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Original article

Seedling resistance of some bread wheat genotypes to *Fusarium pseudograminearum*

Bazı ekmeklik buğday genotiplerinin *Fusarium pseudograminearum*'a fide dönemi dayanıklılıkları

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A B S T R A C T

Fusarium pseudograminearum is one of the most damaging *Fusarium* species that causes root, crown, and foot rots in wheat. Identification of resistant germplasm is one of the most efficient and environmentally sound control methods. However, up to date, limited wheat genotypes with partial resistance are available. Therefore, in this study, the seedling resistance reaction of 200 bread wheat genotypes plus 6 control genotypes obtained from CIMMYT to *Fusarium pseudograminearum* was determined under growth room conditions. Out of the 200 tested genotypes; 1 (0.5%), 35 (17.5%), 112 (56%), 45 (22.5%), and 7 (3.5%) were resistant, moderately resistant, moderately susceptible, susceptible and very susceptible to *Fusarium pseudograminearum*, respectively. Resistant and moderately resistant genotypes could be used in breeding studies for developing crown rot-resistant cultivars.

INTRODUCTION

Wheat (*Triticum* spp.) is the main source of human nutrition and is grown in large areas in the world. Wheat grain is one of the most important carbohydrate sources used in human nutrition. Today, the main food source of nearly half of humanity is wheat. Flour, pasta, bulgur, and starch obtained from wheat are used in human nutrition. Wheat stems are used in the paper-cardboard industry, and as bran and straw in animal nutrition. Underground parts of wheat and stubble residues left in the field are an important source of organic matter. Wheat, the most planted plant type in the world, is the most planted and the most grain-produced cereal type in Türkiye (Geçit 2016, Süzer 2008).

India, China, Russia, the USA, Canada, Australia, Türkiye, Kazakhstan, and Ukraine are the world's largest wheat-producing countries (Anonymous 2019). In 2020, wheat is planted in 219 006 893 hectares of land with a total yield of 760 925 831 tonnes worldwide (Anonymous 2022a). In the same year in Türkiye wheat is planted in 6 922 236 hectares of land with a total yield of 20 500 000 tonnes (Anonymous 2022b).

There are many biotic and abiotic diseases factors affecting the wheat plant. Many fungi, bacteria, viruses, and nematodes can cause diseases in wheat plants (Bockus et al. 2010). *Fusarium*, causes diseases root, crown, and foot rot in cool climate cereals, has a large number of species and infects wide host ranges. Economically, they are very important and can be found in most parts of the world (Bockus et al. 2010, Booth 1971). It has been determined that *Fusarium* species cause root and crown rot disease as well as head blight (Bockus et al. 2010). Species belonging to *Fusarium* can be transported by soil and seeds. Factors such as climate, soil conditions, and ecological characteristics of the production area are important factors affecting the severity of the disease and yield. In addition, factors such as crop pattern in the production area, tolerance of the cultivars to the disease, tillage, fertilization, and fungicide use also affect the damage potential of the disease. The plant is most likely to become infected in an area contaminated with the pathogen. The severity of the disease increases in cases where the air temperature is high, the water content in the soil is low and the plant is under water stress (Ahmadi et al. 2022, Dababat et al. 2018, Smiley and Patterson 1996).

A number of *Fusarium species* are associated with the root, crown, and foot rots of wheat plants. *Fusarium pseudograminearum*, *F. culmorum*, and *F. graminearum* infect the stem base of wheat causing dry rot of roots, basal stem, and crown tissues. Necrosis is also observed (Bockus et al. 2010). The root, crown, and foot rot agents increase their effect with stress factors. Drought-stressed plants during anthesis are the most affected (Liddell et al. 1986). When suitable conditions occur root rot, crown rot, foot rot, and head blight cause significant yield reductions (Smiley and Patterson 1996). The most important sign of the disease is the browning of the roots, crowns, and stems of the infected plants. Honey brown necrosis can be observed on the leaf sheaths, crowns, and sub-crown internode regions of the plants. Pink-colored hyphal growth can also be seen in plant parts under humid conditions. The disease can also be distinguished in adult plants by the presence of whiteheads (Burgess et al. 2001).

