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Araştırma Makalesi/Reserach Article

Determination of the Reactions of Safflower Genotypes to *Puccinia carthami* Under Edirne, Türkiye Conditions

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Abstract

Safflower rust disease caused by *Puccinia carthami* is one of the most important fungal diseases of the safflower plants. In this study, under natural conditions, safflower rust disease resistance of 219 genotypes (159 linoleic and 60 oleic types) was determined under Edirne, Türkiye conditions during the full bloom stage in 2019. Disease reaction was evaluated using a 0-5 scale. As a result of the study, 178, 23, 5, and 3 genotypes were found to be resistant, moderately resistant, moderately susceptible, and susceptible, respectively.
Keywords: *Puccinia carthami,* Safflower Rust, Safflower, Linoleic Type Safflower, Oleic Type Safflower, Disease Resistance

Edirne Şartlarında Aspir Genotiplerinin *Puccinia carthami*'ye Reaksiyonlarının Belirlenmesi

Öz

Puccinia carthami'nin neden olduğu aspir pas hastalığı, aspir bitkisinin en önemli fungal hastalıklarından birisidir. Bu çalışmada, 2019 yılında aspir bitkisinin tam çiçeklenme döneminde Edirne ilinde doğal şartlar altında 219 genotipin (159 linoleik ve 60 oleik tip) aspir pas hastalığına karşı dayanıklılığı belirlenmiştir. Hastalık reaksiyonu 0-5 ıskalası kullanılarak değerlendirilmiştir. Çalışma sonucunda 178, 23, 5 ve 3 genotip sırasıyla dayanıklı, orta derecede dayanıklı, orta derecede hassas ve hassas olarak bulunmuştur.
Anahtar Kelimeler: *Puccinia carthami,* Aspir Pas Hastalığı, Aspir, Linoleik Tip Aspir, Oleik Tip Aspir, Hastalıklara Karşı Dayanıklılık

Introduction

Safflower (*Carthamus tinctorius* L.), a member of the Asteraceae family, is an oil plant with a 50–100 cm height. It is commonly planted in Arabian Peninsula, Iran, Pakistan, and India. Safflower is also planted in Türkiye (Knights et al., 2010; Anonymous, 2020).

Safflower is an annual oil crop with flowers yellow, red, orange, cream and white in color. It has both spiny and spineless types. Safflower is resistant to drought conditions and its oil content ranges between 30-50%. Two types of oil, linoleic (omega 6) and oleic (omega 9), are present in safflower cultivars (Babaoğlu, 2006).

Different biotic and abiotic factors affect safflower plants negatively. Numerous fungi, viruses, bacteria, and parasitic nematodes are responsible for large yield losses (Madhu, 2014). All parts of the safflower plant can be affected. *Puccinia carthami, Alternaria alternata*, *A. carthami, Bremia lactuca, Cochliobolus sativus, Fusarium* spp., *Leveilla taurica, Golovinomyces cichoracearum (Erysiple cichoracearum), Phytophthora drechsleri, Macrophomina phaseolina, Pythium* spp., *Ramularia cynarae (R. carthami* and/or *Cercospora carthami), Thanatephorus cucumeris (Rhizoctonia solani)* and *Sclerotinia sclerotiorum,* have been reported as the disease-causing agents of *Carthamus tinctorius* (Dajue and Mundel, 1996; Ershad, 2009; Esfahani et al., 2018).

One of the leaf diseases of safflower is incited by the rust fungus *Puccinia carthami*. This disease lowers the quality and quantity of safflower plants. *Puccinia carthami* can be both soil-borne or seed-borne. The disease can spread from the plant remains or from diseased plants. The rust fungus

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forms reddish-brown rust pustules on the leaves. These pustules are about 3 cm in diameter and circled with a yellow halo (Park and Lee, 2003; Knights et al., 2010).

