parasites produce chlorophyll, but holo-parasites completely lack chlorophyll and then the most serious parasitic plants. They again could be grouped as facultative parasites that can germinate without a host or obligate parasites that require a host to germinate. The obligate parasites seed only germinate in response to *strigolactones* released by the host plants. The *strigolactones* isolated and identified are *Strigol*, *Alectrol*, *Orobanchol* and orobanchyl acerate (Matusova and Bouwmeester 2005; Yoneyama et al. 2009; Trabelsi et al. 2017). Moreover, most parasitic plants attack roots and referred as root parasites (epirhizoid parasites), while others restricted to stems

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and referred as stem parasites (epiphytoid parasites). The life cycle of root parasites are mostly annuals while tree plant parasites are perennials. They all are dicotyledonous plants under different plant families with reduced growth due to the loss of photosynthesis, and their less developed leaf and root architecture.

The parasitic plants parasitize the host crop for their sustenance, and critically reduce growth and productivity of the host plants. They are deadly pests with the capacity to exploit other plants. They are causing economically significant losses to annual and perennial crops, and threaten the livelihood of human being in many parts of the world. They can incur up to 100% yield reduction on host crops depending on the levels of infestation, crop susceptibility and environmental conditions (Abebe et al. 2013; Fernández-Aparicio et al. 2016a). Heavy infestation of the parasitic weed plants does not only lead to a complete crop failure, but also makes the field parasitic plant sick for many years and hampers host-crops cultivation.

Parasitic weeds problem exacerbated due to an ever increase in population pressure, and associated world climate change, frequent cultivation of host crops and reduced soil fertility (Negewo et al. 2022). Compared with most of the other regular weeds, parasitic weeds are difficult to control because of their life style. The management of parasitic weeds is mainly hindered by their high fecundity, dispersal efficiency, persistent seedbank, and rapid responses to changes in agricultural practice which allow them to adapt to new hosts and manifest increased aggressiveness against rarely obtained resistant cultivars. Their management has been tried using several control methods, but so far no economical, feasible or universally dependable method. There is also inadequate knowledge on parasitic weeds. This document organized to give overview information, knowledge and technology on biology, harmful effects and management of parasitic weeds majorly targeting the situations in Ethiopia.

Methodology

Reviewing research articles and working documents associated to parasitic weeds in Ethiopia such as major parasitic weed species, their distribution, host range, impacts and ongoing management efforts so far reported in the country was done, and discussed in the following sections of this document. The general percentage of plagiarism of the document is found interestingly very low.

Major parasitic weeds in Ethiopia

Parasitic plants so far recorded in Ethiopia are indicated in Table 1. Certain species have a large host spectrum, whereas others have more specific host. Moreover, their distribution, impact and ongoing management effort have been discussed in the document headed with their common names as follows.

Broomrapes

Broomrape is the collective name given to *Orobanche* and *Phelipanche* species indicating the harmful and difficult to control nature of the parasitic weeds. The broomrapes, obligate root holo-parasites have more than 150 species in the world, but few are considered as economic importance.

Species

The most important broomrape species in Ethiopia include *Orobanche crenata, O. cernua, O. cumana* and *O. minor* (nodding broomrape), and *Phelipanche ramose* (branched broomrape) as reported (Tadesse et al. 1999; Stroud and Parker 1989) (Fig. 1).

Orobanche crenata attacks legumes like faba bean (*Vicia faba* L.), pea (*Pisum sativum* L.), lentil (*Lens culinaris* Medik), chickpea (*Cicer arietinum* L.), vetch (*Vicia sativa* L.) and clover (*Trifolium* spp.). It is economically most important *Orobanche* species in the world. Hosts of *O. cernua* are tomato (*Lycopersicon esculentum* Mill.), potato (*Solanum tuberosum* L.), tobacco (*Nicotiana tabacum* L.) and eggplant (*Solanum melongena* L.). The *O. minor* attacks niger (*Guizotia abyssinica* (L. f.) Cass.), clover, lucerne or alfalfa (*Medicago sativa* L.), tobacco, carrot (*Daucus carota* L.), lettuce (*Lactuca sativa* L.), sunflower (*Helianthus annuus* L.) and many other crops. It also occurs on ornamental and wild plants all over Ethiopia. Hosts of *O. cumana* are sunflower and safflower (*Carthamus tinctorious* L.). In certain cases, it parasitizes tomato too. Hosts of *Phelipanche ramosa* are tomato, hemp (*Cannabis sativa* L.), potato, tobacco and also groundnut (*Arachis hypogaea* L.), cowpea [*Vigna unguiculata* (L.) Walp.] and pepper (*Capsicum annuum* L.). It was recorded also on a range of ornamental plants.

