OROBANCHE (OROBANCHE SPP.) IN LENTIL (LENS CULINARIS MEDIC.): HOW HUGE ARE THE LOSSES OF YIELD, QUALITY, MARKETING PRICES AND PROFITABILITY?

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Abstract: This research aimed to inspect the impacts of severe parasitic plants (Orobache spp.) on grain yield, some quality characteristics, marketing price and profitability loss of red lentil in the major lentil growing area of south-east Anatolia. Farmer field trials were carried out in two neighbouring fields planted with Yerli Kırmızı (landrace) and Firat-87 varieties of lentil employing a split-plot experimental design in the Yollar bası location of Viransehir in the 2018–2019 crop growing season. Lentil varieties were placed into main plots and the broomrape infestations (i.e. 0, 5, 10, and 15 plants m−2) in the subplots respectively. Grain yield, hectolitre weights and 1000-kernel weights and protein contents (%) were scored. All grain samples were presented to randomly chosen grain purchasers in the local commodity market and marketing price offers were scored respectively. Results showed that broomrape infestation from zero to 15 broomrapes m−2 reduced the grain yield significantly from 2033.33 kg ha−1 to 833.33 kg ha−1 by 59%. Although being non-significant, Firat-87 (1512.5 kg ha−1) was found to be higher yielding than Yerli Kırmızı (1325 kg ha−1). Regression equations between grain yield reductions vs. broomrape infestation ratios turned out to be significant and reliable with high coefficients of determinations for both varieties. Some visual purchasing criteria such as hectolitre and 1000-kernel weights were not affected seriously. Purchasers offered very similar marketing prices for pulse grains with all severity levels. The economic loss was huge ($555 ha−1). Regression equations derived from grain yield vs. infestation densities were found to be reliable with high coefficients of determinations and can be perfectly used for yield estimates under various levels of broomrape infestations. It was

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concluded that an infestation over 15% might result in a disastrous yield loss in lentil production. Therefore, some agronomic measures must be taken quickly.

**Key words:** red lentil, *Orobanche*, grain yield, quality, marketing prices, profitability.

**Introduction**

Lentil (*Lens culinaris* Med.) is an important food legume crop used both as food and feed due to its protein-rich grain and straw. Worldwide, lentil is cultivated on 3.85 million hectares (m ha) with 3.59 million tons (mt) production under rain fed conditions (Erskine et al., 2011).

Lentil is also a nutritious food legume. The seed has a relatively high content of protein (22%), carbohydrates and calories (3250 kcal kg$^{-1}$) including fast cooking characteristics (Muehlbauer, 1985; Saskatchewan Agriculture and Food, 2005). Lentil (*Lens culinaris* Med.) is a cool-season annual cash crop, classified as a grain legume or pulse in south-east Anatolia (Ozberk et al., 2006).

Turkey is one of the major lentil producer ranking third globally after Canada and India with 410000 tons of annual production on 214,788 ha (TUİK, 2014). Green lentil is grown in the central and transitional zones of Turkey while red lentil is grown in the south-east of Anatolia (Ozberk et al., 2006).

By far, the most economically damaging root parasitic weeds in Europe and neighboring regions are members of the *Orobanchaceae*, mainly species belonging to the genera *Orobanche* and *Phelipanche* (broomrapes) (Joel et al., 2007a; Parker, 2009). In Turkey, 36 species of Orobanche have been recorded (Gilli, 1987). However, only four of them have resulted in considerable damage to crops. *Phelipanche ramosa* (L) Pomel (syn. *O. ramosa* L.), *Phelipanche aegyptiaca* (Pers) Pomel (syn. *O. aegyptiaca* Pers.) (Joel et al., 2007; Parker, 2009) and *O. crenata* Forsk also result in damage in lentil (Kitik et al., 1993; Uludag and Demir, 1997; Aksoy and Uygur, 2003; Bulbul and Uygur, 2009). In a survey carried out in neighbouring Diyarbakır province, it was found that the most abundant broomrape species infesting lentil plants were: *Orobanche crenata* Forsk., and *Phelipanche aegyptiaca* (Pers.) Pomel (syn. *Orobanche aegyptiaca* Pers.). The frequency of the occurrence of broomrape species ranged between 12% and 41% (Ozaslan et al., 2017). In legumes, the most intensive growth of *Orobanche* usually coincides with the flower and pot stages of the host. Broomrapes spend most of their life cycle underground, where they undergo processes of germination, haustorial differentiation from the radicle, haustorial penetration of the host formation of vascular connection with the host, utilization of host nutrients and the storage of resources in a parasite organ called the tubercle or nodule (Fernandez-Aparicio et al., 2011). This results in flower dropping and low amount of pod formation due to an increase in competition receiving more plant nutrients. The wilting symptoms
Orobanche in lentil: how huge losses of yield, quality, marketing prices and profitability?

