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ASSESSMENT OF GRAIN YIELD LOSSES CAUSED BY *PUCCINIA TRITICINA* IN SOME EGYPTIAN WHEAT GENOTYPES

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ABSTRACT: *Leaf rust caused by Puccinia triticina, is an important disease of wheat in Egypt and worldwide. Twelve wheat genotypes were tested for adult plant resistance and estimated for yield losses due to leaf rust under field conditions at Shibin El-Kom location during 2013/14 and 2014/15 growing seasons. The field experiment was surrounded by spreader area of highly susceptible varieties inoculated with a mixture of leaf rust pathotypes as a source of inoculum. Disease severity was recorded each ten days and area under disease progress curve (AUDPC) was calculated. Final leaf rust severity (%) ranged from Tr MR to 80 S in 2013/14 growing season, while in 2014/15 ranged from Tr MR to 70 S. The yield losses in plot weight ranged from 0.52 % on wheat genotype Sids 13 to 17.58 % on Sakha 93 during 2013/14 growing season. While, in 2014/15 it ranged from 0.48 % on the wheat genotype Sids 13 to 19.56 % on the wheat genotype Sakha 93. Moreover, the yield losses of the other tested genotypes were depends on the values of leaf rust severity for each genotype. The yield losses in 1000 kernel and plot weight were correlated strongly with area under disease progress curve.*

Key words: *Wheat, leaf rust, adult plant resistance, yield losses.*

INTRODUCTION

Leaf rust caused by *Puccinia triticina* Eriks., is one of the most important and widespread diseases of common wheat (*Triticum aestivum* L.) in Egypt and worldwide. It is adapted to a wide range of environments, occurs wherever wheat is grown and can cause significant yield losses (Wamishe and Milus, 2004).

Huge losses in wheat yield are attributed to attacks of diseases out of which rusts especially leaf rust has caused significant yield losses in recent years. Leaf rust causes considerable annual yield loss on the susceptible wheat cultivars particularly when infection occurs at early stage of plant growth under suitable environmental conditions for disease incidence and development (Nazim *et al.*, 1983; Kolmer, 1996 and Nazim *et al.*, 2010). Breeding for rust resistance takes a major concern to produce new varieties with a stable, long lasting and durable resistance to rust pathogens over a wide range of environments. A wheat variety that has been resistant in the past may not remain resistant to new races of rust (Brian, 2006). In Egypt, some of the resistant varieties were discarded very shortly after their release and widely cultivation due to the rapidly loss of their field resistance to leaf rust, although they were resistant at the time of release e.g. Giza 139, Mexican varieties, Chenap 70, Super X and Mexipak 69. In contrast, the other locally produced wheat varieties served in agriculture for fairly long periods of time showing high field resistance (Boulot, 2007). Several authors have described the effects of leaf rust infection on yield i.e. Herrera-Foessel *et al.* (2006) found that yield losses for susceptible, race-specific, and slow-rusting genotypes in durum wheat were 51, 5, and 26%, respectively. Moreover, yield losses were associated mainly with a reduction in biomass, harvest index, and kernels per square meter. Ashmawy (2014) found that the Egyptian wheat varieties Sakha 93, Gemmeiza 7 and Sids 1 showed the highest levels of disease severity and AUDPC which gave the highest yield losses. While, the wheat varieties Misr 2, Giza 168, Gemmeiza 11 and Sakha 94 gave low levels of yield losses.

It is important to evaluate commercial cultivars and other improved wheat varieties that may have the potential to replace current susceptible varieties (Pretorius *et al.*, 2007). Few or little information were available for the expression and yield losses of the local wheat varieties commonly grown in Egypt. The objective of this study was to determine the expression and level of adult plant resistance to leaf rust in 12 Egyptian wheat genotypes under field conditions. Also to estimate yield losses on the tested genotypes when exposed to high leaf rust pressure.

