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Investigation of susceptibility of some apricot cultivars to shot-hole [*Stigmina carpophila* (Lev.) M.B. Ellis] disease under natural inoculum conditions

Bazı kayısı çeşitlerinin [*Stigmina carpophila* (Lev.) M.B. Ellis] yaprak delen hastalığına karşı doğal inokülasyon koşullarında duyarlılığının araştırılması

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ABSTRACT

Shot hole, caused by *Stigmina carpophila* (Lev.) M.B. Ellis, is a major fungal disease for apricots and it causes serious economic loss in Turkey. To protect apricots from the various destructive effects of the shot hole disease, excessive fungicide is used, which may lead to severe damage in ecosystem. One of the most beneficial alternative ways to minimize or eradicate hazardous effects of fungicides is to use resistant/moderately resistant varieties. This study was conducted to examine the susceptibility of 9 domestic and 10 foreign (in total 19) apricot cultivars to shot-hole disease in 2014 and 2015. The cultivars were tested under natural inoculation and no fungicide was applied in the trial. Disease symptoms were observed separately on fruits and leaves. Analysis of leaves showed that cultivars named Çağataybey (32.30%), Sakıt-7 (26.30%), and Şekerpare (25.03%) had the highest levels of disease severity while cultivars named Wilson Delicious (11.41%), Ivonne Liverani (12.54%), and Borsi Rozsa (14.35%) had the lowest levels. Findings of fruit evaluations demonstrated that the highest levels of disease severity were found on cultivars named Şekerpare (50.87%), Sakıt-7 (50.15%) and Sakıt-2 (49.85%) while the lowest levels were found on cultivars named Aprikoz (17.45%), Zard (17.69%), and Hasanbey (21.28%). Statistical analysis between leaf and fruit disease severities illustrated a moderate positive correlation. However, no statistical difference was observed between leaf and fruit disease severities in ripening periods. Disease severity levels for fruits and leaves of foreign cultivars were lower than those of domestic cultivars. Determination of disease resistances of domestic-foreign apricot cultivars with high fruit quality is thought to provide a great advantage in selecting the parents to be used as a source of resistance in breeding studies.

INTRODUCTION

Shot-hole disease, caused by the fungus *Stigmina carpophila* (Lev.) M.B. Ellis (Synonym=*Wilsonomyces carpophilus*), affects stone fruits (peach, nectarine, apricot, plum, and cherry), causing serious economic loss worldwide (Ivanova et al. 2012). From these stone fruits, apricot is one of the most economically important plants. Besides, it is widely produced in various locations thanks to its enormous adaptation capability to different ecological conditions. Recently, almost 4.083.861 tons of apricots have been grown worldwide. Turkey is the leading producer, accounting for 846.606 tons of world production (Anonymous 2019).

Despite the use of intensive fungicide for serious infections, it is difficult to control shot-hole disease especially in certain years, depending on the climatic conditions. As a result of the intensive use of fungicide applications, production costs increase and both human health and the environment are under threat. Therefore, the use of resistant cultivars is an important way of controlling the shot-hole disease. In the control of shot-hole disease, the use of copper fungicides significantly reduced the amount of inoculum density and prevented the occurrence of infections (Ilicic et al. 2019).

The fungal pathogen can infect buds, twigs, leaves, blossoms, and fruits of host plant -apricot. The disease is most harmful in the cool and humid periods, extending to the spring. However, it can occur at any time in prolonged rainy weather and can cause damage in all seasons (Evans et al. 2008, Yousefi and Shahri 2014). Shot hole disease symptoms observed on leaves are small reddish or purplish spots, with yellow halo bordering spots. In late stages of the disease, these spots drop out (Ivanova et al. 2012). Shot hole disease symptoms observed on fruits are large and rough, scab-like spots on the fruit skin, causing the skin to crack and ooze. The fungal pathogen overwinters as mycelium or conidia (in temperate climates) on the bark surface of dormant buds (EPPO 2004).

The shot hole is a destructive disease for apricots at humid and cool conditions (Ivanova et al. 2012). The incidence of this disease is 74% in Turkey (Sarac 2018). In recent years, the incidince of shot-hole disease has been increasing because of enlargement of its growing areas and global warming.

Control of the disease is mainly based on cultural practices (destruction of infected plant debris) and fungicide applications (fungicide sprays at leaf when it falls in autumn, before bud break in the spring, and at immature fruit stage) (EPPO 2004, Asma et al. 2017). However, fungicide applications increase production costs and pose a serious risk both for environment and human health. To minimize economic loss caused by shot-hole disease and reduce fungicide application, it is necessary to use disease-resistant / (moderately resistant) cultivars.

