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Using the possibilities of some trap, catch and Brassicaceaen crops for controlling crenate broomrape a problem in lentil fields

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Abstract

Broomrapes are obligate root parasitic weeds and major constraint to many dicotyledon crops especially in Mediterranean agricultural lands. Due to the fact that no single control measure is able to control broomrapes in the field satisfactorily, integrated management is recommended in general. The use of of trap crops or catch crops is an important strategy for controlling the weeds; and allelopathic plants are also utilized for the control. Trap crops, also called false hosts, are plants which stimulate the germination of the parasite seed but cannot be infested and thus reduce the seed population in the soil. On the other hand, catch crops stimulate the germination of the parasite seeds at a high frequency and allow the development of the parasite. Seed bank of the broomrapes are decreased by destroying the catch crops before the seed creating period of broomrape begins (Sauerborn, 1991). Field trials were conducted using flax (*Linum usitatissimum* L.) as a trap plant; lentil (*Lens culinaris* L.) as a catch plant; members of the Brassicaceae species, such as cabbage (*Brassica oleracea* L.), Brussels sprouts (*Brassica oleracea* var. *gemmifera* (DC.) Thell.), broccoli (*Brassica oleracea* L. var. *italica* Plenck), cauliflower (*Brassica oleracea* var. *botrytis* L.), canola (*Brassica napus* L.) and turnip (*Brassica rapa* var. *rapa* L.) as allelopathic plant in the Adana province (Turkey) in 2007-2009. Flax was the most effective treatment by decreasing 52% and 71% in shoot number and 55% and 26% in dry weight of *O. crenata* in the first and second year, respectively. Broccoli of the *Brassicaceae* family, was found to reduce the number of *O. crenata* shoots by 48% and 39% in two years. Regarding the effect of *Brassicaceae* family on *O. crenata*, broccoli was found to reduce the number of *O. crenata* shoots by 39%. It is concluded that growing flax as a trap plant or lentil as a catch crop two months before the sowing of lentil as a crop is can be a main element of integrated broomrape managament, which cause to reduce the soil seed bank of crenata broomrape.

Keywords: Allelopathy; Catch crop; *Orobanche crenata*; Lentil; Trap crop.

Introduction

Turkey ranks third in global lentil production following India and Canada (FAO, 2014). In Turkey, red lentil is grown on an area of 214.788 hektares with 410.000 tons a year production (TUIK, 2014).

The most important plant protection problems in lentil cultivation are the following: lentil seed beetles [(*Bruchus ervi* Fröhl., *Bruchus lentis* Fröhl.)], lentil wilt disease (*Fusarium oxysporum* f. sp. *lentis* Vasudeva and Srinivasan), broomrapes (*Orobanche* spp.) and wild mustard (*Sinapis arvensis* L.) (Anonymous, 2011).

Lentil can be parasitized mainly by two different species of broomrapes, namely Crenate broomrape (*Orobanche crenata* Forsk.) and Egyptian broomrape (*Phelipanche aegyptiaca* (Pers.) Pomel). Due to the broomrapes infestation, lentil yield losses of up to 95% have been reported depending on the severity of the infestation and the planting date (Sauerborn, 1991; Rubiales et al., 2009a). The red lentil fields, which are located in the South East Anatolia Region in Turkey is heavily infested with *O. crenata* and *P. aegyptiaca* / *P. ramosa*, which are determined as mixed populations in 65% of the area. Over 10% of the fields are heavily infested and 25% highly infested. Imazapic and imazethapyr are used in 10.000 ha each. Crop losses up to 100% have been observed. But, 50% and 80% might be average crop loss for highly and heavily infested fields, respectively. Economic loss of about 60 million Euro is estimated annually (Uludag and Demirci, 2005). In the Middle East, the annual yield losses due to these parasitic weeds are estimated to be worth 1.3-2.6 billion dollars (Aly, 2007).

