JOURNAL OF PURE AND APPLIED MICROBIOLOGY, September 2013. Vol. 7(3), p. 1693-1705

Virulence and Host Range of *Sclerotium rolfsii* and *S. cepivorum*

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(Received: 02 April 2013; accepted: 20 May 2013)

The virulence of *Sclerotium rolfsii* and *S. cepivorum*, which have different origins, was evaluated on 20 different hosts. The effect of different temperatures on growth characteristics, sclerotial formation and maturation was also determined. Pathogenicity tests were carried out using a pot culture experiment under greenhouse conditions, and statistical analyses were performed using LSD to compare the means of the experimental results. Differences were found in colony growth, sclerotial formation and maturation within a range of incubation temperatures. Tested *S. rolfsii* isolates exhibited high degrees of virulence on all examined hosts (42-100%), which indicates the high virulence of this species regardless of the isolate origin. *S. cepivorum* isolate was highly pathogenic (approximate degree of virulence of 89-96%) on garlic and onion compared to the other tested hosts (approximate degree of virulence of 0-39%), which indicates that host susceptibility was dependent on the tested species. Because *Sclerotium* spp. can overwinter in plant debris as mycelia and/or sclerotia, which serve as primary inocula for new infections, further integrated control strategies should be undertaken to minimize stand and yield loss of these crops.

Key words: *Sclerotium* spp., Temperatures, Damping-off, Sugar beet, Sclerotia.

Sclerotium spp. are widespread, soil-borne fungi that attack hundreds of cultivated and wild plant species and can cause root rot, stem rot, wilt and foot rot diseases[1, 2]. *Sclerotium rolfsii* has frequently been reported to cause root diseases in at least 500 species of dicotyledonous and monocotyledonous plants, which represent 100 families[3]. Legumes, crucifers, cucurbits, corn or maize, alfalfa, bean, beet, carrot, cotton, garlic, onion and radish are the most common *S. rolfsii* hosts reported worldwide, and the fungus persists in many weed hosts[4, 5, 6, 7].

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S. rolfsii is also considered the most frequent and serious soil-borne fungal pathogen that attacks sugar beet roots in tropical and subtropical regions worldwide[8, 9, 10]. Moreover, a more than 50% yield reduction could occur as a result of Sclerotium infection in some cases[11]. *S. cepivorum* is also an extremely aggressive pathogen that infects alliaceous hosts and causes rot in most of the organs and tissues of the host. However, *Sclerotium* sp. colonizes roots and outer bulb scales, and only sclerotia appear as signs of infection[12].

Sclerotia formation at the end of the *Sclerotium* sp. disease life cycle aids in the survival of the fungus on dead plant material in the soil; therefore, sclerotia serve as the primary inocula for the initial infections of host plants[13, 14]. The lack of information on fungal specialization in particular regions may result in more damage and

yield further loss. Therefore, this study aimed to evaluate the pathogenicity of *S. rolfsii* and *S. cepivorum* isolates that differed in host origins on 20 hosts.

MATERIALS AND METHODS

Sclerotium growth temperatures

Sclerotium spp. cultures isolated from sugar beet (S1), carrot (S2), cotton (S3) and onion (S4) and identified by the Plant Pathology Research Institute, Agricultural Research Center, Egypt, were used in this study. PDA Petri plates were centrally inoculated with 5-mm-agar plugs of 7- day-old PDA cultures of *Sclerotium* spp. The inoculated plates were then incubated at different temperatures that ranged from 17 to 37°C for eight days, and the linear growth was measured regularly after 2, 5, and 8 days. Sclerotia were collected after three weeks, and sclerotial diameters were calculated.

Pathogenicity of *Sclerotium* spp

Inocula were grown in glass bottles (500 g in capacity) that each contained approximately 50 g wet sorghum grains. The bottles were autoclaved for 30 min., aseptically inoculated with Sclerotium and incubated at 20°C and 25°C for *S. cepivorum* and *S. rolfsii,* respectively, for 3-4 weeks and/or until obtaining sufficient growth of the fungus.

Pathogenicity tests were carried out under greenhouse conditions according to the soil infestation technique. Autoclaved clay loam soil was dispensed in 30-cm-diameter sterilized pots, separately inoculated with each isolate at 3g/Kg soil and planted with 10 non-sterilized seeds per pot for each cultivar. Twenty different hosts were tested, and non-infested treatments served as controls. Pots (3 replicates for each treatment) were randomly distributed on a greenhouse bench within a temperature range of 20°C to 25°C. Pre-emergence damping-off was recorded 15 days after planting, and post-emergence damping-off and plant survival were recorded 45 days after planting.

