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Efficacy of some fungicides against *Septoria pistaciarum* Caracc. on Pistacia species in Türkiye

Pistacialarda sorun olan *Septoria pistaciarum* Caracc.'a karşı bazı fungisitlerin etkinliklerinin belirlenmesi

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A B S T R A C T

Pistachio (*Pistacia vera* L.) is considered a strategic agricultural product due to its high nutritional value and demand in international markets. With the expansion of production areas in recent years, pistachio cultivation has increased, while the management of pest and diseases comes to the fore. Septoria leaf spot disease caused by *Septoria pistaciarum* Caracc. is an important fungal pathogen causing leaf spots on pistachio trees. In this study, the efficacy of fungicides from different groups on ten isolates obtained from different Pistacia species was investigated. In the inhibition of mycelial radial growth of the pathogen fungus in vitro, the highest level of inhibition was 85.15% at a dose of 1.25 ml l^{-1} with azoxystrobin + difenoconazole, while the lowest level of inhibition was 10.30% at a dose of 0.3 ml l^{-1} with dodine. In the study carried out in pistachio trees contaminated with *S. pistaciarum* in Karabük province, it was observed that the highest biological activity of boscalid + pyraclostrobin fungicide at a dose of 75 g/100 l of water was 85.81%, and azoxystrobin + tebuconazole fungicide at a dose of 75 ml/100 l of water provided 83.80% disease control. The fungicide with the active ingredient prochloraz (33.44%) showed the lowest biological activity in the control of Septoria leaf spot disease. These results provide important data in terms of disease control by revealing the effectiveness rates of fungicides used in the control of Septoria leaf spot disease in pistachio cultivation.

INTRODUCTION

Pistachio (*Pistacia vera* L.) is a species of Anacardiaceae family and has an economically important place among non-wood forest products in Türkiye. Although there are 11 species in the genus *Pistacia*, only *P. vera* is grown commercially. Other *Pistacia* species, naturally grown, are commonly used by grafting for pistachio production (Ak and Kaşka 1998). Although there has been a significant increase in pistachio production in Türkiye in recent years, this increase in production has been accompanied by the spread of some diseases and this has become an important limiting factor in production.

Although the diseases that limit pistachio production vary according to countries, *Phytophthora* species (Trouillas et al. 2022) *Verticillium dahliae* (Hadizadeh and Banihashemi 2007) and some *Fusarium* species (Aydın et al. 2023, Ören et al. 2023); and fungal diseases of aerial origin are *Botryosphaeria dothidea*, *Alternaria alternata* (Michailides et al. 1994), and *Septoria* species (Crous et al. 2013, Gusella et al. 2024, Sarpkaya 2014). These diseases cause serious damage to leaves, fruits, and roots and reduce both product quality and yield.

Septoria leaf spot disease is recognized as one of the major foliar diseases of pistachio in all pistachio-growing countries in the Mediterranean basin. The typical main symptom of the disease is irregular dark brown leaf spots with a diameter of 2 mm developing on the leaf surface. As the disease progresses, these spots may cover the entire surface of the compound leaves. Subsequently, the affected areas become chlorotic and then brown and necrotic. In necrotic lesions, spore beds of the pathogen (pycnidia) develop, which can be seen as black dots on the brown background of the lesion. Pycnidia produce abundant conidia under high humidity conditions and cottony white mycelium masses may develop on the lesions under humid conditions. Although not common, black spots also develop on fruits and petioles. Severe outbreaks of the disease combined with periods of high drought cause necrosis, premature defoliation, and reduced tree vigour (Gusella et al. 2024, López-Moral et al. 2022). Traditionally, the disease has been associated with three fungal species belonging to the genus *Septoria*: *S. pistaciae*, *S. pistaciarum*, and *S. pistacina* (Chitzanidis 1956). New information on the molecular characterisation of Septoria-like *Pistacia* species pathogens has reported *S. pistaciarum* and *S. pistaciae* as true *Septoria* species. However, *S. pistacina* was reassigned to the genus *Pseudocercospora* and renamed *Pseudocercospora pistacina* (Chitzanidis 1956; Crous et al. 2013). After the disease agent was definitively differentiated in our country (Crous et al. 2013), it was determined that it also caused disease in wild *Pistacia* species.

