Economically Important Parasitic Weeds and Their Management Practices in Crops

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Abstract
A review was made to highlight research conducted yet concerning to important parasitic weeds and their management practices in crops. Accordingly, parasitic plants attach themselves to another plant, their 'host', and draw nutrients from it. Of many species of parasitic plants, only a small percentage of them are found to infest agricultural crops and cause serious problems for farmers in many parts of the world. It has been reported that both root and shoot parasitic plants utilize chemical cues released by host plants a specialized haustorium to attack host-plants. Host-plant defenses against parasitic plants are mediated by hormones and plant trichomes. Loss in yield is a result of competition and extraction of water, nutrient and metabolites caused by the parasite. Moreover, the crop yield losses due parasitic weeds vary from area to area and species to species as well. Of parasitic weeds *Striga*, *Orobanche* and *Cuscuta spp*. are among important one and can severely affect crops yield. Although some anticipating management methods against these weeds have been developed, new strategies continue to be relevant in integrated fashions. Conventional methods applied individually have a limitation. Hence, sustainable management is mandatory. Likewise, continuous study of progress on host range, host-parasite interaction, distribution and managements should be done to have up to date information. Furthermore, there is a need to strength quarantines at all levels to avoid introduction of these weeds to new area and reduce crop losses.
Keywords: Crop losses, haustorium, parasitism, parasitic weeds**,** management options

1. INTRODUCTION
About 4,000 flowering plant species have adapted to parasitize other plants. Unfortunately for farmers, a small number of these species have become weeds, posing severe constraints to major crops including grain and forage legumes (Rubiales and Heide-Jørgensen, 2011). Parasitic weeds are the plants which attack other plants by making connections and deriving part or all of their food from the host. They attach themselves either to the roots or the shoots of the host plants and survive on food material available in them. Due these parasites include some of the world's most devastating agricultural pests and are influential, fascinating components of natural communities (Press MC and Phoenix GK., 2005). 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 level of management practices (Runyon JB *et al*., 2010). The most economically important parasitic weeds are the broomrapes (Orobanche), Striga and dodders (Cuscuta spp.) damaging different crops (Joel *et al*. 2007; Parker, 2009). Putting the fact in view, this review was also focused on these most economically important groups of plant parasites.

Parasitic weeds can be difficult to eradicate because they often produce large numbers of long-lived seeds. In addition, parasitic plants that attack host roots can inflict serious damage to crop plants before the latter emerge from the soil, making it difficult to diagnose infestations before economic losses occur. Few practical and economically sound methods are available for controlling parasitic plant species (Gressel *et al*., 2004; Rispail *et al*., 2007), in part because their physiological connection to host plants limits the usefulness of most herbicides. The search for improved or alternative approaches to controlling parasitic plants in agriculture can be facilitated by an increased understanding of the complex ecological and physiological interactions between parasitic plants and their hosts. Equally, knowledge of agriculturally important parasitic weeds and current control practices being taken by farmers used to design and develop effective management practices. Hence, the objective of this paper was to review research done so far by researchers and scholars regarding to major parasitic weeds and their management practices in crops.

2. CLASSIFICATION OF PARASITIC WEEDS OF CROPS
Parasitism originated independently several times during angiosperm evolution, and the lifestyles of parasitic plants vary greatly across taxa (Nickrent *et al*., 1998). Some species are facultative parasites that are able to survive in the absence of hosts, while others are obligately parasitic and cannot develop independently. A distinction can be drawn between hemiparasitic plants that possess chlorophyll and are able to produce some of their required nutrients through photosynthesis and holoparasitic plants that lack chlorophyll and are completely dependent on host resources, but this distinction is not always clear-cut (Press and Graves, 1995). A more

definitive division can be drawn between parasitic plants that make below-ground attachments to host-plant roots and those that attach above ground to host-plant shoots. Based on these parts they can be categorized to stem and root parasitic weeds which are highlighted below.

2.1. Stem parasitic weed

Parasitizing to stem or attach above ground parts of host-plant. They can be divided into holoparasites, which lack chlorophyll and derive all their resources from their host, and hemiparasites, which contain chlorophyll and derive only part of their resources from their host. Holoparasites commonly reduce the total biomass of the plant community (Pennings and Callaway, 1996). *Cuscuta* species are among holoparasites whereas, *Loranthus* spp are hemi- parasites. Hemi parasite is only partially parasitic, possessing its own chlorophyll (green color) and photosynthetic ability (maybe facultative or obligate). Although hemiparasitic plants also reduce the biomass of their host community, this reduction can occasionally be compensated for, or even exceeded by, the production of the parasite (Joshi *et al*., 2000). Thus, the net effect of hemiparasites on total plant community biomass can be negative, neutral or positive, although negative effects are most typical (Matthies and Egli, 1999; Joshi *et al*., 2000). The fact that hemiparasites are partially autotrophic means that they compete (primarily for light) with their hosts. This difference in resource capture between herbivores and hemiparasites causes the latter to be limited in distribution to relatively nutrient-poor, low-biomass habitats (Smith, 2000).