Statistical analysis

The percentage data of the seedlings damping-off and survival were transformed into the root-square of the %values+ 0.5 before carrying out the analysis of variance (ANOVA) to normalize and stabilize the variance. The least significant difference (LSD) was used to identify differences and compare means. ANOVAs were performed on the data using the SPSS statistical package.

RESULTS

Sclerotium growth temperatures

The results of the present study indicated that *Sclerotium* spp. isolates grew within a

Table 1. Effect of isolates, temperature regime, age of culture and their interaction on the liner growth of *Sclerotium* spp.

Age /day	Isolates	Temperature			
		17ºC	20ºC	27ºC	37ºC
2	S1	24.8	27.2	25.3	12.0
	S2	16.9	19.5	38.5	8.7
	S3	21.9	27.6	42.0	11.9
	S4	36.5	35.3	8.0	8.0
5	S1	58.3	67.4	90.0	19.9
	S2	34.5	44.3	90.0	10.0
	S3	49.6	66.6	90.0	19.5
	S4	89.4	90.0	8.0	8.0
8	S1	90.0	90.0	90.0	20.6
	S2	73.9	89.5	90.0	10.0
	S3	90.0	90.0	90.0	20.1
	S4	90.0	90.0	8.0	8.0

S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton, respectively, and S4 is *Sclerotium cepivorum* isolated from onion. LSD for isolates x age x temperature = 5

temperature range of 17-37°C. At 27°C, isolates from carrot, cotton and sugar beet attained maximal growth (9.0 cm) after 5 days of incubation. The growth of *S. cepivorum* isolate was restricted at 27-37°C, but their maximal growth (9.0 cm) was attained after 5 days of incubation at 17-20°C. However, the growth of all tested isolates was drastically reduced at 37°C, as that temperature did not favor fungal growth (Table 1).

Temperatures ranging from 20 to 37°C were favored for sclerotial formation and maturation of cotton and sugar beet *S. rolfsii* isolates. The favorable temperatures for sclerotial formation and maturation of carrot isolate were ranged from 20 to 27°C, while for onion *S. cepivorum* were ranged from 17 to 20°C (Table 2). Statistical analysis

Table 2. Formation, maturation and sclerotial diameters of *Sclerotium* spp. isolates

Isolates	Host	Sclerotial formation and maturation								Sclerotial diameter (micron)
		17°C		20°C		27°C		37°C		
		Form.	Matu.	Form.	Matu.	Form.	Matu.	Form.	Matu.	
S1	Carrot	+	-	+	+	+	+	-	-	1284.25
S2	Cotton	-	-	+	+	+	+	+	+	1219.44
S3	Sugar beet	-	-	+	-	+	+	+	+	1239.61
S4	Onion	+	+	+	+	-	-	-	-	356.93

S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton, respectively, and S4 is *Sclerotium cepivorum* isolated from onion. LSD = 36.613

Table 3 . Analysis of variance of the effect of fungus, host and their interactions on damping-off disease and plant survival under greenhouse conditions during two seasons

Parameters	Source of variance	D.f	M.S	F value	P>F
First season	Isolate	4	1000.143	1.210E3	0.000
pre-emergence	Host	19	26.444	31.993	0.000
	Isolate x Host	76	7.235	8.753	0.000
	Error	200	0.827		
	Isolate	4	39.344	110.129	0.000
post-emergence	Host	19	11.276	31.562	0.000
	Isolate x Host	76	5.081	14.224	0.000
	Error	200	0.357		
	Isolate	4	878.779	845.060	0.000
Survival	Host	19	30.887	29.702	0.000
	Isolate x Host	76	8.722	8.387	0.000
	Error	200	1.040		
Second season	Isolate	4	260.821	168.091	0.000
pre-emergence	Host	19	68.119	43.901	0.000
	Isolate x Host	76	10.836	6.983	0.000
	Error	200	1.552		
	Isolate	4	18.192	31.491	0.000
post-emergence	Host	19	32.419	56.117	0.000
	Isolate x Host	76	6.467	11.194	0.000
	Error	200	0.578		
	Isolate	4	123.101	74.997	0.000
Survival	Host	19	35.575	21.673	0.000
	Isolate x Host	76	9.280	5.654	0.000
	Error	200	1.641		

Table 4. Effect of the interaction between *Sclerotium* spp. and different hosts on pre-emergence damping-off disease under greenhouse conditions (First season).