The use of resistant varieties is important in the fight against economically important diseases and pests (Mitre et al. 2015). Shahri et al. (2014) conducted a study on determining the resistance of apricot varieties against shot hole disease in Iran. This study suggested that four cultivars (Lasjerdy, Shahroudi29, Shahroudi51 and Ghazi Gahani) be used for apricot production as resistant sources of breeding materials. No study has been conducted on determining disease-resistant cultivars against shot hole disease in apricot in Turkey. This is the first study on examining resistance of apricot against shot hole disease in Turkey.

This study was carried out to determine the susceptibility of some apricot cultivars against shot hole disease caused by *S. carpophila*, one of the most important fungal diseases of stone fruits, especially apricot.

MATERIALS AND METHODS

Apricot cultivars and orchard

In this study, 9 domestic and 10 foreign (in total 19) apricot cultivars were used in Eğirdir Fruit Research Institute, Ministry of Agriculture and Forestry, Republic of Turkey. These cultivars were (i) nineteen cultivars of apricot including three early ripening (Canino, Feriana and F. De Colomer), (ii) seven middle ripening cultivars (Aprikoz (Iğdır), Şekerpare, Wilson Delicious, Harcot, Ivonne Liverani, Çağataybey, and Early Gold), and (iii) nine late-ripening cultivars (Ethembey, Hacıkız, Hasanbey, Roksana, Sakıt-2, Sakıt-6, Sakıt 7, Zard and Borsi Rozsa), all of which had a better yield and horticultural characteristics. They were tested against *S. carpophila* (Table 1). No

Table 1. Using 9 domestic and 10 foreign (in total 19) apricot cultivars in reaction tests

Cultivar name	Harvest Period
Aprikoz (Iğdır)	Middle ripening
Canino	Early ripening
Ethembey	Late ripening
Feriana	Early ripening
Hacıkız	Late ripening
Hasanbey	Late ripening
Precoce de Colomer	Early ripening
Roksana	Late ripening
Sakıt-2	Late ripening
Sakıt-6	Late ripening
Sakıt-7	Late ripening
Şekerpare	Middle ripening
W.Delicious	Middle ripening
Harcot	Middle ripening
I. Liverani	Middle ripening
Çağataybey	Middle ripening
Zard	Late ripening
K.Rozsa	Late ripening
Early Gold	Middle ripening

fungicide applications were done against disease during the experiment. This study was carried out in 2014-2015. Experiments were conducted under natural infection conditions. All cultivars were performed in a completely randomized plot design with 4 replicates for each tree.

Disease evaluation

Disease evaluations were made on fruits and leaves separately. The percentage of infection ratio and the number of available spots on the leaves of cultivars were tested randomly in a total of 100 leaves according to a 1-5 scale (Table 2). In addition, the percentage of infection ratio and the number of available spots on the fruits of cultivars were tested randomly in a total of 20 fruits according to a 1-4 scale (Table 3). Natural inoculation assessments were performed at the beginning of leaf and fruit formation (Ioana et al. 2012). The percentage of disease severity in leaves and fruits was calculated according to the Townsend and Heuberger formula (1943) based on scale values obtained by reaction tests of apricot cultivars. The method used to determine the shot-hole disease infections was based on visual observation, considering the signs and symptoms shown by infected leaves and fruits. The symptoms observed on the apricot cultivars were noted. Resistance levels were grouped according to disease severity rates. The groups were 0–1% resistant; less than 25% less susceptible; between 25–50% susceptible, more than 50% more susceptible (Pauwels and Keulemans 2000, Kaymak et al. 2016).

Table 2. The scale used for the evaluation on leaves of the shot-hole disease

Scale	Description
0	No spot
1	1–7 shots or spots
2	8–15 shots or spots
3	More than 15 shots or spots
4	Half of the torn leaf, shredded the other half intact or covered with small holes in the leaves
5	Each side of the leaf is filled with more than 1 cm or larger holes or tears

Table 3. The scale used for the evaluation on fruits of the shot-hole disease

Scale	Description
0	No spot
1	Smaller than 5 mm up to 5 spots
2	Greater than 5 mm up to 5 or more than 5 pieces smaller than 5 mm spot
3	5 pieces more spot greater than 5 mm
4	More than half of the leaf-covered with spots

Statistical analyses

Statistical analyses were made by SPSS 16 (IBM Corp., Armonk) software package programme. Data was obtained from disease severity scales and reaction test findings of each apricot. By variance analysis (ANOVA), the results were evaluated to determine whether there is a significant variation within and among the cultivars.

