Non-differential interaction between isolates of *Rhizoctonia solani* and flax cultivars

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ABSTRACT

The pathogenicity of 24 isolates of *Rhizoctonia solani* (7 isolates from anastomosis group AG-2 and 17 from AG-4) was evaluated on 10 flax cultivars under greenhouse conditions. Survival, plant height, and dry weight were used as criteria to evaluate pathogenicity. Analysis of variance (ANOVA) showed that the cultivar was a highly significant source of variation in all the tested parameters ($P < 0.0002$). Isolate was always a highly significant source of variation in all the tested parameters ($P = 0.0000$). Cultivar x isolate interaction was always a nonsignificant source of variation. The results of the ANOVA in the present study suggest that physiologic specialization did not occur within *R. solani* isolates pathogenic on flax. They also imply that resistance of the tested cultivars was only horizontal, and there were significant differences among cultivars in this type of resistance. Similarly, pathogenicity of the tested isolates was only aggressiveness, and the isolates significantly differed in this type of pathogenicity. A hierarchical cluster analysis was conducted in order to group the isolates according to disease variables measured on the tested cultivars. Cluster analysis divided the isolates into groups; however, grouping the isolates was not related to their geographic origin nor the AG.

Keywords: cultivars, *Linum usitatissimum, Rhizoctonia solani,* resistance

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Sýkingareiginleikar 24 stofna af *Rhizoctonia solani* (7 stofnar af netjuðum sveppum AG-2 og 17 af AG-4) voru metnir á 10 kvæmum af hör í gróðurhúsi. Lifun, hæð plöntu og þurrefni voru notuð til að meta sýkingareiginleika. Fervikagreining (ANOVA) sýndi að kvæmi var mjög marktæk uppspretta breytileika í öllum þáttum sem skoðaðar voru ($P < 0.0002$). Stofn var alltaf mjög marktæk uppspretta breytileika í öllum þáttum sem skoðaðir voru ($P = 0.0000$). Víxlverkun á milli stofns og kvæmis var aldrei marktæk ástæða breytileika. Niðurstöður fervikagreiningarinnar benda til þess að engin lífeðlisfræðileg sérhæfing hafi átt sér stað í *R. solani* stofnun sem sýkja lín. Jafnframt benda niðurstöðurnar til þess að varnir kvæmanna sem prófaðir voru séu einungis byggðar á almennri mótstöðu og að það væri marktækur munur milli kvæma í þeirri gerð mótstöðu.. Jafnframt að sýkingareiginleikar stofnanna sem prófaðir voru séu eingöngu háðir sýkingarhæfniog að munur hafi verið á stofnunum hvað þetta varðar. Klasagreining skipti sveppastofnunum í hópa en þeir voru hvorki tengdir landfræðilegum uppruna né AG.

INTRODUCTION

Rhizoctonia solani Kühn (teleomorph: *Thanatephorus cucumeris* (Frank) Donk) is one of the more primitive Basidiomycetes. *R. solani* exists in its vegetative form in nearly all agricultural soils. In this non-spore-producing phase, the fungus lives saprophytically on dead plant remains, but it can become vigorously parasitic when roots or other parts of a susceptible host penetrate the infested zone (Watkins 1981).

Current classification of *R. solani* is based largely on grouping of isolates into anastomosis groups (AG_s). Anastomosis, or the fusion of hyphae between different individuals, may result in the sharing of genetic material without sexual reproduction, but it also serves to isolate individuals from other members of the same species that do not share the alleles for somatic compatibility (Agrios 2005).

R. solani attacks flax at an early stage of development, destroying the root and causing thinning or, in severe infection, death of seedlings (Krylova 1981). *R. solani* also causes root rot symptoms, which appear in plants after the flowering stage (Hartman 1996)

Pathogenicity of *R. solani* isolates to flax hypocotyls is not host specific and is controlled by several dominant factors, and separate genetic systems in the fungus control its ability to cause seed rot and hypocotyl infection (Anderson & Stretton 1978).

