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Parasitic flowering plants of woody species in Jordan

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Abstract Parasitic weed occurrence in Jordan was surveyed during the period from 2004 to 2009. Results revealed the presence of seven genera attacking 85 woody plant species belong to 33 botanical families. Parasitic genera were *Cuscuta*, *Orobanche*, *Cistanche*, *Plicosepalus*, *Viscum*, *Osyris* and *Cynomorium*. Among the most severely parasitized species were *Citrus* spp., *Olea europaea*, *Vitis vinifera*, and *Ziziphus spina-christi* by *Cuscuta monogyna*; *Amygdalus communis* and *O. europaea* by *Orobanche cernua, Orobanche palaestina* and *Orobanche schultzii,*; *A. communis*, *Cupressus sempervirens*, *O. europaea* and *V. vinifera* by *Osyris alba*; *Casuarina equisetifolia* and *Haloxylon persicum* by *Cistanche* spp.; *Acacia asak*, *Acacia cyanophylla*, *Acacia farnesiana*, *Acacia nilotica*, *C. equisetifolia*, *Ficus carica*, *Melia azedarach*, *Parkinsonia aculeata*, *Poinciana gilliesii*, *Retama raetam*, *Tamarix pentandra* and *Ziziphus* spp. by *Plicosepalus acaciae*; *A. communis*, *Crataegus azarolus, O. europaea*, *P. granatum*, *R. raetam*, and *Rhamnus palaestina* by *Viscum cruciatum*; and *H. persicum* by *Cynomorium coccineum*. Many of the host species are first time reported while *O. schultzii* was the first record parasitizing woody plants.

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Introduction

Parasitic plants comprise more than 4,000 species in the angiosperms (Press and Phoenix 2005). Although most can potentially attack a huge number of different species (Nilson and Svensson 1997; Westbury 2004), some also show a high level of host preference. These parasites challenge agriculture in many parts of the world (Parker and Riches 1993). They are either hemi- or holo- stem or root parasites (Parker and Riches 1993).

The danger these parasites exert on agriculture is mainly due to their difficult control with available weed control methods, the huge number of seeds produced associated with long seed viability and adaptability to disperse. Morphological and physiological similarities between these and their hosts and the ability of certain parasitic species to develop additional shoots from the epicortical roots (*Plicosepalus*) extended on host stem or impeded haustoria (*Viscum* and *Cuscuta*) especially after damage to or removal of the primary shoot hinder pruning and herbicide application as common methods of weed control.

Parasitic species represent a major threat to fruit and forestry species in different parts of the world and a serious threat to agriculture in Jordan (Qasem 2003).

Parasitic weeds cause severe growth damage, yield failure and in many cases death of host plants. Abu-Irmaileh (1979) reported three parasitic families to occur in Jordan including 3 genera attacking 34 wild and cultivated species. Later on, the same author (Abu-Irmaileh 1982) mentioned that *P. acaciae* parasitize six species of fruit and forest trees. Musselman (1998) listed eight parasitic genera to occur in the country among which 11 species of *Orobanche*, and 10 species of *Cuscuta*. At present, parasitic weeds are commonly observed in different regions in Jordan (Qasem 2006). Certain genera (e.g. *Orobanche* and to certain extents *Cistanche* and *Cynomorium*) are becoming more frequently seen on fruit and forest trees, while *Osyris alba* hosts are first time reported. However, many of the forestry species are attacked by more than one parasitic genera. The ecological effects of these parasites may become more apparent when considering that forestry areas represent only less than 1% of the total country's area while almost 90% is a desert not receiving more than 50–70 mm average annual rainfall. The ecological threat that parasitic species exert on vegetation cover and natural ecosystem becomes more serious when they interact with other ecological stresses e.g. poor soil fertility, frequent grazing, fire hazard, drought, and housing activities. All are of a potential ecological threat on the existence of certain forestry species or on the area devoted to fruit trees plantation. Therefore, this work was specifically designed to record parasitic species attacking woody plants in the country since the extent of this phenomenon has been somehow unknown for certain parasitic genera and such hosts.

Materials and methods

A survey was carried out for the period 2004–2009 during which parasitic species attacking woody host plants were searched for in fruit tree orchards, and natural vegetation in Jordan. The survey covered almost the whole country delineated between 29° 11′ N to 33° 22′ N latitudes, and 34° 19′ E to 39° 18′ E longitudes. Parasitized species were initially recorded based on visual observation of the parasites.

Infestation and severity were visually assessed by observing the damage incurred on the vegetative parts of the host plant, and the number of parasite shoots found adjacent to or surrounding host plants (root parasites) or the bulk of parasite vegetative mass (stem parasites) on host plants. Severity was subjectively rated as light, moderate or high. Incidence was recorded as rare (found only on a few plants in one geographical location or biogeographical region), sporadic (few plants infected in one or more biogeographical regions), limited (many plants localized in certain locations of 1 or 2 biogeographical regions), common (found on more than 10 plants in 1 or 2 biogeographical regions), or very common (found on many plants at multiple locations within more than two biogeographical regions).

