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Effect of Yellow Rust Disease on Quantitative and Qualitative Traits of Some Wheat Genotypes Under Rain-fed Conditions

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Abstract

Yellow rust incited by *Puccinia striiformis* Westend, is one of the most important fungal disease of wheat in the north of Iraq including Kurdistan region. The study was conducted to determine effect of yellow rust disease on grain yield and yield component of seven wheat genotypes with diverse levels of resistance and susceptibility under natural epidemics of the disease during 2011 at Bakrajo Experimental Station, Sulaimani. Two treatments applied for each genotype, the first one protected from the disease using Bayfidan 250EC while the second one exposed to the disease. Results revealed that yellow rust disease significantly decrease grain yield of the tested genotypes by 3.5 to 35% under natural epidemic of the disease at Bakrajo. Yield losses were mainly attributed to significant effect of the disease in reduction of grain weight by 1.6-17.7% and number of grain per spike by 2.3-13%. Positive correlation between the Areas under Disease Progress Curve (AUDPC) values and the amount of grain yield loss in wheat genotypes were detected. Furthermore, the disease significantly affects qualitative characters of wheat grains by decreasing Protein and gluten content of the genotypes.

Keywords: Stripe rust, *Puccinia striiformis*, *Triticum aestivum*, Yield loss, Fungal diseases.

INTRODUCTION

Rust diseases have been a problem for small grains cereals probably since domestication. The pathogens can adapt to many different types of environments, evolve rapidly and spread quickly over long distances [20]. Rust fungi are known as specialized pathogens; each rust species is divided into specialized forms having a specific host genotype to attack under particular environmental conditions [28]. The genus *Puccinia* includes three important species that attack wheat and completely dependent on living tissues for reproduction and survive [12]. Yield losses due to wheat rusts can be substantial depending on the crop development stage, the level of resistance as well the environmental conditions [28].

In Iraq, wheat production is not stable and it may change according to wheat areas, locations and seasons due to many biotic and abiotic factors. The main abiotic constraints are drought in the north and salinity in south and center. Wheat rust diseases are among the biotic constraints that can affect wheat yield quantitatively and qualitatively. Three kinds of rust disease were known to attack wheat in Iraq, Brown rust incited by *P. triticina* f. sp *tritici*, styellow rust incited by *P. striiformis* f. sp. *tritici* and stem rust incited by *P. graminis* f. sp. t*ritici*. Among the three kinds of rusts, brown rust is more important in the central parts of Iraq, stem rust in the south, and yellow rust in the northern [8]. Recently, yellow rust disease is well distributed in all wheat growing areas in Iraq. Disease severities are differing between seasons, according to many factors, particularly wheat cultivars, the time of disease onset and the environmental conditions including the amount of rain fall, humidity and temperature, and the amount of azotic fertilization used by farmers [4]. AL-Maaroof et al. [7] showed that yellow rust caused 33% loss in grain yield of wheat under natural epidemic of the disease. The reduction was due to significant effects of the disease on the thousand grain weight. Yellow rust is an economically important wheat disease in all continents where wheat is grown [26]. It has been detected in more than 60 countries around the world [15]. The high epidemics of the disease in 2010 resulted from high yield losses in Turkey 1.2 million tons, 25 MT in Iran and 25-35% from the total wheat production in Ozpakestan and Morocco [30]). Yellow rust considered to be the most prevalent and damaging rust in Iran and occurred in every season. Torabi, et al.[44] stated that the disease was severe in Iran in 1994 and caused damage in wheat field more than 1.5 million tones. While AL-Maaroof [5] recognized that yellow rust caused 29-50% reduction in grain yield in Iraq in 1994, meanwhile yield reduction was more than 33% on maxipak under natural epidemic of the disease in 1998 [7]. Serious epidemic of yellow rust was detected in most of the wheat growing areas in Iraq which resulted from high reduction in the national grain yield [9].

Past preliminary results show that stripe rust could reduce grain yield by 10–90% in most of the Asian countries. [38]. Yellow rust was quite destructive in China, yield losses reached to 3.2 million tons [45]. Severe losses in wheat yield were detected in different USA states in 2004, yield reduction was significantly high in California (25%). The total estimated yield losses in wheat production in USA was 273 872 t in 2004 [15]. Synman, et al. [41] stated that yellow rust is one of the important wheat diseases in Australia and can cause extensive yield loss. The disease could affect 80% of wheat production area in Turkey, especially in the cooler and humid regions [21]. Yellow rust affects yield by reducing the green leaf area which affects the sugar supply to the developing seed. The flag and second leaves are the most important leaves for producing sugars for the developing grain (Murray, et al., 2005). Significant yield losses can be expected due to flag leaf infection, which is responsible for more than 70% of grain filling [27].

