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Management of *Phelipanche aegyptiaca* Pomel. using trap crops in rotation with tomato (*Solanum lycopersicom* L.)

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Abstract

One of the most susceptible hosts of the *Phelipanche aegyptiaca* (pers.) Pomel is tomato. Broomrape causes yield loss in tomato due to severe infestations in many regions of Iran. A study was conducted to evaluate the effect of some trap crop on reducing *Ph. aegyptiaca* damage in tomato. Trap crops consisting of Egyptian clover, sesame, mungbean, common flax, brown Indianhemp, cotton, pepper and black-eyed pea were studied during 2008 and 2009. Through the first year, trap crops were cultivated in pots and in the next year, tomato was transplanted into those pots. Sesame, brown Indianhemp, common flax and black-eyed pea decreased broomrape biomass by 86, 85.3, 75.2, and 74.4%, respectively. Reducing broomrape biomass caused increases in the tomato yield. Meanwhile, sesame, brown Indianhemp, Egyptian clover and mungbean increased total biomass of tomato by 71.4, 67.5, 65.5, and 62.5 %, respectively. It was found that these plants have a great potential to reduce broomrape damage and they can be used in rotation in broomrape infested fields.

Keywords: *Orobanche*; parasitic plant; total biomass; weed management.

Introduction

Phelipanche and *Orobanche* (broomrapes) are root parasites of several crops in Iran (Minbashi and Mazaheri, 2002). Egyptian broomrape (*Phelipanche aegyptiaca*.) is an obligate parasite plant species widespread in Mediterranean areas, Asia and Southern and Eastern Europe (Hershenhorn *et al.*, 2009). They act by attaching themselves to the roots of many plant species with haustorium and obtain nutrients and water from their host. This parasitic plant causes economic damage in field crop and vegetable production worldwide (Joel, 2000; Press *et al*., 2001; Eizenberg *et al*., 2004; Lopez-Raez et al., 2008;). Control with herbicides or other approaches are not successful for broomrape (Ross *et al.*, 2004) because these parasites cause greatest damage prior to their shoot emergence and flowering. Therefore, the majority of yield loss may occur before diagnosis of infection (Lins *et al*. 2005). In addition to yield loss, due to presence of this species, soil seed bank will be retrieve and each stem produces 500 thousand dusty seed that their longevity are as long as 20 years (Johnson *et al*., 1976; Pieterse, 1979; Kebreab and Murdoch, 1999). Crop rotation which prevents crops from being infected by parasite is an effective method of weed control (Garcia-Torres, 1994). Although, this method and trap crops which are being used to control broomrape are not perfect ways to controling broomrape but it has been suggested that trap crops reduce crop yield losses in contaminated soil (Hershenhorn *et al*., 1996; Ross *et al*., 2004). The variety of host plant is so extensive and includes so many viable crops that such crop rotations are often not the only option (Dhanapal *et al*., 1996). Planting of the trap crops to protect the main crop from a pest or parasitic plant is called trap cropping. The trap crop can be from the same or different family group, than that of the main crop (Hokkanen, 1991). Trap crops as a false-host plants turn out compound exudates that support broomrape germination (Joel *et al*. 1995) but they don't permit the broomrape to attach the roots or develop tubercles and do not hamper the growth and yield of crops (Dhanapal *et al*., 1996). According to Linke *et al*. (1993), soil seed bank of broomrape could be reduced by planting trap crops like sesame, brown Indianhemp, mungbean and common flax in rotation. Kleifeld *et al*. (1994), observed that growing flax (*Linum usitatissimum* L.) in two successive winter seasons or one summer cropping with mungbean (*Phaseolus aureus* Roxbg.) reduced the early infestation of *Orobanche aegyptiaca* and significantly increased tomato vigor and production. It should be considered that using this method alone would not be effective it is necessary to be applied with other control methods such as chemical, mechanical etc. Meanwhile, some researchers recommended that trap crops are a sustainable, economical and an environmentally friendly for the control of broomrape species (Puzzili, 1983; Labrada and Perez, 1988). Integrated weed management (IWM) is the best approach to broomrape management in field crop. IWM involving trap crops is desirable to reduce the herbicides use in agriculture (Chittapur *et al*., 2001). Therefore, the objective of this research was to examine the effect of Egyptian clover, sesame, mungbean, common flax, brown Indianhemp, cotton, pepper and black-eyed pea on reducing the broomrape damage and to increase the yield of tomato in broomrape infested field.

