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Research Article/Araştırma Makalesi

The effects of different amounts of branched broomrape (*Phelipanche ramosa* (L.) Pomel) seeds on some cultivated plants

Farklı oranlarda mavi çiçekli canavar otu (Phelipanche ramosa (L.) Pomel) tohumlarının bazı kültür bitkileri üzerindeki etkileri

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ABSTRACT

Phelipanche ramosa (L.) Pomel (Syn: *Orobanche ramosa* L.), also known as branched broomrape, is a holoparasite belonging to the family Orobanchaceae. Broomrape prefers tomato, eggplant and potato from Solanaceae family and lentil, sunflower and broad bean from legumes as hosts. In this study, it was aimed to determine the effects of different rates of branched broomrape seeds on some plant growth parameters. The study was carried out in the laboratory and climate room of Van Yüzüncü Yıl University Plant Protection Department in 2022. In the study, branched broomrape, tomato, eggplant and pepper plants were used. Before these plants were planted 250, 500, 1000, 2000, and 4000 seeds of branched broomrape were mixed homogeneously to a soil depth of 8 cm in each pot. The experiment was planned according to the completely randomized experimental design with four replications; two tomatoes, two peppers and one eggplant in each pot. According to the results, it was observed that broomrape was attached only to the roots of tomato and eggplant, but not peppers. The increase in the amount of branched broomrape seeds increased the number of tubercles. It was determined that the number of leaves, shoot length, root length, shoot diameter, chlorophyll content, total fresh and dry biomass of tomato and the number of leaves and shoot length in eggplant decreased as the weed infestation increased. It can also be stated that the increased number of seeds did not have a negative effect in terms of intraspecific competition.

Key Words: Branched broomrape, Parasitic plant, Seed, Vegetables.

ÖZ

Mavi çiçekli canavar otu olarak da bilinen *Phelipanche ramosa* (L.) Pomel (Syn: *Orobanche ramosa* L.), Orobanchaceae familyasına ait bir holoparazit bir bitkidir. Canavar otu patlıcangiller familyasından domates, patlıcan ve patatesi; baklagillerden ise mercimek, ayçiçeği ve baklayı konukçu olarak tercih eder. Bu çalışmada, farklı oranlarda canavar otu tohumlarının bazı bitki büyüme parametreleri üzerine etkilerinin belirlenmesi amaçlanmıştır. Çalışma 2022 yılında Van Yüzüncü Yıl Üniversitesi Bitki Koruma Bölümü iklim odası ve laboratuvarlarında yürütülmüştür. Çalışmada canavar otu domates, patlıcan ve biber bitkileri kullanılmıştır. Bu bitkilerin tohumları ekilmeden önce her saksıya 250, 500, 1000, 2000 ve 4000 adet canavar otu tohumu 8 cm toprak derinliğine homojen bir şekilde karıştırılmıştır. Deneme tesadüf parselleri deneme desenine göre dört tekerrürlü; her saksıda iki domates, iki biber ve bir patlıcan bitkisi olacak şekilde planlanmıştır. Elde edilen sonuçlara göre, canavar otunun sadece domates ve patlıcan köklerine tutunduğu, biberde ise tutunmadığı gözlenmiştir. Canavar otu tohumu miktarındaki artış tüberkül sayısını artırmıştır. Canavar otu bulaşıklığı arttıkça domateste yaprak sayısı, sürgün uzunluğu, kök uzunluğu, sürgün çapı, klorofil içeriği, toplam yaş ve kuru ağırlığı, patlıcanda ise yaprak sayısı ve sürgün boyunun azaldığı tespit edilmiştir. Artan tohum sayısının tür içi rekabet açısından olumsuz bir etkiye sahip olmadığı da söylenebilir.

Anahtar Kelimeler: Mavi çiçekli canavar otu, Parazitik bitki, Tohum, Sebze.

