Plant Cell Biotechnology and Molecular Biology 20(5&6):261-274; 2019 ISSN: 0972-2025

COMPARATIVE PATHOGENESIS OF 7 *Fusarium* spp. SPECIES AND *Bipolaris sorokiniana* OBTAINED FROM NECROTIC LESIONS OF WHEAT ROOTS AND BARLEY PLANTS (NORTH-WESTERN MOROCCO)

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Received: 20 March 2019
Accepted: 05 June 2019
Published: 18 June 2019

Original Research Article

ABSTRACT

This work aims to demonstrate the pathogenicity of 37 isolates of *Fusarium* species and 4 isolates of *Bipolaris sorokiniana* on durum wheat (Karim and Amjad varieties), soft wheat (Wafia and Amal varieties) and barley (*Hordeum pusillum* and *Hordeum escourgeon*).All isolates induced root necrosis in inoculated wheat and barley plants. Isolates F10 (*F. solani*), F21, F24, F25 (*F. graminearum*), F27, F28, F29 (*F. culmorum*) and F34 (*F. solani*) are the most pathogenic on tested wheat varieties (hard and soft). Similarly, isolates F9 (*F. solani*), F22, F26 (*F. graminearum*), F29 (*F. culmorum*) and F34 (*F. solani*) are the most pathogenic on barley. *F. solani* and *F. oxysporum*, mentioned as secondary parasites or simple saprophytes or having a very reduced aggressiveness on wheat and barley, induced in these two cereals class 4 of severity, incidences and indices of the disease very high and therefore can be considered as responsible pathogens for root rot. The isolates of *Bipolaris sorokiniana* are also pathogenic on wheat and barley, but their pathogenicity is lower than that induced by the studied isolates of *Fusarium* species. Isolates H4 and H3 could induce a percentage of the S4 severity class in the order of 25% on the plants of the variety Wafia (wheat) and Amjad (durum wheat). The highest percentages of S4 class in barley, Escourgeon and Pisillum, did not exceed 16.7% and were induced by isolate H1. This study also allowed discussing the importance of each pathogen to induce disease in wheat and barley.

Keywords: Wheat; barley; root rot; *Fusarium* sp.; *Bipolaris sorokiniana;* pathogenicity.

INTRODUCTION

Cereal root rot, caused by a varied soil fungal complex containing *Fusarium* and *Bipolaris* species, are among the most important constraints for wheat and barley production around the world [1,2]. These diseases are much more favored in areas with low to medium rainfall, North Africa [3,4]. When root infection is more severe, it can be a serious constraint on yield, with a decrease in grain quality [5]. In Morocco, yield losses due to root rot are not insignificant and may be at the same level as those estimated at the international level [6,7].

In the field, the symptoms of root rot are variable, they translate, according to El Yousfi [8], Wahbi [9], Bockus et al. [10], Nyvall [11], Tinline [12],

Duthie and Hall [13], by a loss of lift, damping off, lesion in coleoptiles, little or no developed roots, brutal withering of seedlings, necrosis on the collar, the deputy crown and roots and appearance of whiteheads during very dry seasons. The study of this disease etiology has indicated that several species responsible for root rot of cereals can be found together, region-wide, of the plot and also on the same spike [14]. Qostal et al. [15] reported that two, three or more pathogens of the fungal complex can be isolated from necrotic lesions of the same plant.

Surveys carried out in wheat (durum wheat and soft) and barley fields in April-May 2017 in northwestern Morocco, allowed to isolate a variable pathogenic fungal complex, consisting of *Bipolaris sorokiniana*, *Curvularia spicifera* and *Fusarium* species such as *Fusarium culmorum, Fusarium solani, Fusarium nivale, Fusarium poae, Fusarium oxysporum, Fusarium graminearum, Fusarium* sp. and *Fusarium roseum*. The present work proposes to study the pathogenic power of isolates of *Fusarium* species and *Bipolaris sorokiniana* on durum wheat (Karim and Amjad varieties), soft wheat (Wafia and Amal varieties) and barley (*Hordeum pusillum* and *Hordeum escourgeon*). Indeed, in the literature, the pathogenic power of these species on wheat and barley is little studied in Morocco.

MATERIALS AND METHODS

Fungal Material

Different fungal species, isolated from wheat (hard and soft) and barley plants from the North-West region of Morocco (Kenitra, Ouezzane and Sidi Kacem regions), are used in this study: four isolates of *Bipolaris sorokiniana* (Table 1) and Thirty-seven *Fusarium* isolates (*Fusarium oxysporum, Fusarium culmurom, Fusarium solani, Fusarium graminearum, Fusarium poae, Fusarium nivale*, and *Fusarium roseum*) (Table 1) 2). All these species are stored on filter paper washers at -20°C in the freezer.

Plant Material

Grain of Wheat with a healthy-looking (durum wheat: Karim and Amjad varieties, soft wheat: Wafia and Amal varieties), and barley (*Hordeum pusillum* and *Hordeum escourgeon*) are disinfected by soaking in a 10% sodium hypochlorite solution for two minutes, rinsed three times with sterile distilled water and then dried on sterile filter paper.

Inoculum Preparation

For the preparation of the inoculum, the thirty-seven isolates of *Fusarium* and the four isolates of *Bipolaris sorokiniana* are grown on the PSA (Potato Sucrose Agar: 200 g potato, 20 g sucrose, 15 g agar-agar and 1000 mL distilled water) and incubated in the dark at 28°C.

After 15 days of incubation for all species, the charged surface of spores is scraped aseptically using a metal spatula and distilled water. The resulting suspension is filtered on muslin to separate the spores from the mycelium. The resulting spore solution is adjusted with distilled water containing 0.05% Tween so as to have a final concentration of 10^6 spores / mL.

Inoculation of Grains

The disinfected wheat and barley grains are inoculated by soaking for 24 hours in a spore's suspension of 10^5 spores / mL. The control grains are soaked in sterile distilled water. After, the grains, inoculated and controls, are dried again on sterile filter paper and transplanted into pots (4 grains per pot) containing a substrate of sterile Mamora sand and peat (75/25). Afterwards, all the pots are brought back to a culture greenhouse.

Table 1. Isolates of *Bipolaris sorokiniana* and their origins

Bipolris sorokiniana isolates	Isolation sources	Locality (Country)
H1	durum wheat	Souk Tlat/Morocco
H2	soft wheat	Megren/Morocco
H3	Barley	Souk Tlat/Morocco
H4	Barley	Ouled Sellam/Morocco

Table 2. Isolates of *Fusarium* species and their origins

Fusarium isolates	Species	Isolation Sources	Locality (Country)
F1	*Fusariums solani*	durum wheat	Souk Tlat/ Morocco
F2	*Fusarium solani*	Soft wheat	Megren/ Morocco
F3	*Fusarium solani*	barley	Souk Tlat/ Morocco
F4	*Fusarium solani*	barley	Ouled Sellam/ Morocco
F5	*Fusarium solani*	Soft wheat	Ouled Sellam/ Morocco
F6	*Fusarium solani*	Barley	Ouled Selam/ Morocco
F7	*Fusarium solani*	Barley	Ouazzane/ Morocco
F8	*Fusarium solani*	Barley	Souk Larbaa/ Morocco
F9	*Fusarium solani*	Barley	Souk Tlat/ Morocco
F10	*Fusarium solani*	barley	Megren/ Morocco
F11	*Fusarium oxysporum*	Durum wheat	Sidi Allal Tazi/ Morocco
F12	*Fusarium oxysporum*	Soft wheat	Ouled Selam/ Morocco
F13	*Fusarium oxysporum*	Soft wheat	Sidi Allal Tazi/ Morocco
F14	*Fusarium oxysporum*	Soft wheat	Ouazzane/ Morocco
F15	*Fusarium oxysporum*	Soft wheat	Souk Larbaa/ Morocco
F16	*Fusarium oxysporum*	Soft wheat	Megren/ Morocco
F17	*Fusarium oxysporum*	Barley	Ouazzane/ Morocco
F18	*Fusarium oxysporum*	Barley	Souk Tlat/ Morocco
F19	*Fusarium oxysporum*	Barley	Megren/ Morocco
F20	*Fusarium graminearum*	Barley	Ouled Selam/ Morocco
F21	*Fusarium graminearum*	Barley	Souk Larbaa/ Morocco
F22	*Fusarium graminearum*	Barley	Megren/ Morocco
F23	*Fusarium graminearum*	Soft wheat	Sidi Allal Tazi/ Morocco
F24	*Fusarium graminearum*	Barley	Ouled Selam/ Morocco
F25	*Fusarium graminearum*	Barley	Sidi Allal Tazi/ Morocco
F26	*Fusarium graminearum*	Barley	Megren/ Morocco
F27	*Fusarium culmorum*	Durum wheat	Ouled Selam/ Morocco
F28	*Fusarium culmorum*	Durum wheat	Souk Larbaa/ Morocco
F29	*Fusarium culmorum*	Durum wheat	Megren/ Morocco
F30	*Fusarium nivale*	Durum wheat	Ouazzane/ Morocco
F31	*Fusarium nivale*	Durum wheat	Souk Tlat/ Morocco
F32	*Fusarium nivale*	Barley	Sidi Allal Tazi /Morocco
F33	*Fusarium nivale*	Barley	Souk Larbaa/ Morocco
F34	*Fusarium roseum*	Durum wheat	Ouazzane/ Morocco
F35	*Fusarium poae*	Durum wheat	Souk Tlat/ Morocco
F36	*Fusarium poae*	Soft wheat	Souk Tlat/ Morocco
F37	*Fusarium poae*	Barley	Souk Tlat/ Morocco

