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# Impact of Wheat Leaf Rust Severity on Grain Yield Losses in Relation to Host Resistance for Some Egyptian Wheat Cultivars

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## ABSTRACT

Leaf rust (*Puccinia triticina*) is a vital disease that cause significant yield losses in wheat fields. The relation between yield losses due to leaf rust disease and host resistance was studied in nine bread wheat cultivars through the two successive growing seasons 2014/2015 and 2015/016. Experiments were conducted in Sids Agricultural Research Station (Middle Egypt) under high disease pressure. Yield losses were determined under field conditions for infected and fungicide protected plants. Rust incidence was also recorded as final rust severity % (FRS %) and area under disease progress curve (AUDPC). In general, yield losses were parallel to leaf rust severity and area under disease progress curve in both of the two growing seasons. Wheat cultivars which revealed high leaf rust severity exhibited maximum values of area under disease progress curve (AUDPC) and yield loss%. However, the wheat cultivars revealed lower leaf rust severity exhibited minimum values of area under disease progress curve (AUDPC) and yield loss%. Leaf rust triggered losses irrespective of the level of resistance obsessed by the cultivars. Giza-168, Sids-13 and Sakha-94 cultivars showed lower levels of both FRS % and AUDPC which exhibited lower levels of losses (2.72% to 5.90%) as compared to the highly susceptible cultivar Gimmeza-7 in which grain reduction reached 12.29% to 18.23%. On the other hand, losses in yield per plot in Giza-168, Sids-13 and Sakha-94 cultivars ranged from 4.09% to 5.72% compared to cultivar Gimmeza-7 ranged from 16.45% to 20.12%. The yield losses were significantly correlated with AUDPC. The cultivars Sids-1 and Gimmeza-9 had great values for susceptibility to leaf rust incidence while, the average grain yield potential for both cultivars was similar to the highest yield commercial cultivars. This indicated that Sids-1 and Gimmeza-9 cultivars have high level of tolerance to leaf rust infection under the Egyptian field condition.

***Key words:*** Wheat, Leaf rust, *Puccinia triticina,* Host resistance and yield losses.

## Introduction

Wheat *(Triticum aestivum* L.) is the first plant ever to be cultivated and has played a key role in man's economic and social development. It is the staple food of nearly 40% of the world population (Braun *et al*. 1998 and Nagarajan, 2005). Wheat plants are suffering from many destructive diseases. Rusts are the most important diseases of wheat because of their ability to move for a long distance and their ability to form new virulent races causing serious losses (Yahyaoui *et al*. 2004 and Huerta-Espino *et al*. 2011).

Leaf rust caused by *Puccinia triticina* (syn. *P. recondita* Rob. Ex Desm. f. sp. *tritici* Eriks. And Henn) in particular, is one of the most dangerous diseases in Egypt and worldwide causing significant losses in grain yield (Long *et al*. 1994 and Khan *et al*. 2013). Susceptible wheat cultivars to leaf rust suffer from yield reductions between 5 to 60% (Smith, Lauren, 2008). Genetic resistance is the most reasonable and preferable technique to minimize yield losses due to leaf rust infection (Kolmer, 1996). Although, leaf rust disease is able within a short time to form new races that are capable of disabling the resistance of the newly produced commercial cultivars (Sayre *et al*. 1998 and Negm *et al*. 2013).

Herrera-Foessel *et al*. (2006) observed that, mean yield losses were affected by degree of cultivar susceptibility and race-specific. Also, yield losses were associated generally with a reduction

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in biomass, harvest index, and kernels per square meter. The occurrence of severe and damaging epidemics of leaf rust lead to that many new wheat cultivars including high yielding were eliminated and discarded very shortly after their release and farmer's use in agriculture (Nazim *el al*. 1990 and Negm, 2004). Leaf rust disease eliminated many wheat cultivars *i.e.* Giza 139, Chenab 70, Super X, Giza 158 and Giza 160 (Nazim *et al*. 1983). The development and release of resistant cultivars is considered to be the only economic and environment safest way to control the disease (Sawhney, 1995; chen *et al*. 2013 and Esmail *et al*. 2015). In most cases the genetic level of partial resistance is the limiting factor in the amount grain loss due to disease infection (Newton and Thomos, 1994). Such form of resistance assumed to be more durable and more stable when compared to other forms of resistance (Broers and Parlevliet, 1989 and Boulot, 2007).