All root and stem parasites and their hosts were photographed. Photographs of root parasites were taken before and after the soil was excavated and the attachment of the parasite and hosts was detected. Where excavation was not possible, host identification for certain parasitic species was based on close proximity of emerged parasites and the absence of other potential hosts. Samples of parasitic species were collected, brought to the laboratory, and detailed taxonomic keys (Post 1932; Edgecombe 1970; Marwat et al. 1993; Parker and Riches 1993; Linke et al. 1996) including internet resources (http://www.parasiticplants.siu.edu/Scrophulariaceae/Orobanche.Gallery.html; http://www.homolaicus.com/scienza/erbario/utility/floraitalica/flora/orobanchehtm; http://128.253.177.187/taxpage/0/0/79/genus/Orobanche.html) were used to identify collected specimens. Information on parasitic species, their hosts, severity of infection and their incidence were tabulated.

Results

Parasitic species and their woody host plants in Jordan are listed in Table 1. Results showed the presence of 7 parasitic genera of six plant families attacking 85 woody plant species. Hosts are from 58 genera of 33 plant families and divided into 32 host species attacked by *Cuscuta* (6 species), 26 species by *Plicosepalus acaciae*, 12 species by *Orobanche* (5 species), 23 species by *Cistanche* (3 species), 14 species by *Viscum cruciatum*, 23 species by *O. alba* and 5 host species by *Cynomorium coccineum* (Table 2). Species are distributed between fruit trees (20 species), forestry trees (27 species) and wild shrubs of range and desert areas (38 species) (Table 3).

Many of the reported hosts were attacked by more than one parasitic genus.

Among all recorded parasites, *V. cruciatum*, *P. acaciae* and *Cuscuta* spp. were most common and destructive to many fruit and forestry species in different parts of the country. *Orobanche* spp., *Cistanche* spp., *C. coccineum* and *O. alba* were less prevalent on woody plants although *Orobanche* spp. are widely spread and most destructive to many vegetable crops in different regions. However, *Orobanche* species parasitizing woody plants were very limited in number, hosts and magnitude of their effects. *O. aegyptiaca*, *O. cernua, O. palaestina* and *O. schultzii* were most frequently observed. *C. monogyna* and *C. campestris* were most common on similar host species. While *P. acaciae* and *V. cruciatum* were mainly restricted to fruit and forestry trees, certain species of *Orobanche* (*O. cernua*, *O. palaestina* and *O. schultzii*) and *Cuscuta* attack fruit trees as well as herbaceous plants.

Cistanche spp. were found parasitizing 17 host species of wild shrubs, fruit and forest trees of seven plant families most belong to the Chenopodiaceae (11 species) (Table 2). Previously unreported hosts for *Orobanche* and *Cistanche* include *Amygdalus communis*, *O. europaea* and *Quercus coccifera* parasitized by *O. palaestina*; *A. communis*, *Olea europaea, Prunus armeniaca* and *Prunus persica* parasitzed by *O. cernua*; *O. europaea, P. armeniaca* and *A. communis* by *O. schultzii*; *Haloxylon persicum* by *Cistanche lutea; Alhagi maurorum*, *Casuarina equisetifolia, Centaurea postii*, *Prosopis farcta, Punica granatum* by *Cistanche tubulosa*; and *Achillea* spp., *Anabasis syriaca*, *H. persicum*, *Haloxylon salicornicum, Suaeda* spp. and *Zilla spinosa* by *Cistanche salsa*.

Hosts severely attacked by *P. acaciae* were *C. equisetifolia*, *Melia azedarach*, *Nerium oleander*, *Pistacia atlantica, Poinciana gilliesii*, *Retama raetam, Rhus tripartita* and *Tamarix pentandra*. The parasite was destructive to *Ziziphus* spp., killing *Ziziphus spina-christi* in many places.

V. cruciatum was destructive to *A. communis*, *Crataegus azarolus*, *O. europaea*, *P. granatum*, *Rhamnus palaestina* and *R. Raetam*.

Cuscuta species included *C. campestris* (parasitizing 13 host species), *Cuscuta epithymum* (7 species), *Cuscuta monogyna* (22 species), *Cuscuta epilinum* (3 species), *Cuscuta indecora* (3 species) and *Cuscuta planiflora* (3 species). Many of the hosts are first time reported including *Amagdalus communis, Citrus aurantifolia, Citrus paradisi, Citrus maxima, Malus domestica, Nerium oleander, O. europaea, Origanum syriacum, Rhus tripartita, Tamarix pentandra, Ziziphus* spp. and many other wild and weedy species. *C. campestris* and *C. monogyna* were most spread. Although *C. campestris* parasitized certain woody trees it was mostly restricted to field crops and herbaceous plants. *C. monogyna* was occasionally observed on fruit trees and woody shrubs. Infection of *C. monogyna* on *Citrus* spp., *O. europaea* and *V. vinifera* was quite severe in certain locations.

The most severely attacked fruit trees by *O. alba* were *A. communis, O. europaea* and *V. vinifera*, and of the forest trees and shrubs were *Acacia cyanophylla, Cupressus sempervirens*, *R. palaestina*, *Calecotome villosa* and *Sarcopoterium spinosa*. However, the finding on *O. alba* and its hosts is the first record in the country.

Among families, Chenopodiaceae and Fabaceae had the highest number of species attacked (12 host species of each), followed by Rosaceae (10 species), Anacardiaceae (6 species), Rutaceae (5 species), Rhamnaceae (4 species), and Labiatae (3 species). However, while certain hosts or plant families were attacked only by one parasitic genera, others were heavily parasitized by more parasitic genera including *Acacia cyanophylla* (3 genera), *C. equisetifolia* (4 genera), *R. raetam* (3 genera), *F. carica* (3 genera), *O. europaea* (5 genera), *R. palaestina* (3 genera), *P. granatum* (5 genera), *A. communis* (4 genera) and *T. pentandra* (3 genera) (Table 2).

