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Quantitative relationship between leaf rust and wheat grain yield in some Egyptian wheat cultivars

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ABSTRACT ---This work was carried out to study the response of seven Egyptian wheat cvs., i.e. Gemmiza 7, Gemmiza 9, Gemmiza 10, Sids 1, Sids 12 , Misr 2 and Sakha 94 to the infection by leaf rust with relation to grain yield under field condition at Sids Agric. Res. Stat., Beni Sweif , Egypt during three growing seasons ,i.e. 2012/2013 , 2013/2014 and 2014/2015 with and without fungicide protection under high disease pressure. Disease severity was recorded weekly and area under disease progress curve AUDPC was estimated. The infection significantly reduced grain yield of all the tested cvs. compared to the protected ones. The loss in the grain yield and 1000 kernel weight of the different wheat cvs. was variable according to the varietal response. The grain yield and 1000 kernel weight of the protected plants of cvs. were higher than that in the infected ones. Also, significant differences were found between the infected and protected cvs. under the study. The loss was determined in the seven wheat cvs. due to leaf rust by calculating AUDPC. It was observed that, as the area under disease progress curve of leaf rust increased the yield loss was also increased. According to the combined analysis, it was clear that cvs. Misr 2, Sakha 94 and Sids 12 showed lower levels of AUDPC being, 91.33, 113.1 and 257.55, respectively and exhibited lower levels of actual yield loss % , being 1.5%, 1.19 and 3.42%, respectively in the thousand kernel weight. Meanwhile, the actual yield loss % of the grain yield per/ plot were 1.28, 1.01 and 1.70 % , respectively. In addition to , the two Gemmiza 9 and Gemmiza 10 cvs. showed intermediate levels of AUDPC, being 478.21 and 430.77 and exhibited lower levels of actual yield loss % , being 2.95 and 3.93 %, respectively in thousand kernel weight . Furthermore, the actual loss % of yield per plot / kg was 1.24 and 5.93% in cvs. Gemmiza 9 and Gemmiza 10, respectively. The five wheat cvs., i.e. Misr 2, Sakha 94, Sids 12, Gemmiza 9 and Gemmiza 10 were found to be tolerant to leaf rust infection. Since, the actual loss ranged from 1.25 to 3.93% in the thousand kernel weight and from 1.01 to 5.93 kg. grain yield per plot as compared to cv. Gemmiza 7, which showed the highest level of actual loss % in the two yield components. In general , the obtained data revealed strong correlation between yield loss and AUDPC.

Key word: Leaf rust, cultivars, Puccinia triticina ,wheat, grain yield .

1 INTRODUCTON

Leaf rust caused by *Puccinia triticina* Eriks. is a widespread disease in wheat (*Triticum aestivum* L.) in Egypt and worldwide causing significant losses in grain yield. The occurrence of severe and damaging epidemics of leaf rust caused many new wheat cvs. to be eliminated and discarded very shortly after their release and farmer's use in agriculture (Stwart *et al.*, 1972 ; Abdl- Hak *et al.*, 1980 and Nazim *et al.*, 1983) The losses in grain yield in susceptible cv. might exceed than 50% in case of an early onset of rust (Yaqoob, 1991). Total grain yield was reduced by 1% for each 1% increase in the rust infection , when the percentage of flag leaf area covered by pustules was assessed visually at flecks stage 11.1% (Khan *et al*., 1997). The disease attacks the leaf blades, although it can also infect the leaf sheath (Huereta - Espino *et al*., 2011) and decreased numbers of kernels per head and lower kernel weight (Marasas *et al*., 2004 and Kolmer *et al*., 2005).