Yield losses due to *Orobanche* ranged from 5 to 100% (Aksoy et al., 2016; Erskine et al., 2011; Bulbul et al., 2009; Australian Department of Agriculture and Food, 1999; Anonymous, 1997). An economical loss of lentil of about 60 million euros is estimated annually (Uludağ and Demirci, 2005; Bulbul et al., 2009). Only in the Middle East, it could reach about 1.3 and 2.6 billion dollars (Aly, 2007).

Materials and Methods

This study was carried out in the farmer fields in Viranşehir location in S. Urfa in the 2018–2019 growing season, wherein broomrape infestations are common. *O. crenata* Forsk. (white flowering), *P. ramosa* (pale blue flowering and branched) and *P. aegyptica* Pers. (blue flowering) were found to be wide-spread in lentil fields (75.51%) in the Eastern Mediterranean region and Southeastern Anatolia (Bulbul et al., 2009; Temel et al., 2012). *O. aegyptica* Pers. was prevalent in the Viranşehir region (Uludağ and Demir, 1997; Bayaa et al., 1998).
A preceding crop was wheat in Viranşehir. Disharrow + float + drill planting + roller combination was employed for planting management. Two farmer fields with 10 ha each in Viranşehir were planted by a drill with a 120 kg ha$^{-1}$ seed rate in both fields on the 30th of October in 2018. A 50 kg ha$^{-1}$ di ammonium phosphate rate (DAP, 18 and 46% of N and P) was applied at sowing. Annual rainfall was quite satisfactory with 712.6 mm and its distribution throughout the cropping season was also well-balanced. All other necessary agronomical measures were taken for healthy crop production. Chemical weed control for narrow-leaf weeds was employed. However, pest control was not applied. A field trial was carried out under moderate volunteering broomrape infestation. Field plots were assigned at the flowering stage of broomrape and the early pod stage of lentil. One m$^2$ plots with 0, 5, 10 and 15 broomrape plants surrounded by the strip at the corners built up a block. Three blocks for each cultivar were assigned as shown above (Picture 1).

![Picture 1. Orobanche plants at flowering and plots surrounded by strips.](image)

A split-plot experimental design was employed. Lentil varieties were placed into main plots and the broomrape infestations (i.e. 0, 5, 10, and 15 plants m$^{-2}$) in the subplots respectively (Table 1).

Subplots were randomly selected taking into account the number of flowering broomrape plants placed in the one m$^2$ acreage. Numbers of broomrape flowers were counted in each plot at the flowering and pod filling stages of lentil and the assignment of plots was performed. Plots were harvested by hand and threshed by a single plant thresher for weighting grain yield on the 30th of May in 2019. The highest yield loss for both cultivars was calculated as:

$$\text{HYL}\% = [1 - \frac{\text{mean grain yield of plots with 15 broomrapes}}{\text{mean grain yield of zero broomrapes}}] \times 100.$$
Table 1. The field randomization plan of the study.

| 1st field | 2nd field |
|-----------|-----------|
| Yerli Kırmızı* | Firat-87* |
| 0** | 5 | 10 | 15** | 10 | 5 |
| 5** | 10 | 0 | 10** | 5 | 15 |
| 10** | 15 | 5 | 5** | 0 | 10 |
| 15** | 0 | 15 | 0** | 15 | 0 |

*main plot, **subplot.