Preferred woody shrubs to different parasitic genera included *Capparis spinosa* (host for *Cuscuta*, *P. acaciae* and *V. cruciatium*), *Atriplex halimus* (*Cistanche* and *Cuscuta*), *Salsola vermiculata* (*Cistanche* spp. and *C. coccineum*), *Prosopis farcta* (*Cistanche, Cuscuta* and *P.* acaciae), and *Ferula communis* (*Cistanche* and *C. coccineum*) (Table 2). However, it has been found that certain common weed species including (*A. maurorum*, *Anabasis syriaca*, *P. farcta*, *Sarcopoterium spinosum*, *Salsola* spp., *Suaeda* spp. and *Z. spinosa*) serve as alternative or primary hosts for certain parasites (*Orobanche*, *Cistanche, Cuscuta, P. acaciae*) which may enable these to exist, spread and tolerate control measures.

Table 1 Parasitic weeds on fruit and forest trees, families, genera and species, hosts and their families, status, prevalence and intensity of infection in Jordan for the period 2004-2009

Parasitic species/host	Family	Status	Severity of infection	Incidence
1. Cuscutaceae				
Cuscuta				
a. *Cuscuta campestris* Yuncker				
Alhagi maurorum Medik	Fabaceae	W	High	Common
Comicarpus africanus (Lour) Dandy	Nactaginaceae	W	Moderate	Rare
Duranta plumieri Jacq	Verbenaceae	C	Moderate	Rare
Ochradenus baccatus Delile	Resedaceae	W	Light	Rare
Olea europaea L.	Oleaceae	C	Light	Rare
Origanum syriacum L.	Labiatae	C	High	Rare
Prosopis farcta (Banks and Sol.) Macbride	Fabaceae	W	High	Very common
Ricinus communis L.	Euphorbiaceae	W	Light	Rare
Tamarix pentandra Pall.	Tamaricaceae	W	High	Very common
Vitis vinifera L.	Vitaceae	C	Moderate	Common
Withania sominiferum Dunal	Solanaceae	W	Moderate	Rare
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	W	High	Very common
Ziziphus lotus Lam.	Rhamnaceae	W	High	Rare
b. *Cuscuta epilinum* Weihe				
Alhagi maurorum Medik.	Fabaceae	W	High	Common
Atriplex leucoclada Boiss.	Chenopodiaceae	W	Light	Rare
Capparis spinosa L.	Capparidaceae	W	Moderate	Rare
c. *Cuscuta epithymum* (L.) L.				
Alhagi maurorum Medik.	Fabaceae	W	High	Common
Atriplex leucoclada Boiss.	Chenopodiaceae	W	Light	Rare
Capparis spinosa L.	Capparidaceae	W	Moderate	Rare
Euphorbia hierosolymitana Boiss.	Euphorbiaceae	W	Moderate	Rare
Sarcopoterium spinosum L.	Rosaceae	W	High	Common
Prosopis farcta (Banks and Sol.) Macbride	Fabaceae	W	High	Very common
Thymus capitatus (L.) Hoffmans & Link	Labiatae	W	High	Rare
d. *Cuscuta indecora* Choisy				
Sarcopoterium spinosum L.	Rosaceae	W	High	Common
Prosopis farcta (Banks and Sol.) Macbride	Fabaceae	W	High	Rare
Thymus capitatus	Labiatae	C	High	Rare
e. *Cuscuta monogyna* Vahl				
Alhagi maurorum Medik	Fabaceae	W	High	Common
Atriplex halimus L.	Chenopodiaceae	W	High	Rare
Atriplex leucoclada Boiss.	Chenopodiaceae	W	Moderate	Rare
Casuarina equisetifolia L.	Casuarinaceae	C	Light	Rare
Citrus maxima Merr.	Rutaceae	C	Light	Rare
Citrus aurantifolia Swingle	Rutaceae	C	Moderate	Very common
Citrus deliciosa Ten.	Rutaceae	C	High	Common
Citrus limon (L.) Burm.	Rutaceae	C	High	Very common
Citrus paradisi Macf.	Rutaceae	C	Moderate	Rare
Commicarpus plumbagineus (Cav.) Standl.	Nyctaginaceae	W	Moderate	Rare
Lantana camara L.	Verbenaceae	W	Moderate	Rare
Malus domestica Borkh.	Rosaceae	C	High	Rare
Nerium oleander L.	Apocynaceae	W	Light	Rare
Olea europaea L.	Oleaceae	C	Light	Common

Table 1 (continued)