Egypt is located in the epidemiological zone of leaf rust (Saari and Prescott, 1985). Moreover, significant annual loss in grain yield , up to 10% in the susceptible wheat cvs., was recorded in many wheat growing areas, particularly, in north Delta provinces of the country (Abdl- Hak *et al.*, 1966; Nazim *et al.*, 1983 and Negm, 2004). The highest significant loss percentages were found in susceptible wheat cvs. Gemmiza 7, Sakha 61 and Giza164. However, insignificant loss percentages were found in resistant cvs. Giza 168 , Misr 2 and Sakha 94. Inverse relation was present between the disease level and grain yield. Sowing of resistant cvs. is recommended to escape heavy yield losses wreaked by the leaf rust disease (Draz *et al.*, 2015). There are different ways to control rust epidemics, current available chemicals may be effective, but are difficult to use in developing countries due to the high cost, lack of timeliness and distribution problems. Therefore, host resistance to rust diseases have been generally provided adequate protection without the need for chemicals (Loughman *et al*., 2005 ; Zhang *et al*., 2007 and Singh *et al*., 2008). The main successful strategy for effective control of wheat rusts, in general and leaf rust in particular, is the utilization of host genetic resistance and/or deployment of resistance cvs. (Negm *et al*., 2013). The use of resistant and tolerant cvs. are the best way to control rust epidemics as introduction of new rusts resistance genes reduces inoculums drastically, consider

that the best approach to save the yield losses occurring due to this disease is to follow durable disease resistant program in commercially adopted cvs., which are otherwise good agronomic traits and quality. Chen *et al*. (2013) mentioned that resistant cvs. are the cheapest most reliable and environment friendly way to control rust diseases.

The present study was carried out to study the response of seven Egyptian wheat cvs. to leaf rust to show its capability to cause losses in grain yield and show the quantitative relationship between severity of the disease and losses in grain yield.

3 MATERIALS AND METHODES

The impact of relationship between leaf rust infection and wheat grain yield to wheat cultivars, *i.e* Gemmiza 7, Gemmiza 9, Gemmiza 10, Sids 1,Sids 12, Misr 2 , Sakha 94, along with *Triticum spelta saharenses* as highly susceptible check variety (Table, 1) were studied at Sids Agric. Res. Stat.

The effect of leaf rust infection on grain yield per plot and 1000-kernel weight was determined in an experiment of split-plot design with three replicates for the three years 2012/12- 2013/14. The main treatments were infected and protected plots. All plants were surrounded by a susceptible spreader (*Triticum spelta saharinsis* and Morocco).In addition, the plants under the study were artificially inoculated with a mixture of leaf rust races at booting stage; Whereas the other treatments were protected by the effective fungicide Sumi-eight5EC (CE) -1- (2 , 4-dichlorophenyl)1-4,4-dimethyl1-2-(1,2,4-triazol-y1)Pent -1-en -3-0L) at the rate of 70cm /200litter water per Faddan at the early dough stage. Plots were harvested, threshed, the yield plot loss and 1000-kernel weight were determined. yield loss was estimated as the difference among the protected and infected plots using simple equation adopted by (Calpouzos *et al*., 1976)

Loss (%) = $1- y_d /y_h \times 100$

Where:

y_d = yield of diseases plants.

yh= yield of healthy plants.

Leaf rust severity and reaction were evaluated for each plot every 7 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 in (Roelfs *et al*., 1992). The final rust severity (FRS) was recorded as outlined by (Das *et al.*, 1993) as the disease severity (%) when the highly susceptible check variety was severely rusted and the disease rate reached the highest and final level of leaf rust severity. The area under disease progress curve (AUDPC) was calculated for each cultivars according to the equation adopted by Pandy *et al.* (1989).

AUDPC =

D [1/2 (Y1 + Yk) + (Y2 + Y3 + - - - + Yk-1)]

Where: D = Days between two consecutive records (time intervals).

Y1 + Yk = Sum of the first and last disease records.

Y2 + Y3 + - - - - - + Yk-1 = Sum of all in between disease records.

Statistical analysis

All the data obtained were statically analyzed for each season individually and combined analysis of variance over three seasons was also determined. Least significant differences (L.S.D at 5%), was used to compare yield components according to (Snedecor, 1957). Correlation coefficient was also used to detect the relationship between yield loss and area under disease progresses curve (AUDPC).

Table 1. Name, pedigree, and year of release of eight wheat genotypes.

