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# Reactions of Short, Intermediate and Long Day Onion Genotypes in Turkish National Onion Breeding Program to Fusarium Basal Rot Disease

## Türkiye Ulusal Soğan Islahı Programı Kısa, Orta ve Uzun Gün Soğan Genotiplerinin Soğan Dip Çürüklük Hastalığına Karşı Reaksiyonları

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**Abstract:** Onion basal rot (*Fusarium oxysporum* f. sp. *cepae*) disease exerts serious threats on global onion (*Allium cepa* L.) production and trade. Present breeding programs mostly focus on development of cultivars resistant to onion basal rot disease. Characterization of breeding material in breeding gene pool is the first step of breeding. This study was conducted to determine the susceptibility of 4 onion cultivars, 30 long-day, 1 intermediate-day and 21 short-day onion genotypes to onion basal rot disease. Significant differences were seen in disease susceptibility of the genotypes (P<0.01 ) in both onion seedling and bulb tests. Onion seedling and bulb tests revealed that resistance was not detected in short and intermediate-day onion genotypes and cultivars, while two of long-day onion genotypes (ACLD 7 and 8) were found to be tolerant. Based on present finding, 3 cultivars, 28 long-day, 1 intermediate-day and 21 short-day genotypes were identified as sensitive. ACLD 7 and 8 long-day onion genotypes, which were identified as promising in seedling tests, were also identified as tolerant in bulb tests and such findings proved the compliance of seedling and bulb tests. Bulbs were obtained from the long-day onion lines (ACLD 7-8 genotypes) that were found to be promising and survived in seedling tests and seeds were obtained from these genotypes to ensure progress of generation and they were included in breeding gene pool.

**Keywords:** Onion, *Allium cepa* L, onion basal rot, reaction

**&**

**Öz:** Soğan dip çürüklüğü *(Fusarium oxysporum* f. sp. *cepae*) küresel soğan (*Allium cepa* L.) üretimi ve ticaretini ciddi şekilde tehdit etmektedir. Islahçılar tarafından soğan ıslah programı oluşturulurken soğan dip çürüklüğüne dayanıklı çeşit geliştirmek öncelikli konular arasındadır. Islah gen havuzundaki materyalin karakterize edilerek özelliklerinin ortaya konulması ıslahın birinci basamağıdır. Bu çalışmada 4 adet soğan çeşidi ile 30 adet uzun gün, 1 adet orta gün ve 21 adet kısa gün soğan genotiplerinin soğan dip çürüklüğü hastalığına karşı hassasiyetlerini belirlemek amaçlanmıştır. Hem fide testi hem de olgun soğan testi aşamalarında hastalık duyarlılığı (P< 0.01 ) bakımından genotipler arasında önemli farklılıklar bulunmuştur. Soğan fide testi ile olgun soğan testleri sonucunda kısa ve orta gün soğan genotip ve çeşitlerinde dayanıklılık tespit edilmezken uzun gün soğan genotiplerinden iki tanesi (ACLD 7 ve 8) tolerant olarak tespit edilmiştir. Çalışmada kullanılan 3 çeşit, 28 adet uzun gün, 1 adet orta gün ve 21 adet kısa gün genotip ise hassas olarak belirlenmiştir. Fide testi aşamasında ümitvar olarak belirlenen ACLD 7 ve 8 numaralı uzun gün soğan genotipleri aynı şekilde soğan baş testi çalışmasında da tolerant olarak bulunmuş fide testi ile soğan baş testi sonuçları birbirini teyit etmiştir. Soğan fide testinde sağ kalan fidelerden ümitvar olarak bulunan uzun gün soğan hatlarından (ACLD 7-8 numaralı genotipler) baş elde edilmiş, elde edilen başlardan da tohum elde edilerek generasyon ilerlemesi sağlanmış ve ıslah gen havuzuna dahil edilmiştir.

