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Research aricle

Determination of Resistance in Winter Wheat Genotypes to the Dryland Root Rots Caused by *Fusarium culmorum* in Turkey

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Abstract. The dryland root rot (foot/crown) caused by *Fusarium* spp. attacks cereals especially wheat and causes severe yield loss by reducing both grain quantity and quality. Among those Fusarium species attacking wheat crop is the *Fusarium culmorum* species which has been reported as the main crown rot causal agent in Turkey. Unfortunately, up-to-date, there is only some wheat genotypes with partial resistant to *Fusarium* spp. Therefore, this study was carried out to find new sources of resistance in diverse wheat genotypes to limit the damage caused by Fusarium disease. In this study, a total of 141 genotypes and breeding lines were obtained from 19 different countries, provided via the International Winter Wheat Improvement Program (IWWIP) and screened for their resistance reactions to a local isolate of *Fusarium culmorum* under three different environmental conditions (growth room, greenhouse and field) in Turkey in 2012. The best performed genotypes in terms of resistant were then rescreened in 2013 for data validation. Out of the 141 phenotyped wheat genotypes, 17 genotypes (12 %) ranked as moderately resistant (MR) at seedling and/or adult growth stage. The genotypes from Mexico seemed to have adult plant resistant rather than seedling resistance which was higher in the USA genotypes. Winter bread wheats PATWIN YR5 and TAST/SPRW//ZAR/5/YUANDONG 3/4/PPB8-68/CHRC/3/PYN//TAM101/AMIGO which possess high level of resistance seem promising for breeding for foot rot.

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Kışlık Buğday Genotiplerinin Türkiye' de Kök Çürüklüğü Etmeni *Fusarium culmorum*'a Karşı Dayanıklılığı'nın Belirlenmesi

Anahtar kelimeler:
Fusarium, dayanıklılık, kök çürüklüğü, buğday

Özet. Kuru alan kök (kökboğazı/dip) çürüklükleri'ne neden olan *Fusarium* türleri tahıllara özellikle buğdaya zarar vermekte, tane sayı ve kalitesini azaltarak önemli verim kaybına neden olmaktadır. Türkiye'de kök çürüklüğü hastalık etmeni Fusarium türleri içinde buğday bitkisine zarar veren başlıca etmen olarak rapor edilen tür *Fusarium culmorum*'dur. Maalesef, günümüze kadar *Fusarium* türlerine karşı sadece birkaç kısmi dayanıklı buğday genotipi bulunmuştur. Bu nedenle, bu çalışma Fusarium hastalığının neden olduğu zararı sınırlandırmak amacıyla çeşitli buğday genotiplerinde yeni dayanıklılık kaynaklarının bulunması amacıyla yürütülmüştür. Çalışmada, Uluslararası Kışlık Buğday Geliştirme Programı (IWWIP) aracılığıyla 19 farklı Ülke'den toplam 141 ıslah materyali (hat ve çeşit) sağlanmıştır ve Türkiye'de 3 farklı ortamda (büyütme odası,sera, tarla) yerel izolat *Fusarium culmorum*'a karşı dayanıklılıklarının belirlenmesi amacıyla 2012 yılında test edilmiştir. Dayanıklılık bakımından en iyi performansı gösteren genotipler verilerin doğrulanması amacıyla 2013 yılında tekrar test edilmiştir. Fenotiplendirme yapılan 141 genotip içinden toplam materyalin %12' lik kısmını oluşturan 17 genotip fide ve/veya yetişkin dönemde orta dayanıklı olarak gruplandırılmıştır. Meksika kaynaklı genotipler, fide dayanıklılığı daha fazla gösteren Amerika kaynaklı genotiplerin aksine yetişkin dönem dayanıklılığı göstermiştir. Yüksek dayanıklılık gösteren kışlık buğdaylar PATWIN YR5 ve TAST/SPRW//ZAR/5/YUANDONG 3/4/PPB8-68/CHRC/3/PYN//TAM101/AMIGO kök çürüklüğü' ne karşı ıslahta ümitvar olarak görülmektedir.