RESULTS AND DISCUSSION

Shot hole disease, caused by *S. carpophila*, is one of the most commonly seen diseases in the apricot orchards in Turkey (Sipahioglu et al. 1999, Özgönen and Erkılıç 2001, Sarac 2018). The disease attacks both leaves and fruits. In case of severe leaf infections as a result of shot-hole disease, energy production system of apricot may collapse. The disease can noticeably reduce the quality of fruits, which may lead to serious economic loss. The leaf and fruit symptoms of the shot-hole disease were given in Figure 1. In this context, some apricot varieties which are resistant or susceptible to shot-hole disease have been phenotypically identified in this study.

Figure 1. Symptoms of the disease shot-hole on the fruit and leaf

In this study, it is shown that since the first infections of shot-hole disease begin on the young leaf, apricot cultivars reactions against leaf infections are important. The average leaf infections of apricot varieties depending on early, middle and late ripening periods were given in Figure 2

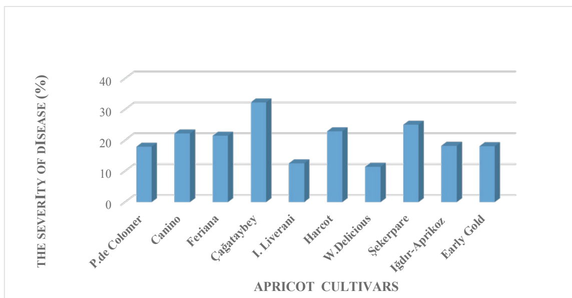

Figure 2. Mean disease severity rates (%) on the leaf of apricot early and middle ripening cultivars

and Figure 3. Regarding leaf infections, the lowest disease severities were determined to be Wilson Delicious, Ivonne Liverani, which are middle ripening cultivars, and Borsi Rozsa, a late ripening cultivar. Therefore, these cultivars with low infections can be suggested for breeding programs.

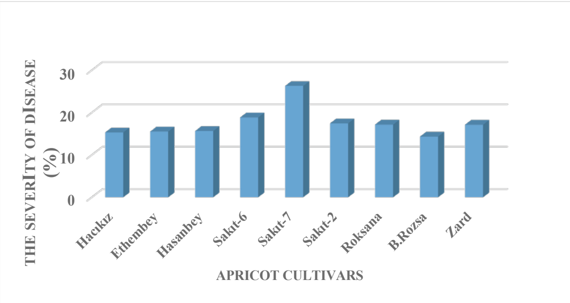

Figure 3. Mean disease severity rates (%) on the leaf of apricot early and middle ripening cultivars

In this study, 19 different cultivars were tested against shot-hole disease. The percentage of disease severity on leaves and fruits of apricot cultivars was evaluated under natural inoculation conditions in 2014 and 2015. The results of the study demonstrated that commercial cultivars had different levels of reactions, ranging from less susceptible to susceptible. Homogeneous test was conducted with disease severity on leaves and fruits of cultivars between 2014 and 2015 years. It has been considered that disease severity rates show a homogeneous distribution over the years.

For each apricot cultivar, the disease severities on the leaves were 32.30% (Çağataybey), 26.30% (Sakıt-7), 25.03% (Şekerpare), 22.89% (Harcot), 22.18% (Canino), 21.44% (Feriana), 18.86% (Sakıt-6), 18.25% (Aprikoz), 18.12% (Early Gold), 17.97% (Precoce de Colomer), 17.47% (Sakıt-2), 17.17% (Roksana), 17.14% (Zard), 15.66% (Hasanbey), 15.53% (Ethembey), 15.335 (Hacıkız), 14.35% (Borsi Rozsa), 12.54% (I. Liverani) and 11.41% (W. Delicious), respectively. According to the study reported by Grantina-Ievina and Stanke (2015), the average incidence of shot-hole disease was 41% in diploid plums and 80% in European plums, while the average severity was in 9 and 15%, respectively. Mitre et al. (2015) reported that plum cultivars named Top End, Jojo, Tophit, Toptaste, Nectarina rosie and Topfirst were slightly attacked by *S. carpophila* (5.3-7.3% attack degree). Results of these studies are in parallel with our findings.