**Anahtar Kelimeler:** Soğan, *Allium cepa* L., soğan dip çürüklüğü, reaksiyon

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## INTRODUCTION

Onion (*Allium cepa* L.) belongs to Alliaceae family and it is an important vegetable species with a high economic value. Annual onion production of Türkiye is about 2.5 million tons and with this production, Türkiye is ranked as 5th by meeting 2.35% of world total onion production (Faostat, 2021). Although onion cultivation is practiced more or less throughout the country, intensive cultivation is carried out especially in Marmara, Central Anatolia and Eastern Mediterranean Regions. Local populations, standard cultivars and hybrid cultivars are commonly used in production activities. While local populations are all placed into long-day (13 hours and more) onion group in terms of daylight hours, standard and hybrid cultivars exhibit a large variation and are placed into short-day (08-10 hours), intermediate-day (10-12 hours) and long-day (≥13 day) groups (Beşirli et al., 2021).

Onion basal rot disease caused by *Fusarium oxysporum* f. sp. *cepae* (FOC), is an important disease encountered in Türkiye and several other countries of the world and it causes significant losses both in the field and during the post-harvest storage. The soil-borne agent infects basal plate and neck of onion bulbs, causing bulb rot and post-harvest losses. The pathogen can also cause damping off the seeds pre-emergence and post-emergence and delay the emergence of onion seedlings (Sumner, 1995; Koike et al., 2007; Galván et al., 2008; Dissanayake et al., 2009). While the disease agent prefers the optimum temperature of 28-32 °C, the disease can also occur at low temperatures such as 15 °C. Among the Fusarium species, FOC is the most common pathogen in onion fields of Türkiye (Türkkan and Karaca, 2006; Bayraktar and Dolar, 2011).

The disease agent can survive for several years in the form of chlamydospores in the soil and can spread through seeds and soil. Use of resistant cultivars is the most effective and economical way to control the disease, since chemical control has minimal effect on the disease and the disease persists for a long time in the form of chlamydospores in the soil (Visser et al., 2006). Previous researchers indicated that onion genotypes reacted differently to FOC and mentioned about resistant lines and cultivars (Özer, 1998; Apaza and Mattos, 2000; Lopez and Cramer, 2004; Özer et al, 2004; Saxena and Cramer, 2009).

As an effective and economical control method, this study was conducted for characterization of the breeding gene pool to develop a cultivar resistant/tolerant to onion basal rot (*Fusarium oxysporum* f sp. *cepae*), commonly encountered in onion growing regions of Türkiye and causing significant losses.

## MATERIAL AND METHOD

### *Material*

In present experiments, Akgün 12, which is known to be tolerant against the disease and Kantartopu 3 cultivar (as a sensitive control) were used as the plant material. In addition, İmralı Kırması 15 and Beşirli 77 onion cultivars of Yalova Onion Gene Pool; 30 long-day, 21 short-day and 1 intermediate-day genotypes of the Onion Gene Pool in "Development of Onion Lines Tolerant to Fusarium (*Fusairum oxysporum* f. sp. *cepae*)" sub-work package of 117G002-numbered TUBITAK 1007 project entitled as "Line and/or Cultivar Development in Winter Vegetable Culture" were also used as the plant material (Table 1).

**Table 1.** Onion genotypes, bulb color and daylight tendency.
*Çizelge 1. Çalışmada kullanılan soğan çeşit ve genotiplerin genotip numarası, baş rengi ve gün uzunluğu eğilimi.*

| Order No | Genotype No | Bulb Color | Order No | Genotype No | Bulb Color |
|---|---|---|---|---|---|
| 1 | ACLD*1 | Yellow | 29 | ACLD56 | Yellow |
| 2 | ACLD2 | Yellow | 30 | ACLD57 | Yellow |
| 3 | ACLD3 | Yellow | 31 | ACSD**18 | Yellow |
| 4 | ACLD4 | Yellow | 32 | ACSD19 | Yellow |
| 5 | ACLD5 | Red | 33 | ACSD20 | Yellow |