Yield losses can be determined using the application of effective fungicides to compare yield produced with infected cultivars carrying different level of resistances (James *et al*. 1968). In Egypt, significant annual losses in grain yield exceeded to 23% in the susceptible wheat cultivars under suitable environmental conditions, particularly in the northern parts of the Delta (Negm, 2004; Hasan *et al*. 2012 and Soliman *et al*. 2016). Although host resistance to rust disease has commonly provided to acceptable protection without the need for chemicals (Longman *et al*. 2005 and singh *et al*. 2008). The Strategy of wheat breeders and pathologists in Egypt aims to increase wheat production through genetic improvement wheat cultivars, agricultural practice application and protective wheat plants against rust diseases.

Therefore, the objectives of our study aimed to determine and compare the efficiency of different level of wheat cultivar resistance in decreasing losses in grain yield when exposed to high leaf rust pressure under Egyptian field conditions.

## Material and Methods

### Experimental Design and Field Plots.

These experiments were conducted at Sids Experimental Research Station in two successive growing seasons 2014/15- 2015/16. Nine Egyptian bread wheat cultivars *i.e.* Gemmiza-7, Gemmiza-9, Gemmiza- 11, Gemmiza- 12, Sids-1, Sids-13, Giza-168, Giza- 171 and Sakha- 94 (Table, 1) were grown under field conditions to find out the impact of relationship between leaf rust infection and losses of grain yield per plot and 1000-kernel weight.

**Table 1:** List of the tested Egyptian bread wheat genotypes and their pedigrees.

| 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.11 | BOW"S"/KVZ"S"//7C/SER182/3/GIZA168/SAKHA61GM5820-3GM-1GM-2GM-0GM | 2011 |
| 4 | Gemmiza.12 | OTUS/3/SARA/THB//VEECMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM | 2011 |
| 5 | Sids.1 | HdHD2172/ Pavon"S"//1158.57/Maya74"S"SD46-4SD-2SD-1SD-0SD | 1996 |
| 6 | Sids.13 | KAUZ'S" / TSI / SNP"S" ICW 94-0375-4AP-2AP-030AP-0APS-3AP-0APS-050AP-0AP-0SD | 2010 |
| 7 | Giza.168 | MAL / BUC // SERI CM93046-8M-0Y-OM-2Y-0P | 1995 |
| 8 | Sakha.94 | OPATA/RAYON//KAUZCMBW90Y3180-0TOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S | 2004 |
| 9 | Giza. 171 | SAKHA 93 / GEMMEIZA 9S.6-1GZ-4GZ-1GZ-2GZ-0S | 2013 |

Split-plot design with three replicates was planned. The tested cultivars were sown in experimental units (plots) (2 x 2.5 $m^2$) each contain 4 rows with 3 m long and 20 cm apart. 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. The experiment was surrounded by a border of highly susceptible wheat genotypes i.e *Morroco*, *Tiriticum spelta saharences* to serve as a predominant and continuous spreader source for the disease infection. The infected plots were artificially inoculated with a mixture of freshly collected urediniospores of the most prevalent leaf rust races and talcum powder in a ratio of 1: 20 (v/v), to maintain a regular rust inoculum with spores on all spreader plants and generate leaf rust epidemic at booting stage (Tervet and Cassell, 1951). Whereas, the protected plots were treated with the effective fungicide Sumi-eight 5 Ec (CE) -1- (2, 4 – dichlorophenyl) at the concentration of 70 ml /100 L water, to keep these plots almost rust free.