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INTRODUCTION

Wheat is grown on 20% of the cultivated land area of the world and is a main food resource for 40% of the world's population (Braun *et al*., 2010). In 2016, an estimated of 742 million tons of wheat (*Triticum aestivum* L.) was produced from 223 million ha (FAO 2018). In 2050, the world's population is expected to reach 9 billion, thus it is estimated that cereal production needs to increase by 50% by 2030 (Alexandratos and Bruinsma 2012). Turkey is one of the 10 largest wheat producers in the world with an average grain yield estimate of 2.5 tonnes - ha and varying wheat production between 16 and 21 million tonnes (Braun *et al*., 2001). So far the wheat production is suffering substantial losses of biotic and abiotic stress factors. Among the biotic stress factors; Fusarium species causing foot, crown and root rots occur in winter cereals worlwide virtually wherever cereal-based farming system predominates (Burgess *et al*., 2001). The disease can be caused primarily by *Fusarium culmorum*, *F. pseudograminearum* (formerly *F. graminearum* group 1), and *F. graminearum* (formerly *F. graminearum* group 2). Those three species have been reported to be associated with wheat and cause significant yield damage in West Asia and North Africa (Egypt, Tunisia, Morocco, Algeria), USA, Canada, Australia, Turkey (Smiley 2005; Tunali 2008; Chakraborty 2010). Fusarium root rot mainly caused by *F. culmorum* is characterized by a decay of the crown and lower stem tissue, resulting in scattered white heads with shriveled or no grain under disease favorable conditions and ultimately in the reduction of grain quality and quantity (Cook 1980). Yield loss due to these pathogens have been reported and reached up to 35% in winter wheat in Pacific Northwest (PNW) of America (Smiley 2005), 25-58% in Australia while the disease can inflict yield losses of up to 89% (Klein 1991; Chakraborty *et al*., 2010) and up to 49% in Tunisia (Chekali 2016). In Turkey, losses have been reported in winter wheat and reached up to 43% (Hekimhan *et al*., 2004), 54% in durum wheat in Central Anatolian Plateau (CAP) (Bagci *et al*., 2001). Aktaş *et al*. (1999) reported disease intensity of 36% in winter cereals as a result of root and crown rots. The CAP coveres 10 million hectares of cultivated land of which winter wheat is considered the main cultivated crop with an annual precipitation between 250-500 mm (Benli *et al*., 2007). About 90% of wheat areas in Turkey are cultivated under rainfed or supplementary irrigation conditions, where drought stress is common (Braun *et al*., 2001) and considered a favorable environment for the dryland foot rot. *Fusarium culmorum* has been reported as the prevelant species causing foot rot in Turkey (Akgül 2008; Bentley 2006; Hekimhan *et al*., 2004; 2010; Nicol *et al*., 2004; Tunali *et al*., 2008, Shikur 2017). Using resistant crops of high yielding potential is the most efficient and economical way to increase wheat productivity and manage soil borne pathogens especially in dryland fields. However, varieties with high level of resistance are still not available (Li *et al*., 2012). Only few sources with partial resistance which have been identified and used for molecular mapping studies such as Kukri (Wallwork *et al*., 2004), 2-49 (Collard *et al*., 2005), W21MMT20 (Bovill *et al*., 2006), CSCR6 (Ma *et al*., 2009), Ernie (Li *et al*., 2010). Based on the foregoing, crop rotation with non-host crop or cultivars is still one of the most recommended methods to reduce the damage caused by *Fusarium* species (Burgess *et al*., 2012) though in rainfed wheat production systems where cereal monoculture is practiced extensively as it is the case in Turkey, rotation offers limited option to control root rot diseases (*F. culmorum*). Therefore, the main objective of this study was to screen diverse winter wheat genotypes to find new sources of resistance against the dryland *F. culmorum* based on multiple screening environments which will ultimately widen the genetic pool by using those sources in the breeding programs.

