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Diverse responses of old, modern and landraces of Syrian wheat genotypes to common root rot under field conditions

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Abstract The yield response of widely grown cultivars and landraces of Syrian wheat challenged with common root rot (CRR: *Cochliobolus sativus*) was measured by comparing plots with and without artificial inoculation under experimental conditions in two consecutive seasons. The results showed that response to CRR differed depending on the susceptibility levels of the wheat cultivars, and that the disease significantly ($P<0.05$) reduced grain yield, number of tillers and kernel weight. The diseased plants had fewer tillers which consequently reduced grain yield per plant. Yield losses of *Triticum durum* cultivars were higher than those of *Triticum aestivum*. In addition, the *T. durum* landrace Horani exhibited the best level of resistance to the disease, which indicates that this landrace might be a candidate donor for resistance in future breeding programmes. As CRR can dramatically reduce wheat grain yields under favorable conditions, management practices that reduce disease severity are highly recommended.

Additional keywords: *Cochliobolus sativus, Triticum aestivum, Triticum durum,* yield loss.

Introduction

Common root rot (CRR), caused by *Cochliobolus sativus* (Ito & Kurib.) Drechsl. ex Dast. [anamorph: *Bipolarissorokiniana* (Sacc. in Sorok.) Shoem.], is an economically important disease of barley, wheat and other small grains in semi-arid climates worldwide (McKay*et al*., 2018). CRR causes a brown to black discoloration of the subcrown internodes (SCIs) of wheat (*Triticum aestivum* L.), which is directly related to yield losses (Mathre *et al*., 2003; Fernandez Holzgang, 2009).

Although fungicides can reduce disease severity, the most effective and environmentally sound means of control is through the use of resistant cultivars (Kumar *et al*., 2002). Wheat interaction with CRR is genotype dependent (Fernandez and Jefferson, 2004) and affected by soil inoculum (Smiley *et al*., 2005). Therefore, prior to controlling CRR, the potential of this disease to cause losses in wheat growing areas should be evaluated.

The impact of CRR on the crop (wheat) is important because reductions in plant biomass are a measure of the combined effects of the disease on photosynthesis and other production processes (Fernandez and Conner, 2011). Therefore, this study was carried out to evaluate wheat yield responses to CRR under experimental conditions that are typical of a large part of the wheat-growing areas of western Asia.

Materials and Methods

Plant material

Ten most widely grown cultivars and landraces of Syrian wheat were used in the study. They included two *Triticum durum* landraces (Horani and Salamoni), four *Triticum aestivum* cultivars (Bouhouth4, Bouhouth6, Cham2 and Doma4), one *T. aestivum* introduced cultivar (Maksibak) and three *T. durum* cultivars (Bouhouth7, Cham3 and Doma1).

Seed inoculation

Nine isolates of *C. sativus,* selected on the basis of cultural and morphological characteristics and virulence (Arabi and Jawhar, 2002), were used. These isolates were obtained from subcrown internodes of bar-

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ley plants showing CRR symptoms. Each isolate was grown on potato dextrose agar (PDA, DIFCO, Detroit, MI, USA) for 10 days at 22 ±1ºC in the dark. After 10-12 days, conidia were collected by flooding the plate with 10 mL of sterile distilled water and scraping the colony surface with a glass slide to dislodge the conidia. Equal volumes of conidial suspension of each isolate were mixed and filtered through a double layer of cheesecloth. The resulting conidial suspension was adjusted to 5 X 10^5 conidia/mL.

Experimental design

The trials were conducted at a site approximately 55 km south of Damascus for two consecutive years (2016-2017), under natural rainfed conditions (350mm annual rainfall). Seed inoculation was performed according to the method described by van Leur (1991), where, 30 g seeds of each cultivar were placed in a plastic Petri dish (12-cm in diameter) containing 10 g sterile neutralized peat, 40 ml spore suspension (5 × 10^5 condia/ml) and 8 drops of natural Arabic gum. Following thorough agitation for 1 min, the seeds were sown at 6 cm depth to promote long subcrown internodes (Kokko *et al.*, 1995) in a randomized complete block design, with three replicate plots (1 m x1 m) separated with a 1-m wide border. Each plot consisted of five rows, 20 cm apart and with 50 seeds per row. Based on laboratory preliminary tests on PDA media, CRR-free seeds were used as controls.