**Disease assessment.**

Adult plant reactions were recorded as host response and rust severity. Rust severity of each cultivar was recorded every 7 days after the initial infection occurred until the early dough stage (Large, 1954) using the modified Cobb's scale (Peterson *et al*. 1948). The host response was evaluated using scale described by Roelfs *et al*. (1992) and Singh *et al*. (2013). Also, final rust severity (FRS %) was assessed as a percentage of disease severity for each of the tested wheat cultivars, when the highly susceptible check variety, was severely rusted and the disease severity reached its maximum and final level (Das *et al*. 1993).

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

$$\mathbf{AUDPC = D\ [1/2\ (Y1 + Yk) + (Y2 + Y3 + - - - - - + Y_{(k-1)}]}$$

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

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

Y2 + Y3 + - - - - - + $Y_{(k-1)}$ = Sum of all in between disease records.

**Yield losses.**

Plots were harvested and threshed. The yield per plot (2×2.5 m) and 1000-kernel weight (TKW) were determined. Yield loss was estimated as the difference among the protected and infected plots using simple equation adopted by Calpouzos *et al.* (1976)

$$\mathbf{Loss\ (\%) = 1\text{-}\ yd\ /\ yh \times 100}$$

Where: Yd = yield of diseases plants.

Yh = yield of healthy plants.

**Statistical analysis.**

All data obtained were statically individually analyzed for each season. Analysis of variance over two 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 losses and area under disease progresses curve (AUDPC).

**Results and Discussion**

Egypt is located in the epidemiological zone of leaf rust (Saari and Prescott, 1985). Early infection of leaf rust usually causes higher yield losses 60–70% depending on the susceptibility of the wheat varieties and the severity of epidemics (Eversmerer *et.al.* 1996 and Appel *et al*., 2009). Host resistance is the most economical and safest method for controlling the disease (Mebrate *et al*., 2008). The present work aimed to study the relationship between rust severity and yield components of nine Egyptian bread wheat cultivars (Gemmiza-7, Gemmiza- 9, Gemmiza- 11, Gemmiza- 12, Sids-1, Sids-13, Giza -168, Giza- 171 and Sakha-94). Wheat cultivars were chosen to show different levels of field resistance against leaf rust infection. All cultivars were grown in split-plot design experiment of with three replicates for two successive growing seasons (2014/2015 - 2015/2016) at Sids Agriculture

Research Station which represents one of the hottest spots of leaf rust incidence under Egyptian conditions.

**Leaf rust incidence:**

Rust incidence was recorded by estimating the epidemiological parameters as final rust severity % (FRS %) and area under disease progress curve (AUDPC) at the adult plant stage under field conditions in the two successive growing seasons (2014/2015 – 2015/2016).

**Final rust severity (FRS %).**

Due to the changes in environmental conditions from one year to another, leaf rust epidemic was found to be more severe in its degree during the second growing season 2015/2016. Data in Table (3) revealed that rust incidence in 2015/2016 was higher than the previous season. Data in Table (2 & 3) indicated that, all tested cultivars showed different final rust severity % ranged between 3.46% and 66.66 %. Disease severity was high for cvs. Gemmiza-7 (53.33% - 66.66%) and Sids-1 (33.30% - 56.66 %). Whereas, the final rust severity % was the lowest on wheat cultivars showing the low levels of susceptibility Sakha 94 (4%) at 2014/2015 and Sids-13 (3.46 %) at 2015/2016. However, the disease severity of all other cultivars were in between. Our results are in agreement with those obtained by Hasan *et al*. (2012); Boulot and Aly (2014) and Draz *et al*. (2015) which concluded that, resistant wheat cultivars, Giza -168, Sakha - 94, Gemmiza - 9, Gemmiza - 10, Gemmiza - 11, Sids - 12 and Sids - 13 may contain some of resistant Lr genes such as Lr2c, Lr9, Lr10, Lr18, Lr19, Lr21, Lr24, Lr26 and Lr29. These Lr genes are considered eminent and exceptional as resistant wheat entries against leaf rust in breeding programs, when compared to the highly susceptible cultivars (sids-1 and Gemmeiza-7).