MATERIAL AND METHOD

Plant Genetic Resources

A set of 141 winter wheat genotypes provided by the International Winter Wheat Improvement Program (IWWIP) representing 19 different countries of a broad geographical spectrum along with the standard 6 breedinglines/varieties known for their resistant reaction to the dryland root rot caused by *F. culmorum* were evaluated in this study (Table 1).

Fusarium Inoculum

A local Fusarium species isolated from naturally infested field in Kırsehir, Turkey (39º 39′ 709″ N, 32º 37′ 14″ E), molecularly identified as *F. culmorum* according to Nicholson *et al*. (1998) was used in all tests. This isolate was selected and used in this study based on its high virulence (88%) against wheat genotype. A monosporic isolate of *F. culmorum* was cultured on Synthetic Nutrient Agar (SNA) medium (KH_2PO_4 1g, KNO_3 1g, $MgSO_4.7H_2O$ 0.5 g, KCl 0.5 g, Glucose 0.2 g, Sucrose 0.2 g, Agar 20 g, 1000 ml distilled water) at 23 °C for 10 days. Propylene bags (48 cm x 20 cm) (Unicorn, Amsterdam, Netherlands) were quarter filled with wheat bran, autoclaved at 121 °C for 20 min for three consecutive days. One week

Table 1. Breedinglines/varieties and their resistant reaction to the root rot caused by *Fusarium culmorum* used at the soil borne disease at CIMMYT-Turkey program.
Çizelge 1. CIMMYT-Türkiye Toprak Kökenli Hastalıklar programında kullanılan bu kontrol hatları/çeşitleri ve Fusarium culmorum' un sebep olduğu kuru alan kök çürüklüğü'ne karşı dayanıklılık bakımından reaksiyonları.

Wheat Genotype	Resistance Rating	Type	Source
Altay 2000	MR	WW	Turkey
Sonmez	MR	WW	Turkey
2-49	MR	SW	Australia
Sunco	MR-MS	SW	Australia
Seri 82	S	FAC	Mexico
Kiziltan 91	HS	FAC	Turkey

Abbreviations stand for: MR= Moderately Resistant, MS= Moderately Susceptible, S= Susceptible, MS= Moderately Susceptible, HS= Highly Susceptible, WW= Winter Wheat, SW= Spring Wheat, FAC= Facultative.

later, 15 ml of sterilised water consisting of mycellium from the monosporic culture was transferred into each bag and left for 2 to 3 weeks at 23 ºC to enhance sporulation and thereafter used as source of inoculum in this study.

Seedling Resistance Screening (Growth room)

Wheat seeds were placed onto a moist blotting paper in sterilled petri dishes and left for 3 days at 23 °C to enhance germination. Seeds were left till 3 cm long radicules roots were formed. A single pregerminated seed was sown in a plastic tube (Stuewe and Sons, Corvallis, OR) measuring (16 cm height x 2.5 cm diam.) containing potting mixture of sterilised sand, field soil, and organic matter (50:40:10, v/v/v). Sand and field soils were sterilised at 110 °C for 2 h and organic fertilizer was sterilized at 70 °C for 5 h. Six additional genotypes with known resistant reaction to crown rot were used as control in this study (Table 1). One week after transplanting pregerminated seeds, each seedling was inoculated with 1 ml of spore suspension of *F. culmorum* at a rate of $1x10^6$ spore per ml of water. To enhance infection; inoculated seedlings were covered with plastic tent and incubated at 75% of relative humidity and watered from bottom and kept in the dark for 48 h before removing the plastic cover and left to grow under the growth room conditions for 49-56 days with 16 h of artificial photoperiod and at 23 °C with relative humidity of 65 ± 5% as per Mitter *et al*. (2006). Each treatment was replicated 5 times and tubes were placed in a completely randomised block design. Trials were repeated once for data validation.