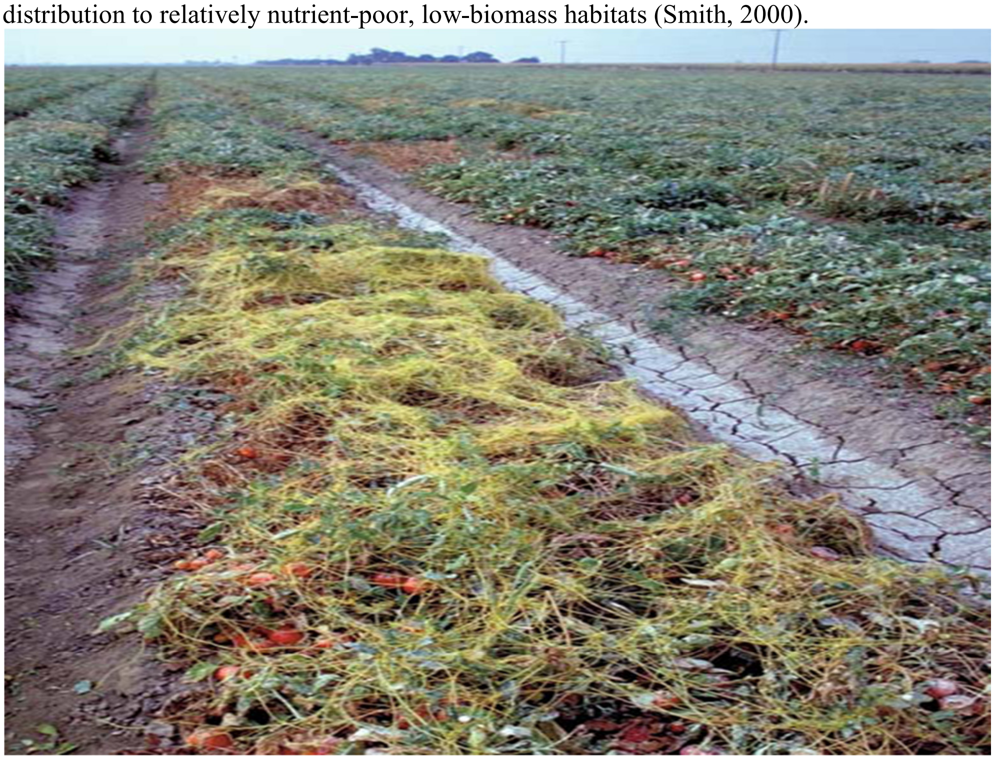

Figure1. *Cuscuta pentagona* parasitizing tomato plants in California.
Source: J.B. Runyon *et al*. (2009)

2.2. Root parasitic weed

Root parasitic weeds make below-ground attachments to host-plant roots. These parasites affect their host from the moment they attach to it and exert the greatest damage prior to their emergence (Joel DM *et al*., 2007; Scholes JD and Press MC, 2008). The interaction between host and root parasitic plant begins with the exudation of secondary metabolites from the roots of the host, which induce germination of the seeds of the parasites (Bouwmeester HJ *et al*., 2003; Humphrey AJ *et al*., 2006) The signalling molecules are produced and exuded by the plants in very low, nano- and picomolar, concentrations. They can be categorized as complete and partial parasite. Orobanche and Striga are among agriculturally important root parasitic weeds.

Figure2. (A) A sorghum field infested with *Striga hermonthica* (pink flowers) in Ethiopia. **(B)** *Orobanche ramosa* parasitizing cabbage in Sudan. **Source:** J.B. Runyon *et al*. (2009)

3. ECONOMICALLY IMPORTANT PARASITIC WEEDS, HOST CROP AND ASSOCIATED LOSSES

Approximately 4,500 species of flowering plants (more than 1% of all angiosperms) are parasitic, obtaining some or all of their water and nutrients from other plants (Nickrent, 2007). Moreover, Westwood *et al*. (2010) reported that among the flowering plants, there are approximately 3,900 known parasitic plant species in more than 20 plant families. A small percentage of these parasitic species infest agricultural crops and cause serious problems for farmers in many parts of the world (Musselman *et al*., 2001).

On a worldwide basis, parasitic weeds represent one of the most destructive and intractable problems to agricultural production in both developed and developing countries (Aly, 2007). Loss in yield is a result of competition and extraction of water, nutrient and metabolites caused by the parasite. The crop yield losses due parasitic weeds vary from area to area and species to species. *Striga* and *Orobanche spp* from the Orobanchaceae family and *Cuscuta spp*. from the family of Convolvulaceae are well-known and agriculturally important. While *Striga* and *Orobanche* can severely affect crop yields in drier and warmer areas of Africa and Asia (Spallek *et al*., 2013), *Cuscuta spp*. Thrive in regions with a warm and more humid climate where the highest *Cuscuta*-dependent crop yield losses also occur (Dawson *et al*., 1994). Under this topic, authors presented these economically important parasitic weeds, host crop and associated losses, crop-weed interaction and their management practices.