**b- Area under disease progress curve (AUDPC).**

AUDPC was a reliable and more convenient estimator of adult plant resistance than any other parameter. Because, it represents both the amount of rust infection and the rate at which the disease or pathogen has increased during an epidemic (Sayre *et al*., 1998 and Boulot, 2007). The wide application of AUDPC rather than other epidemiological parameters, is due to enclosure of all factors that influence or affect the disease development (Das *et al*., 1993 and Lal Ahamed *et al*., 2004). Data in Tables (2 and 3) indicated that, area under disease progress curve (AUDPC) values runs in a parallel line with rust severity%. The results also indicated that, the maximum values of AUDPC were detected on the high level of susceptibility wheat cultivars, *i.e.* Gemmiza-7 (730.66 – 1616.66), Gemmiza-9 (508.33- 541.66) and sids-1 (429.66- 1336.66). On the other hand, the values of AUDPC were decreased in the low level of susceptible wheat cultivars, *i.e.* Sakha-94 (88.0 - 245), sids-13 (79.0 -74.33) and Giza-168 (77.33 - 101.66). It could be easily concluded that, Gemmiza-7 and Sids-1 cultivars showed a highly susceptible response against leaf rust disease. While, the rest 7 cultivars *i.e.* Gemmiza-9, Gemmiza-11, Gemmiza- 12, Sids-12, Sids-13, Giza-168, Giza-171 and Sakha-94 were resistantly response against wheat leaf rust (Tables, 2 and 3). Few years earlier, Negm, (2004); Boulot, (2007) and Soliman *et al*. (2016) conducted similar studies under Egyptian field conditions and their results were in accordance with the results obtained herein.

**Assessment of yield losses.**

Estimating yield loss by a disease is a prerequisite to developing strategies for disease control particularity through breeding objectives for disease resistance (Simmonds, 1988). Resistance of any wheat genotypes to leaf rust can be described as its capacity to reduce the amount of losses in grain yield as a result of infection. The grain yield losses of nine wheat cultivars was evaluated under field conditions in 2014/2015 and 2015/2016 growing seasons to identify the ability of wheat cultivars to tolerate the infection of leaf rust disease. The loss (%) in the total thousand kernel weight (TKW/ g) and grain yield /plot (Kg) were estimated for the nine wheat cultivars under investigation.

**a- Thousand Kernel Weight (TKW/ g)**

Leaf rust disease reduced numbers and weights of kernels per head (Marasas *et al*., 2004 and Kolmer *et al*., 2005). The losses in kernel weight caused by leaf rust infection ranged among 2.0% and 41% consistent with the level of resistance or susceptibility of each cultivar (Bajwa *et al*., 1986). Data in Tables (2 & 3) revealed that, Thousand Kernel Weight (TKW/g) in all tested wheat cultivars was higher in the healthy plants (fungicide protected plants) than that of infected ones. TKW was significantly affected by rust infection. The estimated loss% in TKW/gm of the different wheat cultivars were variable according to the cultivar response and ranged between 2.56% and 12.29% (2014/2015) and 2.72% to 18.23% (2015/2016). The reduction was highly observed for Gemmiza-7, Gemmiza-12 and Giza-171 cultivars. The lowest TKW values were obtained in season 2014/2015 for Sids-1 and Sids-13. While, in season 2015/2016 was obtained for cultivar Giza-168 and Sakha-94. Such results are in agreement with El-Daoudi *et al*. (1984), Herrera-Foessel *et al*. (2006); Kassem *et al*. (2011) and Soliman *et al*. (2016).