Results Notation

Assessment of disease severity

The severity of the disease was evaluated at the flowering stage and the observations concerned the attacks developed at the level of the whole root system namely the collar, sub-collar and seminal roots. In the laboratory, the root portion of the plants was examined visually and the disease was evaluated according to the Greaney et al. (1938) who distinguished six severity classes according to the types of observed symptoms:

S0 : No infection.
S1 : Small necrotic lesions dispersed at the sub-crown and root.
S2 : Distinct necrotic lesions on the basal part of the plant, particularly at the level of the sub-collar and roots.
S3 : Large necrotic lesions on the neck, sub-collar and roots with decreased vigor of the plant.
S4 : Rots of the basal part, chlorosis of the plant, often dwarfing and wilting.
S5 : Dead plant.

The incidence of disease was calculated using the following formula: $I = 100\ [Nm / s]$, that is to say the percentage of diseased plants, Nm to the total number Nt of examined plants. And the index of root rot $IM = 100\ \Sigma\ (Ni\ Si) / (5\ Nt)$, with Ni number of plants of severity class i and Si severity class i.

Re-isolation of Pathogens

The re-isolation of *Fusarium* and *Bipolaris sorokiniana* was done at the ripening stage from the control and inoculated plants. The plants were dug up and removed from their growing medium by washing them thoroughly with running water. Cross sections of 2 cm, made at the roots and neck were made. The different levels of cuts were deposited separately in alcohol at 90 ° for 1 to 2 minutes, rinsed thoroughly with sterile water, dried on sterile filter paper and deposited on PSA medium.

Re-isolation was also performed from foliar lesions. Fragments of foliar lesions from wheat and barley plants were disinfected as before and incubated on filter paper soaked in sterile water in white light Petri dishes at 28 ° C until conidia were obtained. After 7 days of incubation, the cut fragments were examined under an optical microscope in aseptic conditions to detect the presence or absence of the conidia of the fungus. Conidia transfer under microscope was done using a stretched glass capillary previously flame sterilized and cooled in the culture medium. The transferred conidia were deposited on the surface of the PSA culture medium.

Statistical Analysis

Statistical analyzes were performed by analysis of the variance by 5% ANOVA test.

RESULTS

After 75 days of inoculation, all isolates induced variable necrotic lesions on the roots of wheat and barley plants from seed inoculated with the different tested isolates. Re-isolations of pathogens from these lesions were positive. In the tested *Fusarium* (Tables 3, 4 and 5), isolates of *Fuarium culmorum*, F27, F28 and F29, and isolate F34 of *F. roseum* induced the highest severity classes on of the variety Amjad (durum wheat), S4 varies between 41.6 and 50%. In the Wafia and Amal varieties (soft wheat) and the Karim variety (durum wheat), the severity class (S4) induced by these isolates varies between 33.3 and 41 and in barley (*Hordeum pusillum* and *Hordeum escourgeon*) it oscillates between 25 and 33%.

Isolates of *Bipolaris sorokiniana* seem less pathogenic than those of Fusarium isolates tested against wheat (soft and hard). Indeed, isolates H4 and H3 were able to induce a percentage of the S4 severity class of the order of 25% against the plants of the Wafia variety of wheat and Amjad (durum wheat). The highest percentages of S4 class in barley, Escourgeon and Pusillum, did not exceed 16.7 and are induced by isolate H1.

The incidence of the disease in the Amjad variety (Tables 6, 7 and 8) is 100% in isolates F8 (*Fusarium solani*), F21, F24, F25 (*F. graminearum*), F27, F29 (*F. culmorum*) and F34 (*F. roseum*). The highest disease indices were found in isolates of *F. graminearum* (F24 and F25) and those of *F. culmorum* (F29 and F27), respectively 86.6, 83.3, 81.6 and 80%. As for the disease indices, they are 86.6% and 80% in plants of the Amjad variety inoculated respectively by *F. graminearum* (isolate F 24) and by *F. culmorum* (isolate F27) and between 86 and 80% in those Wafia, Amal and Karim varieties infected with *Fusarium oxysporum* (isolate F13), *Fusarium culmorum* (isolates F28 and F7) and *F. roseum* (isolate F 38). In barley (Escourgeon and Pusillum), the highest disease indices vary between 83.3 and 76.6% in plants inoculated with *F. poae* (isolat F36), *Fusarium roseum (*F34) and *F. graminearum* (F26).

In soft wheat, the incidence of *Bipolaris sorokiniana*-induced disease in wheat plants, variety Wafia, varies between 75 (H2 and H4 isolates) and 83% (H1 isolate) and also varies in the Amal variety between 83 (H1, H3 and H4 isolates) and 91.6% (H2 isolate). This incidence in durum wheat ranged from 66.6 (H4 isolate) to 100% (H2 isolate) in Amjad plants and between 75 (H2, H3 and H4 isolates) and 80% (H1 isolate) in those of the Karim variety. In barley, the highest incidences, 91.6 and 83.3% were found in the plants of Escourgeon and Pusillum, inoculated respectively by isolates H1 and H4.

Disease indices in durum wheat reached 68.3 and 51% in Amjad and Karim plants, inoculated with *Bipolaris sorokiniana* (H3 isolate). Indices of the order of 65 and 66.6% are observed in wheat plants, Wafia and Amal varieties, inoculated with isolate H3. Similarly, in barley, the highest disease

indices are 61.6 and 53.3% in barley plants, Escourgeon and Pusillum, respectively infected with *B. sorokiniana* H1 and H4 isolates.

Isolates F10 (*F. solani*), F21, F24, F25 (*F. graminearum*), F27, F28, F29 (*F. culmorum*) and F34 (*F. solani*) are considered the most pathogenic on the tested soft and durum wheat varieties. Similarly, isolates F9 (*F. solani*), F22, F26 (*F. graminearum*), F29 (*F. culmorum*) and F34 (*F. solani*) are the most pathogenic on barley. Isolates of *Bipolaris sorokiniana* are less pathogenic than *Fusarium* isolates.