3.1. Striga (Witchweed)

The root parasite *Striga* (witchweed) is among important pest in both tropical and sub-tropical areas akin to Orobanche (Joel, 2000). *Striga* species belongs to the family Scrophulariaceae, (Reymond P and Farmer EE, 1998). It 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. In Africa, *Striga* negatively affects the lives of over 100 million people, implying that these parasitic weeds are among the most important constraints agricultural development in this region (Mboob, 1999). It is a genus of 28 species of parasitic plants that occur naturally in parts of Africa, Asia and Australia. The genus is now classified in the family of Orobanchaceae although earlier authors placed it in Scrophulariaceae (Gethi *et al*., 2005). Even though most *Striga* spp. do not affect agricultural production, some have devastating effects on crops particularly those planted by subsistence farmers (Mohamed *et al*., 2001; Westerman *et al*., 2007). Economically important *Striga* species are reported from more than 50 countries, especially from East and West Africa and Asia (Howe GA, Jander G, 2008). Gressel *et al*. (2004) and Gethi *et al*. (2005) have been reported existence of about 23 species of Striga in Africa, of which *Striga hermonthica* (Del.) Benth, commonly known as *striga*, is the most socioeconomically important constraint in cereal cultivation in eastern Africa. Below is summarized with some *striga* spp. (Table1). The major agricultural *Striga* species are *Striga hermonthica* (Del.) Benth and *S. asiatica* (L.) infecting cereals (maize, sorghum, millet and upland rice), and *S. gesneriodes* (willd.) Vatke legumes (cowpea) and tobacco. Likewise, other species such as *S. forbesii* (Benth.) and *S. aspera* (Willd.) Benth have been reported to have sporadic effects on cereal crops in their limited locations (Parker, 2009).

Small holder farmers are the most affected by the *Striga* problem because they have limited ways and means of controlling it. Moreover, infestation by striga causes grain yield losses of up to 100%, amounting to estimated annual losses of $40.8 million (Kanampiu *et al*., 2002), and these effects are most severe in degraded environments with low soil fertility and low rainfall, and in subsistence farming systems with few options for use of external inputs (Gurney *et al*., 2006). Likewise, Berner *et al*. (1995) ; Musselman *et al*. (2001) have been pointed out that *Striga* spp. are obligate root hemi parasites and infest an estimated two thirds of the cereals and legumes in sub-Saharan Africa, causing annual crop losses estimated at US$7 billion annually, and negatively influencing the lives of more than 300 million people. Yield loses at individual farms and in susceptible cultivars is estimated at 60–100% (Anonymous, 1997). Farmers have reported losses between 20 % and 80 %, and are eventually forced to abandon highly infested fields (Atera and Itoh, 2011). Weber *et al*., (1995); Kim *et al*., (1997) showed *S. hermonthica* as a serious problem in Guinea savanna of Nigeria and yield losses ranged from 10 to 100%. In western Kenya, a survey of 83 farms revealed that 73% of the farms are infected with *S. hermonthica* (Woomer & Savala, 2009). The average yield loss due to *Striga* is 1.15, 1.10 and 0.99 tons per hectare for maize, sorghum and millet, respectively (MacOpiyo *et al*., 2010). However, the damage can reach as high as 2.8 tons per ha in maize and sorghum in some locations with high *Striga* densities (Andersson & Halvarsson, 2011).

They are fairly wide spread in semi-arid regions crops including certain legumes, maize, pearl millet, sorghum, other cereal crops and sugar cane production (Spoel SH *et al*., 2003; Oswald, 2005; Beckers GJM and Spoel SH, 2006). *Striga spp*. have no roots, instead forming a 'haustorium' that attaches onto and penetrates the roots of its host; they thus become entirely dependent on the host plant, and the losses to the host can be correspondingly severe. Species such as *S. hermonthica* and *S. aspera* have functional leaves and synthesise some organic compounds for themselves, depending on their host mainly for inorganic nutrients and water; *S. gesnerioides* has no functional leaves and correspondingly draws a wider range of nutrients from its host. 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 (Spoel SH *et al*., 2003; Beckers GJM and Spoel SH, 2006). Furthermore, most *Striga* infested areas are characterized by agricultural production systems exhibiting low productivity. Striga germinates close to its hosts in response to specific chemical signals from the root exudates of the host or certain non-hosts plants (Hooper *et al*., 2009), indicating an ingenious adaptation and integration with the hosts (Bebawi and Metwali, 1991). Following germination, the radicle grows and, when approaching the host root cells, undergoes haustoriogenesis giving rise to the functional attachment organ through which parasitism is initiated (Hooper *et al*., 2015).