Table1. Analysis of variance for Tomato and *Phelipanche* characters in response to trap crops treatments in pot experiment

Source Of Variation	D.F	Mean Square						
		Phelipanche			Tomato			
		Total biomass weight	No. of stem	No. of tubercle	Shoot dry weight	Root dry weight	No. of Fruit	Yield
Block	3	0.13	0.99	2.44	0.08	0.145	0.4	21.20
Treatment	8	19.7**	28.5**	987.16**	37.95**	4.78**	7.51**	3819.64**
Error	24	0.22	1.37	5.3	0.54	0.13	0.55	19.77
C.V(%)		14.32	22.18	10.26	4.5	8.86	18.44	10.6

** Indicates significant at P<0.01

Materials and methods

Plant Material

Control the broomrape damage in tomato fields and evaluate the effect of trap crops including Egyptian clover (*Trifolium alexandrinum* L.), sesame (*Sesamum indicum* L.) var. Darab1, mungbean (*Vigna radiata* L.) var. Parto, common flax (*Linum usitatissimum* L). var. Legina., brown Indian-hemp (*Hibiscus canabinus*) var. Farakhil, cotton (*Gossypium hirsutum)* var. Varamin, pepper (*Capsicum annuum L.)* var. Arkalohit, black-eyed pea (*Vigna unguiculata* L.*)* var. Parastou and tomato as control pot; these plants were monitored in this study. The crop seeds were gathered from seed and plant improvement institute of Karaj.

Experimental Site

This outdoor pot experiment was conducted at the Research Farm of Faculty of Agriculture, University of Tehr an, Karaj (1321 msl, 35°48´N latitude, and 51°10´E longitude), Iran, during 2007-08 and 2008-09 (Fig. 1).

Pot Experiments

Broomrape seeds were collected from a severely natural infested tomato field in Hashtgerd, Karaj in 2007 (Fig. 1). Each pot was contaminated at the rate of 50 ml per pot. Pots (In size: 25cm diameters, 25cm heights) were filled with Perlite and garden soil at equal ratio. Seeds of all trap crops sowed in pots in the same time on June 10, 2008. After emergence, plants were thinned to one per each pot except Egyptian clover that it was 3 plants per each pot. Plants were watered as needed and supplemented half-strength Hoagland solution because of limited soil and nutrients in pots (Hoagland and Arnon, 1950). At the end of the growth, when all plant died naturally, whole plants including aerial part and roots were harvested and roots of crops were examined for broomrape tubercle. Pots containing the soil were kept under natural conditions until the next year.Tomato (*S. lycopersicom* L.) var. Super Luna D.P. seedlings were transplanted with two to four leaves in the previous year's pot on May 5, 2009 (each pot one seedling). Plants were irrigated by half-strength Hoagland solution and were grown for 65 days. After appearance of the first symptoms of wilting and necrosis on tomato plant, shoots were cut at soil surface, and fruits were separated from plants. The fresh weights of fruits and dry weights of shoots were determined. Broomrape aerial part emerging above the soil was counted and the root system of the host plants was washed carefully on a 2 mm mesh to determine tomato root dry weight and total number of parasitic tubercles above 2 mm diameter (Hershenhorn *et al*., 1996). Total biomass dry weight of broomrape was recorded.

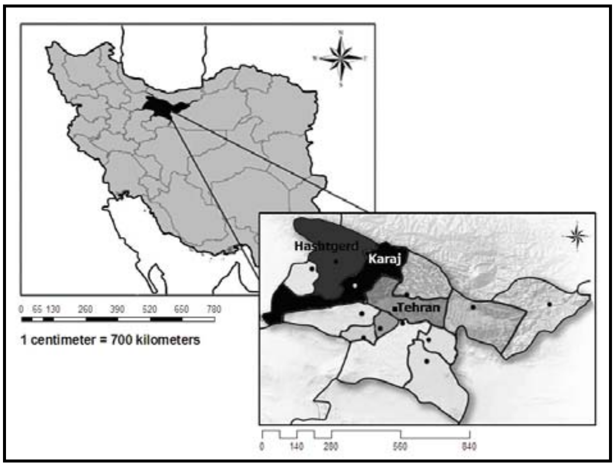

Fig 1. Karaj and Hashtgerd, Iran (Site of experiment and broomrape seed collecting).

