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EFFECT OF STEM RUST INFECTION ON GRAIN YIELD AND YIELD COMPONENTS OF SOME WHEAT CULTIVARS IN EGYPT

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A B S T R A C T

Stem rust, caused by *Puccinia graminis* f. sp. *tritici* is an important disease of wheat worldwide. To estimate grain yield losses due to stem rust, replicated experiments including twelve wheat cultivars i.e. Gemmeiza 7, Gemmeiza 9, Gemmeiza 10, Gemmeiza 11, Sakha 61, Sakha 93, Sakha 94, Sids 12, Sids 13, Giza 168, Misr 1 and Misr 2 were evaluated for adult plant resistance at Sakha Research Station, Kafr El-Sheikh, Egypt during 2011/12 and 2012/13 growing seasons. The field experiment was surrounded by spreader area of highly susceptible varieties i.e. Morroco and Max inoculated with a mixture of stem rust races as a source of inoculum. Disease severity was recorded each 10 days and area under disease progress curve (AUDPC) was estimated and ranged from 100 to 475 in 2011/12 and 100 to 750 in 2012/13. It was found that, yield losses ranged between 2.47 % in the wheat cultivar Misr 2 to 6.29 % in the wheat cultivar Sids 12 during 2011/12, while during 2012/13 ranged from 1.96 % in the wheat cultivar Gemmeiza 7 to 8.21 % in the wheat cultivar Misr 1. High correlation was found between yield losses with disease severity and AUDPC.

Keywords: Wheat, *Puccinia graminis*, partial resistance, yield losses.

INTRODUCTION

Stem rust caused by *Puccinia graminis* f. sp. *tritici*, is the most destructive disease to wheat. Under favorable conditions, stem rust may cause yield losses up to 100 % to the susceptible varieties (Roelfs, 1985 & Leonard and Szabo, 2005).

The new stem rust race which was designated as Ug99 in Uganda in 1999 has threatened wheat production globally (Pretorius *et al*., 2000). Wanyera *et al*. (2006) designated this strain as race TTKS using the letter code stem rust nomenclature system (Roelfs and Martens 1988). A fifth set of differential lines was added, thus Pgt-Ug99 is race TTKSK and variants with added virulence to *Sr* 24 and *Sr* 36 are TTKST and TTTSK, respectively (Jin *et al*. 2008, 2009). Four other variants of the Ug99 race lineage (TTKSF, TTKSP, PTKSK, and PTKST) are present in different parts of Africa (Park *et al*. 2011). Race TTKSK and its variants are virulent to about 90 % of the world's wheat cultivars (Singh *et al*. 2008). Race Ug99 is virulent to a number of stem rust resistance genes, most notably *Sr* 31for which Ug99 was the first reported virulent race. Also, Ug99 is highly damaging which was reported to cause yield losses of more than 71 % in experimental fields (CIMMYT, 2005). Host resistance is the effective control method for stem rust and has been used worldwide for over 50 years, but TTKSK is virulent to most Sr genes (Jin *et al*. 2007). Among 56 designated and a few undesignated stem rust resistance genes in wheat, only eight designated genes in the primary gene pool (*Sr* 13, *Sr* 14, *Sr* 22, *Sr* 28, *Sr* 33, *Sr* 35, *Sr* 42, and *Sr* 45) confer resistance to TTKSK (Pretorius *et al*. 2000; Jin *et al*. 2007; Hiebert *et al*. 2011). Although host resistance to stem rust has generally provided adequate protection without the need for chemicals (Loughman *et al*., 2005 and Singh *et al*., 2008), it is important to evaluate popular commercial cultivars and other improved wheat varieties that may have the potential to replace current susceptible varieties (Pretorius *et al*., 2007).

The objectives of the present investigation were:-

1- To examine the reaction of 12 commercial wheat cultivars to stem rust under field conditions.

2- To assess yield losses due to stem rust infection in 12

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wheat cultivars when exposed to high stem rust pressure.

MATERIALS AND METHODS

This experiment was carried out at Sakha Agricultural Research Station in two successive growing seasons i.e. 2011/12 and 2012/13, using 12 wheat cultivars i.e. Gemmeiza 7, Gemmeiza 9, Gemmeiza 10, Gemmeiza 11, Sakha 61, Sakha 93, Sakha 94, Sids 12, Sids 13, Giza 168, Misr 1 and Misr 2. The wheat cultivars were grown in a randomized complete block design with three replicates. 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 rust incidence and development.