There are various reports on the differences in susceptibility among flax genotypes to *R. solani,* but flax cultivars with resistance or immunity to *R. solani* are not yet known (Omran et al. 1968, Anderson, 1977, Islam 1992, Bos & Parlevliet 1995). Yellow-seeded varieties are more prone to cracking, which renders them more susceptible to seedling blight and root rot than brown-seeded varieties (Hartman 1996).

Differences in susceptibility of flax cultivars to *R. solani* and differences in aggressiveness among fungal isolates have been demonstrated in greenhouse experiments. For example, when 40 varieties of flax were inoculated with the most virulent AG-4 isolates, three fiber and four linseed varieties showed some resistance. Of these, two linseed varieties were resistant to all isolates tested (Anderson 1977). Kangatharalingam (1987) found significant cultivar x isolate interaction in each of two greenhouse experiments conducted to study aggressiveness of *R. solani* isolates on flax cultivars. However, when the data from these two experiments were combined for the analysis of variance, there was nonsignificant cultivar x isolate interaction and highly significant cultivar x isolate x environment interaction.

The specificity of *R. solani* isolates were evaluated on flax cultivars because the concept of specificity in host-pathogen interaction has both theoretical and applied relevance to the understanding and control of many plant diseases. True specificity implies that genetic variation in the host and the pathogen are correlated and may affect the durability of host resistance to the pathogen (Kulkarni & Chopra 1982). Physiologic specialization, i.e. differential adaptation of pathogen isolates to certain host genotypes, could also complicate screening strategies in the development of disease resistant host varieties. This is certainly important in host-pathogen systems where resistance is governed by major genes and distinct physiologic races can be identified. However, isolate-cultivar specificity should also be a consideration in quantitative host-pathogen systems, where physiologic specialization may be less obvious and based on quantitative differences in disease expression (Schilder & Bergstrom 1990).

Specificity in host-pathogen relationships is often indicated by a significant isolate x variety interaction in the analysis of variance (ANOVA) of an experiment where a number of pathogen isolates are tested in all possible combinations on a set of host genotypes. Nonspecificity is identified by the lack of such an interaction (Vanderplank 1982 and 1984).

In Egypt, resistance to *R. solani* is completely lacking in commercial flax (*Linum usitatis-*

simum L.) cultivars (A.A. Aly, *personal observation*). Therefore, more research is needed to identify *R. solani*-resistant genotypes. A clear understanding of the extent of variation in aggressiveness among *R. solani* isolates would be helpful in developing flax cultivars with effective resistance. Therefore, this investigation was undertaken to evaluate the pathogenic variability among isolates of *R. solani* originating from different regions in Egypt and their interactions with flax cultivars.

MATERIALS AND METHODS

Fungal isolates and inoculum production

Isolates of *R. solani* used in the present study were obtained from the fungal collection of the Cotton and Fiber Crops Diseases Research Section, Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt. All the 24 isolates used in the present study originated from flax roots. A substrate for growth of isolates was prepared in 500 ml glass bottles; each bottle contained 50 g barley grains and 40 ml of tap water. Contents of each of bottle were autoclaved for 30 min. Isolate inoculum, taken from one week old culture on potato-dextrose agar medium was aseptically introduced into the bottle and allowed to colonize the substrate for three weeks.

Interaction between flax cultivars and isolates of R. solani

Twenty four isolates of *R. solani*, representing different AGs and locations (Table 1), were used in this study. Batches of autoclaved clay loam soil were separately infested with inoculums of each isolate at a rate of 1g per kg of soil. The infestation process was carried out by thoroughly mixing the inoculums with soil, so the inoculums were evenly distributed in the soil. Infested soil was dispensed in 10 cm diameter clay pots and these were planted with 20 seeds per pot for each of the tested cultivars (Marlin, Electra, Elona, Hermis, Eriana, Escalina, Sakha 1, Sakha 2, Giza 7, and Giza 8). In the control treatments, autoclaved barley (cv. Balady) grains were thoroughly mixed with soil at a rate of 1 g per kg of soil. Pots were distributed on greenhouse benches under a temperature regime ranging from 17±3.5 to 23±4°C. There were three pots (replicates) for each treatment. Surviving plants, plant height by cm calculated as (total height of plants per pot (cm) divided by no. of plants per pot) and dry weight (mg) calculated as (total dry weight of plants per pot (mg) divided by no. of plants per pot) were recorded 45 days after planting. The whole experiment was replicated with almost the same results.