Especially climate change and modern agricultural practices cause diseases to occur more frequently and severely, therefore, effective control of these diseases in production processes gains great importance. Pathogenic characterisation of the disease has not been carried out in our country and most importantly, its control is not known. Detailed study of Septoria leaf spot disease and identification of the disease is very important in terms of control and continuity of pistachio production. In this study, for the sustainability of pistachio production and control of the disease, fungicides from different groups used in the control of similar diseases (called 'Karazenk') were tested and their *in vitro* and *in vivo* effects were performed to be determined.

Table 1. *Septoria pistaciarum* isolates used in the study

Isolate Codes	District	Location	North	East	Altitude	Sampling Date	Host
S-M-14	Merkez	Bulak Mezarlığı (Aykol Aile Kab.)	41°14'48''	32°39'33''	505	24.08.2021	*P. atlantica*
S-M-15	Merkez	Bulak Mezarlığı (Ahmet Uysal)	41°14'48''	32°39'32''	507	25.08.2021	*P. vera*
S-M-37	Merkez	Bulak Mezarlığı (Yol Kenarı)	41°14'50''	32°39'31''	508	06.09.2021	*P. vera*
S-M-43	Merkez	Bulak Mezarlığı (Gazi Ünv. Emekli Öğr.)	41°14'49''	32°39'33''	504	07.09.2021	*P. vera*
S-S-53	Safranbolu	Mezarlık (Canbülbül Aile Mezarlğı)	41°14'29''	32°41'47''	470	12.09.2021	*P. vera*
S-S-62	Safranbolu	Mezarlık (Emine Köklü)	41°14'29''	32°41'46''	470	14.09.2021	*P. atlantica*
S-S-63	Safranbolu	Mezarlık (Şevki Sazık)	41°14'29''	32°41'47''	470	16.09.2021	*P. atlantica*
S-S-76	Safranbolu	Mezarlık	41°14'27''	32°41'46''	470	26.09.2021	*P. atlantica*
S-S-81	Safranbolu	Mezarlık	41°14'26''	32°41'46''	469	19.09.2021	*P. terebinthus*
01-M	Adana/ Karaisalı	Çakmak Köyü Murtluca Mevkii	-	-	260	22.09.2022	*P. terebinthus*

MATERIALS AND METHODS

Plant and fungal material

The fungal material used in the project study was 9 isolates of *Septoria pistaciarum* obtained in the TUBITAK-2209-A (Project No: 1919B012005296) titled 'Investigation of Septoria Leaf Spotting Agents which is a Problem in Pistachio and Other Pistacia species in Karabük Province' previously carried out at Karabük University Faculty of Forestry. In addition, leaves infected with *S. pistaciarum* were collected from wild *P. terebinthus* trees in Çakmak neighbourhood of Karaisalı District of Adana Province and used as material (Table 1).

The studies were carried out in the laboratories of Karabük University, Faculty of Forestry. Potato Dextrose Agar (PDA) was used for fungal cultures, adding streptomycin sulphate to prevent bacterial contamination.

The active ingredients and ratios, trade names, formulation forms, and doses of the fungicides used for the control of the disease are given in Table 2.

Table 2. Fungicides used in the study

Active Substance and Ratio	Commercial Name	Formulation	Doses (dose/ml)
Boscalid + Pyraclostrobin (26.7%+6.7%)	Signum	WG (Suda Eriyen Granül)	0.3 mg, 0.6 mg, 1.2 mg, 2 mg
Azoxystrobin + Tebuconazole (120 g/l + 200 g/l)	Azimut	SC (Süspansiyon Konsantre)	0.2 µl, 0.4 µl, 0.75 µl, 1.25 µl
Prochloraz (450 g/l)	Tommi	EC (Emülsiyon Konsantre)	0.3 µl, 0.6 µl, 1 µl, 1.5 µl
Isopyrazam + Difenoconazole (100 g/l + 40 g/l)	Embrelia	SC (Süspansiyon Konsantre)	0.2 ml, 0.4 ml, 0.8 ml, 1 ml
Dodine (65%)	İzolprex	WP (Islanabilir Toz)	0.3 ml, 0.6 ml, 1 ml, 1.5 ml

After *in vitro* studies, the doses found to be effective were used in field trials on 30-year-old pistachio trees in the Safranbolu district of Karabük province.

