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VIRULENCE SURVEY OF LEAF RUST CAUSED BY *Puccinia triticina* ERIKS, AND POSTULATED GENES IN 17 EGYPTIAN WHEAT CULTIVARS

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ABSTRACT

Leaf rust (*Puccinia triticina*) collections were obtained from rust-infected wheat leaves throughout the survey of wheat fields and nurseries in the East Delta region in Egypt (Damietta and Dakahlia Governorates) in order to determine the virulence of wheat leaf rust fungus in 2010/11. Single uredinial isolates (56 in total) were derived from twenty two wheat leaf rust collections and tested for virulence phenotype at seedling stage on 17 Egyptian wheat cultivars and 20 lines of Thatcher wheat that conformed near-isogenic for leaf rust resistance genes *i.e. Lr1*, *Lr2a*, *Lr2c*, *Lr3*; *Lr9*, *Lr16*, *Lr24*, *Lr26*; *Lr3ka*, *Lr11*, *Lr17*, *Lr30*; *Lr10*, *Lr18*, *Lr21*, *Lr2b*; *Lr14b*, *Lr15*, *Lr35* and *Lr42*. Thirty three virulence formulae of *P. triticina* were found. Virulence phenotype TKTT, which is virulent to each of the tested resistance genes except *Lr9* only, was the first most common virulent phenotype. PKTT is virulent to all resistance genes except *Lr2a* and *Lr9*, and the second most common virulent phenotype. TTTT exhibited the third most common virulent phenotype. On the other hand, leaf rust resistance genes i.e. *Lr9* and *Lr2a* exhibited the highest efficacy (73.22%) and (46.42%), respectively than the rest (*Lr's*). However, Gemmeiza 10, Beni Sweif 4 and Sakha 94 proved that they have 18 genes. While, Giza168, Sids1 and Beni Sweif 5 probably are free from any gene at least against these isolates in this study. Virulence phenotype that showed avirulence to leaf rust resistance genes in the Thatcher differential lines increased in frequency in the East-Delta region in 2010/11 growing season. The high diverse populations of *P. triticna* in this region will continue to present a challenge for the development of wheat cultivars with effective durable resistance.

Keywords: Avirulence/virulence formulae, Leaf rust resistance genes (*Lr's*), Near-isogenic lines (NIL's), *Puccinia triticina* Eriks.

INTRODUCTION

Among several diseases that constrain wheat production, leaf rust caused by *Puccinia triticina* Eriks. is probably the most widely distributed disease as it affects winter, facultative and spring wheats (Singh *et al.*, 1999). Genetic resistance is the most economical and environmental control measures. The ability to diversify the genetic base for resistance depends on knowledge of resistance genes present in the germplasm used in a breeding program. Named race-specific genes for resistance to rusts in wheat can be postulated if a wheat line is inoculated with series of pathogen races that possess diverse combinations of avirulence and virulence genes. This method, which is based on the gene for-gene-relationship, has been described and used by several researchers (Browder and Eversmyer, 1980; Knott and Johnosn, 1983 and Singh, 1993), Genes *Lr9* from *Aegilops umbellulata*, *Lr26* from Secale Cereale, *Lr24* cereale, *Lr24* from *Thinopyrum ponticum* and *Lr41* (=39) from *Triticum tauschii* have proven to be no more durable for resistance than *Lr1*, *Lr2a*, *Lr11* or *Lr17*, which were derived from common hexaploid wheat. For all of these genes, virulent phenotypes of *P. triticina* quickly increased, rendering the resistance genes largely ineffective. Wheat cultivars with combinations of leaf rust resistance genes have selected more complex leaf rust phenotypes that have combinations of virulence. When wheat cultivars with strongly selective seedling resistance genes are removed from cultivation, the virulent *P. triticina* phenotypes

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may also decline, which can restore the effectiveness of the resistance genes. Cyclical changes in frequency have been noted for virulence to genes *Lr9*, *Lr16* and *Lr24* (Kolmer, 1989 and Kolmer *et al.*, 2008 and 2009).

The objectives of this study were to characterize the virulence of populations of *P. triticina*, gene efficacy, postulated gene(s) in 16 Egyptian wheat cultivars and common gene between them, to be used in the program of wheat rust resistance in Egypt.

MATERIALS AND METHODS

The samples collected were from the East-Delta Governorates *i.e.* Damietta and Dakahlia, Egypt. Wheat leaves having the symptoms of leaf rust disease caused by *Puccinia triticina* Eriks. including certain cultivated commercial cultivars and wheat rust trap nurseries, throughout the above mentioned Governorates. The obtained races were used in the identification of pathotype, gene(s) efficacy and probable genes in Egyptian wheat cultivars in 2010/2011 growing season.

