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REDUCTION IN GRAIN YIELD CAUSED BY LEAF RUST INFECTION IN SEVEN EGYPTIAN WHEAT CULTIVARS

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ABSTRACT: *Leaf rust caused by Puccinia triticina, is the most a widespread foliar disease of wheat in Egypt and worldwide. Yield losses of seven wheat cultivars as affected by leaf rust infection were estimated under field conditions at El-Nubariya Agricultural Research Station, during 2013/14 and 2014/15 growing seasons. Disease severity (%) was recorded (seven days intervals),and each of final rust severity(%) area under disease progress curve (AUDPC) was calculated for the tested cultivars. Final rust severity (%) ranged from 10 % to 90 % in 2013/14 growing season, while it was ranged from in 20 % to 80 %.2014/15. Also, area under disease progress curve (AUDPC) ranged from 101.50 to 1330.0 in 2013/14 growing season, but it was ranged from 185.50 to 1225 during 2014/15 season. The losses grain yield per plot ranged from 3.89% to 32.9 during 2013/14 growing season 5 % on the check variety Giza 139.Likewise, loss in 1000 kerne weigh ranged from 3.54% to 31.24% in 2013/14 from 4.65% to 28.49% in 2014/15, relevant to the two cvs.,sids-12 and Giza139 (check variety) ,respectively. Moreover, yield losses of the other tested cultivars were in between depends on the percentages of rust severity and AUDPC values for each. While, during 2014/15 yield losses per plot ranged from 4.81 % in the wheat cultivar Sids 12 to 28.21 % in the check variety Giza 139. The amount of losses in 1000 kernel weight and plot weight were positively correlated with area under disease progress curve, which means that high levels of has-genetic resistance are needed to reduce or avoid a significant yield loss.*

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

INTRODUCTION

Leaf rust caused by *Puccinia triticina* Eriks. is one of the major biotic stresses of wheat (*Triticum aestivum* L.), making different fluctuations in its production in Egypt and worldwide. Leaf rust is the most widespread wheat rust disease due to its annual occurrence, prolonged presence throughout crop life cycle, high virulence diversity in its populations, and its epidemic nature. It breaks out during anthesis period at the time of grain formation and milling. Also, it lasts long to inflict heavy damage to grain yield, if moderate temperature and high humidity is available and dominate during the growing season (Rattu *et al*., 2010).

Leaf rust causes a 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). It occurs annually in a wide range of climates, wherever wheat is grown and causes significant and economic yield losses, reached to 40% under favorable environmental conditions for the disease (Knott, 1989).

Genetic resistance is still the most effective, economical, and environment friendly method, instead of using expensive

hazardous chemical applications (Pink, 2002 and Shah *et al*., 2014).

It is of great importance to evaluate popular commercial wheat cultivars and other improved wheat varieties that may have the potentiality to reduce the losses in grain yield and replace current susceptible cultivars (Pretorius *et al*., 2007). This study was therefore carried out to determine the level of adult plant resistance to leaf rust in seven Egyptian wheat cultivars, under field conditions. Also, to estimate grain yield losses in the tested cultivars, when exposed to high pressure of leaf rust disease.

MATERIALS AND METHODS

To determine grain yield losses caused by leaf rust infection in seven Egyptian wheat cultivars, the present investigation was carried out at El-Nubariya Agricultural Research Station, during two successive growing seasons i.e. 2013/14 and 2014/15. Wheat seeds of the tested wheat cultivars i.e. Giza 168, Sakha 93, Sakha 94, Gemmeiza 7, Gemmeiza 9, Sids 12 and Giza 139 (as a check variety), were grown in a randomized complete block design (RCBD), with three replicates. Each of the tested cultivars was grown in plots, 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 and/or recommended sowing date (the first half of December), to expose the plants to suitable environment of rust incidence and development. The plots were surrounded by a spreader area, planted with a mixture of highly susceptible wheat genotypes to leaf rust i.e. Morocco and Thatcher.

Artificial inoculation was carried out using a mixture of the more dominant leaf rust races and talcum powder at a ratio of 1:20 (v/v), according to Tervet and Cassel (1951). To maintain crop stand/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^3 /100 litter water) was applied on 10 and 26 February and 8 March.

Leaf rust severity (%) were recorded in all of the tested cultivars, every 7 days intervals from the first 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).