Disease evaluation

Subcrown internodes (SCIs) were examined 8 weeks post-inoculation by measuring the percentage of SCIs surface showing CRR symptoms using a 0-5 scale, as described by Kokko *et al.* (1995), where 0 (resistant); 1 = HT (highly tolerant): small light brown lesions covering 1-10% of the SCI; 2 = T (tolerant): light brown lesions covering 11-25% of the SCI; 3 = MS (moderately susceptible): light brown/black lesions covering 26-40% of the SCI; 4 = S (susceptible): black lesions covering 41-75% of the SCI; 5 = HS (highly susceptible): black lesions covering 76-100% of the SCI.

1000-kernel weight (TKW) and yield estimation

Three central rows of each replicate plot were harvested at maturity stage to measure grain yield (gr/plant). A 500-seed subsample from each row was used to calculate 1000-kernel weight (TKW). The number of tillers per plant was determined on individual hand-harvested plants.

Statistical analysis

Data was subjected to analysis of variance using the STAT-ITCF statistical programme (2nd Version). Differences between means were evaluated for significance by using Newman-Keuls test at 5% probability level (Anonymous, 1988)

Results and Discussion

CRR produced brown-dark lesions on SCIs, and these symptoms were more severe on the susceptible cultivar Bouhouth7 (Fig. 1). The results are in agreement with our pre-

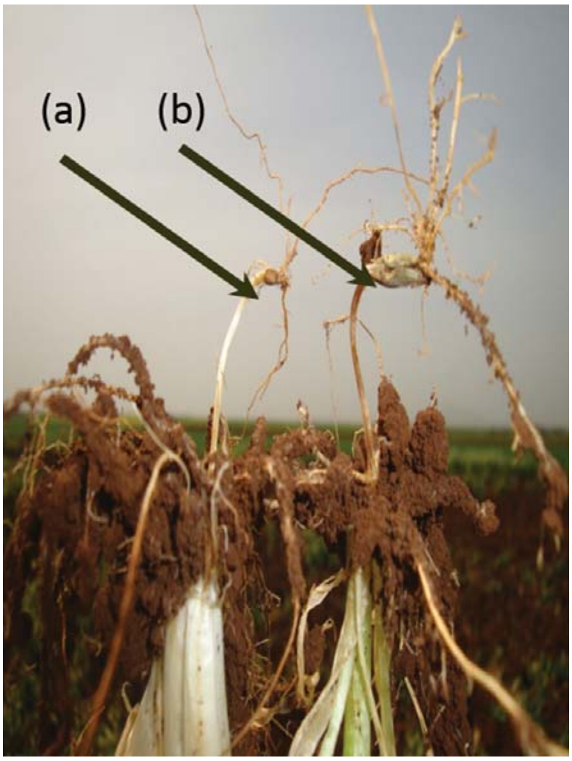

Figure 1. Common root rot symptoms (*Cochliobolus sativus*)on the wheat (a) highly tolerant landrace 'Horani' and(b) highly susceptible cv. Bouhouth 7, under field conditions.

vious observations under natural field conditions (Arabi and Jawhar, 2002). The reactions of the 10 wheat cultivars to *C. sativus* are presented in Table 1. Significant differences ($P<0.05$) in disease severity were detected among cultivars, with values being consistently higher in the susceptible cultivars, in both years of experimentation. In both seasons, landrace Salamoni was highly susceptible with mean disease severity 83.4 %. The *T. durum* landrace Horani proved to be the most tolerant having 9.9% disease severity (Table 1). In general, the *T. durum* cultivars were more tolerant than those of *T. aestivum* (Table 1).

The effects of CRR on grain yield are presented in Table 2. During the first growing season (2016), no significant differences in yield were observed between plants obtained from inoculated and non-inoculated seeds. During the second growing season (2017), grain yield was reduced by CRR in relation to the non-inoculated seeds in all other cultivars except for the highly tolerant landrace Horani.

Moreover, CRR significantly ($P<0.05$) reduced the TKW of the cvs Bouhouth6 and Maksibak by 18.9 % and 8.6 % in 2016, and by 14.3% and 29.5 % in 2017, respectively (Table 3). The reduction of TKW in the other cultivars differed greatly depending on the cultivar (Table 3).

