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Mitigate *Phelipanche aegyptiaca* Pers. infestation considering natural environment conservation

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ABSTRACT
Growing cover crops with allopathic characteristics is a way to biologically control the weed *P. aegyptiaca*. Allelochemicals are present in almost all plants and in many plant tissues including leaves, stems, flowers, fruits, seeds and roots. This experiment was conducted to compare effects of allopathic crops on the germination rate of *P. aegyptiaca* seeds. Weed infestations were tested in Polyethylene (PE) bags and pot experiments. 27 crops, of different families, were grown in 2-Kg pots containing sterile soil infested with 0.6 g of seed. The control pots contained only 0.6 g of *P. aegyptiaca* seeds. Two month-old plants were incorporated into the soil from the surface and then tomato seedlings (*Lycopersicum esculentum* Mill.) were planted in the pots. Cotton (Malvaceae family) was among the cultured plants, used as a trap crop to thoroughly eradicate the threat of *P.aegyptiaca.* The most significant reduction in broomrape shoot and capsule number was demonstrated in those pots that contained cotton and sorghum, and in those that contained tomato; tomato dry weight significantly augmented. The results from the PE bags were in parallel with those of the pots. The germination rates of *P. aegyptiaca* (%) next to the plants in PE bags ranged from 8.333% to 55.333% respectively in millet and pepper. Except for sunflower, vetch, soy bean, chick pea, sainfoin, alfalfa, zucchini and sesame, which demonstrated catch crop, activity, the other cultivated plants; corn, oat, beet, sugar beet, triticale, caster-oil plant, millet, fiber flax, pepper, cotton and sorghum were determined as trap crops for the weed *P .aegyptiaca.*

Keywords: catch crop, cotton, declining broomrape infestation, pepper, trap crop*)*

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INTRODUCTION
Weed species of the group Orobanchaceae are the most economically damaging root parasites to affect crops in warm dry regions of the Mediterranean, Middle East and neighboring regions and in particular those species belonging to the genera *Orobanche* and *Phelipanche* (broomrapes) (Joel et al. 2007, Parker 2009). The crop species most commonly attacked by these parasites were from the plant families *Compositae*, *Solanaceae* (Romanova et al. 2001, Ross et al. 2004), *Fabaceae* (Goldwasser et al. 1997), *Umbelliferae,*

Cruciferae, Cucurbitaceae, Labiatae, Rosaceae, Astraceae, chenopodiaceae (Romanova et al. 2001, Abanga et al. 2007). The *Phelipanche* lifecycle is a highly specialized form of parasitism (Stewart and Press 1990). The seeds germinate in the soil only after a preconditioning period of suitable moisture level and temperature, and only in response to a specific chemical that acts as a germination stimulant exuded by the root of a host plant, ensuring that only seeds within the host root's rhizosphere will germinate. The parasite requires the release of the chemical signal xenognosin for germination, which ensures the presence of a potential host root. This allows the seeds to germinate within a few millimeters of a suitable host root (Parker et al. 1993). Currently, there is no consistent and sustainable method for the control of *Phelipanche* anywhere in the world (Goldwasser and Kleifeld 2004). Additionally, existing methods for broomrape control (Foy et al. 1989) are expensive and generally only partially effective. Crop rotation to a non-host crop is also not the complete solution because *Phelipanche* can parasitize weeds that lead to parasitic seed production even when non-host crops are grown in infested soil (Ross et al. 2004). However, it is noticeable that the collocation of 'weed management' emphasizes regulation of a weed population to maintain a weed infestation to a manageable level, taking into account both economic and ecological aspects (Hakansoon 2003). Hence, Crop rotation with trap plants (Ross et al., 2004) and catch plants (Acharya et al. 2002) has long been proposed and practiced as a control measure for broomrape in infested soil, and includes both of the afore mentioned aspects of its management (Krishnamurty et al. 1977; Ramaiah 1987, Qasem and Foy 2007). To fulfil this aim, knowledge of the range of host plants for Egyptian broomrape including hosts, false hosts and non-hosts is essential research.

The interaction of plant species with *Phelipanche* can be classified in to three distinct categories. Firstly, host plants stimulate parasitic seed germination, tubercle development and seed production; secondly, false-host plants stimulate parasitic seed germination without tubercle formation; and thirdly, non-host plants do not stimulate parasitic seed germination or attachment. Line et al., (1989) reported a 30% reduction in the crenate broomrape (*Phelipanche crenata* Forsk.) seed bank after one such catch crop cycle. In Oregon, USA, wheat (*Triticum aestivum* L.) was found to be a false-host of *O.minor* (Ross et al., 2004), and therefore, has the potential to be implemented in to an integrated *O.minor* management system. Sorghum (*Sorghum Vulgare* Pers.), maize (*Zea mays* L.), mung been (*Phaseolus aureus* Roxb.) and cucumber (*Cucumis sativus* L.) have been identified as trap crops for *P. ramosa* (Parker and Riches 1993) and sweet pepper has been identified as a trap crop for Egyptian broomrape. Kleifeld et al., (1996) found that flax (*Linum usitatissimum* L.) and mung bean (*Phaseolus aureus* Roxbg.) can be used as trap crops for *P. ramosa* (AbuIrmaileh 1984 and Ramaiah 1987), were heavily attacked in the field by Egyptian broomrape. Flax (linseed) has been cited as an efficient trap crop for *O.crenata* Forsk. (Ibrahim et al., 1973), *O. cernua* Loefl. and *P. ramosa* (Krishnamurty et al. 1977). Goldwasser, in 1991 from an investigation found that flax was heavily parasitized by *P. aegyptiaca.* Based on his research flax can be assigned as a catch crop for *P. aegyptiaca* (Goldwasser et al., 1991). Root exudates from basil (*Ocimum* spp.), carrot, cucumber, corn, onion (*Allium* spp.), soybean [*Glycine max* (L.) Merr.],