Introduction

Phelipanche ramosa (L.) Pomel (Syn: *Orobanche ramosa* L.), belonging to the family Orobanchaceae, is one of the most problematic and destructive holoparasitic species in agricultural fields worldwide (Rubiales and Fernández-Aparicio, 2012; Habimana et al., 2014; Fernández-Aparicio et al., 2016). Serious yield and quality losses in host plants are caused by broomrape, for which there is no effective control method, including chemical control (Tepe, 2014; Fidan, 2023). Depending on environmental conditions, host susceptibility, invasion and intensity of infestation, it can cause yield losses up to 100% in cultivated plants. It has been reported that broomrape causes 50-100% yield loss in broad bean, 33% in tobacco, 33% in sunflower, 24% in carrot and 21-29% in tomato (Aksoy and Pekcan, 2014; Habimana et al., 2014; Fernández-Aparicio et al., 2016). The plant not only reduces the yield and quality of host plants, but also causes economic losses, thus posing a serious threat to food security in many countries of the world (Parker and Riches, 1993; Elzein and Kroschel, 2003; Demirbaş, 2011). The fruit consists of a 0.5-2 cm capsule and each capsule contains 1,000-5,000 seeds. One plant can produce 40-100 capsules (Strelyaeva, 1978; Perny, 1989; Joel et al. 2007). Individuals can produce more than 200.000 seeds (Lopez and Garcia, 1993), which can remain viable in the soil for 13 years or more (Cubero and Moreno, 1979). In a study, it was reported that only 0.003% of the *Orobanche crenata* seed bank successfully attached to the roots of the host and 9% of these germinated. Approximately 43% of the germinated seeds are lost through various natural processes (dispersal, predation, decomposition) and therefore only 57% of the total number of seeds produced remain in the soil. As a result of this high seed production, the annual soil seed bank has more than tripled in eight years (Lopez and Garcia, 1993).

In addition to its distinctive features such as producing a lot of seeds, spreading over large areas by wind, water and other sources, the rapid increase in the cultivation areas of the broomrape hosts causes the problem to grow gradually (Ramaiah 1987; Parker, 1991; Rubiales et al., 2009). It is important to understand the relationship between the parasite plant seeds and the host plant in order to determine the time to start the control and to understand in which phenological period the control will be effective. In this study, it was aimed to determine the effects of different amounts of broomrape seeds in the soil on the development of host plants in the context of host-parasite relationship. It is thought that the information obtained from this study will provide the basis for optimising integrated control programmes and for long-term planning to reduce the seed bank.

Materials and Methods

Rio Grande tomato, Yalova Çarliston 341 pepper and Aydın Siyah 55 eggplant varieties were used in the study. *Phelipanche ramosa* (L.) seeds were collected from tomato growing areas in Van/Türkiye in 2019. The seeds used in the study were sterilized with 70% ethanol, then washed with sterile water and dried on blotting paper. The studies were carried out in the climate room and laboratory of the herbology in 2022.

The experiments were conducted in 2 litre pots containing sterile peat-perlite mixture at a ratio of 2:1. Only tomato, eggplant and pepper seeds were planting in the control groups. In the other groups, 250, 500, 1000, 2000 and 4000 broomrape seeds were mixed homogeneously to a depth of 8 cm in each pot before sowing the seeds (Grenz et al., 2008). It was established according to the random plots experimental design with four replications; two tomato, two pepper and one eggplant plants in each pot. Hoagland nutrient solution was applied to the seedlings after the first true leaves appeared. The plants were regularly supplied with water and Hoagland nutrient solution as needed. The experiment was established on 31.01.2022 and ended on 20.04.2022. The development parameters observed at the end of the study are as follows:

Shoot and root length (cm): At the end of the experiment, shoot length was determined by measuring the area from the root collar to the growing tip and root length was determined by measuring the area from the root collar to the root tip.

Shoot diameter (mm): It was determined by measuring the 2 cm upper stem region of the root collar of the plants with a digital caliper.

Number of leaves: It was determined by counting all leaves on the plant when the experiment was completed.

Chlorophyll content: The amount of chlorophyll in the leaves was determined with SPAD meter (Minolta SPAD-502, Osaka, Japan) according to the method used by Birgin (2021) by measuring from the third and fourth leaves from top to bottom and averaging the values.

Fresh and dry biomass of roots and shoot (g): The method of (Kaçar, 1984) was used to determine the fresh and dry biomass of the plants. The fresh biomasss of both shoot parts and roots were determined with an assay balance. The fresh shoot and roots were placed in paper bags and dried in drying cabinets at 70 °C for 48 hours and then weighed and the dry biomass were determined.

Number of tubercles: The number of tubercles formed as a result of the attachment of germinated broomrape seeds to the roots of the plants was determined by counting.

Statistical Analysis

The data obtained from the experiment were evaluated by using SPSS statistical package programme according to the random plots experimental design at $p<0.05$ significance level. Differences between treatments were determined by 'Duncan's Multiple Range Test'.

Results and Discussions

When the parameters obtained from this study are examined, the changes in tomato, the number of tubercles and the percentage change rate compared to the control are given in Tables 1 and 2. According to the results of statistical analyses, the differences between all parameters except shoot diameter were found significant. In addition, when the treatments were compared with the control, the changes in leaf number, root length, total dry biomass and chlorophyll content were in the same group. However, the decrease in shoot length was also reflected in the results of the analyses and especially the lowest and highest treatments were in different groups. In total fresh biomass, 250 seeds treatment was in a different group from all other treatments. There was an increase in the number of tubercles depending on the number of seeds. According to the results of statistical analysis, 4000 seeds application was in a different group. In tomato plant, increasing seed amount increased the number of tubercles and decreased the shoot length and total fresh biomass (Table 1).