Plots were surrounded by spreader area planted with a mixture of highly susceptible wheat genotypes to stem rust i.e. Morocco and Max to spread inoculum. To provide and maintain the rust inoculum pressure the experiment was also inoculated by injection method twice in a week during the growing season. To maintain crop stand/vigor normal agronomic practices including recommended fertilization dose and irrigation schedule were followed. To keep protected plots almost free from stem rust, the fungicide Sumi-eight 5 EC (1H-1,2,4-Triazole-1-ethanol,.beta.-[(2,4-dichlorophenyl)methylene] -.alpha.-(1,1-dimethylethyl)-,(.beta.E) (35 cm /100 litter water) was applied at 10, 26 February and 8 March.

Stem rust severity and reaction were evaluated for each plot every 10 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 area under disease progress curve (AUDPC) was calculated for each variety 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.

Table 1: List of the local wheat cultivars that were used, pedigree and year of release.

No.	Variety	Pedigree	Year of release
1	Gemmeiza 7	CMH74A.630/SX//SER182/3/AGENT. GM4611-2GM-3GM-1GM-0GM.	1999
2	Gemmeiza 9	ALD"S"/HUAC"S"//CMH74A.630/SX. GM4583-5GM-1GM-0GM.	1999
3	Gemmeiza 10	MAYA74"S"/0N//160-147/3/BB/GLL/4/CHAT"S"/5/ CROW"S". GM5820-3GM-1GM-2GM-0GM.	2004
4	Gemmeiza 11	B0W"S"/KVZ"S"//7C/SERI82/3/GIZA168/SAKHA61. GM7892-2GM-1GM-2GM-1GM-0GM.	2011
5	Sakha 61	INIA/RL4220//7C/YR"S"CM15430-2S-5S-0S-0S	1980
6	Sakha 93	Sakha 92/TR 810328 S 8871-1S-2S-1S-0S	1999
7	Sakha 94	OPATA/RAYON//KAUZ.CMBW90Y3280-0TOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S.	2004
8	Giza 168	MIL/BUC//Seri CM93046-8M-0Y-0M-2Y-0B	1999
9	Sids 12	BUC//7C/ALD/5/MAYA74/ON//1160-147/3/BB/GLL/4/ CHAT"S"/6/MAYA/VUL//CMH74A.630/4*SX.SD7096-4SD-1SD-1SD-0SD.	2007
10	Sids 13	KAUZ "S"//TSI/SNB"S". ICW94-0375-4AP-2AP-030AP -0APS-3AP-0APS-050AP-0AP-0SD.	2010
11	Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR. CMSSOYO1881T-050M-030Y-O3OM-030WGY-33M-0Y-0S.	2011
12	Misr 2	SKAUZ/BAV92. CMSS96M0361S-1M-010SY-010M-010SY-8M-0Y-0S.	2011

At maturity the crop was harvested and yield of each cultivar of 42 m was weighted by conventional balance. The influence of stem rust severities on yield was determined by comparing the yield of infected and protected cultivars. 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.

Data of 1000-kernel weight (g) and grain yield (kg) was calculated following Hassan (2004). Randomly selected thousand kernel from each entry 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 cultivar.

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 AUDPC.

RESULTS AND DISCUSSION

The present study clearly showed that the wheat cultivars showed high stem rust disease severity exhibited maximum values of AUDPC and yield losses. While the wheat cultivars showed low disease severity displayed minimum values of AUDPC and yield losses. It was also evident that the susceptible wheat cultivars suffered more yield losses than those of moderately resistant to resistant to stem rust.

Reaction of commercial wheat cultivars to stem rust:

The reaction of the commercial wheat cultivars to stem rust at adult plant stage under field conditions is shown in Tables 2 and 3.

The fungicide-protected plots remained almost free from stem rust during the two growing seasons of this study (2011/12 and 2012/13).

In 2011/12 growing season, all of the tested wheat cultivars showed different disease severity ranged from 5 to 30 % (Tables 2 and 3). The cvs. Gemmeiza 9, Gemmeiza 10 and Sakha 94 showed the least disease severity (10 R), followed by Misr 1 and Misr 2 (10 MR and 10 MS). While, the rest of the tested cvs. exhibited rust severity ranged from 5 % to 30 %.