Statistical Analysis

Experimental design was a randomized complete block design with four replications and eight trap crops per each block and a control pot (9 pots per block in both years) also was included. One-way ANOVA was applied using SAS software (version 9.1) to assess all effects. Significant differences among treatment means were identified by Duncan multiple range test at the 0.05 level of significance (SAS, 1998). The SPSS software (version 16.0) was used to estimate correlation between all traits together.

Results

Results of ANOVA showed that the effect of treatments on measured traits of tomato and broomrape were significant (P<0.05) (Table 1).

Effects of trap crops on the growth of Phelipanche

Total biomass dry weight of broomrape

Sesame, brown Indianhemp, common flax and Black-eyed pea led to the reduction of total biomass of broomrape by 98.6, 85.3, 75.2, and 74.4%, respectively (Fig. 2). Due to significant reduction in broomrape total biomass caused by sesame and brown Indianhemp, tomato fruit yield increased significantly (Table 2). Fig. 8 shows that there is a negative correlation between broomrape biomass and tomato yield which means by decreasing the amount of broomrape biomass the tomato yield increases. Pepper, control (without trap crop), and Egyptian clover had lowest effect on broomrape control.

Table 2. Correlation between tomato and broomrape traits.

Characteristics	(1)	(2)	(3)	(4)	(5)	(6)
(1) Tomato Biomass	1					
(2) No. Fruits	0.625**	1				
(3) Yield	0.557**	0.606**	1			
(4) Broomrape Biomass	-0.595*	-0.331*	-0.793**	1		
(5) No. Broomrape Stem	-0.607**	-0.812**	-0.812**	0.852**	1	
(6) No. Broomrape Tubercle	-0.594**	-0.415**	-0.885**	0.834**	0.769**	1

*and ** significant for p<0.05 and p<0.01 respectively.

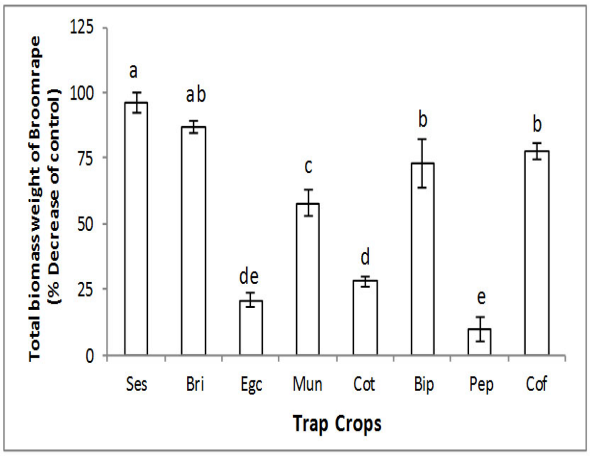

Fig 2. *Phelipanche aegyptiaca* total biomass weight per tomato plant (per pot) grown in potting media after trap crops treatments in pot experiments (% Decrease of control). Bars with the same letter do not differ significantly (Duncan test, P<0.05). Error bars represent standard error of the mean. (Ses=sesame, Egc=Egyptian clover, Mu=mungbean, Bri= Brown Indianhemp, Cot=cotton, Blp=Black-eyed pea, Pep=pepper, Cof=Common Flax)

