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Effects of Genotype, Sowing Time and Seed Fungicide Pre-Treatments on Root and Crown Rot and Grain Yield in Bread Wheat

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ABSTRACT
This study was carried out to investigate the effects of sowing time, cultivar and seed fungicide applications on root and crown rot disease and grain yield of bread wheat with different earliness traits (Esperia, mid-early; Genesi, late and Anapo, early) in the experiment station of the Department of Field Crops, Faculty of Agriculture, Tekirdağ Namık Kemal University. Four different fungicides pre-treatments (prothioconazole + tebuconazole, carboxin + thiram, prochloraz + tiriticonazole and control) were applied to the seeds of the varieties before sowing in three different times, on 1 November, 15 November and 30 November 2016. The experiment was designed as a split-split-plot with 3 replications. The results of the variance analysis showed that the effect of applying different seed fungicide pre-treatment root and crown rot of bread wheat varieties was statistically significant. While the lowest root and crown rot with 2.67 % was obtained from the second sowing time, the highest root and crown rot was determined with a value of 3.64% for the earliest sowing on 01 November. Among the four different fungicide pre-treatments, the highest root and crown rot (5.59%) was obtained in the control application, while the lowest root and crown rot was obtained in prothioconazole + tebuconazole, carboxin + thiram and prochloraz + triticonazole, with 1.96%, 2.10% and 2.19% root and crown rot, respectively. These data indicate that early sowing may increase root and crown rot severity.

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Ekmeklik Buğdayda Genotip, Ekim Zamanı ve Tohum Fungusiti Ön Uygulamalarının Kök ve Kök Boğazı Çürüklüğü ve Tane Verimi Üzerine Etkileri

ÖZET
Bu çalışma, Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü deneme alanında ekim zamanı, çeşit ve tohum ilacı uygulamalarının buğdayda kök ve kök boğazı çürüklüğü hastalıkları ile buğday dane verimine etkilerini araştırmak amacıyla yürütülmüştür. Araştırmada vejetasyon süreleri farklı olan 3 adet ekmeklik buğday çeşidi (Esperia:orta erkenci, Genesi: geççi ve Anapo: erkenci) kullanılmıştır. Ekimden önce bu çeşitlerin tohumlarına dört farklı fungisit (prothioconazole + tebuconazole, karboxin + thiram, prochloraz + tiriticonazole ve kontrol) uygulanarak 1 Kasım, 15 Kasım ve 30 Kasım 2016 olmak üzere 3 farklı zamanda ekimler yapılmıştır. Deneme, Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü deneme alanlarında, bölünen bölünmüş parseller deneme desenine göre 3 tekrarlamalı olarak düzenlenmiştir. Çalışmada, varyans analizi sonuçlarına göre farklı tohum fungusiti uygulamalarının ekmeklik buğday çeşitlerinin kök ve kök çürüklüğü üzerine etkisi istatistiki olarak önemli bulunmuştur. Farklı ekim zamanlarında en düşü kök ve kök boğazı çürüklüğü %2.67 ile ikinci ekim zamanında elde edilirken, en yüksek kök ve kök boğazı çürüklüğü %3.64 ile en erken ekim olan 01 Kasım ekiminde

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belirlenmiştir. Dört farklı tohum fungusit uygulamasında en yüksek kök boğazı çürüklüğü (%5.59) kontrol uygulamasından elde edilirken, en düşük kök boğazı çürüklüğü %1.96, %2.10 ve %2.19 ile sırasıyla aynı istatistiki grupta yer alan prothioconazole + tebuconazole, karboxin + thiram ve prochloraz + triticonazole ön uygulamalarından elde edilmiştir. Elde edilen veriler, erken ekim zamanının kök ve kök boğazı çürüklüğünün şiddetini arttırdığını göstermektedir.