No.	Genotypes	Pedigree	Year of release
1	Gemmiza.7	CMH 74A.360 / SX // SERI 8213 / AGENT CGM4611-2GM-3GM-1GM-0GM	1999
2	Gemmiza.9	ALD''S'' / Huac''s'' // CMH 74A.630/SX CGM4583-5GM-1GM-0GM	1999
3	Gemmiza.10	MAYA47"S"/ON//II60-147/3/BB/GLL/4/CHAT"S" /5/ CROW"S"CGM7892-2GM-1GM-2GM-1GM-0GM	2004
4	Sids.1	HdHD2172/Pavon"S"//1158.57/Maya74"S"SD46-4SD-2SD-1SD-0SD	1996
5	Sids.12	BUC//7C/ALD/5/MAYA74/ON//1160.147/3/BB/GLL/4/CHAT"S"/6/MAYA/VUL// CMH74A.630/4*SXSD7096-4SD-1SD-1SD-0SD	2007
6	Misr.2	SKAUZ/BAV92CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S	2011
7	Sakha.94	OPATA/RAYON//KAUZCMBW90Y3180-0TOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S	2004
8		*Triticum spelta saharensis*	

3 RESULTES

The obtained results show that, leaf rust severity and yield were significantly different among the eight cvs., where showed different levels of field resistance during the three years period. There was quantitative relationship between grain yield and leaf rust, where cvs. showed high leaf rust severity exhibited maximum values of AUDPC and yield loss. While, cvs. showed low disease severity exhibited minimum values of AUDPC and yield loss. The estimated yield components of the different treatments of the inoculated treatments were greatly lowered than that of the protected treatments . In addition, significance of leaf rust development and disease stress on yield were determined.

Leaf rust pressure was high and uniform throughout the experiment. The fungicide – protected plots remained free from leaf rust during the entire crop season.

During 2012/13 growing season, the most wheat cvs. showed high leaf rust severity % exhibited rust incidence interim of final rust severity % was higher on the high level of susceptible cvs. Gemmiza 7 (76.66%), Sids 1 (70.00%) and T.s.s (86.66%), as check variety for the infected treatments. On the other hand, the final rust severity % was the lowest values on the low level of susceptible (partial resistance) wheat cultivars i.e. Misr 2 (9.00%) and Sakha 94 (8.60%) for the infected treatments (Table 2). With respect to AUDPC values run in parallel line with rust severity % .The values of AUDPC that found in the high level of susceptible wheat cultivars were Gemmiza 7 (1043.30), Sids 1 (643.33) and T.s.s (1266.66) for the infected treatments .On the other hand, the values of AUDPC were lower in the low level of susceptible (partial resistance) wheat cultivars i.e. Misr 2 (164.00) and Sakha 94 (8.60) for the infected treatments (Table 2).

During 2013/14 growing season data presented in (Table, 3) reveal that rust incidence in term of final rust severity was higher on the high level of susceptible cvs. Gemmiza 7 (90.00%), Sids 1 (86.66%) and T.s.s (96.66%) as check variety for the infected treatments . On the other hand, the final rust severity % was the lowest values on the low level of susceptible cvs. Sids 12 (13.33), Misr 2 (6.66%) and Sakha 94 (5.33%) for the infected treatments. With respect to AUDPC values run in parallel line with rust severity % .The values of AUDPC that found in the high level of susceptible wheat cultivars were Gemmiza 7 (1112.66), Sids 1 (1475.00) and T.s.s (1741.66) for the infected treatments. On the other hand, the values of AUDPC were lower in the low level of susceptible wheat cultivars i.e. Sids 12 (146.66), Misr 2 (76.66) and Sakha 94 (172.00) for the infected treatments.

During 2014/15 growing season, data in Table (4) reveal that rust incidence in term of final rust severity% was higher on the high level of susceptible wheat cultivars i.e. Gemmiza 7 (60.00%), Gemmiza 9 (46.66%), Sids 1 (43.33%) and *T.s.s* (76.66%) as check variety, for the infected treatments . On the other hand the final rust severity % was the lowest values on the low level of susceptible wheat cultivars i.e. Sids 12 (13.33), Misr 2 (2.66%) and Sakha 94 (10.66%) for the infected treatments. With respect to AUDPC values run in parallel line with rust severity% .The values of AUDPC that found in the high level of susceptible wheat cultivars were Gemmiza 7 (630.66), Gemmiza 9 (441.66), Sids 1 (389.66) and T.s.s (1105.00), for the infected treatments. On the other hand, the values of AUDPC were lower in the low level of susceptible wheat cultivars i.e. Sids 12 (132.00), Misr 2 (33.33) and Sakha 94 (65.33) for the infected treatments.