Adult Plant Screening (Greenhouse and Field)

A single wheat seed was sown in each plastic tube (Stuewe and Sons, Corvallis, OR) (21 cm height x 3.8 cm diam.) filled with the same potting mixture as mentioned above and was inoculated with 0.25 g of wheat bran *F. culmorum* consisted of about $5x10^5$ spore per ml. Wheat bran were soaked in 1 ml water to estimate relative spore concentration by using a hemocytometer. The plants were left to grow under the greenhouse from October to June (winter wheat growing season) and harvested at maturity as lined with natural field conditions. In order to enhance disease symptoms, water was reduced near heading stage to stimulate post anthesis drought stress. The method used in this test was similar to that described by Wallwork *et al*. (2004). Plants were watered whenever needed. Each treatment was replicated 6 times and placed in a completely randomised block design. For field assay, wheat genotypes (141 genotype) plus the breedinglines/varieties (6 genotypes) were planted at ILCI private agricultural research institute in Kırsehir, Turkey in 2012. For each genotype, 5 g seeds were hand planted in row of 1 m long and replicated 3 times in a completely randomised block design. In 2013, a set of 69 selected genotypes based on their performance in 2012 screening and showed promising resistant reaction were re-evaluated under the same field conditions for data validation. At harvest time, up to 20 tillers of each genotype (replicate) was randomly selected, peeled, and assessed for *F. culmorum* disease symptoms as per Erginbas-Orakci *et al*. (2012; 2016).

Statistical Analysis

Plants were harvested and assessed based on the browning/rotting percentage on the crown which describes the stem (1 cm above soil level) according to the modified 1-5 scale: 1= 1-9% Resistant (R), 2= 10-29% Moderately Resistant (MR), 3= 30-69% Moderately Susceptible (MS), 4= 70-89% Susceptible (S), 5= 90-100% Highly Susceptible (HS) (Wildermuth and McNamara 1994; Erginbas-Orakci *et al*., 2016). The data were analyzed according to standart analysis of variance. Significant differences between the

genotype was performed based on the Least Significant Difference (LSD). JMP10 statistical package program was used for tests.

RESULT

The tested genotype showed disease severity ranged between 1% and 89% (Wildermuth and McNamara 1994). The genotypes were categorized into 5 groups based on their reaction ranging from Resistant (R) to Highly Susceptible (HS). The breedinglines/varieties used in the study gave the expected reactions against the disease under the different screened environments. The tetraploid Kiziltan 91 used in this study showed higher susceptible expression than the hexaploid Seri 82. Out of the 141 genotype screened in 2012 a subset of 69 promising genotype were selected based on their resistant reaction to *F. culmorum* under the three different screening environments (growth room, greenhouse and field) in the 1st run. The results of the validation study resulted in 16 genotype with same or better resistant reaction to the foot rot disease when compared to the breedinglines/varieties used in the study (Table 2). Two of the 16 genotype gave resistant reaction to crown rot at both seedling and adult stages in particularly PATWIN YR5 and TAST/SPRW//ZAR/5/YUANDONG3/4/PPB8-68/CHRC /3/PYN//TAM101/AMIGO and considered moderately resistance against *Fusarium culmorum*. Based on the grouping genotype screened for adult plant resistance (APR) in both greenhouse and field resulted in 2.8% MR-R, 59.5% MS, and 37.5% S-HS. While genotype screened for seedling resistant gave 11.3% R-MR, 54.6% MS, and 34% S-HS. The highest frequencies of resistant reaction to *F. culmorum* were obtained from those genotype originated from Romania, Turkey, USA, IWWIP, Mexico - IWWIP (Table 2). Genotypes KS82142/PASTOR, DEFENSE, EXCALIBUR/WBLL1, PATWIN-YR5, ALAMOOT/4/KAL/ BB/CJ/3/HORK can be considered as valuable sources for foot rot (*F. culmorum*). The set was also screened against other soil borne disease cereal cyst nematode (*Heterodera filipjevi*) as well as main foliar diseases caused by the 3 rusts species (Table 3). The performance of selected resistant genotypes and their reaction for multiple diseases (CCN and Rusts) are given in Table 3 (Rust data is obtained from IWWIP). The data has indicated that entry 26, 62, 65, 67, 73, and 111 which were good for crown rot were also good for all rust diseases tested (stripe, leaf and stem rust). Agronomy and grain quality parameters for selected lines were performed on those genotypes and will be of high importance to the breeding programs to pyramide the different traits in a high yielding widely cultivated varieties (Table 4; Data is obtained from IWWIP).