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INTRODUCTION

The reactions of all living things to biotic and abiotic stress factors are closely related to the genetic backgrounds of living beings and the environmental conditions in which they grow. Plants are affected differently by diverse biotic and abiotic stress factors. Diseases are among the most important biotic stress factors. Although it depends on the growing regions and conditions, fungal diseases are among the most important biotic stress factors. The adverse effects of root and crown rot diseases caused by fungi such as *Fusarium culmorum, Fusarium pseudograminearom, Gaumannomyces graminis, Bipolaris sorokiniana, Rhizoctonia cerealis* are increasing in production area of wheat, which is the most important cultural plant in the world. These fungi that cause disease are of soil origin and can also be spread with seeds. On a global scale, many studies have been conducted on the yield losses caused by nematodes that form crown rot diseases. Studies in Europe, the USA, West Asia, North Africa, Australia and Canada showed that the yield losses in cereals vary between 5 and 50% due to these soil origin factors (Singh et al., 2005). Crown rot and cereal root rot causes yield loses in wheat of up to 50% in rainfed cereal production system throughout the world (Burgess et al., 1981; Klein et al., 1991; Smiley et al., 2005). Fusarium species have also been reported to cause product losses up to 17% in wheat as a result of severe crown infections caused by seed/soil originated infections (Parry and Nicholson, 1996). Many of the identified resistant sources are found in un-adapted germplasm which requires considerable breeding investment to develop suitable commercial cultivars (Singh et al., 2009).

A root and crown rot disease, which has been observed in the Thrace region in recent years, causes significant losses in wheat grain yield and quality. In the management against the disease, the factors such as the genetic structure (variety), the environmental conditions and soil characteristics in which the genotype is grown, and the cultural practices applied during the growth period of the genotype are significantly effective. It has been determined by previous studies that severe infections induced root and crown rot disease from *Fusarium spp* cause significant yield losses in wheat and disease severity can vary between 20-80% (Uçkun and Yıldız 2004; Hekimhan and Boyraz, 2011). Studies carried out in disease-contaminated areas have shown that these diseases increase yield loss up to 42% in varieties produced in these regions (Hekimhan et al., 2004). According to a study using different types of cereals, it has been explained yield increases ranging from 7–89% with the use of nematicides (Bolat et al., 2004). Within the framework of national root and crown project studies, it has been stated that although there are decreases in disease severity with low nitrogen dosage applications, this does not have a positive effect on yield (Bağcı et al., 2006). In another study, it was reported that increasing nitrogen doses increased root and crown rot disease severity in wheat (Smiley et al. 1996).

This study aims to determine the effects of different sowing time and seed fungicide pre-treatment with different active ingredients on root and crown rot grain yield in bread wheat varieties with different earliness groups.

MATERIALS and METHODS

The research was conducted as a split-split-plot design with 4–replications in the experimental station of Department of Field Crops, Faculty of Agriculture, Tekirdağ Namık Kemal University. Esperia (1), Anapo (2), and Genesi (3) varieties, which are in the early, medium and late maturation groups, were used as materials in the study. Three wheat varieties were sown at three different times, on November 1 (1^{st} sowing), November 15 (2^{nd} sowing) and November 30 (3^{rd} sowing) in 2016. The seeds of these varieties were sprayed with 4 different seed fungicides (carboxin + thiram (1), prothioconazole + tebuconazole (2), prochloraz + tiriticonazole (3) and control (4)). Sowing was done in plots of 6.12 square meters (0.17 m between rows, 6 m in rows) consisting of 6 rows by sowing machine, and sowing density was adjusted to 500 plants per square meter. Composed fertilizer (20.20.0), urea (46%) and ammonium nitrate fertilizers (26%) were applied at 200 kg ha^{-1} for seedbed preparation stage, 180 kg ha^{-1} for tillering stage and 200 kg ha^{-1} for stem elongation stage, respectively. To prevent weed development, broadleaf and grass weed herbicide mixture was applied. No application has been made in the trial area for disease and pest control. For the necessary measurements, weighing and quality analysis on seeds taken from each plot at harvest maturity. The plots were harvested by the plot combine harvester.

A root and crown rot disease severity observations were fulfilled in two periods in each plot where different applications made by counting and recording infected and non-infected plants. The main purpose in endurance studies under natural conditions was to choose durable and non-durable plants. Nine weeks later, plant roots were washed and disease severity was evaluated 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., 2012). The data obtained in the experiment were analyzed by using the JUMP 5.0 statistical package program, and the difference between the averages was determined by the LSD test.