	Sclerotium spp.									
	[a]S1		S2		S3		S4		Control	
Host	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]
Carrot	100.00	10.03	100.00	10.03	100.00	10.03	41.70	6.50	0.00	0.71
Been	100.00	10.03	96.70	9.86	83.30	9.15	6.70	2.68	0.00	0.71
Lentil	98.30	9.94	88.30	9.42	53.30	7.33	0.00	0.71	0.00	0.71
Lupines	100.00	10.03	100.00	10.03	93.30	9.69	0.00	0.71	0.00	0.71
Onion	0.00	0.71	66.70	8.20	66.70	8.20	0.00	0.71	0.00	0.71
Fenugreek	100.00	10.03	100.00	10.03	85.00	9.25	40.00	6.36	0.00	0.71
Garlic	56.70	7.56	73.30	8.59	66.70	8.20	23.30	4.88	0.00	0.71
Wheat	38.30	6.23	48.30	6.99	58.30	7.67	0.00	0.71	0.00	0.71
Alfalfa	91.70	9.60	96.70	9.86	90.00	9.51	0.00	0.71	0.00	0.71
Sugar beet	100.00	10.03	98.30	9.94	96.70	9.86	10.00	3.24	0.00	0.71
Forage beet	98.30	9.94	98.30	9.94	93.30	9.69	0.00	0.71	0.00	0.71
Table beet	100.00	10.03	100.00	10.03	90.00	9.51	0.00	0.71	0.00	0.71
Chickpea	100.00	10.03	100.00	10.03	100.00	10.03	0.00	0.71	0.00	0.71
Peas	96.70	9.86	100.00	10.03	86.70	9.34	0.00	0.71	0.00	0.71
Radish	75.00	8.69	96.70	9.86	75.00	8.69	0.00	0.71	0.00	0.71
Potato	0.00	0.71	22.20	4.76	0.00	0.71	0.00	0.71	0.00	0.71
Hegazy clover	85.70	9.28	88.90	9.46	78.90	8.91	0.00	0.71	0.00	0.71
Maize	16.67	4.14	26.70	5.22	10.00	3.24	0.00	0.71	0.00	0.71
Grain sorghum	78.30	8.88	75.00	8.69	41.70	6.50	0.00	0.71	0.00	0.71
Cotton	100.00	10.03	100.00	10.03	100.00	10.03	0.00	0.71	0.00	0.71

a=S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton respectively and S4 is *Sclerotium cepivorum* isolated from onion. b= data transformed into root square of % values + 0.5 before ANOVA . LSD for interaction (Isolate x Host) = 1.464

Table 5. Effect of the interaction between *Sclerotium* spp. and different hosts on post-emergence damping-off disease under greenhouse conditions (First season)

	Sclerotium spp.									
	[a]S1		S2		S3		S4		Control	
Host	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]
Carrot	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71
Been	0.00	0.71	0.00	0.71	16.70	4.15	0.00	0.71	0.00	0.71
Lentil	1.70	1.25	0.00	0.71	46.70	6.87	0.00	0.71	0.00	0.71
Lupines	0.00	0.71	0.00	0.71	6.70	2.68	0.00	0.71	0.00	0.71
Onion	100.00	10.03	0.00	0.71	33.30	5.81	91.00	9.57	0.00	0.71
Fenugreek	0.00	0.71	0.00	0.71	10.00	3.24	0.00	0.71	0.00	0.71
Garlic	40.00	6.36	0.00	0.71	33.30	5.81	53.30	7.33	0.00	0.71
Wheat	28.30	5.37	15.00	3.94	35.00	5.96	0.00	0.71	0.00	0.71
Alfalfa	1.70	1.48	0.00	0.71	10.00	3.24	0.00	0.71	0.00	0.71
Sugar beet	0.00	0.71	0.00	0.71	3.30	1.95	0.00	0.71	0.00	0.71
Forage beet	0.00	0.71	0.00	0.71	5.00	2.35	0.00	0.71	0.00	0.71
Table beet	0.00	0.71	0.00	0.71	5.00	2.35	0.00	0.71	0.00	0.71
Chickpea	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71
Peas	3.30	1.95	0.00	0.71	13.30	3.71	0.00	0.71	0.00	0.71
Radish	10.00	3.24	1.70	1.48	5.00	2.35	0.00	0.71	0.00	0.71
Potato	66.70	8.20	55.60	7.49	100.00	10.03	0.00	0.71	0.00	0.71
Hegazy clover	3.30	1.95	3.30	1.95	12.20	3.56	0.00	0.71	0.00	0.71
Maize	23.33	4.88	46.70	6.87	46.70	6.87	0.00	0.71	0.00	0.71
Grain sorghum	0.00	0.71	11.70	3.49	11.60	3.48	0.00	0.71	0.00	0.71
Cotton	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71