Leaf rust severity % was recorded using a modified Cobb`s scale (Petereon *et al.,* 1948), weekly (7days interval) during the growing seasons. Also, final rust severity (%) was estimated for each treatment under study as the disease severity (%), when the rust infection (leaf rust severity%) reached it`s maximum and final level in the control (untreated and inoculated) plants (Das *et al*.,1993).

The area under disease progress curve (AUDPC) was calculated for each cultivar according to the equation adopted by Pandey *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 weighted by conventional balance. The influence of leaf rust infection on grain yield was determined by comparing the yield of diseased and healthy plants of each cultivar, under study.. 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

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

Statistical analysis:, least significant difference (L.S.D. at 5%) was used to compare yield components according to Snedecor, (1957), While correlation coefficient was used to detect the relationship between yield loss % and each of AUDPC and FRS%.

RESULTS AND DISCUSSION

Disease reaction of the tested wheat cultivars to leaf rust infection:-

The reaction of the seven commercial wheat cultivars to leaf rust (*Puccinia triticina)* at adult plant stage, under field conditions during the two growing seasons the study (2013/14 and 2014/15).Two epidemiological parameters, final rust severity%, and area under disease progress curve were estimated for each cultivar, under study is shown in Table (1).

Final rust severity % (FRS):

During 2013/14 growing season, all of the tested wheat cvs. showed different levels of final rust severity (FRS %) ranged from 10 to 90 % . The wheat cultivars Sids 12, Giza 168, Sakha 94 and Gemmeiza 9, showed the lowest percentages of disease severity i.e. 10 % per each. While, the rest of the tested cultivars as well as the check variety; Giza139, exhibited high percentages final rust severity reached to 90 %..

In 2014/15 growing season, the wheat cultivars Sids 12, Giza 168 and Sakha 94 showed the least percentages of disease severity (%) i.e. 20 % for each. While, the cvs. Gemmeiza 9, Gemmeiza 7, Sakha 93, and Giza 139, showed the highest final rust severity % (ranged from 30 % to 80 %). These results in accordance with those previously obtained by Gamalat Hermas (2014), since, the obtained results during 2010/11, 2011/12 and 2012/13 growing seasons revealed that the wheat culti as seasons of the study. vars Misr 1, Misr 2 and Giza 168 showed high levels of adult plant resistance to leaf rust, as they exhibited low percentages of final rust severity, and low values of AUDPC. It expressed in all the tested cultivars, during the two growing In contrast, Sids 1 and Morocco exhibited high leaf rust severity percentages and high AUDPC values. Also, Shahin and El-Orabey (2014) on their study during 2013/14 and 2014/15growing seasons indicated that wheat cultivars Sids 12, Sids 13 and Misr 2 showed the lowest percentages of disease severity. On the other hand, the wheat cvs. Sakha 93, Gemmeiza 7 and Sids 1 showed the highest percentages of rust severity (each with 70 %).

Area under disease progress curve (AUDPC):-

Data in Table (1) also indicated that AUDPC values run in a parallel line with the final rust severity (%) as it expressed in all the tested cultivars, during the two growing seasons of the study. In 2013/14 growing season, the obtained results showed that the highest values of AUDPC were estimated in the two cvs. Giza139 (check variety) and Sakha 93 i.e. 1330 and 1015, respectively. Whereas, cvs. Sakha 94, Gemmeiza 9, Sids 12, Giza 168 and Gemmeiza 7, exhibited low estimates of AUDPC i.e. 101.5, 101.5, 101.5, 165 and 255.5, respectively.

In 2014/15 growing season, the check variety, Giza 139 and cv. Sakha 93 showed maximum values of AUDPC i.e. 1225 and 910. While, the other cvs. Giza 168, Sakha 94, Sids 12, Gemmeiza 9 and Gemmeiza 7 showed the lowest or minimum values of AUDPC i.e. 185.5, 185.5, 185.5, 220.5 and 290.5, respectively (Table,1).

Table (1): Final rust severity (%) and area under disease progress curve (AUDPC) of leaf rust in seven wheat cultivars, under field conditions at El-Nubariya Agricultural Research Station, during 2013/14 and 2014/15 growing seasons.