**b- Grain yield per plot/kg**

The effect of leaf rust infection on grain yield losses of wheat genotypes possibly in consequence of the effect on the photosynthetic area of the top three leaves especially flag leaf, which shares with its sheath by about 75% in determining the grain weight. Grain shrivels and nutrients formed mainly in the flag leaf are utilized by the fungus instead of transported to the grain (Hasan *et al*. 2012). Data presented in Table (2 & 3) revealed that, the grain yield per plot/kg in all tested wheat cultivars was higher in the healthy plants (fungicide protected plants) than that of the infected ones. The estimated loss% in the grain yield (kg/plot) ranged from 4.09% to 16.45% in 2014/2015 and 4.11% to 20.12% in 2015/2016 growing season. Loss% in grain yield per plot/kg was high for cvs. Gemmiza-7, Gemmiza-9, Gemmiza-12 and Giza-171. Whereas, the Loss% was the lowest for cvs. Sids-13, Giza-168 and Sakha-94. These results were confirmed by Salman *et al*. (2006) and Draz *et al*. (2015) which revealed that yield losses increased proportionately with the increase in severity of the disease.

**Table 2:** The impact of leaf rust infection on grain yield per plot (2× 2.5m) and 1000 kernel weight (g) for 9 Wheat cultivars under field conditions at Sids Research Station in 2014 / 2015 growing season.

| NO | cultivar | Rust incidence | | Mean 1000 Kernel weight (TKW g) | | Loss % | Mean grain yield / plot (kg) | | Loss % |
|---|---|---|---|---|---|---|---|---|---|
| | | FRS [1] | AUDPC [2] | Protected | Infected | | Protected | Infected | |
| 1 | Gemm.7 | 53.33[a] | 730.66[a] | 56.92 | 49.92 | 12.29 | 2.560 | 2.140 | 16.45 |
| 2 | Gemm. 9 | 30.00[b] | 508.33[b] | 44.75 | 41.47 | 7.32 | 2.512 | 2.317 | 7.76 |
| 3 | Gemm 11 | 8.33[cd] | 131.66[d] | 53.61 | 51.30 | 4.31 | 2.250 | 2.080 | 7.55 |
| 4 | Gemm 12 | 8.33[cd] | 165.00[d] | 45.37 | 41.96 | 7.51 | 2.035 | 1.878 | 7.71 |
| 5 | Sids.1 | 33.30[b] | 429.66[c] | 46.08 | 44.90 | 2.56 | 2.810 | 2.670 | 4.98 |
| 6 | Sids 13 | 5.00[cd] | 79.00[d] | 42.83 | 41.61 | 2.85 | 2.620 | 2.470 | 5.72 |
| 7 | Giza 168 | 6.66[d] | 77.33[d] | 43.52 | 41.16 | 5.42 | 2.961 | 2.802 | 5.36 |
| 8 | Giza 171 | 10.00[cd] | 126.33[d] | 44.83 | 41.66 | 7.07 | 2.700 | 2.491 | 7.74 |
| 9 | Sakha.94 | 4.00[c] | 88.00[d] | 42.99 | 40.45 | 5.90 | 2.274 | 2.181 | 4.09 |
| L.S.D 0.05 | | 5.112 | 135.361 | 0.481 | | | 0.0130 | | |

1= (FRS) Final rust severity %, 2= (AUDPC) Area under disease progress curve.

- Means having the same letters (s) are not significantly different. Duncan's multiple range test at (P≤0.05).

**Table 3:** The impact of leaf rust infection on grain yield per plot (2× 2.5m) and 1000 kernel weight (g) for 9 Wheat cultivars under field conditions at Sids Research Station in 2015 / 2016 growing season.