a=S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton respectively and S4 is *Sclerotium cepivorum* isolated from onion. b= data transformed into root square of % values + 0.5 before ANOVA . LSD for interaction (Isolate x Host) = 0.962

Table 6. Effect of the interaction between *Sclerotium* spp. and different hosts on plant survival under greenhouse conditions (First season)

	Sclerotium spp.									
	[a]S1		S2		S3		S4		Control	
Host	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]
Carrot	0.00	0.71	0.00	0.71	0.00	0.71	58.30	7.67	100.00	10.03
Been	0.00	0.71	3.30	1.95	0.00	0.71	93.30	9.69	100.00	10.03
Lentil	0.00	1.25	11.70	3.49	0.00	0.71	100.00	10.03	100.00	10.03
Lupines	0.00	0.71	0.00	0.71	0.00	0.71	100.00	10.03	100.00	10.03
Onion	0.00	0.71	33.30	5.81	0.00	0.71	8.30	2.97	100.00	10.03
Fenugreek	0.00	0.71	0.00	0.71	5.00	2.35	60.00	7.78	100.00	10.03
Garlic	3.30	1.95	26.70	5.22	0.00	0.71	23.30	4.88	100.00	10.03
Wheat	33.40	5.82	36.70	6.10	6.70	2.68	100.00	10.03	100.00	10.03
Alfalfa	6.60	2.66	3.30	1.95	0.00	0.71	100.00	10.03	100.00	10.03
Sugar beet	0.00	0.71	1.70	1.48	0.00	0.71	90.00	9.51	100.00	10.03
Forage beet	1.70	1.48	1.70	1.48	1.70	1.48	100.00	10.03	100.00	10.03
Table beet	0.00	0.71	0.00	0.71	5.00	2.35	100.00	10.03	100.00	10.03
Chickpea	0.00	0.71	0.00	0.71	0.00	0.71	100.00	10.03	100.00	10.03
Peas	0.00	0.71	0.00	0.71	0.00	0.71	100.00	10.03	100.00	10.03
Radish	15.00	3.94	1.70	1.48	20.00	4.53	100.00	10.03	100.00	10.03
Potato	33.30	5.81	22.20	4.76	0.00	0.71	100.00	10.03	100.00	10.03
Hegazy clover	11.10	3.41	7.80	2.88	9.00	3.08	100.00	10.03	100.00	10.03
Maize	60.00	7.78	26.70	5.22	43.30	6.62	100.00	10.03	100.00	10.03
Grain sorghum	21.70	4.71	13.30	3.71	46.70	6.87	100.00	10.03	100.00	10.03
Cotton	0.00	0.71	0.00	0.71	0.00	0.71	100.00	10.03	100.00	10.03

a=S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton respectively and S4 is *Sclerotium cepivorum* isolated from onion. b= data transformed into root square of % values + 0.5 before ANOVA . LSD for interaction (Isolate x Host) = 1.641

Table 7. Effect of the interaction between *Sclerotium* spp. and different hosts on pre-emergence damping-off disease under greenhouse conditions (Second season).