Table 1. Isolates of *Rhizoctonia solani* from flax roots used in this study.

Isolate No.	Geographic origin	Anastomosis group
1	Kafr El-Sheikh	AG- 4
2	Kafr El-Sheikh	AG -4
3	Kafr El-Sheikh	AG -2
4	Kafr El-Sheikh	AG- 4
5	Kafr El-Sheikh	AG- 4
6	Kafr El-Sheikh	AG- 4
7	Kafr El-Sheikh	AG- 4
8	Kafr El-Sheikh	AG -2
9	Kafr El-Sheikh	AG- 4
10	Damiatta	AG- 4
11	Damiatta	AG -2
12	Damiatta	AG- 4
13	Damiatta	AG- 4
14	Damiatta	AG- 4
15	Damiatta	AG- 4
16	Damiatta	AG- 4
17	Damiatta	AG -2
18	Damiatta	AG -2
19	Gharbiya	AG- 4
20	Gharbiya	AG- 4
21	Gharbiya	AG- 4
22	Gharbiya	AG -2
23	Gharbiya	AG- 4
24	Gharbiya	AG -2

Statistical analysis of the data

The experimental design of the present study was a randomized complete block with three replicates. Analysis of variance (ANOVA) of the data and correlation were performed with MSTAT-C Statistical Package. The least significant difference (LSD) was used to compare isolate and cultivar means. Percentage data

were transformed into (X) $^{1/2}$ before carrying out the ANOVA to normalize data and stabilize variances throughout the data range. Cluster analysis of *R. solani* isolates was performed with the software package SPSS 13.

RESULTS

The cultivar was a highly significant source of variation in all the tested parameters. The isolate was always a highly significant source of variation, while cultivar x isolate interaction was always a nonsignificant source of variation (Table 2). The isolate was the most important factor in determining the variation in all the tested parameters in particular plant height and dry weight. The contribution of the cultivar to variation in survival was greater than those of the factors of plant height and dry weight, and the contribution of cultivar x isolate interaction to variation in plant height and dry weight were all negligible (Table 3).

Due to the lack of significant cultivar x isolate interaction, cultivars and isolates were compared by using their general means. In terms of survival the cultivars were divided into two distinct groups. One group included the introductions (Marlin, Electra, Elona, Hermis, Eniana, and Escalina) and the other group included the local cultivars (Sakha1, Sakha2, Giza7 and Giza8. The introductions were less susceptible than the local cultivars. Within each group, the differences were nonsignificant. However, the differences were highly significant between cultivars from the two groups (Table 4). The tested isolates showed variable levels of pathogenicity. There was no relationship between pathogenicity of isolates and their AGs. As to plant height (Table 5) the introductions tended to be more resistant than the local cultivars. All the isolates significantly reduced plant height; however, the ability to reduce plant height varied from one isolate to another.

Dry weight of the introductions tended to be less affected by infection compared with that of the local cultivars (Table 6). All the isolates significantly reduced dry weight; however, their ability to reduce dry weight was variable.

Correlation among variables used for evaluating the pathogenicity of *R. solani* isolates on flax cultivars is shown in Table 7. The correlation between survival and plant height was negative and significant on Electra, positive and significant on Hermis, Escalina, Giza 7 and Giza 8, and nonsignificant on the other cultivars. For all cultivars, survival and dry weight were not correlated. For all cultivars, plant height and dry weight were not correlated.

Four groups of similar isolates (isolates 8,

Table 2. Analysis of variance of the interaction between flax cultivars and isolates of *Rhizoctonia solani* under greenhouse conditions.