Grain yield and yield losses

The mean grain yield was significantly higher for fungicide –protected plots compared with the non-protected plots due to the differences in the levels of disease severity of leaf rust. During 2012/2013 growing season. Data presented in (Table, 2) show that the thousand kernel weight (TKW) of the healthy plants (protected treatment) of all the tested cvs. was higher than that of the infected ones, where significantly affected by rust infection. Thousand kernel weight (g) of cvs. Gemmiza 7 , Gemmiza 9 and Gemmiza 10 were 50.22 and 57.79, 43.91 and 48.47 and 39.79 and 44.51 g for the infected and protected treatments, respectively,. While the thousand kernel weight (g) of the partially resistant cvs. Sids 12 (45.07 and 47.39), Misr 2(44.33 and 47.49) and Sakha 94(45.45 and 46.97 for the infected and the protected treatments, respectively. The total loss % in the thousand kernel weight (TKW) ranged from 3.23 to 20.96%. The coefficient of determination was estimated to show how much the yield was affected by the level of disease incidence. The actual loss (%) was estimated according to coefficient of determination (R^2) values to obtain the loss due to leaf rust infection. The actual loss % was 12.74, 4.92 and 10.27 % of cvs. Gemmiza 7, Gemmiza 9 and Gemmiza 10, respectively compared with T.s.s (20.24%).Meanwhile, it was 3.89, 4.49 , 5.20 and 3.19% with cvs. Sids 1, Sids 12, Misr 2 and Sakha 94 , respectively.

Table 2. Effect of leaf rust infection on grain yield and 1000 kernel weight of 8 wheat cultivars , field experiment at Sids Agric. Res. Stat. during 2012 / 2013 growing season.

NO.	Cultivars	Rust incidence		Mean 1000 kernel weight (g)				[3] R^2	Mean grain yield / plot (Kg.)				[3] R^2
		[1] FRS	[2]AUDPC	Infected	Protected	Total loss (%)	*Actual loss (%)		Infected	Protected	Total loss (%)	*Actual loss (%)	
1	Gemm.7	76.66ab	1043.3 b	50.22	57.79	13.09	12.74	0.974	2.79	3.65	24.43	14.9	0.610
2	Gemm. 9	50.00 c	479.66 cd	43.91	48.47	9.40	4.92	0.524	3.38	3.74	9.62	9.50	0.988
3	Gemm.10	43.33 c	424.00 d	39.79	44.51	10.60	10.27	0.969	2.37	2.6	8.84	5.80	0.657
4	Sids.1	70.00 b	643.33 c	46.98	48.97	4.06	3.89	0.960	3.41	3.6	5.27	4.95	0.941
5	Sids.12	30.00 d	394.00 d	45.02	47.39	5.00	4.49	0.898	3.12	3.24	3.7	3.69	0.999
6	Misr.2	9.00 e	164.00 e	44.33	47.49	6.65	5.80	0.873	3.14	3.34	5.98	5.62	0.940
7	Sakha.94	8.60 e	102.00 e	45.45	46.97	3.23	3.19	0.988	2.88	2.96	2.7	2.60	0.966
8	T.S.S	86.66 a	1266.66 a	35.96	45.50	20.96	20.24	0.966	1.06	1.51	29.80	24.97	0.838
L.S.D. at 5%		12.04**	191.72**	0.82					0.12				
L.S.D. at 1%				1.14					0.16				

[1] (FRS) Final rust severity % [2] (AUDPC) Area under disease progress curve [3] (R^2) Coefficient of determination
*Actual losses estimated according to R^2 values.

Table 3. Effect of leaf rust infection on grain yield per plot and 1000 kernel weight of 8 wheat cultivars under field conditions at Sids Agric.Res. Stat. during 2013 / 2014 growing season.