Wheat cultivar	2013/14 growing season		2014/15 growing season		Mean	
	Final rust severity (%)	AUDPC	Final rust severity (%)	AUDPC*	FRS%**	AUDPC
Giza 168	10	165.00	20	185.50	15	175.3
Sakha 93	70	1015.00	60	910.00	65	962.5
Sakha 94	10	101.50	20	185.50	15	143.05
Gemmeiza 7	30	255.50	40	290.50	35	273.0
Gemmeiza 9	10	101.50	30	220.50	20	161.0
Sids 12	10	101.50	20	185.50	15	143.5
Giza 139 (check)	90	1330.00	80	1225.00	85	1277.5
L.S.D. at 5 %	**5.88**	**48.39**	**14.87**	**67.16**	**-**	**-**

* AUDPC: Area under disease progress curve.
** FRS (%): Final rust severity (%).

According to the obtained results and on the basis of FRS (%) and AUDPC estimates on the in the two growing seasons under study the tested cvs. could be classified into two main groups The first group included the wheat cultivars which displayed minimum percentages of FRS (%) and low estimates of AUDPC (less than 300). Therefore, they were characterized as slow rusting varieties or partially resistant cultivars. This group included Giza 168, Sakha 94, Gemmeiza 7, Gemmeiza 9 and Sids 12.cultivars. Meanwhile, the second group included the highly susceptible wheat cvs., which revealed higher values of FRS (%) and higher estimates of AUDPC, than those of partially resistant ones. Thus, they were identified as the fast-rusting group of cultivars.. This group included only the two wheat cvs. Sakha 93 and Giza 139.

The previous reports of Wang *et al*., (2005) emphasized that AUDPC is a good and the most reliable estimator of adult plant resistance, under field conditions, as the cultivars which had low AUDPC estimates, may have an adequate and good level of adult plant resistance. Also, Lal Ahamed *et al*. (2004) reported that the susceptible wheat cultivar Agra Local, showed the highest value of AUDPC (1300), while the partially resistant cultivar Kundan showed the least AUDPC value (217). Under the Egyptian field condition, Shahin and El-Orabey (2015) found that the wheat varieties Giza 168 and Gemmeiza 7 exhibited partial resistance, as they showed the lowest values of FRS (%) (did not exceeded up to 250) and the lowest estimates of AUDPC (less than 250). In addition, Fahmi *et al*. (2015) classified the tested wheat varieties into three groups according to the values of FRS (%) and AUDPC. The first group included the wheat cvs. Sids 12, Sids 13, Misr 1, Misr 2, Shandweel 1, Beni Sweif 4 and Beni Sweif 5, which have a complete or race-specific type of resistance. While, the second group included cvs., Giza 165, Giza 168, Sakha 8, Sakha 94, Sakha 95,

Gemmeiza 5, Gemmeiza 7, Gemmeiza 9, Gemmeiza 10, Gemmeiza 11 and Sohag 3, that showed high levels of slow rusting or partial resistance. On the other hand, the third group was the other tested varieties, which characterized as the highly susceptible or fast-rusting ones i.e. Giza 160, Giza 163, Giza 164, Sakha 69, Sakha 93, Sids 1 and Giza 139. The PR cvs. showed the lowest values of final rust severity (%) and lowest estimates of AUDPC, compared to the other varieties under the same field conditions.

Grain yield and yield losses:

Data in Tables (2 and 3) revealed that, 1000 kernel weight (g) and grain yield per plot (kg) showed a significant difference between protected and infected wheat plants of the tested cultivars. These differences were, in fact, due to the differences in disease severity percentages, expressed in the tested cultivars. In 2013/14, the loss % of the 1000 kernel weight ranged from 3.54 % to 31.24 %. The check variety Giza 139, as well as the two susceptible cvs. Sakha 93 and Gemmeiza 7 showed the higher values of loss (%) in 1000 kernel weight (31.24%, 23.18% and 11.74%, respectively), compared to the other cultivars. While, the partially resistant cultivars Sids 12, Sakha 94, Gemmeiza 9 and Giza 168 gave the lowest values of loss (%) of 1000 kernel weight i.e. 3.54%, 3.95%, 4.48% and 5.06 %, respectively.

In 2014/15, the loss % in the 1000 kernel weight ranged from 4.65 % to 28.49 %. The susceptible cvs. Giza 139, Sakha 93, Gemmeiza 7 and Gemmeiza 9, revealed the highest amounts of loss % in 1000 kernel weight (28.49 %, 22.35 %, 16.24 % and 10.69 %, respectively), meanwhile by the three PR cvs. Giza 168, Sakha 94 and Sids 12, showed the lowest 1000 kernel loss (%)(6.24%, 25.48% and 4.65% respectively).