Variable and source of variation[a]	D.F.	F. value	P > F
Survival			
Replication	2	2.2502	0.1064
Cultivar (C)	9	18.2412	0.0000
Isolate (I)	24	44.2699	0.0000
C x I	216	0.8675	
Error	498		
Plant height			
Replication	2	0.2841	
Cultivar (C)	9	26.4819	0.0000
Isolate (I)	24	186.5257	0.0000
C x I	216	0.1717	
Error	498		
Dry weight			
Replication	2	6.4258	0.0018
Cultivar (C)	9	3.6875	0.0002
Isolate (I)	24	19.1338	0.0000
C x I	216	0.0149	
Error	498		

[a] Replication is random, while each cultivar and isolate is fixed.

Table 3. Relative contribution of flax cultivar, *Rhizoctonia solani* isolate, and their interaction to variation in flax seedling blight variables under greenhouse conditions.

	Relative contribution[a] to variation in		
Source of variation	Survival %	Plant height cm plant^{-1}	Dry weight mg plant^{-1}
Cultivar (C)	11.58	5.02	6.53
Isolate (I)	74.90	94.19	90.31
C x I	13.20	0.78	0.63

[a] Calculated as percentage of the sum of squares of the explained (model) variation.

Table 4. Effect of flax cultivar and *Rhizoctonia solani* isolate on survival of seedlings under greenhouse conditions in %.

Isolate	Cultivars										
No	Marlin	Electra	Elona	Hermis	Eriana	Escalina	Sakha 1	Sakha 2	Giza 7	Giza 8	Mean
1	86.6	88.3	88.3	88.3	88.3	88.3	81.6	81.6	85.0	81.6	86.1
2	88.3	88.3	88.3	88.3	90.0	88.3	85.0	83.3	88.3	83.3	88.1
3	88.3	86.3	88.3	86.6	88.3	86.6	86.6	58.0	88.3	81.6	86.1
4	88.3	88.3	91.6	90.0	90.0	88.3	90.0	86.6	86.6	81.6	88.1
5	88.3	86.6	86.6	85.0	88.3	88.3	83.3	83.3	81.6	81.6	86.3
6	85.0	86.6	88.3	88.3	88.3	88.3	81.6	83.3	83.3	80.0	86.3
7	88.3	88.3	88.3	90.0	90.0	86.6	83.3	83.3	81.6	81.6	87.1
8	91.6	86.6	88.3	88.3	91.6	90.0	86.6	86.6	85.0	85.0	88.0
9	81.6	81.6	81.6	83.3	95.0	83.3	80.0	80.0	78.3	78.3	82.3
10	81.6	85.0	81.6	81.6	83.3	81.6	78.3	80.0	78.3	76.6	80.8
11	83.3	85.0	83.3	85.0	86.6	83.3	78.3	80.0	81.6	81.6	82.8
12	80.0	80.0	83.3	85.0	83.3	85.0	76.6	76.6	81.6	76.6	80.8
13	83.3	81.6	81.6	81.6	85.0	81.6	76.6	76.6	81.6	76.6	80.6
14	81.6	81.6	80.0	81.6	86.6	81.6	76.6	76.6	81.6	73.3	80.1
15	85.0	85.0	85.0	85.0	86.6	85.0	81.6	81.6	78.3	78.3	81.1
16	80.0	83.3	81.6	81.6	86.6	83.3	80.0	80.0	76.6	75.0	80.0
17	78.3	75.0	75.0	78.3	80.0	76.6	75.0	73.3	71.6	73.3	75.6
18	76.6	80.0	76.6	80.0	83.3	78.3	75.0	76.6	75.0	73.3	77.5
19	76.6	73.3	78.3	76.6	78.3	78.3	73.3	70.0	70.0	71.6	71.6
20	75.0	75.0	75.0	78.3	76.6	80.0	71.6	75.0	71.6	75.0	75.3
21	78.3	80.0	78.3	76.6	80.0	75.0	70.0	70.0	76.6	76.6	76.6
22	81.6	80.0	78.3	76.6	80.0	75.0	70.0	70.0	76.6	70.0	75.8
23	76.6	78.3	78.3	80.0	83.3	76.6	76.6	76.6	73.3	76.6	77.6
24	76.6	78.3	78.3	76.6	78.3	75.0	73.3	71.6	73.3	71.6	75.1
control	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Mean	**83.2**	**83.3**	**83.3**	**83.7**	**85.8**	**83.3**	**79.8**	**79.5**	**80.0**	**78.4**	**82.0**