Table 3. Percentage of severity classes of root rot disease in inoculated soft wheat plants

Isolates	Soft wheat									
	Severity class (%)									
	Wafia					Amal				
	S0	S1	S2	S3	S4	S0	S1	S2	S3	S4
H1 (*Bipolaris sorokiniana)*	16.6^{d}	16.6^{c}	41.6^{a}	25^{b}	0^{e}	16.6^{b}	16.6^{c}	25^{b}	25^{c}	16.6^{d}
H2 (*Bipolaris sorokiniana*)	25^{c}	16.6^{c}	33.3^{b}	25^{b}	0^{e}	8.33^{c}	33.3^{a}	25^{b}	33.3^{b}	0^{f}
H3 (*Bipolaris sorokiniana*)	16.6^{d}	16.6^{c}	16.6^{d}	25^{b}	25^{b}	0^{d}	25^{b}	33.3^{a}	25^{c}	16.6^{d}
H4 (*Bipolaris sorokiniana)*	25^{c}	16.6^{c}	25^{c}	16.6^{c}	16.6^{c}	16.6^{b}	16.6^{c}	25^{b}	25^{c}	16.6^{d}
F1 (*Fusarium solani*)	25^{c}	16.6^{c}	8.33^{e}	25^{b}	25^{b}	0^{d}	25^{b}	25^{b}	16.6^{d}	33.3^{b}
F2 (*Fusarium solani*)	16.6^{d}	16.6^{c}	16.6^{d}	16.6^{c}	33.3^{a}	0^{d}	16.6^{c}	33.3^{a}	33.3^{b}	25^{c}
F3 (*Fusarium solani*)	8.33^{e}	8.33^{d}	16.6^{d}	33.3^{a}	33.3^{a}	16.6^{b}	25^{b}	25^{b}	25^{c}	16.6^{d}
F4 (*Fusarium solani*)	25^{c}	16.6^{c}	16.6^{d}	16.6^{c}	25^{b}	8.33^{c}	16.6^{c}	25^{b}	33.3^{b}	16.6^{d}
F5 (*Fusarium solani*)	25^{c}	33.3^{a}	16.6^{d}	8.33^{d}	16.6^{c}	0^{d}	16.6^{c}	25^{b}	33.3^{b}	33.3^{b}
F6 (*Fusarium solani*)	16.6^{d}	25^{b}	25^{c}	25^{b}	8.33^{d}	0^{d}	16.6^{c}	16.6^{c}	33.3^{b}	33.3^{b}
F7 (*Fusarium solani*)	16.6^{d}	16.6^{c}	33.3^{b}	16.6^{c}	16.6^{c}	8.33^{c}	16.6^{c}	25^{b}	25^{c}	25^{c}
F8 (*Fusarium solani*)	16.6^{d}	16.6^{c}	8.33^{e}	33.3^{a}	25^{b}	8.33^{c}	8.33^{d}	25^{b}	33.3^{b}	25^{c}
F9 (*Fusarium solani*)	25^{c}	16.6^{c}	25^{c}	16.6^{c}	16.6^{c}	0^{d}	25^{b}	25^{b}	16.6^{d}	33.3^{b}
F10 (*Fusarium solani*)	25^{c}	8.33^{d}	16.6^{d}	25^{b}	25^{b}	8.33^{c}	16.6^{c}	16.6^{c}	25^{c}	33.3^{b}
F11 (*Fusarium oxysporum*)	16.6^{d}	16.6^{c}	33.3^{b}	16.6^{c}	16.6^{c}	16.6^{b}	16.6^{c}	25^{b}	8.33^{e}	33.3^{b}
F12 (*Fusarium oxysporum*)	25^{c}	8.33^{d}	25^{c}	16.6^{c}	25^{b}	16.6^{b}	25^{b}	16.6^{c}	16.6^{d}	25^{c}
F13 (*Fusarium oxysporum*)	8.33^{e}	25^{b}	25^{c}	33.3^{a}	8.33^{d}	25^{a}	16.6^{c}	16.6^{c}	25^{c}	16.6^{d}
F14 (*Fusarium oxysporum*)	16.6^{d}	25^{b}	25^{c}	16.6^{c}	16.6^{c}	0^{d}	25^{b}	25^{b}	33.3^{b}	16.6^{d}
F15 (*Fusarium oxysporum*)	16.6^{d}	8.33^{d}	25^{c}	25^{b}	25^{b}	16.6^{b}	25^{b}	25^{b}	25^{c}	8.33^{e}
F16 (*Fusarium oxysporum*)	25^{c}	16.6^{c}	16.6^{d}	8.33^{d}	33.3^{a}	25^{a}	16.6^{c}	16.6^{c}	16.6^{d}	25^{c}
F17 (*Fusarium oxysporum*)	33.3^{b}	16.6^{c}	16.6^{d}	25^{b}	8.33^{d}	8.33^{c}	8.33^{d}	33.3^{a}	25^{c}	25^{c}
F18 (*Fusarium oxysporum*)	25^{c}	16.6^{c}	25^{c}	16.6^{c}	16.6^{c}	25^{a}	8.33^{d}	25^{b}	25^{c}	16.6^{d}
F19 (*Fusarium oxysporum*)	25^{c}	8.33^{d}	25^{c}	16.6^{c}	16.6^{c}	16.6^{b}	16.6^{c}	16.6^{c}	25^{c}	25^{c}
F20 (*Fusarium graminearum*)	16.6^{d}	8.33^{d}	25^{c}	25^{b}	25^{b}	8.33^{c}	16.6^{c}	16.6^{c}	33.3^{b}	25^{c}
F21 (*Fusarium graminearum*)	33.3^{b}	8.33^{d}	16.6^{d}	16.6^{c}	25^{b}	8.33^{c}	8.33^{d}	25^{b}	25^{c}	33.3^{b}
F22 (*Fusarium graminearum*)	8.33^{e}	16.6^{c}	16.6^{d}	25^{b}	33.3^{a}	8.33^{c}	16.6^{c}	25^{b}	25^{c}	25^{c}
F23 (*Fusarium graminearum*)	25^{c}	8.33^{d}	8.33^{e}	33.3^{a}	25^{b}	16.6^{b}	8.33^{d}	25^{b}	33.3^{b}	16.6^{d}
F24 (*Fusarium graminearum*)	16.6^{d}	8.33^{d}	16.6^{d}	25^{b}	33.3^{a}	0^{d}	16.6^{c}	25^{b}	33.3^{b}	25^{c}
F25 (*Fusarium graminearum*)	16.6^{d}	16.6^{c}	25^{c}	16.6^{c}	25^{b}	0^{d}	8.33^{d}	33.3^{a}	25^{c}	33.3^{b}
F26 (*Fusarium graminearum*)	0^{f}	16.6^{c}	41.6^{a}	25^{b}	16.6^{c}	8.33^{c}	0^{e}	25^{b}	25^{c}	41.6^{a}
F27 (*Fusarium culmorum*)	8.33^{e}	8.33^{d}	16.6^{d}	33.3^{a}	33.3^{a}	0^{d}	0^{e}	8.33^{d}	50^{a}	41.6^{a}
F28 (*Fusarium culmorum*)	0^{f}	16.6^{c}	25^{c}	33.3^{a}	25^{b}	8.33^{c}	8.33^{d}	16.6^{c}	33.3^{b}	33.3^{b}
F29 (*Fusarium culmorum*)	8.33^{e}	8.33^{d}	25^{c}	25^{b}	33.3^{a}	0^{d}	8.33^{d}	25^{b}	25^{c}	41.6^{a}
F30 (*Fusarium nivale*)	33.3^{b}	25^{b}	16.6^{d}	16.6^{c}	8.33^{d}	25^{a}	16.6^{c}	16.6^{c}	25^{c}	16.6^{d}
F31 (*Fusarium nivale*)	41.6^{a}	16.6^{c}	8.33^{e}	25^{b}	8.33^{d}	16.6^{b}	16.6^{c}	25^{b}	33.3^{b}	8.33^{e}
F 32 (*Fusarium nivale*)	16.6^{d}	33.3^{a}	16.6^{d}	16.6^{c}	16.6^{c}	16.6^{b}	33.3^{a}	16.6^{c}	33.3^{b}	8.33^{e}
F 33 (*Fusarium nivale*)	16.6^{d}	25^{b}	25^{c}	25^{b}	8.33^{d}	16.6^{b}	8.33^{d}	33.3^{a}	25^{c}	16.6^{d}
F 34 (*Fusarium roseum*)	0^{f}	8.33^{d}	25^{c}	33.3^{a}	33.3^{a}	0^{d}	8.33^{d}	25^{b}	33.3^{b}	33.3^{b}
F35 (*Fusarium poae*)	33.3^{b}	33.3^{a}	16.6^{d}	16.6^{c}	0^{e}	25^{a}	25^{b}	16.6^{c}	16.6^{d}	16.6^{d}
F36 (*Fusarium poae*)	33.3^{b}	33.3^{a}	16.6^{d}	16.6^{c}	0^{e}	16.6^{b}	25^{b}	25^{b}	25^{c}	8.33^{e}
F37 (*Fusarium poea*)	41.6^{a}	25^{b}	8.33^{e}	16.6^{c}	8.33^{d}	16.6^{b}	16.6^{c}	25^{b}	33.3^{b}	8.33^{e}