sunflower, sugar pea, and tomato stimulated *P. ramosa* germination (Yoneyama et al., 2001).

Allelopathic characteristics of plants provide criteria for a choice of cover crops in broomrape-infested fields. Allelopathy is the ability of a plant to inhibit the germination of another plant through the production of allelochemicals which may be present in any part of a plant, such as leaves, roots, fruits, stems, rhizomes and seeds, from where they are released to the soil through volatilization, root exudation, leaching and the decomposition of plant residue. Some plants inhibit seed germination and growth of other plants by producing toxic chemicals; allelochemicals or allelopathins. Several aromatic and medicinal plants that produce and store large amounts of secondary metabolites have a potentially pronounced effect on the growth and distribution of flora in their vicinity. Although the degree of selectivity is often not adequate for widespread commercial use, research on allelopathic mulch and cover crops have had promising results (Alagesaboopathi 2011 and Fuji and Hamano 2003). A recent study was conducted to determine the allelopathic potential of different crops for their abilities to incite *Phelipanche aegyptiaca* seed germination and consequently provide an evaluation of their impact on reducing a seed bank of *Phelipanche* spp. as well as infestation of the main crop.

MATERIAL AND METHODS

Plant material

Broomrape seeds were collected from a tomato field contaminated with P. aegyptiaca in the south eastern Tehran in 2009. Other seeds; tomato, wheat, barley, rye, sun flower, soy bean, chick pea, zucchini, mung bean, corn, vetch, oat, beet, sugar beet, triticale, sainfoin, caster-oil plant, mill, sesame, fibber flax, alfalfa, red been, cucumber, bell pepper, cotton and sorghum were kindly provided by Shahed University of Tehran.

Seed sterilization

Seeds of *P. aegyptiaca,* in small bags made of Mira cloth were wetted and surface-sterilized by immersion in 80% ethanol for 1 min, followed by 10 min in a mixture of 1% sodium hypochlorite in 0.01% aqueous Tween 20 as Amsellem described (polyoxyethylenesorbitan monolaurate). Crop seeds were surface sterilized by soaking in 1% sodium hypochlorite for 15 min. All seeds were rinsed three times in sterile, glass-distilled water and dried over night at room temperature (Amsellem et al. 2001).

Assaying germinability of P. aegyptiaca seeds

The apparent maximal germination rate was first tested in the absence of host plants by sprinkling 100 surface-sterilized *P. aegyptiaca* seeds on four 15-mm-diam GF/A paper discs, which were then placed on another layer of GF/A paper moistened with 1 ml sterilized water in a 10-cm Petri dish. The Petri dishes (four replicates) were sealed with parafilm, wrapped in aluminum foil, and placed in growth chambers (25Cº, 14h, and 100 µmol m^{-2} s^{-1}) for a preconditioning period. Two weeks later, the Petri dishes were opened and each was treated with 0.5 ml aqueous solution (5ppm) of GR24 (provided by Dr. Samedani, Plant Protection Institute, Yaman St, Velenjak Ave, Tehran/ Iran) a synthetic Strigol analog germination stimulant (Hassan-Ali 1983). The Petri dishes were resealed, wrapped, and returned to the growth chambers. Ten days after GR24 application, seed germinability was determined under a stereoscopic

microscope by counting the number of seeds having an emerged radical.