As reported outside Ethiopia, the other economically important broomrapes species are *O. foetida* Poiret on faba bean, chickpea and clover, and *P. aegyptiaca* (Pers.) Pomel on tomato, potato, tobacco, eggplant, pepper, pea, vetch, faba bean, carrot, celery (*Apium graveolens* Dulce), parsley [*Petroselinum crispum* (Mill.) Nym], cumin (*Cuminum cyminum* L.), cabbage (*Brassica* spp), cauliflower (*Brassica oleracea var. botrytis*), rapeseed (*Brassica napus* L.), mustard (*Sinapis arvensis* L.), hemp, sunflower, spinach (*Spinacia oleracea* L.), etc.

Biological and ecological characteristics

Broomrapes are devoid of leaves and totally dependent on their hosts for most of their life cycle. They have high seed production capacity i.e., numerous dust-like tiny

Table 1 Description of parasitic weeds recorded at different parts of Ethiopia

Common name	Family	Species	Parasitism
Broomrapes	Orobancheaceae	*Orobanche crenata* Forskal, *O. cernua* Loefl, *O. Cumana* Wallr, *O. minor* SM	Holo-parasites
		Phelipanche ramose (L.) Pomel	
Witch weeds		*Striga asiatica* (L.) Kuntze, *S. hermonthica* (Del.) Benth	Hemi-parasites
		Alectra vogelii Benth	
Dodders	Convolvulaceae	*Cuscuta campestris* Yunck., *C. epilinum* Weihe	Holo-parasites
Mistletoes	Loranthaceae	*Englerina lecandii* (Engl.) Balle, *Erianthemum dregi* (Eckl. & Zeyh) VanTiegh., *Phragmanthera regularis* (Schweinf) M.G. Gilbert	Hemi-parasites
	Viscaceae	*Tapinanthus globiferus* (A.Rich.)Van Tiegh., *Viscum tuberculatum* A.Rich., *V.congolense* De wild., *V. triflorum* DC	

seeds. A single plant can bear half a million seeds per a season that capable of heavily infesting crop field and rapidly increasing the seed bank of a given site. The seeds remain viable for many years, possibly 10 or more, spread from one field to another by water, wind, animals and man, and remain viable after passing through the alimentary system of animals (Rubiales and Fernández-Aparicio 2012).

The condition for germination of broomrapes is very stringent and follow certain defined sequence in terms of water absorption, pre-conditioning and sensitivity to germination stimulants. They spend most of their life cycle underground, before emergence of the shoot and diagnosis of infection. These include seeds conditioning, reception of a chemical stimulus from host and germination, haustorium differentiation from radicle and attachment to the host plant, and tubercle initiation and development (Uematsu et al. 2007; Westwood , 2013). Their seed germination is triggered by crop root exudates, up on germination only a radicle emerges from the seed, form a haustorium when reached a host, intrusive cells of the haustorium penetrate the host, the parasite develops a tubercle that grows on the host root surface underground, lateral roots of the tubercle can also develop haustoria whenever a host root develops nearby and at later, the tubercle develops flowering shoot(s) that emerge above the soil surface (Joel 2000; Rubiales 2014). They have mostly single point of entry into the host and about 45–60 days to emerge above ground to produce a floral stalk. According to Joel (Joel 2000), the life cycle of root parasitic angiosperms; orobanche, phelipanche and striga are very similar (Fig. 2).

In nature broomrapes are thermophilic that they require dry condition and light soils to be an invasive. Threatening both the large and small scale subsistence farming communities, alarming infestation occurred since 1980s in Ethiopia (Abebe et al. 2013; Gebremariam 2005; Mekonnen 2016; Esraa et al. 2017). They are increasingly become main threat to commercial and industrial crops. The *O. crenata* is getting worse in pulse crops mainly on faba bean in northern highlands, whereas *O. cernua* and *P. ramosa* are seriously important in horticultural crops mainly on tomato in Central Rift Valley areas of the country. They are major biotic limiting factors to the production of crops under Fabaceae, Solanaceae and Asteraceae plant families. There dense infestation force farms to give up growing such economically valuable crops. They are found as big challenges to pulse