Parasitic species/host	Family	Status	Severity of infection	Incidence
Origanum syriacum L.	Labiatae	C	High	Rare
Prosopis farcta (Banks and Sol.) Macbride	Fabaceae	W	High	Rare
Rhus tripartita DC.	Anacardiaceae	W	Moderate	Rare
Ricinus communis L.	Euphorbiaceae	W	Light	Rare
Tamarix pentandra Pall.	Tamaricaceae	W	High	Common
Vitis vinifera L.	Vitaceae	C	High	Common
Ziziphus lotus Lam.	Rhamnaceae	W	Moderate	Rare
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	W	High	Common
f. *Cuscuta planiflora* Ten.				
Amygdalus communis L.	Rosaceae	C	Light	Rare
Capparis spinosa L.	Capparidaceae	W	Light	Rare
Crataegus azarolus L.	Rosaceae	W	Light	Rare
2. Orobanchaceae				
2.1. *Orobanche*				
a. *Orobanche ramosa* L.				
Eriobotrya japonoca Lindl.	Rosaceae	C	Moderate	Rare
Punica granatum L.	Punicaceae	C	Light	GH
Rosa damascena Mill.	Rosaceae	C	Light	GH
Withania somnefera Dunal	Solanaceae	W	Light	Rare
b. *Orobanche aegyptiaca* Pers.				
Prunus persica (L.) Batsch	Rosaceae	C	Light	Sporadic
c. *Orobanche cernua* Loefl.				
Amygdalus communis L.	Rosaceae	C	High	Limited
Ficus carica L.	Moraceae	C	Moderate	Limited
Olea europaea L.	Oleaceae	C	Light	Limited
Prunus armeniaca L.	Rosaceae	C	Moderate	Rare
Prunus persica (L.) Batsch	Rosaceae	C	Light	Sporadic
Punica granatum L.	Punicaceae	C	Light	GH
Quercus coccifera L.	Fagaceae	C	Light	Limited
d. *Orobanche palaestina* Reut.				
Amygdalus communis L.	Rosaceae	C	Moderate	Sporadic
Olea europaea L.	Oleaceae	C	High	Rare
Quercus coccifera L.	Fagaceae	W	Moderate	Rare
e. *Orobanche schultzii* Mutel				
Amygdalus communis L.	Rosaceae	C	Moderate	Limited
Olea europaea L.	Oleaceae	C	High	Limited
Prunus armeniaca L.	Rosaceae	C	High	Rare
Prunus persica (L.) Batsch	Rosaceae	C	High	Sporadic
2.2. *Cistanche*				
a. *Cistanche lutea* (Desf.) Hoffmanns. and Link				
Haloxylon persicum Bunge ex Boiss. and Buhse	Chenopodiaceae	W	Light	Limited
b. *Cistanche tubulosa* (Schrenk) Hook				
Acacia cyanophylla L. (NC)	Fabaceae	C	Light	Rare
Atriplex glauca L.	Chenopodiaceae	W	High	Limited
Atriplex halimus L.	Chenopodiaceae	W	High	Very common
Casuarina equisetifolia L. ex J.R. and G. Forst	Casuarinaceae	C	Light	Limited
Eucalyptus camaldulensis Dehnh. (NC)	Myrtaceae	C	Moderate	Rare
Haloxylon persicum Bunge ex Boiss. & Buhse	Chenopodiaceae	W	High	Very common

Table 1 (continued)

Parasitic species/host	Family	Status	Severity of infection	Incidence
Olea europaea L. (NC)	Oleaceae	C	Light	Rare
Opuntia ficus-carieca L. (NC)	Cactaceae	C	Moderate	Rare
Pinus sp. (NC)	Pinaceae	C	Moderate	Rare
Prosopis farcta (Banks and Sol.) Macbride	Fabaceae	W	Moderate	Limited
Punica granatum L.	Punicaceae	C	Light	Rare
Salicornia herbacea L.	Chenopodiaceae	W	Light	Limited
Salsola vermiculata L.	Chenopodiaceae	W	Light	Common
Suaeda asphaltica Boiss.	Chenopodiaceae	W	Moderate	Common
Suaeda vera Forsk.	Chenopodiaceae	W	Light	Limited
Tamarix pentandra Pall.	Tamaricaceae	W	Light	Rare
c. *Cistanche salsa* (C. A. Mey.) Benth. et Hook.				
Achillea sp.	Compositae	W	Moderate	Limited
Anabasis setifera Moq.	Chenopodiaceae	W	Moderate	Common
Anabasis syriaca Iljin.	Chenopodiaceae	W	Moderate	Common
Atriplex halimus L.	Chenopodiaceae	W	Moderate	Common
Ferula communis L. (NC)	Umbelliferae	W	Light	Limited
Haloxylon persicum Bunge ex Boiss. and Buhse	Chenopodiaceae	W	Moderate	Common
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Chenopodiaceae	W	Moderate	Very common
Salsola sp.	Chenopodiaceae	W	Moderate	Common
Zilla spinosa (L.) Prantl	Cruciferae	W	Light	Limited
3. Loranthaceae				
Plicosepalus				
a. Plicosepalus acaciae				
Acacia asak (Forssk.) Willd.	Fabaceae	C	Light	Rare
Acacia cyanophylla L.	Fabaceae	C	Light	Rare
Acacia farnesiana (L.) Willd.	Fabaceae	C	Moderate	Common
Acacia nilotica (L.) Willd. ex Del.	Fabaceae	C	Light	Rare
Anagyris foetida L.	Fabaceae	W	Light	Rare
Capparis spinosa L.	Capparidaceae	W	Light	Rare
Casuarina equisetifolia L. ex J.R. & G. Forst	Casuarinaceae	C	High	Very common
Ceratonia siliqua L.	Fabaceae	W	Light	Rare
Ficus carica L.	Moraceae	C	Moderate	Common
Juglans regia L.	Juglandaceae	C	Light	Rare
Melia azedarach L.	Meliaceae	C	High	Rare
Nerium oleander L.	Apocynaceae	W	High	Rare
Parkinsonia aculeata L.	Fabaceae	C	Moderate	Common
Pistacia atlantica Desf.	Anacardiaceae	W	High	Rare
Pistacia vera L.	Anacardiaceae	C	Light	Rare
Poinciana gilliesii Wallich ex Hook.	Fabaceae	C	High	Common
Prosopis chilensis (Mol.) Stuntz.	Fabaceae	W	Moderate	Rare
Prosopis farcta (Banks and Sol.) Macbride	Fabaceae	W	Light	Rare
Punica granatum L.	Punicaceae	C	Moderate	Common
Retama raetam (Forssk.) Webb & Berthel	Fabaceae	C	High	Very common
Rhus tripartita (Ucria) Grande	Anacardiaceae	W	High	Common
Salix alba L.	Salicaceae	W	Light	Rare
Tamarix pentandra Pallas	Tamaricaceae	W	High	Very common
Ziziphus jujuba Mill.	Rhamnaceae	C	High	Common
Ziziphus lotus Lam.	Rhamnaceae	W	High	Rare