Although *F. pseudograminearum* and *F. graminearum* are fungi that cause root rot in wheat, *F. graminearum* is mostly the causative agent of ear blight in wheat, while *F. pseudograminearum* is more dominant as a root rot agent (Chakraborty et al. 2006). *Fusarium* root, crown, and foot rot, caused by *F. pseudograminearum* (formerly *F. graminearum* group 1) (Aoki and O'Donnell 1999), is a cereal disease that occurs in many arid and semi-arid cropping regions of the world. Yield losses due to this disease have been recorded up to 35% in the Pacific Northwest (PNW) region of the USA (Smiley et al. 2005) and 25-58% in Australia (Chakraborty et al. 2010). Seedling blight can also occur (Bockus et al. 2010, Kazan and Gardiner 2018). This disease is also present in Türkiye (Gebremariam et al. 2018, Hekimhan and Boyraz 2011, Tunali et al. 2008, Yıldırım et al. 2016). Ölmez and Tunalı (2019) reported that *F. pseudograminearum* and *F. culmorum* were the most important crown rot pathogens in the Southeastern Anatolia region of Türkiye. These isolates constituted 13% of the isolated *Fusarium species.* Hekimhan and Boyraz (2011) and Gebremariam et al. (2018) also reported *F. pseudograminearum* causing root rot from the Thrace and Central Anatolia wheat fields in Türkiye. Management of *Fusarium* root, crown, and foot rots is difficult. Genetic resistance is the most promising and efficient way to control the diseases caused by soil-borne pathogens (Erginbas-Orakci et al. 2013, Gebremariam et al. 2020, Wallwork et al. 2004).

In this study, two hundred bread wheat (*Triticum aestivum* L.) genotypes obtained from CIMMYT, Mexico were screened under growth room conditions and their seedling resistance status was determined. In addition, 6 control genotypes (2-49, Altay 2000, Seri 82, Sunco, Süzen 97, Carisma) were also used in this study. We aimed to find new sources for resistance for *F. pseudograminearum* in bread wheat genotypes and to contribute to the usage of cultivars, especially in breeding programs.

MATERIALS AND METHODS

This study was carried out under controlled environment conditions at the Transitional Zone Agricultural Research Institute located in Eskişehir, Türkiye. *Fusarium pseudograminearum* isolate was obtained from International Maize and Wheat Improvement Center (CIMMYT)-Türkiye. Two hundred bread wheat genotypes were obtained from CIMMYT, Mexico. In addition, 6 control genotypes (2-49, Altay 2000, Seri 82, Sunco, Süzen 97, Carisma) were also used.

For inoculum production, oven bags (25 cm x 38 cm) were filled with 200 g wheat bran and humidified with 30 ml water, and autoclaved at 121 ºC for 20 min for 3 consecutive days. Sterilized wheat bran was inoculated with *F. pseudograminearum* propagules and incubated for 4 weeks at 23 ºC. Seeds were washed under running tap water and were placed into 1% NaOCl solution for 3 min and rinsed three times with sterile distilled water. Surface sterilized 8 wheat seeds were placed on the moistened blotting paper in sterilized Petri dishes and left for 3 days at 19 ºC for germination. Germinated seeds were planted into the plastic tubes (16 cm height x 2.5 cm diam.) (Stuewe and Sons, Corvallis, OR, USA) containing sand: soil: animal manure (50:40:10 v/v/v). During the seeding, seeds were inoculated with wheat bran colonized by *F. pseudograminearum*. Each tube received 1 g of wheat bran containing $1x10^6$ *F. pseudograminearum* spores. Then these tubes were transferred to a controlled growth room. Each treatment was replicated 6 times and arranged in a randomized complete block design. The trial was repeated once for data validation.

Experiments were terminated 4 weeks after fungal inoculation. Roots were washed and evaluated for the resistance status using the Wildermuth and Mc Namara (1994) scale modified by Erginbas Orakci et al. (2018) based on the percentage of the browning of the crown region. In this scale, browning and rotting percentages were classified as followed: 1-9%= 1 (resistant), 10-29%= 2 (moderately resistant), 30-69%= 3 (moderately susceptible), 70-89%= 4 (susceptible) and 90-99%= 5 (very susceptible). Results were subjected to statistical analysis. Scale values were square-root transformed, and an analysis of variance was performed (JMP software (v 11), SAS Institute). For separation of means, LSD test was used.