**Table 1.** Continue.
*Çizelge 1. Devam.*

| Order No | Genotype No | Bulb Color | Order No | Genotype No | Bulb Color |
|---|---|---|---|---|---|
| 6 | ACLD6 | Red | 34 | ACSD21 | Yellow |
| 7 | ACLD7 | Red | 35 | ACSD25 | Yellow |
| 8 | ACLD8 | Red | 36 | ACSD26 | Yellow |
| 9 | ACLD9 | Yellow | 37 | ACSD27 | Yellow |
| 10 | ACLD10 | Yellow | 38 | ACSD28 | Yellow |
| 11 | ACLD11 | Red | 39 | ACSD35 | Yellow |
| 12 | ACLD13 | Yellow | 40 | ACSD36 | Yellow |
| 13 | ACLD14 | Yellow | 41 | ACSD37 | Yellow |
| 14 | ACLD16 | Yellow | 42 | ACSD38 | Yellow |
| 15 | ACLD22 | Red | 43 | ACSD39 | White |
| 16 | ACLD23 | Yellow | 44 | ACSD40 | Yellow |
| 17 | ACLD24 | Yellow | 45 | ACSD41 | Yellow |
| 18 | ACLD29 | Red | 46 | ACSD42 | Yellow |
| 19 | ACLD30 | Red | 47 | ACSD51 | Yellow |
| 20 | ACLD31 | Yellow | 48 | ACSD52 | Yellow |
| 21 | ACLD32 | Yellow | 49 | ACSD58 | Yellow |
| 22 | ACLD33 | Yellow | 50 | ACSD59 | Yellow |
| 23 | ACLD44 | Yellow | 51 | ACSD60 | Yellow |
| 24 | ACLD45 | Yellow | 52 | ACID***43 | Red |
| 25 | ACLD48 | Yellow | 53 | ACID Kantartopu 3 | Yellow |
| 26 | ACLD49 | Yellow | 54 | ACID Beşirli 77 | Red |
| 27 | ACLD50 | Yellow | 55 | ACLD Akgün 12 | Yellow |
| 28 | ACLD55 | Yellow | 56 | ACLD İmralı Kırması 15 | Yellow |

*ACLD: *Allium cepa* L. long-day, **ACSD: *Allium cepa* L. short-day, ***ACID: *Allium cepa* L. intermediate-day.

***Method***

***Onion Seedling Tests***

Seed surface sterilization of the genotypes was carried out by keeping them in 1% sodium hypochlorite for 3 minutes. Treated seeds were kept in sterile water for 5 minutes and left to dry on sterile drying papers. *Fusarium oxysporum* f. sp. *cepae*, previously diagnosed and with a known virulence, were cultured on PDA nutrient medium at 20 °C for 10 days (Bayraktar et al., 2010). To allow the conidia to pass into the water on developing culture, sterile water was added to the petri dish, mixed gently and filtered through sterile cheesecloth and the spore density was adjusted to $1x10^6$ spore $ml^{-1}$ density with the help of a hemocytometer. Seeds of each onion line were inoculated in 5 ml of spore suspension for 1 hour. Control seeds were kept in 5 ml sterile distilled water for 1 hour. Then, the autoclave-sterilized substrate (Klasmann Potgrond P) was placed into viols and a total of 100 seeds were planted for each line with 4 replications, 25 seeds in each replication. Experiments were conducted in randomized blocks design. Climate cabin conditions were set as 22 °C temperature, 60% relative humidity and 16/8 hours (light/dark) photoperiods. Disease counts were made on onion seedlings as diseased/healthy. Final assessments were made 30 days after planting, with the use of the following equations, counts were calculated as % by comparing with the control as pre-emergence damping-off and post-emergence damping-off.

$$\%\ Seedling\ Emergence: Number\ of\ seeds\ emerged / Total\ number\ of\ seeds\ planted\ x\ 100 \quad (1)$$

$$\%\ Survived\ seedling: Number\ of\ survived\ seeds / Number\ of\ seeds\ emerged\ in\ control\ x\ 100 \quad (2)$$

$$\%\ Disease: 100 - Survived\ seedling\ (\%) \quad (3)$$

$$Preemergence\ damping\ off\ (\%): Control\ seedling\ emergence\ (\%) - Pathogen\ treatment\ seedling\ emergence\ (\%) \quad (4)$$

$$Post-emergence\ damping\ off\ (\%): \%\ Disease - Preemergence\ damping\ off\ (\%) \quad (5)$$