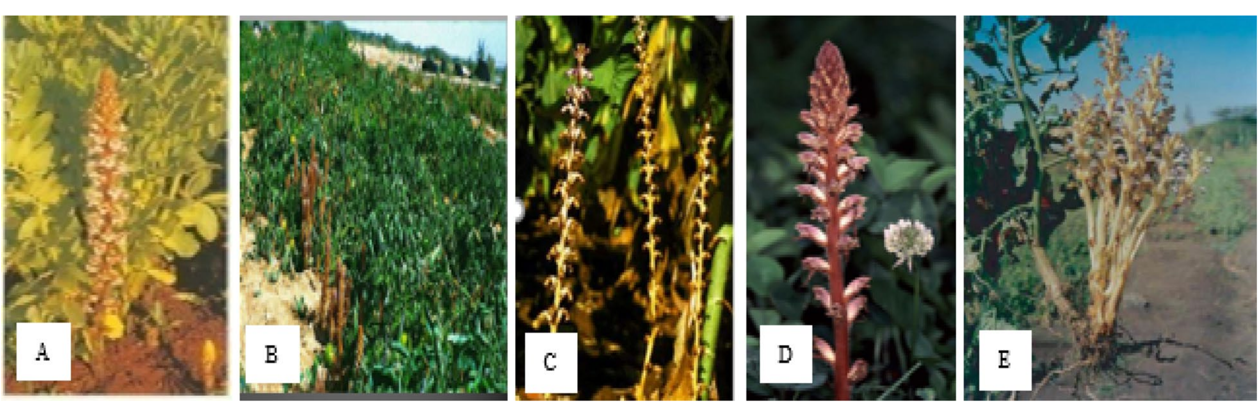

Fig. 1 Broomrape species; (**A**) *Orobanche crenata* (**B**) *O. cernua* (**C**) *O. cumana* (**D**) *O. minor* and (**E**) *Phelipanche ramose*

Fig. 2 Life cycle of crenate broomrape; (**A**) seeds in water bubble (**B**) underground tubercles (**C**) emerging shoots (**D**) flowering shoots and (**E**) seeds shedding mature parasitic plant; Source: (Negewo et al. 2022)

and vegetable production; the average yield loss is estimated to 36% but under highly infested fields can extend to 100% (Abebe et al. 2013; Gebremariam 2005).

Broomrapes infestation is increasing from time to time due to dispersion of the seed via irrigation water, wind, agricultural machinery and tools, and movement of laborers and animals (Gebremariam 2005). The preponderant of the economically important crops; faba bean, tomato are seen as the main obstacle for proper rotation practices. It is also a challenge to the tomato processing plant of the country.

Management

Broomrapes management techniques can be grouped and discussed under several major categories like phytosanitary measures; physical, cultural, mechanical, biological and chemical control methods; growing resistant, tolerant and/or transgenic crops, and integrated management strategies.

Phyto-sanitary measures The alarming cross-border and local dispersal of broomrape is largely due to the effective way in which the parasite spread to a large extent through human-mediated actions (Goldwasser and Rodenburg 2013). The sanitary practices suggested as possible solution at different levels are; use of weed free nursery site or soil sterilization if weed free sites cannot be found, locating nursery sites around the source of water canal to reduce spread of weed seeds, control of alternate hosts in nursery site, infested field and banks of water canals, minimizing the movement of infested soil through cleaning of farm implements (hoes, spades, etc.), farm machineries (tractors and other transport vehicles), and harvesting materials; controlling irrigation water free movement from field to field to prevent spread of the weed seeds, preventing free movement of grazing animals on infested fields, avoiding the use of hay from infested plants and fields; treating manure i.e., composting, and burning the stubbles of crops and weeds in infested fields. In general, these phyto-sanitary measures are suggested aiming to reduce the broomrape seed bank, while minimizing the production of new seeds and their dispersal (Goldwasser and Rodenburg 2013; Panetta and Lawes 2005).

Physical, cultural and/or mechanical control

a. Solarization

   Mulching soil with polyethylene sheet for several weeks can kill broomrape seeds in the upper soil layer. For instance, when an infested field solarized for 2 months, it can reduce the seeds by greater than 90% (Ashrafi et al. 2009). The success for in soil desiccation of the parasite seeds via solarization requires moist soil, high air temperature and solar radiation, and adequate length of exposure.

b. Flooding

   Broomrape seeds lose their viability after a month storage in water. A flood maintained continuously for about two months prior to draining and planting tomato well suppressed parasitic weeds (Sherif 1988). Factors influencing the success of the flooding practice like the weed species, length of period, temperature extent and soil type deserve further study.

c. Land preparation

   Deep inversion ploughing at 45–50 cm can be considered as one initial step in an integrated effort for the management of serious broomrape infestation where soil and plough machine conditions permit (Morozov 1998).

d. Sowing date adjustment

   Delaying or early sowing of a crop may decrease the parasitic weed infestation and then the damage it can causes. Delayed sowing of faba bean reduced *O. crenata* infection on the crop in the infested areas (Kemal 2015). The late sowing creates sub-optimal soil temperature that decrease seed germination and obstruct seedling development of crenate broomrape. The optimum temperature for its seed germination is 15–25 °C, and it decreases at a temperature of less than 5 °C.

e. Growing non-host crops
In the broomrapes infested field, purposive growing of non-host crops found very important. However, to do so it is necessary to know the host preferences of the particular parasitic weed population in the field (Abu-Shall and Ragheb 2014).