Two values in the same column followed by the same letter are not significantly different at the 5% threshold

Table 4. Percentage of severity classes of root rot disease in inoculated durum wheat plants

Isolates	Durum wheat									
	Severity class %									
	Amjad					Karim				
	S0	S1	S2	S3	S4	S0	S1	S2	S3	S4
H1 (*Bipolaris sorokiniana)*	8.3^{d}	33.3^{a}	33.3^{a}	25^{c}	0^{g}	33,3^{a}	25^{b}	16,7^{e}	16,7^{d}	8,3^{e}
H2 (*Bipolaris sorokiniana*)	0^{e}	33.3^{a}	33.3^{a}	16.6^{d}	16.6^{e}	25^{b}	25^{b}	33.3^{c}	16,7^{d}	0^{f}
H3 (Bipolaris *sorokiniana*)	8.3^{d}	16.6^{c}	25^{b}	25^{c}	25^{d}	25^{b}	16.7^{c}	33.3^{c}	25^{c}	0^{f}
H4 (*Bipolaris sorokiniana)*	33.3^{a}	25^{b}	16.6^{c}	16.6^{d}	8.3^{f}	25^{b}	16,7^{c}	25^{d}	16,7^{d}	16,6^{d}
F1 (*Fusarium solani*)	8.33^{d}	25^{b}	16.6^{c}	25^{c}	25^{d}	8,33^{d}	33,3^{a}	16,6^{e}	16,6^{d}	25^{c}
F2 (*Fusarium solani*)	16.6^{c}	8.33^{d}	25^{b}	25^{c}	25^{d}	16.6^{c}	16.6^{c}	25^{d}	25^{c}	16.6^{d}
F3 (*Fusarium solani*)	16.6^{c}	25^{b}	25^{b}	16.6^{d}	16.6^{e}	0^{e}	8.33^{d}	25^{d}	33.3^{b}	33.3^{b}
F4 (*Fusarium solani*)	8.33^{d}	25^{b}	25^{b}	16.6^{d}	16.6^{e}	16.6^{c}	25^{b}	16.6^{e}	8.33^{e}	25^{c}
F5 (*Fusarium solani*)	16.6^{c}	16.6^{c}	16.6^{c}	25^{c}	25^{d}	8.33^{d}	25^{b}	25^{d}	16.6^{d}	25^{c}
F6 (*Fusarium solani*)	8.33^{d}	8.33^{d}	16.6^{c}	33.3^{b}	33.3^{c}	16.6^{c}	25^{b}	25^{d}	25^{c}	8.33^{e}
F7 (*Fusarium solani*)	8.33^{d}	0^{e}	33.3^{a}	33.3^{b}	25^{d}	33.3^{a}	16.6^{c}	8.33^{f}	8.33^{e}	33.3^{b}
F8 (*Fusarium solani*)	0^{e}	16.6^{c}	25^{b}	25^{c}	33.3^{c}	25^{b}	8.33^{d}	16.6^{e}	25^{c}	25^{c}
F9 (*Fusarium solani*)	8.33^{d}	8.33^{d}	16.6^{c}	25^{c}	25^{d}	16.6^{c}	16.6^{c}	25^{d}	25^{c}	16.6^{d}
F10 (*Fusarium solani*)	8.33^{d}	8.33^{d}	16.6^{c}	25^{c}	25^{d}	0^{e}	25^{b}	16.6^{e}	25^{c}	33.3^{b}
F11 (*Fusarium oxysporum*)	16.6^{c}	16.6^{c}	16.6^{c}	33.3^{b}	25^{d}	16.6^{c}	16.6^{c}	25^{d}	16.6^{d}	25^{c}
F12 (*Fusarium oxysporum*)	8.33^{d}	25^{b}	25^{b}	8.33^{e}	33.3^{c}	0^{e}	0^{e}	33.3^{c}	33.3^{b}	16.6^{d}
F13 (*Fusarium oxysporum*)	8.33^{d}	16.6^{c}	25^{b}	25^{c}	25^{d}	8.33^{d}	8.33^{d}	41.6^{b}	25^{c}	16.6^{d}
F14 (*Fusarium oxysporum*)	16.6^{c}	16.6^{c}	25^{b}	16.6^{d}	25^{d}	25^{b}	8.33^{d}	41.6^{b}	25^{c}	16.6^{d}
F15 (*Fusarium oxysporum*)	16.6^{c}	16.6^{c}	16.6^{c}	25^{c}	16.6^{e}	16.6^{c}	8.33^{d}	16.6^{e}	25^{c}	33.3^{b}
F16 (*Fusarium oxysporum*)	16.6^{c}	25^{b}	25^{b}	16.6^{d}	16.6^{e}	16.6^{c}	16.6^{c}	8.33^{f}	33.3^{b}	25^{c}
F17 (*Fusarium oxysporum*)	25^{b}	33.3^{a}	25^{b}	8.33^{e}	8.33^{f}	0^{e}	0^{e}	50^{a}	33.3^{b}	16.6^{d}
F18 (*Fusarium oxysporum*)	16.6^{c}	16.6^{c}	33.3^{a}	16.6^{d}	16.6^{e}	25^{b}	16.6^{c}	16.6^{e}	25^{c}	16.6^{d}
F19 (*Fusarium oxysporum*)	25^{b}	25^{b}	25^{b}	16.6^{d}	8.33^{f}	16.6^{c}	16.6^{c}	8.33^{f}	33.3^{b}	33.3^{b}
F20 (*Fusarium graminearum*)	8.33^{d}	16.6^{c}	16.6^{c}	33.3^{b}	25^{d}	16.6^{c}	16.6^{c}	25^{d}	16.6^{d}	25^{c}
F21 (*Fusarium graminearum*)	0^{e}	25^{b}	25^{b}	25^{c}	25^{d}	16.6^{c}	16.6^{c}	16.6^{e}	16.6^{d}	33.3^{b}
F22 (*Fusarium graminearum*)	16.6^{c}	16.6^{c}	16.6^{c}	33.3^{b}	16.6^{e}	8.33^{d}	8.33^{d}	25^{d}	25^{c}	33.3^{b}
F23 (*Fusarium graminearum*)	8.33^{d}	25^{b}	16.6^{c}	25^{c}	25^{d}	0^{e}	8.33^{d}	33.^{3c}	41.6^{a}	16.6^{d}
F24 (*Fusarium graminearum*)	0^{e}	8.33^{d}	25^{b}	25^{c}	41.6^{b}	16.6^{c}	8.33^{d}	25^{d}	25^{c}	25^{c}
F25 (*Fusarium graminearum*)	0^{e}	0^{e}	25^{b}	33.3^{b}	41.6^{b}	16.6^{c}	16.6^{c}	25^{d}	16.6^{d}	25^{c}
F26 (*Fusarium graminearum*)	8.33^{d}	8.33^{d}	16.6^{c}	33.3^{b}	33.3^{c}	16.6^{c}	8.33^{d}	25^{d}	16.6^{d}	33.3^{b}
F27 (*Fusarium culmorum*)	0^{e}	8.33^{d}	0^{d}	41.6^{a}	50^{a}	16.6^{c}	0^{e}	16.6^{e}	33.3^{b}	33.3^{b}
F28 (*Fusarium culmorum*)	8.33^{d}	0^{e}	25^{b}	25^{c}	41.6^{b}	8.33^{d}	8.33^{d}	16.6^{e}	25^{c}	41.6^{a}
F29 (*Fusarium culmorum*)	0^{e}	8.33^{d}	16.6^{c}	33.3^{b}	41.6^{b}	8.33^{d}	8.33^{d}	16.6^{e}	33.3^{b}	33.3^{b}
F30 (*Fusarium nivale*)	16.6^{c}	25^{b}	25^{b}	25^{c}	8.33^{f}	16.6^{c}	25^{b}	25^{d}	25^{c}	8.33^{e}
F31 (*Fusarium nivale*)	25^{b}	25^{b}	16.6^{c}	16.6^{d}	16.6^{e}	25^{b}	16.6^{c}	25^{d}	25^{c}	8.33^{e}
F 32 (*Fusarium nivale*)	16.6^{c}	25^{b}	16.6^{c}	25^{c}	16.6^{e}	25^{b}	8.33^{d}	33.3^{c}	16.6^{d}	16.6^{d}
F 33 (*Fusarium nivale*)	16.6^{c}	33.3^{a}	16.6^{c}	33.3^{b}	16.6^{e}	33.3^{a}	16.6^{c}	25^{d}	16.6^{d}	8.33^{e}
F 34 (*Fusarium roseum*)	0^{e}	8.33^{d}	16.6^{c}	33.3^{b}	41.6^{b}	0^{e}	8.33^{d}	16.6^{e}	41.6^{a}	33.3^{b}
F35 (*Fusarium poae*)	16.6^{c}	25^{b}	33.3^{a}	16.6^{d}	8.33^{f}	25^{b}	16.6^{c}	25^{d}	25^{c}	8.33^{e}
F36 (*Fusarium poae*)	16.6^{c}	33.3^{a}	33.3^{a}	8.33^{e}	8.33^{f}	8.33^{d}	16.6^{c}	16.6^{e}	25^{c}	16.6^{d}
F37 (*Fusarium poae*)	8.33^{d}	33.3^{a}	25^{b}	16.6^{d}	16.6^{e}	33.3^{a}	16.6^{c}	16.6^{e}	33.3^{b}	0^{f}