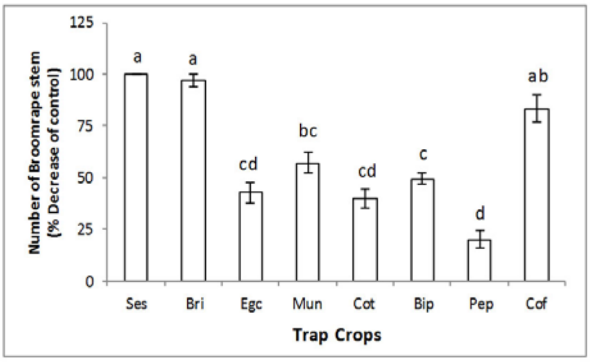

Fig 3. *Phelipanche aegyptiaca* stem number per tomato plant (per pot) grown in potting media after trap crops treatments in pot experiments (% Decrease of control). Bars with the same letter do not differ significantly (Duncan test, P<0.05). Error bars represent standard error of the mean. (Ses= sesame, Egc=Egyptian clover, Mu=mungbean, Bri=Brown Indianhemp, Cot=cotton, Blp=Black-eyed pea, Pep=pepper, Cof=Common Flax)

Number of broomrape stem

Sesame, brown Indianhemp, common flax resulted in high control of broomrape stem so that the number of stems decreased by 100, 96 and 83%, respectively, compared to control one (check) and all of them were categorize in a same statistical group. Mungbean, black-eyed pea, cotton, and Egyptian clover had relatively significant effect on reducing stem number compared to the other trap crops. Pepper had the lowest effect on decreasing number of broomrape stems in which it declined this trait only 20 % (Fig. 3).

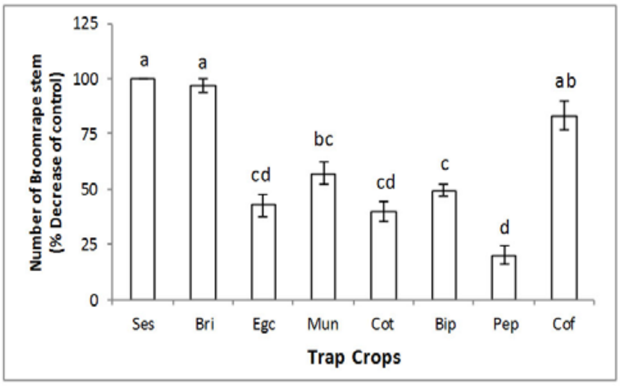

Fig 4. *Phelipanche aegyptiaca* tubercle number per tomato plant (per pot) grown in potting media after trap crops treatments in pot experiments (% Decrease of control). Bars with the same letter do not differ significantly (Duncan test, P<0.05). Error bars represent standard error of the mean. (Ses=sesame, Egc=Egyptian clover, Mu=mungbean, Bri= Brown Indianhemp, Cot=cotton, Blp=Black-eyed pea, Pep=pepper, Cof=Common Flax)

Number of broomrape tubercles

Maximum decrease in number of tubercle was observed in to sesame, which was resulted to approximately 98 %. Effect of black-eyed pea and brown Indianhemp were similar which reduced number of tubercles by 91.1 and 87.7%, respectively. Cotton and Egyptian clover were found the least efficient treatments in reducing the number of tubercle among all treatments. Mungbean and pepper had moderate effect on broomrape tubercle and reduced this trait by 50 percent and were classified in the same group after common flax and were not statistically different from each other (Fig. 4).

Effect of trap crops on the yield of Tomato

Total biomass weight of Tomato

The highest total biomass weight was caused by sesame (71.4%) compared with the control, brown Indianhemp, Egyptian clover and mungbean increased total biomass by 67.5, 65.5, and 62.5%, respectively. It was observed that these crops effects on biomass were not statistically different. This may be due to control of broomrape. Effect of cotton, black-eyed pea and pepper were positive and they increased

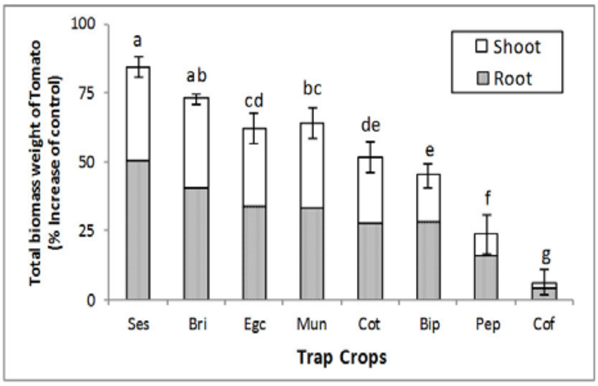

Fig 5. Tomato total biomass (per pot) of plant grown in potting media after trap crops treatments in pot experiments (% Increase of control). Bars with the same letter do not differ significantly (Duncan test, P<0.05). Error bars represent standard error of the mean for total biomass. (Ses=sesame, Egc=Egyptian clover, Mu=mungbean, Bri= Brown Indianhemp, Cot=cotton, Blp=Black-eyed pea, Pep=pepper, Cof=Common Flax)