Orobanche and *Phelipanche* species are root holoparasitic plants, depending entirely on their hosts for all of their nutritional requirements and causing severe damage to economically important dicotyledonous plants (Hershenhorn et al., 2009). These are obligate root-parasitic weeds that spend most of their life cycle in the soil subsurface (Eizenberg et al., 2012). The seeds of broomrape remain dormant in the soil; they only germinate in response to germination stimulants released from the roots of host plants after waiting in the warm and moist environment (Anonymous, 2001). Most of the germination stimulants identified so far are strigolactones (Matusova et al., 2005; Yoneyama et al., 2010), which also function as host recognition signals for arbuscular mycorrhizal fungi and a novel class of plant hormones inhibiting shoot branching (Yoneyama et al., 2010). After the germination period, the main periods of development are attaching to the host roots and connecting with the host tissues and tubercle formation (Joel et al., 2007; Parker and Riches, 1993). Broomrape seeds can remain viable in the soil for more than 10 years (Linke et al., 1989).

Orobanche crenata has been known to threaten legume crops (e.g., faba bean, lentil, pea and common vetch) since antiquity. This parasitic weed is mainly restricted to the Mediterranean basin, southern Europe and the Middle East and is an important pest in grain and forage legumes (Rubiales et al., 2009b). Italy, Spain, Morocco and especially the Mediterranean region of Turkey are known as the native land of broomrape (Sauerborn, 1991). The current geographical distribution of *O. crenata* encompasses coastal areas of the Mediterranean Sea, as well as parts of the interiors of the Iberian, Italian and Anatolian peninsulae and northern Iraq and Iran (Grenz and Sauerborn, 2007). *Orobanche crenata* is displayed in "Invasive Species Compendium" as present in India, Iran, Iraq, Israel and Pakistan while widespread in Jordan, Lebanon, Syria and Turkey of Asian countries (CABI, 2015).

Thirty seven species of broomrape were recorded in Turkey (Gilli, 1982), but the number of broomrape species reached thirty nine when two new species belonging

to the genus *Orobanche* were added to the flora of Turkey (Zare and Dönmez, 2013) in 2013. Although there are many species of broomrape, very few of them [*Phelipanche aegyptiaca* (Pers.) Pomel., *P. ramosa* L., *Orobanche crenata* Forsk., *O. cernua* Loefl. / *O. cumana* Wallr.] cause economic damages. Among these harmful species, *O. crenata* is widespread in the red lentil fields located in the Southeast Anatolia region of Turkey (Kıtıkı et al., 1993; Uludag and Demir, 1997; Orel-Aksoy and Uygur, 2003).

Hand weeding, late sowing, deep tillage, sowing of resistant varieties, chemical control, solarization and biological control are among the recommended methods for controlling broomrapes.

However, except for fumigation and solarization, the other methods are not effective under field conditions alone (Linke et al., 1989; Parker and Riches, 1993). Current methods for controlling parasitic weeds focus on reducing the soil seed bank, preventing seed set and inhibiting seed movement from infested to non-infested areas (Fernandez-Aparicio et al., 2008; Rubiales et al., 2009a). The use of catch crops (Acharya et al., 2002) and trap crops (Sauerborn, 1991) have been suggested as tools to reduce broomrape in infested soil.

Using natural or synthetic allelopathic materials has been stated as a way to control broomrape (Sauerborn, 1991). Allelopathy is the phenomenon where natural compounds are released from the root, shoot, leave or flower of a plant to influence other plants (Rice, 1995); and it may be used to control some weeds. Plants from the *Brassicaceae* family are characterized by chemical compounds called glucosinolates. The decomposing tissues of these plants release glucosinolates which are then converted to isothiocyante compounds that are toxic to other plants (Bell and Muller, 1973; Haramoto and Gallandt, 2005; Bangarwa et al., 2011).