The disease also results from changes in grain quality. The major changes include losses of test weight, which in turn, reduced the yield of flour from the affected grain, increasing dough breakdown values and reducing extensor graph heights [31].

The current study is conducted to evaluate the effect of yellow rust disease on qualitative and quantitative traits of some wheat genotypes under rain-fed conditions.

MATERIALS AND METHODS

The experiments were conducted at Bakrajo Research Station Directorate, 10km south of Sulaimania (Lat. N35.32.375, Long.E045.73.825, Elev.703) during the growing seasons 2011, which is rain feed area.

Development of yellow rust on different wheat genotypes

Seven wheat genotypes were used in the experiment, four of them (Al-8/70, Al-84, Al-8/172 and Al-124) representing the advance promising resistance lines of improving rust resistance program in Iraq. While Araz, Tamuz 2 and SaberBeg are local cultivars. The tested genotypes explored diverse range of wheat reaction to yellow rust disease started from resistant reaction (R) in genotype AL-124 to highly susceptible reaction (HS) in SaberBeg, while Araz and AL-8/70 were susceptible (S), Tamuz 2 was moderately susceptible to susceptible (MS-S), AL-84 was moderately resistant to moderately susceptible (MR–MS), and Al-8/172 was moderately resistant (MR) [10]. A total of 120g seeds from each genotype were grown in 25m^2 plots using RCBD with three replications with one-meter interval between two plots and two meter between blocks. Two treatments were applied to each genotype; the first one protected from yellow rust disease by using two applications of Bayfidan 250EC (Traidemnol) at the rate of 0.5L/ha. While the second treatment was exposed to the disease under the natural epidemic of yellow rust in the field. The field was entirely cultivated with the boarder susceptible cultivars as a trap and spreader of *P. striiformis* inoculums in the field.

Disease Scoring And Data Analyses

Infection types and disease severities were assessed at different wheat growth stages using Lewellen score [24], where 0= no visible infection; R= Resistant, necrotic area with or without small pustules; MR= moderately resistant, small pustules surrounded by necrotic areas, M= intermediate; pustules of variable size, some necrosis or chlorosis. MS= moderately susceptible, medium sized pustules, no necrosis but some chlorosis possible, S= susceptible, large pustules, no necrosis or chlorosis. While disease severities were estimated by using the modified Cobb scales [32], which depends on comparing the infected wheat leaves with the theoretical diagram showing the frequency of uredia for particular percentage disease severity. Data were randomly collected from 30 plants/plot including lines no. 2, 5 and 7 in each plot.

The coefficient of infection (C.I) of yellow rust on each cultivar was calculated by multiplying the severity times with a constant values given to the host response; where immune (I) =0.0, R=0.2, MR =0.4, M= 0.6, MS =0.8 and S=1.0. This makes it easy to rank or statistically compare between genotypes or nurseries [35].

C. I = DS *IT

Where DS=Disease severity، IT=Infection type.

The AUDPC was calculated by the trapezoidal integration of the disease severity in time, considering the whole period evaluated as follows,

AUDPC =

Where X= the disease severity (percentage of plant diseased); n = the number of evaluations, and ((ti+1)- ti) the time interval (days) between two consecutive evaluations [16].

Effect of yellow rust on grain yield and yield components

To estimate grain yield loss in each cultivar due to yellow rust disease, Spikes of each cultivar in each treatment was harvested from on meter square from the center of each plot at the time of maturity of the crop. The spikes were threshed and the grain yield of each genotype was weighted by electronic balance. Effect of yellow rust disease on grain yield was determined by comparing the yield of diseased and healthy genotypes. Yield losses due to yellow rust was calculated on the basis of Area under Disease Progress Curve (AUDPC). While yield component losses were estimated by selection of 50 spikes from each plot randomly at maturity stage, kernels of the spikes were mechanically separated and the ingredients of yield components such as grains weight of the spike, number of grains/spike, weight of 1000 grains were calculated for each genotype in each plot and treatments, while number of spikes in 1m^{2}were counted before harvesting. The data were statistically analyzed by using (L.S.D) program at 0.05 level, [23]. The percentage of loss in grain yield and yield components were calculated in each treatment by using the following equation: -

Percentage of yield loss% =[1-(Yd/Yh)] x 100

Where, Yh= grain yield or yield components (weight of spike grains, number or weight of 1000 grains of the health plants (protected plants). Yd = grain yield or yield component (weight of spike grains, number or weight of 1000 grains of the infected plants (unprotected plants).