Collected rust samples were left at room temperature for 24 hours to minimize the humidity in the samples. After that the samples were preserved in desiccator in fridge till usage.

Host series with known *Lr* genes included the leaf rust survey with observed infection (low or high) were preserved at 15-25°C as shown in Table 1 cited after (Singh, 1991). The source of leaf rust genes (near-isogenic lines NIL's) was the germplasm unit at CIMMYT (International Maize and Wheat Improvement Center), while the local cultivars were kindly supported by Wheat Breading Research Dept. (ARC), Giza, Egypt.

The infected specimens were transferred on either of the susceptible cultivars *i.e.* Morocco, *Triticum Spelta Saharensis*, Giza139 and Thatcher in seedling stage. The method of inoculation was carried out as described by Stakman *et al.* (1962). Seedlings of eight days old were sprayed with tap water and the leaves were gently rubbed between fingers, moistened with water and again sprayed with atomizer within the inocubation chambers. Inoculation was carried out by shaking or brushing rusted materials over the plants and sprayed gently again with water in order to induce "dew" over the plants. Finally, the inoculated plants were kept in damp chambers for 24 hours to allow the rust spore to germinate and cause infection. The plants were transferred and placed on benches in greenhouse and kept for 14 days. After developing the rust cultures, three single pustules were separately isolated from each specimen for reproduction on the highly susceptible leaf rust wheat cultivars to obtain enough urediospores for inoculation, purification, multiplication and scoring infection type according to Mains and Jakson (1926). After twenty one days of sowing, seedlings were prepared for scoring of infection types, that were recorded as either high (IT3-4) or low (IT0-2+) according to Long and Kolmer (1989), Long *et al.* (1998, 2000 and 2002). Race designations were assigned as described by Long and Kolmer (1989) and Statler *et al.* (1982). A four letter code describe the low or high infection type of each isolate to the 16 differential lines, each letter corresponds to the infections types of four differentials as shown in Table 2. The Thatcher lines with genes *Lr1*, *2a*, *2c* and *3* were the four lines in the first set of differentials, lines with genes *Lr9*, *16*, *24* and *26* were the second set of differentials, lines with genes *Lr3ka*, *11*, *17* and *30* conformed the third set of differentials; and lines with genes *Lr10*, *18*, *21* and *2b* conformed the forth set of differentials.

Resistance Gene(s) Postulation

Near-isogenic lines (*Lr's*) known host A and Egyptian wheat cultivars unknown host B both were tested at seedling stage against 56 isolates of *Puccinia triticina* according to the method adopted by Statler (1984) as follows:-

	Host B (unknown)	
	H : H	H : L
Lr(known) Host A		
	L : H	L : L

In such method the absence of L : H or H : L reactions between the tested host B and the known gene host A, indicated the presence of such gene in the tested host exhibiting symbol (-0). On the other hand, when host B proved to have H (High infection type) versus L (Low infection type) in host A this behaviour would indicate the absence of such gene in host B = (-). The presence of L (in host B): H (in host A) indicated the presence of such gene in B and it

Table 1. Host series with known *Lr* genes included in the leaf rust survey with observed seedling infection types (0-4 scale) 18-24°C**

Lr genes	Test line cross	Genome location	Number	Origin of seed resource	Low infection type
1	Tc*6/Centenario	-	RL6003	Malakof	0;
2a	tc*6/Webster	5D	RL6016	Webester	;,;1
2c	Tc*6/Loros	2DS	RL6047	Brivit	;1,2+3
3	Tc*6/Democrat	6BL	RL6002	Democrate	0;,12
9	Transfer/6*Tc	6BL	RL6010	*Triticum umbellutatum*	0;
16	Tc*6/Exchange	2BS	RL6005	Exhange To sr23	1+
24	Tc*6/agent	3DL	RL6064	A-elongatism to sr24	;1-
26	Tc*6/ST1-25	1BL	RL6078	Imperial rye to sr31, YrA	0;,1+
3ka	Tc*6/Aniversario	6BL	RL6007	Klien Aniversario	1,2
11	Hussar	2A	W976	Hussar	$1N^{x}$
17	Klein Lucero/6*Tc	2AS	RL6008	Klien Lucko	0;
30	Tc*6/Terenzio	4BL	RL6049	Terenzio	2,3-
10	Tc*6/Exhange	1AS	RL6004	Lee	;,1-
18	Tc*7/Africa43	5BL	RL6009	*T. timphevi*	2^{x}
21	Tc*6/RL5406	1DL	RL6043	*T. tauchii*	1,2
2b	Tc*6/ ST-1-25	2DS	RL6019	Carina	$;1,1^{+}$
14b	Tc*6/Maria Escobar	7BL	RL6006	Bowie	$;,;1^{+}$
15	Tc*6/Kenya1483	2DS	RL6052	Kenya 1-12E	
35		2B	RL6080	*T. speltoides*	
42		1D		*T. tauschii*	
25	Transec	4AB	RL6084	Rosen rye	0;