Particularly, the plants of *Brassica* genus are known to suppress weeds. For example, when mixed into the soil, the canola (*Brassica napus* L.) leaves suppressed common goosefoot (*Chenopodium album* L.), red pigweed (*Amaranthus retroflexus* L.) and barnyardgrass [*Echinochola crus-galli* (L.) P. B.] populations at a similar effectiveness to the standard herbicide application (Narwal, 1999). Crops belonging to the *Brassica* family are the most studied species for allelopathic potential to control weeds and among the *Brassica* species, garden radish (*Raphanus sativus*) has been most studied to control johnsongrass (*Sorghum halepense*) in Turkey (Uludag et al., 2006). Uygur et al. (1990) examined the effect of garden radish extracts on germination of 25 weed and 32 crop species. They found that garden radish extracts totally inhibit the germination of 11 weeds such as *Sorghum halepense*, *Alhagi* spp., *Alopecurus myosuroides*, *Capsella bursa-pastoris, Convolvulus arvensis, Cuscuta* spp., *Daucus carota, Hirschfeldia incana, Ochtodium aegyptiacum* and 4 crop species namely lettuce, tobacco, bean and clover (Uygur et al., 1990). Smilarly a study was carried out to determine the allelopathic potential of six *Brassica* species [White radish (*Raphanus sativus* L.), garden radish (*R. sativus* L.), black radish (*R. sativus* L. var. *niger*) little radish (*R. sativus* L. var. *radicula*), turnip (*Brassica campestris* L. ssp. *rapa*), rapeseed (*Brassica napus* L. ssp. *oleifera* DC.)] widely cultivated in Turkey on the germination and seedling growth of cutleaf ground-cherry (*Physalis angulata* L.) using shoot powder extracts and the research results imply that *Brassica* species have great potential for *P. angulata* control (Uremis et al., 2005). Cabbage (*Brassica oleracea* L.), from

Brassicaceae family reduced the number of broomrape (*Orobanche ramosa* L. / *O. aegyptiaca* Pers.) branches by 28% in potato fields in Turkey (Nemli et al., 2009). There are some studies conducted in Turkey on the effect of some plants from Brassicaceae family, but studies related to trap and catch crops are much less. In a study conducted under laboratory conditions in Turkey regarding the effect of the root exudates of flax and lentil on the germination of broomrape seeds, flax as a trap plant was found to highly improve the germination of broomrape (Arslan and Uygur, 2013). Flax as a trap plant was found to be effective tin capturing *O. crenata* for the first time with this study conducted a lentil field in Adana province.

Red lentil fields in Turkey are continuously facing the problem of *O. crenata* as are all legume fields in the world. Flax as a trap plant; lentil as a catch plant; and brussels sprout, cabbage, broccoli, cauliflower, canola and turnip as allelopathic plants were investigated under the field conditions in this study, to reduce *O. crenata* damage in lentil fields.

Materials and Methods

The field experiments were conducted in the research area of the Biological Control Research Station located in Adana. Turkey in 2007 (first trial) and in the research and application area of the Department of Plant Protection in the Faculty of Agriculture at the University of Cukurova in Adana, Turkey in 2008 (second trial). The experiments were organized as randomized complete design with four replications. The plot size was 6.6 m^2 and a distance of 1 and 1.5 meters was left between the plots and blocks, respectively. The experiments were conducted in fields which were already infested with broomrapes. The plants investigated for their effectiveness in controlling crenate broomrape were sown manually on October 10, 2007 and October 08, 2008 for both experiments. Some information on the plants is given in Table 1 below.

Table 1. Plants investigated for their effectiveness in controlling *O. crenata*.

Common name	Scientific name	Variety	Quantity of sown seed (g/m^2)
Cabbage	*Brassica oleracea* L.	Brunswick-May	3.0
Brussel sprouts	*Brassica oleracea* var. *gemmifera* (DC.) Thell.	Oliver-Syngenta	3.0
Cauliflower	*Brassica oleracea* var. *botrytis* L.	Igloo-Global Seeds	3.0
Broccoli	*Brassica oleracea* L. var. *italica* Plenck	Monopoly-Syngenta	3.0
Turnip	*Brassica rapa* var. *rapa* L.	Local-Bursa Tohum	3.0
Red lentil	*Lens culinaris* L.	Kırmızı, Local	20.0
Canola	*Brassica napus* L.	8310	3.2
Flax	*Linum usitatissimum* L.	Local	20.0

The emergence and development of the sown plants were observed periodically. Plants grown were mixed in the soil with the rototiller, 63 and 56 days after sowing in 2007 and 2008, respectively. The seeds of lentil were sown in the plots on the same day.