***Onion Bulb Tests***

The candidate genotypes and cultivars identified as tolerance in seedling tests were subjected to onion bulb tests. A mixture of sterile garden soil, livestock manure and river sand (1:1:1) was used as the growing medium. The seedlings, which reached the 3-leaf stage for 4 weeks, were planted in 0.5 liter pots containing the same sterile growing medium in the unheated greenhouse environment (25-30 °C and %60 RH). Experiments were again conducted in randomized blocks design with 4 replications, 20 pots in each replication and one seedling in each pot. A total of 80 seedlings were planted for each genotype. *Fusarium oxysporum* f. sp. *cepae* culture, used in onion seedling test, was cultured on PDA medium at 20 °C for 10-15 days. The growing culture was prepared as indicated in the onion seedling test and the spore density was adjusted to $3x10^5$ spore $ml^{-1}$ density with the help of a hemocytometer. About 10 and 21 days after planting, 40 ml of spore suspension was given twice per seedling and 40 ml sterile water was given in control treatments. Onions grown in a greenhouse for about 9 weeks were not irrigated for the last two weeks before assessments (Galván et al., 2008; Taylor et al., 2013). Harvested onions were evaluated over a 0-3 scale (Table 2) and percent disease severity was calculated according to the Townsend-Heuberger formula over the scale values (Townsend and Heuberger, 1943);

$$Severity\ of\ Disease\ (\%) = \Sigma\ (n\ x\ V\ /\ Z\ x\ N)\ x\ 100 \quad (6)$$

where; n: number of plants in each disease severity scale; V: scale value; Z: highest scale value; N: total number of plants observed

**Table 2.** Bulb onion assessment scale for onion basal rot disease (Galván et al., 2008).
*Çizelge 2. Soğan dip çürüklüğü hastalığı baş soğan değerlendirme skalası.*

| Scale Value | Description |
|---|---|
| 0 | No symptoms |
| 1 | Slightly infected (<20% basal rot) |
| 2 | Moderately infected (20-50% basal rot) |
| 3 | Highly infected (>50% basal rot and rotten onion bulb) |

***Statistical Analysis***

Experimental data in percentages were subjected to angle transformation before the analysis and then subjected to analysis of variance with the use of JMP®, Version 7 software (SAS Institute Inc., Cary, NC, 1989-2019). Significant means were compared with the use of LSD Multiple Comparison Test.

## RESULTS AND DISCUSSION

### *Onion Seedling Tests*

In pathogen-free control treatments of long, intermediate and short-day onion genotypes of the gene pool, where their susceptibility to Onion Basal Rot disease was evaluated, no cultivars and genotypes, except for genotype 37 (44%), had germination rate of below 50%. The lowest germination rate (30%) was obtained from genotype 30 and the highest (97%) from genotype 6 (Table 3-4).

The highest virulence of the isolate used in this study reached the disease rates of 96%, 95.45% and 92.86% in Kantartopu 3 genotypes, 35 and 30, respectively. The lowest was determined as 25% and 31.46% disease rates in genotypes 8 and 7, respectively. Sasaki et al. (2015) classified virulence levels of *Fusarium oxysporum* f. sp. *cepae* isolates as; high virulence for disease severity of >70%, moderate virulence for disease severity of between 30-70% and low virulence for disease severity of <30%. Although the isolate used in this study differed based on genotypes, its virulence up to 96% resulted in classification of isolate as high virulence with average virulence of 66.8% in all genotypes.

Considering both the germination results of the genotypes in control treatments and the virulence level of the pathogen isolate, the suitability of the seeds and pathogen isolate for the disease testing evaluations has been demonstrated (Sasaki et al., 2015; Mandal and Cramer, 2021).