0 = no uredia or other macroscopic signs of infection.
; = no uredia, but hypersensitive necrotic or chlorotic flecks of varying size present.
1 = small uredia often surrounded by necrosis.
2 = small to medium uredia often surrounded by chlorosis or necrosis.
3 = medium sized uredia that may associated with chlorosis or rarely necrosis.
X = random distribution of variable-sized on single leaf with a pure culture.
+ = uredia somewhat larger than normal for the infection type.
- = uredia somewhat smaller than normal for the infection type.
C = more chlorosis than normal for infection type.
N = more necrosis than normal for infection type.
x = Tested at 15-18°C because of its temperature sensitive response.
z = No low infection type observed.
4 = large sized uredia.
** = cited after (Singh 1991).

Table 2. Code for the 16 North American differential hosts for *Puccinia triticina* (Pt) in ordered sets of four differential applied for race identification*

Pt Code		Subset	Infection types produced on Near-isogenic lines *Lr's*			
		Host set : 1	*1*	*2a*	*2c*	*3*
		Host set : 2	*9*	*16*	*24*	*26*
		Host set : 3	*3K*	*11*	*17*	*30*
		Host set : 4	*10*	*18*	*21*	*26*
1	B		L	L	L	L
2	C		L	L	L	H
3	D		L	L	H	L
4	F		L	L	H	H
5	G		L	H	L	L
6	H		L	H	L	H
7	J		L	H	H	L
8	K		L	H	H	H
9	L		H	L	L	L
10	M		H	L	L	H
11	N		H	L	H	L
12	P		H	L	H	H
13	Q		H	H	L	L
14	R		H	H	L	H
15	S		H	H	H	L
16	T		H	H	H	H

* Long and Kolmer (1989)

may have another ones (0). The presence of cultures having H:L and L:H in the comparisons indicates that either of the hosts did not have the same genes (+). But may have anothers.

In the diallil comparisons between the tested cultivars the symbols would have quit different indications, since (-0) indicates that both cultivars have the same gene for resistance, (0) indicates that cultivar B carries at least one gene present in cultivar A, (-) indicates that cultivar B may have one gene not present in cultivar A. On the other hand, cultures having (+) indicated that both cultivars may carry gene (s) not present in the other.

RESULTS

Incidence of leaf rust in East-Delta region showed lower severities. On the susceptible wheat cultivars *i.e.* Morocco, *Tiriticum spelta saharensis,* Giza 139 and Giza 163 in late April, rust severity was ranged from 50 to 70S, in the lower leaves of these cultivars. While, the rest of commercial wheat cultivars i.e. Gemmeiza 7, Gemmeiza 10 Beni Sweif 5, 6, Sohag 3, Sakha 8, Sakha 69 and Sakha 93 showed rust severity ranging between 10 and 30S in Damietta and Dakahlya Govearnorates.

Avirulence / virulence formulae (phenotypes)

Thirty three virulence phenotypes of *Puccinia triticina* Eriks. were found in the previously mentioned governorates in 2010/2011 growing season are listed in Table 3. The single uredinial isolates (56 in total) of *Puccinia triticina* derived from twenty two collections made in Wheat Disease Research Department in Giza in 2010/ 2011 were tested for virulence to the Thatcher near-isogenic lines (Table 3). Phenotyes TKTT (25%), PKTT (10.71%), TTTT (7.14%) were the three most common virulent phenotypes in Damietta and Dakahlya Governorates, Egypt.

Virulence frequencies

Frequencies of virulences differed among populations of *P. triticina* in their governorates in 2010/2011 shown in Table 4. Virulence to genes *Lr's i.e. Lr1, 2c, 3, 16, 24, 26, 3ka, 11, 17, 30, 10, 18, 21, 2b, 14b, 15, 35* and *42* was equal or over 75.0%. While, genes *Lr2a* and *Lr9* exhibited the lowest virulence frequency *i.e.* 53.58% and 26.78%, respectively.

Data in Table 5 showed the infection types produced by thirty three pathotypes and their frequency of *P. triticina* (Pt). The letters B through T minus vowels are used for race designation. Pt code consists of the designation for subset 1 followed by that for subset 2 etc. Race TTTT is virulent (high infection type) on all of the 16 differential hosts. Low and high infection type indicate an incompatible and a compatible host-pathogen interaction, respectively.