Isolation method of fungi

Nine of the fungal isolates used in the study were obtained from previous studies which were stored in the Phytopathology laboratories of Karabük University, Faculty of Forestry before. An isolate was obtained from infected *Pistacia terebinthus* leaves. To ensure the culture continuity of the long-term stored samples, the isolates stored at -20 °C were kept in a sterile cabinet for 6 hours after they were removed. Then, small pieces were taken with a sterile scalpel and inoculated on PDA. For the isolation of the fungus, the single spore isolation method proposed by Sarpkaya (2014) was used. According to this method, spore suspension was obtained by scraping the pycnidium beds on the leaves in sterile 10 ml distilled water. The spore suspension was diluted 1/10 and the dilution process was continued until 2-3 x 10^6 conidia were obtained. 30-40 µl of the final suspension was added to each Petri dish and spread on the medium with a Drigalski spatula.

In vitro fungicide efficacy experiments

The PDA medium was sterilised in an autoclave and then placed in a water bath to cool to 45 °C. The fungicides listed in Table 2 were added at the recommended doses to each 90 mm diameter Petri dish and then 20 ml of fungicidal PDA was poured into each Petri dish. They were allowed to cool and become semi-solid in a sterile environment. Four Petri dishes were used for each dose, while four Petri dishes without fungicide were prepared as a control (Alberoni et al. 2005, Avenot and Michailides 2007). The experiments were carried out by a randomised experimental design.

From the cultures grown in the incubator for 21 days, mycelial discs with a diameter of 5 mm were taken from the active growth zone using a Koch borer and placed in the middle of the Petri dishes. Petri dishes to which no fungicide was added were used as a negative control group. They were incubated in the dark in incubators maintained at 24±1 °C.

At the end of the weekly controls, the mycelial radial growth of the fungal cultures was measured from four directions with the help of a ruler on the 28th day, and the experiment was terminated. After radial growth measurements, the samples were carefully separated from the medium and no medium residue was left on the surface. The wet weights of the mycelium were weighed on a precision balance and recorded. For the determination of dry weights, the samples were wrapped in aluminium foil, placed in an oven, and dried in an oven at 60 °C for 45 min according to the method of Yılmaz and Çolak (2008) and then weighed on a precision balance to determine the mycelium dry weights of the isolate groups.

Field fungicide efficacy determination studies

Fungicide efficacy trials against Septoria leaf spot disease were carried out on 40-year-old pistachio trees naturally infected with *S. pistaciarum* in Safranbolu in Karabük. The treatments were carried out after the natural infection of pistachio trees. Since there is no registered fungicide against Septoria leaf spot disease of pistachio in our country, the study was carried out with the fungicides listed in Table 2. Fungicide efficacy was evaluated using three different doses obtained from studies on inhibition of mycelial growth (Table 3). Fungicide applications were made under 20 atm pressure with the help of a motorised atomiser (Palmera PA-768) with 25 l capacity and conical nozzle type and 4.8 l of water was used for each tree. The first applications were made twice, the first on May 17th, 2023 and the second on June 7th, 2023. Evaluations and counts were carried out after 90 days.

Evaluation of results and statistical analyses

In *in vitro* fungicide efficacy trials, percentage efficacy was calculated by applying Abbott's (1925) formula to the results obtained from mycelial radial growth, mycelial wet weight, and mycelial dry weight measurements. The experiment was planned according to random plots experimental design with five replicates and each replicate was arranged to contain three Petri dishes. Data were analysed by the ANOVA method and differences between means were determined by LSD (Least Square Differences) test ($p<0.05$). All statistical analyses were performed using JMP 14.3.0 software.