Effect of yellow rust on quality of the grains

The qualitative characters of the grains were conducted in the central laboratories of quality control in Baghdad / General Company of grains commerce except the protein test which was conducted in Seed Technology Center, Ministry of Science and Technology.

Infralyzer 400 used to determine protein content in the hole seeds of each genotypes, 10 gm of seed from each genotype were taken (three samples from each one) then conformed to flour by a grinder (5 gm) samples from each treatment were put in the instrument .Results were recorded on the monitor of the instrument after electronic comparison inside the instrument. The Glutamic 2200 used to evaluate the wet gluten of the flour of the genotypes. Ten gram of flour from each genotype and treatment were taken (three samples from each one) after adjustment of the wet content of the flour to (14 %). The dry gluten obtained by desiccation of wet gluten ball by using the oven (glutaric2020) for two minutes.

RESULTS AND DISCUSSIONS

Host reaction of different wheat genotypes with *Puccinia striiformis*

Table (1) results shows that there are wide range of host reaction between the tested genotypes with the pathogen population of *P. striiformis* started from high resistance reaction in Al-124 genotype to high susceptibility in SaberBeg, susceptible in Araz and Al-8/70, moderate susceptible to susceptible in Tamuz 2, moderate resistance to moderate susceptibility in Al-84, and moderate resistance in Al-8/172. Table (1) also shows that there are high significant differences between the tasted genotypes in coefficient of infection value (C.I) The highest value of (C.I) was recorded in SaberBeg (100.0) followed by 82.7 in Al-8/70 while the lowest value of (C.I) was recorded on Al-124 (0.9) followed by 4.9 in Al-8/ 172. Coefficient of infection value in SaberBeg was significantly surpassed all other genotypes. Significant differences also detected between all other genotypes in C.I value except Al-124 and Al-8/172, (table 1). The coefficient of infection value facilitates the statistical ranking or comparison between genotypes with different responses to the disease. Adding of two separate factors in a single value results in nearly equal coefficient but from different disease score.

The differences in genetic background of resistance reflect the differences in the infection type toward the disease. The infection type in some cultivars may be changed by time due to appearance of new virulence in the pathogen population. Some cultivars may stay resistant to many years but after a period it become susceptible, Al-Maaroof [5] refer that the infection type of Al-Eze was moderately resistant at the time of release in 1995 while after a decade infection type of the same cultivar changed to susceptible [3]. This shows the ability of the pathogen to change itself to new virulence's and more aggressive genotypes which may happen by sexual reproduction, combination or crossing methods and other mechanisms that the pathogen could develop itself, so it is very important to study the pathogen population every year to recognize the new virulence that may come from other countries particularly the disease is air borne, which made it very difficult to control, and it may overcome resistance of some cultivars after a time of release as resistant cultivars as it is clear in boom and burst cycle [35], many researchers confirmed this fact [11, 42]. They mentioned to the ability of rust pathogens to develop themselves and produce new races that were not be founded before. The resistant reaction of Al-124 and Al-8/172 may be due to presence of more than one resistant genes in their genetic back grounds which are absent in other susceptible cultivars. Possessing of more than one resistant gen increase the time of resistance stability in each cultivar, also the pathogen needs more time to develop virulence against the resistant gens, as it is mentioned by [3, 25, 29].

Table 1. Host reaction of different wheat genotypes with yellow rust under natural epidemic of the disease at Bakrajo Experimental Station, Sulaimania.

Genotype	Infection Type	Disease Severity %	C.I
SaberBeg	HS	100.0	100.0
Araz	S	77.5	77.5
Tamuz 2	MSS	50.0	45.0
AL-8/70	S	82.7	82.7
AL-84	MR-MS	25.6	20.5
AL-8/172	MR	12.3	4.9
AL-124	R	4.3	0.9
Mean	-	50.3	23.7
LSD 0.05		6.3	4.3

Effect of yellow rust disease on thousand grain weight

Data analyses of table (2) revealed that yellow rust disease significantly decreased thousand kernels weight of the tested genotypes. The disease has significantly decrease the mean of this traits by 8.6 at Plevel in the unprotected treatment (36.67) comparing with the protected treatment (40.12) despite the genotype. The highest reduction (17.7 %) was observed in the highly susceptible cultivar SaberBeg, followed by 11.3 % in the susceptible genotype Al-8/70. The amount of reduction in thousand grain weight mainly depends on the AUDPC values and responses of different genotypes to the disease. The highest reduction in SaberBeg and Al-8/70 resulted from high AUDPC value of about 252 and 158 respectively. Yellow rust significantly decreased 1000 grain weight in Araz, Tamuz 2, Al-84 and Al-8/172 by 9.7, 8.8, 6.5 and 5.7 respectively, while no any significant effect of the disease was observed on the resistant genotype Al-124. Significant differences in 1000 kernel weight between the genotypes were clear. Tamuz 2 significantly surpassed all other genotypes in 1000 kernels weight (46.93) followed by Al-8/172. While SaberBeg (31.45) showed the lowest value. In presence of yellow rust, no significant differences were detected between Al-124 and Al-8/172, although there were significant differences between them in disease absence.