| NO | cultivar | Rust incidence | | Mean 1000 Kernel weight (TKW g) | | Loss % | Mean grain yield / plot (kg) | | Loss % |
|---|---|---|---|---|---|---|---|---|---|
| | | FRS [1] | AUDPC [2] | Protected | Infected | | Protected | Infected | |
| 1 | **Gemm.7** | **66.66[a]** | **1616.66[a]** | **51.21** | **41.87** | 18.23 | **3.061** | **2.445** | 20.12 |
| 2 | **Gemm. 9** | **23.33[bc]** | **541.66[bc]** | **48.55** | **46.67** | 3.87 | **3.023** | **2.706** | 10.48 |
| 3 | **Gemm 11** | **26.66[bc]** | **540.00[bc]** | **46.00** | **43.41** | 5.61 | **3.054** | **2.770** | 9.29 |
| 4 | **Gemm 12** | **23.33[bc]** | **424.00[bcd]** | **45.55** | **42.42** | 7.52 | **2.340** | **2.163** | 7.56 |
| 5 | **Sids.1** | **56.66[a]** | **1336.66[a]** | **45.65** | **43.33** | 5.04 | **2.065** | **2.913** | 4.96 |
| 6 | **Sids 13** | **3.46[d]** | **74.33[e]** | **41.00** | **40.13** | 3.56 | **2.751** | **2.638** | 4.11 |
| 7 | **Giza 168** | **3.80[d]** | **101.66[de]** | **41.40** | **40.27** | 2.72 | **2.913** | **2.791** | 4.18 |
| 8 | **Giza 171** | **33.33[b]** | **648.33[b]** | **48.39** | **45.65** | 5.66 | **3.156** | **2.882** | 8.68 |
| 9 | **Sakha.94** | **13.33[cd]** | **245.00[cde]** | **41.95** | **40.67** | 3.05 | **2.281** | **2.171** | 4.82 |
| **L.S.D 0.05** | | **14.126** | **332.40** | **0.844** | | | **0.071** | | |

1= (FRS) Final rust severity %, 2= (AUDPC) Area under disease progress curve.

- Means having the same letters (s) are not significantly different. Duncan's multiple range test at ($P \leq 0.05$).

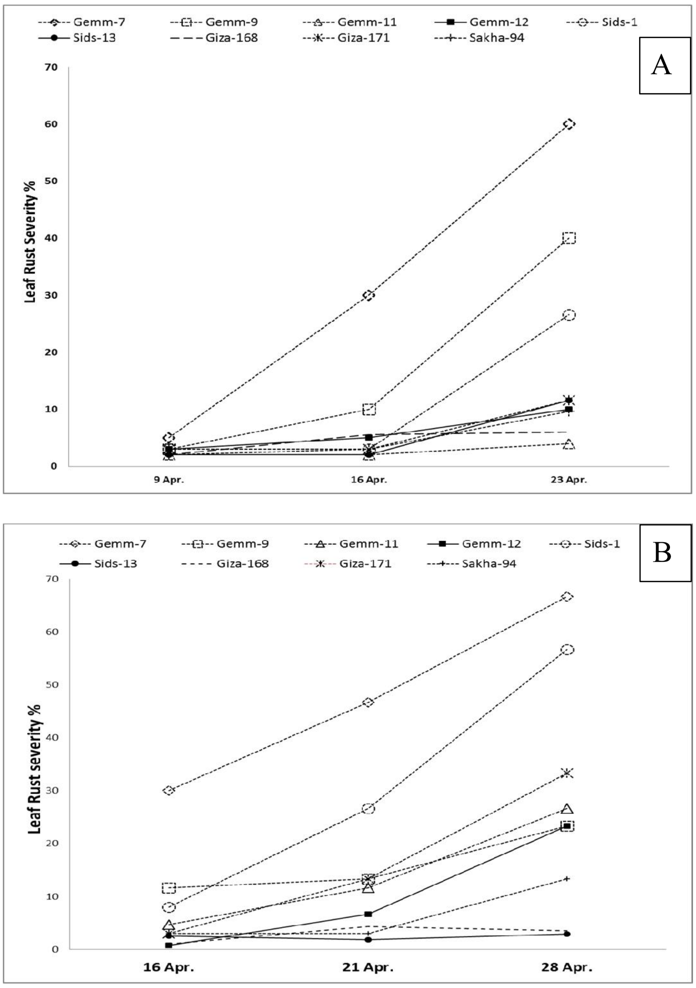


**Fig 1:** Area under disease progress curve (AUDPC) for nine Egyptian bread wheat cultivar. A (2014-2015) and B (2015-2016) growing seasons.