The loss % of grain yield per plot in 2013/14, ranged from 3.89 % to 32.95 %. The check variety Giza 139, as well as the two susceptible cvs., Sakha 93 and Gemmeiza 7, showed the highest amounts of loss % (32.95%, 24.23% and 11.89%, respectively), compared to the other cultivars under study. Meanwhile, PR wheat cultivars Sids 12, Sakha 94, Gemmeiza 9 and Giza 168, exhibited the lowest values of loss % i.e. 3.89%, 3.90%, 4.02% and 4.17%, respectively.

In 2014/15, the loss % in grain yield per plot ranged from 4.81 % to 28.21 %. However, Giza 139 (check variety) and the three susceptible cvs.; Sakha 93, Gemmeiza 7 and Gemmeiza 9, gave the highest values of loss % (28.21%, 23.66%, 14.71% and 10.44 %, respectively). In contrast, the partially resistant cvs., Sids 12, Sakha 94 and Giza 168 showed the lowest amount of loss % in grain yield per plot, as it was 4.81%, 4.96 %and 5.43 % respectively (Table,3).

The previous studies in Egypt, carried out by Nazim *et al*. (1983), Hermas, Gamalt (2014), Shahin and El-Oraby (2016) and Soliman *et al*. (2016) evaluate the reduction in grain yield of same local wheat cultivars commonly grown in the farmer`s fields under different epiphytotic levels of leaf rust .They, in general, emphasized that loss in grain yield of the tested cultivars was significantly differed according to the varietal response or the level of host-genetic resistance to leaf rust passed by the studied cultivars, Since they reported that high infection with leaf rust can severely reduce grain yield in the highly susceptible cultivars, while growing the resistant cultivars will reduce the loss in grain yield .On the other hand, they reported that yield loss was strongly correlated with each of final rust severity (FRS%) and area under disease progress curve (AUDPC). Also, they suggested that, high levels of resistance are needed, not only to avoid the future occurrence of an epidemic, but also to prevent significant yield loss.

Table 2: Effect of leaf rust infection on 1000 kernel weight (g) and plot weight (kg) of seven wheat cultivars at El-Nubariya Agricultural Research Station, during 2013/14 growing season.

Wheat cultivar	1000 kernel weight (g)			Plot weight (kg)		
	Infected	Protected	Loss (%)	Infected	Protected	Loss (%)
Giza 168	32.21	33.93	5.06	19.31	20.15	4.17
Sakha 93	22.93	29.85	23.18	13.54	17.87	24.23
Sakha 94	30.41	31.66	3.95	18.75	19.51	3.90
Gemmeiza 7	25.57	28.97	11.74	13.41	15.22	11.89
Gemmeiza 9	29.88	31.28	4.48	19.11	19.91	4.02
Sids 12	33.22	34.44	3.54	20.25	21.07	3.89
Giza 139 (check)	19.17	27.88	31.24	10.01	14.93	32.95
L.S.D. at 5 %	**2.37**	**0.96**	**-**	**1.64**	**0.83**	**-**

Table 3: Effect of leaf rust infection on 1000 kernel weight (g) and plot weight (kg) of seven wheat cultivars at El-Nubariya Agricultural Research Station, during 2014/15 growing season.

Wheat cultivar	1000 kernel weight (g)			Plot weight (kg)		
	Infected	Protected	Loss (%)	Infected	Protected	Loss (%)
Giza 168	31.87	33.99	6.24	21.09	22.30	5.43
Sakha 93	23.31	30.02	22.35	13.68	17.92	23.66
Sakha 94	31.72	33.53	5.40	19.37	20.38	4.96
Gemmeiza 7	24.44	29.18	16.24	13.28	15.57	14.71
Gemmeiza 9	31.5	35.27	10.69	19.22	21.46	10.44
Sids 12	34.62	36.31	4.65	22.77	23.92	4.81
Giza 139 (check)	20.13	28.15	28.49	10.97	15.28	28.21
L.S.D. at 5 %	**1.52**	**0.73**	**-**	**2.36**	**0.95**	**-**

Relationship between AUDPC and loss% in the 1000 kernel weight and loss% in plot weight:

The relationship between loss% in 1000 kernel weight and loss that in plot weight with AUDPC estimates was assessed through the regression analysis of the obtained data, during 2013/14 and 2014/15 growing seasons. A significant positive relation has been found between AUDPC

and loss in 1000 kernel weight during the two growing seasons (R^2 = 0.975 and 0.878) (Fig. 1). Also, regression analysis revealed a significant linear relationship (R^2 = 0.976 and 0.908 in 2013/2014 and 2014/2015, respectively) between loss in plot weight and AUDPC.