MATERIALS AND METHODS

To determined wheat yield losses caused by leaf rust, the present investigations were carried out at the farm of Faculty of Agriculture, Minufiya University, Shibin El-Kom during two successive growing seasons i.e. 2013/14 and 2014/15. Wheat seeds of 12 wheat genotypes i.e. Giza 168, Sakha 94, Gemmeiza 7, Gemmeiza 9, Gemmeiza 10, Gemmeiza 11, Sids 1, Sids 12, Sids 13, Misr 1, Misr 2 and Sakha 93 (as check variety) were grown in a randomized complete block design (RCBD) with three replicates. Each of the tested genotypes was grown in plot, the plot size was 6 × 7 m = 42 m^2, each plot contained 20 rows with 7 m long and 30 cm between rows. The experiment was planted 15 days after the regular sowing date (the first half of December) to expose the plants to suitable environment of leaf rust incidence and development. The plots were surrounded by spreader area planted with a mixture of highly susceptible wheat genotypes to leaf rust i.e. Morocco and Thatcher to spread inoculum.

Inoculation and disease assessment:

Artificial inoculation was carried out using a mixture of leaf rust races and talcum powder at a ratio of 1:20 (v/v) according to Tervet and Cassel (1951). To maintain crop stand and vigor normal agronomic practices including recommended fertilization dose and irrigation schedule were followed. To keep protected plots free from leaf rust, the fungicide Sumi-eight 5 EC (CE) -1- (2,4 -Dichlaro phenyl) (35 cm /100 litter water) was applied on 10 and 26 February and 8 March.

Leaf rust severity (%) and reaction were determined in all of the tested genotypes every ten days intervals from rust appearance along with the stages of plant growth using the modified Cobb·s scale (Peterson *et al.*, 1948) and the host response scale described by Roelfs *et al.* (1992), respectively.

The area under disease progress curve (AUDPC) was calculated for each genotype according to the equation adopted by Pandy *et al.* (1989).

$$AUDPC = D\,[1/2\,(Y_1 + Y_k) + (Y_2 + Y_3 + --- + Y_{k-1})]$$

Where:

D = days between two consecutive records (time intervals)

$Y_1 + Y_k$ = Sum of the first and last disease records.

$Y_2 + Y_3 + ----- + Y_{k-1}$ = Sum of all in between disease scores.

At the time of maturity the crop was harvested and yield of each plot of 42 m^2 was weighed by conventional balance. The influence of leaf rust severities on yield was determined by comparing the yield of diseased and healthy plots. Yield loss was estimated using the simple equation as follows:-

Loss % = 1-yd/yh X 100 (Colpauzos *et al.*, 1976)

Where: yd = yield of diseased plants

yh = yield of healthy plants

Yield assessment:

Randomly selected thousand kernels from each genotype were counted with a seed counter and were weighed with an electronic balance to calculate 1000-kernel weight. The grain weight from the threshed spikes was measured entire harvested plots was weighed with an electronic balance to calculate grain yield per plot for each genotype.

Statistical analysis:

Least significant differences (L.S.D. at 5%) was used to compare yield components according to (Snedecor, 1957), correlation coefficient was used to detect the relationship between yield loss and AUDPC.

RESULTS AND DISCUSSION

Reaction of commercial wheat genotypes to leaf rust infection:-

The reaction of the commercial wheat genotypes to leaf rust infection at adult plant stage under field conditions is shown in Table (1). The fungicide-protected plots remained almost free from leaf rust during the two growing seasons of this study (2013/14 and 2014/15).

Table 1: Final leaf rust severity (%) and area under disease progress curve (AUDPC) of leaf rust in 12 wheat genotypes under field conditions at Shibin El-Kom location during 2013/14 and 2014/15 growing seasons.