**Table 3.** Reactions of long-day onion genotypes to onion basal rot disease.
*Çizelge 3. Uzun gün soğan genotiplerinin Soğan Dip Çürüklüğü hastalığına karşı reaksiyonları.*

| Genotype No | CONTROL Avr. Seedling Emergence (%) (1) | Pre-emergence Damping-off (%) (4) | Post-emergence Damping-off (%) (5) | Pathogen Treated TOTAL % Disease (3) |
|---|---|---|---|---|
| ACLD 1 | 84.88 | 5.95 | 40.48 | 46.43 |
| ACLD 2 | 91.00 | 1.10 | 53.85 | 54.95 |
| ACLD 3 | 80.75 | 10.00 | 46.25 | 56.25 |
| ACLD 4 | 74.79 | 0.00 | 67.57 | 67.57 |
| ACLD 5 | 74.88 | 4.05 | 39.19 | 43.24 |
| ACLD 6 | 97.96 | 12.37 | 36.08 | 48.45 |
| ACLD **7** | **89.92** | **0.00** | **31.46** | **31.46** |
| ACLD **8** | **92.88** | **2.17** | **22.83** | **25.00** |
| ACLD 9 | 84.75 | 2.38 | 42.86 | 45.24 |
| ACLD 10 | 88.92 | 17.05 | 30.68 | 47.73 |
| ACLD 11 | 86.05 | 11.54 | 47.44 | 58.97 |
| ACLD 13 | 84.09 | 20.27 | 66.22 | 86.49 |
| ACLD 14 | 79.55 | 10.00 | 61.43 | 71.43 |
| ACLD 16 | 68.18 | 8.33 | 71.67 | 80.00 |
| ACLD 22 | 76.14 | 20.90 | 58.21 | 79.10 |
| ACLD 23 | 65.91 | 24.14 | 44.83 | 68.97 |
| ACLD 24 | 84.09 | 18.92 | 39.19 | 58.11 |
| ACLD 29 | 80.68 | 18.31 | 50.70 | 69.01 |
| ACLD **30** | **56.63** | **50.00** | **42.86** | **92.86** |
| ACLD 31 | 53.46 | 0.00 | 75.47 | 75.47 |
| ACLD 32 | 71.83 | 25.35 | 56.34 | 81.69 |
| ACLD 33 | 80.67 | 11.25 | 50.00 | 61.25 |
| ACLD 44 | 98.00 | 7.14 | 51.02 | 58.16 |
| ACLD 45 | 74.79 | 24.32 | 60.81 | 85.14 |
| ACLD 48 | 94.00 | 27.66 | 45.74 | 73.40 |
| ACLD 49 | 82.83 | 21.95 | 46.34 | 68.29 |
| ACLD 50 | 90.88 | 0.00 | 62.22 | 62.22 |
| ACLD 55 | 84.83 | 3.57 | 54.76 | 58.33 |
| ACLD 56 | 85.83 | 25.88 | 43.53 | 69.41 |
| ACLD 57 | 97.00 | 13.40 | 52.58 | 65.98 |
| Akgün 12 | 62.58 | 24.19 | 48.39 | 72.58 |

Pathogen isolate differed based on genotypes in onion seedling tests, but the pathogen isolate caused post-emergence damping-off in onion seedlings predominantly in long-day onion genotypes, although the

average pre-emergence and post-emergence damping-off rates were found to be close to each other in short-day onion genotypes. For instance, in long-day onion genotype 22, post-harvest damping-off ratio was 58.21%, while pre-harvest damping-off ratio was 20.9%. Likewise, in short-day onion genotype 35, post-emergence damping-off ratio was 43.9%, while pre-emergence damping-off ratio was 51.5% (Table 3). Similar to previous literature, present findings also revealed that disease agent caused significant pre- and post-emergence damping-off ratios (Sumner, 1995; Koike et al., 2007; Galván et al., 2008; Dissanayake et al., 2009). Significant differences were observed in the reaction of cultivars and genotypes subjected to onion seedling testing to the disease agent. While genotypes 2-5-6-7-8-9 were found to be prominent in long-day onion genotypes, short-day onion genotypes 19-25-26-27 and 42 had lower disease ratios than the other genotypes (Table 3-4).