RESULTS AND DISCUSSION

Wheat genotypes tested showed different reactions to the *Fusarium pseudograminearum* (Figure 1). Out of the 200 wheat genotypes tested; 1 (0.5%), 35 (17.5%), 112 (56%), 45 (22.5%) and 7 (3.5%) were resistant, moderately resistant, moderately susceptible, susceptible and very susceptible to *F. pseudograminearum*, respectively. The majority of the genotypes showed moderately susceptible reactions to *F. pseudograminearum* (Table 1 and Figure 2).

Figure 1. Resistant (left) and susceptible bread wheat genotypes (right) at seedling stage under growth room conditions

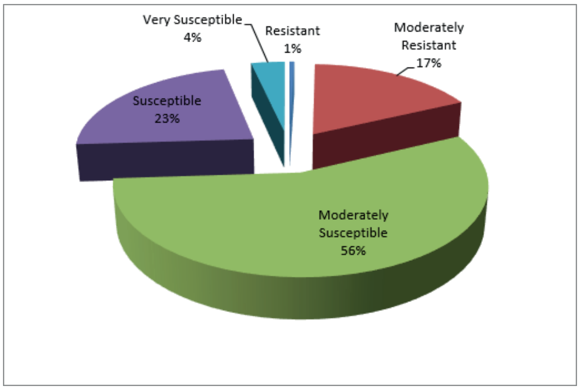

Figure 2. Seedling reaction percentages of 200 bread wheat genotypes to *Fusarium pseudograminearum*

Only one genotype (genotype no: 68) showed resistant reaction to *F. pseudograminearum* (scale value= 1.3). Genotypes 4, 117, 128, 183 (scale values of 2,3), 1, 2, 9, 30, 60, 86, 98, 102, 124, 141, 153, 162, 166, 177 (scale values 2.2), 123 (scale value 2) 29, 115, 157, 175, 187 scale values 1.8), 42, 63, 82, 89, 90, 150 (scale values 1.7), 8, 104, 154, 179, 180 (scale values 1.5) were placed in moderately resistant group. Control genotypes 2-49 (genotype no: 201), Altay 2000 (genotype no: 202) and Sunco (genotype no: 204) received scale values 2.2. Control genotype Carisma (genotype no: 206) received scale value of 1.8. These control genotypes were also placed in the moderately resistant group (Table 1).

Genotypes 3, 5, 7, 10, 11, 12, 15, 21, 24, 26, 27, 28, 32, 33, 34, 35, 38, 40, 41, 45, 46, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 61, 62, 64, 65, 66, 67, 69, 70, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 83, 84, 87, 91, 92, 93, 95, 96, 97, 99, 100, 101, 103, 106, 109, 110, 111, 112, 113, 114, 116, 118, 119, 125, 126, 127, 129, 130, 132, 133, 137, 138, 139, 140, 144, 146, 147, 149, 151, 156, 158, 160, 161, 163, 164, 165, 167, 168, 169, 170, 172, 178, 181, 184, 189, 190, 191, 193, 195, 196, 197, 198 and 200 exhibited moderately susceptible reactions to *F. pseudograminearum*. Majority of the genotypes were placed in this group (Table 1). Bread wheat genotypes 4, 6, 13, 16, 17, 18, 19, 23, 25, 31, 36, 39, 43, 44, 47, 55, 59, 71, 85, 88, 94, 105, 107, 108, 120, 121, 122, 134, 135, 136, 142, 143, 155, 159, 171, 173, 174, 176, 182, 185, 186, 188, 192, 194, and 199 and control wheat genotypes Seri 82 (genotype no: 203) and Süzen 97 (genotype no: 205) showed susceptible reactions to *F. pseudograminearum* and genotypes 20, 22, 37, 131, 145, 148, and 152 exhibited very susceptible reactions to *F. pseudograminearum*.