DISCUSSION

To date a wide range and diverse germplasm from around the globe obtained from CIMMYT-Mexico and IWWIP (International Winter Wheat Improvement Program) has been phenotypically screened in terms of their resistance to Fusarium crown rot (Erginbas-Orakci *et al*., 2013a). Wheat genotype resistant to crown rot is limited, therefore, developing and/or identifying a new genotype with acceptable level of resistance will greatly benefit wheat producers 'farmers'. Implementing the resistant germplasm with other cultural practices such as crop rotation and other Integrated Pest Managemengt (IPM) will ultimately reduce the damage and increase the grain yield (Erginbas-Orakci *et al*., 2010). The damage on cereals caused by soil borne pathogens especially the Fusarium genus are known in wheat producing areas globally (Smiley *et al*., 2005; Chakraborty *et al*., 2010). The present investigation demonstrated that *F. culmorum* is highly agressive on wheat genotypes. Using resistant genotypes of high yielding potential is the most effective and economical way to control soil borne pathogens, especially under drought areas where cereals are cultivated and monoculture cropping systems exist (Erginbas-Orakci *et al*., 2013b). Efforts has been made by pathologists around the globe to find Quantitative Trait Loci (QTLs) against the crown rot. However, only few sources were identified with partial resistance (Wallwork *et al*., 2004; Collard *et al*., 2005; Ma *et al*., 2009; Li *et al*., 2010). The results of this study clearly show high variation in their resistance reaction between and/or among the tested genotypes. All genotypes assessed for crown symptoms at seedling stage for seedling resistance in growth room, at adult plant resistance under greenhouse and field conditions showed various reactions to the pathogen *F. culmorum*. The genotypes were ranked according to the browning/rotting severity on the crown and were compared to the controls used in this study. The genotypes which showed consistency in disease ratings both at seedling and adult stages over the 2 growing season were considered reliable and promising lines. As reported by Smiley and Yan (2009), a high degree of variation in response to crown rot disease over years and found it difficult to establish reliable tolerance standards in wheat genotypes. Therefore, the slightly variation between the lines and controls (which seen more adapted) in our study might be due to the uneven

Table 2. Mean crown rotting data of 17 promising winter wheat genotypes including controls assessed under growth room, greenhouse and field conditions at 2 consecutive years (2012/13).

Çizelge 2. Büyütme odası, sera ve tarla koşullarında ümitvar 17 kışlık buğday genotipi ile kontrol hat/çeşitlerin kök boğazı çürüklüğüne ait 2012-2013 yılı ortalama verileri.