RESULTS and DISCUSSION

Variance analysis results of the root and crown rot disease severity observations rates obtained from the experiment sown in three different sowing times and four different seed herbicide pre-treatment were applied to the bread wheat variety belonging to three different earliness groups indicated that the effect of applying different seed fungicide pre-treatment on root and crown rot disease was statistically significant, while the sowing time, variety, sowing time x variety, sowing time x fungicide pre-treatment, variety x fungicide pre-treatment and sowing time x variety x fungicide pre-treatment interactions were statistically insignificant. The efficacy of fungicides seed treatment against *Fusarium culmorum* crown rot in wheat was examined and some fungicides seed treatments such as Triticonazole, Pyraclostrobin, Imazalil, Triademefon, Tebuconazole and Difenoconazole were registered for wheat and barley to suppress crown rot, common root rot and other fungal diseases (McMullen et al., 2000; Burrows et al., 2006). To determine the significances between the average values obtained, a significance test was performed and the results are given in Table 1.

Çizelge 1. Kök ve kök boğazı çürüklüğü hastalık şiddetinin gözlem ortalamaları ve önemlilikleri
Table 1. The means of root and crown rot disease severity observation and their significances

Ekim zamanı (EZ) *Sowing time (ST)*			Çeşit (Ç) *Variety (V)*			Fungusit ön uygulaması (FÖU) *Fungicide pre-treatment (FPT)*			
1	2	3	1	2	3	1	2	3	4
3.639±0.529[a]	2.665±0.527[b]	2.754±0.471[b]	3.226± 0.544	3.088± 0.502	2.903± 0.517	1.955± 0.277[b]	2.095± 0.225[b]	2.192± 0.235[b]	5.593± 0.302[a]
LSD = 0.686						LSD = 1.998			

EZ x Ç interaksiyonu *ST x V interaction*		EZ x FÖU interasiyonu *ST x FPT interaction*		Ç x FÖÜ interaksiyonu *V x FPT interaction*		EZ x Ç x FÖU interaksiyonu *ST x V x FPT interaction*			
1 * 1	4.250	1 * 1	2.556	1 * 1	2.500	1 * 1 * 1	3.667	2 * 2 * 3	2.000
1 * 2	3.250	1 * 2	2.667	1 * 2	2.143	1 * 1 * 2	3.000	2 * 2 * 4	6.333
1 * 3	3.417	1 * 3	2.778	1 * 3	2.222	1 * 1 * 3	3.333	2 * 3 * 1	1.000
2 * 1	2.222	1 * 4	6.556	1 * 4	5.556	1 * 1 * 4	7.000	2 * 3 * 2	1.000
2 * 2	3.273	2 * 1	1.667	2 * 1	1.889	1 * 2 * 1	2.000	2 * 3 * 3	1.500
2 * 3	2.500	2 * 2	1.400	2 * 2	2.143	1 * 2 * 2	2.333	2 * 3 * 4	4.667
3 * 1	2.900	2 * 3	1.500	2 * 3	2.333	1 * 2 * 3	2.333	3 * 1 * 1	1.500
3 * 2	2.727	2 * 4	5.222	2 * 4	5.778	1 * 2 * 4	6.333	3 * 1 * 2	2.000
3 * 3	2.636	3 * 1	1.429	3 * 1	1.571	1 * 3 * 1	2.000	3 * 1 * 3	2.333
		3 * 2	1.857	3 * 2	2.000	1 * 3 * 2	2.667	3 * 1 * 4	5.000
		3 * 3	2.222	3 * 3	2.000	1 * 3 * 3	2.667	3 * 2 * 1	1.333
		3 * 4	5.000	3 * 4	5.444	1 * 3 * 4	6.333	3 * 2 * 2	2.000
						2 * 1 * 1	1.000	3 * 2 * 3	2.667
						2 * 1 * 2	1.000	3 * 2 * 4	4.667
						2 * 1 * 3	1.000	3 * 3 * 1	1.500
						2 * 1 * 4	4.667	3 * 3 * 2	1.667
						2 * 2 * 1	2.333	3 * 3 * 3	1.667
						2 * 2 * 2	2.000	3 * 3 * 4	5.333

Sowing times: 1.(1 November), 2. (15 November), 3. (30 November); Varieties : 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + thiram), 2 (Prothioconazole + tebuconazole), 3 (Prochloraz + tiriticonazole) and 4 (control)

Although the effect of different sowing time on root and crown rot disease is statistically significant, it can be seen from Table 1 that the order from low to high is 30 November (2.67%), 15 November (2.75%) and 1 November (3.64%), respectively. This result indicates that early sowing can increase root and crown rot disease severity. In the case of bread wheat varieties, the latest Genesi variety showed the lowest root and crown rot disease severity (2.90%), while the highest rate (3.23%) was observed in Esperia variety, which is the earliest. Pariyar et al. (2014) stated that in their studies that 6 different wheat genotypes applied Tiabendazole seed treatment, 4 of 6 wheat genotypes caused a significant decrease in the severity of crown rot ($P < 0.05$) and the highest crown score reduction was recorded in Series 82 and Demir 2000 genotypes.