Table 2: Effect of stem rust infection on yield components of 12 Egyptian wheat cultivars at Sakha agricultural research station during season 2011/12.

Cultivar	Final rust severity (%)	AUDPC	1000 kernel weight (gm)			Plot weight (kg)		
			Infected	Protected	Loss (%)	Infected	Protected	Loss (%)
Gemmeiza7	5 S	100	42.60	43.70	2.52	17.20	17.75	3.10
Gemmeiza9	10 R	145	43.50	44.40	2.03	22.43	23.00	2.48
Gemmeiza10	10 R	145	41.38	42.30	2.17	23.13	23.75	2.61
Gemmeiza11	10 S	165	42.39	43.50	2.55	24.53	25.25	2.85
Sakha 61	5 S	100	39.50	41.12	3.94	13.80	14.50	4.83
Sakha 93	10 S	165	37.13	39.50	6.00	20.35	21.50	5.35
Sakha 94	10 R	145	43.74	44.80	2.37	21.65	22.25	2.70
Giza 168	10 S	145	42.74	44.34	3.61	23.54	24.50	3.92
Sids 12	30 S	475	41.74	44.74	6.71	22.96	24.50	6.29
Sids 13	20 S	325	41.20	43.40	5.07	22.35	23.75	5.89
Misr 1	20 MR	215	40.40	41.50	2.65	22.48	23.20	3.10
Misr 2	10 MS	145	41.30	42.16	2.04	22.53	23.10	2.47
L.S.D. at 5%			0.156			0.163		

In 2012/13 growing season, all of the tested cultivars exhibited susceptible infection type. The cvs. Gemmeiza 7, Sakha 61, Gemmeiza 9, Gemmeiza 10, Gemmeiza 11, Giza 168, Sakha 93 and Sakha 94 showed rust severity ranged from 5 S to 10 %. While, the cvs. Sids 13, Sids 12 Misr 1 and Misr 2 showed higher rust severity ranged from 20 to 40 %. Denbel *et al*., (2013) found that the wheat variety Pavon 76 was resistant at adult plant stage and has low terminal rust severity (30 MS) under heavy stem rust epidemic and its resistance may be attributed to the presence of the effective gene *Sr* 2. While, the wheat varieties Abolla, Bobicho, Galema, Hawi, Kubsa, Wetera and Sofumer showed a high rust severity (40 % - 50 %).

The rust severity of the cvs. Misr 1 and Misr 2 was 20 MR and 10 MS, respectively in season 2011/12, while in season2012/13 the rust severity of the same genotypes were 40 % and 30 %. This high severity occurred in these cultivars in season 2012/13 may be due to the appearance of new stem rust race (s). Emebet *et al*.,

(2006) found that the wheat varieties Hawi and Simba were highly susceptible at both seedling and adult growth stages despite their resistance in previous studies for stem rust isolates from Debre Zeit and Ambo. Also, the wheat cultivars Simba and Wetera were susceptible at both growth stages (Denbel *et. al*., 2013) and this may be due to the widest virulence race in this study.

However, they were resistant to Debre Zeit and Ambo isolates of stem rust of wheat both in the seedling and adult plant growth stages (Emebet *et al*., 2006).

Area under disease progress curve (AUDPC): Data in Tables 2, 3 and Figure 1 indicates that AUDPC run in a parallel line with disease severity. In 2011/12 growing season, the results obtained showed that the highest values of AUDPC were observed on cvs. Sids 12 and Sids 13 (475 and 325). Whereas, cvs. Gemmeiza 7, Sakha 61, Gemmeiza 9, Gemmeiza 10, Giza 168, Sakha 94, Misr 2, Gemmeiza 11, Sakha 93 and Misr1 exhibited low values of AUDPC i.e. 100, 100, 145, 145, 145, 145, 145, 165, 165 and 215, respectively. According to these results in season 2011/12, the wheat cultivars were classified into two main groups, the first group included the fast rusting wheat cultivars that displayed the highest values of AUDPC (more than 215) i.e. Sids 12 and Sids 13. The second group included the slow rusting wheat cultivars that displayed the lowest values of AUDPC (less than 325) i.e. Gemmeiza 7, Sakha 61, Gemmeiza 9, Gemmeiza 10, Giza 168, Sakha 94, Misr 2, Gemmeiza 11, Sakha 93 and Misr1. In 2012/13 growing season, data in Tables 2 and 3 indicates that the cvs. Misr 1, Misr 2, Sids 12 and Sids 13 showed the highest values of AUDPC (fast rusting) i.e. 750, 475, 475 and 425, respectively. Macharia and Wanyera (2012) found that the wheat line 102091 showed low level of AUDPC, while the wheat cultivars Chozi and Duma showed high levels of AUDPC to stem rust.