Date presented in Tables (6, 6A and 6B) revealed the response of 56 pathotypes of *P. triticina* against twenty *Lr's* (leaf rust near-isogenic lines) and seventeen Egyptian wheat cultivars on the basis of Low-infection type (LIT) and High infection type (HIT).

None of the cultures used would attack Sids 13. Thus this cultivar may have an *Lr* gene not represented in the tested *Lr* line set or has combination of *Lr* genes for which the test cultivar has no host pathogenicity combination. So this cultivar was omitted from the analysis and tables.

These data indicated that wheat cultivar Sakha 94 probably has included 18 *Lr's i.e.* 1, 2a, 2c, 3, 16, 24, 26, 3ka, 17, 30, 10, 18, 21, 2b, 14b, 15, 35 and 42. Beni Sweif 6 involved 2 leaf rust resistance genes *i.e.* 3ka and 2b. The rest of cultivars exhibited *Lr's* between them, except cultivars Giza 168, Sids 1 and Beni Sweif 5 that showed the categories (+) or (-) and this indicated that these cultivars and monogenic lines do not carry the same resistance genes or at least the cultivars do not contain the gene in the tested *Lr's* Table (6A).

Data presented in Table (6B) showed that *Lr3* was recorded in the 12 Egyptian wheat cultivars with a frequency of 75.0%, while *Lr2a* was found in the 4 Egyptian wheat cultivars *i.e.* Sakha 94, Gemmeiza 7, Gemmeiza 11 and Sids 12. However, *Lr9* was absent in either of the tested cultivars at least against their pathotypes. These results were established according to the absence of cultures in LIT : HIT or LIT : HIT and HIT : LIT (category 0 or -0). The rest of tested cultivars followed the categories (+) or (-) and this indicated that both (cultivars and monogenic lines) do not carry the same resistance genes or at least the cultivar does not contain the gene in *Lr's*, respectively.

Data in Table 7 revealed the comparisons of wheat cultivars against certain leaf rust pathotypes. These data showed that cv. Sakha 95 and Sakha 94; Gemmeiza 7 and Gemmeiza 11; Gemmeiza 9 and Giza 168; Gemmeiza 10 and both of Sakha 95 and Giza 168; Gemmeiza 11 and each of Sakha 95 and Gemmeiza 7; Sids1 and both of Sakha 93, Gemmeiza 9, Gemmeiza 10, Sids 12, Beni Sweif 4, Beni Sweif 6, Shandwill 1; Sids 12 and Giza 168; Beni Sweif 4 and both of Sakha 94 and Giza 168; Beni Sweif 6 and Sakha 93; Shandwill 1 and Sakha 95; Misr 1 and Sakha 95; Misr 2 and Giza 168, share a common gene.

On the other hand, the reciprocal comparison between tested cultivars demonstrated the presence of common genes shared between the following ones *i.e.* Sakha 93 and each of Sids 1, Beni Sweif 6; Between Sakha 94 and Sakha 95; Between Sakha 95 and Gemmeiza 10, Gemmeiza 11, Beni Sweif 4, Shandwill 1, Misr 1; between Giza 168 and Gemmiza 9, Gemmeiza 10, Sids 12, Beni Sweif 4, Misr 2; Between Gemmeiza 7 and Gemmeiza 11; Between Gemmeiza 9 and Sids 1; Between Gemmeiza 10 ands Sids 1; Between Gemmeiza 11 and Gemmeiza 7; Between Sids 12

Table 3. Avirulence / virulence formulae of *Puccinia triticina* (Pt) leaf rust pathotypes identified in Damietta and Dakahlya Governorates, Egypt in 2010/2011 growing season