The significant reductions in crop yields realized from striga infestations result from a series of physiological changes in the host plants following striga parasitism. These include weakening of the host, wounding of its outer root tissues and absorption of its supply of moisture, photosynthates and minerals (Tenebe and Kamara, 2002). There is also a "phytotoxic" effect expressed within days of attachment to its host whose underlying mechanism has not yet been established (Gurney *et al*., 2006). Crops such as wheat (Ejeta, 2007) and Napier grass (Atera & Itoh, unpublished data, 2012) previously unaffected by *Striga* are now showing serious infestation in Sahel. As germination and parasitism of striga weed highly interrelated with their possible host crops, works aimed to reduce crops and yield losses should focus and/or understand biology of both plants. Moreover, as many scholars suggest, some crops are being infected by striga even though they had not reported as host yet. Hence, future study should consider identification of striga host range, especially of suspected host crop (s) and those that have close genetic relation with already reported host crops.

Table1. List of Some Agriculturally Important Striga species

No.	Common species	Distribution and Host-crop (s)	References
1	*Striga gesnerioides* (Willd.) Vatke Benth.	Threat cowpea production in many parts of Africa	(Parker and Riches, 1993).
		Tobacco and numerous Poaceae, Fabaceae and Convolvulaceae. S. gesnerioides parasitizes certain legumes (e.g. cowpea)	(Cochrane & Press 1997; EPPO 1999; Vasey *et al*. 2005)
		Problem in Nigeria, South Africa, Zimbabwe and Florida in the United States. Parasitize legumes (cowpea)	(EPPO 1999; Musselman 1996; Boukar *et al*. 2004)
2	*S. asiatica* (L.) Kuntz Loureiro	Serious weed in India, South Africa, the United States, Mauritius, Zimbabwe, Uganda, Pakistan and Zambia.	(Waterhouse & Mitchell 1998)
		Poaceae (grass family), especially the crop plants maize (corn), sorghum, rice and sugarcane, but sometimes wheat, barley, millet and others. Wild plants and weeds of the following genera: *Sorghum*, *Digitaria*, *Paspalum*, *Echinochloa*, *Imperata*, *Pennisetum*, *Cynodon*, *Chrysopogon*, *Elionurus*, *Eleusine*, *Eragrostis*, *Loudetia*, *Hyparrhenia*	(Cochrane & Press 1997; EPPO 1999; Vasey *et al*. 2005)
3	*S. hermonthica* (Del.) Benth.	Poaceae, especially sorghum, but also maize, *Panicum*, *Setaria*, sugarcane and wheat	(Cochrane & Press 1997; EPPO 1999; Vasey *et al*. 2005)

			(Spoel SH *et al*., 2003; Beckers GJM and Spoel SH, 2006).
		Serious problem in Nigeria	Weber *et al*., (1995); Kim *et al*., (1997)
		It is a problem in Saudi Arabia, Nigeria, Sudan, Uganda, Cameroon, Niger, Mali, Benin, Togo, Ghana, Ethiopia, Madagascar and Kenya, causing serious damage to crops such as maize, sugarcane, upland rice and finger millet	(EPPO 1999; Kim *et al*. 2002; Musselman & Hepper, 1986).
		In western Kenya, a survey of 83 farms revealed that 73% of the farms are infected with *S. hermonthica*	(Woomer & Savala, 2009).
4	*S. aspera* (Willd.) Benth.		(Spoel SH *et al*., 2003; Beckers GJM and Spoel SH, 2006).
	S. aspera	A significant problem of maize crops in Nigeria, Cameroon, Ivory Coast and Ethiopia, and also of rice crops in the Ivory Coast and Senegal	(Parker & Riches 1993)
5	*S. curviflora*	stated that was 'major causes of concern' in sugarcane in Queensland	AQIS (1999)
6	*S. parviflora*	stated that was 'major causes of concern' in sugarcane; has also been recorded as a weed of corn crops in Queensland	AQIS (1999);
7	*S. angustifolia* (Don) Saldanha	A serious weed in India affecting rice, sorghum and sugarcane	(Waterhouse & Mitchell 1998)
8	*S. latericea*	A cause of damage to sugarcane in Ethiopia and Somalia	(Parker & Riches 1993).
9	*S. aequinoctialis* Chev. Ex Hutch. & Dalz.	W. Africa	
10	*S. angolensis* Vatke	Angola	
11	*S. bilabiate* (Thunb.) O. Ktze.	Africa	
12	*S. brachycalyx* Sckan	Africa	
13	*S. chrysantha* A. Raynal	Central Africa	
14	*S. dalzielii* Hutch.	W. Africa	
15	*S. elegans* (elegant witchweed) Benth.	Angola, Malawi, S. Africa, Zimbabwe	
16	*S. forbesii* (giant mealie witchweed) Benth.	Africa, Madagascar	
17	*S. gastonii* A. Raynal	Chad and Central African Republic	Mohamed *et al*. (2001)
18	*S. gracillima* Melch.	Tanzania	
19	*S. hallaei* A. Raynal	Gabon, Democratic Republic of Congo	
20	*S. hirsuta* Benth.	Madagascar	
21	*S. junodii* Schinz	S. Africa, Mozambique	
22	*S. klingii*(Engl.) Skan	W. Africa, Nigeria, Ghana, Cameroon, Togo	
23	*S. lepidagathidis* A. Raynal	Senegal, Guinea, Guinea Bissau.	
24	*S. lutea* Lour.	Sudan, Ethiopia	
25	*S. macrantha* (Benth.) Benth.	W. Africa, Nigeria, Ivory Coast, Togo	
26	*S. passargei* Engl.	W. & C. Africa, Arabian peninsula	
27	*S. pinnatifida* Getachew	Ethiopia	
28	*S. primuloides* A. Chev.	Ivory Coast, Nigeria	
29	*S. yemenica* Musselman and Hepper	Ethiopia	Musselman & Hepper (1986); Mohamed *et al*. (2001)
30	*S. pubiflora* Klotzsch	Somalia	