**Table 4.** Reactions of intermediate and short-day onion genotypes to onion basal rot disease.
*Çizelge 4. Kısa ve Orta gün soğan çeşit/genotiplerinin Soğan Dip Çürüklüğü hastalığına karşı reaksiyonları.*

| Genotype No | CONTROL Avr. Seedling Emergence (%) (1) | Pre-emergence Damping-off (%) (4) | Post-emergence Damping-off (%) (5) | Pathogen Treated TOTAL % Disease (3) |
|---|---|---|---|---|
| ACSD 18 | 80 | 32.5 | 41.25 | 73.75 |
| ACSD 19 | 81 | 8.6 | 48.15 | 56.79 |
| ACSD 20 | 76 | 21.1 | 44.74 | 65.79 |
| ACSD 21 | 81 | 24.7 | 50.62 | 75.31 |
| ACSD **25** | **91** | **11.0** | **28.57** | **39.56** |
| ACSD 26 | 86 | 18.6 | 39.53 | 58.14 |
| ACSD 27 | 77 | 9.1 | 48.05 | 57.14 |
| ACSD 28 | 67 | 23.9 | 49.25 | 73.13 |
| ACSD 35 | 66 | 51.5 | 43.94 | 95.45 |
| ACSD 36 | 82 | 24.4 | 46.34 | 70.73 |
| ACSD 37 | 44 | 63.6 | 22.73 | 86.36 |
| ACSD 38 | 78 | 28.2 | 44.87 | 73.08 |
| ACSD 39 | 69 | 20.3 | 40.58 | 60.87 |
| ACSD 40 | 71 | 59.2 | 23.94 | 83.10 |
| ACSD 41 | 68 | 69.1 | 13.24 | 82.35 |
| ACSD **42** | **96** | **14.6** | **27.08** | **41.67** |
| ACID 43 | 95 | 23.2 | 47.37 | 70.53 |
| ACSD 51 | 80 | 45.0 | 22.50 | 67.50 |
| ACSD 52 | 66 | 16.7 | 56.06 | 72.73 |
| ACSD 58 | 79 | 36.7 | 34.18 | 70.89 |
| ACSD 59 | 71 | 56.3 | 30.99 | 87.32 |
| ACSD 60 | 80 | 23.8 | 48.75 | 72.50 |
| Beşirli 77 | 90 | 28.9 | 48.89 | 77.78 |
| İmralı Kırması 15 | 86 | 24.4 | 45.35 | 69.77 |
| **Kantartopu 3** | **75** | **42.7** | **53.33** | **96.00** |

There were significant differences in reactions of cultivars and genotypes against the disease. While genotypes 8 and 7, which were placed into the same statistical group, were found to be prominent in long-day onion genotypes, genotypes 19-25-42 were found to be prominent in short-day onion genotypes (Table 5).

**Table 5.** Variance analysis for reactions of long. intermediate and short-day onion genotypes to onion basal rot disease.
*Çizelge 5. Uzun-Kısa ve Orta gün soğan çeşit/genotiperin Soğan Dip Çürüklüğü hastalığına reaksiyonlarının varyans analizi.*

| Long-day GENOTYPE NO: | Survived Seedling (%) (2) | Intermediate/short-day GENOTYPE NO: | Survived Seedling (%) (2) |
|---|---|---|---|
| ACLD 8 | 75.00±2.17a | ACSD 25 | 60.44±10.48a |
| ACLD 7 | 68.54±2.25a | ACSD 42 | 58.33±2.95ab |
| ACLD 5 | 56.76±3.12b | ACSD 19 | 43.21±5.38abc |
| ACLD 9 | 54.76±2.75b | ACSD 27 | 42.86±12.39bc |
| ACLD 1 | 53.57±4.56b | ACSD 26 | 41.86±10.40bcd |
| ACLD 10 | 52.27±2.62b | ACSD 39 | 39.13±6.32cde |