f Trap-cropping
Trap crops promote broomrape seed germination but do not support parasitism. Involvement of flax, coriander, basil, fenugreek and Egyptian clover as rotation crop on *O. crenata*, sorghum, cow pea, chilli, lucerne, soybean and chickpea on *O. cernua*, and flax, phaseolus bean, sorghum, snap bean, maize and cucumber on *P. ramosa* can serve as successful trap crops (Habimana et al. 2014). Trap crop varieties with high inductor and allelopathic potential can shorten the time interval required between the host crops growing.

g. Catch-cropping
Catch crops promote parasitic weed seeds germination and support parasitism but are destroyed prior to their flowering e.g. susceptible faba bean and brassica. They can result a reduction of orobanche seed bank by more than 33% when planted before host crop planting (Fernández-Aparicio et al. 2013).

h. Fertilization
Nitrogen and phosphorus deficiency enhance exudation of strigolactones, the most potent germination-inducing factors for the parasites. Broomrape dense infection tends to be associated with less fertile soil condition. However, nutrient management using organic or/and inorganic fertilizer can impair strigolactones production, and then promote both resistance and tolerance in crops to parasitism besides the toxic effects on seeds and seedlings of broomrapes (Trabelsi, et al. 2017; Mulugeta, et al. 2019).
High levels of N have been reported to reduce *P. ramosa* in tomato and tobacco. Use of 350 kg Urea + 500 kg DAP + 500 kg KNO_3 for hybrids, compost i.e., 1/3 of the above + 14,000 kg compost ha^{-1} or Urea, ammonium nitrate and ammonium sulfate at 207 kg N ha^{-1} found effective in reducing *P. ramosa* parasitism and enhancing growth of tomato plants (Gebremariam 2005). Moreover, the author indicated that goat manure application at 20 t ha^{-1} found effective in reducing *P. ramosa* parasitism and enhancing growth of tomato plants. It is also reported that the ammonium nitrogen fertilization at 75 kg N ha^{-1} reduced *O. crenata* infection on faba bean with substantially increase in the crop grain yield (Kemal 2015).

i Irrigation
Under dry conditions, parasite development with respect to host plant is favored. However, under irrigation in the dry months, the high temperature and moisture induce broomrape seeds degradation (Gebremariam 2005). The authors also described that frequent irrigation before crop establishment, and at every four to 6 days' interval depending on soil types after the crop establishment found effective in promoting growth of the crop and suppressing the parasite infection.

j Hand weeding
The broomrapes are widely hand pulled as traditional and available control method among farming communities, but found late and ineffective in reducing the immediate damage, though important in limiting further increase of the seed bank (Labrada 2008). The parasitic weed shoots need to be weeded before seed setting and immediately discarded since they can continue developing flowers and spreading seeds. It requires to be practiced frequently that cause high cost, considerable mechanical damage to crop plants and significant reduction of the host crop yield.

Biological control

Biological control on broomrapes was tried in Ethiopia a long year back (Negewo et al. 2022) but since then no progressive work done. The broomrape-fly, *Phytomyza orobanchia*, was widely used in the Soviet Union and some East European countries. No outstanding success has so far been achieved using this biological agent, mainly because of some hyper-parasites e.g. *Opius occulisus.* Orobanche specific *Fusarium oxysporum* was also used in tobacco and in sunflower, this agent is still on process to be developed as myco-herbicide (Klein and Kroschel 2002).

Use of blow ground bio-agents or microbial regarded as ideal broomrape control agents because of the root parasitic plants nature i.e., having long underground lifetime, and the un-emerged plants cause vast damage on the host. The *Bacterial* and *Trichoderma* spp. as soil treatment found effective in reducing the parasite infection and increasing yields of faba bean (Esraa et al. 2017; Fernández-Aparicio et al. 2016b). Moreover, natural pesticides or botanicals are considered to be less pollutant because they usually biodegrade quicker. Leaf powder of *Xanthium abyssinicum* strongly interfered the germination of *P. ramosa* seeds that was resulted an increased tomato fruit yield (Gebremariam 2005).

Chemical control

Chemical control using herbicides like sulphonyl urea chlorsulfuron, imidazolinone compounds imazaquin, imazethapyr or imazapyr is still being explored. As broomrape lacks chlorophyll, photosynthesis inhibitors cannot be used for its control. Herbicides should be targeted at the early stage of the parasite, i.e. located under the soil surface. There are few herbicides but almost none of them can control it with a sufficient margin of selectivity. Glyphosate can be used with a few crops if applied in low doses. Glyphosate application at low dose (60 g ha^{-1}) achieved good result in faba bean field (Mekonnen 2016). Moreover, soil-applied sulfonyl urea herbicides were shown to be effective in tomato (Slavov et al. 2005). Strigolactones usage in the absence of a host can also lead to a reduction in parasitic weed seed bank.