No.	Cultivars	Rust incidence		Mean 1000 kernel weight (g)				[3] R^2	Mean grain yield / plot (Kg.)				[3] R^2
		[1] FRS	[2]AUDPC	Infected	Protected	Total loss (%)	Actual loss (%)		Infected	Protected	Total loss (%)	*Actual loss (%)	
1	Gemm.7	90.00[ab]	1112.66 b	49.45	55.26	10.51	6.49	0.618	1.890	2.553	25.96	11.99	0.462
2	Gemm. 9	23.33 [c]	513.33 [c]	43.6	46.58	6.41	2.45	0.383	2.557	2.940	13.26	11.11	0.838
3	Gemm.10	34.58 [b]	598.33 [c]	33.81	37.48	9.80	9.55	0.975	1.950	2.327	16.20	15.60	0.963
4	Sids.1	86.66 [a]	1475.00[b]	45.87	47.08	2.57	0.88	0.346	2.990	3.050	1.96	1.77	0.907
5	Sids.12	13.33 [d]	146.66 [d]	42.35	45.55	7.01	3.24	0.463	2.807	2.900	3.17	2.95	0.933
6	Misr.2	6.66 [d]	76.66 [d]	38.96	41.01	4.99	4.35	0.872	2.940	3.083	3.34	3.07	0.922
7	Sakha.94	5.33 [d]	172.00 [d]	44.13	44.70	1.29	1.25	0.981	2.983	3.030	1.55	1.20	0.779
8	T.S.S	96.66 [a]	1741.66[a]	32.89	39.81	17.38	17.34	0.998	1.137	1.583	28.17	26.11	0.927
L.S.D. at 5%		16.10	269.05	1.50					0.077				
L.S.D. at 1%				2.06					0.104				

[1] (FRS) Final rust severity % [2] (AUDPC) Area under disease progress curve [3] (R^2) Coefficient of determination
*Actual losses estimated according to R^2 values.

During 2013/14 growing season, the thousand kernel weight/gm (TKW) of the healthy plants (protected treatments) of all wheat cultivars was higher than that of infected ones of all tested cultivars and was significantly affected by rust infection TKW/gm of cultivars; Gemmiza 7 , Gemmiza 9 and Gemmiza 10 were (49.55 & 55.26), (43.6 & 46.58) and (33.81 & 37.48) for infected and protected treatments, respectively. While TKW/gm of partially resistant cultivars Sids 12 (42.35 & 45.55), Misr 2(38.96 & 41.01) and Sakha 94 (44.13 & 44.7) for infected and protected treatments, respectively. The total loss % in the thousand kernel weight/gm ranged from 1.29 to 17.38 %. Coefficient of determination (R^2) values was high in cvs. Gemmiza 10 (0.975 and 0.963), Misr 2 (0.872 and 0.922) , Sakha 94 (0.981 and 0.779) and T.s.s (0.998 and 0.927) in thousand kernel weight/g and in grain yield per plot/Kg, respectively. On the other hand (R^2) values were low in cvs. Gemmiza 9 (0.383), Sids 1 (0.346) and Sids 12 (0.463) in the thousand kernel weight/gm, where, coefficient of determination values in grain yield per plot/Kg to these cvs. were higher than that in the thousand kernel weight/g. The actual loss % was 6.49, 2.45 and 9.55 % of cvs. Gemmiza 7, Gemmiza 9 and Gemmiza 10, respectively, compared with T.s.s (17.34%), while, it was 0.88, 3.24, 4.35, and 1.25 % with cvs. Sids 1, Sids 12, Misr 2 and Sakha 94, respectively (Table, 3).