Fungicide efficacy on plants was experimented according to the randomised block design with 3 replicates and 1 tree in each replicate. Symptom development from the leaves collected on the plants 90 days after the treatments were counted according to the scale values specified in Table 4 and fungicide efficacy was determined. No fungicide was applied to the control group plants.

Table 3. Fungicides and doses used in the field against Septoria leaf spot disease

Active Substances	Formulation	Doses (dose/100 l water)		
		1st dose	2nd dose	3rd dose
Boscalid + Pyraclostrobin	WG	20 gr	40 gr	75 gr
Azoxystrobin + Tebuconazole	SC	10 ml	30 ml	75 ml
Prochloraz	EC	20 ml	50 ml	100 ml
Isopyrazam + Difenoconazole	SC	20 ml	40 ml	80 ml
Dodine	WP	20 ml	50 ml	100 ml

Table 4. Karazenk (*Pseudocercospora pistacina*) disease Evaluation Scale* (Anonymous, 2024a)

Scales	Description
0	No spot
1	Spot rates on compound leaves till 20%
2	Spot rates on compound leaves between 21-40%
3	Spot rates on compound leaves between 41-60%
4	Spot rates on compound leaves between 61-80%
5	Spot rates on compound leaves more than 80%

* Since Septoria leaf spot disease is not included in the Agricultural Control Technical Instruction specified by the General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry, it was evaluated according to the evaluation scale of Karazenk disease, which causes damage as leaf spot disease.

RESULTS

Efficacy of fungicides on mycelial radial growth of S. pistaciarum

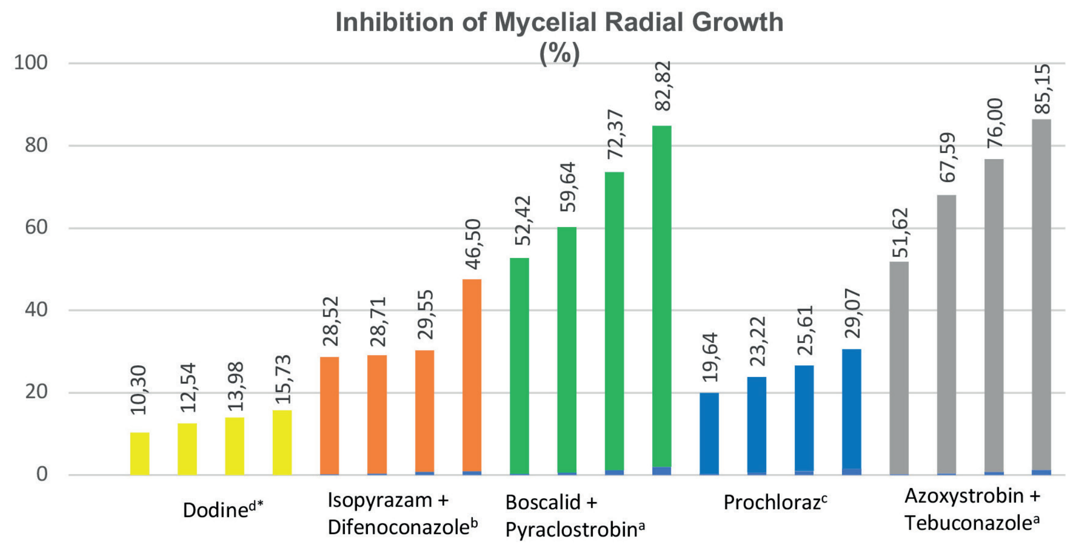
The effects of the selected fungicides on the mycelial radial growth of 10 *S. pistaciarum* isolates are presented in Table 5. As the fungicide doses increased, the percentage inhibition of mycelial radial growth of all isolates increased. The highest mean inhibition was observed at the dose of azoxystrobin + tebuconazole fungicide, 1.25 ml l^{-1} with 85.15% and at the dose of boscalid + pyraclostrobin fungicide, 2 g l^{-1} with 82.82%. The lowest inhibition was observed at 0.3 ml l^{-1} dose of dodine (10.30%) and 0.3 ml l^{-1} dose of prochloraz (19.64%) (Table 6).