Table 1. The effect of the number of broomrape seeds on tubercles and some morphological parameters in tomato

Number of seeds per pot	Number of tubercles	Number of leaves	Shoot length (cm)	Root length (cm)	Shoot diameter (mm)	Total fresh biomass (g)	Total dry biomass (g)	Chlorophyll content (SPAD value)
Control (0)	0,0±0,0c	12,1±0,5a	80,3±1,1a	19,75±0,8a	5,32±0,3a	107,5±2,2a	12,2±0,4a	35,9±2,8a
250	4,2±0,4bc	9,8±0,9b	67,3±3,3b	15,75±0,4b	4,62±0,0a	94,0±4,6a	6,1±1,2b	28,3±0,5b
500	6,5±1,1bc	9,6±0,1b	58,8±4,3c	14,00±0,7b	4,91±0,1a	74,2±7,6b	6,1±0,5b	28,9±1,1b
1000	10,0±2,7b	8,7±0,4b	52,0±1,5cd	14,50±0,6b	4,72±0,1a	78,6±5,4b	6,8±0,4b	29,0±0,9b
2000	11,7±1,7ab	9,0±0,7b	53,6±1,9cd	16,50±1,8b	4,93±0,2a	73,5±3,6b	6,4±0,3b	29,0±0,9b
4000	19,0±5,5a	9,2±0,5b	48,5±0,9d	14,75±1,0b	4,56±0,1a	65,7±4,2b	6,7±0,8b	28,2±1,7b
Average	10,3±1,6	9,7±0,3	60,1±2,4	15,87±0,5	4,84±0,0	82,3±3,4	7,4±0,51	29,9±0,8

a, b, c: The difference between the means shown with different letters in the same column is statistically significant ($p<0.05$).

Table 2. Rates of variation (%) of broomrape seed number on some morphological parameters in tomato compared to control

Number of seeds per pot	Number of leaves	Shoot length	Root length	Shoot diameter	Total fresh biomass	Total dry biomass	Chlorophyll content
250	-18,56	-16,18	-20,3	-13,16	-12,52	-49,55	-21,23
500	-20,63	-26,76	-29,1	-7,71	-31,01	-50,04	-19,51
1000	-27,81	-35,30	-26,6	-11,28	-26,84	-43,85	-19,23
2000	-25,74	-33,29	-16,5	-7,33	-31,60	-47,11	-19,37
4000	-23,68	-39,66	-25,3	-14,29	-38,87	-45,07	-21,64

The changes in the parameters of eggplant plants are given in Table 3 and Table 4. According to the results of statistical analyses, the differences between the treatments in root length and chlorophyll content were found insignificant, while the differences between the other parameters were found significant. The increase in seed amount had a negative effect on the number of leaves, but there was no difference between 1000, 2000 and 4000 groups. This result was also reflected in shoot length, total fresh and dry biomass. Similar results were observed in the number of tubercles.

Table 3. The effect of the number of broomrape seeds on tubercles and some morphological parameters in eggplant

Number of seeds per pot	Number of tubercles	Number of leaves	Shoot length (cm)	Root length (cm)	Shoot diameter (mm)	Total fresh biomass (g)	Total dry biomass (g)	Chlorophyll content (SPAD value)
Control	0,0±0,0c	16,0±1,8a	58,0±2,4a	18,7±1,3a	7,4±0,7a	139,6±15,8ab	18,1±3,4ab	36,6±3,0ös
250	4,7±0,8b	13,5±0,6ab	49,5±2,9ab	20,2±1,7a	7,4±0,1a	146,5±7,3a	29,7±3,7a	39,2±0,4
500	6,5±0,8b	11,5±0,5bc	48,0±4,4b	18,2±2,1a	6,7±0,4a	114,2±7,7b	17,8±2,1ab	37,2±0,8
1000	7,0±0,9b	10,0±0,0c	37,2±2,6c	17,7±1,3a	7,1±0,4a	75,7±11,6c	14,6±3,2b	35,4±2,0
2000	11,2±2,0a	9,7±0,2c	41,2±1,3bc	16,2±1,3a	6,3±0,2a	68,0±3,9c	13,1±3,6b	33,6±1,4
4000	11,7±1,5a	9,0±0,7c	35,2±3,3c	14,0±1,7a	4,5±0,2b	47,9±2,9c	8,8±1,0c	33,2±1,5
Average	8,2±0,82	11,6±0,5	44,8±1,9	17,5±0,7	6,5±0,2	96,5±8,0	16,5±1,7	35,9±0,7

a, b, c: The difference between the means shown with different letters in the same column is statistically significant ($p<0.05$).