Hydroponic Polyethylene Bag study

After random selection of healthy seedlings from10-day germinated seeds, they were placed in the hydroponic polyethylene bag system as described by Goldwasser et al., 1997; Ross et al. 2004. A 19 × 24-cm piece of Whatman GFA glass fiber sheet was placed on each fiberglass sheet of 19× 24 cm, then 3 of each of the given sheets were prepared for locating in to each 22.5 × 25-cm polyethylene bag. The sheets were mounted with a file-hanging rod in a frame wrapped with black plastic to prevent light penetration to the roots. It should be emphasized that, cellulose-containing paper cannot be used as the backing and capillary source of medium, because cellulose can be degraded by cellulolytic microorganisms, releasing sugars for growth of secondary organisms. After preparation of the sheets, the surface of each GFA sheet was wetted with sterilized Hoagland nutrient solution (half strength) (Goldwasser et al., 1997). Then the surface-sterilized *P. aegyptiaca* seeds around 0.33 mg (approximately 100 seeds) were sprinkled onto Whatman GFA glass fiber paper, then roots of 10-day-old transplants with two or four leaves were washed and mounted on PE bags paper precisely above the parasite seeds. The paper was then inserted in to a clear polyethene bag (22.5 by 25 cm), which contained 20 ml sterilized Hoagland nutrient solution (Hoagland and Arnon, 1950) (half strength) (Goldwasser et al. 1997). Polyethylene bags were kept within black containers and placed in a germinator machine with artificial light and temperature (20C° night temperature and 25C° day temperature, under 100µ$Em^{-2}s^{-1}$ fluorescent light during a 14-h photoperiod) and replenished with nutrient solution as needed.

Observations of plant growth, parasite seed germination, and radical attachment and development were made and recorded periodically on the entire root system using a stereoscopic microscope (magnification, ×10-×60). Broomrape germination was determined by emergence of a radicle from the seed. Germination was quantified every 7 days for 28 days. Total *P. aegyptiaca* seed number was 3oo (100 seeds in each sheet) in each polyethylene bag at the start of the experiment to determine final germination percentages. Six plants were cultured in each bag, 4 replicates were used for each treatment. The synthetic parasitic plant germination stimulant GR24 was used at 0.01 gL^{-1} on seed stock to assess conditions and to establish a standard proportion of *Phelipanche* seed sensitive to germination stimulants.

Pot study

A stock of dry clay loam soil (with 55% clay, 25% silt and 20% sand; 7-10% $CaCO_3$, 2% organic matter (OM), and pH 7.1-7.2) artificially contaminated with *P. aegyptiaca* seeds (60 mg seeds Kg^{-1}soil, approximately 3 500 seeds) and kept beside non-infested soil. 27 of the afore-mentioned plants were sown (6 plants per pot) in 2-L pots filled with contaminated clay loam soil. 100 pots, each containing 2 L of infested soil with *P. aegyptiaca,* were planted with 27 crops, 4 pots for each crop. Control pots were modified with the addition of *P. aegyptiaca* seeds. The source of *P. aegyptiaca* seeds was the same as that for the growth chamber experiment. The pots were placed in the greenhouse and irrigated as needed. The plants were kept at 20-25°C, relative humidity (RH) of 60%, and 14h day

length. The pots were exposed to natural light as well as artificial light (14 hd^{-1}). Artificial lighting (400 W high pressure mercury lights, MBFRU, Osram Ltd, St Albans, Hertford, UK) producing 100W m^{-2} was used. When a whole plant had reached its vegetation stage (nearly two months) the foliage was cut and oven dried (70 Cº for 48h). The plant foliage was then blended with soil surface in each pot. It is essential to emphasize that the root systems were not moved or cut within the given pots. That step was terminated 61 days after planting (DAP) by cutting and blending the dried plant shoots with the soil surface (Kleifeld et al. 1994).

Finally three tomato seedlings were sown in each of those pots containing crop residue. Check treatment pots also were prepared. Following an emergence of the first trifoliate leaf, the tomato plants were thinned to one plant per pot. The pots were irrigated as needed. After 86 DAP, the tomato plants and emerged the *Phelipanche* plants were collected and dried in an oven (at 70 Cº for 48h). Tomato dry weight, *P. aegyptiaca* shoot and capsule dry weight were recorded. The experiment was conducted in a completely randomized design in which the treatments were replicated 4 times. All the F tests were subjected to Duncan's multiple range test at the 5% level of significance.

Statistical analysis:

Data were subjected to analysis of variance (ANOVA). Experiments were conducted in a completely randomized design (CRD) and analyzed by virtue of SAS (SAS 1996). Each treatment was replicated 4 times. Both PE and pot experiments were repeated twice and the results were considered. The significance ($P \leq 0.05$) of differences between treatments was determined by Duncan's multiple range test.

RESULTS

Hydroponic Polyethylene Bag study

GR24, the standard, stimulated germination in 53% of *P. aegyptiaca* seeds that were treated in an assay condition. All crops except zucchini, cotton, and pepper showed low levels of *Phelipanche* parasite infestation compared to Tomato. *P. aegyptiaca* germinated between 14 and 28 days after planting (DAP) and attached between 28 and 42 (DAP). *P. aegyptiaca* germination (%) as a result of interaction with catch crop plants ranged from 8.333% in millet to 55.333% in pepper. Millet, barely and sesame caused lower germination (%) of *P. aegyptiaca* seeds than did other tested members of *Poaceae* family. Moreover, among the *Poaceae* family the highest germination (%) occurred in those *P. aegyptiaca* seeds that were next to sorghum, cotton and pepper roots. The results from this research as well as other growth chamber experiments indicate that cotton, pepper, sorghum and GR24 can stimulate approximately equivalent proportions of *P. aegyptiaca* germination (up to 55.333%) (Rose et al. 2004, Rodriguez-Conde et al. 2004). Of all the tested crops pepper generally stimulated a greater proportion of *P. aegyptiaca* germination (55.333%) and millet stimulated the least germination response (8.333%). *P. aegyptiaca* seeds germinated in the presence of crops from the *Apiaceae, Asteraceae, Alliaceae, Zygophyllaceae, Euphorbiaceae, Pedaliaceae, Linaceae, Malvaceae, Cucurbitaceae, Chenopodiaceae, Poaceae, Solanaceae* and *Fabaceae* families (Table 1) however, attachment wasn't seen in wheat, barley, maize, oat, sorghum, triticale, millet or rye (*Poaceae*), as well as wild rue (*Zygophyllaceae)*,