3.2. Orobanche (broomrape)

The root parasite Orobanche (broomrape) is vicious weed in both tropical and sub-tropical areas (Joel, 2000). *Orobanche spp.* is obligate root holoparasites that constrain the production of many crops, primarily in the

Mediterranean region, the Middle East, and northern Africa (Parker and Riches, 1993). *Orobanche* spp., belonging to the closely related family Orobanchaceae, have no chlorophyll or leaves and are therefore totally dependent on their hosts for all nutrients. The centers of origin of *Orobanche species* are thought to be Italy, Spain, Turkey and Morocco (Sauerborn, 1991). Then different species achieved broader distribution through international trade and commercial exchange of contaminated seeds which contributed to the worldwide spread of these species. Out of the 140 known species of *Orobanche* (Kroeschel and Klein, 2002), about ten species are of economic importance, and represent a serious threat to a wide range of cultivated hosts, namely; *Orobanche aegyptiaca* Pers./*Orobanche ramosa* L., *Orobanche cernua* Loefl., *Orobanche cumana* Wallr., *Orobanche crenata* Forsk., *Orobanche minor* Sm. and *Orobanche foetida* Poir.

Orobanche species considered serious pests, have the widest host ranges and heavily damage a variety of crops, including tomato, potato, eggplant, faba bean, lentil, peanut, chickpea, cucumber, cabbage, and sunflower (Parker and Riches, 1993). On the other hand, *Orobanche cumana* has a host range limited to Asteraceae, and it is an important pest of cultivated sunflowers (Parker and Riches, 1993; Press and Graves, 1995). The loss, averaged across all broomrape species, is estimated at approximately 34%. Infestation by *Orobanche* spp. can result in total crop loss (Bernhard *et al*., 1998). However, previous works shown that the level of infestation and associated losses highly vary among species depend on their aggressiveness and host crops/ varieties. Rubiales *et al.* (2009b) reported that *Orobanche crenata* Forsk. (*Crenate broomrape*) is an important pest of most grain and forage legumes being widely distributed in the Mediterranean basin and Middle East. *Orobanche foetida* Poir. in contrast is of importance only on faba bean (*Vicia faba* L.) in Beja region of Tunisia (Kharrat *et al.* 1992) although it has recently also been found in Morocco infecting common vetch (*Vicia sativa* L.) (Rubiales *et al*., 2005b). *Orobanche minor* Sm. is widely distributed but of economic importance on clover (*Trifolium sp*.) only (Eizenberg *et al*. 2005). *Phelipanche aegyptiaca* (Pers.) Pomel (syn. *Orobanche aegyptiaca* Pers.) is an important pest of legumes but also of many vegetable crops in the Middle East and Asia (Parker, 2009). S. gesnerioides and Alectra vogelii cause considerable yield reduction of grain legume crops, particularly cowpea (*Vigna unguiculata* (L.) Walp), throughout semi-arid areas of sub-Saharan Africa (Parker and Riches 1993). Sauerborn and Saxena (1980) reported that *Orobanche crenata* is an obligatory parasitic plant of broad bean and other leguminous cultures, and generates serious damages on these cultures, ranging from five to 100 percent. In developing countries like Ethiopia and Sudan the damage is worse, reaching up to 100% yield loss, especially when it comes to drone prone (Ejeta *et al*., 2002). Yield reduction is dependent on the severity of infestation, but may range from 5 to 100%.

Orobanche **s**eeds germination occurs when they are preconditioned (warm moist conditions for several days) then exposed to germination stimulants exuded by host roots and some nonhosts. Upon germination, a germ tube, which is in close proximity to the host roots, elongates towards the root of the host, develops a haustorium through which the parasite attaches and deprives its host from water, mineral nutrients and carbohydrates, causing stunted growth of the susceptible host plants which contribute to reduction of its yield. In general *orobanche* spp having vast distribution and many host crops are causing huge economic losses in different parts of world, especially of developing countries.