Kırmızı-Local, a variety of lentil was used in both of the experiments. The numbers of broomrape shoots were counted on May 03, 2008 and May 12, 2009 for the first and second trials. A wooden frame sized at 0.5 m^2 was placed randomly at four different sites in the middle rows of the plots; broomrape shoots in the frame were counted and then cut from soil surface as well as lentil plants were harvested from the soil surface. The dry weight (obtained keeping 24 h at 105 °C) of broomrape and lentil were evaluated (Uygur, 1985). The potential effect of investigated plants to shoot number and dry weight of crenata broomrape and lentil biomass were calculated using the Abbott formula (Rosenheim and Hoy, 1989). The data obtained from the experiment was analyzed statistically using JMP 5.0 provided by SAS Institute. LSD (Least significant difference) at 0.05 levels was used as a multiple range test to determine the statistical difference among the treatments.

Results and Discussions

Effect of the investigated plants on the shoot number and dry weight of broomrape also the dry weight of lentil is given in Tables 2-3.

The average number of broomrape shoots was 31.82/m^2 and 166/m^2 for the first and second trial, respectively in control plots.The field experiments were conducted in two different locations so the initial infestation density is very likely to have been different. Another reason for the lower density of broomrape in the first trial might be the drought in 2008. The average annual rainfall in Adana province is 645.6 mm, while only 300 mm was recorded in 2008; a similar drought was noted in the province in 1972. Unlike in 2008, nearly 800 mm of rainfall was received in Adana during 2009 (MGM, 2014). The main environmental factors (except the germination stimulants) affecting the broomrape germination include temperature and moisture (Pieterse and Verkleij, 1994). Furthermore, the spread of stimulant in the rhizosphere depends on soil water content (Linke et al., 1989).

Among the investigated plants, it was found that flax was the most effective application in reducing the broomrape shoots: by 52% and 71% in the first and second year, respectively. In the first year of the experiment, the reduction was noted to be 48% for broccoli and 44% for lentil as catch crop (Lentil CC). In the second year lentil was found to have the best effectiveness rate with 55% and broccoli with 29% following flax. Among the Brassicaceaen crops tested against the shoots of crenate broomrape, broccoli was the most effective plant (48%, 29%) in both experiments (Table 2).

Regarding to the dry weight of broomrape, flax plants were found to be the most effective (55%) in reducing the dry weight of broomrape in the first trial. Similarly, flax was the most effective treatment (26%) in the second trial; Lentil CC followed as the second most effective treatment (15%) (Table 2).

Among the investigated trap and catch crops, it was found that flax was the most effective application in increasing the dry weight of cultivated lentil by 55% and 26% in the first and second year, respectively (Table 3).

Table 2. The effect of some plants on the shoot number and dry weight of *O. crenata.*

	First year (2007-2008)		Second year (2008-2009)		First year (2007-2008)		Second year (2008-2009)	
	Shoot number m^{-2}	Effect (%)	Shoot number m^{-2}	Effect (%)	Dry weight (g m^{-2})	Effect (%)	Dry weight (g m^{-2})	Effect (%)
Brussels sprouts	21.50^{abc}	31	260.75^{a}	*	9.04^{ab}	18	87.63^{ab}	*
Broccoli	16.25^{bc}	48	118.00^{cd}	29	6.74^{ab}	39	90.17^{a}	*
Cauliflower	20.75^{abc}	34	172.50^{bc}	*	7.75^{ab}	29	92.88^{a}	*
Canola	27.75^{ab}	12	220.38^{ab}	*	10.56^{a}	4	100.07^{a}	*
Cabbage	24.75^{abc}	21	243.75^{a}	*	11.69^{a}	*	86.63^{ab}	*
Turnip	22.63^{abc}	28	163.25^{bc}	2	7.27^{ab}	34	97.48^{a}	*
Flax	15.00^{c}	52	47.50^{e}	71	4.92^{b}	55	61.87^{c}	26
Lentil as catch crop	17.50^{bc}	44	74.88d^{e}	55	11.07^{a}	*	70.87^{bc}	15
Control	31.38^{a}		166.00^{bc}		10.98^{a}		83.66^{ab}	