As shown in Table 4, the number of tillers decreased significantly ($P<0.05$) by 28 and 27% in the cvs Bouhouth6 and Cham3, in 2016, and by 37.5 and 39.5%, in 2017, respectively (Table 4). Diseased plants had fewer tillers resulting in reduced grain yield per plant. Similar results were reported by Fernandez *et al.* (2014) and Duczek and Jones-Flory (1993), who found that wheat plants infected by *C. sativus* early in the season produced fewer tillers than those infected later in the season, which was reflected in yield per plant. The current study also showed that the average response of wheat cultivars to CRR differed with the susceptibility level. These findings are in agreement with those of Rush and Mathieson (1990) and Bhandari and Shrestha (2004).

Overall, CRR had a negative effect on TKW and the number of tillers produced in susceptible wheat cultivars grown under rainfed conditions in southern Syria. The reduction in total grain yield may be attributed mainly to the reduction in the number of tillers, as reported by Conner *et al.* (1996). However, according to Fernandez and Con-

Table 1. Reaction of wheat genotypes to Common root rot (CRR; *Cochliobolus sativus*) under field conditions in two growing seasons (2016, 2017).

Cultivar	Origin	Severity (% subcrown internodes infected area)		
		Year 2016	Year 2017	Mean effect
Horani	Landrace	A11.3d[y]	A8.5d	9.9d
Cham3	Syrian (Developed by SGCASR)*	A10.3d	A9.2d	9.7d
Doma4	"	A11.2d	B15.9d	13.6d
Cham2	"	A15.2d	B22.5d	18.9c
Doma1	"	A31.2c	B17.0d	24.1c
Bouhouth4	"	A33.2c	B27.9c	30.6c
Bouhouth6	"	A42.6ab	B48.2ab	45.4ab
Maksibak	Introduced	A66.5ab	B58.9b	62.7b
Bouhouth7	Syrian (Developed by SGCASR)*	A84.9a	B77.2a	81.1a
Salamoni	Landrace	A82.97a	A84.0a	83.5a
Mean		A42.11	B36.92	

[y] Means (three replicates/cultivar) preceded by different capital letters (row) and followed by different lowercase letters (column) differ significantly at $P<0.05$ according to Newman-Keuls test. *SGCASR: Syrian General Commission of the Agricultural Scientific Research.

Table 2. Effect of Common root rot (CRR; *Cochliobolus sativus*) on grain yield in wheat cultivars under field conditions in two growing seasons (2016, 2017).

Cultivar	Grain yield (g/plant)			
	Year 2016		Year 2017	
	Non	Ino.	Non	Ino.
Horani	A2.4c[y]	A2.0c	A18.2bc	A16.7ab
Cham3	A4.2bc	A4.0bc	A16.7C	B7.7c
Doma4	A3.6c	A4.6bc	A33.0a	B19.1a
Cham2	A8.2ab	A8.9a	A18.7bc	B8.7c
Doma1	A4.5bc	A4.7bc	A16.7bc	B13.6bc
Bouhouth4	A2.9c	A3.0c	A19.8bc	B12.3bc
Bouhouth6	A5.8bc	A3.8bc	A28.3ab	B11.5bc
Maksibak	A2.8c	A3.2c	A16.9bc	B9.9c
Bouhouth7	A4.8bc	A4.1bc	A18.2bc	B12.6bc
Salamoni	A11.1a	A7.1ab	A25.3abc	B10.4c
Mean	A5.03	A4.5	A20.9	B12.9
Mean	B4.8		A16.6	

[y] Means (three replicates/cultivar) preceded by different capital letters (row) and followed by different lowercase letters (column) differ significantly at *P*<0.05 according to Newman-Keuls test. Non: Non-inoculated seeds (control), Ino.: Inoculated seeds (Kokko *et al.*, 1995).

Table 3. Effect of Common root rot (CRR; *Cochliobolus sativus*) on 1000-kernel weight (TKW) of wheat cultivars during two growing seasons (2016, 2017).

Cultivar	1000-kernel weight (g)			
	Year 2016		Year 2017	
	Non	Ino.	Non	Ino.
Horani	A36.0ay	B34.0b	A37.6ab	B34.0b
Cham3	A28.6bc	A27.3bc	A35.3ab	B27.3bc
Doma4	A34.0ab	A33.0bc	A37.0ab	B30.6bc
Cham2	A28.1bc	A29.0bc	A28.6ab	A28.6bc
Doma1	B39.0a	A40.6a	A41.0a	A38.6a
Bouhouth4	B23.0c	A24.6c	A29.6b	B24.6c
Bouhouth6	A37.0a	B30.0bc	A35.0ab	B30.0bc
Maksibak	A28.0bc	B25.6bc	A36.3ab	B25.6bc
Bouhouth7	B25.6c	A28.3bc	A32.3ab	B28.3bc
Salamoni	B28.6bc	A27.6bc	A35.3ab	B32.6bc
Mean	A30.8	B28.0	A35.5	B30.1
Mean	B29.7		A32.8	