**Table 5.** Devamı.
*Çizelge 5. Continue.*

| Long-day GENOTYPE NO: | Survived Seedling (%) (2) | Intermediate/short-day GENOTYPE NO: | Survived Seedling (%) (2) |
|---|---|---|---|
| ACLD 6 | 51.55±5.32b | ACSD 20 | 34.21±12.06cf |
| ACLD 2 | 45.05±4.21c | ACSD 51 | 32.5±10.31cf |
| ACLD 3 | 43.75±4.79cd | İmralı K. 15 | 30.24±2.33cf |
| ACLD 24 | 41.89±2.70cde | ACSD 36 | 29.27±5.97cg |
| ACLD 44 | 41.84±3.91cde | ACSD 58 | 29.11±5.52cg |
| ACLD 55 | 41.67±2.38cde | ACID 43 | 29.47±10.73cg |
| ACLD 11 | 41.03±4.19cde | ACSD 60 | 27.5±7.50dh |
| ACLD 33 | 38.75±4.79def | ACSD 38 | 26.92±2.22dh |
| ACLD 50 | 37.78±2.57ef | ACSD 28 | 26.87±2.99dh |
| ACLD 57 | 34.02±2.06fg | ACSD 52 | 27.27±9.09eh |
| ACLD 4 | 32.43±4.41gh | ACSD 18 | 26.25±4.15eh |
| ACLD 49 | 31.71±2.82ghı | ACSD 21 | 24.69±6.98fgh |
| ACLD 23 | 31.03±3.98gj | Beşirli 77 | 22.22±9.43fı |
| ACLD 29 | 31.00±3.25gj | ACSD 40 | 16.9±3.98ghı |
| ACLD 56 | 30.59±2.72gj | ACSD 41 | 17.65±11hı |
| ACLD 14 | 28.57±6.60hk | ACSD 37 | 13.64±7.87ıj |
| Akgün 12 | 27.40±3.23ıjk | ACSD 59 | 12.68±8.33ıjk |
| ACLD 48 | 26.60±2.13jk | ACSD 35 | 4.55±2.62jk |
| ACLD 31 | 24.53±3.77kl | Kantartopu 3 | 4±4.42k |
| ACLD 22 | 20.90±3.45lm | P<0.01 CV: 14.77% LSD: 12.6 | |
| ACLD 16 | 20.00±5.44m | | |
| ACLD 32 | 18.31±2.82mn | | |
| ACLD 45 | 14.86±2.70no | | |
| ACLD 13 | 13.51±3.12o | | |
| ACLD 30 | 7.14±0.00p | | |
| P<0.01 CV: 5.34% LSD: 5.09 | | | |

### *Onion Bulb Tests*

Long-day genotypes 2-5-6-7-8-9 were selected as tolerant and genotype 22 as sensitive; short-day genotypes 19-25-26-42 were selected as tolerant and Kantartopu 3 cultivar as sensitive in onion seedling tests subjected to onion bulb tests. Among the long-day genotypes, genotypes 7 and 8 were also found to be tolerant in bulb tests. Although there was a slight change in the disease rate when onions were stored at room temperature for one month after the harvest in which the presence of latent infection was investigated, there was a significant difference as compared to sensitive genotype (genotype 22). Likewise, genotype 22, which was identified as sensitive in seedling tests, was also found to be sensitive in bulb tests and such findings confirmed the compliance of seedling and bulb tests (Table 6).