LSD (transformed data) for cultivar= 0.082 ($P < 0.05$) or 0.109 ($P < 0.01$). Isolate= 0.130 ($P < 0.05$) or 0.172 ($P < 0.01$).
Cultivar x isolate interaction is nonsignificant.

Table 5. Effect of flax cultivar and *Rhizoctonia solani* isolate on plant height (cm per plant) of seedlings under greenhouse conditions

Isolate	Cultivars										
No	Marlin	Electra	Elona	Hermis	Eriana	Escalina	Sakha 1	Sakha 2	Giza 7	Giza 8	Mean
1	17.6	17.4	17.4	17.6	17.6	17.6	17.4	17.2	16.9	16.6	17.3
2	16.5	16.3	16.3	16.5	16.8	16.5	16.3	16.1	15.5	15.4	16.2
3	17.3	17.1	17.1	17.3	17.5	17.3	17.0	16.9	16.6	16.4	17.1
4	17.1	16.9	16.9	17.1	17.3	17.1	16.8	16.6	16.4	16.2	16.8
5	17.1	16.9	16.9	17.1	17.3	17.1	16.8	16.6	16.3	16.2	16.8
6	17.5	17.0	17.0	17.5	17.7	17.5	17.2	17.0	16.8	16.6	17.1
7	17.5	17.3	17.2	17.5	17.7	17.5	17.6	17.4	17.2	17.2	17.4
8	17.7	17.5	17.4	17.7	17.9	17.7	17.8	17.3	17.0	16.8	17.5
9	16.7	16.5	16.5	16.7	17.0	16.8	16.5	16.2	16.0	15.9	16.5
10	17.9	17.7	17.8	17.9	18.2	17.9	17.7	17.5	17.3	17.2	17.7
11	18.0	17.8	17.8	18.0	18.3	18.0	17.8	17.6	17.4	17.3	17.8
12	17.6	17.4	17.4	17.6	17.9	17.6	17.4	17.2	17.0	16.8	17.4
13	18.1	17.7	17.9	18.1	18.4	18.1	17.8	17.6	17.4	17.2	17.8
14	18.1	17.9	17.9	18.1	18.3	18.1	17.7	17.5	17.3	17.2	17.8
15	16.1	15.9	16.1	16.1	16.3	16.0	15.8	15.6	15.4	15.2	15.8
16	16.8	16.7	16.6	16.8	17.0	16.8	16.2	15.9	15.7	16.0	16.4
17	14.0	13.8	13.8	14.0	14.2	14.0	13.7	13.5	13.4	13.2	13.8
18	17.8	17.6	17.6	17.8	18.0	17.8	17.5	17.3	17.1	17.0	17.5
19	13.8	13.6	13.7	13.7	14.0	13.8	13.4	13.3	13.4	13.3	13.6
20	17.6	17.4	17.3	17.6	17.8	17.6	17.3	17.1	16.9	16.7	17.3
21	17.4	17.2	17.2	17.4	17.6	17.3	17.0	16.9	16.7	16.6	17.1
22	14.0	13.9	13.9	14.0	14.2	14.1	13.7	13.5	13.3	13.2	13.8
23	16.0	15.8	15.8	16.0	16.2	16.7	15.7	14.9	15.3	15.1	15.7
24	16.3	16.1	16.0	16.3	16.5	16.3	16.0	15.9	15.7	15.6	16.1
control	**19.2**	**19.1**	**18.6**	**19.2**	**19.2**	**19.2**	**19.2**	**19.2**	**19.2**	**19.2**	**19.1**
Mean	**16.9**	**16.7**	**16.7**	**16.9**	**17.2**	**17.0**	**16.7**	**16.5**	**16.3**	**16.1**	**16.7**

LSD for cultivar 0.173 ($P < 0.05$) or 0.228 ($P < 0.01$). Isolate= 0.274 ($P < 0.05$) or 0.361 ($P < 0.01$). Cultivar x isolate interaction is nonsignificant.