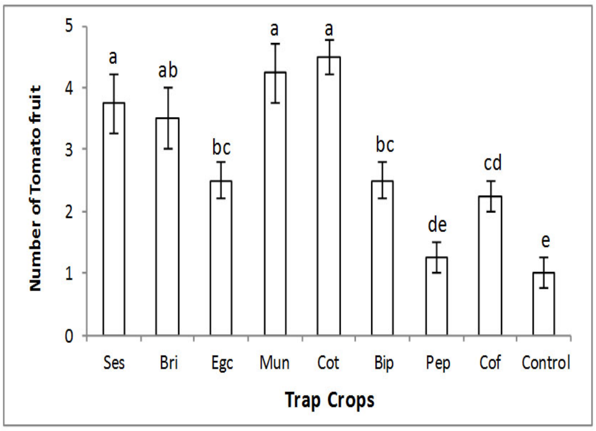

Fig 6. Tomato fruit number (per pot) of plant grown in potting media after trap crops treatments in pot experiments. Bars with the same letter do not differ significantly (Duncan test, P<0.05). Error bars represent standard error of the mean. (Ses=sesame, Egc=Egyptian clover, Mu=mungbean, Bri= Brown Indianhemp, Cot=cotton, Blp=Black-eyed pea, Pep=pepper, Cof=Common Flax)

total biomass by 49.4, 37.9, and 18.2 % respectively. The lowest total biomass of tomato was found in common flax and control pot treatments (Fig. 5).

Number of tomato fruits

The best effect of trap crops on number of tomato fruits was seen in cotton, mungbean, sesame, and brown Indianhemp and they were not statistically different. Egyptian clover, black-eyed pea, and common flax had the medium effect on increasing the number of tomato fruit. Pepper could not incr-ease fruit number compared with control treatment (check). Trap crops effects on tomato traits were indirect, and the reason was reducing broomrape by the most effective crops mentioned above directly (Fig. 6).

Tomato yield

Fruit yield of tomato in brown Indianhemp and sesame was the highest (Average of 18-fold the control). Reduction of

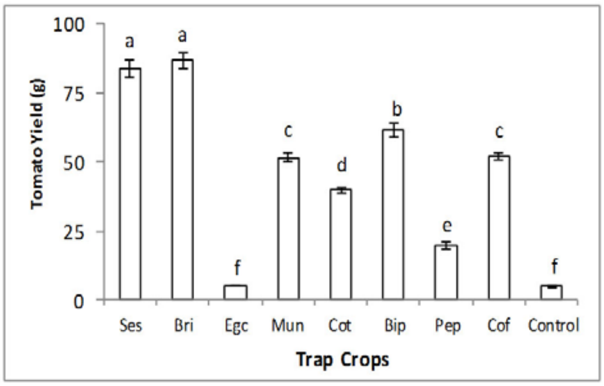

Fig 7. Tomato Yield (per pot) of plant grown in potting media after trap crops treatments in pot experiments gram per pot). Bars with the same letter do not differ significantly (Duncan test, P<0.05). Error bars represent standard error of the mean. (Ses=sesame, Egc=Egyptian clover, Mu=mungbean, Bri=Brown Indianhemp, Cot=cotton, Blp=Black-eyed pea, Pep=pepper, Cof=Common Flax)

broomrape damage which was reflected in tomato yield was good in Black-eyed pea, common flax, and mungbean, each 12.9-, 10.9-, 10.8- fold than control respectively. Egyptian clover was a weak trap crop in increasing tomato yield and had observed no difference with control (Fig. 7).