Finding new sources of resistance to the root rot pathogens

Table 1. Seedling resistance of 200 bread wheat genotypes and 6 control genotypes to *Fusarium pseudograminearum* under growth room conditions. Wildermuth and Mc Namara (1994) scale modified by Erginbas-Orakci et al. (2018) (1-5 scale) was used for disease assessment

Genotype+	Scale value[1]	Resistance[2,3]
22	5^{a}	VS
37, 145, 148	4.8^{ab}	VS
20, 131, 152	4.5^{abc}	VS
142, 143	4.3^{bcd}	S
36, 107, 122, 176	4.2^{cde}	S
71, 188	4^{cdef}	S
19, 23, 43, 44, 94, 135, 159, 171, 192	3.8^{defg}	S
203 (Seri 82)	3.8^{defg}	S
6, 16, 31, 39, 55, 59, 88, 105, 121, 136, 155, 185,	3.7^{efgh}	S
4, 13, 17, 18, 25, 47, 85, 108, 120, 134, 173, 174, 182, 186, 194, 199	3.5^{fghi}	S
205 (Süzen 97)	3.5^{fghi}	S
3, 28, 35, 38, 40, 66, 67, 75, 76, 80, 81, 91, 97, 137, 163, 165, 167, 170, 190, 193	3.3^{ghij}	MS
11, 21, 56, 57, 61, 64, 69, 77, 84, 93, 95, 100, 103, 106, 113, 114, 118, 127, 130, 133, 138, 144, 147, 158, 160, 172,195	3.2^{hijk}	MS
10, 12, 27, 32, 41, 50, 51, 52, 58, 74, 78, 79, 87, 92, 99, 110, 112, 126, 129, 139, 146, 149, 168, 189, 191, 200	3^{ijkl}	MS
5, 15, 24, 34, 46, 48, 49, 53, 54, 62, 72, 73, 96, 116, 119, 151, 161, 164, 169, 181, 196, 197, 198	2.8^{jklm}	MS
7, 70, 83, 109, 111, 125, 140, 184	2.7^{klmn}	MS
26, 33, 45, 65, 101, 132, 156, 178	2.5^{lmno}	MS
14, 117, 128, 183	2.3^{mno}	MR
1, 2, 9, 30, 60, 86, 98, 102, 124, 141, 153, 162, 166, 177	2.2^{nop}	MR
201 (2-49)	2.2^{op}	MR
202 (Altay 2000)	2.2^{op}	MR
204 (Sunco)	2.2^{opq}	MR
123	2^{opqr}	MR
29, 115, 157, 175, 187	1.8^{pqrs}	MR
206 (Carisma)	1.8^{pqrs}	MR
42, 82, 90	1.7^{qrst}	MR
63, 89, 150	1.7^{rst}	MR
8, 104, 154, 179, 180	1.5^{st}	MR
68	1.3^{t}	R

* Means followed by the different letters are statistically significant (P= 0.05)
1 Numbers are mean of 6 replications
2 R= Resistant, MR= Moderately resistant, MS= Moderately susceptible, H= Susceptible, VS= Very susceptible
3 Resistant= 1-1.4, Moderately resistant = 1.5-2.4, Moderately susceptible = 2.5-3.4, Susceptible = 3.5-4.4,
Very susceptible = 4.5-5
+= 201= 2-49 control genotype, 202= Altay 2000 control genotype, 203= Seri 82 control genotype, 204= Sunco control genotype, 205= Süzen 97 control genotype, 206= Carisma control genotype

has been limited. In our current study, 1 and 35 genotypes exhibited resistant and moderately resistant reactions, respectively. Similar results were obtained with the seedling test done with another important wheat root and crown rot pathogen *Fusarium culmorum* (Gebremariam et al. 2020). They tested the seedling reactions of 165 spring wheat lines obtained from CIMMYT, Mexico under growth room conditions using an aggressive isolate of *F. culmorum*. In their study, 2 and 20 lines exhibited resistant and moderately resistant reactions, respectively. Similar to our current results, the majority of the lines showed moderately susceptible and susceptible reactions to *F. culmorum*.