Growing resistant and/or tolerant crops

Growing resistant and/or tolerant crops leads the fight against the root parasitic weeds, but without unequivocal success. It has been demonstrated in certain tomato varieties in pot experiment. Screening of tobacco and tomato varieties demonstrated some variations in resistance to *P. ramose* (Gebremariam 2005). Moreover, tolerance with highest seed yield potential found in faba bean genotype variety 'Hashenge' (Abebe et al. 2015).

Growing transgenic crops

The use of transgenic crops, crops engineered with target-site herbicide resistance is perhaps one of the most promising solutions for parasitic weeds infestation in many fields. Using herbicides complete control was achieved without affecting the crop or its yield like glyphosate on transgenic oilseed rape, and chlorsulfuron and asulam on tobacco (Slavov et al. 2005).

Integrated management of broomrape

Integrated management is a technique that combines different preventive measures and control methods into given farming system. As a strategy it is required to develop being no single dependable broomrape suppression technique. For instance, manuring the farm lands augments the broomrape killing effect of solarization (Ashrafi et al. 2009). Nitrogen at 92 kg ha^{-1} and irrigation at four days' interval gave effective control of *P. ramosa* in tomato (Gebremariam 2005). The *O. crenata* tolerant faba bean variety with twice glyphosate application and continues hand weeding found effective (Mekonnen 2016). The author reported that orobanche tolerant variety 'Hashenge', two times glyphosate application when the crop start flowering and one week after the first spray, and continues hand weeding before seed setting give better yield in Wollo areas. Besides he suggested that the practice also reduced orobanche seed bank in the soil. Moreover, the *O. crenata* tolerant faba bean with bio-fertilizer resulted acceptable crop yield. The tolerant faba bean variety with *Rhizobium leguminosarum* and *Trichoderma harzianum* played a good role in reducing *O. crenata* infection and increasing the crop productivity (Kidane et al. 2019). It is well accepted that use of tolerant varieties with improved agronomic practices is the most economical and safe ways in controlling such weeds. Host-plant tolerance/resistance as major component of an IM strategy is largely advised, being effective, durable, economical and practical for low-input farming systems.

Witch weeds

Witch weeds are obligate root hemi-parasitic plants mainly on cereals and affect sorghum (*Sorghum bicolor* L. Moench), maize (*Zea mays* L.), etc. and also on grain legumes like groundnut (*Arachis hypogaea* L.) in the dry land areas of tropical countries including Ethiopia. Their infestation can cause serious yield reduction in most rural community that estimated from 40 to 100% yield loss (Hussien 2006).

Species

The most important witch weed species in Ethiopia are *Striga asiatic, S. hermonthica* and *Alectra vogelii* (Fig. 3). They are named based on their flower color commonly as purple witch weed, red witch weed and yellow witch weed, respectively.

Biological and ecological characteristics

Witch weeds produce large number of minute seeds which easily disperse by wind, water or plant debris, and remain viable in soil for more than ten years. *Striga asiatica* is serious problem in eastern and southern Ethiopia, while *S. hermonthica* in western and northern on sorghum and maize, and *Alectra vogelii* on groundnut in Rift Valley areas of the country (Hussien et al. 2006). However, it is most important on grain legumes like cowpea [*Vigna unguiculata* (L.) Walp.], soybean [*Glycine max* (L.) Merr.], mung bean [*Vigna radiate* (L.) Wilczek] and common bean (*Phaseolus vulgaris* L.) in sub-Saharan Africa.

Management Witch weeds management can be performed using the following major techniques; phyto-sanitary measures; cultural control- intercropping, crop rotation, row planting, soil fertility management, moisture harvesting, hand weeding; growing resistant and/or tolerant variety: 'Abshir', 'Gobye', 'Brhan'; growing herbicide resistant varieties; host induced gene silencing; microbial approach-use of *Fusarium* species as myco-herbicide, arbuscular micorizal fungi (AMF); chemical control and integrated management.

Fig. 3 Witch weed species; (**A**) *Striga asiatica* (**B**) *S. hermonthica* and (**C**) *A. vogelii*

a. *Phyto*-sanitary measures

Phyto-sanitary measures help to reduce witch weeds seed bank, while minimizing the production of new seeds and their dispersal as discussed in detail on broomrape in the sub-"Phyto-sanitary measures". Section of this document.

b. Intercropping

In areas where striga incidence is severe, intercropping of sorghum with legumes such as green gram or mung bean [*Vigna radiate* (L.) R. Wilczek], cowpea, soybean and groundnut help in suppressing them through suicidal germination and improving soil fertility (Hussien 2006; Franke et al. 2006). In addition, intercropping cowpea or soybean at first weeding of sorghum in two row planting pattern found more effective in reducing the infestation, and improving soil fertility and crop productivity. Some of the intercrops have the ability to smother striga, while others produce root exudates that prevent germination of its seed, e.g. sunflower, cotton (*Gossypium hirsutum* L.).