In the study, among the apricot cultivars, the disease severities on fruit were 50.87% (Şekerpare), 50.15% (Sakıt-7), 25.03% (Şekerpare), 22.89% (Harcot), 22.18% (Canino), 21.44% (Feriana), 49.85% (Sakıt-2), 49.57% (Sakıt-6), 47.02% (Ethembey), 43.66% (Harcot), 40.08% (Çağataybey), 37.78% (Roksana), 37.58% (Borsi Rozsa), 36.74% (P. de Colomer), 35.96% (W. Delicious), 34.47% (Early Gold), 29.66% (Feriana), 27.76 % (I. Liverani), 24.80% (Canino), 23.71% (Hacıkız), 21.28% (Hasanbey), 17.69% (Zard) and 17.45% (Aprikoz), respectively.

In this study, a moderate positive correlation was observed between leaf and fruit disease severities. However, regarding ripening periods, no statistical difference was detected between leaf and fruit disease severities. Disease severity on fruits and leaves of foreign cultivars was lower than that of domestic cultivars. Moreover, the results of disease severity on leaves showed that 3 cultivars (Çağataybey, Sakıt-7 and Şekerpare) were categorized as susceptible while 16 cultivars were classified as less susceptible) (Table 4). When the results of the previous studies and this study are evaluated, it is revealed that the severity of the disease may vary from year to year according to the regions, countries and climatic conditions. As explained above, this study was conducted under natural inoculation and high disease pressure occurred. To understand main resistant level that the cultivars have, artificial inoculation is required under control conditions. On the other hand, the results of infection severity on apricot fruits showed that 2 cultivars (Zard and Aprikoz-Iğdır), 12 cultivars, and 5 cultivars were classified as more susceptible, susceptible and less susceptible, respectively (Table 5). On the other hand, in a study by Mehlenbacher et al. (1991) and Shahri et al. (2014), some resistant apricot cultivars (Moongold, Lasjerdy, Shahroudi29, Shahroudi51 and Ghazi Gahani) and moderately resistant cultivars (Boccuccia, Ivonne Liverani, Hungarian Best, Moniqui, Goldrich, Stark Early Orange, Tyrinthe, Ananas, Erevani, and Reliable) against shot-hole diseases were reported. This also supports the findings of Trandafirescu and Indreias (2011) who determined that apricot cultivars named Patriarca Temprano, Joubert Foulon, Marculesti 72, Precoce de Colomer, Rosii Timpurii, Baracca and Stella were tolerant. These cultivars can be used as a source of resistance to increase the resistance level of domestic cultivars through breeding. This approach may result in developing resistant domestic cultivars. The resistance gene/genes in apricot cultivars needs to determined. The use of the marker assisted selection (MAS) technique should be given importance. Thus, it is thought that with the use of MAS, breeding studies can be completed in a shorter time and with less labor, and more successful results can be obtained (Asma et al. 2017). Besides, the resistance levels of each cultivar grown in different locations may differ under different environmental factors. For this reason, these studies should be carried out in different locations. As a result, an environmentally friendly control method against shot-hole disease can be used in apricot production. For instance, the resistance of some peach cultivars were evaluated against the shot-hole disease in Iran (Ahmadpour et al. 2011). This evaluation results indicated that Redtop, Springcrest and Early Elberta cultivars were resistant (Ahmadpour et al. 2011).

Table 4. Mean disease severity rates (%) on the leaf of apricot cultivars

Cultivar Name	The severity of disease (%)	Reaction levels
Çağataybey	32.30 a	Susceptible
Sakıt-7	26.30 b	Susceptible
Şekerpare	25.03 b	Susceptible
Harcot	22.89 bc	Less Susceptible
Canino	22.18 bcd	Less Susceptible
Feriana	21.44 bcd	Less Susceptible
Sakıt-6	18.86 cde	Less Susceptible
Iğdır-Aprikoz	18.25 cde	Less Susceptible
Early Gold	18.12 cde	Less Susceptible
P.de Colomer	17.97 cde	Less Susceptible
Sakıt-2	17.47 def	Less Susceptible
Roksana	17.17 def	Less Susceptible
Zard	17.14 def	Less Susceptible
Hasanbey	15.66 efg	Less Susceptible
Ethembey	15.53 efg	Less Susceptible
Hacıkız	15.33 efg	Less Susceptible
K.Rozsa	14.35 efg	Less Susceptible
I.Liverani	12.54 fg	Less Susceptible
W.Delicious	11.41 g	Less Susceptible

* a-g: The same letter are not significantly different (p<0.05) according to Duncan's multiple range test