Discussion

Some old studies done to investigate the control of *Orobanche* in infested soils by trap crops, proposed that root exudates of the trap crop heighten germination. These experiments were on the basis of applying such exudates on *Orobanche* seeds in Petri dishes (Hameed *et al*., 1973; and Krishnamurty and Chandwani, 1975). This is in agreement with the results of this research which revealed that crops like sesame and brown Indianhemp may stimulate broomrape germination by exudation (exudating) stimulant compound while the attachment between parasite and crops either doesn't occur or dose not develop which itself results in reduction the population of broomrape. Under this condition tomato complete its growth state successfully without or less infection by parasitic plant (Eplee, 1984). These results are consistent with the reports of Kliefeld *et al*., (1994). Dale and Press, (1998) reported that most host root puffiness near to broomrape attachment were not developed and enlargement at the point of infection was considerably less. Broomrape could attack plants that their root exudates contain enzymes such as peroxidases (Antonova and Ter Borg, 1996) and pectin methyl esterases (Losner-Goshen et al., 1998). These substances may make host root cell frailer and more vulnerable. Due to lack or little production of these enzymes by trap crops, vessel connection may have been corrupted. Perez *et al*. (2005) showed that faba bean, pea, chickpea, lentil, and vetch from resistant legume genotypes caused necrosis of the infected tissues and of broomrape tubercles. The other involving factors could be allelopathic effects of trap crops on broomrape (Chittapur et al., 2001) which needs further invetegations. The number of parasitasion of host plant by the more broomrape would be the more yield loss occure (Hibberd *et al.* 1998). The results of our research are consistent with finding of NamvarReezaei *et al*. (2007), in which they reported sesame, alfalfa (*Medicago sativa*), and Black-eyed pea caused 98, 96, and 85.5 % reduction in broomrape density. In addition, pepper could not reduce

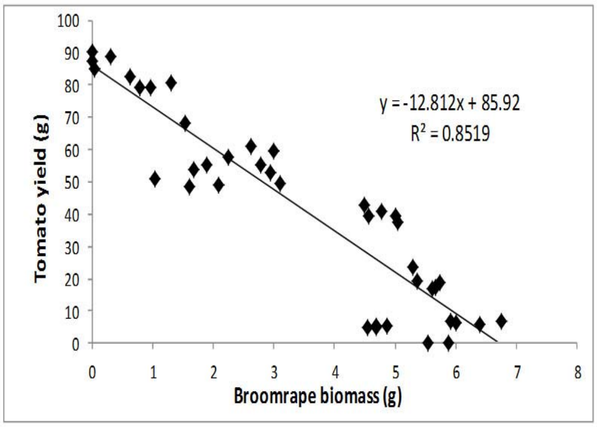

Fig 8. Tomato yield as influenced by broomrape biomass

broomrape damage. In another research, Mazaheri *et al*. (1989) reported that white mustard (*Sinapis alba*), common flax, and sorghum (*Sorghum vulgare*) could reduce broomrape density by 57.4, 41.9, and 8.6% and consequently increased crop yield by 19.4, 13.7, and 8.6%, respectively. As a whole, crop rotation or intercropping with sesame and brown Indianhemp could deplete infected soil from broomrape seeds. Our results highlight the presence of plant defense mechanisms in the sesame and brown Indianhemp and their absence in tomato. Therefore, sesame and brown Indianhemp could be used as an effective trap crop to decrease broomrape; this fact was shown in our pot experiments as well as Bischof and Koch (1974) trap crop on Egyptian broomrape.

Conclusion

Generally, trap crops sesame and brown Indianhemp were the best treatments in reducing broomrape damage. Among other trap crops, Black-eyed pea and mungbean showed good results and significantly increased tomato yield more than control. The effective trap crops are those that have so wide and deep root that release plenty volumes of germination motivator. When trap crops are used as fodder or green manure, they are efficient. In some cases intercropping could have the same effects as trap crops but be more effective than monocultures (Bouhatous and Jacquard, 1994). Based on our observation we suggest that sesame and the other effective crops on broomrape control should be planted season prior to transplant tomato in field or as a mixture with tomato, because sesame like tomato is a summer crop and should be planted in June in which weather conditions is favorable.

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