Two values in the same column followed by the same letter are not significantly different at the 5% threshold

Table 5. Percentage of severity classes of root rot disease in inoculated barley plants

Isolates	Barley									
	severity class%									
	Escourgeons					Pusillum				
	S0	S1	S2	S3	S4	S0	S1	S2	S3	S4
H1 (*Bipolaris sorokiniana)*	8.3^{g}	25^{b}	33.3^{a}	16.7^{d}	16.7^{b}	33.3^{b}	25^{c}	16.7^{c}	8.33^{d}	16.7^{c}
H2 (*Bipolaris sorokiniana*)	25^{e}	33.3^{a}	25^{b}	16.7^{d}	0^{d}	25^{c}	50^{a}	16.7^{c}	8.33^{d}	0^{e}
H3 *(Bipolaris sorokiniana*)	16.7^{f}	33.3^{a}	25^{b}	16.7^{d}	8.3^{c}	33.3^{b}	33.3^{b}	16.7^{c}	16.7^{c}	0^{e}
H4 (Bipolaris sorokiniana)	16.7^{f}	16.7^{c}	25^{b}	33.3^{a}	8.3^{c}	16.7^{d}	33.3^{b}	33.3^{a}	0^{f}	16.7^{c}
F1 (*Fusarium solani*)	8.33^{g}	16.6^{c}	16.6^{c}	25^{b}	25^{a}	16.6^{d}	25^{c}	8.33^{d}	25^{b}	25^{b}
F2 (*Fusarium solani*)	33.3^{d}	33.3^{a}	16.6^{c}	8.33^{d}	16.6^{b}	16.6^{d}	33.3^{b}	16.6^{c}	16.6^{c}	16.6^{c}
F3 (*Fusarium solani*)	33.3^{d}	16.6^{c}	16.6^{c}	16.6^{c}	16.6^{b}	8.33^{e}	16.6^{d}	25^{b}	25^{b}	25^{b}
F4 (*Fusarium solani*)	33.3^{d}	16.6^{c}	25^{b}	16.6^{c}	8.33^{c}	25^{c}	25^{c}	33.3^{a}	8.33^{d}	8.33^{d}

Isolates	Barley									
	severity class%									
	Escourgeons					Pusillum				
	S0	S1	S2	S3	S4	S0	S1	S2	S3	S4
F5 (*Fusarium solani*)	25^{e}	8.33^{d}	25^{b}	16.6^{c}	25^{a}	33.3^{b}	25^{c}	16.6^{c}	8.33^{d}	16.6^{c}
F6 (*Fusarium solani*)	16.6^{f}	25^{b}	16.6^{c}	25^{b}	16.6^{b}	16.6^{d}	25^{c}	33.3^{a}	16.6^{c}	8.33^{d}
F7 (*Fusarium solani*)	50^{b}	8.33^{d}	8.33^{d}	16.6^{c}	16.6^{b}	16.6^{d}	16.6^{d}	16.6^{c}	25^{b}	25^{b}
F8 (*Fusarium solani*)	41.6^{c}	25^{b}	16.6^{c}	8.33^{d}	8.33^{c}	41.6^{a}	16.6^{d}	8.33^{d}	16.6^{c}	16.6^{c}
F9 (*Fusarium solani*)	25^{e}	16.6^{c}	16.6^{c}	16.6^{c}	25^{a}	0^{f}	16.6^{d}	25^{b}	5^{e}	33.3^{a}
F10 (*Fusarium solani*)	16.6^{f}	25^{b}	25^{b}	16.6^{c}	16.6^{b}	8.33^{e}	25^{c}	25^{b}	16.6^{c}	25^{b}
F11 (*Fusarium oxysporum*)	33.3^{d}	16.6^{c}	25^{b}	16.6^{c}	8.33^{c}	33.3^{b}	25^{c}	16.6^{c}	8.33^{d}	16.6^{c}
F12 (*Fusarium oxysporum*)	33.3^{d}	16.6^{c}	25^{b}	16.6^{c}	8.33^{c}	25^{c}	16.6^{d}	16.6^{c}	25^{b}	16.6^{c}
F13 (*Fusarium oxysporum*)	41.6^{c}	16.6^{c}	16.6^{c}	8.33^{d}	16.6^{b}	25^{c}	25^{c}	16.6^{c}	25^{b}	8.33^{d}
F14 (*Fusarium oxysporum*)	25^{e}	16.6^{c}	8.33^{d}	25^{b}	25^{a}	16.6^{d}	16.6^{d}	33.3^{a}	16.6^{c}	16.6^{c}
F15 (*Fusarium oxysporum*)	41.6^{c}	8.33^{d}	0^{e}	33.3^{a}	16.6^{a}	25^{c}	25^{c}	25^{b}	0^{f}	25^{b}
F16 (*Fusarium oxysporum*)	25^{e}	16.6^{c}	8.33^{d}	25^{b}	25^{a}	41.6^{a}	16.6^{d}	16.6^{c}	16.6^{c}	8.33^{d}
F17 (*Fusarium oxysporum*)	33.3^{d}	8.33^{d}	16.6^{c}	25^{b}	16.6^{b}	25^{c}	16.6^{d}	16.6^{c}	16.6^{c}	25^{b}
F18 (*Fusarium oxysporum*)	16.6^{f}	16.6^{c}	33.3^{a}	16.6^{c}	16.6^{b}	8.33^{e}	33.3^{b}	25^{b}	25^{b}	8.33^{d}
F19 (*Fusarium oxysporum*)	33.3^{d}	8.33^{d}	8.33^{d}	25^{b}	25^{a}	16.6^{d}	33.3^{b}	25^{b}	8.33^{d}	16.6^{c}
F20 (*Fusarium graminearum*)	8.33^{g}	25^{b}	25^{b}	33.3^{a}	8.33^{c}	16.6^{d}	33.3^{b}	25^{b}	8.33^{d}	16.6^{c}
F21 (*Fusarium graminearum*)	25^{e}	16.6^{c}	16.6^{c}	25^{b}	16.6^{b}	8.33^{e}	33.3^{b}	16.6^{c}	16.6^{c}	25^{b}
F22 (*Fusarium graminearum*)	16.6^{f}	25^{b}	16.6^{c}	16.6^{c}	25^{a}	16.6^{d}	25^{c}	25^{b}	8.33^{d}	25^{b}
F23 (*Fusarium graminearum*)	8.33^{g}	16.6^{c}	25^{b}	33.3^{a}	16.6^{b}	33.3^{b}	25^{c}	16.6^{c}	16.6^{c}	8.33^{d}
F24 (*Fusarium graminearum*)	8.33^{g}	8.33^{d}	25^{b}	33.3^{a}	25^{a}	25^{c}	16.6^{d}	16.6^{c}	25^{b}	16.6^{c}
F25 (*Fusarium graminearum*)	16.6^{f}	25^{b}	16.6^{c}	25^{b}	16.6^{b}	8.33^{e}	16.6^{d}	16.6^{c}	33.3^{a}	25^{b}
F26 (*Fusarium graminearum*)	0^{h}	33.3^{d}	16.6^{c}	25^{b}	25^{a}	0^{f}	16.6^{d}	25^{b}	25^{b}	33.3^{a}
F27 (*Fusarium culmorum*)	8.33^{g}	16.6^{c}	25^{b}	25^{b}	25^{a}	16.6^{d}	8.33^{e}	16.6^{c}	33.3^{a}	25^{b}
F28 (*Fusarium culmorum*)	8.33^{g}	33.3^{a}	25^{b}	16.6^{c}	16.6^{b}	16.6^{d}	16.6^{d}	8.33^{d}	33.3^{a}	25^{b}
F29 (*Fusarium culmorum*)	8.33^{g}	25^{b}	25^{b}	16.6^{c}	25^{a}	0^{f}	16.6^{d}	25^{b}	25^{b}	33.3^{a}
F30 (*Fusarium nivale*)	50^{b}	16.6^{c}	16.6^{c}	8.33^{d}	8.33^{c}	33.3^{b}	16.6^{d}	16.6^{c}	25^{b}	8.33^{d}
F31 (*Fusarium nivale*)	16.6^{f}	25^{b}	25^{b}	25^{b}	8.33^{c}	25^{c}	25^{c}	25^{b}	16.6^{c}	8.33^{d}
F 32 (*Fusarium nivale*)	41.6^{c}	16.6^{c}	8.33^{d}	16.6^{c}	16.6^{b}	41.6^{a}	16.6^{d}	16.6^{c}	8.33^{d}	16.6^{c}
F 33 (*Fusarium nivale*)	25^{e}	25^{b}	25^{b}	16.6^{c}	8.33^{c}	16.6^{d}	33.3^{b}	25^{b}	16.6^{c}	8.33^{d}
F 34 (*Fusarium roseum*)	33.3^{d}	8.33^{d}	16.6^{c}	16.6^{c}	25^{a}	16.6^{d}	16.6^{d}	25^{b}	33.3^{a}	25^{b}
F35 (*Fusarium poae*)	50^{b}	25^{b}	16.6^{c}	0^{e}	8.33^{c}	41.6^{a}	25^{c}	8.33^{d}	16.6^{c}	8.33^{d}
F36 (*Fusarium poae*)	58.3^{a}	8.33^{d}	16.6^{c}	16.6^{c}	0^{d}	33.3^{b}	25^{c}	25^{b}	8.33^{d}	8.33^{d}
F37 (*Fusarium poae*)	33.3^{d}	33.3^{a}	16.6^{c}	8.33^{d}	0^{d}	33.3^{b}	25^{c}	16.6^{c}	16.6^{c}	8.33^{d}