* Negative effects were not given.

Table 3. The effect of some plants on lentil biomass.

	First year (2007-2008)		Second year (2008-2009)	
	Dry weight (g)	Effect (%)	Dry weight (g)	Effect (%)
Brussels sprout	543.3^{ab}	19	380.2^{ef}	*
Broccoli	455.8^{b}	*	515.2^{cd}	*
Cauliflower	508.6^{ab}	11	385.0^{ef}	*
Canola	534.5^{ab}	17	357.1^{f}	*
Cabbage	455.1^{b}	*	458.0^{de}	*
Turnip	577.0^{a}	26	359.8^{f}	*
Flax	591.3^{a}	29	789.8^{a}	43
Lentil as catch crop	470.1^{b}	3	641.1^{b}	16
Control	458.4^{b}		551.9^{c}	

* Negative effects were not given.

Results of the first and second year indicated that the flax reduced the shoot number of *O. crenata* by 52% and 71%; the dry weight of the species by 55% and 26% and increased the dry weight of lentil by 29% and 43%, respectively.

In addition, used as a catch plant, lentil, sowned two months before the cultivated lentils' sowing date, reduced the number of broomrape shoots by 50%. Kleifeld et al. (1994) investigated the effect of flax (*Linum usitatissimum* L.) and some plants as trap and catch crops for the control of Egyptian broomrape (*Phelipanche aegyptiaca* Pers.). The results indicated that growing flax in two successive winter seasons or one summer cropping with mung beans (*Phaseolus aureus* Roxbg.) reduced early infestation of *P. aegyptiaca.* In other research, twenty different crops were tested in vitro to determine

their effects on the germination and development of broomrape seeds. According to the findings of the study, the researchers have reported that in fields infested with *O. crenata*, crops such as bean, flax, alfalfa, wheat and oat used in the crop rotation may reduce the soil seed bank of this broomrape (Abbes and Kharrat, 2008). Similarly, another study was carried out by Vazan et al. (2007). The results indicated that flax and lentil were effective in reducing the broomrape germination; and flax was a strong trap crop whilst lentil was a weak one (Vazan et al., 2007). In another pot experiment regarding trap plants, the sowing of flax before tomatoes was found to reduce the broomrape [*Phelipanche aegyptiaca* (Pers) Pomel.] biomass by 75% and also to increase the tomato yield (Babaei et al., 2010). The results of the forementioned studies support our work conducted in Adana where the flax was grown as a trap plant or red lentil plants were grown as a catch crop before the sowing of crop which reduced the population of *O. crenata*. The work on sowing flax as a trap crop, which can be used to control the infestation of broomrape, has been reported from some other countries (Al-Menoufy, 1991; Sauerborn, 1991; Kleifeld et al., 1994; Siami et al., 2007; Matiwade et al., 2010; Babaei et al., 2010; Ghotbi et al., 2012). However, no field research has been reported from Turkey in this regard. Despite the report of some studies on the effects of flax on *P. ramosa* (Hameed et al., 1973; Sauerborn, 1991; Abebe et al., 2005), *P. aegyptiaca* (Kleifeld et al., 1994; Babaei et al., 2010; Ghotbi et al., 2012), *O. cernua* (Krishnamurty et al., 1977; Sauerborn, 1991; Abebe et al., 2005) and *O. crenata* (Al-Menoufy, 1991; Sauerborn, 1991) as a trap plant, Kleifeld et al. (1994) indicated that flax may be parasitized by some virulent species of *P. aegyptiaca.*