No.	No. or isolates frequency	Pathotypes	Avirulence / virulence formulae	Frequency (%)
1	(1)	BBBB	*1,2a,2c,3;9,16,24,26,3ka,11,17,30;10,18,21,2b;/*	1.78
2	(1)	CJTM	*1,2a,2c;9,26;18,21;/*	1.78
3	(1)	CSRS	*1,2a,2c;26;7;26;/*	1.78
4	(1)	CTTT	*1,2a,2c;/*	1.78
5	(1)	FDKD	*1,2a;9,16,26;3ka;10,18,2b;/*	1.78
6	(1)	FDRT	*1,2a;9,16,26;17;/*	1.78
7	(1)	FFLF	*1,2a;9,16;11,17,30;10,18;/*	1.78
8	(1)	FKTR	*1,2a;9;21;/*	1.78
9	(1)	FKTT	*1,2a;9;/*	1.78
10	(1)	KFTT	*1;9,16;/*	1.78
11	(2)	KKTT	*1;9;/*	3.57
12	(2)	KTTT	*1;/*	3.57
13	(1)	MDTT	*2a,2c;9,16,26;/*	1.78
14	(1)	NKRR	*2a,3;9;11;21;/*	1.78
15	(1)	NSKQ	*2a,3;26;3ka;21,26;/*	1.78
16	(1)	PHRT	*2a;9,24;17;/*	1.78
17	(1)	PJRT	*2a;9,26;17;/*	1.78
18	(1)	PKST	*2a;9;30;/*	1.78
19	(1)	PKTR	*2a;9;21;/*	1.78
20	(1)	PKTS	*2a;9;2b;/*	1.78
21	(6)	PKTT	*2a;9;/*	10.71
22	(1)	PSTR	*2a;26;21;/*	1.78
23	(1)	PTPK	*2a;11;10;/*	1.78
24	(1)	PTTT	*2a; /*	1.78
25	(1)	TKJS	*9;3ka,30;2b;/*	1.78
26	(1)	TKPT	*9;11;/*	1.78
27	(1)	TKST	*9;30;/*	1.78
28	(1)	TKTM	*9;18,21;/*	1.78
29	(1)	TKTS	*9;2b;/*	1.78
30	(14)	TKTT	*9;/*	25.0
31	(1)	TTTF	*10,18;/*	1.78
32	(1)	TTTS	*26;/*	1.78
33	(4)	TTTT	*-/*	7.14
Total	56	33		

Table 4. Percentage virulence frequency of wheat leaf rust (*Puccinia triticina*) isolates and *Lr's* genes efficacy (%) during 2010/2011 growing season

No.	*Lr's*	No. of		Total number of isolates	Virulence frequency (%)	Avirulence frequency (%)
		Avirulent isolates	Virulent isolates			
1	*1*	42	14	56	75.00	25.00
2	*2a*	30	26	56	53.58	46.42**
3	*2c*	51	05	56	91.1*	8.90
4	*3*	53	03	56	94.66*	5.34
5	*9*	15	41	56	26.78	73.22**
6	*16*	50	06	56	89.32	10.68
7	*24*	54	02	56	96.44*	3.56
8	*26*	46	10	56	82.2	17.8
9	*3ka*	52	04	56	92.88*	7.12
10	*11*	51	05	56	91.10*	8.90
11	*17*	50	06	56	89.32	10.68
12	*30*	51	05	56	91.10*	8.90
13	*10*	51	05	56	91.10*	8.90
14	*18*	50	06	56	89.32	10.68
15	*21*	48	08	56	85.76	14.24
16	*2b*	48	08	56	85.76	14.24
17	*14b*	52	04	56	92.88*	7.12
18	*15*	48	08	56	85.76	17.24
19	*35*	47	09	56	83.98	16.02
20	*42*	49	07	56	87.54	12.46

** high efficacy gene

* low efficacy gene

Table 5. Infection types produced by 33 pathotypes and percentage frequency of *Puccinia triticina* (Pt) isolated from Dakahlya and Damietta Governorates, Egypt, against leaf rust resistance genes and differential sets samples under greenhouse conditions at seedling stage during 2010/2011 growing season

No.	Pathotype	Infection type produced by 33 pathotypes on 16 near-isogenic lines (NIL)																Frequency (%)
		1	2a	2c	3	9	16	24	26	3ka	11	17	30	10	18	21	26	
1	BBBB (1)	L*	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	1.78
2	CJTM (1)	L	L	L	**	L			L		L	L						1.78
3	CSRS (1)	L	L	L					L			L					L	1.78
4	CTTT (1)	L	L	L														1.78
5	FDKD (1)	L	L			L	L		L	L				L	L		L	1.78
6	FDRT (1)	L	L			L	L					L						1.78
7	FFLF (1)	L	L			L	L				L	L	L	L	L			1.78
8	FKTR (1)	L	L			L									L			1.78
9	FKTT (1)	L	L			L												1.78
10	KFTT (1)	L				L	L											1.78
11	KKTT (2)	L				L												3.57
12	KTTT (2)	L																3.57
13	MDTT (1)		L	L		L	L		L									1.78
14	NKRR (1)		L		L	L					L					L		1.78
15	NSKQ (1)		L		L				L	L						L	L	1.78
16	PHRT (1)		L			L		L				L						1.78
17	PJRT (1)		L			L			L			L						1.78
18	PKST (1)		L			L							L					1.78
19	PKTR (1)		L			L									L			1.78
20	PKTS (1)		L			L											L	1.78
21	PKTT (6)		L			L												10.71
22	PSTR (1)		L						L							L		1.78
23	PTPK (1)		L								L			L				1.78
24	PTTT (1)		L															1.78
25	TKJS (1)					L				L			L				L	1.78
26	TKPT (1)					L					L							1.78
27	TKST (1)					L							L					1.78
28	TKTM (1)					L									L	L		1.78
29	TKTS (1)					L											L	1.78
30	TKTT (14)					L												25.0
31	TTTF (1)													L	L			1.78
32	TTTS (1)																L	1.78
33	TTTT (4)																	7.14
Total		(56) isolates																