Relationship between FRS (%) and loss% in the 1000 kernel weight and loss% in plot weight:

The relationship between loss% in 1000 kernel weight and loss in plot weight and FRS (%), was determined through regression analysis, during 2013/14 and 2014/15 growing seasons.

As illustrated in Fig.,2, yield loss% either in 1000 kernel weight or in plot weiht was strongly correlated with final rust severity(FRS%), expressed in the tested cultivars. However,a Positive and significant relation has been found between FRS (%) and loss in 1000 kernel weight during the two growing seasons (R^2 = 0.996 and 0.980) (Fig. 2). Also, regression analysis revealed a significant linear relationship (R^2 = 0.997 and 0.983) was found between loss in plot weight and FRS (%).

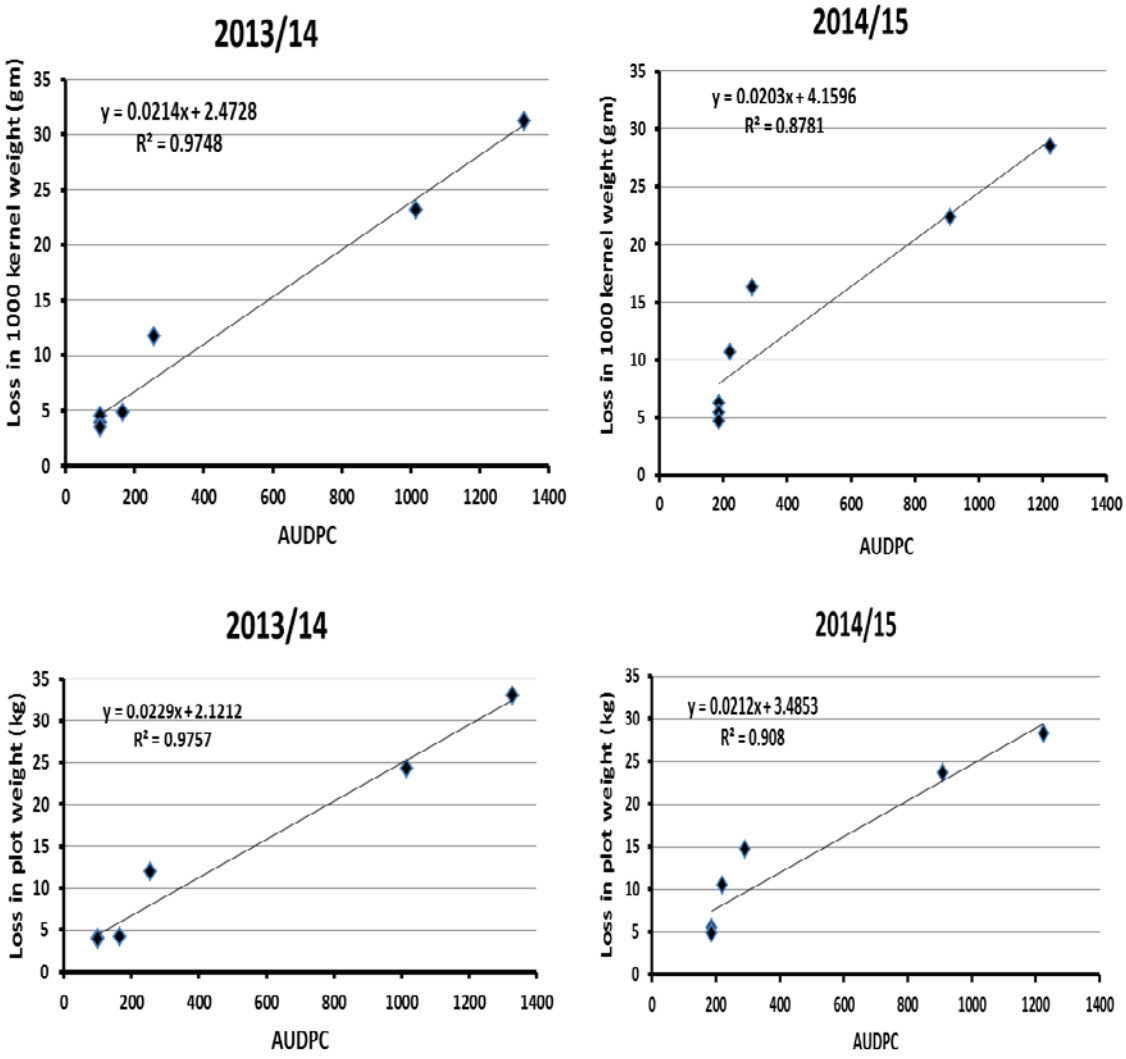

Fig. (1): Association between AUDPC and loss(%) in both 1000 kernel weight and plot weight for seven Egyptian wheat cultivars tested at Nubariya Agricultural Research Station, during 2013/14 and 2014/15 growing seasons.

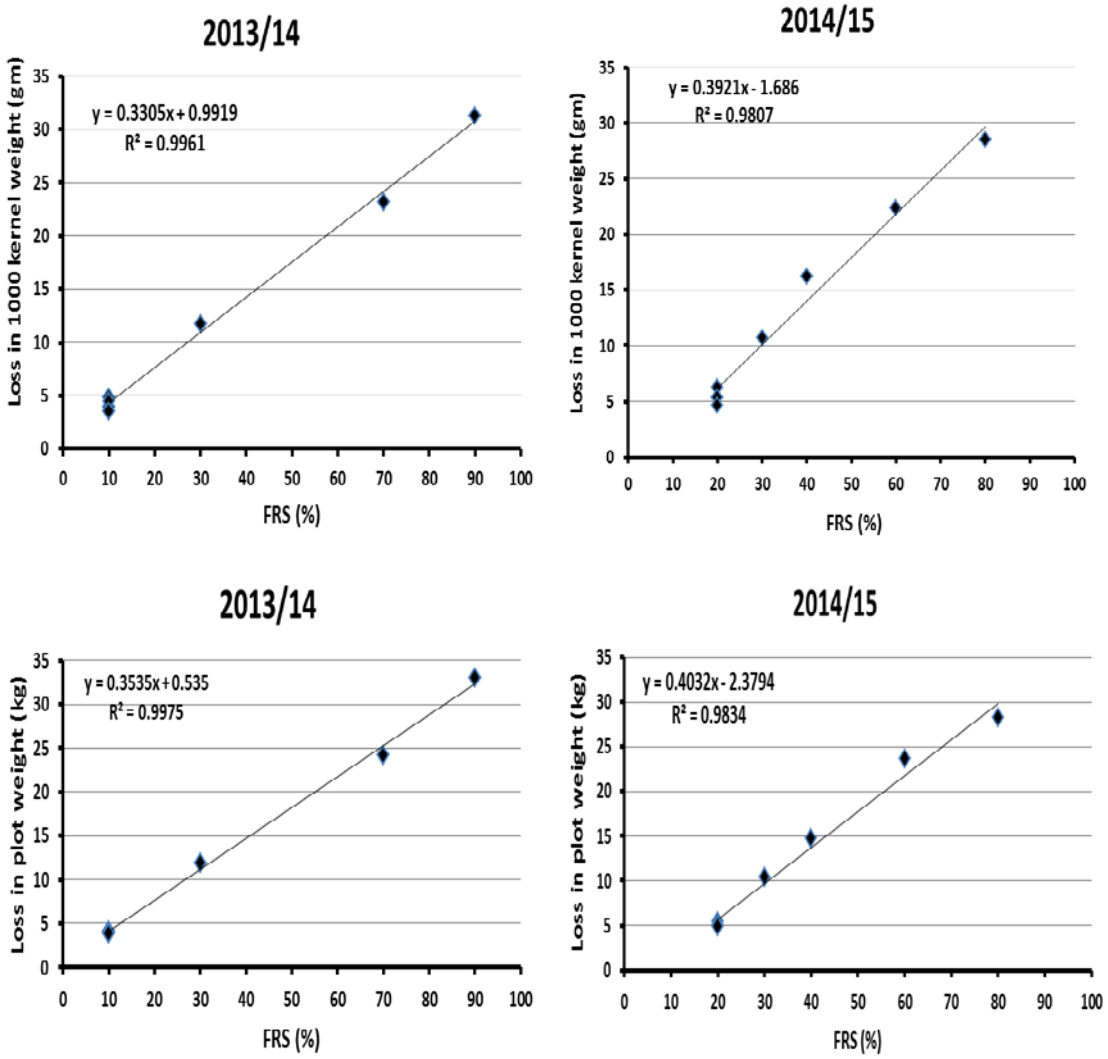

Fig. (2): Association between FRS (%) with loss in 1000 kernel weight and loss in plot weight for seven Egyptian wheat genotypes tested at Nubariya Agricultural Research Station during 2013/14 and 2014/15 growing seasons.