garlic (*Alliaceae)*, pepper (*Solanaceae)*, beet and sugar beet (*Chenopodiaceae)*, castor oil plant (*Euphorbiaceae)*, or cotton (*Malvaceae)*. Pepper, cotton, sorghum, tomato and zucchini were more susceptible to Egyptian broomrape as inferred from the number of parasites observed on their roots (12 to 20 parasites per plant as recorded 28 DAP) (Table 2).

Pot study

The results from the glasshouse experiment indicated that growth of cotton, sorghum and pepper in *P. aegyptiaca* infested soil reduced parasitic attachment to fully-grown tomatoes through mixed planting. All tested plants either greatly reduced or completely inhibited parasitic attachment to tomatoes. This result suggests that cotton, sorghum, vetch, sainfoin, wild rue, soybean, and rye could be used to deplete numbers of *P. aegyptiaca* capsules (Table 3).

The effect of parasite infestation was a reduction in height of tomatoes and chlorosis of the leaves, which formed obtuse angles with the main shoot. Also, most of the flowers dropped before setting fruit, so that the reported biomass of the infested tomato plants in our experiment was about a quarter that of the non-infested ones. The number of *P. aegyptiaca* attachments per tomato plant differed among treatments ($P<0.0001$). In terms of instances of tomato grown in soil with no former planting there were about 4.66 parasitic attachments in each tested pot. Tomato grown after cotton did not possess any parasitic attachments. Germination of *P. aegyptiaca* was significantly higher in pots without any former plants. There was a significant decline in dry weight per capsule of *P. aegyptiaca* within the pots that had formerly contained sunflower, chick pea, soy bean, wild rue and cotton. However, dry weight per capsule of *P. aegyptiaca* was significantly increased in those pots that had contained tomato and zucchini as former plants. With the exceptions of millet from the Poaceae family and zucchini from Cucurbitaceae family, most other cultivated plants used as cover crops led to a decrease in Phelipanche seedling dry weight (Table 3).

In addition to the benefit of depletion of the *P. aegyptiaca* seed bank in the soil, there is also an added economic benefit of growing fiber flax, caster-oil plant, wild rue and cotton on *P. aegyptiaca*-infested sites in the form of tomato seedling dry weight augmentation. The most significant reduction in dry weight of broomrape was demonstrated in those pots that had formerly been planted with cotton, sainfoin, caster oil, chick pea, soy bean, garlic, wild rue and sorghum (Table 3). However, the least number of Phelipanche capsules was seen in those pots that had contained cotton, sorghum, vetch, sainfoin, wild rue, soybean, and rye. Furthermore, our findings show that cotton decreased early infestation of the parasite; thereby it can be used to significantly augment tomato dry weight (Table 3). The recorded number of Egyptian broomrape parasites demonstrated no change when the crop rotation was tomato-tomato. Tomato dry weight showed severe damage as a result of Egyptian broomrape infestation as well as unsuitable crop rotation of sunflower-tomato. However, sunflower used as a trap crop could be used to decrease dry weight of *P. aegyptiaca* seedlings. Tomato dry weight harvested after planting sunflower, reduced by approximately 50% compared to the control treatment, regardless of former planting.

Table 1. Plant Species response to Egyptian broomrape in the hydroponic polyethylene bag study

No Germination or tubercle development	Germination without tubercle development [a]	Germination and tubercle development [b]
	Pepper (*Capsicum annum*)	Tomato (*Lycopersicon esculentum* Mill.)
	Wheat (*Triticum aestivum* L)	
	Barley (*Hordeum vulgare* L)	Sun flower (*Helianthus annuus* L.)
	Corn (*Zea mays* L)	
	Sorghum (*Sorghum vulgare* L)	
	Oat (*Avena sativa* L)	
	Rye (*Secale cereal* L)	
	Triticale (*Triticum secale*)	Vetch (*Vicia villosa* L.)
	Millet (*Panicum miliaceum*)	Soy bean (*Glycine max* Merrill)
		Chick pea (*Cicer arietinum* L.)
		Sainfoin (*Onobirichis vignarediata*)
	Beet (*Beta vulgaris* L)	Alfalfa (*Medicago sativa* L.)
	Sugar beet (*Beta vulgaris saccharifera* L)	
	Caster-oil plant (*Ricinus communis* L)	Zucchini (*Cucurbita* spp)
	Cotton (*Gossypium hirsutum* L)	
	Fiber flax (*Linum usitatissimum* L)	
		Sesame (*Sesamum indicum* L.)
	Wild rue (*Peganum harmala*)	
	Garlic (*Allium sativum*)	

a Based on observation of at least one germinated Egyptian broomrape seed per test plant without tubercle development
b Based on observation of at least one developed Egyptian broomrape tubercle per test plant