* L = low infection type ** (blank) H = High infection type

Lr's = leaf rust resistance gene

Number of isolates = 56= (33 pathotypes)

Table 6. Matching between 20 monogenic lines of leaf rust (*LR's*) and 16 Egyptian wheat cultivars against 56 isolates of *Puccinia triticina* Eriks. at seedling stage in 2010/2011 growing season

No.	Egyptian wheat cultivars	*Lr* genes																			
		1	*2a*	*2c*	*3*	*9*	*16*	*24*	*26*	*3ka*	*11*	*17*	*30*	*10*	*18*	*21*	*26*	*14b*	*15*	*35*	*42*
1	Sakha 93	0	+	0	0	+	0	+	0	0	0	+	0	0	+	+	0	0	+	0	+
2	Sakha 94	0	0	0	0	+	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0
3	Sakha 95	+	+	+	0	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+
4	Giza 168	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	Gemmeiza 7	0	0	0	0	+	0	0	0	0	0	0	0	+	+	0	0	+	0	0	0
6	Gemmeiza 9	0	+	+	0	+	+	0	+	+	0	0	+	0	0	0	+	+	+	0	0
7	Gemmeiza 10	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Gemmeiza 11	0	0	0	0	+	0	0	0	0	0	0	0	+	+	0	0	+	0	0	0
9	Sids 1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10	Sids 12	0	0	0	0	+	0	0	0	+	0	0	+	0	0	0	+	0	0	0	0
11	Beni Sweif 4	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Beni Sweif 5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13	Beni Sweif 6	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+	0	+	+	+	+
14	Shandwill 1	0	+	0	0	+	0	+	0	0	0	+	+	0	0	0	0	0	+	0	0
15	Misr 1	0	+	0	0	+	0	+	0	0	0	+	0	0	0	0	0	0	+	0	0
16	Misr 2	+	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Lr's = leaf rust resistance genes

Table 6A. Postulated resistance genes for leaf rust monogenic lines in 16 Egyptian wheat cultivars at seedling stage in 2010/2011 growing season

No.	Egyptian wheat cultivars	Postulate *Lr's** genes in wheat cultivars	Genes No.
1	Sakha 93	*1,2c,3,16,26,3ka,11,30,10,2b,14b* and *35*	12
2	Sakha 94	*1,2a,2c,3,16,24,26,3ka,17,30,10,18,21,2b,14b,15,35* and *42*	18
3	Sakha 95	*3* and *3ka*	2
4	Giza 168	-	-
5	Gemmeiza 7	*1,2a,2c,3,16,24,26,3ka,11,17,30,21,2b,15,35* and *42*	16
6	Gemmeiza 9	*1,3,24,11,17,10,18,21,35* and *42*	10
7	Gemmeiza 10	*1,2c,3,9,24,26,3ka,11,17,30,10,18,21,2b,14b,15,35* and *42*	18
8	Gemmeiza 11	*1,2a,2c,3,16,24,26,3ka,11,17,30,21,2b,15,35* and *42*	16
9	Sids 1	-	-
10	Sids 12	*1,2a,2c,3,16,24,26,11,17,10,18,21,14b,15,35* and *42*	16
11	Beni Sweif 4	*1,2c,3,16,24,26,3ka,11,17,30,10,18,21,2b,14b,15,35* and *42*	18
12	Beni Sweif 5	-	-
13	Beni Sweif 6	*3ka* and *2b*	2
14	Shandwill 1	*1,2c,3,16,26,3ka,11,10,18,21,2b,14b,35* and *42*	14
15	Misr 1	*1,2c,3,16,26,3ka,11,30,10,18,21,2b,14b,35* and *42*	15
16	Misr 2	*2c,3,16,24,26,3ka,11,17,30,10,18,21,2b,14b,15,35* and *42*	17

* *Lr's* = Leaf rust resistance genes

Table 6B. The frequency of identified leaf rust resistance genes (*Lr's) within 16 Egyptian wheat varieties at seedling stage in 2010/2011 growing season**

No.	*Lr's* genes	No. of varieties carrying *Lr* genes	Frequency %
1	*1*	10	62.5
2	*2a*	4	25.0
3	*2c*	10	62.5
4	*3*	12	75.0
5	*9*	-	-
6	*16*	9	56.25
7	*24*	8	50.0
8	*26*	10	62.5
9	*3ka*	11	68.75
10	*11*	10	62.5
11	*17*	8	50.0
12	*30*	8	50.0
13	*10*	9	56.25
14	*18*	8	50.0
15	*21*	10	62.5
16	*2b*	10	62.5
17	*14b*	8	50.0
18	*15*	7	43.75
19	*35*	11	58.75
20	*42*	10	62.5