During 2014/2015 growing season, the thousand kernel weight/g (TKW) of the healthy plants (protected treatments) of all wheat cultivars was higher than that of infected ones of all tested cultivars and was significantly affected by rust infection thousand kernel weight/gm of cultivars; Gemmiza 7 , Gemmiza 9 and Gemmiza 10 were (48.70 and 56.94 g), (42.29 and 46.16/g) and (40.10 and 44.81g) for infected and protected treatments, respectively, While, the thousand kernel weigh (g) of the partially resistant cvs. Sids 12 (40.85 and 43.78 g), Misr 2(41.84 and 64.26 g) and Sakha 94 (40.59 and 41.81 g) for infected and protected treatments, respectively. Total loss % in the thousand kernel weight/gm ranged from 2.91 % to 19.30 %. The actual losses % was 13.95, 2.32 and 9.28% of cvs. Gemmiza 7, Gemmiza 9 and Gemmiza 10, respectively compared with T.s.s (18.16%), while it was 0.17, 6.66, 6.53 and 1.94 % foe cvs. Sids 1, Sids 12, Misr 2 and Sakha 94, respectively (Table, 4).

During 2012/2013 growing season, the grain yield of the healthy plants (protected treatments) of all cultivars was higher than that of the infected ones. In partially resistant cvs. Sids 12, Misr 2 and Sakha 94 the grain yield was 3.12 and 3.24 k.g/plot), (3.14 and 3.34 kg/plot) and (2.82 and 2.96 kg/plot) for infected and protected treatments, respectively. While the highly susceptible wheat cvs. Gemmiza 7, Gemmiza 9 Gemmiza 10, Sids 1 and check variety T.s.s were (2.79 and 3.65 kg/plot), (3.38 and 3.74 kg/plot),(2.37 and 2.60 kg/plot), (3.41 and 3.60 kg/plot) and (1.06 and1.51 kg/plot) for infected and protected treatments, respectively. Total loss % in grain yield per plot, ranged from 2.70 to 29.80%. The estimated loss% of cvs. Gemmiza 7, Gemmiza 9 and Gemmiza 10 was 24.43, 9.62 and 8.84%, respectively compared with check variety T.s.s (29.80%). While the lower levels of susceptibility were 5.27, 3.70 , 5.98 and 2.79 % for cvs, Sids 1, Sids 12, Misr 2 and Sakha 94, respectively, which gave significantly lower total loss% (Table, 2).

Table 4. Effect of leaf rust infection on grain yield per plot and 1000 kernel weight of 8 wheat cvs. , field experiment at Sids Agri. Res.Stat. during 2014 / 2015 growing season.

NO.	Cultivars	Rust incidence		Mean 1000 kernel weight (g)					Mean grain yield / plot (Kg.)				
		[1] FRS	[2]AUDPC	Infected	Protected	Total loss(%)	*Actual Loss (%)	[3] R^2	Infected	Protected	Total loss (%)	*Actual loss (%)	[3] R^2
1	Gemm.7	60.00 [b]	630.66 [b]	48.70	56.94	15.5	13.95	0.900	1.80	2.10	14.28	10.06	0.705
2	Gemm. 9	46.66 [c]	441.66 [b]	42.29	46.16	8.38	2.32	0.277	2.21	2.51	11.95	8.59	0.719
3	Gemm.10	33.33 [d]	270.00 [cd]	40.10	44.81	10.28	9.28	0.903	1.84	2.01	8.45	4.01	0.475
4	Sids.1	43.33 [cd]	389.66 [bc]	43.80	46.1	4.82	0.173	0.036	3.15	3.31	4.83	4.31	0.894
5	Sids.12	13.33 [e]	132.00 [d]	40.85	43.78	6.67	6.66	0.999	2.33	2.91	7.20	3.72	0.517
6	Misr.2	2.66 [e]	33.33 [d]	41.84	46.26	9.54	6.53	0.685	2.76	2.91	5.15	3.46	0.672
7	Sakha.94	10.66 [e]	65.33 [d]	40.59	41.81	2.91	1.94	0.667	2.83	2.90	2.41	2.39	0.995
8	T.S.S	76.66 [a]	1105.0 [a]	26.59	32.95	19.30	18.16	0.941	0.931	1.31	28.93	27.54	0.952
L.S.D. at 5%		12.15	245.96	1.15					0.088				
L.S.D. at 1%				1.58					0.115				

[1] (FRS) Final rust severity % [2] (AUDPC) Area under disease progress curve [3] (R^2) Coefficient of determination
*Actual losses estimated according to R^2 values.