Safflower rust is common in the world as well as in Türkiye (Deadman et al., 2005; Khan, 1972; Klisiewicz, 1977; Gürcan, 1976). Karaca (1965) reported the disease in Central Anatolia region of Türkiye and Sağır and Kızıl (1998) reported safflower rust from Diyarbakır, Türkiye.

There are limited studies related to safflower rust in Türkiye. Under field conditions, Karakaya et al. (2004) evaluated the response of safflower genotypes to the rust disease in Ankara province of Türkiye. In their study, the disease was detected on the leaves of all genotypes tested. The lowest and highest disease incidences were observed on the Afyon and Syrian 1 genotypes, respectively. Afyon genotype had significantly fewer symptoms than the genotypes Sivas, Syrian 1, Cyprebregon, Syrian Hama, PI 251982, PI 537598, and Gila. In another study, Kalafat et al. (2009) determined the reactions of 210 safflower genotypes to rust disease under field conditions in Ankara, Türkiye. Thirty, 26, 27, and 127 genotypes were found as resistant, moderately resistant, moderately susceptible, and susceptible, respectively. In another study carried out in Edirne, Türkiye among the linoleic type safflowers 18, 67, 46, and 15 genotypes were found as resistant, moderately resistant, moderately susceptible, and susceptible, respectively. In the same study, among the oleic type safflowers 16, 30, and 18 genotypes were found as moderately resistant, moderately susceptible, and susceptible, respectively. No resistant genotypes were observed among the oleic type safflowers (Anonymous, 2015).

In this study, reactions of 219 safflower genotypes to rust disease were evaluated under field conditions in Edirne, Türkiye.

Materials and Methods

In this study, under field conditions, a total of 219 safflower genotypes were evaluated for their reaction to rust disease caused by *Puccinia carthami* at the Trakya Agricultural Research Institute (TARI) located in Edirne-Türkiye. *Puccinia carthami* has been identified morphologically (Park and Lee, 2003). Sixty oleic type and 159 linoleic type safflower genotypes were planted in April 2019. Plantings were made as 3 rows and 2 meters in length with 0.34 m row spacing. Among the oleic types, 8 of them are foreign and domestic registered varieties (Montola 2001, Ole, S-317, Remzibey-05, Olas, Montola-2000, Asol and Olein), 34 of them were lines developed by TARI and the other 18 genotypes were foreign populations around the World provided by USDA Gene Bank, Pullman, WA, USA and pure lines (Seledas-248, Seledas-249, Seledas-250, and Seledas-251) selected from these populations.

Out of 159 tested linoleic type safflower genotypes, 22 genotypes were domestic and foreign registered varieties (Girard, Finch, Quiriego 88, Gila, Rio, Royal, UC-148=W6 9814, LMVFB-1, Centennial, Yenice, Dinçer, Linas, Rancho, S-541, AC Stirling, Dart, Oker, Balcı, Göktürk, Zirkon, Hasankendi, and Safir), 56 were advanced candidate lines developed by the TARI through the breeding program, 29 were pure lines selected from the populations by TARI and the remaining 52 safflower genotypes were populations received from the USDA Gene Bank, Pullman, WA, USA.

During this study, no artificial inoculation was performed and the experiment was conducted under natural inoculum conditions in the field. Twenty leaf samples were collected from each randomly selected plant in each plot and scored in the laboratory (total of 20x219 leaves were collected). These leaves were evaluated for their resistance status to safflower rust using a 0-5 scale (Table 1) (Sağır and Kızıl, 1998).

Table 1. Safflower rust 0-5 evaluation scale (Sağır and Kızıl, 1998)

Scale value	Reaction type
0	No disease
1	1-5% of the leaf area diseased
2	6-10% of the leaf area diseased
3	11-25% of the leaf area diseased
4	26-50% of the leaf area diseased
5	More than 50% of the leaf area diseased

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Mean scale ranged between the values 0.00–1.49, 1.50–2.49, 2.50–3.49, and 3.50–5.00 were considered as resistant, moderately resistant, moderately susceptible, and susceptible, respectively (Table 2) (Kalafat et al., 2009).