Table 2. Egyptian broomrape germination and tubercle development per test plant in the hydroponic polyethylene bag study; quantified 42 days after planting

Crops	Germination % [a]	Tubercle development $\times 10^{-1}$
Tomato (*Lycopersicon esculentum* Mill.) (check)	48.16 abc	2.2034 ab
Pepper (*Capsicum annum*)	55.333 a	0 d
Sun flower (*Helianthus annuus* L.*)*	18.333 fgh	1.0833 c
Wheat (*Triticum aestivum* L.)	17.667 fgh	0 d
Barley (*Hordeum vulgare* L.)	10.333 h	0 d
Corn (*Zea mays* L.)	36.333 abcdef	0 d
Sorghum (*Sorghum vulgare* L.)	51.333 ab	0 d
Oat (*Avena sativa* L.)	21.000 efgh	0 d
Rye (*Secale cereal* L.)	35.333 abcdefg	0 d
Triticale (*Triticum secale*)	27.667 defgh	0 d
Millet (*Panicum miliaceum*)	8.333 h	0 d
Zucchini (*Cucurbita pepo*)	50.333 abc	1.8736 b
Sainfoin (*Onobirichis vignarediata*)	44.667 abcd	0.2333 d
Vetch (*Vicia villosa* L.)	36.000 abcdef	0.2963 d
Soy bean (*Glycine max Merrill*)	14.33 gh	1.1525 c
Chick pea (*Cicer arietinum* L.)	18.667 fgh	1.0782 c
Caster-oil plant (*Ricinus communis* L.)	33.333 bcdefg	0 d
Alfalfa (*Medicago sativa* L.)	16.667 fgh	0.2732 d
Beet (*Beta vulgaris* L.)	24.667 defgh	0 d
Sugar beet (*Beta vulgaris saccharifera* L.)	22.333 defg	0 d
Cotton (*Gossypium hirsutum* L.)	53.000 ab	0 d
Fibber flax (*Linum usitatissimum* L.)	37.000 abcdef	0 d
Wild rue (*Peganum harmala*)	29.667 bcdefgh	0 d
Garlic (*Allium sativum*)	42.333 abcde	0 d
Sesame (*Sesamum indicum* L.)	11.000 h	0.2518 d
Control- GR24 (*O. aegyptiaca* seeds vigour) (check)	51 ab	3.1087 a

[a] Percentage of germination= number of germinated seeds/ total seeds × 100

Table 3. Evaluation of cultivating 27 cover crops in order to find one that has the influential rule on declining *O.aegyptiaca* infestation in tomato contaminated field as well as the estimation of tomato yield enhance