OE	CNAME	TK ACC	OC	Field	Greenhouse	Growth-room	Field	Greenhouse	Growth room	Seedling Stage Resistance: SSR , Adult Stage Resistance: ASR
26	KS82142/PASTOR	050117	United States of America-IWWIP	.	2.8	2.0	2.0	2.0	2.0	SSR
38	DEFENSE	980221	France	2.5	3.0	2.0	3.0	2.7	2.4	SSR
47	F02106G2-1FZ101	110613	Romania	2.5	2.7	1.0	3.0	3.3	2.0	SSR
49	ES85-19/V-763-254/3/RSK/NAC//CTK/VEE	101320	Turkey	2.0	3.7	2.0	3.0	1.3	1.8	SSR
57	EXCALIBUR/WBLL1	100037	Mexico	2.0	2.7	4.0	2.0	1.8	3.0	ASR
62	ABI 86*3414/X84W063-9-39-2//KARL92	020486	United States of America	3.0	2.5	2.2	2.0	1.5	1.5	SSR
65	85ZHONG33/ZLATOSTRUI//PLK70/LIRA	000022	IWWIP	1.0	2.0	2.0	4.0	3.5	2.0	SSR
67	BONITO-44	010268	Mexico-IWWIP	1.5	2.8	1.0	.	2.2	2.5	ASR
68	SABALAN//KRC66/SERI/5/JUP/4/CLLF/3/II14-53/ODIN//CI134431/SEL6425/WA00477	030084	IWWIP	2.5	2.7	2.0	2.0	2.3	2.3	SSR
69	PATWIN YR5	100894	United States of America	2.0	2.2	2.0	.	2.3	2.0	ASR-SSR
73	ALAMOOT/4/KAL/BB//CJ/3/HORK	090859	Iran-Karadj	2.5	2.5	2.0	4.0	1.3	2.2	SSR
78	W95-091 (=KS85-663-8-9//WI81-133/THUNDERBIRD)/AKRON	101038	United States of America	3.0	3.7	2.0	4.0	2.2	2.4	SSR
95	OWL//OMBUL/ALAMO	120001	Iran-Karadj	3.0	3.3	1.0	2.0	1.5	1.4	SSR
111	00*0100-51	101287	United States of America	2.5	3.5	2.0	4.0	2.5	2.3	SSR
113	TX98D3447/TX99D4657	100010	Unites States of America	3.0	2.5	2.0	2.0	2.5	1.7	SSR
120	TAST/SPRW//ZAR/5/YUANDONG 3/4/PPB8-68/CHRC/3/PYN//TAM101/AMIGO	060026	IWWIP	2.0	2.8	2.0	2.0	1.0	2.4	ASR-SSR
124	4WON-IR-257/5/YMH/HYS//HYS/TUR3055/3/DGA/4/VPM/MOS	090433	IWWIP	3.0	3.7	2.0	1.0	1.2	1.8	SSR
	2 49 - control		Australia	2.2	2.3	2.2	2.2	2.3	2.4	
	Altay 2000- control		Turkey	2.5	2.8	2.4	2.4	2.3	2.4	
	Sonmez - control		Turkey	2.5	2.5	2.4	2.5	2.4	2.4	
	Sunco -control		Australia	3.0	2.0	3.0	2.8	2.2	3.0	
	Seri 82 -control		Mexico	3.5	3.4	3.6	3.5	3.2	4.0	
	Kiziltan 91 - control		Turkey	3.0	3.5	4.4	3.4	3.3	4.4	
	LSD			0.27	0.51	0.27	0.13	0.50	0.62	
	Prob			<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	

Table 3. The best performed winter wheat genotypes against to the root rot pathogen *Fusarium culmorum* supported by data from leaf disease rust (including avaliable resistance gene data) and from other soil borne disease ceral cyst nematodes under field and/or controlled conditions in Turkey.
Çizelge 3. Kök çürüklüğü etmeni Fusarium culmorum' a karşı en iyi performans gösteren kışlık buğday genotipleri ve Türkiye'de tarla ve/veya kontrollü koşullar altında diğer toprak kökenli hastalık etmeni tahıl kist nematodu ve yaprak pas hastalıkları' na karşı (mevcut dayanıklılık geni verileri) dayanıklılık reaksiyonları.