Table 2. Reaction types of safflower genotypes used in this study (Kalafat et al., 2009)

Scale range	Reaction types
0.00 – 1.49	Resistant
1.50 – 2.49	Moderately Resistant
2.50 – 3.49	Moderately Susceptible
3.50 – 5.00	Susceptible

Results and Discussion

This study was carried away in 2019 at Trakya Agricultural Research Institute research field located in Edirne, Türkiye. There were 219 safflower genotypes which consisted of linoleic and oleic types. The rust disease was observed at various levels (Figure 1). The reactions of these genotypes were determined using a 0-5 scale (Table 1). The reaction types were assessed using the values in Table 2 and the results were presented in Table 3.

Among the linoleic type safflower genotypes, Girard, Finch, Quiriego, Gila, Rio, Royal, UC-148 (=W6 9814), LMVFB-1, Centennial, Yenice, Dinçer, Linas, Rancho, AC Stirling, Dart, Oker, Balcı, Göktürk, Zirkon, Hasankendi, Safir and 131 genotypes were found as resistant (R). Four lines were moderately resistant (MR) and cultivar S-541 and 2 lines were moderately susceptible (MS). Among the oleic type safflowers, genotypes S-317, Remzibey-05, Olein, and 23 lines were resistant (R), cvs Montola 2001, Olas, Montola-2000 and 16 lines were moderately resistant (MR), cv Asol and 11 lines were moderately susceptible (MS) and cv Ole and 2 lines were susceptible (S). In this current study, it appeared that the resistance status of linoleic types was superior to oleic types.

There are limited studies related to safflower rust in Türkiye. Studies performed by Karakaya et al. (2004) and Kalafat et al. (2009) showed the resistance diversity among the genotypes. In their studies, genotypes were grouped as resistant, moderately resistant, moderately susceptible, and susceptible. The same diversity groups were also observed in our current study. In our current study, cv. Gila was found as resistant. This cultivar received a 2.837 mean scale value in the Karakaya et al. (2004) study. In our current study, cvs Remzibey 05, Yenice, and Dinçer were observed as resistant to safflower rust. However, Emir et al. (2010) reported Remzibey 05, Yenice and Dinçer cultivars as susceptible, moderately susceptible, and resistant under Ankara conditions, respectively. Especially the difference in the Remzibey 05 cultivar could be due to fungus races or hot and dry weather conditions in Ankara as compared to more humid Edirne conditions. Races of *Puccinia carthami* occur (El-Sherif et al., 1980). Oleic type cultivar Ole exhibited a susceptible response to rust in our current study, however, this cultivar was reported as moderately susceptible in another study (Anonymous, 2015). Linoleic types Royal, Centennial, Yenice, Linas, Sahuaripa 88, and Oker exhibited resistant responses in our current study, on the other hand, they were placed in the moderately susceptible group in another study (Anonymous, 2015). Linoleic types Seledas-155 and Seledas-211 were resistant in our current study as well as in Anonymous (2015) study.

Figure 1. Rust disease observed in safflower genotypes

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Table 3. Reactions of safflower genotypes to rust disease caused by *Puccinia carthami*. For evaluation a 0-5 scale was used (Sağır and Kızıl, 1998; Kalafat et al., 2009)