	Sclerotium spp.									
	[a]S1		S2		S3		S4		Control	
Host	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]
Carrot	16.70	4.15	83.30	9.15	91.70	9.60	0.00	0.71	0.00	0.71
Been	6.70	2.68	10.00	3.24	0.00	0.71	6.70	2.68	0.00	0.71
Lentil	0.00	0.71	0.00	0.71	10.00	3.24	0.00	0.71	0.00	0.71
Lupines	96.70	9.86	93.30	9.69	93.30	9.69	0.00	0.71	0.00	0.71
Onion	0.00	0.71	0.00	0.71	8.30	2.97	0.00	0.71	0.00	0.71
Fenugreek	20.00	4.53	30.00	5.52	40.00	6.36	20.00	4.53	0.00	0.71
Garlic	6.70	2.68	3.30	1.95	26.70	5.22	0.00	0.71	0.00	0.71
Wheat	13.30	3.71	26.70	5.22	16.70	4.15	23.30	4.88	0.00	0.71
Alfalfa	66.70	8.20	50.00	7.11	70.00	8.40	70.00	8.40	0.00	0.71
Sugar beet	26.70	5.22	3.30	1.95	10.00	3.24	26.70	5.22	0.00	0.71
Forage beet	23.30	4.88	20.00	4.53	36.70	6.10	10.00	3.24	0.00	0.71
Table beet	30.00	5.52	23.30	4.88	36.70	6.10	66.70	8.20	0.00	0.71
Chickpea	76.70	8.79	86.70	9.34	93.30	9.69	76.70	8.79	0.00	0.71
Peas	46.70	6.87	36.70	6.10	50.00	7.11	60.00	7.78	0.00	0.71
Radish	53.30	7.33	46.70	6.87	70.00	8.40	53.30	7.33	0.00	0.71
Potato	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71
Hegazy clover	70.00	8.40	68.30	8.29	70.00	8.40	71.70	8.50	0.00	0.71
Maize	33.30	5.81	73.30	8.59	46.70	6.87	76.70	8.79	0.00	0.71
Grain sorghum	20.00	4.53	65.00	8.09	30.00	5.52	23.30	4.88	0.00	0.71
Cotton	50.00	7.11	91.70	9.60	70.00	8.40	46.70	6.87	0.00	0.71

a=S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton respectively and S4 is *Sclerotium cepivorum* isolated from onion. b= data transformed into root square of % values + 0.5 before ANOVA . LSD for interaction (Isolate x Host) = 2.005

Table 8. Effect of the interaction between Sclerotium spp. and different hosts on post-emergence damping-off disease under greenhouse conditions (Second season)

	Sclerotium spp.									
	[a]S1		S2		S3		S4		Control	
Host	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]
Carrot	49.90	7.10	16.70	4.15	8.30	2.97	0.00	0.71	0.00	0.71
Been	3.30	1.95	6.60	2.66	30.70	5.59	0.00	0.71	0.00	0.71
Lentil	53.30	7.33	6.70	2.68	30.00	5.52	0.00	0.71	0.00	0.71
Lupines	3.30	1.95	0.00	0.71	6.70	2.68	0.00	0.71	0.00	0.71
Onion	58.30	7.67	100.00	10.03	91.70	9.60	100.00	10.03	0.00	0.71
Fenugreek	20.00	4.53	13.30	3.71	3.30	1.95	0.00	0.71	0.00	0.71
Garlic	73.30	8.59	63.40	7.99	60.00	7.78	100.00	10.03	0.00	0.71
Wheat	16.70	4.15	40.00	6.36	13.30	3.71	0.00	0.71	0.00	0.71
Alfalfa	0.00	0.71	11.70	3.49	5.00	2.35	0.00	0.71	0.00	0.71
Sugar beet	30.00	5.52	66.70	8.20	80.00	8.97	0.00	0.71	0.00	0.71
Forage beet	60.00	7.78	46.70	6.87	36.70	6.10	0.00	0.71	0.00	0.71
Table beet	30.00	5.52	36.60	6.09	43.30	6.62	0.00	0.71	0.00	0.71
Chickpea	13.30	3.71	10.00	3.24	0.00	0.71	0.00	0.71	0.00	0.71
Peas	3.30	1.95	13.30	3.71	0.00	0.71	0.00	0.71	0.00	0.71
Radish	26.70	5.22	26.70	5.22	26.60	5.21	0.00	0.71	0.00	0.71
Potato	100.00	10.03	100.00	10.03	88.90	9.46	0.00	0.71	0.00	0.71
Hegazy clover	5.00	2.35	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71
Maize	10.00	3.24	1.70	1.48	0.00	0.71	0.00	0.71	0.00	0.71
Grain sorghum	6.70	2.68	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71
Cotton	20.00	4.53	0.00	0.71	17.00	4.18	0.00	0.71	0.00	0.71

a=S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton respectively and S4 is *Sclerotium cepivorum* isolated from onion. b= data transformed into root square of % values + 0.5 before ANOVA . LSD for interaction (Isolate x Host) = 1.224