Genotype	2013/14		2014/15	
	Final rust severity (%)	AUDPC	Final rust severity (%)	AUDPC
Giza 168	20 S	157.50	10 S	80.50
Sakha 94	10 S	80.50	5 S	49.00
Gemmeiza 7	60 S	560.00	70 S	805.00
Gemmeiza 9	20 S	157.50	20 S	157.50
Gemmeiza 10	10 S	80.50	5 S	49.00
Gemmeiza 11	30 S	280.00	20 S	157.50
Sids 1	80 S	840.00	70 S	805.00
Sids 12	5 MR	49.00	Tr MR	42.00
Sids 13	Tr MR	42.00	Tr MR	42.00
Misr 1	10 S	80.50	5 S	49.00
Misr 2	5 MR	49.00	5 MR	49.00
Sakha 93 (check)	60 S	560.00	70 S	805.00
L.S.D. at 5 %		**55.921**		**44.332**

During 2013/14 growing season, all of the tested wheat genotypes showed different final rust severity ranged from Tr MR to 80 S. The wheat genotypes Sids 13, Sids 12 and Misr 2 showed the least disease severity i.e. Tr MR, 5 MR and 5 MR, respectively. While, the rest of the tested genotypes exhibited rust severity ranged from 10% to 80%.

In 2014/15 growing season, also the wheat genotypes Sids 12, Sids 13 and Misr 2 showed the least disease severity i.e. Tr MR, Tr MR and 5 MR, respectively. While, the wheat genotypes Sakha 93, Gemmeiza 7 and Sids 1 showed the highest rust severity ranged (each with 70 %). Gamalat Hermas (2014) found that during 2010/11, 2011/12 and 2012/13 growing seasons the wheat genotypes Misr 1, Misr 2 and Giza 168 showed high levels of adult plant resistance to leaf rust. These genotypes exhibited low percentage of rust severity and low values of AUDPC. In contrast, Sids 1 and Morocco exhibited high rust severity percentages and high AUDPC values.

Area under disease progress curve (AUDPC):-

Data in Table (1) indicated that AUDPC run in a parallel line with disease severity. In 2013/14 growing season, the results obtained showed that the highest values of AUDPC were observed on the wheat genotypes Sids 1, Sakha 93 and Gemmeiza 7 i.e. 840, 560 and 560, respectively. Whereas, the wheat genotypes Sids 13, Sids 12 and Misr 1 exhibited low values of AUDPC i.e. 42, 49 and 49, respectively.

In 2014/15 growing season, data in Table (1) indicated that Sakha 93, Gemmeiza 7 and Sids 1 showed the highest values of AUDPC (each with 805). While, Sids 12, Sids 13 Sakha 94, Gemmeiza 10, Misr 1 and Misr 2 showed lower values of AUDPC i.e. 42, 42, 49, 49, 49 and 49, respectively.

According to these results in seasons 2013/14 and 2014/15, the tested genotypes could be classified into three main groups on the basis of FRS (%) and AUDPC values. The first group included the wheat varieties with race-specific resistance or complete resistance which displayed resistant infection type and the lowest values of FRS (%) and AUDPC. This group included the wheat varieties Sids 12, Sids 13 and Misr 2.

The second group included the wheat genotypes which displayed susceptible infection type and low values of FRS (%) and AUDPC (less than 300). Therefore, they were characterized as slow rusting varieties or partially resistant varieties. This group included the wheat genotypes Giza 168, Sakha 94, Gemmeiza 9, Gemmeiza 10 and Gemmeiza 11.

The third group included the wheat varieties which revealed the highest values of FRS (%) and AUDPC (more than 300) and were identified as the fast-rusting genotypes. This group included the wheat varieties Sakha 93, Gemmeiza 7 and Sids 1.

Wang *et al.*, (2005) found that AUDPC is a good indicator of adult plant resistance under field conditions. Cultivars which had low AUDPC and terminal severity values thus may have good level of adult plant resistance.

Lal Ahamed *et al.* (2004) found that the wheat cultivar Agra Local showed the highest value of AUDPC (1300), the wheat cultivar Kundan showed least AUDPC value (217). While the wheat cultivars Trap (317), Galvez-78 (344), Mango (412), Chris (504) and PBW-348 (737). Khan *et al.* (1997) reported that the wheat cultivars Chenab 70, WL 711, Pak. 81 were fast rusting cultivars, while the cultivars Pavon, FSD and INQ-91 were slow rusting cultivars. Shahin and El-Orabey (2015) found that the wheat varieties Giza 168 and Gemmeiza 7 showed partial resistance which they showed lowest values of FRS (%) and AUDPC (not more than 250).