The present investigation is supported with the former research of smith, *et al*. [40] who found that stripe rust causes 46% loss in grain yield in rain fed areas. Afzal, et al. [2], referred to significant negative correlation between kernel weight with and proportion of leaf area affected by stripe rust. The correlation coefficient (-0.9185) depicted high significant effect of stripe rust on decreasing 1000 kernel weight ultimately the wheat yield. From these we could conclude that the disease cause reduction in the mean of thousand grain weight and the yield of susceptible cultivars, similar studies also confirmed this fact [5, 19, 25, 37, 39].

Effect of yellow rust on number of kernels per spike

The results of table (3) refer to significant effect of yellow rust disease on the numbers of kernels in each spike at P, the disease significantly decreased number of kernels/spike in the susceptible cultivars SaberBeg, Al-8/70 and Araz by 13.0, 10.7 and 9.6 respectively. While in the moderately resistant to moderately susceptible cultivars Tamuz 2 and AL-84 by 8.3 and 6.0 % respectively. No any significant effect of the disease was observed on the resistant and moderately

Table 2. Effect of *P. striiformis f. sp. tritici* on thousand kernels weight of different wheat genotypes under natural epidemic of the disease at Bakrajo Experimental Station

Genotype	Treatment[1]	AUDPC	1000 kernels weight (g)	Reduction %
SaberBeg	Unprotected	252.0	28.40	17.7
	Protected	0.0	34.50	
	Mean	126.0	31.45	
Araz	Unprotected	129.1	36.43	9.7
	Protected	0.0	40.36	
	Mean	64.6	38.40	
Tamuz 2	Unprotected	79.2	44.76	8.8
	Protected	0.0	49.10	
	Mean	39.6	46.93	
AL-8/70	Unprotected	158.0	35.56	11.3
	Protected	0.0	40.10	
	Mean	79.0	37.83	
AL-84	Unprotected	40.0	31.30	6.5
	Protected	0.0	33.45	
	Mean	20.0	32.38	
AL-8/172	Unprotected	21.6	40.33	5.7
	Protected	0.0	42.80	
	Mean	10.8	41.57	
AL-124	Unprotected	7.9	39.90	1.6
	Protected	0.0	40.53	
	Mean	3.95	40.12	
Mean	Unprotected	98.26	36.67	8.6
	Protected	0.0	40.12	
LSD 0.05	Cultivars	6.5	0.78	
	Treatments	4.7	0.43	
	Interaction	9.1	1.23	

Bayfidan was applied twice for yellow rust control during the season.

resistant genotypes AL-124 and AL-8/172. High significant differences in number of kernels/spike were detected between the genotypes at Plevel despite the disease. The highest number of kernels in each spike was detected in AL-84 (79.15) followed by Tamuz 2 (74.32) which were significantly surpassed all other genotypes in the mean of this trait. While the less value was detected in SaberBeg (39.32). No any significant differences were observed in the mean of kernels number/spike between Al-84, Al-8/172 and Al-124. Significant differences also detected between the cultivars in the presence of the disease. The highest number of kernels/spike was recorded in Al-84 followed by Tamuz 2 and Al-124, while the lowest number (36.57) recorded in SaberBeg. The results show clear significant differences in number of kernels/spike in the presence and absence of the disease table (3). Positive relationship was found between AUDPC and the rate of reduction, the highest AUDPC 252.0 in SaberBeg resulted in 13.0 % reduction and significantly surpassed all other treatments followed by Al-8/70 with 158 AUDPC and 10.7% reduction, while the lowest reduction in number of kernels /spike in Al-124 (2.3%) resulted from the lowest AUDPC value which was 7.9. These results explain how yellow rust affect yield of wheat by decreasing the numbers of kernels/spike, this is similar to the results of other researcher [3, 5] who showed similar effect of yellow and leaf rust diseases on different wheat genotype at different location in Iraq. Number of kernels in each spike depends on the growth and development of pills and ovary of the flowers which depends on translocation of water and nutrient substance between the flowers and among the spikes in each plant. Yellow rust infection causes deficiencies in water, nutrient and hormones balance inside the spikes which lead to decrease number of grain in each spike [17, 33].