Two values in the same column followed by the same letter are not significantly different at the 5% threshold

Table 6. Incidence (%) and root rot index (%) in inoculated soft wheat plants

Isolates	Soft wheat			
	Wafia		Amal	
	Incidence%	Index%	Incidence%	Index%
H1 (*Bipolaris sorokiniana)*	83^{c}	55^{d}	83.3^{c}	61.6^{d}
H2 (*Bipolaris sorokiniana*)	75^{d}	56.6^{d}	91.6^{b}	56.6^{e}
H3 (Bipolaris *sorokiniana*)	83^{c}	65^{c}	83.3^{c}	66.6^{d}
H4 *(Bipolaris sorokiniana*)	75^{d}	56.6^{d}	83.3^{c}	61.6^{d}
F1 (*Fusarium solani*)	75^{d}	61.6^{c}	100^{a}	71.6^{c}
F2 (*Fusarium solani*)	83.3^{c}	53.3^{d}	100^{a}	75^{bc}
F3 (*Fusarium solani*)	91.6^{b}	75^{bd}	91.6^{b}	63.3^{d}
F4 (*Fusarium solani*)	75^{d}	60^{cd}	91.6^{b}	66.6^{d}
F5 (*Fusarium solani*)	75^{d}	51.1^{d}	100^{a}	73.3^{c}
F6 (*Fusarium solani*)	83.3^{c}	56.6^{d}	100^{a}	76.6^{b}
F7 (*Fusarium solani*)	83.3^{c}	58.3^{d}	91.6^{b}	68.3^{d}
F8 (*Fusarium solani*)	83.3^{c}	66.6^{c}	91.6^{b}	71.6^{c}
F9 (*Fusarium solani*)	75^{d}	56.6^{d}	100^{a}	71.6^{c}
F10 (*Fusarium solani*)	75^{d}	63.3^{c}	91.6^{b}	71.6^{c}
F11 (*Fusarium oxysporum*)	83.3^{c}	60c^{d}	83.3^{c}	65^{d}
F12 (*Fusarium oxysporum*)	75^{d}	61.6^{c}	83.3^{c}	61.6^{d}
F13 (*Fusarium oxysporum*)	91.6^{b}	86.6^{a}	75^{d}	58.3^{e}
F14 (*Fusarium oxysporum*)	83.3^{c}	58.3^{d}	100^{a}	68.3^{d}

Isolates	Soft wheat			
	Wafia		Amal	
	Incidence%	Index%	Incidence%	Index%
F15 (*Fusarium oxysporum*)	83.3^{c}	66.6^{c}	83.3^{c}	56.6^{e}
F16 (*Fusarium oxysporum*)	75^{d}	61.6^{c}	75^{d}	60de
F17 (*Fusarium oxysporum*)	66.6^{e}	51.6^{d}	91.6^{b}	70^{cd}
F18 (*Fusarium oxysporum*)	75^{d}	56.6^{d}	75^{d}	60de
F19 (*Fusarium oxysporum*)	75^{d}	61.6^{c}	83.3^{c}	65^{d}
F20 (*Fusarium graminearum*)	83.3^{c}	66.6^{c}	91.6^{b}	70^{cd}
F21 (*Fusarium graminearum*)	66.6^{e}	58.3^{d}	91.6^{b}	73.3^{c}
F22 (*Fusarium graminearum*)	91.6^{b}	71.6^{b}	91.6^{b}	68.3^{d}
F23 (*Fusarium graminearum*)	75^{d}	65^{c}	83.3^{c}	65^{d}
F24 (*Fusarium graminearum*)	83.3^{c}	70b^{c}	100^{a}	73.3^{c}
F25 (*Fusarium graminearum*)	83.3^{c}	58.3^{d}	100^{a}	76.6^{b}
F26 (*Fusarium graminearum*)	100^{a}	68.3^{c}	91.6^{b}	78.3^{b}
F27 (*Fusarium culmorum*)	91.6^{b}	75^{b}	100^{a}	86.6^{a}
F28 (*Fusarium culmorum*)	100^{a}	73.3^{b}	91.6^{b}	75b^{c}
F29 (*Fusarium culmorum*)	91.6^{b}	73.3^{b}	100^{a}	80^{b}
F30 (*Fusarium nivale*)	66,6^{e}	48,3^{e}	75^{d}	58,3^{e}
F31 (*Fusarium nivale*)	58,3^{f}	48,3^{e}	83,3^{c}	55^{e}
F 32 (*Fusarium nivale*)	83,3^{c}	56,6^{d}	83,3^{c}	55^{e}
F 33 (*Fusarium nivale*)	83,3^{c}	56,6^{d}	83,3^{c}	63,3^{e}
F 34 (*Fusarium roseum*)	100^{a}	78,3^{b}	100^{a}	78,3^{b}
F35 (*Fusarium poae*)	66,6^{e}	46,6^{e}	75^{d}	55^{e}
F36 (*Fusarium poae*)	66,6^{e}	43,3^{e}	83,3^{c}	56,6^{e}
F37 (*Fusarium poae*)	58,3^{f}	45^{e}	83,3^{c}	60de

Two values in the same column followed by the same letter are not significantly different at the 5% threshold