Grain yield and yield losses:-

Data in Tables (2 and 3) revealed that 1000 kernel weight and grain yield per plot differences between protected and infected wheat genotypes were due to the differences in disease severity level of leaf rust. In 2013/14, the loss % of the 1000 kernel weight ranged from 0.65 % to 15.07 %. The wheat genotypes Gemmeiza 7, Sakha 93, Gemmeiza 11 and Sids 1 gave the highest values of loss (%) of 1000 kernel weight (15.07, 14.30, 8.10 and 8.01 %, respectively) compared to the other tested genotypes.

In 2014/15, the loss % in the 1000 kernel weight ranged from 0.67 % to 15.73 %. The wheat genotypes Sakha 93, Gemmeiza 7, Sids 1 and Gemmeiza 9 gave the highest values of loss % of the 1000 kernel weight (15.73 %, 15.49 %, 6.77 % and 6.34 %, respectively) followed by Gemmeiza 11, Gemmeiza 10, Sakha 94, Giza 168, Misr 1, Misr 2, Sids 12 and Sids 13.

The loss % of yield per plot in 2013/14 ranged from 0.52 % to 17.58 %. The wheat genotypes Sakha 93, Gemmeiza 7, Gemmeiza 11 and Sids 1 showed the highest values of loss % of yield per plot (17.58, 16.91, 9.65 and 8.90 %, respectively) compared to the other genotypes.

In 2014/15, the loss % of yield per plot ranged from 0.48 % to 19.56 %. The wheat genotypes Sakha 93, Gemmeiza 7, Gemmeiza 11, Sids 1 and Gemmeiza 9 gave the highest values of loss % of yield per plot (19.56, 18.11, 8.75, 8.39 and 8.09%, respectively). While, the wheat genotypes Sids 13, Sids 12, and Misr 2 showed the lowest values of loss % of yield per plot. Although the wheat genotype Sids 1 has high rust severity the yield loss did no exceed 9% this mainly due to this genotype is tolerant. Ashmawy (2014) found that Sids 1 was tolerant since it showed lower value of yield loss during 2011/12 and 2012/13 growing season.

Table 2: Effect of leaf rust severity on 1000-kernel weight (g) and plot weight (kg) of 12 wheat genotypes at Shibin El-Kom location during 2013/14 growing season.

Genotype	1000-kernel weight (g)			Plot weight (kg)		
	Infected	Protected	Loss (%)	Infected	Protected	Loss (%)
Giza 168	35.16	36.56	3.83	21.33	22.62	5.70
Sakha 94	33.77	34.59	2.37	20.72	21.27	2.59
Gemmeiza 7	29.76	35.04	15.07	15.38	18.51	16.91
Gemmeiza 9	34.51	37.08	6.93	20.16	21.83	7.65
Gemmeiza 10	29.92	31.56	5.20	21.91	22.82	3.99
Gemmeiza 11	40.18	43.72	8.10	21.44	23.73	9.65
Sids 1	29.41	31.97	8.01	18.33	20.12	8.90
Sids 12	39.24	39.56	0.81	19.98	20.09	0.55
Sids 13	39.49	39.68	0.48	22.78	22.9	0.52
Misr 1	40.04	40.58	1.33	22.13	22.46	1.47
Misr 2	41.41	41.68	0.65	22.64	22.81	0.75
Sakha 93 (check)	29.24	34.12	14.30	15.61	18.94	17.58
L.S.D. at 5 %	**0.182**	**0.246**		**1.477**	**0.928**	

Table 3: Effect of leaf rust severity on 1000-kernel weight (g) and plot weight (kg) of 12 wheat genotypes at Shibin El-Kom location during 2014/15 growing season.