[y] Means(three replicates/cultivar) preceded by different capital letters (row) and followed by different lowercase letters (column) differ significantly at *P*<0.05 according to Newman-Keuls test. Non: Non- inoculated seeds (control), Ino.: Inoculated seeds (Kokko *et al.*, 1995).

ner (2011), CRR directly affected the carbon fixation and other physiological processes in wheat leaves by reducing the upward movement of water and nutrients in plants.

CRR had a direct impact on total grain yield of wheat, and therefore, this disease should be considered when managing wheat diseases. Moreover, continued ef-

Table 4. Effect of Common root rot (CRR; *Cochliobolus sativus*) on the number of tillers of wheat cultivars during two growing seasons (2016, 2017).

Cultivar	Number of tillers/plant			
	Year 2016		Year 2017	
	Non	Ino.	Non	Ino.
Horani	A5.6by	A5.6a	A6.0a	B5.3a
Cham3	A6.3ab	B4.6ab	A7.6a	B4.6a
Doma4	A8.0b	B6.3a	A7.0a	B6.3a
Cham2	A5.3b	B4.6ab	A6.6a	B5.0a
Doma1	A5.6b	B5.0ab	A6.6a	B5.6a
Bouhouth4	A6.3ab	B5.6a	A6.3a	B5.3a
Bouhouth6	A5.0b	B3.6b	A8.0a	B5.0a
Maksibak	A5.0b	A5.0ab	A6.6a	B5.0a
Bouhouth7	A6.3ab	B5.6a	A6.3a	B5.0a
Salamoni	A7.6a	B6.0a	A7.6a	B4.3a
Mean	A6.1	A5.2	A6.9a	B5.1a
Mean	A5.2		A5.1	

y Means (three replicates/cultivar) preceded by different capital letters (row) and followed by different lowercase letters (column) differ significantly at $P<0.05$ according to Newman-Keuls test. Non: Non-inoculated seeds (control), Ino.: Inoculated seeds (Kokko *et al*., 1995).

forts are required to monitor the occurrence of CRR in cereal fields in Syria to develop a better understanding of the potential risk of its establishment and intensification. The highly CRR tolerant landrace Horani can be considered as a promising parent in wheat breeding programmes.

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Απόκριση παλαιών, νέων και γηγενών Συριακών γονοτύπων σίτου στην ασθένεια “κοινή σήψη ριζών” σε συνθήκες αγρού

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Περίληψη Η απόκριση ευρέως καλλιεργούμενων και γηγενών Συριακών ποικιλιών σίτου στη μόλυνση από το μύκητα *Cochliobolus sativus*, αξιολογήθηκε μετά από σύγκριση πειραματικών τεμαχίων με και χωρίς τεχνητή μόλυνση κατά τη διάρκεια δύο διαδοχικών καλλιεργητικών περιόδων. Τα αποτελέσματα έδειξαν ότι η απόκριση στο παθογόνο διέφερε ανάλογα με το επίπεδο ευπάθειας των ποικιλιών σίτου και ότι η ασθένεια μείωσε σημαντικά (P <0,05) την παραγωγή, το βαθμό αδελφώματος και το βάρος των σπόρων Τα προσβεβλημένα φυτά εμφάνιζαν μικρότερο βαθμό αδελφώματος με αποτέλεσμα τη μείωση της παραγωγής ανά φυτό. Η απώλεια στην παραγωγή των ποικιλιών του *Triticum durum* ήταν μεγαλύτερη από αυτή των ποικιλιών του *Triticum aestivum*. Επιπλέον, η γηγενής ποικιλία Horani του *T. durum* εμφάνισε το υψηλότερο επίπεδο αντοχής στην ασθένεια. Ως εκ τούτου, η συγκεκριμένη ποικιλία θα μπορούσε να είναι υποψήφιος δότης ανθεκτικότητας στην ασθένεια σε μελλοντικά προγράμματα βελτίωσης ποικιλιών. Επειδή κάτω από ευνοϊκές συνθήκες η ασθένεια μπορεί να προκαλέσει σημαντική μείωση της παραγωγής σίτου, συνιστάται η εφαρμογή μέτρων διαχείρισης που θα μειώσουν την ένταση της προβολής.

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