				Adult Plant Response (June 2012)							
OE	**Cross name**	**TK ACC**	**OC**	**Stripe Rust**	**Leaf Rust**			**Stem**	**Stem Rust-Gene**	**Leaf rust-Gene**	**CCN *Heteroder a Filipjevi* Reaction**
				Haymana	**Adapazarı**	**Izmir**	**Haymana**	**Izmir**			
26	KS82142/PASTOR	050117	United States of America -Oregon. Turkey Cimmyt Icarda	TMS	0	TMS	5MR	5 MR	Sr2		MR
38	DEFENSE	980221	France	0	0	TMS	80S	40 S	**HET**		MR
47	F02106G2-1FZ101	110613	Romania	0	0	10 MS	30MSS	20 S			MS
49	ES85-19/V-763-254/3/RSK/NAC//CTK/VEE	101320	Turkey	TMS	0	5 MS	40S	30 S	Sr2		MS
57	EXCALIBUR/WBLL1	100037	Mexico	T-20MS/0	TMS	TMS	70S	20 MS	Sr2. Sr24		MR
62	ABI 86*3414/X84W063-9-39-2//KARL92	020486	United States of America -Kansas	TMS	0	0	0/10S	5 MS	Sr2		MS
65	85ZHONG33/ZLATOSTRUI//PLK70/LIRA	000022	Turkey-Cimmyt-Icarda	TMS	0	0	0	TMR	Sr2. Sr24		MS
67	BONITO-44	010268	Mexico- Turkey-Cimmyt-Icarda	0	TMR	TMR	10MSS	10 S	Sr2	Lr34	MS
68	SABALAN//KRC66/SERI/5/JUP/4/CLLF/3/II14-53/ODIN//CI134431/SEL6425/WA00477	030084	Turkey-Cimmyt-Icarda	70SMS/0	10MR	5 MS	20MSS	TMS	Sr2		MS
69	PATWIN YR5	100894	United States of America	0	TMR	0	0	TMS	HET		MR
73	ALAMOOT/4/KAL/BB//CJ/3/HORK	090859	Iran-Karadj	0	5MR	TMS-10 MS	20MSS	0	Sr2		MR
78	W95-091 (=KS85-663-8-9//WI81-133/THUNDERBIRD)/AKRON	101038		0	0	0	60S	10 MS	Sr2		MS
95	OWL//OMBUL/ALAMO	120001	Iran-Karadj	0	20MSS	70 S	90S	10 S			MS
111	00*0100-51	101287	US-AGRIPRO	0	5MR	0	0	TMS			
113	TX98D3447/TX99D4657	100010	US-ARS-NC	100S	0	0	20MR	0	Sr2		-
120	TAST/SPRW//ZAR/5/YUANDONG 3/4/PPB8-68/CHRC/3/PYN//TAM101/AMIGO	060026	Turkey-Cimmyt-Icarda	0	20MSS	10 MS	0	10 MS	Sr2	Lr34	-

Table 3. Continue.
Çizelge 3. Devamı.

OE	Cross name	TK ACC	OC	Adult Plant Response (June 2012) Stripe Rust	Leaf Rust			Stem Rust	Stem Rust-Gene	Leaf rust-Gene	CCN *Heteroder a Filipjevi*
124	4WON-IR-257/5/YMH/HYS//HYS/TUR3055/3/DGA/4/VPM/MOS	090433	Turkey-Cimmyt-Icarda	0	TMS	TMR	60S	10 MS	Sr2		-
	Altay 2000-control	010627	Turkey	0	5MS	10 MS	10S	50 S	Sr2		S
	Bezostaja-control	950189	Russia	60MSS	30MSS	TMS	60S	100S	HET	Lr34	S
	Bayraktar-control	010571	Turkey	0	TMR	TMS	0	5 S	Sr2		HS
	Karahan-control	920007	Turkey	70MS	10MS	10 MS	10MSS/0	10 MR/MS	Sr2		MS
	Mufitbey-control	020211	Turkey Cimmyt Icarda	0	TMR	TMS	50S	50 S	Sr2		HS

OE: Original entry.TK: Turkey. ACC: Accession. OC: Origin country. Adult plant severity and infection type asssed according to the Cobb's scale (Peterson *et al*.,1948) for rust diseases;
T: Trace severity. MR: Moderately resistant. MS: Moderately susceptible. S: Susceptible. MSS:Moderately susceptible to susceptible.S:susceptible. HS: highly susceptible. CCN: Cereal Cyst Nematode; 1 to 5 scale (Dababat *et al*., 2014) was used to group the genotypes according to their reaction against *Heterodera filipjevi*.