Genotype	1000-kernel weight (g)			Plot weight (kg)		
	Infected	Protected	Loss (%)	Infected	Protected	Loss (%)
Giza 168	35.94	37.16	3.28	22.08	23.21	4.87
Sakha 94	34.45	35.32	2.46	20.58	20.98	1.91
Gemmeiza 7	28.04	33.18	15.49	16.19	19.77	18.11
Gemmeiza 9	32.37	34.56	6.34	20.44	22.24	8.09
Gemmeiza 10	30.24	31.68	4.55	22.47	23.35	3.77
Gemmeiza 11	37.96	40.12	5.38	22.11	24.23	8.75
Sids 1	30.84	33.08	6.77	18.24	19.91	8.39
Sids 12	36.57	36.82	0.68	21.31	21.47	0.75
Sids 13	38.65	38.91	0.67	22.99	23.1	0.48
Misr 1	39.22	39.88	1.65	22.71	22.99	1.22
Misr 2	39.61	39.93	0.80	21.77	21.96	0.87
Sakha 93 (check)	24.81	29.44	15.73	15.79	19.63	19.56
L.S.D. at 5 %	**0.213**	**0.227**		**1.351**	**0.849**	

Association between AUDPC with loss in the 1000 kernel weight and loss in plot weight:

The association of 1000 kernel weight and loss in plot weight with AUDPC was assessed through regression analysis during 2013/14 and 2014/15 growing seasons. Positive relation between AUDPC and loss in 1000 kernel weight during the two growing seasons (R^2 = 0.607 and 0.608) (Fig. 1). Also, regression analysis revealed a significant linear relationship (R^2 = 0.758 and 0.744) between loss in plot weight and AUDPC. This trend is in a harmony with losses reported in previous studies obtained by (Wanyera *et al.*, 2009 and Loughman *et al.*, 2005) Ochoa and Parlevliet (2007) reported that yield loss was correlated strongly with area under disease progress curve, which means that high levels of partial resistance are needed to prevent significant yield loss. On overall basis cultivars with maximum disease severity had lower mean grain yield and vice versa (Shaner *et al.*, 1978). Ochoa and Parlevliet (2007) reported that yield loss was correlated strongly with AUDPC. El-Shamy *et al.* (2011) found that a significant correlation between mean disease severity and percentage loss for 1000-kernel and grain yield/plant.