Table 5. Combined analysis of the effect of leaf rust infection on grain yield and 1000 kernel weight of 8 wheat cvs., field experiment at Sids Agric. Res. Stat. during 2012/20113 and 2014/15 growing seasons.

NO.	Cultivars	Rust incidence		Mean 1000 kernel weight (g)					Mean grain yield / plot (Kg.)				
		[1] FRS	AUDPC	Infected	Protected	Total loss(%)	*Actual Loss (%)	[3] R^2	Infected	Protected	Total loss (%)	*Actual loss (%)	[3] R^2
1	Gemm.7	75.55 [ab]	928.87[b]	49.45	56.66	12.72	10.71	0.842	2.16	2.76	21.73	21.68	0.998
2	Gemm. 9	39.99 [c]	478.21 [c]	43.47	47.07	7.64	2.95	0.387	2.71	3.06	11.43	1.24	0.109
3	Gemm.10	37.08 [cd]	430.77 [d]	37.90	42.26	10.31	3.93	0.382	2.05	2.31	11.25	5.93	0.516
4	Sids.1	66.66 [b]	835.99 [b]	45.55	47.38	3.86	3.70	0.960	3.18	3.32	4.21	3.73	0.887
5	Sids.12	18.88 [de]	257.55 [d]	42.74	45.57	6.21	3.42	0.551	2.75	3.01	8.63	1.70	0.198
6	Misr.2	6.10 [e]	91.33 [e]	41.71	44.92	7.14	1.52	0.214	2.94	3.11	5.46	1.28	0.236
7	Sakha.94	8.19 [e]	13.11[e]	43.39	44.49	2.47	1.193	0.482	2.89	2.963	2.46	1.01	0.412
8	T.S.S	86.66 [a]	1371.10[e]	31.81	39.42	19.30	10.76	0.558	1.04	1.32	21.21	9.98	0.471
L.S.D. at 5%		19.70	359.81	0.43					0.08				
L.S.D. at 1%		27.35	499.3	0.58		0.78			0.10		0.77		

[1] (FRS) Final rust severity % [2] (AUDPC) Area under disease progress curve [3] (R^2) Coefficient of determination
*Actual losses estimated according to R^2 values.

4 DISCUSSION

Leaf rust (*Puccinia triticina)* has been ones of the main biotic stress which affects wheat (*Triticum aestivum* L.) plants and consequently the grain yield which is inversely proportional to the degree of rust infection. Estimation the loss caused by a disease is a prerequisite to develop strategies for disease control particularly through breeding programs for disease resistance (Simmmonds, 1988). Resistance of any cultivar to leaf rust can be described as its capacity to reduce the amount of loss in grain yield due to infection.

Leaf rust severity (%) and yield components data interims of 1000 kernel weigh (TKW) and yield per plot were used to develop a model of the relationship between yield and disease this relationship was valued to determine if the effect of disease on yield was similar for cultivars grown in Egypt carrying different levels of field resistance to leaf rust infection. Also, the total loss (%) and the actual loss (%) ,due to rust infection were estimated for the tested cultivars to determine the capacity of the Egyptian wheat cultivars to tolerant these infection. Significance of the disease stress on yield was tested, also the parameters coefficient of regression, coefficient of correlation and coefficient of determination were estimated to determine the effect of leaf rust infection on yield discarding the other factors than disease stress.

The effect of leaf rust infection on grain yield of wheat cultivars may be due to affecting the photosynthetic area of the top three leaves especially flag leaf, which shares with its sheath by about 75 percentage in determining the grain weight, while the ear shares by only 25 percent. Grain shrivels and nutrients produced primarily in the flag leaf are used by the fungus rather than transported to the grain (Buchenau, 1975; Johnston, 1931; Seck *et al.,* 1988 and subba Rao *et al*., 1989) .

El-Daoud *et al*. (1996) reported that grain yield of wheat cultivars was decreased and the amount of loss was dependent upon the disease severity (%).

The present study aimed to estimate grain yield loss due to rust infection and characterize the relationship between leaf rust incidence and wheat yield components, based on three years of data obtained from eight wheat cultivars in field experiment of split plot design, where protected plots were included with infected ones in which the disease was allowed to develop using field plots as experimental units (Wallen, 1975 and Carlson and Main. 1976).