These estimates results are in a harmony with those reported in the previous studies carried out by Wanyera *et al*. (2009) and Loughman *et al*. (2005). Ochoa and Parlevliet (2007) as they reported that yield loss% was strongly correlated with area under disease progress curve, On overall basis cultivars with maximum disease severity had lower mean of grain yield and vice versa (Shaner *et al*., 1978). Ochoa and Parlevliet (2007) reported that yield loss was strongly correlated with AUDPC. Likewise, El-Shamy *et al*. (2011) found that a significant correlation between mean disease severity and loss% in 1000-kernel and grain yield/plant.

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النقص في محصول الحبوب المتسبب عن الاصابة بمرض صدأ الاوراق في سبعة اصناف قمح مصرية

وليد محمد العرابى ، نجوه إبراهيم عبد الملك ، ممدوح عبد المنعم عشماوى ، محمد عبد الحليم أبو زيد

قسم أمراض القمح – معهد بحوث أمراض النباتات – مركز البحوث الزراعية – الجيزة – مصر

الملخص العربي

يعتبر مرض صدأ الاوراق في القمح المتسبب عن الاصابة بفطر بكسينيا تريتسينا اكثر امراض المجموع الخضري انتشارا في مصر و معظم دول العالم . تم تقدير الفاقد في المحصول في سبعة اصناف من القمح بعد اصابتها بمرض صدأ الاوراق تحت ظروف الحقل في محطة البحوث الزراعية بالنوبارية خلال موسمي الزراعة 2014/2013 و 2015/2014 . تم تسجيل شدة الاصابة كل سبعة ايام لتقدير شدة الاصابة النهائية للمرض و حساب المساحة الواقعة تحت منحني الاصابة المرضي لكل صنف تحت الدراسة . تراوحت شدة الاصابة النهائية للمرض بين 10% الي 90% في الموسم الزراعي 2014/2013 ، بينما 2015/2014 تراوح بين 20% الي 80% . و ايضا تراوحت قيم المساحة الواقعة تحت منحني الاصابة المرضي من 101.5 الي 1330 في الموسم الزراعي 2014/2013 ، بينما تراوحت تلك القيم من 158,5 الي 1225 . و من ناحية اخري فقد تراوح الفاقد في محصول الحبوب للحوض بين 3.89% في الصنف سدس 12 الي 32.90% في صنف المقارنة جيزة 139 خلال موسم 2014/2013 . بالاضافة الي ذلك فقد اعتمد الفاقد في المحصول في باقي التراكيب الوراثية المختبرة علي قيم شدة الاصابة النهائية و قيم المساحة الواقعة تحت منحني الاصابة المرضي لكل صنف من الاصناف المختبرة و ايضا قد تراوحت الخسارة في وزن الألف حبة ما بين 3,54 الي 31,24% في موسم 2014/2013 و 4,65 الي 28,49% في موسم 2015/2014 ، و ذلك فيما يتعلق بصنفي القمح سدس 12 ، جيزة 139 (المستخدم كمقارنة) علي التوالي . بالاضافة الى ذلك مقدار الخسارة فى وزن الالف حبة ووزن الحوض ارتبطت ايجابيا مع المساحة الواقعة تحت منحنى المرضى . وفى النهاية فان مقدار الخسارة الناتجة عن الاصابة بمرض صدا الاوراق سواء فى وزن الالف حبة او وزن الحبوب للقطعة التجريبية ،قد ارتبط ايجابيا ومعنويا مع كل من المساحة الواقعة تحت منحنى الاصابة المرضى ،والشدة النهائية للمرض. وبالتالى فالحاجة ملحة الى زراعة اصناف القمح التى تتمتع بمستويات عالية من المقاومة الوراثية ،وذلك لتقليل الخسارة العالية فى محصول القمح.