Oleic type safflower genotypes

No:	Genotype	Mean scale value	Reaction Type	No:	Genotype	Mean scale value	Reaction Type
1	W6 9818	3.7	S	**31**	TRE-OA06-04-631110T	1.85	MR
2	W6 9819	2.75	MS	**32**	Seledas-248	2.5	MS
3	W6 9820	2.4	MR	**33**	Seledas-249	2	MR
4	W6 9821	2.1	MR	**34**	Seledas-250	0.65	R
5	W6 9822	2.75	MS	**35**	Seledas-251	0.65	R
6	W6 9824	2.4	MR	**36**	TRE-OA08-01-131110T	1.05	R
7	1013	2.75	MS	**37**	TRE-OA08-01-132210T	2.5	MS
8	1136	3.2	MS	**38**	TRE-OA08-01-423110T	1.85	MR
9	1137	3.40	MS	**39**	TRE-OA08-01-423210T	1.9	MR
10	1138	2.60	MS	**40**	TRE-OA08-02-222210T	1.15	R
11	1139	2.55	MS	**41**	TRE-OA08-03-211220T	2.35	MR
12	MONTOLA 2001	2.15	MR	**42**	TRE-OA08-03-324110T	1.6	MR
13	OLE	3.70	S	**43**	TRE-OA09-01-221120T	0.15	R
14	HONGHUA (BJ-45)	2.70	MS	**44**	TRE-OA09-01-221210T	1.05	R
15	S-317	1.35	R	**45**	TRE-OA09-03-431110T	1.05	R
16	REMZİBEY-05	1.40	R	**46**	TRE-OA09-04-621110T	0.1	R
17	OLAS	1.90	MR	**47**	TRE-OA09-04-621120T	0.15	R
18	Montola-2000	2.00	MR	**48**	TRE-OA09-04-621220T	0.05	R
19	Seledas-187	1.30	R	**49**	TRE-OA09-04-621410T	0	R
20	TRE-OA05-02-212110T	1.95	MR	**50**	TRE-OA10-02-512110T	2.25	MR
21	TRE-OA05-02-231110T	0.90	R	**51**	TRE-OA10-03-331110T	4.05	S
22	TRE-OA05-04-141110T	3.00	MS	**52**	TRE-OA10-03-511110T	1.35	R
23	TRE-OA05-05-113110T	0.65	R	**53**	TRE-OA10-04-321110T	1.55	MR
24	TRE-OA05-05-151110T	0.90	R	**54**	TRE-OA10-04-411120T	0.3	R
25	TRE-OA05-05-251110T	1.45	R	**55**	OLEİN	0	R
26	ASOL	3.10	MS	**56**	TRE-OA11-01-621110T	0.35	R
27	TRE-OA05-06-173110T	1.85	MR	**57**	TRE-OA11-01-621120T	1.15	R
28	BJ-2032	2.05	MR	**58**	TRE-OA11-04-231110T	1.7	MR
29	TRE-OA06-01-412110T	2.05	MR	**59**	TRE-OA11-04-241110T	0.85	R
30	TRE-OA06-04-321120T	1.10	R	**60**	TRE-OA11-04-412110T	0.1	R

Linoleic type safflower genotypes

No:	Genotype	Mean scale value	Reaction Type	No:	Genotype	Mean scale value	Reaction Type
1	Seledas-1	0	R	**81**	TRE-LA05-03-111110T	0.1	R
2	Seledas-7	0	R	**82**	TRE-LA05-03-222110T	0	R
3	N-259 (BJ-1476)	0.45	R	**83**	TRE-LA05-04-111110T	0.1	R
4	GIRARD	0	R	**84**	TRE-LA05-04-131110T	0.2	R
5	FINCH	0	R	**85**	TRE-LA05-04-221110T	0.05	R
6	QUIRIEGO 88	0	R	**86**	TRE-LA05-05-121110T	0.05	R
7	1011	0.4	R	**87**	TRE-LA05-06-141110T	0.05	R
8	GILA	0.2	R	**88**	TRE-LA05-07-131110T	0.05	R

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Table 3. Reactions of safflower genotypes to rust disease caused by *Puccinia carthami*. For evaluation a 0-5 scale was used (continued) (Sağır and Kızıl, 1998; Kalafat et al., 2009)