Family	Cover crops	LTS ¥(mm)	LOS«(mm)	DWTS§(mg)	DWOS¤(mg)	N OSh$^{\Omega}$	N OC•	POCDW▪(mg)	OG%☼
Solanaceae	Tomato (*Lycopersicon esculentum* Mill.)	190.41 g	109.98 abc	1005 abc	408 abc	2.333 abc	2.166 ab	9.3 a	0.0665 ab
	Pepper (*Capsicum annum*)	216.67 fg	164.67 ab	516.3 abc	402.3 abc	0.667 bc	7 ab	0.4 ab	0.0190 ab
Asteraceae	Sun flower (*Helianthus annuus* L*)*	181.67 g	80.89 abc	335 bc	175 abc	3.667 ab	0.887 ab	0.01 b	0.1045 ab
Poaceae	Wheat (*Triticum aestivum* L)	117.33 h	91.11 abc	936 abc	168.7 abc	1.667 abc	2.5 ab	0.3 ab	0.04571 ab
	Oat (*Avena sativa* L)	115.5 h	41.03 bc	817.7 abc	153.7 abc	2.333 abc	2.167 ab	0.1 ab	0.0665 ab
	Rye (*Secale cereal* L)	118.33 h	151 abc	779.7 abc	176 abc	1.333 abc	0 b	0 b	0.038 ab
	Barley (*Hordeum vulgare* L)	100.41 h	116.77 abc	540.3 abc	408 abc	2.667 abc	10.367 a	0.4 ab	0.076 ab
	Triticale (*Triticum secale*)	128.33 h	88.67 abc	705 abc	278 abc	2 abc	0.72 ab	2.1 ab	0.0571 ab
	Millet (*Panicum miliaceum*)	166.66 h	183.13 ab	348.7 bc	660.3 a	3.667 ab	6.867 ab	0.6 ab	0.1045 ab
	Corn (*Zea mays* L)	251.00 defg	183.67 ab	437.7 abc	168.7 abc	2.333 abc	2.887 ab	1.0 ab	0.0665 ab
	Sorghum (*Sorghum vulgare* L)	103 h	41.83 bc	259 c	33.3 c	0.667 bc	0.333 b	0.1 ab	0.0188 ab
Fabaceae	Vetch (*Vicia villosa* L)	321.67 bcd	92.25 abc	1043.7 abc	142.7 abc	2.333 abc	0.417 b	0.1 ab	0.0665 ab
	Soy bean (*Glycine max Merrill*)	270.00 cdef	56.55 abc	595.7 abc	64.3 bc	3.667 ab	0.583 b	0.01 b	0.1045 ab
	Chick pea (*Cicer arietinum* L)	298.33 cde	62.07 abc	864.3 abc	86 bc	3.667 ab	0.8 ab	0.02 b	0.1045 ab
	Alfalfa (*Medicago sativa* L)	296.67 cde	152.33 abc	825.3 abc	372 abc	2.333 abc	3.5 ab	0.4 ab	0.0665 ab
	Sainfoin (*Onobirichis vignarediata*)	236.67 efg	37.58 bc	537.3 abc	64 bc	1.667 abc	0 b	0 b	0.0474 ab
Chenopodiaceae	Beet (*Beta vulgaris* L)	303.33 cde	204.67 a	868 abc	430 abc	1.667 abc	5.333 ab	1.6 ab	0.0474 ab
	Sugar beet (*Beta vulgaris saccharifera* L)	242.67 defg	87.89 abc	1064 abc	88 bc	2 abc	1.22 ab	1.1 ab	0.0571 ab
Cucurbitaceae	Zucchini (*Cucurbita spp*)	380.00 ab	71.44 abc	1205 a	573.3 ab	2.667 abc	2 ab	11.0 a	0.076 ab
Malvaceae	Cotton (*Gossypium hirsutum* L)	250.00 defg	0 c	1227 a	0 cd	0 c	0 b	0 b	0 b
Linaceae	Fiber flax (*Linum usitatissimum* L)	393.33 a	72.08 abc	1072.7 ab	278.3 abc	2.333 abc	1.083 ab	1.62 ab	0.0665 ab
Pedaliaceae	Sesame (*Sesamum indicum* L)	246.67 defg	149.39 abc	929 abc	196 abc	3.667 ab	4.72 ab	0.2 ab	0.1045 ab
Euphorbiaceae	Caster-oil plant (*Ricinus communis* L)	308.67 bcde	98.33 abc	1143.7 ab	116 bc	1.333 abc	1.5 ab	3.1 ab	0.038 ab
Zygophyllaceae	Wild rue (*Peganum harmala*)	340.00 abc	54.11 abc	1104.7 ab	81 bc	1.333 abc	0.333 b	0.02 b	0.038 ab
Alliaceae	Garlic (*Allium sativum*)	296.67 cde	58 abc	773.3 abc	59 bc	2 abc	1.2 ab	0.1 ab	0.0571 ab
	Control + O	278.67 cdef*	154.72 abc	864.7 abc	367.7 abc	4.667 a	4.5 ab	2.1 ab	0.1331 a

*In each column data's followed by the same letter have no significant difference ($P \leq 0.05$).

LTS¥ = Length of Tomato seedling
LOS« = Length of *Orobanche aegyptiaca* seedling
DWTS§ = Dry Weight of Tomato seedling
DWOS¤ = Dry Weight of *Orobanche aegyptiaca* seedling
NOSh$^{\Omega}$ = Number of *Orobanche aegyptiaca* shoot
NOC• = Number of *Orobanche aegyptiaca* capsule
P OCDW▪ = Per *Orobanche aegyptiaca* capsule Dry weight
OG%☼ = Orobanche aegyptiaca germination% (number of germinated seeds/ total seeds × 100)