3.3. Dodder (*Cuscuta species*)

They are obligate holo-parasites, typically exhibiting broad host ranges, and inflict serious damage to many crops (Dawson *et al*., 1994). As *cuscuta* is the only parasitic genus in the Convolvulaceae family, there is high similarity among the species within this genus (Garcia *et al*., 2014). Parasitic plants of the genus Cuscuta have no chlorophyll, or only a reduced amount, and are not usually photosynthetically active (Hibberd *et al*., 1998; Garcia *et al*., 2014). Only a few *Cuscuta species* still show residual photosynthesis (Hibberd *et al*.,1998) and have thus been designated as cryptically photosynthetic (Funk *et al*., 2007; McNeal *et al*., 2007a,b). However, all Cuscuta species depend (absolutely) on a host plant to complete their life cycle, and Cuscuta can be considered an obligate holoparasitic. To find and catch potential hosts, Cuscuta recognizes plant volatiles as chemo-attractants which guide seedling growth and increase the chances of successful infection (Runyon *et al*., 2006). *Cuscuta* species can be found on all continents; for example, five species are native to central Europe (Mabberley, 1997), of which *C. europaea* is the most prominent. Agriculturally, the most important *Cuscuta* species are *C. pentagona* and *C. campestris*, which show an almost worldwide distribution and have a wide host spectrum. Agriculturally, the most important *Cuscuta* species are *C. pentagona* and *C. campestris*, which show an almost worldwide distribution and have a wide host spectrum. Severe crop loss due to *Cuscuta* is reported for 25 crop species in 55 countries (Lanini and Kogan, 2005). Highest species diversity for dodder occurs in the Americas, from Canada to Chile (Yuncker, 1932; Stefanovic *et al*., 2007).

Cuscuta spp. has a wide host range, including many cultivated crops such as chickpea, lentil, tomato, tobacco, clover, forage legumes (alfalfa, clover, and lespedeza), potato, carrot, sugar beets, chickpea, onion, cranberry, blueberry, and citrus and dicotyledonous weeds as well as trees and shrubs, but only a few grasses or mono cotyle-donous weeds (Dawson *et al*., 1994; Albert *et al*., 2008). According to Fathoulla & Duhoky (2008) field dodders parasitize many different plants, inducing negative impact on the growth and yield of infested hosts and having significant effect on the structure and functioning of plant communities infested by these holoparasites. Damage can ultimately lead to total destruction and death of the host. Hosts are attacked nonspecifically and sometimes even simultaneously, and one crop species may serve as a host for several dodder species (Cudney and Lanini, 2000). Severe crop loss due to Cuscuta is reported for 25 crop species in 55 countries (Lanini and Kogan, 2005). *Cuscuta pentagona* is a major weed of tomatoes in California, causing yield losses of 50–75% (Goldwasser *et al*., 2001). In China, several *Cuscuta* species inflict severe damage on soybeans (Dawson *et al*., 1994).

Field dodder causes most damage during massive infestation of newly-established leguminous crops (alfalfa or clover), challenging the very feasibility of crop production (Dawson *et al*., 1994). Damage caused to these crops consists mainly of reduced fresh biomass yield, which may be upwards of 50%, and significantly reduced seed production (Cudney *et al*., 1992). Mishra (2009) reported some 60% yield reduction in alfalfa infested with *C. campestris*. Stojanović and Mijatović (1973) reported a yield reduction of around 80% in alfalfa crops infested with *C. campestris*, and some 20% in red clover crops. Rather than causing host death, Cuscuta infestation seems to weaken host plants and to render them more susceptible to secondary diseases such as infection by microbes or insect and nematode infestation (Lanini and Kogan, 2005). Like other parasitic weeds, many *cuscuta* spp are causing huge economic losses there by parasitising host crops with the varying degree across area.

4. MANAGEMENT PRACTICES OF PARASITIC WEEDS IN CROPS

As far as parasitic weeds can cause losses on crops, attention should be given to their management strategies to reduce these losses. Farmers in developing countries do not know the biology of these plants: some even think that they reproduce by rhizomes and stolons, others have never seen tiny seeds produced by these parasites, ignore the existence of a subterranean growth phase, and other details. Not knowing their enemy makes it really difficult for farmers to design effective control strategies. Thus, awareness creation (continuous training) is crucial. Control strategies include: inducing “suicidal germination,” inhibiting germination, and reducing the production of germination stimulants by crop plants. In addition, the newly discovered role of strigolactones in the recruitment of symbiotic AMF (Akiyama *et al*., 2005) has opened new possibilities for modifying the production of germination stimulants by host plants. Some eco-biological characteristics of these plants are also emphasized. Their management should be based on good knowledge of their seed germination, factors affecting it, plant growth and others.