Linoleic type safflower genotypes

9	RIO	0.05	R	**89**	TRE-LA05-08-241210T	0.45	R
10	ROYAL	0.15	R	**90**	Seledas-192	0.25	R
11	1122	0.1	R	**91**	Seledas-204	0.05	R
12	1123	0.45	R	**92**	Seledas-205	0.05	R
13	UC-148 = W6 9814	0.1	R	**93**	Seledas-210	0.05	R
14	LMVFB-1	0.1	R	**94**	Seledas-211	0	R
15	W6 9828	0.4	R	**95**	Seledas-215	0.1	R
16	14-5	0.15	R	**96**	Seledas-222	0.15	R
17	CENTENNIAL	0.25	R	**97**	Seledas-226	0.1	R
18	YENİCE	0.2	R	**98**	Seledas-234	0.15	R
19	DİNÇER	0.1	R	**99**	BALCI	0	R
20	Seledas-86	0.2	R	**100**	Seledas-190	0.05	R
21	LINAS	0	R	**101**	Seledas-244	0	R
22	Seledas-101	0.2	R	**102**	Seledas-247	0.05	R
23	Rancho	1.35	R	**103**	BJ-892	0.05	R
24	Seledas-114	3.15	MS	**104**	TRE-LA08-03-211110T	0.05	R
25	Seledas-115	0.1	R	**105**	TRE-LA08-03-431140T	0	R
26	Seledas-133	1.5	MR	**106**	TRE-LA08-04-142110T	0	R
27	S-541	2.95	MS	**107**	TRE-LA08-04-142120T	0	R
28	14-5 ISO	2.3	MR	**108**	TRE-LA08-04-211120T	0	R
29	SAHUARIPA 88	1	R	**109**	TRE-LA08-05-242110T	0	R
30	SAN JOSE 89	0.3	R	**110**	TRE-LA08-05-243120T	0.25	R
31	BJ-768	0.35	R	**111**	GÖKTÜRK	0.85	R
32	BJ-774	0.3	R	**112**	TRE-LA09-01-331410T	0.4	R
33	BJ-830	0.05	R	**113**	S-742	0	R
34	BJ-846	0.3	R	**114**	TRE-LA09-02-221110T	0.05	R
35	BJ-929	0	R	**115**	TRE-LA09-02-221310T	0.3	R
36	LESAF 175	0	R	**116**	TRE-LA09-02-221510T	0	R
37	S-742	0	R	**117**	TRE-LA09-02-611220T	0.3	R
38	1039	0	R	**118**	BJ-892	0.05	R
39	1045	0.1	R	**119**	TRE-LA09-02-721110T	0.05	R
40	11-5	0	R	**120**	TRE-LA09-04-111120T	0	R
41	REHBEIN	0	R	**121**	TRE-LA09-04-131110T	0	R
42	BJ-898	0	R	**122**	TRE-LA09-05-631120T	0.1	R
43	IL-111	0.15	R	**1123**	S-742	0.15	R
44	Seledas-140	0.1	R	**124**	TRE-LA09-06-311220T	0	R
45	Seledas-141	0.15	R	**125**	BJ-892	0.15	R
46	BJ-697	0.2	R	**126**	TRE-LA09-06-311510T	0.1	R
47	BJ-982	0.3	R	**127**	TRE-LA09-06-	0	R

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					321210T		
48	BJ-1126	0	R	**128**	TRE-LA09-06-321510T	0	R

Table 3. Reactions of safflower genotypes to rust disease caused by *Puccinia carthami*. For evaluation a 0-5 scale was used (continued) (Sağır and Kızıl, 1998; Kalafat et al., 2009)