Farmers will benefit from growing resistant and tolerant cultivars and genotypes. Resistance to this disease is limited and some genotypes show tolerant reactions (Kazan and Gardiner 2018). Resistance breeding should focus on obtaining resistant cultivars preferably containing resistance to a few root rot pathogens at the same time. In this study, we identified some bread wheat genotypes showing resistant or moderately resistant responses to *F. pseudograminearum*.

Different researchers investigated the resistance status of wheat plants against root and crown rot disease caused by *F. pseudograminearum* in their studies using different wheat genotypes. Wildermuth and Mc Namara (1994) determined the resistance of 28 different wheat genotypes against *F. pseudograminearum*. They used a scale of 0-4 in their study to determine resistance and the line 2-49 received a scale value of 1.7 and was determined as resistant. In our current study, 2-49 bread wheat line, which was also used as a control genotype, received a 2.2 scale value and was placed into a moderately resistant group to *F. pseudograminearum* under controlled conditions. Wallwork et al. (2004) observed the resistance status of bread and durum wheat genotypes against *F. pseudograminearum* and *F. culmorum*. In their study, the bread wheat line 2-49 showed good resistance against *F. pseudograminearum*. It was also determined that the bread wheat cultivar Sunco was sufficiently resistant to *F. pseudgoraminearum*. In the present study, Sunco and 2-49 bread wheat genotypes were determined as moderately resistant to *F. pseudograminearum*.

In another study carried out by Mitter et al. (2006), the resistance status of 19 different wheat genotypes to *F. pseudograminearum* was determined. Sunco and Lang cultivars were determined as the most resistant cultivars against the disease.

Li et al. (2008) evaluated different wheat genotypes using different inoculation methods of *F. pseudograminearum*. They found that the two bread wheat genotypes, Sunco and 2-49, were resistant with scale values of 2.16 and 2.05, respectively. This was in agreement with our current study for both genotypes.

Erginbas Orakci et al. (2016) reported in their study that Sunco, Altay 2000, and 2-49 genotypes were moderately resistant; Seri 82 genotype was susceptible to *F. pseudograminearum*. These responses agreed with the results obtained from our current study where Seri 82 control genotype had a scale value of 3.8 and was found as susceptible. In our current study, control genotypes 2-49, Altay 2000, and Sunco received scale values of 2.2 and showed a moderately resistant reaction against *F. pseudograminearum*.

In another study carried out by Demirci (2003), it was determined that *F. graminearum* caused high disease severity in 10 wheat cultivars, and only the Mızrak cultivar was moderately susceptible with a slight difference.

In conclusion, wheat genotypes resistant and moderately resistant to *F. pseudograminearum* were determined in our current study. One and 35 bread wheat genotypes were found resistant and moderately resistant to *F. pseudograminearum*, respectively. These genotypes are recommended for crosses in breeding programs.

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ÖZET

Fusarium pseudograminearum buğdayda kök ve kök boğazı çürüklüğüne sebep olan en tahripkar *Fusarium* türlerinden birisidir. Dayanıklı genotiplerin seçilmesi en etkili ve çevre ile dost bir mücadele yöntemlerinden birisidir. Günümüzde kısmi dayanıklılık gösteren sınırlı sayıda genotip bulunmaktadır. Bu çalışmada CIMMYT'den temin edilen 200 adet ekmeklik buğday genotipinin ve 6 adet kontrol genotipinin *Fusarium pseudograminearum*'a karşı dayanıklılık durumları iklim odası şartlarında tespit edilmiştir. 200 adet ekmeklik buğday hattının *Fusarium pseudograminearum*'a karşı 1 adedinin (%0.5) dayanıklı, 35 adedinin (%17.5) orta derecede dayanıklı, 112 adedinin (%56) orta derecede hassas, 45 adedinin (%22.5) hassas ve 7 adedinin (%3.5) ise çok hassas olduğu bulunmuştur. Dayanıklı ve orta derecede dayanıklı olarak bulunan genotipler ıslah çalışmalarında kök ve kök boğazı çürüklüğü hastalığına karşı dayanıklı çeşitler geliştirmede kullanılabilinir.

Anahtar kelimeler: ekmeklik buğday, *Triticum aestivum*, *Fusarium pseudograminearum*, hastalığa dayanıklılık, kök ve kök boğazı çürüklüğü

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