In the statistical analysis, the fungicides containing the active substances azoxystrobin + tebuconazole and boscalid + pyraclostrobin were in the same group with the highest effect, while the fungicide with the active substance dodine showed the lowest effect in inhibiting the mycelial development of the pathogen fungus *in vitro* (Figure 1).

conducted with isopyrazam + difenoconazole fungicide, the average mycelial dry weights of the isolates obtained at 0.2, 0.4, 0.8 and 1 ml l^{-1} doses were 0.50, 0.46, 0.42, and 0.39 g, respectively. The mean mycelial dry weights of boscalid + pyraclostrobin fungicide at 0.3, 0.6, 1.2, and 2 ml l^{-1} doses were 0.47, 0.44, 0.42 and 0.39 g, respectively. For prochloraz, 0.30, 0.25, 0.20, and 0.18 g mycelial dry weight was obtained at the doses (0.3, 0.6, 1, 1.5 ml l^{-1}), respectively. The average mycelial dry weights of the isolates were 0.38, 0.31, 0.24, and 0.18 g for azoxystrobin + tebuconazole fungicide (0.2, 0.4, 0.75 and 1.25 ml l^{-1}), respectively.

Biological activity of fungicides on Septoria leaf blight disease under field conditions

The results of fungicide efficacy trials against Septoria leaf spot disease of pistachio trees are given in Table 7. A statistically significant difference was observed between the biological efficacies of the fungicides used in the study. The fungicides with the highest control efficacy were boscalid + pyraclostrobin and azoxystrobin + difenoconazole, while the lowest efficacy was obtained from prochloraz.



* There is a statistical difference between different letters following the same line (LSD test, P<0,05).

Figure 1. Mycelial radial growth inhibition of some fungicides tested against some selected isolates of *Septoria pistaciarum* (%)

Efficacy of fungicides on mycelial dry weight of S. pistaciarum

The effects of fungicides on the mycelial dry weight of 10 *S. pistaciarum* isolates are given in Table 6. Mycelial dry weight of all isolates decreased with increasing doses of fungicides. Mycelial weights of 0.48, 0.45, 0.41, and 0.38 g were obtained at the doses (0.3, 0.6, 1, and 1.5 ml l^{-1}) of the isolates in the study with dodine fungicide. In the study

In the statistical analysis of the doses of fungicides, there was no difference between the averages of biological activity percentages. However, an increase in the efficacy of all fungicides was observed with increasing doses. In the study conducted with boscalid + pyraclostrobin, disease control was achieved at 59.75%, 70.03%, and 85.81% at doses of 20, 40 and 75 g/100 l, respectively. In the trials with azoxystrobin

Table 5. Mycelial radial growth inhibition of some fungicides tested against some selected isolates of S. pistaciarum according to doses (%)