c. Herbicide resistance

Herbicides like imazapyr and pyrithiobac applied as seed dressing to maize reported to give efficient control of striga (Woomer and Savala 2008). This effort is most advanced in Kenya, where one variety of the imazapyr resistant (IR) maize hybrid registered for commercial release. The IR maize hybrid reduced striga expression at large, improved yields and increased farmer's net return by more than 50%. Moreover, application of 2,4-D and ametryne found effecting in reducing striga infestation in sorghum field (Mulugeta et al. 2019).

d. Integrated management

Integrated management offers the best possibility for reducing difficult to control striga impact. It may involve measures aimed at avoiding striga introduction into new areas, reducing the amount of seed already in the soil with those aimed at avoiding addition of new seed to the soil. Moreover, use of resistant or tolerant crop variety, and soil fertility and moisture management should be part of any striga integrated management strategy. They are more sustainable in enhancing host crop productivity in the areas prone to striga infestation (Kamara 2020; Sibhatu 2016). While assessing indigenous striga management practices in sorghum, (Woldewahid et al. 1998) observed that farmers traditionally employ a variety of measures like growing of better performing varieties, dry and late planting, inter-row cultivation and hand weeding to cope up with the courage.

Agronomic practices consisting row planting, mineral fertilizer and 2,4-D application led to appreciable reduction in striga infestation and an increase in sorghum yield by 40% (Mulugeta, et al. 2019). It was also found that combined use of row planting, fertilizers application and hand pulling at flowering reduced striga shoots count by 50% and increased sorghum grain yield by 48% (Reda 1997). Implementing cultural practices that favor AMF, such as reducing tillage and chemical application, could improve growth and increase drought tolerance in crops, and potentially reduce striga infestations. Seed of striga resistant sorghum (INTSORMIL varieties or Brhan), 80 kg ha^{-1} of urea and the use of tied-ridging as a water conservation measures drastically reduced striga infection, and increased vigor and yield of the crop plant as much as 4 t ha^{-1} (Ejeta and Tessema 2019). The *S. hermonthica* control package that included use of striga tolerant maize varieties, fertilizer application and intercropping or rotation with legumes cultivars (soybean, cowpea) was found effective in reducing the parasite infestation and increasing yields of maize (Hussien 2006; Franke et al. 2006).

Dodders

Dodders are facultative stem and leaf holo-parasitic weed plants. They cause sever debilitation and reduction in host crops growth and yields, and threaten livelihood of human being in the world. Established host plants are usually not killed by dodder, but can be weakened and thus more susceptible to other pests, including insect and nematode invasion (Cudney et al. 1992).

Species

In the world, about 10 to 15 dodder species reported occurring as significant problems. (Alemayehu and Ashagrie 1991) reported that from dodders parasitic weed group *Cuscuta campestris* Yunck (field dodder) and *C. epilinum* Weihe (flax dodder) are the only species found economically important in Ethiopia (Figs. 4, 5). Furthermore, the two exotic *Cuscuta* species have been reported as widely distributed and troublesome species in the country (Parker 2001).

Biological and ecological characteristics

The germination of dodders is more spontaneous without stimulation from the host crops and moisture is the major requirement. In dodders, parasitization of the host

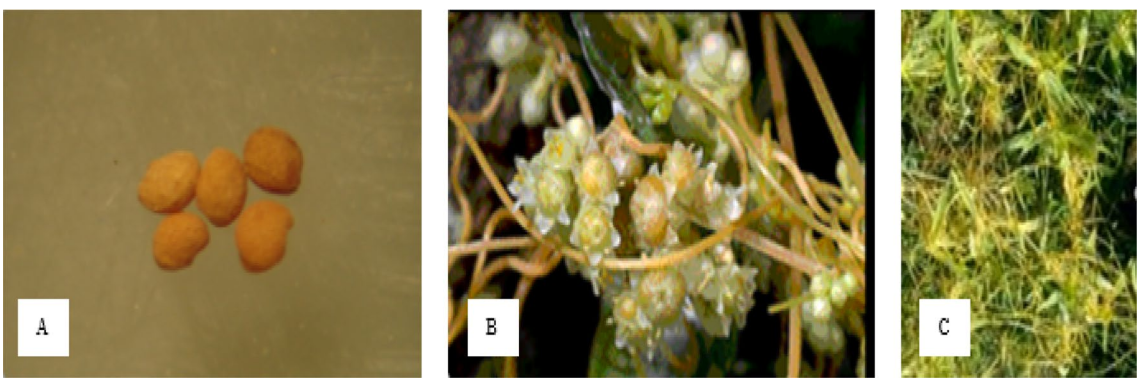

Fig. 4 *C. campestris;* (**A**) seed (**B**) spick and (**C**) infection on niger seed