Grain yield and yield losses: The 1000 kernel weight and grain yield per plot differences between protected and infected wheat genotypes due to the differences in the level of disease severity of stem rust as shown in Tables 2 and 3. In 2011/12, the loss % of the 1000 kernel weight ranged from 2.03 % to 6.71 %. The cvs. Sids 12 and Sids 13 gave the highest values of loss % of 1000 kernel weight (6.71 and 5.07, respectively) compared to the other genotypes. In 2012/13, the loss % in the 1000 kernel weight ranged from 2.20 % to 6.17 %. The cvs. Misr 1, Misr 2, Sids 12 and Sids 13 gave the highest values of loss % of the 1000 kernel weight (6.17 %, 5.69 %, 5.83 % and 5.44 %, respectively) followed by cvs. Gemmeiza 10, Gemmeiza 9, Giza 168, Gemmeiza 11, Gemmeiza 7, Sakha 61, Sakha 94 and Sakha 93.

Table 3: Effect of stem rust infection on yield components of 12 Egyptian wheat cultivars at Sakha agricultural research station during season 2012/13.

Cultivar	Final rust severity (%)	AUDPC	1000 kernel weight (gm)			Plot weight (kg)		
			Infected	Protected	Loss (%)	Infected	Protected	Loss (%)
Gemmeiza7	5 S	120	41.60	42.70	2.58	17.50	17.85	1.96
Gemmeiza9	10 S	165	42.20	43.30	2.54	22.40	23.50	4.68
Gemmeiza10	10 S	145	41.37	42.30	2.20	22.70	23.80	4.62
Gemmeiza11	10 S	165	42.39	43.50	2.55	24.46	25.20	2.94
Sakha 61	5 S	100	38.75	40.12	3.41	13.80	14.50	4.83
Sakha 93	10 S	165	36.93	38.50	4.08	20.52	21.52	4.65
Sakha 94	10 S	165	41.10	42.80	3.97	21.20	22.30	4.93
Giza 168	10 S	145	42.75	43.85	2.51	23.15	24.40	5.12
Sids 12	30 S	475	41.97	44.57	5.83	22.80	24.30	6.17
Sids 13	20 S	425	40.00	42.30	5.44	22.15	23.40	5.34
Misr 1	40 S	750	38.00	40.50	6.17	21.25	23.15	8.21
Misr 2	30 S	475	39.75	42.15	5.69	21.90	23.50	6.81
L.S.D. at 5%			0.176			0.119		

The loss % of yield per plot in 2011/12 ranged from 2.47 % to 6.29 %. The cvs. Sids 12 and Sids 13 showed the highest values of loss % of yield per plot (6.29 % and 5.89 %) compared to the other genotypes. In 2012/13, the loss % of yield per plot ranged from 1.96 % to 8.21 %. The cvs. Misr 1, Misr 2, Sids 12 and Sids 13 gave