Considering the fungicide pre-treatments with different active substances, prothioconazole + tebuconazole, carboxin + thiram, and prochloraz + triticonazole pre-treatments included in the same statistical group showed the lowest root and crown rot disease ratios of 1.96%, 2.1% and 2.19% respectively, while the highest root and crown rot disease severity was given by control application with 5.59% statistically insignificant sowing time x variety interaction may mean that there may be no significant root and crown rot disease severity differences among varieties with different earliness characteristics. Despite the statistically insignificant differences between sowing time x fungicide pre-treatment interaction means, it may mean that fungicide pre-treatments may not cause statistically important reducing in the severity of root and crown rot disease severity regarding the sowing time. Although the differences between variety x fungicide pre-treatment averages were statistically insignificant; it can be said that fungicide pre-treatment can lead to proportionally lower root and crown rot disease severity compared to control applications regardless of the earliness properties of varieties.

In the light of the mentioned findings, it can be concluded that sowing time, variety and especially seed fungicide pre-treatments have a significant effect on root and crown rot disease severity for bread wheat. Moreover, the results indicate that late genotypes may be more resistant to root and crown rot disease severity, whereas early planting may increase the severity of root and crown rot disease. It is understood that seed fungicide pre-treatments can be the more effective method in reducing root and crown rot disease severity compared to cultivar and planting time. The order of efficacy of seed fungicide pre-applications used in the study regarding the reduction of root and crown rot disease severity; carboxin + thiram, prochloraz + tiriticonazole and prothioconazole + tebuconazole.

Variance analysis results of the grain obtained from the experiment sown in three different sowing times and four different seed herbicide pre-treatment were applied to the bread wheat variety belonging to three different earliness groups indicated that the effect of sowing time, variety and applying different seed fungicide pre-treatment on root and crown rot was statistically significant, while all interactions were statistically insignificant. To determine the significances between the average values obtained, a significance test was performed and the results are given in Table 2.

In case of differences in the mean of grain yields of different sowing time; the highest grain yield was obtained at the 2nd sowing time (November 15) with 441.9 kg da^{-1}, followed by the 1st sowing time (November 01) with 420.4 kg da^{-1}. The lowest grain yield was found at the 3rd sowing time (November 30) with 405.5 kg da^{-1}. There was an 8.2% difference between the 2nd and 3rd sowing times when the highest and lowest seed yields were obtained. Yield loss due to these pathogens have been reported and reached up to 35% in winter wheat in Pacific Northwest (PNW) of America (Smiley et al., 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).

Among the means of the varieties with different earliness characteristics; Anapo with the earliest variety gave the highest grain yield with a value of 462.8 kg da^{-1}, while the lowest grain yield (395.5 kg da^{-1}) was determined for Esperia with the medium early variety. The Anapo variety, which gives the earliest and highest grain yield, yielded 14.5% higher grain yield than the mid-early Esperia variety with the lowest grain yield. 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 a high level of resistance are still not available (Li et al., 2012).

Regarding the fungicide pre-treatments with different active substances, differences between grain yield means for carboxin + thiram, prochloraz + tiriticonazole and prothioconazole + tebuconazole pre-treatments were not important and they were included in the same statistical group which gave the highest grain yield with values of 462.8, 453.4 and 450.9 kg da^{-1} respectively, while the lowest grain yield mean was obtained by control application with 323.1 kg da^{-1}. It can be generalized that the general average of grain yield obtained by fungicide pre-treatments with different active substances was 29.1% higher than the control application.