Fig. 5 *C. epilinum;* (**A**) spick and (**B**) infection on flax

is very rapid (27–31 days) with multiple haustorial connections with the host stem, leaf, petiole, fruits and even on their own stems. They are fast growing parasitic plants having faster nutrient translocation, because exceptionally the xylem bridge is accompanied by phloem. They are consisting of little more than leafless yellow or orange twining stems, with leaves reduced to small scales, forming a parasitic web over the above-ground parts of both crop and other weed plants. They were found causing significant reduction in chlorophyll content in infested host plants (Saric-Krsmanovic et al. 2018).

Cuscuta campestris reported as a weed in 25 crops from oil, pulse, vegetable, fruit and tree crops in 55 countries (Kogan and Lanini 2005). In Ethiopia, it attacks niger [*Guizotia abyssinica* (L.) Cass.] and lentil (*Lens culinaris* Medik) crops growing in different parts of the country, while *C. epilinum* solely attack linseed (*Linum usitatissimum* L.). Their seeds are heavy and then distribute usually via infested crop seeds or forage unlike other weed seeds (Yeshanew et al. 1993).

Management In most cases, dodder management practices in crop fields are distractive on both the parasitic and host plants. Working against seed bank is solely found effective. Thus, its management depends almost completely on preventing seed production, crop rotation, seed-cleaning, hand weeding, and to some extent herbicidal control under high infestation (Parker 2021).

a. Cultural

Hand removal with the host crops or hand combing practiced for small infestations before seeding. For larger infestations it needs to mow, cultivate or burn with the crop plant to prevent seed production.

b. Chemical

Herbicides like butralin and imazethapyr spray found effective in reducing the weed infestation at early growth stage. Spraying none selective herbicides can kill the weed with its host plant and then prevent seed production under dense infestation.

Mistletoes

Mistletoes, shoot attacking hemi-parasites, parasitize economically important fruit and tree plants. They are perennial epiphytes, which are capable of photosynthesizing but dependent for water and mineral nutrients on the host plant. They are physically and physiologically connected to their host through haustoria, establishing a functional connection to the host xylem to acquire water, minerals, nutrients and some photosynthates (Mathiasen et al. 2008). They cause disruption of normal physiological and biochemical functioning of host plants causing severe deformity, abnormal branching, killing of the distal parts of plant branches, production of fewer flowers, fruits and viable seeds, etc. It is very certain that mistletoes reduce final yield of host plants so drastically as it kills branches, though total loss appear when host plant is killed.

Species

Mistletoes are taxonomically placed in two separate families based on their flower morphology; Loranthacea (900 species, 65 genera) produce comparatively large showy flowers while those of Viscaceae (400 species, 7 genera) tend to be small and inconspicuous (Mathiasen et al. 2008). Both of them have been considered as among the most serious agricultural pests of economic importance.

In southern and south western Ethiopia, approximately 30–40 mistletoe species are known to exist. Out of the known species *Englerina lecardii* and *Phragmanthera regularis* from Loranthacea, and *Tapinatus globiferus, Viscum tuberculatum, V. congolense* and *V. triflorum* from Viscaceae family occur on fruit and tree species (Hedberg 1994; Yirgu 2013). In Bahir Dar University of the country main campus vegetation, three species of mistletoes *Erianthemum dregi*, *Phragmanthera regularis*

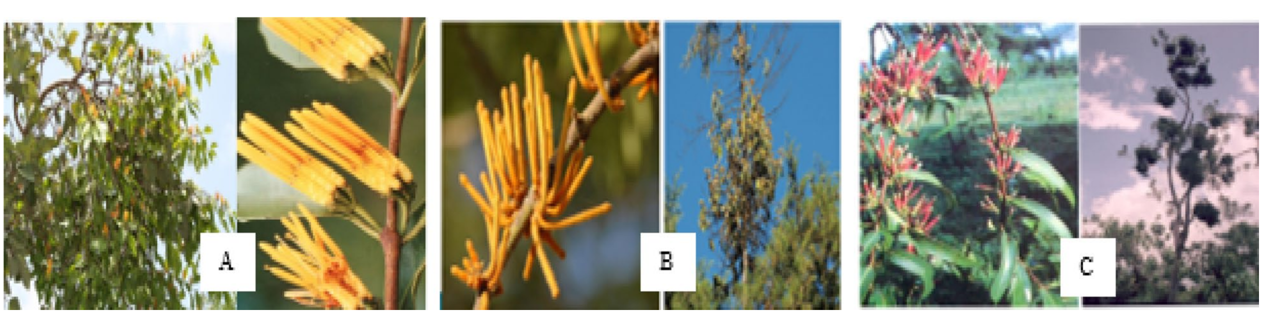

Fig. 6 Mistletoes plant and flower parts; (**A**) *Englerina lecardii* (***B***) *Phragmanthera regularis* and (***C***) *Tapinanthus globiferus*