Table 6. Effect of flax cultivar and *Rhizoctonia solani* isolate on dry weight (mg per plant) of seedlings under greenhouse conditions.

Isolate	Cultivars										
No	Marlin	Electra	Elona	Hermis	Eriana	Escalina	Sakha 1	Sakha 2	Giza 7	Giza 8	Mean
1	47	44	41	43	52	40	42	39	40	40	43
2	35	34	30	34	40	28	30	26	28	28	31
3	37	35	32	34	42	30	32	28	30	30	33
4	59	57	53	55	64	51	54	50	52	52	55
5	59	57	53	55	59	51	49	46	48	48	52
6	59	57	52	58	63	50	54	46	52	52	54
7	60	58	53	55	65	48	55	51	53	53	55
8	45	42	38	40	50	36	40	38	39	39	41
9	31	29	25	27	35	23	25	21	24	24	26
10	20	18	14	16	24	12	14	10	12	12	15
11	30	28	24	26	35	22	25	21	23	23	25
12	50	52	48	50	55	46	45	29	43	43	47
13	52	50	46	48	56	44	46	42	44	44	47
14	30	28	24	26	35	22	25	21	23	23	25
15	30	28	24	26	35	22	25	22	24	24	26
16	20	18	14	16	24	12	14	12	12	12	15
17	38	35	32	34	42	30	32	30	31	31	33
18	62	60	56	58	65	45	55	51	53	53	56
19	50	48	44	46	54	42	44	40	42	42	45
20	50	48	43	45	45	41	44	40	42	42	45
21	50	48	43	46	45	42	44	40	42	42	45
22	46	44	40	42	51	38	44	40	42	42	43
23	49	48	45	47	54	43	44	40	42	42	45
24	38	36	32	34	43	31	33	30	32	32	34
control	**85**	**83**	**79**	**83**	**84**	**79**	**83**	**83**	**83**	**83**	**82**
Mean	**44**	**43**	**39**	**42**	**49**	**38**	**40**	**36**	**38**	**38**	**41**

LSD for cultivar= 5.973 (P≤ 0.05) or 7.861 (P≤ 0.01). Isolate = 9.444 (P≤ 0.05)or 12.430(P≤ 0.01). Cultivar X Isolate interaction is nonsignificant.

Table 7. Correlation among variables used for evaluating pathogenicity of *Rhizoctonia solani* isolates on seedlings of flax cultivars under greenhouse conditions

Cultivar	Variable	Variables	
		Plant height cm plant^{-1}	Dry weight mg plant^{-1}
Marlin	Survival (%)	0.247	0.072
	Plant height (cm/plant)		-0.015
Electra	Survival (%)	-0.415*	-0.122
	Plant height (cm/plant)		0.093
Elona	Survival (%)	0.369	0.135
	Plant height (cm/plant)		0.016
Hermis	Survival (%)	0.477*	0.156
	Plant height (cm/plant)		0.040
Eriana	Survival (%)	0.312	0.235
	Plant height (cm/plant)		0.274
Escalina	Survival (%)	0.448*	0.101
	Plant height (cm/plant)		0.028
Sakha 1	Survival (%)	0.362	0.001
	Plant height (cm/plant)		0.041
Sakha 2	Survival (%)	0.331	0.082
	Plant height (cm/plant)		-0.004
Giza 7	Survival (%)	0.508*	0.068
	Plant height (cm/plant)		0.056
Giza 8	Survival (%)	0.480*	0.028
	Plant height (cm/plant)		0.025

Linear correlation coefficient is significant at $P < 0.05$ (*) .