Table 4. The best performed winter wheat genotype against to the root rot pathogen Fusarium *culmorum* supported by data from agronomy and quality parameters.
Çizelge 4. Kök çürüklüğü etmeni Fusarium *culmorum' a karşı en iyi performans gösteren kışlık buğday genotipleri ve agronomi ve kalite özellikleri.*

				Days to Heading		Vernalization Genes			Glu-D1 C
OE	**CNAME**	**TK ACC**	**OC**	**Eskisehir**	**Izmir**	**VrnA1(v/w)**	**Vrn-B1**	**Vrn-D3**	**Subunits**
26	KS82142/PASTOR	050117	United States of America-Oregon.Turkey Cimmyt Icarda	145	115	Vrn-A1w	Vrn-B1a		5+10
38	DEFENSE	980221	France	159	132	Vrn-A1w			NA
47	F02106G2-1FZ101	110613	Romania	155	120	Vrn-A1w			5+10
49	ES85-19/V-763-254/3/RSK/NAC//CTK/VEE	101320	Turkey	153	118	Vrn-A1w			NA
57	EXCALIBUR/WBLL1	100037	Mexico	151	115	Vrn-A1w	HET	Vrn-D3b	5+10
62	ABI 86*3414/X84W063-9-39-2//KARL92	020486	United States.Kansas State	152	121	Vrn-A1w		Vrn-D3b	2+12
65	85ZHONG33/ZLATOSTRUI//PLK70/LIRA	000022	Turkey Cimmyt Icarda	156	121	NA	Vrn-B1a	Vrn-D3b	2+12
67	BONITO-44	010268	Mexico-Turkey Cimmyt Icarda	153	121	NA			2+12
68	SABALAN//KRC66/SERI/5/JUP/4/CLLF/3/II14-53/ODIN//CI134431/SEL6425/WA00477	030084	Turkey Cimmyt Icarda	150	121	Vrn-A1w	Vrn-B1a		2+12
69	PATWIN YR5	100894	United States	146	121	NA		Vrn-D3b	5+10
73	ALAMOOT/4/KAL/BB//CJ/3/HORK	090859	Iran-Karadj	152	121	NA			2+12
78	W95-091 (=KS85-663-8-9//WI81-133/THUNDERBIRD)/AKRON	101038		151	121	Vrn-A1w		Vrn-D3b	5+10
95	OWL//OMBUL/ALAMO	120001	Iran-Karadj	151	121				5+10
111	00*0100-51	101287	US-AGRIPRO	146	121	Vrn-A1w			5+10
113	TX98D3447/TX99D4657	100010	US-ARS-NC	150	121	Vrn-A1w			5+10
120	TAST/SPRW//ZAR/5/YUANDONG 3/4/PPB8-68/CHRC/3/PYN//TAM101/AMIGO	060026	Turkey Cimmyt Icarda	146	121		Vrn-B1a		NA
124	4WON-IR-257/5/YMH/HYS//HYS/TUR3055/3/DGA/4/VPM/MOS	090433	Turkey Cimmyt Icarda	149	121	Vrn-A1w	Vrn-B1a		5+10
	Altay 2000 control	010627	Turkey	148	121				
	Bezostaja control	950189	Russia	145	121	Vrn-A1w			5+10
	Bayraktar control	010571	Turkey	151	121	Vrn-A1w		Vrn-D3b	5+10
	Karahan control	920007	Turkey	149	121	Vrn-A1w	Vrn-B1a		5+10
	Mufitbey control	020211	Turkey Cimmyt Icarda	154	121	NA	Vrn--B1b		5+10
	Mean of all lines tested (year 2012)			120	120				

OE: Original entry.TK: Turkey. ACC: Accession. OC: Origin country.

inoculation and environmental factors. Symptoms were more distinct under the greenhouse when compared to the field as this was contributed to the optimal environment for the disease to develop under the greenhouse. Also sterilized soil was used for the greenhouse trials versus field soil with its complex ecosystem which might affect disease development.
Severity of the disease can be assessed in many ways depending on the objectives of the screening whether it is aiming to screen for adult plant or seedling resistance. Use of seedlings will speed the selection of resistant progeny in wheat breeding programs where resistance to the disease is an objective (Wildermuth and McNamara 1994).

Resistance has been found more than one soil borne pathogens enabling the breeders to use these genotypes for soilborne disease complex. In this study, 17 wheat genotypes were found to be MR to the crown rot and well adapted to the Turkish dryland conditions and therefore are recommended for crosses in the breeding programs.

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