Accordingly, there is a need to know better the factors affecting germination and haustorium formation and attachment to host plants, parasite growth and seed production. In general seed germination is enhanced by germination stimulants from plant roots. These characteristics limit the development of successful control measures which can be accepted and applied, especially by subsistent farmers. Promising future strategies for the control of parasitic plant infestations include transgenic plants expressing specifically designed small RNAs (Roney *et al*., 2007; Runo *et al*., 2011, 2012; Alakonya *et al*., 2012). Many control methods have been tried to manage parasitic weeds. However, there is no one single method can give satisfactory control. Conventional methods, both individually and in combination, have a limited impact on controlling parasitic weeds (Verkleij & Kuijper, 2000). The knowledge and understanding of already recommended and employed management practices at farmers and other stockholder’s conditions are crucial to devise for the future options. Below is presented with the overview of management practices that should get due attention by researchers or practitioners.

4.1. Preventive methods

Large areas of new fields are at a risk of invasion unless introduction of its seeds is carefully prevented, and farmers and others are educated on how to be on alert for new infestations (Panetta & Lawes, 2005). One of the most important control methods is to prevent the introduction and distribution of the parasite seeds from infested to un-infested areas. Negligence and lack of knowledge are responsible for the spread and the increase of parasitic weeds problem. National and international trade of contaminated crop seeds contributes to the seed dispersal over long distances. Local seed production in infested areas, uncontrolled movement of grazing animals, moving contaminated farm machinery and equipment, improper phytosanitary measures and the spread of contaminated manure intensify spread of parasitic weeds. Improper farming practices could be easily overcome by raising the awareness about the biology of weeds and the means of its spread among farmers, technical staff and officials.

Planting uncontaminated or certified seeds ensures clean fields during the season if the soil was not previously infested with parasitic weeds. Fresh contaminated manure aggravates parasitic weeds problem. Farmers should be instructed to use fermented manure, as fermentation process kills the seeds of the parasite. Pre-plant composting fresh manure under plastic mulch in the planting rows causes weed seeds to lose viability within six weeks, and reduces parasitic weeds infestation on many crops. Proper phytosanitary measures in and around the field are necessary to reduce the spread of parasitic weeds. Farm equipment and machinery should be cleaned prior to their use in uninfested fields. Parasitic weeds shoots should be removed prior to flower opening. The collected shoots and other parts should be burnt or disposed of properly.

4.2. Cultural methods

It is traditional methods of weed control that can be practiced by many farmers in developing countries. This includes, crop rotation, weeding, planting date, fertilization and deep plowing. Crop rotation, including trap and catch crops, will gradually decrease parasitic weeds infestation. But complete control will be achieved after a very long period, due to the long life-span of parasitic weed seeds. It can however reduce the infestation level if integrated with other control methods. Crop rotation is already a current farmers practice. In many farms, susceptible crops are abandoned. Rotating with trap and catch crops can reduce parasitic weeds seed bank if properly managed. Weeding of parasitic weeds is mainly accomplished after the parasitic damage has already been done. It is not likely to show any yield increase in the short term. Weeding is laborious and time-consuming, and not very promising in highly infested areas. However, in combination with other methods, it can reduce the seed bank very efficiently. Additionally, is difficult to practice in some parasitic weeds due to their nature. Planting date could be manipulated so as to avoid infestation, as environmental factors affect germination and development of the parasite. Germination of many parasitic weeds, mainly Orobanche species tends to be very much reduced below 8°C and further development is greatly reduced at low temperatures (Saxena *et al*., 1994). Delaying the planting date affects parasitic weeds more than its hosts. The change of the sowing date seems not to be very promising due to uncertainty of the environmental conditions, specifically temperature and rainfall situation. Parasitic weeds tend to be associated with less fertile soil conditions. High levels of nitrogen fertilizer or chicken manure showed a suppressive effect. The main effects could be due to: reduction of stimulant exudation; direct damage to weeds seeds and seedlings in the soil; reduced osmotic pressure in the parasite relative to the host; a toxic effect of nitrogen on the parasite development; alternation of host root and shoot balance. Plowing may reduce the infestation, if the top soil layer is properly turned to the bottom.

4.3. Physical methods

These methods include flooding, soil Solarization, bio fumigation, microwave and others. Soil solarization, mulching, hot water, Fresnel lens, biological control, natural herbicides and some cultural treatments have been successfully tried and were found to be effective and safe methods to control weeds (Khanh *et al.,* 2005; Sahile *et al.,* 2005; Benoit *et al*., 2006; Ramakrishna *et al*., 2006; Abouziena. H.F, 2008; Candidoa *et al*., 2011; Abouziena *et al*., 2015). Flooding requires the availability of water which is scarce in Near East countries. Flooding for an extended period can kill the parasite seeds in the soil. Solarization has proven effective in reducing several soil borne pests including parasitic weeds. It is not applicable in rain-fed systems for economic reasons, but under irrigation systems, soil Solarization with plastic sheets could be an additional measure to reduce the weeds infestation. Furthermore, there is a residual effect over several years following the Solarization treatment, resulting in increased crop yields (Abu-Irmaileh, 2003).