DISCUSSION

The application of trap and catch crops should be a regular inclusion in crop rotation and fallow management of infested fields. This method of weed control is not only useful to alleviate invasion of the weed but also to fortify the soil, which is covered by the given plants. It must be emphasized that, crop rotation has direct and indirect impact on weeds especially parasitic weeds in infested areas. While trap and catch crops in a rotation may to some extent a parasite's seed bank, other rotation crops may have allelopathic effects on parasitic seeds. Allelochemicals are present in almost all plants and in many plant tissues: leaves, stems, flowers, fruits, seeds and roots. However, activities of the mentioned chemicals used for Phelipanche control will be weak as a result of rapid volatilization (Kleifeld et al. 1994). Many natural compounds are reported to have a high potential to form the basis of commercially successful herbicides and their half-lives in the environment are often much shorter than those of synthetic compounds. Furthermore, they may offer improved selectivity, better toxicological and environmental safety and increased efficacy. The aqueous leaf, stem and root extracts of *Andrographis paniculata Nees* on investigation demonstrated an inhibitory effect on seed germination and growth of *Seasmum indicum* L. (Ellu). Given that the investigation also showed that the extracts brought about considerable inhibition to the germination of ellu seeds and in root and shoot growth. The allelopathic effect of leaf, stem and root extracts of *A. paniculata* decreased the seed germination of ellu with increased concentrations of extracts. The extracts also inhibited the shoot and root length of *S.indicum* seedlings with increased concentration of *A.paniculata* extracts. The inhibitory effect might be due to the presence of allelochemicals in the extracts of *A.paniculata.* In a Leaucaena leucosephla plantation, Chou (1990) found an almost total lack of understory after 3 to 4 years of growth, except for its own seedlings. He stated that the absence of weeds was due to a heavy accumulation of Leaucaena plant residue, such as that from leaves and branches. Aqueous extracts from fresh leaves, seeds, litter, and soil showed significant phytotoxic effect on many test species, but Leucaena. Decomposing leaves also suppressed the growth of plants in pots. This is exactly what this study aims to confirm, based on the results from our recent experiment. As our results have demonstrated, cover and trap crops both make an effective contribution to a significant decline in tomato seedling losses. These results can also emphasize the allelopathic efficiency of applied plant tissue in our pot experiment. Phenolic derivatives, such as the dihydroquinone sorgoleone, produced by Sorghum bicolor, are extremely phytotoxic in hydroponic culture (Einhellig and Souza 1992). Moreover, according to the results of Barnes et al., synthetic derivatives of coumarines have been known to be good herbicides. Other aromatic compounds, such as DIBOA, are as active in reducing plant growth as many herbicides (Barnes et al. 1986).

Dongola in 2006 reported that crop sequence had a remarkable impact on the control of *Phelipanche ramosa* and on yield of a subsequent tomato crop. Based on his paper, infestation of *Phelipanche* decreased by 37% at Elgeli in the crop sequence of onion-onion, onion-tomato and tomato yield was increased by 38%. At Alafoon the crop sequence onion-onion-onion/tomato and/or onion-alfalfa-alfalfa-tomato decreased *Phelipanche* infestation by (90-95%) and tomato yield

was increased by 60% (Dongola, 2006). Some legume crops increase soil fertility that contributes to the ability of susceptible crops to compete with their parasites. An increase in soil fertility may also stimulate a reduction in the secretion of germination stimulants by a crop's roots (Yoneyama et al., 2007). It has been frequently recorded that adding green manure to soil reduces an infestation of *Phelipanche* in fields, accounting for one of the many advantages of using cover crops (Dadon et al., 2004). Manure fertilization that adds Nitrogen compounds has the potential to control *Phelipanche* species, negatively affecting its ability to germinate as well as elongation of the seedling radicle. In addition, manure fertilization augments the killing effect of solarization on *O. crenata* seeds (Haidar and Sidhamed 2000).

It is likely that trap crops alone cannot completely eliminate a seed bank of *O. minor* from the soil in a single cycle (Lins et al. 2006). With this in mind, integrated management of *Phelipanche* spp. must be utilized to broaden the focus of control strategies. For example these strategies for *P. aegyptiaca* must aim to reduce a parasitic weed's seed bank in the soil and limit growth of the parasite on a host plant. Management of *P. aegyptiaca* early in its life cycle is critical for the prevention of *P. aegyptiaca* seed production and loss of tomato seed yield. Studies on the use of trap crops in *Phelipanche*-infested fields suggest that root exudates of the trap crop enhance germination. Trap crops listed in a paper by Ferna´ ndez-Aparicio are cotton (*Gossypium hirsutum* L.) (the source of the first isolated germination stimulant strigol) probably for all *Phelipanche* species, linseed (*Linum usitatissimum* L.) for *P. ramosa* and *P. aegyptiaca*, mungbean (*Phaseolus aureus* Roxb.) for *P. aegyptiaca*, Egyptian clover (*Trifolium alexandrinum* L.) for *O. crenata*, sunhemp (*Crotalaria juncea* L.) and mung bean [*Vigna radiata* (L.) Wilczek] for *P. cernua* Loefl. Fenugreek has been identified as a stimulant for *P. ramosa* seed germination, but not the seeds of *O. foetida* Poir. ; *O. crenata* seed germination is inhibited (Ferna´ ndez-Aparicio et al. 2008), which all given traps are able to mitigate *Phelipanche* and *Phelipanche* infestations in field. Moreover, this study has determined that *Poaceae* family consisting of barely, wheat, oat, triticale, sorghum, millet, corn and rye; as well as pepper, beet, sugar beet, caster-oil plant, cotton, wild rue and garlic can be identified from the other crops in the study as a group of trap crops; a suicidal agent group. In the other words, they incited *P. aegyptiaca* seed germination on a crop's root. However, no radical improvement was observed. Based on these results, crops of the *Poaceae* family induced less seed germination of *P. aegyptiaca* in proportion to *Alliaceae, Zygophyllaceae, Euphorbiaceae, Pedaliaceae, Linaceae, Malvaceae, Cucurbitaceae, Chenopodiaceae, Fabaceae, Asteraceae, Solanaceae* families. In parallel with the results of research by Rose and Rodrigues it was also determined that the most significant reduction in broomrape shoots was recorded in those pots that had formerly contained cotton, pepper and sorghum, all of which have been identified as trap crops for *P. aegyptiaca*. Furthermore, cotton decreased early infestation of the parasite; thereby significantly augmenting tomato dry weight (Rose et al. 2004; Rodriguez-Conde et al. 2004). Cotton (*Gossypium hirsutum* L) of the *Malvaceae* family is an example of a trap crop (the source of the first isolated germination stimulant