17, 24, 1; isolates 11, 14, 2, 3, 9, 15; isolates 5, 19, 6, 7, 4, 13, 23, 20, 21 and isolates 18, 12, respectively) were identified by cluster analysis (Fig.1). The aggressiveness patterns of isolates 10 and 16 were quite different from the others. Grouping the isolates by cluster analysis was neither related to their geographic origins nor to AGs. For example, isolates 8, 17 and 24 belonged to AG-2; however, their aggressiveness patterns were quite different from those of isolates 22 and 18, which also belonged to AG-2. Isolates 24 and 1 differed in geographic origin and AG however, they were identical in their aggressiveness patterns.

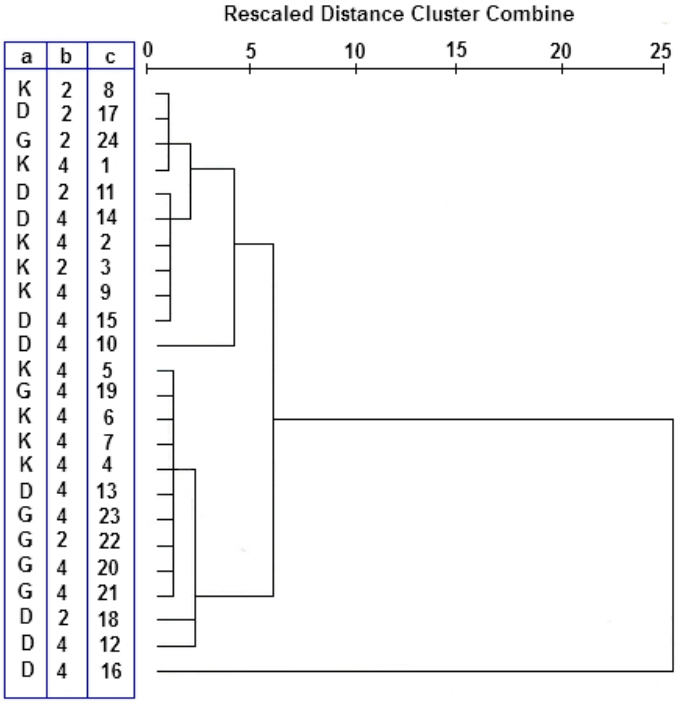

Figure 1. Phenogram based on average linkage cluster analysis of aggressiveness of 24 isolates of *R. solani* on 10 flax cultivars. Aggressiveness of isolates was evaluated based on survival, plant height, and dry weight. [a] Geographic origins of the isolates were Kafr El–Sheikh (K) Damiatta (D), and Gharbiya (G).
[b] Ansotomosis group. [c] Isolate number .

DISCUSSION

The ANOVA in the present work showed that cultivar x isolate interaction was a nonsignificant source of variation in all the tested parameters.

The statistically nonsignificant interaction between flax cultivars and isolates of *R. solani* in this study suggests that physiologic specialization does not occur within R. solani isolates pathogenic on flax. Therefore, results of flax screening tests for seedling blight resistance would not change considerably depending on the isolate(s) used. Thus, screening of flax cultivars for seedling blight resistance can be achieved even by using a limited number of *R. solani* isolates.

It has also been suggested that the presence of a significant cultivar x isolate interaction in the ANOVA is evidence of a differential (vertical) host-pathogen relationship (Vanderplank 1984). Lack of a significant interaction is taken to indicate that association is non-differential (horizontal), implying that differences in cultivar susceptibility are consistent relative to one another, regardless of pathogen isolates. In many hostpathogen relationships the two types of resistance may act together in determining the outcome of the association between the host and the pathogen (Vanderplank 1984).

Accordingly, the ANOVA in the present work implies that resistance of the tested cultivars was only horizontal and there were significant differences among cultivars in this type of resistance. Similarly, pathogenicity of the tested isolates was only aggressiveness and the isolates significantly differed in this type of pathogenicity.