Linoleic type safflower genotypes

49	BJ-1171	0.3	R	**129**	TRE-LA09-06-321920T	0.05	R
50	BJ-1221	0.25	R	**130**	TRE-LA09-06-721110T	0.25	R
51	BJ-1300	0.15	R	**131**	AsTurkmenSel-1	1.7	MR
52	BJ-2741	0.65	R	**132**	ZİRKON	0.05	R
53	BJ-2147	0.55	R	**133**	TRE-OA06-04-211110T	0	R
54	BJ-2151	0.2	R	**134**	HASANKENDİ	0.05	R
55	1029	0.2	R	**135**	TRE-LA10-01-211210T	0	R
56	1032	0.2	R	**136**	TRE-LA10-01-214120T	0.05	R
57	AC Stirling	0	R	**137**	TRE-LA10-01-511110T	0.05	R
58	Dart	0	R	**138**	TRE-LA10-01-513310T	0.05	R
59	Oker	0.1	R	**139**	TRE-LA10-01-531120T	0	R
60	1041	0.1	R	**140**	TRE-LA10-03-211110T	0	R
61	1054	0.05	R	**141**	TRE-LA10-03-221110T	0.05	R
62	1069	0.1	R	**142**	TRE-LA10-03-221120T	0.2	R
63	1086	0.25	R	**143**	TRE-LA10-03-221210T	0.05	R
64	1120	0.2	R	**144**	TRE-LA10-03-221220T	0.2	R
65	1121	0.1	R	**145**	TRE-LA10-03-321210T	0	R
66	Lesaf-414	0.4	R	**146**	TRE-LA10-03-321310T	0	R
67	Enana	0.8	R	**147**	TRE-LA10-04-112110T	0.15	R
68	1042	0.15	R	**148**	TRE-LA10-04-322110T	0.25	R
69	N-8 (1118)	0.25	R	**149**	TRE-LA10-07-221110T	0	R
70	Seledas-153	0	R	**150**	TRE-LA10-07-311110T	0.05	R
71	Seledas-155	0.1	R	**151**	SAFİR (K)	0.15	R
72	WSRC01	0.05	R	**152**	TRE-LA11-01-231110T	0.05	R
73	TRA-03-01-811120T	0.3	R	**153**	TRE-LA11-02-113110T	0	R
74	Seledas-144	0.2	R	**154**	TRE-LA11-02-116210T	0.25	R
75	Seledas-161	0.85	R	**155**	TRE-LA11-03-111110T	0.1	R
76	Seledas-166	0.35	R	**156**	TRE-LA11-04-122210T	0.25	R
77	Seledas-169	2.1	MR	**157**	TRE-LA11-06-331110T	0	R
78	Seledas-171	0.55	R	**158**	TRE-LA11-06-331220T	3.05	MS
79	Seledas-186	0	R	**159**	TRE-LA11-07-212110T	0.55	R
80	SIDWILL	0.05	R				

Environmental conditions and possible fungus races may be responsible for these results. Also, amount of natural inoculum may have an effect. Based on our results, it can be said that the resistance status of linoleic types was superior to oleic types. Safflower genotypes tested in our current study exhibited a wide array of resistance, however, the majority of these genotypes were placed in the resistant group.

In the USA, Claassen et al. (1949) observed that the majority of safflower genotypes were susceptible, however, introductions from Türkiye and Romania were immune. In their study, individual plant selection from 'Yenice 1813' produced progeny that were resistant, susceptible, or segregating. Under greenhouse conditions, Al-Beldawi and Walleed (1976) tested *Carthamus tinctorius* plants grown in soil infested with teleutospores of *Puccinia carthami*. No variety showed strong resistance but, of the six varieties investigated, Nebraska 1284 and American 3 both had over 50% of plants free from infection 80 days after sowing. Zazzarini and Cappelli (1981), in Italy, reported severe rust attacks. Of 6 cvs, Safflola 202 appeared the most resistant cultivar to *P. carthami*.

Growing resistant genotypes is one of the preferred methods in diseases control. Resistant and moderately resistant genotypes identified in this current study can be used in breeding studies as genitor lines.

Authors' Contributions

M.S.A., and A.K. conceived the study, carried out disease evaluation and wrote the manuscript. M. B. provided plant materials and carried out agronomic studies. All authors approved the final manuscript.

Conflicts of Interest Statement

The authors declare that there is no conflict of interest.

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