The combined data analysis of three seasons, (2012/2013, 2013/2014 and 2014/2015) showed that the grain yield of all tested wheat cultivars were significantly affected by rust infection. Moreover, the grain yield of the protected plants of all tested wheat cultivars was higher than that of infected ones. The effect of leaf rust infection can cause great damage to susceptible wheat cultivars. The effect of infection on the yield was due to the early death of the heavily infected leaves and consequently reducing the photosynthesis area and causing losses of nutrients and water contents of the plant and grains. Finally this lead to the reduction in grain yield of the highly infected plants (Stoy, 1963; Skorda, 1968; Nazim, *et al.*,1983; El-Daoudi, *et al* .,1990; Mousa, 2001; Negm, 2004 ; Hassen, *et al.*, 2012 and Draz, *et al*., 2015).

The effect of leaf rust infection on grain yield in terms of grain yield per plot and the thousand kernel weight of cvs. Gemmiza 7, Gemmiza 9, Gemmiza 10, Sids 1,Sids 12, Misr 2 , Sakha 94 and *Triticum spelta saharenses* in the three seasons showed the same trend. In general combined analysis showed that yield components of the tested wheat cultivars were significantly affected by rust infection. Moreover, the grain

yield of the healthy protected plants was higher than that of the infected ones according to the level of disease severity of leaf rust. It was noticed that over the growing seasons, the tested wheat cultivars showed different disease severity. However, the wheat cultivars showed high leaf rust severity exhibited maximum values of area under disease progressive curve (AUDPC) and yield loss% while the wheat cultivars showed low leaf rust disease severity exhibited minimum values of area under disease progressive curve (AUDPC) and yield loss%.

According to the combined data, it was clear that the five cvs. Misr 2 , Sakha 94 ,Sids 12, Gemmiza 9 and Gemmiza 10 showed lower levels of final rust severity (FRS) and area under disease progressive curve (AUDPC), which exhibited lower levels of actual yield losses % ranged from 1.25% to 5.90% in the thousand kernel weight and from 1.24% to 3.93% in yield per plot. Therefore, these wheat cultivars could be classified as posses adequate levels of partial (field) resistance and were tolerant and exhibited lower levels of actual yield losses% compared to the highly susceptible two cvs. Gemmiza 7 and *Triticum spelta saharenses.* (check), which showed the highly level of actual loss% (10.71 and 10.76%) and (21.68 and 9.98%) in the two yield components, respectively, and characterize as fast rusting or highly susceptible wheat cvs. Finally , cv. Sids 1 showed the relatively higher values of final rust severity%(FRS) (66.66) and area under disease progress curve (AUDPC) (835.99) and showed low level of actual loss% (3.70 and 3.73 %) in the thousand kernel wheat and grain yield per plot, respectively and could be classified as posses the characterize of tolerance.

According to the values of coefficient of determination (R^2) cvs. Misr 2 , Sakha 94, Sids 12, Gemmiza 9 and Gemmiza 10, which showed lower levels of actual yield loss% and considered partially resistant cvs. to leaf rust. Whereas, the cv. Sids 1 considered as fast rusting but tolerant to leaf rust.

The ability of wheat cvs. to endure heavy rust infection without sustaining severe yield loss, would provide valuable protection through tolerance to the disease. (Caldwell, 1968) stated that such tolerance should offer a more permanent type of protection against loss from disease, because it would not impose selection pressure on the pathogen population. (Van der Plank, 1968) observed that some cultivars had the ability to tolerate an epidemic in field planting and therefore a very little or no effect of disease incidence on yield and quality occurred. (Sayre, *et al.* 1998) reported that grain yield losses in slow-rusting cultivars were similar to those observed in the immune or resistant has been more dramatic in protecting yield potential. Yield losses was correlated strongly with AUDPC which mean that high levels of partial resistance are needed to prevent significant yield loss (Ochoa and parlevliet 2007; Hassan, *et al.*, 2012 and Draz, *et al*., 2015) .

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