**Table 6.** Disease status of long-day genotypes in bulb tests.
*Çizelge 6. Uzungün soğan genotiplerinin soğan baş testindeki hastalık durumu.*

| Genotype No | Disease Index - Harvest | Disease Index- 4-week storage | Disease Ratio (%) - Harvest (6) | Disease Ratio (%) - 4-week storage (6) |
|---|---|---|---|---|
| ACLD 2 | 0.52 | 1.27 | 18.75±4.11b | 40.28±15.77c |
| ACLD 5 | 0.58 | 0.58 | 19.44±3.93b | 19.44±3.40d |
| ACLD 6 | 0.58 | 1.43 | 19.44±5.20b | 47.88 b±12.93bc |
| ACLD 7 | 0.33 | 0.375 | 11.11±1.96c | 12.50±2.40d |
| ACLD 8 | 0.18 | 0.54 | 6.25±1.20d | 18.05±12.19d |
| ACLD 9 | 0.58 | 1.79 | 19.44±3.40b | 59.72±4.61ab |
| ACLD 22 | 1.45 | 2.06 | 48.57±10.13a | 68.75±3.61a |
| | | | P: <0.01 CV:12.67% | P: <0.01 CV:16.58% |

However, in short-day onion genotypes 25 and 42, which were identified as tolerant in seedling tests, the disease severity was determined as between 46 - 68% in assessments made at harvest and as between 57 - 73% in assessments made at end of one-month storage, considering the presence of latent infection by

storing one month after harvest. Since disease rates were above 50%, these genotypes were identified as sensitive. Likewise, Kantartopu 3 cultivar, which was identified as sensitive in seedling tests, was found to be sensitive with as disease severity ratio of 81% in bulb tests (Table 7).

**Table 7.** Disease status of short-day genotypes in bulb tests.
*Çizelge 7. Kısagün soğan genotiplerinin soğan baş testindeki hastalık durumu.*

| Genotype No | Disease Index - Harvest | Disease Index- 4-week storage | Disease Ratio (%) - Harvest (6) | Disease Ratio (%) - 4-week storage (6) |
|---|---|---|---|---|
| ACSD 26 | 2.5 | 2.7 | 83.33±7.4a | 86.66±4.7a |
| Kantartopu 3 | 2.45 | 2.45 | 81.66±2.9a | 81.66±2.8a |
| ACSD 25 | 2.05 | 2.2 | 68.31±15.9ab | 73.31±10.5a |
| ACSD 19 | 1.46 | 2 | 48.86±12.5b | 55.53±8.2b |
| ACSD 42 | 1.40 | 2 | 46.64±5.4b | 57.77±3.14b |
| | | | P: <0.05 CV:10% | P: <0.01 CV:6% |

Plant resistance mechanism against onion basal rot disease has not been fully elucidated, yet. Grouping cultivar and genotype populations according to how they respond to FOC is an effective way for a progress in resistance breeding (Mandal and Cramer, 2021; Saxena and Cramer, 2009).

Since onion is a foreign-pollinated vegetable, each onion is genetically heterogeneous, which may explain the presence of resistant plants among the cultivars tested. In this case, repeated selection of uninfected plants may result in populations with progressively higher rates of Fusarium resistant individuals (Galván et al. 2008). Higher resistance selections were obtained as a result of this strategy (Gutierrez and Cramer, 2005; Sharma and Cramer, 2023).

Previous researchers indicated that onion genotypes reacted differently to FOC and mentioned about existence of tolerant and resistant lines and cultivars (Özer, 1998; Apaza and Mattos, 2000; Lopez and Cramer, 2004; Özer et al., 2004; Saxena and Cramer, 2009, Taylor et al., 2013; Mandal and Cramer, 2021).

## CONCLUSION

Present onion seedling and bulb tests revealed that 30 long-day, 21 short-day and 1 intermediate-day genotypes and 4 onion cultivars exhibited different reactions against onion basal rot disease and there were genotypes with lower disease reaction. Among them, ACLD 8 and 7 long-day onion genotypes were found to have lower disease rates in both seedling and bulb tests as compared to other genotypes. These genotypes should be included in the National Onion Breeding Program and used in development of onion cultivars resistant to Onion Basal Rot disease. Considering the findings of previous studies, sensitivity differences due to variety - isolate interactions should also be taken into consideration.

## CONFLICT OF INTEREST

Authors declare no conflict of interests.

## AUTHOR CONTRIBUTIONS

ZP, GB and İS involved in performance of experiments, HB involved in study design and manuscript draft.

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