strigol) probably for all *Phelipanche* species (Ferna´ndez-Aparicio et al., 2008). In addition to the benefit of *P. aegyptiaca* in depletion of the weed's seed bank in the soil, there is also the benefit of an extra economic from growing fiber flax On *P. aegyptiaca*-infested sites in the form of the marketable product of tomato (Qasem and Foy 2007). Additionally, a recent study has demonstrated that commonly grown cotton, pepper and sorghum, more than the other examined plants have the potential to reduce a seed bank of *P. aegyptiaca* in the soil.

Appling effective influential catch or trap crops as a method of bio-control to decrease *Phelipanche* through suitable rotation has to be considered as an imperative option for weed control. The remarkable impact of crop rotation on *P. aegyptiaca* seed bank as well as on crop yield are undeniable. The PE bag method enabled us to monitor the parasitism process from germination to inflorescence and identify the stage at which parasitism halted and ceased to progress. According to Bischof and Koch's experiment in 1974, pepper was suggested as a trap crop, without verification under field conditions. The result of that experiment is similar to the results obtained at the end of this recent investigation. Pepper was introduced as a trap crop. Pepper effectively induces germination of *P. aegyptiaca* seeds. As pointed out above, a trap crop may be infested by the parasite but it shouldn't allow the production of seeds, which may be added to a seed bank in the soil (Hershenhorn et al. 1996). The assessment defined in this paper that tomato plants in pots that had formerly contained sorghum, rye, sainfoin, wild rue, soy bean and pepper were only lightly infested and weakened by *P. aegyptiaca*. Furthermore, cotton cultivation desists infestation of tomato roots by *P. aegyptiaca*. As Kleifeld et al. demonstrated in 1994, of the three winter crops (flax, clover and vetch) and the two summer crops (mung bean and sorghum) used in the field experiment as trap crops for *P. aegyptiaca*, only vetch var. Sadot in winter, and Sorghum var. Hazera 610 in summer, were not attacked by the *P. aegyptiaca* (Kleifeld et al., 1994). Flax, which has been suggested by many investigators as a trap crop for *Phelipanche* species (*P. ramosa*; *P. cernua*), was severely parasitized by *P. aegyptiaca*. Likewise, our results identified flax as a catch crop able to reduce *P. aegyptiaca* in infested soil. Clover was suggested as a trap crop by Al-Menoufy (1989) for *O.crenata* mung bean was suggested by Krishnamurty et al., (1977) for *P. cernua*; both were heavily parasitized by *P. aegyptiaca*. Seeds of *P. aegyptiaca* and *P. cernua* germinated effectively in vitro in the presence of sadot vetch roots grown in a water culture. Another variety of vetch, Yovel, was severely attacked by *O.crenata* and *P. aegyptiaca* in the next field (Kleifeld et al., 1994). Meanwhile, vetch could be a *P. aegyptiaca* catch crop, which was severely attacked by *P. aegyptiaca.* Sorghum was mentioned as a trap crop for *O.cernua*. Stimulation of germination of *Phelipanche* seeds by a host plant or its residue could be maintained in the soil under field conditions for at least one year (Joel et al., 1998) and could be the reason for increased *P. aegyptiaca* infestation on tomatoes following the winter legume crops. The same effect of heavier *Phelipanche* infestation and reduction in the vigor and yield of the next year's tomato crop, following the previous sorghum, could be related to the stimulatory effect of crop residue in the soil. Although trap crops achieved a significant effect in reducing early *Phelipanche* infestation on a following

host crop, its effect in a heavy infested field was very limited. This effect was recorded only from crops that were attacked by *Phelipanche* that had been controlled before seed production, and not from real trap crops. Foy et al. (1989) discussed the efficacy of trap crops as a method for reducing *Phelipanche* infestation. It should be acknowledged that only a small proportion of parasite seeds was affected by the trap crop roots in the layer of tilled soil. Trap crops in general, that is from catch and false-host plants, may be integrated with other methods used for *Phelipanche* control directed at the upper soil layer infestation where the activity of the chemicals used for *Phelipanche* control may be weak as a result of rapid volatilization (Kleifeld et al. 1994). This study determined that cotton and sorghum were suitable for application as trap crops for *P. aegyptiaca,* they both facilitated a remarkable decline to shoot and capsule numbers of *Phelipanche* as well as *Phelipanche* dry weight. It is noticeable that, sorghum caused a reduction in tomato yield thus generally putting sorghum in rotation with tomato would not be profitable.

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