Table 9. Effect of the interaction between *Sclerotium* spp. and different hosts on plant survival under greenhouse conditions (Second season)

	Sclerotium spp.									
	[a]S1		S2		S3		S4		Control	
Host	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]	%	Trans.[b]
Carrot	33.40	5.82	0.00	0.71	0.00	0.71	100.00	10.03	100.00	10.03
Been	90.00	9.51	83.40	9.16	69.30	8.35	93.30	9.69	100.00	10.03
Lentil	46.70	6.87	93.30	9.69	60.00	7.78	100.00	10.03	100.00	10.03
Lupines	0.00	0.71	6.70	2.68	0.00	0.71	100.00	10.03	100.00	10.03
Onion	41.70	6.50	0.00	0.71	0.00	0.71	0.00	0.71	100.00	10.03
Fenugreek	60.00	7.78	56.70	7.56	56.70	7.56	80.00	8.97	100.00	10.03
Garlic	20.00	4.53	33.30	5.81	13.30	3.71	0.00	0.71	100.00	10.03
Wheat	70.00	8.40	33.30	5.81	70.00	8.40	76.70	8.79	100.00	10.03
Alfalfa	33.30	5.81	38.30	6.23	25.00	5.05	30.00	5.52	100.00	10.03
Sugar beet	43.30	6.62	30.00	5.52	10.00	3.24	73.30	8.59	100.00	10.03
Forage beet	16.70	4.15	33.30	5.81	26.60	5.21	90.00	9.51	100.00	10.03
Table beet	40.00	6.36	40.10	6.37	20.00	4.53	33.30	5.81	100.00	10.03
Chickpea	10.00	3.24	3.30	1.95	6.70	2.68	23.30	4.88	100.00	10.03
Peas	50.00	7.11	50.03	7.11	50.00	7.11	40.00	6.36	100.00	10.03
Radish	20.00	4.53	26.60	5.21	3.40	1.97	46.70	6.87	100.00	10.03
Potato	0.00	0.71	0.00	0.71	11.10	3.41	100.00	10.03	100.00	10.03
Hegazy clover	25.00	5.05	31.70	5.67	30.00	5.52	28.30	5.37	100.00	10.03
Maize	56.70	7.56	25.00	5.05	53.30	7.33	23.30	4.88	100.00	10.03
Grain sorghum	73.30	8.59	35.00	5.96	70.00	8.40	76.70	8.79	100.00	10.03
Cotton	30.00	5.52	8.30	2.97	13.00	3.67	53.30	7.33	100.00	10.03

a=S1, S2 and S3 are *Sclerotium rolfsii* isolated from sugar beet, carrot and cotton respectively and S4 is *Sclerotium cepivorum* isolated from onion. b= data transformed into root square of % values + 0.5 before ANOVA . LSD for interaction (Isolate x Host) = 2.062

indicated that the sclerotial diameters of *Sclerotium* spp. isolates were significantly different within the same species and between the two tested species (Table 2).

Pathogenicity of *Sclerotium* spp.

The results of the pathogenicity test revealed that all tested *S. rolfsii* isolates that originated from different hosts were more pathogenic against all of the tested hosts than the control. *S. cepivorum* was the least virulent isolate on all tested hosts, except onion and garlic, in the two seasons.

The ANOVA results showed that fungus, host and fungus x host (F x H) interactions were all highly significant sources of variation in pre-emergence, post-emergence and plant survival in the two seasons (Table 3). These highly significant (F x H) interactions indicates differences in the