Fungicides	Doses (dose/L)	Inhibition of Mycelial Radial Growth Inhibition by Isolates (%)										Mean of Inhibition (%)
		SS-62	SS-53	SS-81	SS-63	SM-14	SM-37	SM-82	SM-43	SM-15	01-M	
Dodine	0.3 ml	18.47	7.63	17.02	7.98	0.59	25.82	16.67	0.82	0.99	7.04	10.30
Dodine	0.6 ml	23.98	8.47	18.10	12.91	1.35	26.17	19.05	2.60	1.05	11.71	12.54
Dodine	1 ml	24.36	11.28	19.04	16.59	2.32	26.29	21.26	2.43	1.12	15.07	13.98
Dodine	1.5 ml	24.62	12.11	20.30	21.15	3.98	28.23	23.34	4.09	1.38	18.05	15.73
Isopyrazam + Difenoconazole	0.2 ml	30.98	28.53	31.52	27.25	25.49	26.96	24.31	32.55	27.40	30.20	28.52
Isopyrazam + Difenoconazole	0.4 ml	29.39	29.48	30.29	31.59	30.40	27.99	24.82	26.25	31.50	25.36	28.71
Isopyrazam + Difenoconazole	0.8 ml	29.86	30.35	31.88	37.09	22.28	29.57	38.59	20.79	34.30	20.83	29.55
Isopyrazam + Difenoconazole	1 ml	39.92	30.39	54.44	56.02	54.44	30.43	66.04	45.38	42.50	45.45	46.50
Boscalid + Pyraclostrobin	0.3 g	75.53	70.64	64.86	61.80	34.42	38.08	33.69	41.73	56.82	46.62	52.42
Boscalid + Pyraclostrobin	0.6 g	84.14	73.93	66.76	71.66	48.15	38.54	42.76	52.76	67.97	49.68	59.64
Boscalid + Pyraclostrobin	1.2 g	86.18	75.83	78.50	73.88	67.53	46.76	85.21	68.10	78.97	62.75	72.37
Boscalid + Pyraclostrobin	2 g	91.15	85.12	89.28	86.12	85.12	59.41	91.13	84.91	80.02	75.97	82.82
Prochloraz	0.3 ml	31.02	59.32	25.00	6.98	4.45	14.48	13.26	5.83	12.24	23.85	19.64
Prochloraz	0.6 ml	32.33	59.62	25.74	10.86	9.86	16.05	17.55	20.83	13.80	25.53	23.22
Prochloraz	1 ml	33.82	59.97	27.19	14.23	12.96	16.68	18.91	29.81	15.59	26.91	25.61
Prochloraz	1.5 ml	34.88	60.65	28.73	17.68	16.69	18.50	28.81	39.47	17.44	27.85	29.07
Azoxystrobin + Tebuconazole	0.2 ml	68.01	48.95	59.36	35.37	69.92	62.21	35.01	22.29	54.79	60.29	51.62
Azoxystrobin + Tebuconazole	0.4 ml	79.41	73.69	69.12	47.43	79.75	74.54	58.37	51.08	72.11	70.41	67.59
Azoxystrobin + Tebuconazole	0.75 ml	87.34	75.08	72.89	58.40	87.96	76.02	69.51	68.97	82.35	81.46	76.00
Azoxystrobin + Tebuconazole	1.25 ml	88.05	87.08	85.55	70.39	91.29	95.97	74.53	76.15	91.02	91.48	85.15

Table 6. Mycelial dry weights according to the doses of some fungicides tested against some selected isolates of *Septoria pistaciarum* (g)

Fungicides	Doses (dose/L)	Mycelial Dry Weights According to Isolates (g)										Means of Mycelial Dry Weights (g)
		SS-62	SS-53	SS-81	SS-63	SM-14	SM-37	SM-82	SM-43	SM-15	01-M	
Dodine	0.3 ml	0.49	0.42	0.56	0.49	0.34	0.47	0.55	0.51	0.48	0.49	0.48
Dodine	0.6 ml	0.44	0.37	0.53	0.44	0.30	0.44	0.54	0.49	0.46	0.45	0.45
Dodine	1 ml	0.39	0.32	0.44	0.42	0.30	0.39	0.51	0.45	0.45	0.42	0.41
Dodine	1.5 ml	0.34	0.27	0.42	0.39	0.29	0.35	0.50	0.41	0.45	0.39	0.38
Isopyrazam + Difenoconazole	0.2 ml	0.32	0.52	0.59	0.56	0.48	0.56	0.47	0.56	0.49	0.40	0.50
Isopyrazam + Difenoconazole	0.4 ml	0.27	0.49	0.57	0.52	0.45	0.53	0.46	0.55	0.46	0.34	0.46
Isopyrazam + Difenoconazole	0.8 ml	0.25	0.44	0.54	0.49	0.29	0.51	0.41	0.54	0.38	0.33	0.42
Isopyrazam + Difenoconazole	1 ml	0.21	0.41	0.52	0.48	0.25	0.47	0.40	0.51	0.32	0.31	0.39
Boscalid + Pyraclostrobin	0.3 g	0.53	0.47	0.48	0.48	0.40	0.41	0.47	0.51	0.49	0.47	0.47
Boscalid + Pyraclostrobin	0.6 g	0.47	0.41	0.45	0.42	0.39	0.39	0.45	0.50	0.48	0.46	0.44
Boscalid + Pyraclostrobin	1.2 g	0.46	0.38	0.41	0.40	0.35	0.37	0.41	0.49	0.46	0.44	0.42
Boscalid + Pyraclostrobin	2 g	0.42	0.37	0.37	0.36	0.32	0.33	0.40	0.43	0.44	0.43	0.39
Prochloraz	0.3 ml	0.52	0.39	0.27	0.14	0.17	0.38	0.35	0.27	0.22	0.25	0.30
Prochloraz	0.6 ml	0.32	0.31	0.26	0.14	0.16	0.32	0.25	0.27	0.20	0.22	0.25
Prochloraz	1 ml	0.25	0.24	0.22	0.12	0.15	0.30	0.22	0.21	0.13	0.20	0.20
Prochloraz	1.5 ml	0.23	0.16	0.18	0.11	0.14	0.25	0.21	0.21	0.11	0.18	0.18
Azoxystrobin + Tebuconazole	0.2 ml	0.16	0.47	0.38	0.44	0.40	0.43	0.32	0.40	0.40	0.40	0.38
Azoxystrobin + Tebuconazole	0.4 ml	0.15	0.38	0.30	0.34	0.33	0.34	0.26	0.32	0.28	0.40	0.31
Azoxystrobin + Tebuconazole	0.75 ml	0.14	0.30	0.20	0.26	0.26	0.23	0.22	0.27	0.17	0.39	0.24
Azoxystrobin + Tebuconazole	1.25 ml	0.10	0.20	0.15	0.18	0.19	0.12	0.17	0.19	0.08	0.37	0.18