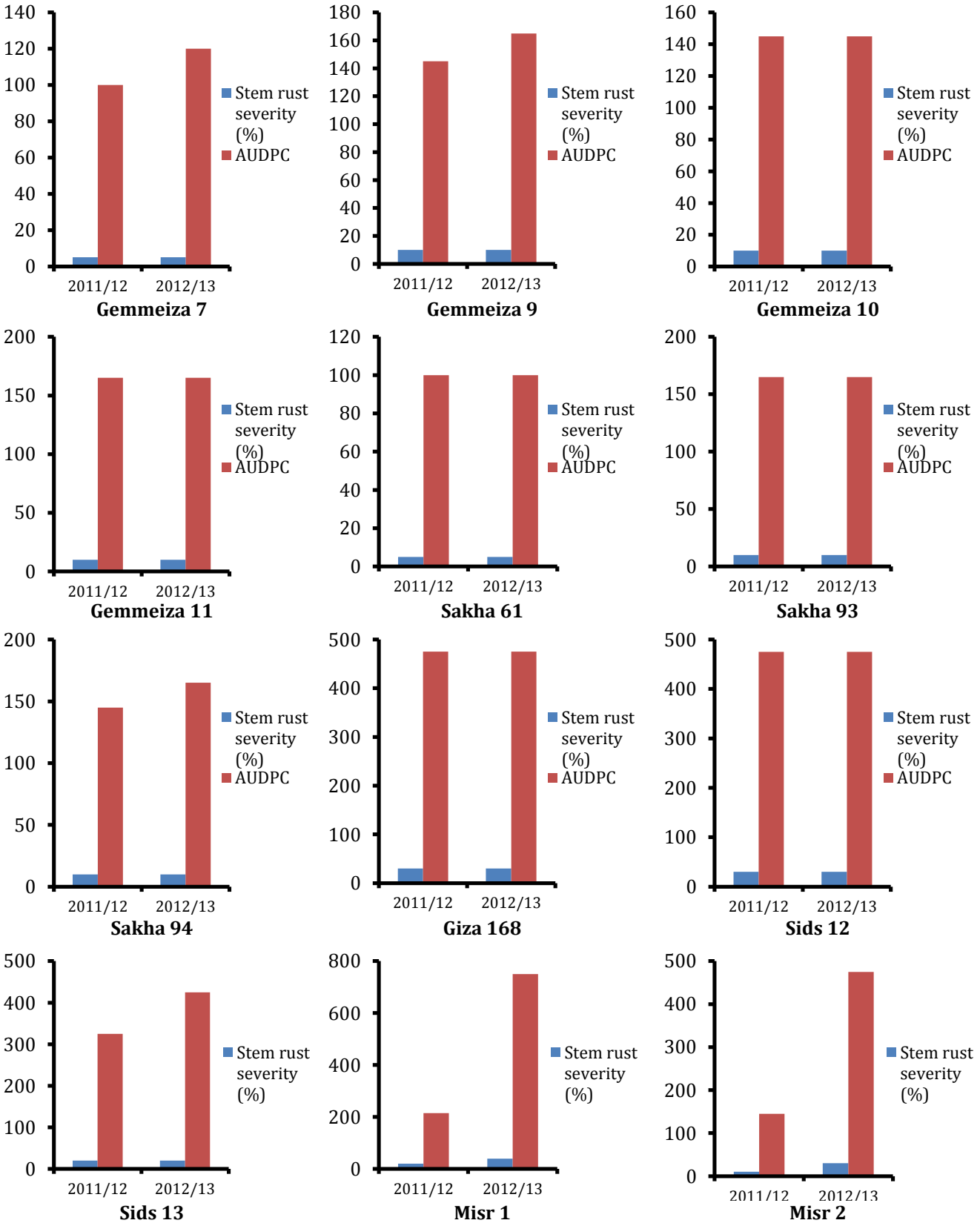

Figure 1. Final rust severity (%) and area under disease progress curve (AUDPC) for *Puccinia graminis* f. sp. *tritici* on 12 Egyptian wheat cultivars under field conditions at Sakha agricultural research station in 2011/12 and 2012/13 growing seasons.

the highest values of loss % of yield per plot (8.21 %, 6.81 %, 6.17 % and 5.34 %, respectively). While, the cvs. Gemmeiza 7, Gemmeiza 11, Gemmeiza 10, Sakha 93, Gemmeiza 9, Sakha 61, Sakha 94 and Giza 168 showed the lowest values of loss % of yield per plot. 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.

This study showed that stem rust reduced yield irrespective of the type and level of resistance possessed by the cultivars (Singh *et al*., 2008 and Pretorius *et al*., 2007). The effect of rust on grain yield may be due to the energy expenditure in plant defense mechanisms rather than for growth and grain information (Smedegaard-Petersen and Tolstrup, 1985). Moreover, the tissue damage caused by hypersensitive reactions also contributes to yield reduction (Khanna *et al*., 2005). The present study showed that infection with stem rust can severely reduce grain yield on susceptible cultivars. Therefore, growing slow rusting cultivars will reduce the loss in grain yield.