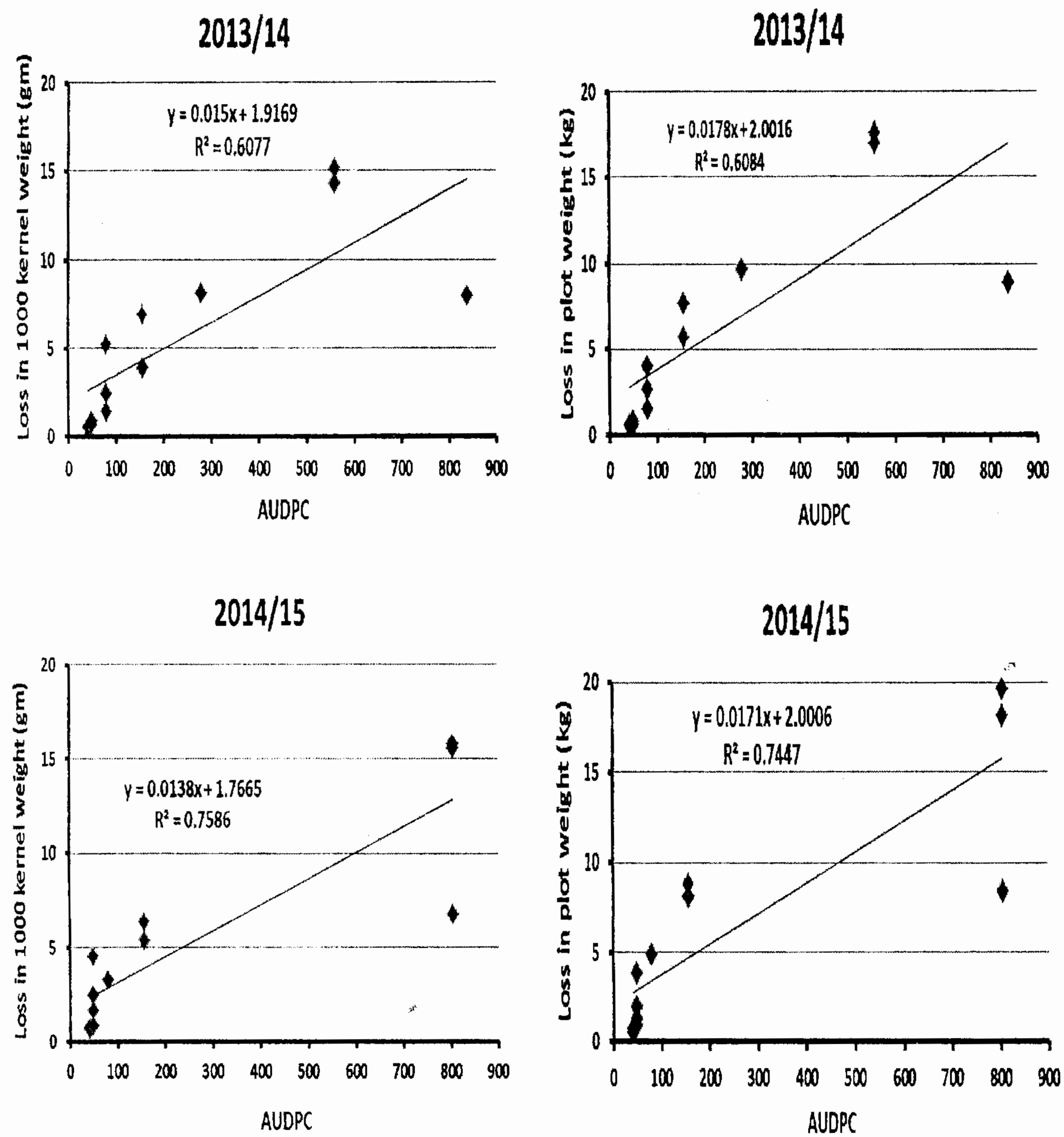

Fig. 1: Association between AUDPC with loss in 1000.kernel weight and plot weight for 12 Egyptian wheat genotypes tested during 2013/14 and 2014/15 growing seasons.

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تقدير الفاقد فى محصول الحبوب المتسبب عن الفطر بكسينيا تريتسينا فى بعض تراكيب القمح الوراثية المصرية

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الملخص العربى

يعتبر صدأ الأوراق فى القمح المتسبب عن الإصابة بالفطر بكسينيا تريتسينا مرض مهم فى مصر ومعظم دول العالم. تم إختبار ١٢ تركيب وراثى من القمح وتقدير الفاقد فى المحصول نتيجة الإصابة بمرض صدأ الأوراق تحت ظروف الحقل فى موقع شبين الكوم خلال المواسم الزراعية ٢٠١٣/١٤ و ٢٠١٤/١٥. التجربة الحقلية كانت محاطة بمنطقة ناشرة للمرض مزروعة بأصناف عالية الإصابة ومعدية بخليط من سلالات فطر صدأ الأوراق كمصدر للعدوى. تم تسجيل نسبة الإصابة كل ١٠ أيام وحساب المساحة الواقعة تحت منحنى المرض. نسبة الإصابة النهائية تراوحت بين Tr MR إلى 80 S فى موسم ٢٠١٣/١٤ بينما فى موسم ٢٠١٤/١٥ تراوحت بين Tr MR إلى 70 S . الفاقد فى المحصول تراوح بين 0.52 % فى التركيب الوراثى سدس ١٣ إلى 17.58 % فى سخا ٩٣ خلال ٢٠١٣/١٤. بينما فى الموسم ٢٠١٤/١٥ تراوح بين 0.48 % فى التركيب الوراثى سدس ١٣ إلى 19.56 % فى التركيب الوراثى سخا ٩٣. بالإضافة إلى ذلك الفاقد فى المحصول فى باقى التراكيب الوراثية المختبرة إعتمد على قيم نسبة الإصابة لكل تركيب وراثى. إرتبطت الخسائر فى وزن الألف حبة ووزن الحوض بشدة على المساحة الواقعة تحت منحنى المرض.