+ difenoconazole, 10, 30, and 75 ml/100 l water doses of the fungicide were used and the efficacy levels obtained were 57.13%, 68.08%, and 83.80%, respectively. For isopyrazam + difenoconazole fungicide, efficacy levels of 42.44%, 58.26%, and 65.62% were obtained at 20, 40, and 80 ml/100 l water doses, respectively. Dodine provided 39.60%, 46.42%, and 52.29% disease control at doses of 20, 50 and 100 ml/100 l water, respectively. Prochloraz showed biological efficacy of 33.44%, 39.90%, and 48.30% in trials with 20, 50, and 100 ml/100 l water doses, respectively (Table 7).

Table 4. Biological efficacy results of different doses of fungicides used under field conditions in controlling Septoria leaf blight disease

Fungicides	Doses (100 l)	Effect (%)
	20 g	59.75
Boscalid + Pyraclostrobin[a]	40 g	70.03
	75 g	85.81
	10 ml	57.13
Azoxystrobin + Tebuconazole[a]	30 ml	68.08
	75 ml	83.80
	20 ml	33.44
Prochloraz[d]	50 ml	39.90
	100 ml	48.30
	20 ml	42.44
Isopyrazam +Difenoconazole[b]	40 ml	58.26
	80 ml	65.62
	20 ml	39.60
Dodine[c]	50 ml	46.42
	100 ml	52.29

DISCUSSION

Pistachio production in the world is carried out by direct garden establishment or grafting of wild *Pistacia species* and there are many wild *Pistacia species* in our country (Ak and Kaşka 1998). Species of the genus Septoria cause leaf spots on pistachios and other Pistaceae, prevent the plant from photosynthesizing, and cause premature leaf fall, resulting in yield losses. In the studies carried out with *Septoria-like* fungi in our country, the causal organisms were clearly separated from each other, and the causal agent of Karazenk disease in pistachio was redefined as *Pseudocercospora pistacina*, while it was revealed that *Septoria pistaciarum* causes leaf spots not only in pistachio but also in other Pistacias (Crous et al. 2013, Sarpkaya 2014).

Although there are many effective fungicides in the control of 'Karazenk' disease, which is widespread in pistachio production areas in the Southeast region, studies on the control of Septoria leaf spot disease caused by *S. pistaciarum* are limited. Call and Matheron (1994) reported that all fungicides reduced the severity of the disease in field studies conducted in the United States of America with chlorothalonil, benomyl, and copper hydroxide.