Table 1 (continued)

Parasitic species/host	Family	Status	Severity of infection	Incidence
Ziziphus spina-christi (L.) Willd	Rhamnaceae	W	High	Very common
4. Viscaceae				
Viscum				
a. Viscum cruciatum Sieber ex Boiss.				
Amygdalus communis L.	Rosaceae	C, W	High	Very common
Calicotome villosa (Poir.) Link	Fabaceae	W	Light	Rare
Capparis spinosa L.	Capparidaceae	W	Light	Rare
Crataegus azarolus L	Rosaceae	W	High	Very common
Crataegus monogyna Jacq.	Rosaceae	W	Moderate	Very common
Olea europaea L.	Oleaceae	C	High	Very common
Pistacia lentiscus L.	Anacardiaceae	W	Light	Rare
Prunus armeniaca L.	Rosaceae	C	Light	Rare
Prunus cerasifera Ehrh.	Rosaceae	C	Light	Rare
Prunus domestica L.	Rosaceae	C	Light	Rare
Punica granatum L.	Punicaceae	C	High	Very common
Retama raetam (Forssk.) Webb & Berthel	Fabaceae	C	High	Common
Rhamnus palaestina Boiss.	Rhamnaceae	W	High	Very common
Salix alba L.	Salicaceae	W	Light	Rare
5. Santalaceae				
Osyris				
a. Osyris alba L.				
Acacia cyanophylla Lindl.	Fabaceae	C	Moderate	Rare
Amygdalus communis L.	Rosaceae	C & W	High	Common
Anagyris foetida L.	Fabaceae	W	Moderate	Rare
Asparagus aphyllus L. Rank	Liliaceae	W	Moderate	Rare
Calicotome villosa (Poir) Link.	Fabaceae	W	High	Rare
Casuarina equisetifolia L.. (NC)	Casuarinaceae	C	Moderate	Rare
Cistus creticus L. (NC)	Cistaceae	W	Light	Rare
Clematis cirrhosa L.	Ranunculaceae	W	Moderate	Rare
Crataegus azarolus L. (NC)	Rosaceae	W	Moderate	Rare
Cupressus sempervirens L.*var. horizontalis* (Miller) Gordon	Cupressaceae	C	High	Common
Cupressus sempervirens L. *var. pyramidalis* Nyman	Cupressaceae	C	High	Common
Euphorbia hierosolymitana Boiss	Euphorbiaceae	W	Light	Rare
Ficus carica L. (NC)	Moraceae	C	Moderate	Rare
Olea europaea L.	Oleaceae	C	High	Sporadic
Pinus halepensis Mill.	Pinaceae	C	Light	Rare
Pistacia palaestina Boiss	Anacardiaceae	W	Moderate	Rare
Prunus domestica L.	Rosaceae	C	Moderate	Rare
Quercus coccifera L.	Fagaceae	W	High	Rare
Retama raetam (Forskal) Webb & Berth	Fabaceae	C	Moderate	Rare
Rhamnus palaestina Boiss	Rhamnaceae	W	High	Common
Rhus coriaria L.	Anacardiaceae	W	Moderate	Rare
Sarcopoterium spinosum (L.) Spach	Rosaceae	W	High	Common
Thymus capitatus (L.) Hoffmanns. & Link	Labiatae	W	Moderate	Rare
Vitis vinifera L.	Vitaceae	C	High	Rare
Ziziphus lotus Lam. (NC)	Rhamnaceae	W	Moderate	Rare
6. Cynomoriaceae				
Cynomorium				

Table 1 (continued)

Parasitic species/host	Family	Status	Severity of infection	Incidence
a Cynomorium coccineum L.				
Atriplex leucoclada Boiss.	Chenopodiaceae	W	High	Limited
Ferula communis L. (NC)	Umbelliferae	W	Light	Limited
Haloxylon persicum Bunge ex Boiss. and Buhse	Chenopodiaceae	C	Light	Rare
Salsola vermiculata L.	Chenopodiaceae	W	High	Limited
Salvia palaestina Bentham	Labiatae	W	Light	Rare

W wild, *C* cultivated

Rare: only on few plants in 1–2 sites of a biogeographical region

Sporadic: few plants infected in one or more biogeographical regions

Limited: on many plants localized in certain locations of 1 or 2 biogeographical regions