**Correlation between AUDPC and losses of grain yield.**

Correlation (R) between epidemiological parameter AUDPC and yield components was estimated through regression analysis during 2014/15 and 2015/16 growing seasons. Strong correlation was found between yield losses and AUDPC. Figure (2) illustrated the positive relationship between AUDPC and losses in 1000 kernel weight (R2 = 0.594 and 0.766) and losses in Grain yield per plot/kg (R2 = 0.734 and 0.693). This trend was in a harmony with finding obtained by Hasan *et al*. (2012); Draz *et al*. (2015) and Soliman *et al*. (2016) who stated that, yield losses were correlated intensely with area under disease progress curve. It means that high levels of partial resistance are required to inhibit significant yield damage. The susceptible cultivars with low level of losses in grain yield are considered as tolerant varieties (Parker *et al*. 2004). It is necessary to take into consideration yield performance because a high yielding line with high leaf rust tolerance will have a greater value for wheat breeders and producers. In our study, the reduction in yield components was parallel to AUDPC in both two growing seasons. Giza-168, Sids-13 and Sakha-94 showed lower levels of FRS and AUDPC which exhibited lower levels of yield losses. These cultivars are perfect parents for crossing with other slow-rusting lines that have better resistance to achieve high yield potential with high level of resistance to leaf rust disease. On the other hand, Sids-1 cultivar showed high level values of FRS and AUDPC. In despite of that, its average grain yield potential is similar to the highest yield commercial cultivars. This result indicated that, sids-1 cultivar have high level of tolerance to leaf rust infection.

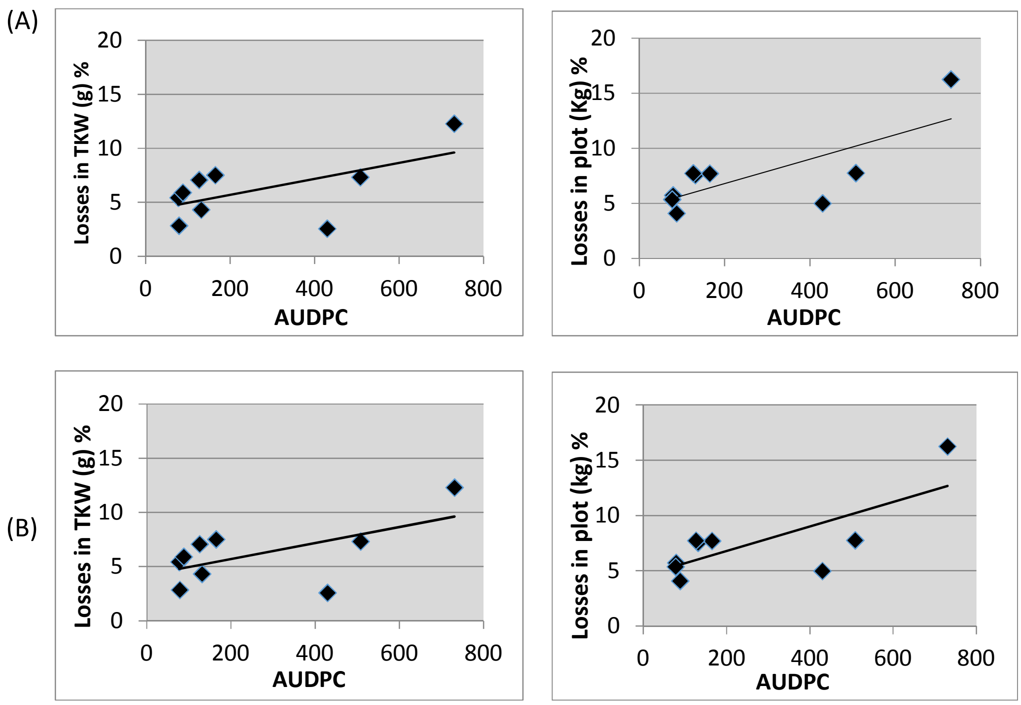


**Fig. 2:** Regression between area under disease progress curve (AUDPC), 100 kernel weight (TKW) and grain yield per plot (A) 2014/2015 and (B) 2015/2016.

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