The most effective fungicides were boscalid + pyraclostrobin and azoxystrobin + difenoconazole group fungicides in the *in vitro* mycelial radial growth inhibition study with *S. pistaciarum* isolates used in the study. Pappas et al. 2010, in a study conducted with 36 isolates of *Septoria pyricola,* found that fungicides containing boscalid and azoxystrobin were highly effective. In *in vitro* fungicide efficacy studies carried out against *S. petroselini*, which is a problem in parsley, it was found that fungicide containing tebuconazole was highly effective in inhibiting mycelial development. Erdurmuş et al. (2024) determined the susceptibility levels of the isolates to azoxystrobin, tebuconazole, and mancozeb by radial growth test in their study on the determination of fungicide susceptibilities against *Alternaria alternata*, early leaf blight of tomato and determined that some isolates were highly susceptible to the mentioned fungicides.

In the fungicide efficacy experiment conducted in pistachio orchards contaminated with natural *S. pistaciarum* in field studies, boscalid + pyraclostrobin and azoxystrobin + difenoconazole fungicides were found to be highly effective compared to the others. On the other hand, the lowest efficacy was observed with prochloraz fungicide. Fungicides with this active ingredient are widely used in many crops in the world with licences (Anonymous 2024b). However, since Septoria leaf spot disease is not defined in the agricultural control technical instructions of our country, there is no registration.

Pistachio areas in our country have increased by 37% in the last decade and although most of the production is carried out in the Southeastern Anatolia Region, pistachio cultivation is also increasing in the Aegean, Mediterranean, Marmara and Central Anatolia regions (İlikçioğlu 2022). With the expansion of production in different regions, different diseases may occur in pistachios. Septoria leaf spot disease is seen as an important factor that will limit pistachio production. The data obtained from this study have an important place in controlling the disease.

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Author's Contributions

Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

ÖZET

Antep fıstığı (*Pistacia vera* L.), yüksek besin değerine sahip olması ve uluslararası pazarlarda da talep görmesi nedeniyle stratejik bir tarım ürünü olarak kabul edilir. Son yıllarda üretim alanlarının genişlemesiyle birlikte, Antep fıstığı yetiştiriciliği artarken, hastalık ve zararlılarla mücadele ön plana çıkmaktadır. *Septoria pistaciarum* Caracc.'ın, sebep olduğu Septoria yaprak lekesi hastalığı Antep fıstığı ağaçlarında yaprak lekeleri oluşturan önemli bir fungal patojendir. Bu çalışmada farklı Pistacia türlerinden elde edilen on izolat üzerinde farklı gruptan yer alan fungisitlerin etkinlikleri araştırılmıştır. Patojen fungusun *in vitro* miseliyal radial gelişimin inhibe edilmesinde azoxystrobin + difenoconazole etken maddeli fungisitin 1.25 ml l^{-1} dozunda %85.15 düzeyinde en yüksek oranda gelişimin engellendiği, dodine'in 0.3 ml l^{-1} dozunda fungal gelişimin %10.30 ile en düşük düzeyde inhibe edildiği görülmüştür. Karabük ilinde *S. pistaciarum* ile bulaşık Antep fıstığı ağaçlarında yürütülen çalışmada boscalid + pyraclostrobin etken maddeli fungisitin 75 g/100 l su dozunda %85.81 oranında en yüksek biyolojik etkinliği göstediği, azoxystrobin + tebuconazole etken maddeli fungisitin 75 ml/100 l su dozunda %83.80 düzeyinde hastalık kontrolü sağladığı görülmüştür. Septoria yaprak lekesi hastalığının kontrolünde en düşük biyolojik etkinliği prochloraz (%33.44) etken maddeli fungisit göstermiştir. Bu sonuçlar, Antep fıstığı yetiştiriciliğinde Septoria yaprak lekesi hastalığı ile mücadelede kullanılan fungisitlerin etkililik oranlarını ortaya koyarak, hastalık kontrolü açısından önemli veriler sunmaktadır.

Anahtar kelimeler: *Septoria pistaciarum*, Antep fıstığı, fungisit, hastalık kontrolü

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