Considering studies conducted so far on both trap crop and catch crop together, studies on trap crops are more common than catch crops. As a result of a study conducted in Nepal regarding catch plants, *Brassica campestris* var. *toria* which is sold as a green vegetable in the local market was found to be the best host for *P. aegyptiaca*. Field experiments were conducted for two consecutive years in order to determine the effect of *B. campestris* var. *toria* for reducing the soil seed bank reserves of *P. aegyptiaca.* In this study, during the production season of 1997-98, *B. campestris* var. *toria* was found to reduce the seed bank of *P. aegyptiaca* by 33.35% and by 27.95% in 1998-1999 as a catch crop (Acharya et al., 2002). Schnell et al. (1994) investigated the effect of 14 different plants including lentil, for reducing the seed bank of *O. crenata* in pea fields. As a result, it was reported that legume crops generally resulted in greatest reductions in *O. crenata* seed banks. As long as the seed bank is not controlled, the need to control the parasite will persist whenever a susceptible host is grown in an infested field (Eplee and Norris, 1995; Fernandez-Aparicio et al., 2007; Rubiales et al., 2009c). In this study, red lentil reduced the number of shoots of *O. crenata* by 44% in 2008 and 55% in 2009 as a catch crop. Considering that a shoot of *O. crenata* has an average of 50 capsules and that each capsule has over 4.000 seeds, a plant can produce more than 200.000 seeds (Parker and Riches, 1993). Red lentil as a catch crop, which causes about a 50% decrease in the number of shoots of *O. crenata,* is very important for controlling this species.

A study was conducted in potato fields in the Aegean region of Turkey aim to determine the effect of *Brassicaceae* crops against broomrape (*P. ramosa* / *O. aegyptiaca*) and the use of the waste of cabbage plants. In conclusion, the decreasing effect of the cabbage on the number of broomrapes branches was reported as reaching 28% (Nemli et al., 2009). As the result of our study, carried out in the Mediterannean region of Turkey, while cabbage caused a decrease in the number of shoots of *O. crenata* at a rate of 21% in the first trial, it caused an increase of the number of shoots in the second trial. Another study was conducted about garden radish effect on johnsongrass (*Sorghum halepense*) in

Turkey. The results showed that garden radish (*Raphanus sativus*) could be used either as a cover crop or a rotational crop and also that other allelopathic *Brassiceae* crops are important as a substitute of garden radish to control johnsongrass (Uludag et al., 2005). The effect of radish from *Brassicacea* family on broomrape was investigated in pot experiments conducted in Turkey. According to the results, 1% and 5% doses of radish leaves decreased broomrape shoots 57% and 84%, respectively (Öztürk and Demirkan, 2010). In our field study, turnip decreased the number of crenate broomrape shoots by an average rating of 15% over the period of two years.

Currently, there is not an economical and effective method that can be used alone for controlling broomrapes. Therefore, integrated control systems, containing a combination of appropriate methods changing at the different ecological and socioeconomic conditions, should be implemented (Sauerborn, 1991; Parker and Riches, 1993; Eple and Norris, 1995; Linke et al., 1989; Hershenhorn et al., 2009; Restuccia et al., 2009).

As a result, sowing flax as a trap plant before sowing lentil caused a significant reduction of both the number of shoots and the dry weight of *O. crenata*. So flax can be used as a trap plant for crenata broomrape. The other important finding of this study is that sowing lentils as a catch crop two months before the standard lentil sowing date caused approximately 50% decrease in the number of *O. crenata* shoots. On the other hand, broccoli, from the Brassicaceae family and known to have allelopathic effects, decreased the number of *O. crenata* shoots but further investigation on this issue is needed. Some other plants such as brussels sprout, cauliflower and turnip had some effect generally one of years and they did not give acceptable results for both years. We suppose that their effect could be acceptable if it searched many times.

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