Table 7. Incidence (%) and root rot index (%) in inoculated durum wheat plants

Isolats	Durum wheat			
	Amjad		Karim	
	Incidence	Index	Incidence	Index
H1 (*Bipolaris sorokiniana)*	91.6^{b}	55^{d}	80^{cd}	41.6^{e}
H2 (*Bipolaris sorokiniana*)	100^{a}	60^{cd}	75^{d}	48.3^{e}
H3 *(Bipolaris sorokiniana*)	91.6^{b}	68.3^{c}	75^{d}	51.6^{d}
H4 (Bipolaris sorokiniana)	66.6^{e}	48.3^{e}	75^{d}	48.3^{e}
F1 (*Fusarium solani*)	91.6^{b}	66.6^{c}	91.6^{b}	63.3^{c}
F2 (*Fusarium solani*)	83.3^{c}	66.6^{c}	83.3^{c}	61.6^{c}
F3 (*Fusarium solani*)	83.3^{c}	58.3^{d}	100^{a}	78.3^{b}
F4 (*Fusarium solani*)	91.6^{b}	63.3^{c}	83.3^{c}	55^{d}
F5 (*Fusarium solani*)	83.3^{c}	65^{c}	91.6^{b}	65^{c}
F6 (*Fusarium solani*)	91.6^{b}	75^{b}	83.3^{c}	65.6^{c}
F7 (*Fusarium solani*)	91.6^{b}	73.3^{b}	83.3^{c}	58.3^{d}
F8 (*Fusarium solani*)	100^{a}	75^{b}	75^{d}	63.3^{c}
F9 (*Fusarium solani*)	91.6^{b}	68.3^{c}	83.3^{c}	61.6^{c}
F10 (*Fusarium solani*)	91.6^{b}	66.6^{c}	100^{a}	73.3^{b}
F11 (*Fusarium oxysporum*)	83.3^{c}	71.6^{b}	83.3^{c}	63.3^{c}
F12 (*Fusarium oxysporum*)	91.6^{b}	66.6^{c}	100^{a}	63.3^{c}
F13 (*Fusarium oxysporum*)	91.6^{b}	68.3^{c}	91.6^{b}	66.6^{c}
F14 (*Fusarium oxysporum*)	83.3^{c}	63.3^{c}	75^{d}	51.6^{d}
F15 (*Fusarium oxysporum*)	83.3^{c}	56.6^{d}	83.3^{c}	70b^{c}
F16 (*Fusarium oxysporum*)	83.3^{c}	58.3^{d}	83.3^{c}	66.6^{c}
F17 (*Fusarium oxysporum*)	50^{f}	53.3^{d}	100^{a}	73.3^{b}
F18 (*Fusarium oxysporum*)	83^{c}	60^{cd}	75^{d}	58.3^{d}
F19 (*Fusarium oxysporum*)	75^{d}	51.6^{d}	83.3^{c}	66.6^{c}
F20 (*Fusarium graminearum*)	91.6^{b}	70^{bc}	83.3^{c}	63.3^{c}
F21 (*Fusarium graminearum*)	100^{a}	70^{bc}	83.3^{c}	66.6^{c}
F22 (*Fusarium graminearum*)	83.3^{c}	63.3^{c}	91.6^{b}	73.3^{b}
F23 (*Fusarium graminearum*)	91.6^{b}	66.6^{c}	100^{a}	73.3^{b}
F24 (*Fusarium graminearum*)	100^{a}	80^{ab}	83.3^{c}	70b^{c}
F25 (*Fusarium graminearum*)	100^{a}	83.3^{a}	83.3^{c}	63.3^{c}
F26 (*Fusarium graminearum*)	91.6^{b}	78^{b}	83.3^{c}	68.3^{c}

Isolats	Durum wheat			
	Amjad		Karim	
	Incidence	Index	Incidence	Index
F27 (*Fusarium culmorum*)	100[a]	86.6[a]	83.3[c]	73.3[b]
F28 (*Fusarium culmorum*)	91.6[b]	78.3[b]	91.6[b]	68.3[c]
F29 (*Fusarium culmorum*)	100[a]	81.6[a]	91.6[b]	75[b]
F30 (*Fusarium nivale*)	83.3[c]	56.6[d]	83.3[c]	65[c]
F31 (*Fusarium nivale*)	75[d]	55[d]	75[d]	63.3[c]
F 32 (*Fusarium nivale*)	83.3[c]	60[cd]	75[d]	58.3[d]
F 33 (*Fusarium nivale*)	91.6[b]	68.3[c]	66.6[e]	50[de]
F 34 (*Fusarium roseum*)	100[a]	73.3[b]	100[a]	80[a]
F35 (*Fusarium poae*)	91.6[b]	53.3[d]	75[d]	55[d]
F36 (*Fusarium poae*)	83.3[c]	51.6[d]	75[d]	61.6[c]
F37 (*Fusarium poae*)	91.6[b]	60[cd]	66.6[e]	50[de]

Two values in the same column followed by the same letter are not significantly different at the 5% threshold.

Table 8. Incidence (%) and root rot index (%) of barley

Isolates	Barley			
	Escourgeons		Pusillum	
	Incidence	Index	Incidence	Index
H1 (*Bipolaris sorokiniana)*	91.6[b]	61.6b[c]	66.6[e]	50[cd]
H2 (*Bipolaris sorokiniana*)	75[d]	46.6[d]	75[d]	41.6[d]
H3 (*Bipolaris sorokiniana*)	83.3[c]	53.3[c]	66.6[e]	43.3[d]
H4 *(Bipolaris sorokiniana)*	83.3[c]	60[bc]	83.3[c]	53.3[c]
F1 (*Fusarium solani*)	91.6[b]	68.3[b]	83.3[c]	63.3[bc]
F2 (*Fusarium solani*)	66.6[e]	50[cd]	91.6[b]	55[c]
F3 (*Fusarium solani*)	66.6[e]	46.6[d]	91.6[b]	68.3[bc]
F4 (*Fusarium solani*)	66.6[e]	50[cd]	75[d]	50[cd]
F5 (*Fusarium solani*)	75[d]	61[b]	66.6[e]	50[c]
F6 (*Fusarium solani*)	83.3[c]	60[bc]	100[a]	55[c]
F7 (*Fusarium solani*)	50[fg]	48.3[d]	83.3[c]	75[a]
F8 (*Fusarium solani*)	58.3[f]	43.3[d]	58.3[f]	50[cd]
F9 (*Fusarium solani*)	75[d]	60[bc]	100[a]	75[a]
F10 (*Fusarium solani*)	83.3[c]	58.3[c]	91.6[b]	65[bc]
F11 (*Fusarium oxysporum*)	66.6[e]	50[cd]	66.6[e]	50[cd]
F12 (*Fusarium oxysporum*)	66.6[e]	50[cd]	75[d]	58.3[c]
F13 (*Fusarium oxysporum*)	58.3[f]	48.3[d]	75[d]	53.3[c]
F14 (*Fusarium oxysporum*)	75[d]	61.6[b]	83.3[c]	60[bc]
F15 (*Fusarium oxysporum*)	58.3[f]	55[c]	75[d]	55[c]
F16 (*Fusarium oxysporum*)	75[d]	61.6[b]	58.3[f]	63.3[b]
F17 (*Fusarium oxysporum*)	100[a]	66.6[b]	75[d]	60[bc]
F18 (*Fusarium oxysporum*)	83.3[c]	60b[c]	91.6[b]	58.3[c]
F19 (*Fusarium oxysporum*)	66.6[e]	60b[c]	83.3[c]	55[c]
F20 (*Fusarium graminearum*)	91.6[b]	61.6[b]	83.3[c]	65[b]
F21 (*Fusarium graminearum*)	75[d]	58.3[c]	91.6[b]	63.3[b]
F22 (*Fusarium graminearum*)	83.3[c]	61.6[b]	83.3[c]	60[bc]
F23 (*Fusarium graminearum*)	91.6[b]	66.6[b]	66.6[e]	48.3[d]
F24 (*Fusarium graminearum*)	91.6[b]	71.6[b]	75[d]	58.3[c]
F25 (*Fusarium graminearum*)	83.3[c]	60[bc]	91.6[b]	70[ab]
F26 (*Fusarium graminearum*)	100[a]	68.3[b]	100[a]	75[a]
F27 (*Fusarium culmorum*)	91.6[b]	68.3[b]	83.3[c]	76.6[a]
F28 (*Fusarium culmorum*)	91.6[b]	60[bc]	83.3[c]	75[a]
F29 (*Fusarium culmorum*)	91.6[b]	63.9[b]	100[a]	75[a]
F30 (*Fusarium nivale*)	50[fg]	41.[6d]	66.6[e]	51.6[c]
F31 (*Fusarium nivale*)	83.3[c]	56.6[c]	75[d]	51.6[c]
F 32 (*Fusarium nivale*)	58.3[f]	50[cd]	58.3[f]	48.4[d]
F 33 (*Fusarium nivale*)	75[d]	51.6[c]	83.3[b]	53.3[c]
F 34 (*Fusarium roseaum*)	66.6[e]	58.3[c]	83.3[b]	76.6[a]
F35 (*Fusarium poae*)	50[fg]	38.3[e]	58.3[f]	45[d]
F36 (*Fusarium poae*)	41.6[h]	83.3[a]	66.6[e]	46.6[d]
F37 (*Fusarium poae*)	66.6[e]	36.6[e]	66.6[e]	48.3[d]