Association between AUDPC with loss in the 1000 kernel weight and loss in plot weight: The association of the 1000 kernel weight and loss in plot weight with AUDPC was determined through regression analysis during 2011/12 and 2012/13 growing seasons. Positive relation between AUDPC and loss in 1000 kernel weight during the two growing seasons (R^2 = 0.492 and 0.466) (Fig. 2). Also, regression analysis revealed a significant linear relationship (R^2 = 0.783 and 0.674) between loss in plot weight and AUDPC. 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.

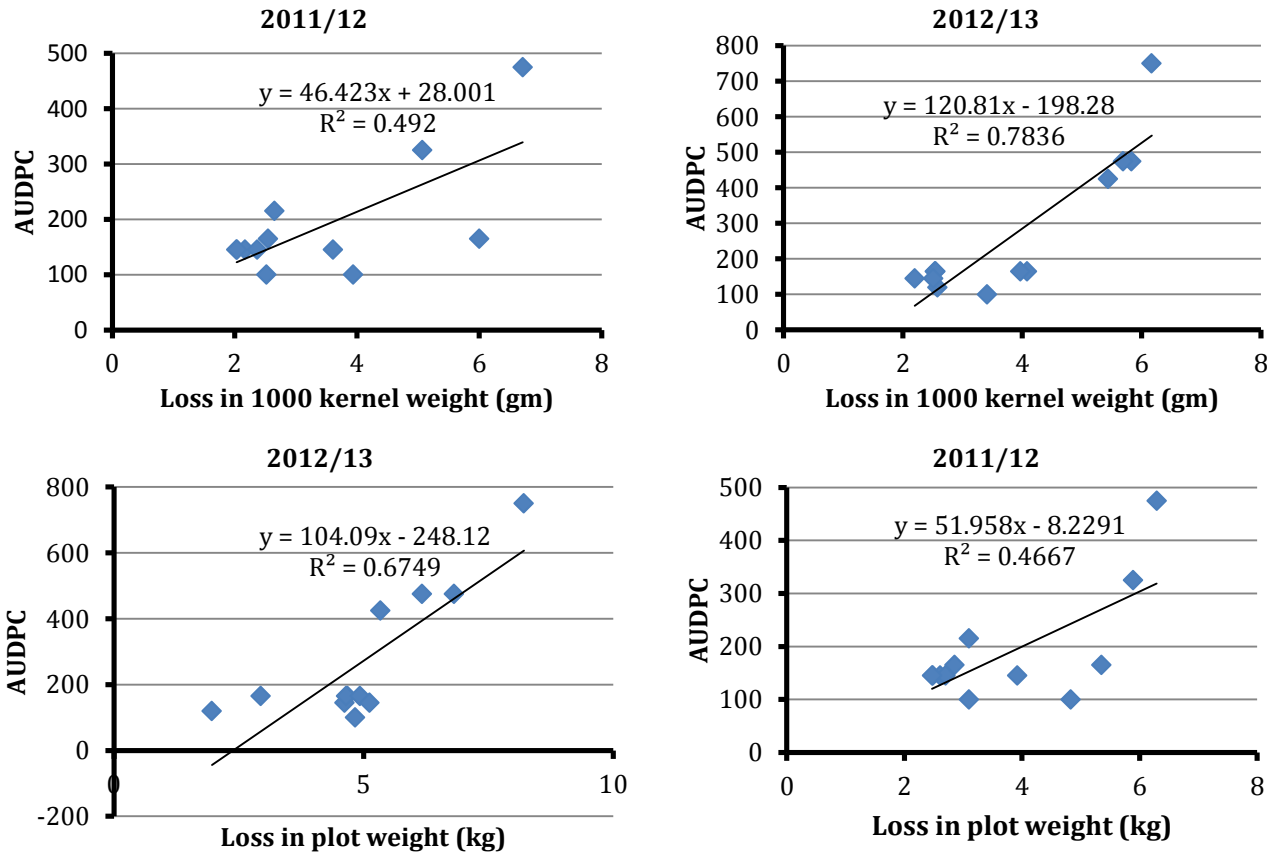

Figure 2. Association between AUDPC with loss in 1000 kernel weight and loss in plot weight for 12 Egyptian wheat cultivars tested during 2011/12 and 2012/13 growing seasons.

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