and *Tapinatus globiferus* were identified and reported on 11 species of host trees mainly on *Sesbania sesban, Jacaranda mimosifolia, Casuarina equisetifolia* and *Cordia africana* (Hishe and Abraha 2013). More important mistletoe species in the country like *Englerina lecardii, Phragmanthera regularis* and *Tapinanthus globiferus* are shown in Fig. 6.

Biological and ecological characteristics

They are facultative stem or branch hemi-parasitic flowering plants that attack fruit and tree plants; coffee (*Coffea arabica* L.), citrus (*Citrus* spp), peach [*Prunus persica* (L.) Batsch.], cocoa (*Theobroma cacao* L.), apple [*Malus domestica (Borkh.*)] and forest tree plants. The mistletoe infections are perennial with a span of 6 to 7 years between infection of the host and the first production of seed. They have fruits surrounded by sticky substance, viscin, by which they adhere to twigs or branches of host plants where they deposit or spread usually by birds (Roxburgh and Nicolson 2005). The seed germinates without special stimulation from the host and the radicle penetrates the host bark to the cambial layer.

Mistletoes have higher transpiration rates and conductance than their respective hosts, and can be responsible up to 40% decline in crop production threatening livelihood of human being (Yirgu 2017). They can kill branches of the host and sometimes the host plants as a whole that proportionally reduce or totally stop final yield of the trees. Bark cracking and gum or resin exudation may also occur which in turn may predispose the host to invasion by insects or secondary fungal pathogens. They are found as very important parasitic weed plant in south and southwest part of Ethiopia.

Management Being not an easy task to manage the already established mistletoes, its management shall be planned to minimize spread to non-infected or new stands by creating different barriers. The techniques include phyto-sanitary measures, and cultural and chemical control methods.

Phyto-sanitary measures Control of mistletoe growth in trees adjacent to orchards/plantation through pruning or selective felling used to indirectly control or reduce seed production and threat of spread via birds. Moreover, severe mistletoes infestations are more often the result of weak tree growth, than its causes. Thus, maintaining optimum tree crop vigor through good crop husbandry is an important practice to indirectly suppress mistletoes infection.

Cultural

a. Pruning

Virtually the only direct control method available for the control of mistletoes is pruning. It is suitable only for high value tree crops. It involves the host tree branch rather than just the parasite, so it needs to cut the tree host branch 15–20 cm below the point of attachment. It is done for evergreen hosts at the time of the parasite flowering, while for deciduous hosts when the tree dropped its leaves (Parker 2001).

b. Shading

Mistletoes rely mainly on their photosynthesis for vigorous growth, hence shading by host or other foliage is detrimental on their growth. Shade from shade tree plants has significantly reduced the density and vigor of mistletoes (Parker 2001).

c. Agronomic management

A fast growing tree will generally tend to suppress mistletoes growth. Hence, any crop management practices which improve tree growth i.e., fertilization, irrigation and adequate control of under story weeds reduce the importance of mistletoes.

Chemical control: Trunk injection with herbicides like 2,4-D and Ethephon 2%, toxic salt like copper sulphate solution, and diesel oil emersion found effective in controlling mistletoes (Parker 2001).

Conclusions

The problem of parasitic weed species is getting worse on economically important crops in different parts of Ethiopia. An increasing pressure of population and corresponding decreases in fallowing and soil fertility, and lack of knowledge are responsible for the continuous increase of their harmful effects. Studies on the parasitic weeds are minimal as compared to other problems in farming communities. Many control methods are not or weakly used by farmers and still in the country no harmonized parasitic weeds management strategy well developed. Undeniably, the management of parasitic weeds has proved to be exceptionally difficult. In the absence of simple direct parasitic weeds control measures, there is a need to upgrade the knowhow of farmers and develop an integrated management program. The management effort shall target their earlier life stages, prior to attachment for successful control. Host tolerance and/or resistance with agronomic control methods appeared to be the most appropriate measure when available and affordable.

The development of future strategy for preventing new introduction, minimizing impacts on infested areas and checking further dispersal by creation of necessary knowhow is very important. There is a need to make accessible available management technologies and information to growers, and enhance the linkage between research and extension. Parasitic weeds effective management requires strategic approaches considering biology of the weeds and socio-economic aspects of a particular agro-ecology. At all, limiting the parasitic weeds spread, alleviating their damage to host crops and promoting food security for future generations are found critical.

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