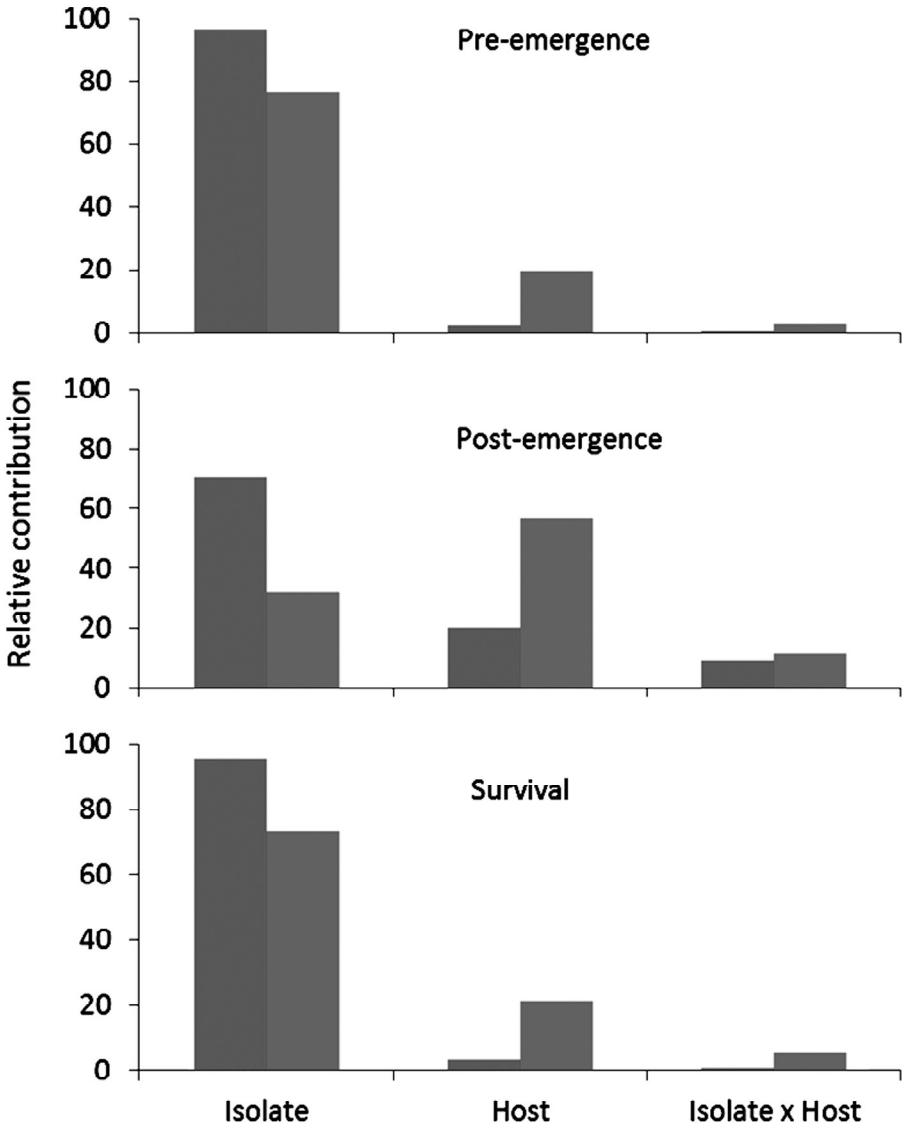

Fig. 1. Relative contribution of isolate, host and their interaction to the variation of damping-off disease and plant survival

virulence of fungal isolates or species according to the tested hosts. The relative contributions indicated that the fungus was the most important source of variation in seedling damping-off and plant survival, while the fungus x host interaction was the least important factor in the two seasons (Fig. 1).

Because of the significant interaction (F x H), the virulence of the fungal isolates and/or species in both seasons varied according to the tested hosts in pre-emergence, post-emergence and plant survival. In the first season, the pre-emergence results revealed that although all tested isolates were pathogenic on sugar beet, only the S2 isolate was pathogenic on potato. Meanwhile, isolates S1 and S4 were not pathogenic on onion, but the S2 and S3 isolates were pathogenic. Additionally, S3 was pathogenic on garlic and wheat with no significant difference; however, S4 was pathogenic on garlic and significantly different from S3 but nonpathogenic on wheat. Finally, except of S1 which could not infect onion as well as S2 the only isolate infected potato; *S. rolfsii* isolates were attacked all tested hosts. Meanwhile, *S. cepivorum* S4 was attacked only bean, carrot, fenugreek, garlic and sugar beet (Table 4).

Regarding post-emergence, the S1, S3 and S4 isolates were pathogenic on garlic and onion, with a significant difference for S1 and S4 only. However, the S2 isolate was not pathogenic on either host. On the other hand, the S2 and S3 were virulent on grain sorghum with no significant difference. The *S. rolfsii* isolates S1, S2, and S3 were generally pathogenic on 50, 30, and 85% of the tested hosts, respectively, while *S. cepivorum* S4 was pathogenic on 10% only, of the tested hosts (Table 5).