Hectolitre and 1000-kernel weights and protein (%) content of lentil grains were also scored through the methods given by Williams et al. (1986). Seed samples of the experiment with an increasing amount of broomrape damage were presented to randomly chosen 3 grain purchasers in the local commodity market in mid-June in 2019. ANOVA and mean separation were performed for marketing price estimates employing a split-split-plot experimental design with 3 replications. Purchasers, varieties and infestation ratios were placed into main plots, subplots and sub-subplots respectively. Coefficients of correlation among such characteristics were estimated. Regression relations between grain yield, hectolitre weight and 1000-kernel weights vs. broomrape infestations were further investigated (Finlay and Wilkinson, 1963; Eberhard and Russel, 1966). The economic loss (US$ ha⁻¹) was calculated as:

\[ EL = HYL(\%) \times \text{mean grain yield of non-damaged grains} \times \text{mean marketing price of non-damaged grains}. \]

The JMP statistical software was employed for statistical analysis and figures.

**Results and Discussion**

*O. aegyptica* Pers. (blue flowering) and *O. ramosa* (pale blue flowering and branched) were dominating species with a little amount of *O. crenata* Forsk (white flowering) in Viranşehir in 2018–2019. The sowing time was earlier than that of a common practice. The adopted practice is to plant lentil in late October or early December. The grain yields of lentil crop under various broomrape infestations are given in Table 2.

The analysis of variance (not given here) for grain yield indicated that there were significant differences between broomrape infestation ratios \(F=232.27^{**}\) and infestation ratios x varieties interaction \(F=5.30^{*}\), but no difference was found between cultivars \(F=17.30, p>0.0532\). Table 3 shows the mean differences of significant variables through LSD.

Although being non-significant, Firat-87 seemed to be higher yielding than Yerli Kırmızı. Increasing infestation ratios reduced grain yield significantly. Plots
free from broomrape gave the high yield (2033.33 kg ha\(^{-1}\)), whereas the plots with 15 broomrape plants reduced grain yield to 833.33 kg ha\(^{-1}\) dramatically.

Table 2. Grain yields of cultivars under various broomrape infestations.

| Replication | Yerli Kırmızı Yield (kg ha\(^{-1}\)) | Firat-87 Yield (kg ha\(^{-1}\)) |
|-------------|-------------------------------------|---------------------------------|
|             | 2000                               | 2250                            |
| 1           | 1500                               | 1650                            |
| 1           | 1200                               | 1500                            |
| 1           | 950                                | 750                             |
| 2           | 1950                               | 2350                            |
| 2           | 1450                               | 1800                            |
| 2           | 1350                               | 1600                            |
| 2           | 850                                | 950                             |
| 3           | 1700                               | 1950                            |
| 3           | 1300                               | 1450                            |
| 3           | 900                                | 1150                            |
| 3           | 750                                | 750                             |

Table 3. LSD groups for significant variables for grain yield of lentil.

| Varieties/ratios | 0  | 5  | 10 | 15  | Average/groups (kg ha) |
|------------------|----|----|----|-----|-------------------------|
| Firat-87         | b1a| 1633.33c | 1416.66d | 816.66f | 1512.00a |
| Yerli kırmızı    | 1883.33b| 1416.66d | 1150.00e | 850.00f | 1325.00a |
| Average/groups (kg/ha) | 2033.33a | 1525.00b | 1283.33c | 833.33d |

HYL\% = \[1 - (833.33 / 2033.33)\] \times 100 = 59\%. Grain yield loss seems to be dramatic due to the increasing amount of broomrape infestation.

ANOVA for 1000-kernel weights (not given here) indicated the absence of any significant source of variation. Although being non-significant, there was a slight difference between varietal means in favour of Firat-87. Although being non-significant, there were some differences among the means of 1000 KW depending upon infestation ratios in favour of less infestation. ANOVA for hectolitre weights showed that there was not any significant source of variation. Although being non-significant, the mean of Firat-87 seemed to be slightly higher than that of Yerli Kırmızı. Although being non-significant, increasing infestation ratios reduced the hectolitre weights slightly. The negative influence of broomrape infestation on lentil quality was discussed by the Australian Department of Agriculture and Food (1999). However, broomrape infestation in our study did not affect any quality characteristics.