Table 5. Mean disease severity rates (%) on the fruit of apricot cultivars

Cultivar Name	The severity of disease (%)	Reaction levels
Şekerpare	50.87 a	More Susceptible
Sakıt-7	50.15 a	More Susceptible
Sakıt-2	49.85 ab	Susceptible
Sakıt-6	49.57 ab	Susceptible
Ethembey	47.02 ab	Susceptible
Harcot	43.66 abc	Susceptible
Çağataybey	40.08 abcd	Susceptible
Roksana	37.78 abcde	Susceptible
K.Rozsa	37.58 abcde	Susceptible
P.de Colomer	36.74 abcdef	Susceptible
W.Delicious	35.96 abcdef	Susceptible
Early Gold	34.47 bcdef	Susceptible
Feriana	29.66 cdefg	Susceptible
I.Liverani	27.76 defg	Susceptible
Canino	24.80 defg	Less Susceptible
Hacıkız	23.71 efg	Less Susceptible
Hasanbey	21.28 fg	Less Susceptible
Zard	17.69 g	Less Susceptible
Aprikoz (Iğdır)	17.45 g	Less Susceptible

* a-g: The same letter are not significantly different (p<0.05) according to Duncan's multiple range test

This is the first study on determining the resistance level of some commercial apricot cultivars against shot-hole disease in Turkey. Determination of disease resistances of domestic-foreign apricot cultivars with high fruit quality is thought to provide a great advantage in selecting the parents to be used as a source of resistance in breeding studies. This data will be useful to plan new plantings of apricots for growers. Additionally, these results suggested that development of resistant varieties will be a crucial step for sustainable apricot production since it will decrease fungicide application in Turkey.

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ÖZET

Stigmina carpophila (Lev.) M.B. Ellis'in neden olduğu yaprak delen kayısı için önemli bir fungal hastalıktır ve Türkiye'de kayısıda ciddi ekonomik kayba neden olur. Kayısıları yaprak delen hastalığının çeşitli yıkıcı etkilerinden korumak için, ekosistemde ciddi hasara yol açabilecek aşırı fungisit kullanılmaktadır. Fungisitlerin tehlikeli etkilerini en aza indirmenin veya ortadan kaldırmanın en faydalı alternatif yollarından biri, dayanıklı/orta dayanıklı çeşitler kullanmaktır. Bu çalışma, 2014 ve 2015 yıllarında 9 yerli ve 10 yabancı (toplam 19) kayısı çeşidinin yaprak delen hastalığına karşı duyarlılığını incelemek amacıyla yapılmıştır. Çeşitler doğal inokulasyon altında test edilmiştir ve denemede fungisit kullanılmamıştır. Hastalık belirtileri meyve ve yapraklarda ayrı ayrı gözlenmiştir. Yaprak analizleri, Çağataybey (%32.30), Sakıt-7 (%26.30) ve Şekerpare (%25.03) olarak adlandırılan çeşitlerin en yüksek hastalık şiddetine, Wilson Delicious (%11.41), Ivonne Liverani (%12.54) ve Borsi Rozsa (%14.35) olarak adlandırılan çeşitlerin ise en düşük seviyeye sahip olduğunu göstermiştir. Meyve değerlendirmelerinin sonucunda, en yüksek hastalık şiddeti seviyeleri Şekerpare (%50.87), Sakıt-7 (%50.15) ve Sakıt-2 (%49.85) olarak adlandırılan çeşitlerde, en düşük seviyeler ise Aprikoz (%17.45), Zard (%17.69) ve Hasanbey (%21.28) çeşitlerinde hesaplanmıştır. Yaprak ve meyve hastalık şiddetleri arasındaki istatistiksel analizde pozitif yönlü orta düzeyde pozitif bir korelasyon göstermiştir. Bununla birlikte, olgunlaşma dönemlerinde yaprak ve meyve hastalık şiddetleri arasında istatistiksel olarak fark gözlenmemiştir. Yabancı çeşitlerin meyve ve yaprak hastalık şiddetleri, yerli çeşitlere göre daha düşüktür. Islah çalışmalarında dayanıklılık kaynağı olarak kullanılacak ebeveynlerin seçilmesinde, yüksek meyve kalitesine sahip yerli-yabancı kayısı çeşitlerinin hastalık dayanımlarının belirlenmesinin büyük bir avantaj sağlayacağı düşünülmektedir.

Anahtar kelimeler: kayısı, çeşit, hastalık, yaprak delen, *Stigmina carpophila*

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