The application of cluster analysis has been

suggested previously for assessing similarity and/or dissimilarity in gene-for-gene host-parasite relationships (Lebeda and Jendrulek, 1987, Priestely et al. 1984). The method was also used to express exactly the genetic similarity among 48 physiological races of *Bremia lactucae* Regel (Lebeda & Jendrulek 1987), 17 isolates of *Pyrenophora tritici-repentis* (Schilder & Bergstrom 1990), 41 isolates of *Ascochyta rabiei* (Porta-Puglia et al., 1996), 20 isolates of *Macrophomina phaseolina*. (Aly et al. 2007), and 52 isolates of *R. solani* (El-Samawaty et al. 2008).

In this study, a hierarchical cluster analysis was conducted in order to group 24 isolates of *R. solani* according to disease variables measured on the tested cultivars. Cluster analysis divided the isolates into groups; however, grouping the isolates was neither related to their geographic origin nor their AG.

REFERENCES

Agrios GN 2005. *Plant Pathology* 5th ed. Elsevier Academic Press, San Diego, California, 384 p.

Aly AA, Abdel-Sattar MA, Omar MR &Abd-Elsalam KA 2007. Differential interaction between isolates of *Macrophomina phaseolina* and Egyptian cotton cultivars. *Pest Technology* 1, 127-132.

Anderson NA 1977. Evaluation of the *Rhizoctonia* complex in relation to seedling blight on flax. *Plant Disease Reporter* 61, 140-142.

Anderson NA & Stretton HM 1978. Genetic control of pathogenicity in *Rhizoctonia solani*. *Phytopathology* 68, 1314-1317.

Bos L & Parlevliet JE 1995. Concepts and terminology on plant/pest relationships: Towards consensus in plant pathology and crop protection. *Annual Review of Phytopathology* 33, 69-102.

El-Samawaty A, Asran-Amal A, Omar MR & Abd-Elsalam KA, 2008. Anastomosisi groups, pathogenicity, and cellulase production of *Rhizoctonia* solani from cotton. *Pest Technology* 2, 117-124.

Hartman M 1996. Diseases. In: Rowland J. (ed.) *Growing Flax: Production, management, and diagnostic guide.* The Flax Council of Canada. pp. 39- 42.

Islam MR 1992. Control of flax diseases through genetic resistance. *Zeitschrift Pflanzenkrheit Pflanzenschutz* 99, 550-557.

Kangatharalingam N 1987. *Variability in Rhizoctonia solani Kühn Pathogenic on Flax*. Ph.D. Thesis. South Dakota State University, Brokkings, 99 p.

Krylova TV 1981. Rhizoctonisis of fiber flax. *Mikologiya Fitopatologiya* 15, 511-513.

Kulkarni RN & Chopra VL 1982. Environment as the cause of differential interaction between host cultivars and pathogenic races. *Phytopathology* 72, 1384-1386.

Lebeda A & Jendrulek T 1987. Application of cluster analysis for establishment of genetic similarity in gene-for gene host-parasite relationships. *Journal of Phytopathology* 119, 131-141.

Omran AO, Frederikson RA & Atkins IM 1968. Heritability of seedling disease characteristics in flax. *Crop Science* 8, 750-753.

Porta-Puglia A, Crino P & Mosconi C 1996. Variability in virulence to chickpea of an Italian population of *Ascochyta rabiei. Plant Disease* 80, 39-41.

Priestley RH, Bayles RR & Ryall J 1984. Identification of specific resistance against *Puccinia striiformis* (yellow rust) in winter wheat varieties: II. Use of cluster analysis. *Journal of the National Institute of Agricultural Botany* 16, 477-485.

Schilder AMC & Bergstrom GC 1990. Variation in virulence within the population of Pyrenophora tritici-repentis in New York. *Phytopathology* 80, 84-90.

Vanderplank JE 1982. *Host-Pathogen Interactions in Plant Diseases.* Academic Press, New York, 207 p.

Vanderplank JE 1984. *Disease Resistance in Plants*. 2nd ed. Academic Press, Orlando, Florida, 194 pp.

Watkins GM ed. 1981. *Compendium of Cotton Diseases*. The American Phytopathological Society. St. Paul, Minnesota, 87 p.

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