Regressions between grain yield vs. broomrape infestation turned out to be significant (F=76, 45**) for Firat-87 and Yerli Kırmızı (F=74, 78**) indicating the presence of the effects of broomrape infestation on grain yield. Regression
equations were estimated as \( y=1830^{**} -67.33^{**}x \) with \( R^2\% = 87.02 \) for Yerli Kırmızı and \( y=2160^{**} -86.33^{**}x \) with \( R^2\% = 87.27 \) for Firat-87. A high coefficient of determination indicated the reliability of equations. Yield reductions due to increasing broomrape infestations are given in Figures 1 and 2.

![Figure 1. The regression line and equation for Yerli Kırmızı.](image1)

![Figure 2. The regression line and equation of Firat-87.](image2)

Analysis of variance (not given here) for marketing prices indicated the absence of any significant sources of variation. Replications (\( F=0.12^{em} \), purchasers (\( F=4.48^{em}, p>0.09 \), varieties (\( F=5.30^{em}, p>0.06 \)) and infestation ratios (\( F=0.11^{em} \)) turned out to be non-significant. Although being non-significant, purchasers seemed to be offering marketing prices subjectively employing visual characteristics. Moreover, Firat-87 tended to receive a higher marketing price offer (0.468 US$kg\(^{-1}\)) than Yerli Kırmızı (0.460 US$kg\(^{-1}\)). Increasing broomrape infestations did not affect marketing prices negatively.

The economical loss (EL) for the experiment was approximately \( 0.59 \times 2.033 \text{ ton ha}^{-1} \times \text{US$ 462.06 ton}^{-1} = \text{US$ 554.22 ha}^{-1} \)

Relatively early planting of lentil suffered from broomrape severely (Temel et al., 2012). Volunteering broomrape plants developed very fast and attacked young lentil seedlings. When lentil is planted late into humid soil, plants can escape from severe broomrape attacks and late planting of early maturing type of lentil was recommended by Temel et al. (2012). There were some statistically significant differences among the varieties showing a response to broomrape infestation. Firat-87 was found to be high-yielding. Yerli Kırmızı (Landrace) was the yield-limiting variety among entries. Late planting of Altın Toprak-98 was recommended for the
farmers in the region because of its high-yielding performance and early maturing ability (Temel et al., 2012). Broomrape infestation can reduce grain yield severely as pointed out (Anonymous, 1997). Fifteen broomrapes m\(^{-2}\) reduced grain yield by 59\% compared to non-damaged plots. Grain yield reduction was 51.5\% in a study carried out in the same region by Ozberk et al. (2016). Regression between grain yield vs. broomrape infestations for both varieties turned out to be significant giving $F=74.78^{**}$ and $76.45^{**}$ respectively. Regression equations with high coefficients of determinations can be used for yield estimates under various broomrape infestations. Both 1000-kernel weights and hectolitre weights seemed to be slightly decreasing depending on the increasing broomrape infestations as indicated (Ozberk et al., 2016) earlier.

Analysis of variance for marketing price offers indicated that broomrape infestation and replications (purchasers) were found to be non-significant. The presence of broomrapes until 15 per m\(^{2}\) did not affect negatively on some quality traits and marketing prices. Another study carried out in the same region indicated the absence of any marketing price differences among the grains suffering from the various amounts of broomrape infestation (Ozberk et al., 2016).