4.4. Host-plant Resistance or Tolerance

Resistance is the best long-term strategy for limiting the damage caused by parasitic weeds. Conventional plant breeding has produced few crops with stable resistance, while genetic engineering offers the possibility of creating novel resistance mechanisms that may be introduced into many commercial crops. Genetic engineering might help to overcome some of these difficulties (Bouwmeester *et al*., 2003), but societal concerns about genetically modified technology may prevent widespread adoption (Humphrey *et al*., 2006). While tolerant crop plants are not suitable for solving the weeds problem, because they maintain parasitic weed/s development to maturity and hence contribute to the steady increase of the seed bank in the soil, breeding of resistant crop plants as a long-term measure for parasitic weed/s control appears more attractive than costly and doubtful chemical or physical control procedures (Bouwmeester *et al*., 2003). Generally, considering its practical relevance and ecological safe, future varietal development should focus on resistance or tolerance of crops to parasitic weeds with the all possible options.

4.5. Biological and Chemical control

Bioagents include insects and fungi seem to be of interest for the biological control of some parasitic weeds. Natural enemies can reduce the fly population considerably. Several fungi have been reported to be virulent on parasitic weeds. For example, current investigations concentrate mainly on *Fusarium oxysporum* f. sp. *orthoceras*, a pathogen with high potential to control *Orobanche Cumana* (Abuelgasim and Kroschel, 2003). Even though biological control methods are very crucial and successfully promoted for the management of many agricultural pests, however, only little effort has been done in case of this weed. Thus, attention should be paid to develop and promote potential biological agents.

Chemical method includes the application of soil fumigations, seed dressing with selective herbicides, pre-plant and/or pre-emergence application of herbicides (glyphosate, Imidazolinones and the Sulfonylureas). The most limiting factor in the use of the promising herbicides is their degree of selectivity among the crops at the required rate for parasite control, and the critical time of application, especially of the foliar applied systemic herbicides. Different herbicides are recommended for various weeds. Glyphosate was the first promising herbicide developed for *Orobanche crenata* control in faba bean (Scmitt *et al*., 1979). Promising results were also obtained by soaking or coating the seeds of faba bean, pea seeds, or lentils in low concentration of imazethapyr or imazapyr, respectively (Garcia-Torres *et al.*, 1999). Seed germination and crop growth were not affected by phytotoxicity of both herbicides. Herbicide application is too technical and expensive in subsistent farming. Intensive farmer training and effective extension services are required.

4.6. Integrated Management (IWM)

There is no single technology to control these parasitic weeds (Joel *et al*., 2007; Parker, 2009; Rubiales *et al*., 2009b). Although all control measures have their merits, in the long term parasitic weeds should be managed through the implementation of an integrated approach, where containment is essential (Ransom, 1996). The only way to cope with parasitic weeds is through an integrated approach, employing a variety of measures in a concerted manner, starting with containment and sanitation, direct and indirect measures to prevent the damage caused by the parasites, and finally eradicating the parasite seed bank in soil. For example, one of the most effective ways of managing striga is the use of forage legumes in the genus *Desmodium* (Fabaceae) as an intercrop which provides the key chemical components for inhibiting development of striga in the field (Khan *et al*., 2008; Midega *et al*., 2014). *Desmodium* spp. suppress striga through a combination of mechanisms, including abortive germination of striga seeds that fail to develop and attach onto the hosts' roots (Khan *et al*., 2002; Tsanuo *et al*., 2003). Considering many advantages of IWM, there is a need to demonstrate any available and compatible options together. Likewise, any future works/efforts should consider the concept and development of integrated management to reduce the losses due to parasitic weeds.

5. CONCLUSION AND FUTURE DIRECTIONS

Parasitic weeds are among serious pest of crops in both developing and developed countries. They are categorized as root-parasitic or stem parasitic based on parts of plants they attached to it. The life cycle of parasitic weeds is closely associated with their host and, hence information and works target to the host–parasite interaction is crucial to reduce agricultural and any other damages cause. Parasitic weeds have a wide range of host-plants including agricultural crops. They are causing drastic crop yield losses and needs to be managed. So far, few practical and economically sound management practices have been developed to control these weeds. However, these practices couldn't manage parasitic weeds at required level.

Therefore, Sustainable management practices are needed to reduce the losses and risks due to weeds. To realize this, the first step is to make the farmer aware of the biology of the parasite and the means of its spread. On farm research and extension practices should incorporate farmers, in order to assess whether the introduced management method is too technical or easy to adopt. In addition to this, Extension and quarantine facilities should be staffed with the appropriate subject matter specialists to prevent the introduction of the parasite from being introduced to un-infested areas. Search for improved or alternative approaches should be facilitated by, increased understanding of the complex ecological and physiological interactions between parasitic plants and their hosts. Similarly, Environmental impact assessment of the introduced practices should be assessed in order to develop ecologically justifiable control strategies.

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