Common: on certain plant species in > one biogeographical regions

Very common: on many plant species in different locations of different biogeographical regions

GH in glasshouses

NC attachment was not confirmed

Table 2 Distribution of hosts between parasitic genera in Jordan for the period 2004–2009

Host plant/parasitic species	*Cuscuta* spp.	*Orobanche* spp.	*Cistanche* spp.	*Plicosepalus. acaciae*	*Viscum cruciatum*	*Osyris alba*	*Cynomorium. coccineum*
Acacia asak				X			
Acacia cyanophylla			X	X		X	
Acacia farnesiana				X			
Acacia nilotica				X			
Achillea sp.			X				
Alhagi maurorum	X						
Amygdalus communis	X	X			X	X	
Anabasis setifera .			X				
Anabasis syriaca.			X				
Anagyris foetida				X		X	
Asparagus aphyllus						X	
Atriplex glauca			X				
Atriplex halimus	X		X				
Atriplex leucoclada	X						X
Calicotome villosa					X	X	
Capparis spinosa	X			X	X		
Casuarina equisetifolia	X		X	X		X	
Ceratonia siliqua				X			
Cistus creticus						X	
Citrus maxima	X						
Citrus aurantifolia	X						
Citrus deliciosa	X						
Citrus limon	X						
Citrus paradisi	X						
Clematis cirrhosa						X	
Comicarpus africanus	X						
Commicarpus plumbagineus	X						

Table 2 (continued)

Host plant/parasitic species	*Cuscuta* spp.	*Orobanche* spp.	*Cistanche* spp.	*Plicosepalus. acaciae*	*Viscum cruciatum*	*Osyris alba*	*Cynomorium. coccineum*
Crataegus azarolus .	X				X	X	
Crataegus monogyna					X		
Cupressus sempervirens L. *var. horizontalis*						X	
Cupressus sempervirens L. *var. pyramidalis*						X	
Duranta plumieri	X						
Eriobotrya japonoca		X					
Eucalyptus camaldulensis			X				
Euphorbia hierosolymitana						X	
Ferula communis			X				X
Ficus carica		X		X		X	
Haloxylon persicum.			X				X
Haloxylon salicornicum.			X				
Juglans regia				X			
Lantana camara	X						
Malus domestica	X						
Melia azedarach				X			
Nerium oleander.	X			X			
Ochradenus baccatus	X						
Olea europaea	X	X	X		X	X	
Opuntia ficus-carieca			X				
Origanum syriacum	X						
Parkinsonia aculeata				X			
Pinus halepensis.			X			X	
Pinus sp.							
Pistacia atlantica				X			
Pistacia lentiscus.					X		
Pistacia palaestina						X	
Pistacia vera				X			
Poinciana gilliesii				X			
Prosopis chilensis	X			X			
Prosopis farcta	X		X	X			
Prunus armeniaca.	X	X			X		
Prunus cerasifera.					X		
Prunus domestica		X			X	X	
Prunus persica	X	X					
Punica granatum		X	X	X	X	X	
Quercus coccifera		X				X	
Retama raetam				X	X	X	
Rhamnus palaestina				X	X	X	
Rhus coriaria.						X	
Rhus tripartite	X			X			
Ricinus communis	X						
Rosa damascena		X					
Salicornia herbacea			X				
Salix alba					X		
Salsola sp.			X				
Salsola vermiculata			X				X

Table 2 (continued)

Host plant/parasitic species	*Cuscuta* spp.	*Orobanche* spp.	*Cistanche* spp.	*Plicosepalus. acaciae*	*Viscum cruciatum*	*Osyris alba*	*Cynomorium. coccineum*
Salvia palaestina							X
Sarcopoterium spinosum	X					X	
Suaeda asphaltica			X				
Suaeda vera			X				
Tamarix pentandra	X		X	X			
Thymus capitatus	X					X	
Vitis vinifera	X					X	
Withania sominiferum	X	X					
Zilla spinosa			X				
Ziziphus jujuba				X			
Ziziphus lotus .	X			X		X	
Ziziphus spina-christi .	X			X			

X parasitized

Self-parasitism

Seeds of *V. cruciatum* were found germinated on stem and twigs of the same parasite (self-parasitism) (Fig. 1) and seedlings of this parasite were observed at different developmental stages.

Discussion

Parasitic weeds challenge farmers worldwide (Parker and Riches 1993) and are difficult to control and poorly managed under field conditions (Qasem 2006). Absence of any suitable and effective method of control including selective and effective herbicides is another obstacle that may be added to the problems they exert on agriculture.

The present survey showed a huge number of host species that facilitate spread of parasitic weeds in Jordan. The high variation in host range reflects a high physiological adaptation of the parasites to different host species. On the other hand, certain species requiring host stimulants (e.g. *Orobanche*) appeared have a wide host range indicating the presence of seed germination stimulant/s in root exudates of different hosts and their role in enhancing seed germination and overcoming seed dormancy. These chemicals however, may have also an ecological implication in any control program for these parasites.

Certain parasites are highly host-specific while others are not. However, certain strategic crops such as *A. communis, O. europaea* and *V. vinifera* were severely attacked.