Regarding the host survival, maize was the most survived host in the soil inoculated with S1 isolate, while wheat and grain sorghum were the most survived with S2 and S3 isolates, respectively. Except for onion and garlic, which exhibited the lowest degrees of survival, none of the other hosts was affected by isolate S4 (Table 6).

In the pre-emergence in the second season, none of the tested isolates was pathogenic on potato, and only the S3 isolate was pathogenic on onion. Additionally, S3 was pathogenic on garlic and wheat with no significant difference; S4 was pathogenic on wheat and not significantly different from S3 but nonpathogenic on garlic. *S. rolfsii* isolates were generally pathogenic on 90% of the tested hosts exhibiting maximal (93-96%) infection on lupines. Meanwhile, *S. cepivorum* isolate was pathogenic on 70% of the tested hosts with the maximal infection (76%) on chickpea (Table 7).

In post-emergence, all isolates were pathogenic on onion, but only S1 was significantly different from the others. The same result was obtained for garlic, but only S4 was significantly different from the others. *S. cepivorum* isolate was pathogenic (100% infection) only on garlic and onion. *S. rolfsii* isolates were pathogenic on 75-95% of the tested hosts with the maximal infection (88-100%) on potato (Table 8).

Host survival results revealed that bean and lentil were the most survived hosts, with respect to the S1 and S2 isolates, respectively. However, grain sorghum and wheat showed equally high survival with respect to isolate S3. Onion and garlic exhibited the lowest degrees of survival when exposed to the S4 isolate, while no other hosts were affected (Table 9).

DISCUSSION

The mycological characteristics of *Sclerotium* spp. fungi have frequently been reported[15, 16]. The optimal temperature for fungal growth was 27-30°C, and maximal growth occurred at 25°C after 7 days of incubation, which was significantly reduced below 20°C and above 35°C [15]. Sclerotia formed on PDA and other media as white aggregates that differentiated within 2-3 weeks to dark-brown to black sclerotia measuring 0.3 to 3.0 mm in diameter. Significant morphological variations with respect to the growth rate and sclerotial diameter[17] were found between the tested isolates of *Sclerotium* in this study, and significant morphological and pathological variations have frequently been reported[18, 19].

Soil infestation with *Sclerotium* spp. showed a significant reduction in emergence for all tested host seeds compared with the control, which caused approximately 4-100% damping-off over seasons. The infection characteristics of damping-off disease caused by *Sclerotium* spp. were significantly different between some hosts. Different degrees of effects due to such fungi have

frequently been reported on the faba bean[20], garlic[16], onion[21], potato[22], radish[23], soybean[24,25] and sugar beet[8].

Tested isolates of *S. rolfsii* exhibited high degrees of virulence means (approximately 42-100%) on all examined hosts, which indicates that this species is highly virulent toward these hosts regardless of the isolate origin and/or they have no specialization. Moreover, this species exhibited about 52.5%, 85.8% and 91.5% virulence means on maize, sugar beet and cotton respectively. This result indicates the importance of crop rotation in the control of *S. rolfsii*[9]. However, *S. cepivorum* isolates were highly pathogenic (approximately 89-96% virulence) on garlic and onion compared with the other tested hosts (approximately 0-39% virulence), which indicates that host susceptibility was dependent on the tested species. The significant negative effects of *Sclerotium* spp. on plant growth[1,9] could be attributed to severe root colonization, which might lead to plant death because the fungus attacked all plant parts that contacted the soil under favorable environmental conditions[4]. Moreover, virulence variations could also be correlated with the synthesis of oxalic acid and enzymes[26, 27].

CONCLUSION

Damping-off is a disease with a significant economic impact on many plant species worldwide. Our understanding of the susceptibility of common hosts to *Sclerotium* spp. and their influence on disease severity in subsequently grown crops remains incomplete. Because *Sclerotium* spp. can overwinter in plant debris as mycelia and/or sclerotia, which can serve as primary inocula for new infections, further integrated control strategies should be undertaken to minimize stand and yield losses of these crops.

ACKNOWLEDGMENTS

The authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University for its funding of this research through the Research Group Project No. RGP-VPP-298.

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