Two values in the same column followed by the same letter are not significantly different at the 5% threshold

DISCUSSION AND CONCLUSION

The pathogenicity of different fungal isolates of *Fusarium* sp. and *Bipolaris sorokiniana*, originating from the necrotic lesions of wheat and barley roots in the Gharb region (northwestern Morocco), taking into account the incidence and severity of the disease and the decay index, showed that each isolate causes different responses in the plants of these cereals.

All isolates of *Bipolaris sorokiniana* and *Fusarium* species induced root necrosis to the tested wheat and barley varieties. These typical symptoms of root rot are blackish lesions developed on the roots or collar of the plants, with a very variable extent and depending on the extent of attack of each isolate. In aggressive isolates, particularly those of *F. graminearum*, the roots of some barley and wheat plants showed partially or completely scalded ears with pink and sometimes black spots. In wheat and barley plants, isolates of *B. sorokiniana* induced foliar lesions, initially appearing as small brown necrotic spots and, over time, increasing in size and causing total leaf dryness.

Roots with different necrotic lesions were used for re-isolation of pathogens and confirmation of their involvement in the development of root rot. The obtained isolates during re-isolation showed the same macroscopic and microscopic characteristics as the inoculated isolates. Re-isolations from foliar lesions confirmed the presence of *B. sorokiniana* in these lesions.

The obtained results in this study demonstrated the importance of the *Fusarium* fungal complex and *B. sorokiniana* in the induction of root rot on the tested wheat and barley varieties. Severity classes, incidence, and disease index differ among isolates of the studied pathogens, but all isolates were able to induce disease in wheat and barley plants. This situation may be due to different factors that influence the expression of the aggressiveness of fungal pathogens: ability of each pathogen to induce the disease, resistance level of each variety of the host plant and different environmental factors. The results also showed that there is no relationship between the isolate and the species from which was isolated. Isolates from barley are pathogenic on wheat (hard and soft) and isolates originating from barley have induced disease in barley.

In this work, isolates of *Fusarium solani*, *F. graminearum* and *F. culmorum* are the most pathogenic on wheat (soft and hard) and barley varieties and the least pathogenic are those of *Bipolaris sorokiniana*. In the literature, *F. solani* and *F. oxysporum* are cited as secondary parasites or simple saprophytes or with a much reduced aggressiveness on wheat and barley [17,18,19,20, 21,22]. It is for the first time in Morocco, that the pathogenic power of *F. solani*, isolated among a diversified fungal complex variable according to the geographical locality and the species of cereals, was studied. Isolates of this species induced in wheat and barley grade severity 4, a very high incidence and index of the disease. As for isolates of *F. oxysporum*, they induced an index of disease that exceeded 80 in Wafia, Amal and Karim varieties.

Isolates of *F. graminearum* and *F. culmorum* are among the most pathogenic isolates on the tested wheat and barley varieties in this study. These two species, the most studied in the case of Fusarium wilt, are considered the most pathogenic for plants in general and for cereals in particular [23]. *F. graminearum* is considered a very formidable pathogen of cereals such as corn, wheat, barley, oats and rye [24] and rice [25,26,27]. This fungus, easily disseminated by wind and splash of rain, is the causal agent of *Fusarium* head blight and damping-off [28]. *Fusarium culmorum* is the most widespread and pathogenic species among the other Fusarium species associated with crown and crown rot of wheat and barley [8,29,30]. It is considered together with other *Fusarium* species, mainly *F. graminearum* and *F. avenaceum*, as agents responsible for *Fusarium* root rot, a cereal crop disease. According to Łacicowa et al. [31] the virulence of *F. culmorum* against cereals is higher at high temperatures. The study conducted by Wiwart et al. [32] reported that the effect of *F. culmorum* can be observed at the early stage of wheat seedling development**.**

F. roseum (isolate F34) was also highly pathogenic on wheat (hard and soft) and barley. This pathogen was able to induce in plants the

highest severity class (S4) and a very important disease index. According to Boulif [33], root rot caused by *Fusarium roseum* and *Bipolaris sorokiniana* dominate in Morocco. Indeed, the two pathogens combine to attack wheat whenever this crop is subject to water stress (drought). *F. roseum* is often present in whole grains (reserve, embryo, teguments) and at the end of the run, especially after alternating dryness and moisture, this pathogen can settle on the root crown [34].

The isolates of *F. nivale* and *F. poae* are also pathogenic with respect to the tested varieties of wheat (hard and soft) and barley. The pathogenicity of these two pathogens, estimated by the severity, incidence and index of the disease, remains less important compared to that found in plants inoculated with the other isolates of the studied *Fusarium* species. This result is identical to those reported by Gosman et al. [35] and Brennan et al. [36]. These authors considered *F. nivale* and *F. poae* as two less aggressive species compared to other species of the cereals fungal complex.

The isolates of *Bipolaris sorokiniana* are also pathogenic with respect to tested wheat and barley varieties, but their pathogenicity remains lower than that induced by the other studied *Fusarium* species. This pathogen can cause different types of diseases (damping-off, root rot, leaf spot lesions and black spot), and consequently, substantial losses in quantity and quality of yields [37, 38]. According to Tinline [39], *B. sorokiniana* is the first invader of the rhizomes of wheat and barley plants even before *F. culmorum* and *F. acuminatum* and is considered the most formidable pathogen for graminaceous plants, especially barley. *B. sorokiniana* is the cause of other diseases that affect the ear and leaves [40] and it is able to cause leaf spots on Sorghum, rice, leaves, grains and roots of many cereals [41,1,42, 43,44].

This work shows that the different *Bipolaris sorokiniana* isolates and the studied 7 *Fusarium* species, involved in the complex causing root rot of cereals, are able to induce disease, to varying degrees in wheat and barley. *Bipolaris sorokiniana* has been encountered with one or two species of *Fusarium* and in other cases it is the *fusarium* species (two or three species) that are found in the root necrotic lesions of a single plant [15]. It is difficult to know what part each fungal species has in association to alter the roots of wheat and barley, and the study of certain species associations, composed of two, three or more, will probably specify the part that each pathogen has in the development of root rot. Studies, conducted by Bahous et al. [45], have shown the existence of competitive interactions between six rice leaf pathogens to colonize the leaf surfaces of inoculated plants and these interactions influence well the formation of the secondary inoculum of each pathogen on foliar lesions.

Isolates of *Fusarium* species and *B. sorokiniana*, responsible for root rot in northwestern Morocco, the regions of Gharb and Loukkos are endowed with significant pathogenicity towards wheat and barley and will grow with time, This requires a reorientation of selection and control programs (chemical and biological) by promoting resistance to these parasites, while knowing that the possible occurrence of other virulent pathogens must be monitored.

ACKNOWLEDGMENTS

The Authors would like to acknowledge the support through the R and D Initiative – Appel à projets autour des phosphates APPHOS – sponsored by OCP (OCP Foundation, R&D OCP, Mohammed VI Polytechnic University, National Center of Scientific and technical Research CNRST, Ministry of Higher Education, Scientific Research and Professional Training of Morocco MESRSFC) under the project entitled *Sélection et utilisation des *Trichoderma* spp. pour l'amélioration de l'efficacité des phosphates et la lutte contre la pourriture racinaire du blé au Maroc * project ID *AGR-DOI-1/2017*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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