Infection of certain host species by different parasitic genera at the same time is another unusual phenomenon, which may indicate host/parasite compatibility and similarity in response to the host internal chemicals. Chemicals produced by a single host plant that stimulate germination and growth of different parasites may be similar and parasites may share common chemical responses. However, differences in growth and development of different parasitic genera on the same host plant were evident. While *P. acaciae* produced a massive vegetative growth on *R. raetam*, *V. cruciatum* and *O. alba* showed smaller growth by comparison on the same host. Growth of *V. cruciatum* on *P. granatum* was substantially higher than that of *P. acaciae*. Similar variations were also observed in growth and development of the same parasitic species on different host species which may indicate parasite host preference and compatibility differences. While *A. communis*, *Vitis vinifera* and *Cupressus* spp. appeared excellent hosts for *O. alba*, *Pinus halepensis* was less so. *P. acaciae* was vegetative and developed extensively on *C. equisetifolia*, *F. carica, M. azedarach*, *Parkinsonia aculeata*, *Pistacia atlantica*, *Poinciana gilliesii*, *R. raetam*, *T. pentandra*, and *Z. spina-christi* but its growth was greatly restricted on *Anagyris feotida*,

Table 3 Distribution of host species of parasitic weeds in Jordan based on growth form and economic importance

Fruit trees	Forest trees	Shrubs/other woody perennials
Amygdalus communis	*Acacia asak.*	*Achillea* sp.
Citrus maxima.	*Acacia cyanophylla*	*Alhagi maurorum*
Citrus aurantifolia	*Acacia farnesiana*	*Anabasis setifera*
Citrus deliciosa .	*Acacia nilotica*	*Anabasis syriaca*
Citrus limon	*Casuarina equisetifolia*	*Anagyris foetida*
Citrus paradise	*Ceratonia siliqua*	*Asparagus aphyllus*
Eriobotrya japonoca	*Crataegus azarolus*	*Atriplex glauca*
Ficus carica	*Crataegus monogyna*	*Atriplex halimus*
Juglans regia	*Cupressus sempervirens* L. *var.*	*Atriplex leucoclada*
Malus domestica	*pyramidalis*	*Calicotome villosa*
Olea europaea	*Cupressus sempervirens* L.*var.*	*Capparis spinosa.*
Opuntia ficus-carieca	*horizontalis*	*Cistus creticus*
Pistacia vera	*Eucalyptus camaldulensis*	*Clematis cirrhosa*
Prunus armeniaca	*Melia azedarach.*	*Comicarpus africanus*
Prunus cerasifera	*Nerium oleander*	*Commicarpus*
Prunus domestica	*Parkinsonia aculeata*	*plumbagineus .*
Prunus persica	*Pinus halepensis*	*Duranta plumieri*
Punica granatum	*Pinus* sp.	*Euphorbia hierosolymitana*
Vitis vinifera	*Pistacia atlantica.*	
Ziziphus jujube	*Pistacia lentiscus*	*Ferula communis*
	Pistacia palaestina	*Haloxylon persicum*
	Poinciana gilliesii	*Haloxylon salicornicum*
	Prosopis chilensis	*Lantana camara*
	Quercus coccifera	*Ochradenus baccatus*
	Retama raetam	*Origanum syriacum*
	Rhamnus palaestina .	*Prosopis farcta*
	Salix alba	*Rhus coriaria*
	Tamarix pentandra	*Rhus tripartita*
	Ziziphus lotus	*Ricinus communis*
	Ziziphus spina-christi	*Rosa damascena*
		Salicornia herbacea
		Salsola sp.
		Salsola vermiculata
		Salvia palaestina
		Sarcopoterium spinosum
		Suaeda asphaltica
		Suaeda vera
		Thymus capitatus
		Withania sominiferum
		Zilla spinosa

Ceratonia siliqua, *Juglans regia*, *Pistacia vera* and *Prosopis farcta*. Germinated seeds of *P. acaciae* failed to develop on *P. lentiscus* but the same parasite produced a massive growth on *P. atlantica*. *V. cruciatum* was very well developed and produced a massive vegetative growth on *A. communis* but its growth and development on *Prunus domestica*, *Prunus cerasifera* and *P. armeniaca* was highly restricted. *C. monogyna* forms a heavy and thick mattress like robes on *Citrus limon* and *Citrus deliciosa* but its growth on *Citrus paradise* and *Citrus maxima* was extremely confined. However, these differences in growth of the same parasitic species among different host species may reflect differences in mechanical, physiological and/or biochemical resistant mechanisms between different host species.

The claim that parasites do not kill their hosts seems not to hold for certain parasitic species and the opposite results were evident. *V. cruciatum* was found destructive to many hosts including *A. communis, O. europaea* (mainly old olive trees) and *P. granatum*. *P. acaciae* killed plants from *Acacia* spp., *C. equisetifolia*, *N. oleander*, *P. atlantica*, *R. raetam, T. pentandra* and *Z. spina-christi* in different parts of the Jordan Valley. *C. monogyna* was destructive to *C. deliciosa* and *Citrus limon* in certain sites in the same area. *O. alba* killed many *A. communis*, *Calicotome villosa, Cupressus* trees, *R. palaestina* and *V. vinifera*. *Cistanche* spp. appeared less destructive to woody species than other parasites but this may be greatly affected by the intensity of parasites infection although *A. maurorum*, *H. persicum, P. farcta* and *Z. spinosa* were completely destroyed in many cases. In addition to their parasitism effects and exhaustion of host food, nutrients and/or water, certain parasitic species (e.g. *Cuscuta* spp. and *O. alba*) developed a

Fig. 1 Seed and seedling of *V. cruciatum* attached on the stem of the same parasite (self-parasitism)

thick mattress of vegetative growth over the host canopy that totally prevented photosynthesis and killed hosts.