* *Lr's* = Leaf rust resistance genes

Table 7. Comparison of 16 Egyptian wheat cultivars inoculated with 56 isolates of *Puccinia triticina* on the basis of (LIT : HIT)* involved in the tested wheat cultivars in 2010/2011 growing season

Egyptian wheat cultivars	Sakha 93	Sakha 94	Sakha 95	Giza 168	Gemmeiza 7	Gemmeiza 9	Gemmeiza 10	Gemmeiza 11	Sids 1	Sids 12	Beni Sweif 4	Beni Sweif 5	Beni Sweif 6	Shandwill 1	Misr 1	Misr 2
Sakha 93		+	+	+	+	+	+	+	-	+	+	+	-	+	+	+
Sakha 94	+		-	+	+	+	+	+	+	+	+	+	+	+	+	+
Sakha 95	+	0		+	+	+	-	-	+	+	-	+	+	-	-	+
Giza 168	+	+	+		+	-	-	+	+	-	-	+	+	+	+	-
Gemmeiza 7	+	+	+	+		+	+	-0	+	+	+	+	+	+	+	+
Gemmeiza 9	+	+	+	0	+		+	+	-	+	+	+	+	+	+	+
Gemmeiza 10	+	+	0	0	+	+		+	-	+	+	+	+	+	+	+
Gemmeiza 11	+	+	0	+	-0	+	+		+	+	+	+	+	+	+	+
Sids 1	0	+	+	+	+	0	0	+		0	0	+	0	0	+	+
Sids 12	+	+	+	0	+	+	+	+	-		+	+	+	+	+	+
Beni Sweif 4	+	+	0	0	+	+	+	+	-	+		+	+	+	+	+
Beni Sweif 5	+	+	+	+	+	+	+	+	+	+	+		+	-	+	+
Beni Sweif 6	0	+	+	+	+	+	+	+	-	+	+	+		+	+	+
Shandwill 1	+	+	0	+	+	+	+	+	-	+	+	0	+		+	+
Misr 1	+	+	0	+	+	+	+	+	+	+	+	+	+	+		+
Misr 2	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	

* (LIT: HIT): Low infection types : High infection type

and Sids 1; Between Beni Sweif 4 and Sids 1; Between Beni Sweif 5 and Shandwill 1; Between Beni Sweif 6 and Sids 1; and Between Shandwill 1 and Sids 1, respectively.

The presence of the symbol (+) indicates that both compared cultivars did not contain the same leaf rust resistance genes. While, the presence of (-) indicates that either of the tested cultivars differed at least in one gene for resistance.

DISCUSSION

Wheat (*Triticum aestivum* L.) is one of the most important food crops in the world. No doubt wheat rusts are one of the major limiting factors of wheat mass production. Leaf rust disease incited by (*Puccinia triticina* Eriks.) is a prevalent disease in Egypt and is the subject of the present work.

The obtained results gave evidence to the presence of thirty three virulence formulae originated from fifty six leaf rust isolates. Similar results were reported by Nazim *et al.* (1983); Najeeb *et al.* (2005); Youssef (2006); Youssef *et al.* (2010 and 2011). The existence of such virulence formula reflects the variability and the dynamic genetic nature of the causative agent of leaf rust and its response to the changing environmental conditions Long *et al.* (2000) and McCallum and Seto-Gah (2006). The widespread use of wheat cultivars in the United States with genes that are effective in seedlings and that condition resistance to specific leaf rust phenotypes has led to the development of *P. triticina* population that is highly diverse for virulence. Cultivars with single specific genes for leaf rust resistance quickly selected for virulent leaf rust phenotypes (Kolmer *et al.*, 2009; Long *et al.*, 2000 and McCallum and Seto-Goh, 2006).

Concerning the effective genes of leaf rust (*Lr's*), the obtained results indicated that *Lr9* was considered the most effective gene followed by *Lr2a*. These results indicated that our cultivars lacked *Lr9*. Similar results were recorded by (Imbaby and Ageez, 1998; Shereif, 2002; Shereif *et al.*, 1996; Wamishe and Milus, 2004 and Najeeb *et al.*, 2005) who demonstrated that *Lr9* recorded high efficacy in Egyptian wheat cultivars.

As regard to the postulated leaf rust resistance genes which where identified within 16 local cultivars revealed the probability of presence of 19 out of 20 resistance genes. *Lr3* was represented in ca (75.0%), followed by *Lr3ka* and *Lr35* (68.75%). On the other hand, *Lr9* was not represented in the comprised within the tested cultivars. The rest of cultivars lied in between. These results are not considered an indication to the lack of the other tested cultivars from resistance genes, but they may have genes other than these tested (category +). The second probability is the presence of such genes in the tested cultivars but the existence of suppressors or modifiers prevented their expression (Knott, 1989).