Çizelge 2. Tane verimi ortalamaları (kg da^{-1}) ve önemlilikleri
Table 2. The means of grain yield (kg da^{-1}) and their significances

Ekim zamanı (EZ) *Sowing time (ST)*			Çeşit (Ç) *Variety (V)*			Fungusit ön uygulaması (FÖU) *Fungicide pre-treatment (FPT)*			
1	2	3	1	2	3	1	2	3	4
420.2 ab ±19.95	441.9 a ±21.68	405.5 b ±19.33	395.5 b ±24.09	462.8 a ±14.58	409.4 b ±16.73	453.4 a ±10.83	462.8 a ±11.17	450.9 a ±10.76	323.1 b ±19.71
LSD:25.641			LSD:45.976			LSD: 32.548			

EZ x Ç interaksiyonu *ST x V interaction*		EZ x FÖU interasiyonu *ST x FPT interaction*		Ç x FÖU interaksiyonu *V x FPT interaction*		EZ x Ç x FÖU interaksiyonu *ST x V x FPT interaction*			
1 * 1	394.5	1 * 1	447.4	1 * 1	422.1	1 * 1 * 1	419.5	2 * 2 * 3	509.6
1 * 2	460.1	1 * 2	459.6	1 * 2	463.9	1 * 1 * 2	464.1	2 * 2 * 4	405.0
1 * 3	406.0	1 * 3	450.3	1 * 3	434.8	1 * 1 * 3	435.0	2 * 3 * 1	475.6
2 * 1	409.8	1 * 4	323.5	1 * 4	261.0	1 * 1 * 4	259.1	2 * 3 * 2	445.0
2 * 2	491.8	2 * 1	477.4	2 * 1	479.0	1 * 2 * 1	467.8	2 * 3 * 3	444.6
2 * 3	424.1	2 * 2	484.8	2 * 2	492.0	1 * 2 * 2	488.0	2 * 3 * 4	331.3
3 * 1	382.1	2 * 3	467.5	2 * 3	489.3	1 * 2 * 3	488.7	3 * 1 * 1	410.0
3 * 2	436.5	2 * 4	337.8	2 * 4	390.8	1 * 2 * 4	396.0	3 * 1 * 2	451.0
3 * 3	397.8	3 * 1	435.3	3 * 1	458.9	1 * 3 * 1	454.8	3 * 1 * 3	421.0
		3 * 2	443.7	3 * 2	432.3	1 * 3 * 2	426.7	3 * 1 * 4	246.6
		3 * 3	434.8	3 * 3	428.6	1 * 3 * 3	427.3	3 * 2 * 1	449.6
		3 * 4	308.0	3 * 4	317.4	1 * 3 * 4	315.3	3 * 2 * 2	455.0
						2 * 1 * 1	437.0	3 * 2 * 3	469.6
						2 * 1 * 2	476.6	3 * 2 * 4	371.6
						2 * 1 * 3	448.3	3 * 3 * 1	446.3
						2 * 1 * 4	277.3	3 * 3 * 2	425.3
						2 * 2 * 1	519.6	3 * 3 * 3	414.0
						2 * 2 * 2	533.0	3 * 3 * 4	305.6

Sowing times: 1.(1 November), 2. (15 November), 3. (30 November); Varieties: 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + thiram), 2 (Prothioconazole + tebuconazole), 3 (Prochloraz + tiriticonazole) and 4 (control)

CONCLUSION

In the study conducted to investigate the effects of sowing time, cultivar and seed fungicide applications on root and crown rot and grain yield in wheat, the effect of different sowing time on root and crown rot disease was found statistically insignificant. However, the results of sowing time were; 30 November (2.714%), 15 November (3.313%) and 01 November (3.639%), respectively (Table 1). This result indicates that early sowing can increase root and crown rot disease severity.

Considering the fungicide pre-treatments with different active substances, prothioconazole + tebuconazole, carboxin + thiram, and prochloraz + triticonazole pre-treatments included in the same statistical group showed the lowest root and crown rot disease ratios of 1.96%, 2.1% and 2.89% respectively, while the highest root and crown rot disease severity was obtained by control application with 5.59%.

The findings reveal that sowing time, variety and especially seed fungicide pre-treatments have a significant effect on root and crown rot disease severity for bread wheat. Moreover, the results indicate that early genotypes may be more resistant to root and crown rot disease severity, whereas early sowing may increase the severity of root and crown rot disease. It is understood that seed fungicide pre-treatments can be the more effective method in reducing root and crown rot disease severity compared to cultivar and planting time.

In case of differences in the mean of grain yields of different sowing time; the highest grain yield was obtained at the 2nd sowing time (15 November) with 441.9 kg da^{-1}, followed by the 1st sowing time (01 November) with 420.2 kg da^{-1}. The lowest grain yield was found at the 3rd sowing time (November 30) with 405.5 kg da^{-1}. There was a 17.44% difference between the 1st and 3rd sowing times when the highest and lowest seed yields were considered.

Competing interests and Acknowledgements

Authors have declared that no competing interests exist.

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