Broomrape infestation did not affect any visual quality characteristics such as 1000-kernel weights and hectolitre weight as obtained by Ozberk et al. (2016). Comparing the grain yields of the highest broomrape infested plots versus those of non-damaged plots, the losses showed the importance of broomrape management in the red lentil growing belt of the country. The economic loss was about US$555 ha\(^{-1}\). Confirming our findings, this was also huge (US$ 396.77 ha\(^{-1}\)) under 8–9 broomrape m\(^{2}\) infestations in a similar region (Ozberk et al., 2016). Breeding resistance is the most economic, feasible and environmentally friendly method of control. However, resistance to broomrape is difficult to access due to the scarcity of complex nature and low heritability. Breeding for resistance is a difficult task (Rubiales, 2003). So far, no source of resistance has been available in lentil (Muehlbauer et al., 2006). Nevertheless, Fernandez-Aparicio et al. (2008) have observed a wide range of responses to crenate broomrape resistance under field conditions. Low infection rates seemed to be based on a combination of various escape and resistance mechanisms. Moreover, some in-vitro screening techniques may be used to rank and identify lentil accessions with potential broomrape resistance. There are numbers of cultural practices including delayed sowing, hand weeding, no-tillage, nitrogen fertilization, intercropping, and trap plants such as Brussels sprout, cabbage, broccoli, canola, turnip and crop rotations to contribute to seed bank demise. Taking into account simplicity in application, planting time modifications can be employed as agronomical measures. However, there is a conflict between early planting and late planting. Late planting of early-maturing types of lentil are recommended (Temel et al., 2012; Rubiales and Fernandez-Aparicio, 2011), whereas farmer practice in the region is to plant lentil relatively
early for the emergence and rapid vigorous seedling development. Therefore, plant can compete with broomrape development as partially suggested by Silim et al. (1999). Crop rotation, solarisations and the use of the trap plant formerly used to be planted in large scale in the region such as Linum usitatissimum L. are other possible measures (Aksoy and Uygur, 2003). An increase in farmer awareness was also recommended urgently (Ozaslan et al., 2017).

**Conclusion**

It was concluded that 15% of broomrape infestation resulted in early 60% yield loss with the US$ 555 ha⁻¹ economic loss. It is predicted that 20% or slightly more of broomrape infestation might result in a disaster giving the zero amount of grain at harvest. Thus, immediate agronomical measures given above must be taken in the region and neighboring countries.

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**Koliko su veliki gubici prinosa, kvaliteta, tržišne cene i profitabilnosti?**

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**Rezime**

Cilj ovog istraživanja bio je da se ispitaju uticaji veoma štetnih parazitskih biljaka (**Orobanche** spp.) na prinos zrna, neke karakteristike kvaliteta, tržišnu cenu i gubitak profitabilnosti crvenog sočiva u glavnoj oblasti uzgajanja sočiva u jugoistočnoj Anatoliji. Poljski ogledi su sprovedeni u dva susedna polja zasejana sortama sočiva Yerli kırmızı (landrace) i Firat-87 korišćenjem oglednog dizajna podeljenih parcela u lokalitetu Yollar basi Viransehira u vegetacionom periodu useva 2018–2019. Sorte sočiva su postavljene u glavne parcele, a zakorovljenost volovodom (tj. 0, 5, 10, i 15 biljaka m⁻²) je stavljena u potparcele. Izračunati su prinos zrna, hektolitarska masa, masa hiljadu zrna i sadržaj proteina (%). Svi uzorci zrna predstavljeni su slučajno izabranim kupcima zrna na lokalnom tržištu robe i ocenjene su ponude tržišnih cene. Rezultati su pokazali da zakorovljenost volovodom od 0-15 biljaka m⁻² značajno smanjuje prinos zrna od 2033.33 kg ha⁻¹ do 833.33 kg ha⁻¹ za 59%. Iako nije značajno, sorta Firat-87 (1512.5 kg ha⁻¹) je imala viši prinos nego sorta Yerli Kırmızı (1325 kg ha⁻¹). Regresiono jednačine odnosa smanjenja prinosa useva prema zakorovljenosti volovodom pokazale su se značajnim i pouzdanim sa visokim koeficijentima determinacije za obe sorte. Neki vizuelni kriterijumi kao što je hektolitarska masa i masa hiljadu zrna nisu bili ozbiljno oštećeni. Kupci su ponudili vrlo slične tržišne cene za zrna mahunarki sa svim nivoima oštećenja. Ekonomski gubitak je bio ogroman ($555 ha⁻¹). Regresione jednačine izvedene iz prinosa zrna nasuprot gustinama zakorovljenosti bile su pouzdanu visokim koeficijentima determinacije i mogu se savršeno koristiti za procene prinosa pri različitim nivoima zakorovljenosti volovodom. Zaključeno je da zakorovljenost od preko 15% može dovesti do katastrofalnih gubitaka prinosa u proizvodnji sočiva. Stoga se neke agromorske mere moraju brzo preduzeti.

**Ključne reči:** crveno sočivo, **Orobanche**, prinos zrna, kvalitet, tržišne cene, profitabilnost.

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