Table 4. Rates of variation (%) of broomrape seed number on some morphological parameters in eggplant compared to control

Number of seeds per pot	Number of leaves	Shoot length	Root length	Shoot diameter	Total fresh biomass	Total dry biomass	Chlorophyll content
250	-15,63	-14,66	8,00	0,00	4,98	63,76	7,18
500	-28,13	-17,24	-2,67	-9,58	-18,13	-1,98	1,72
1000	-37,50	-35,78	-5,33	-4,18	-45,71	-19,32	-3,33
2000	-39,06	-28,88	-13,33	-14,84	-51,24	-27,36	-8,19
4000	-43,75	-39,22	-25,33	-38,19	-65,68	-51,37	-9,20

Pepper, which is outside the host range of broomrape, did not exhibit the formation of tubercles on its roots and remained uninfected when exposed to varying doses of the plant's seeds. For this reason, pepper was excluded from the evaluation. In a survey study conducted by Yergin Özkan et al. (2024) in vegetable cultivation areas, although *P. ramosa* was observed on pepper plants, when the root region was examined in detail, it was determined that the attachment was not to the roots of the pepper plants but to parasitize different weed species in the field. In addition, there is no record that pepper is the host of the broomrape weed in Türkiye. However, in a study conducted in the Golan Heights, *O. aegyptiaca* was reported to parasitize pepper (Hershenhorn et al., 1996).

In this study in which the effect of increasing seed amount of broomrape on the development parameters of tomato, pepper and eggplant plants was investigated, the number of tubercles in tomato and eggplant increased up to a certain rate. In particular, shoot length and total fresh and dry biomass decreased. It is known that broomrape negatively affects the total biomass of plants because it obtains water and nutrients from host plants. It can be said that these biomass losses in plants are a result of the competition between broomrape and cultivated plants (Faradonbeh et al., 2020). In addition, broomrape infestation disrupts the hormonal balance of the host plant, which negatively affects the opening and closing of stomata and reduces the biomass of plants (Frost et al., 1997; Constantine et al., 2013). In studies on *O. crenata*, it has been stated that the number of tubercles is directly related to the number of seeds in the soil (Manschadi et al., 1996; 2001). In another study with this species, which is a problem in legumes, it was observed that the amount of seed banks and tubercles had a hyperbolic function (Grenz et al., 2005). In this study, it can be explained that the increase in the number of tubercles up to a certain level is related to intraspecific competition resulting from the limited carrying capacity of the host which provides stabilization in the plant at high infestation levels.

In a similar study conducted by Grenz et al. (2008) in sunflower, 50, 200 and 1600 *O. cumana* seeds per kilogram were mixed into the soil. The increase in the seed amount of *O. cumana* had a negative effect on yield. In parallel with the increase in the number of seeds in the soil, it was determined that the attachment also increased. The results obtained from the study were similar to those of the present study and the number of leaves was the most affected plant part in both studies. When these results are evaluated together with the chlorophyll results, it can be said that the parasitic plant does not significantly affect photosynthesis but damages the host with strong assimilation. Similarly, as stated by Fidan (2023), it was understood that the broomrape infestation affected mostly the lower leaves of the plant and there were no great differences in chlorophyll content with the transport of mobile elements to the upper parts of the plant.

Ecological theory predicts that resource limitations determine the competitive environment between organisms. For example, food supply strongly influences infection dynamics and interactions within and between parasite species. Competition between parasite species, especially for hosts, is expected to lead to changes in the level of virulence. This is an extremely important factor for the individual performance of the parasitic plant. In a study by Nabity et al. (2021), results supporting this information were obtained in the species *Phoradendron californicum* Nutt., known as American mistletoe, and it was found that virulence decreased as intraspecific competition increased. In addition, it was stated that even changes in the genotypes of the same species affect the attachment and virulence differently. Similarly, many studies have reported that these differences may be due to the amount of strigolactone produced by host plants (El-Halmouch and Thalouam, 2006; Lopez-Ráez et al., 2008; Awad et al., 2006; Xie et al., 2007).

Conclusions

As a result, it can be determined that seed density in the soil and intraspecific competition are found to be important for the number of tubercles or attachment of broomrape. Therefore, it can be said that shoot length, number of leaves and total biomass are the most important affected parameters. High seed number increases the success of the plant's spread, but also makes parasite-host plant competition more important. It is important to determine the level of parasitism under these conditions in order to provide a new approach in the control of broomrape. In addition, the fact that this species does not parasitize pepper plants belonging to the Solanaceae family can be considered as an advantage in breeding studies and crop rotation practices in terms of resistance.

Conflict of Interest: The authors declare that there is no conflict of interest between them.

Author contributions

The authors declare that they contributed equally to the article.

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