Concerning the matching between the tested commercial wheat cultivars in all possible combination. The present results indicated that the cultivar Gemmeiza 11 may exhibit common gene with the cultivar Gemmeiza 7 symbol (-0), and probably has another common gene with the cultivar Sakha 95 symbol (0). Gemmeiza 10 probably has at least one gene for leaf rust resistance found in either of Sakha 95, Giza 168 and Sids 1 (0). Shandwill 1 likely involved at least one gene present in Sakha 95, Sids 1 and Beni Sweif 5 symbol (0). Sakha 94 probably carried one gene found in the cultivar Sakha 95. The cultivar Giza 168 probably carried at least one gene present in Gemmeiza 9, Gemmeiza 10, Sids 12, Beni Sweif 4 and Misr 2

The widespread use of wheat cultivars in the U.S with genes that are effective in seedling and that condition resistance to specific leaf rust phenotypic has led to the development of *P. triticina* populations that is highly diverse for virulence. Cultivars with single specific genes for leaf rust resistance were quickly selected for virulence leaf rust. Certain combinations of seedling resistance genes may condition high levels of resistance in widely grown wheat cultivars for a limited time. Given the large population size of *P. triticina* in the U.S and effects of mutations, it would be expected that isolates with combinations of virulence to the resistance genes would eventually appear. Wheat cultivars with combinations of genes that confer nonspecific resistance such as *Lr34* and possibly *Lr46* (Zhang *et al.*, 2008). Combined with seedling genes such as *Lr16* and *Lr23*

(Kolmer and Oelke 2006 and Oelke and Kolmer 2005) have displayed highly effective levels of durable resistance in spring wheat.

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حصر العدوانية فى بعض سلالات صدأ الأوراق البنى لفطر *Puccinia triticina* والجينات المتوقعة فى ١٧ صنف من الأقماح المصرية

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جمعت عينات من أوراق القمح المصابة بصدأ الأوراق ومن حقول القمح التجارية وحقل مصايد الأصداء فى منطقة شرق الدلتا فى مصر لكى تقدر العدوانية فى فطر صدأ أوراق القمح موسم ٢٠١٠/٢٠١١. اختبرت ٥٦ عزلة من البثرات الفردية مشتقة من ٢٢ عينة صدأ الأوراق من أجل الشكل المظهرى العدوانى فى مرحلة البادرة على سلالات أحادية الجين من قمح Thatcher من أجل تعريف جينات المقاومة لصدأ الأوراق *Lr1*, *Lr2a*, *Lr2c*, *Lr3*; *Lr9*, *Lr16*, *Lr24*, *Lr26*; *Lr3ka*, *Lr11*, *Lr17*, *Lr30*; *Lr10*, *Lr18*, *Lr21*, *Lr2b*; *Lr14b*, *Lr15*, *Lr35* and *Lr42* فى محافظتى الدقهلية ودمياط ٢٠١٠/٢٠١١، يلاحظ أن هناك ٣٣ صيغة عدوانية. الشكل المظهرى العدوانى TKTT يسبب عدوانية لكل جينات المقاومة بإستثناء *Lr9* فقط وهو أول الأشكال العدوانية الأكثر إنتشارا. PKTT يظهر العدوانية لكل جينات المقاومة باستثناء *Lr9* and *Lr2a* حيث كان هو الشكل المظهرى الثانى الأكثر إنتشارا. TTTT الشكل المظهرى الثالث الأكثر إنتشارا. على الجانب الآخر الجينات المقاومة لصدأ الأوراق- *Lr2a* and *Lr9*(73.22%) (46.42%) إمتلكت أعلى كفاءة عن باقى جينات المقاومة لصدأ الأوراق ، مع ذلك جميزة ١٠، بنى سويف ٤ ، سخا٩٤ يفترض إمتلاكهم ١٨ جين بينما جيزة ١٦٨ وسيدس ١ وبنى سويف ٥ إحتمال خالى من أى جين على الأقل ضد تلك العزلات فى هذه الدراسة. الشكل المظهرى العدوانى والغير عدوانى لجينات المقاومة لصدأ الورقة فى السلالات المفرقة تزداد فى منطقة شرق الدلتا فى ٢٠١٠/٢٠١١. الاختلافات المتعددة فى عشيرة *Puccinia triticina* فى هذه المنطقة سوف تستمر لوجود التحدى الواضح من تكشف أصناف قمح بها مقاومة متينة ذات كفاءة عالية.