The present survey clearly showed that parasitic species are different in their geographical distribution in the country. This appeared somehow strongly correlated with climatic and edaphic factors. *C. monogyna* and *P. acaciae* are mainly localized in the Tropical/Sudanian area in the Jordan Valley, although *C. monogyna* was also found on *O. europaea* trees at about 300–400 m a.s.l. and at 800 m a.s.l. on the same host in Tafela area and Mediterranean region. *V. cruciatum* is distributed between tropical, sub-tropical (Irano-Turanian) regions and in the Mediterranean at more than 1,000 m a.s.l. *O. alba* was found in sub-tropical and Mediterranean region at about 200–1,100 m a.s.l.

Cistanche spp. and *C. coccineum* are desert species (Saharo-Arabian regions): the first was found on sandy and saline soils where many halophytes mainly members of the Chenopodiaceae are dominating in different sites (Al-Azraq, Wadi Rum and Eastern desert). This is mainly limited to the Eastern desert area where rainfall is very limited and species usually emerge at high temperature late in the spring. *C. coccineum* is spreading in the northern parts of Jordan as well as in the desert and Petra area and down to Wadi Rum on barely sandy soils. In addition, the parasite attacks members from Chenopodiaceae and other families on calcareous soils at more than 900 m a.s.l in the northern parts of the country.

Many of the wild shrubs and woody perennial forage and weedy host species serve as alternative hosts to many parasitic genera including *Cistanche* spp. (*A. maurorum*, *C. postii, P. farcta* and *Z. spinosa*), *O. alba* (*E. hierosolymitana, R. coriaria* and *S.spinosum*), *C. coccineum* and *C. monogyna* (*A. maurorum* and *P. farcta*), and *P. acaciae* (*C. spinosa* and *P. farcta*).

In conclusion, many fruit and forestry species, woody shrubs or sandy dune species appeared under threat of these parasites Many wild plant species were attacked by one or more parasitic species emphasizing their role in disseminating parasitic plants. Certain species attacking fruit trees are restricted to high lands (e.g. *O. alba*) while others (*P. acaciae* and *V. cruciatum*) spread in the Jordan Valley (tropical), the surrounding area (sub-tropical) and high lands (Mediterranean) indicating the role of environmental conditions in parasite distribution and their ecological tolerance. However, the survey covered most of the country's area but probably other parasites or host species of more or less importance may be found in the small unreached desert areas. There is a high potential for these species to spread and invade new areas and parasitize new hosts in the absence of local farmers trained on control measures.

Further studies are still needed on the biology and possibly other potential hosts of *Cistanche* spp. and *C. coccineum* since information on the two genera are very limited worldwide. Our results showed that *C. tubulosa* is potentially able to attack economic fruit trees including *O. europaea*, *P. grantum*, and possibly *V. vinifera* and others. Attachment of this parasite to the roots of *P. granatum* was confirmed, while the parasite was found in the vicinity of other fruit trees although attachment to *O. europaea* and *P. persica* was not checked. The same parasite was reported to occur in *V. vinifera* plantation but this was not verified. *Cistanche* spp. were widely distributed on sandy soils in the desert where some vegetable and fruit trees are usually grown under irrigation in certain parts of the area. Available information on the dispersal mechanism and on agents involved of these parasites and of *O. alba*, *V. cruciatum* and even *P. acaciae* are very limited worldwide and totally absent from Jordan. It has been reported that the Yellow vented bulbul (*Pycnonotus xanthopygos* Hemprich and Ehrenberg) is mainly responsible for seed dispersal of *P. acaciae* in the Jordan Valley and Dead Sea area (Green et al. 2009) but similar studies on other parasitic genera are lacking.

Studies on possible epiparasitism or self-parasitism of certain parasitic species is another important future research venue that may allow better understanding of the physiological nature of their parasitic habit. It has been observed that seeds of *V. cruciatum* germinated on branches of this parasite and seedlings were detected at different developing stages on stem and twigs of this parasite. Epiparasitism is a phenomenon documented for certain parasitic species (Parker and Riches 1993). This however, may indicates that parasite internal chemicals enhance its seed germination which may be regarded as a useful tool for artificial propagation of this species facilitating more specific studies on the biology and nature of their parasitism.

Control methods followed by local farmers are generally traditional. Pruning is frequently practiced against *V. cruciatum* and to a certain extent for *Cuscuta* spp. probably, studies on natural enemies of these parasites are important since the present survey revealed that some of the parasites are attacked by different insects. The larvae of *Thrips* sp. was found in seed capsule (*C. tubulosa*), in the stem of *O. schultzii*, or on leaves and branches of *V. cruciatum* (*Ceroplastes rusci*). Al-Khesraji et al. (1987) reported that different natural enemies attacked *Cynomorium* and *Cistanche* spp. in southern desert of Iraq including *Tropinota squalida* attacking species of both genera, *Aphis gossypii* on *Cistanche* spp., larvae of *Eumerus* spp. and those of Lepidoptera (Fam. Sesiidae) on both genera and the larvae was found very effective on *Cynomorium*.

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