Table 3. Effect of *P. striiformis f. sp. tritici* on number of kernels/spike in different wheat genotypes under natural epidemic of the disease at Bakrajo Experimental Station

Genotype	Treatment[1]	AUDPC	No. of kernels/Spike	Reduction %
SaberBeg	Unprotected	252.0	36.57	13.0
	Protected	0.0	42.06	
	Mean	126.0	39.32	
Araz	Unprotected	129.1	53.58	9.6
	Protected	0.0	59.58	
	Mean	64.6	56.58	
Tamuz 2	Unprotected	79.2	71.11	8.3
	Protected	0.0	77.53	
	Mean	39.6	74.32	
AL-8/70	Unprotected	158.0	61.69	10.7
	Protected	0.0	69.09	
	Mean	79.0	65.39	
AL-84	Unprotected	40.0	76.69	6.0
	Protected	0.0	81.61	
	Mean	20.0	79.15	
AL-8/172	Unprotected	21.6	63.39	3.6
	Protected	0.0	65.73	
	Mean	10.8	64.56	
AL-124	Unprotected	7.9	63.44	2.3
	Protected	0.0	64.99	
	Mean	3.95	64.22	
Mean	Unprotected	98.26	60.92	7.4
	Protected	0.0	65.80	
LSD 0.05	Cultivars	6.5	1.97	
	Treatments	4.7	1.01	
	Interaction	9.1	2.73	

Bayfidan was applied twice for yellow rust control during the season.

Effect of yellow rust on grain yield

Data analysis of table (4) shows high significant effect of yellow rust disease on grain yield of different wheat genotypes at Plevel. Yellow rust significantly decreased the overall mean of the genotypes by 15.6 % comparing with the control. The highest reduction in grain weight (35.5%) was observed in the highly susceptible cultivar SaberBeg followed by the susceptible cultivars Al-8/70 and Araz by 19.2 % and 17.6 % respectively. The disease significantly decreased grain yield weight in SaberBeg, Al-8/70, Araz, Tamuz 2 and Al-84 by 12- 37 % comparing with the control treatment, while no significant reduction was observed in grain weight of resistant genotype Al-124 and moderately resistant cultivar Al-8/172. In the presence of the disease no significant differences found among AL-8/70, Tamuz 2 and Al-84 but there were high significant differences between other genotypes at P0.05. The lowest grain yield (173.3g) was found in SaberBeg, while the highest grain yield (464.18) was recorded on Al-124. No significant differences in grain yield among Tamuz 2, Al-8/70 and Al-84 in the absences of the disease but there were high significant differences among other genotypes, the highest grain yield (473.4g) was found in Al-124 which was significantly surpassed all other genotypes except Al-8/172. While SaberBeg showed the lowest value (290.9g), followed by Araz (378.5g). Positive correlation between AUDPC and reduction percent was found in all the genotypes, the highest AUDPC value in SaberBeg (252) resulted from the highest reduction in grain yield which was 35.5 % AUDPC, while the lowest one in Al-124 (7.9) resulted from non-significant reduction by 3.7 %.

This result shows that yellow rust disease is very dangerous and causes high reduction in grain yield on susceptible wheat cultivars in Kurdistan region especially on the susceptible wheat cultivars. Tables (4) results shows that yellow rust disease significantly decreased grain yield of the susceptible cultivars 8/70, SaberBeg and Araz compared with other cultivars, grain reduction mainly occurred by decreasing thousand grains weight and numbers of kernels in spikes, while no any significant effect of the disease was observed on other yield components. Reduction of 17.6 – 35.5% of susceptible cultivars grains is mainly related to effect of *P. striiformis* photosynthesis process in leaf, sheath, spike, even the awn [22]. The disease mainly affects the rate and coefficient of photosynthesis particularly at the critical stages of plant growth (flowering to maturity) which results from shrinkage and reduction of kernel size [43]. Also the fungi increased the respiration rate in the infected plants due uncoupling agents which leads to lost high rate of Dioxycarbonate (CO_2) in photosynthesis process, which is responsible for dry matter production in the plants. Beside movement of nutrient and soluble substance and accumulation around the fungi loci to support its growth and reproduction. Decreasing translocation of nutrients from the source to the sink inside the plant leads to shrinkage and production of small grain (Roelfs, and Bushnell, 1985). This study results are similar to finding of [3, 18]. Al-Maaroof, [5] attributed grain yield reduction by yellow rust disease to effect of the fungi reducing thousand grain weights mainly and number of grains in spike secondly. Also he mentioned that the amount of reduction depends on reducing growth stage at the time yellow rust infection, infection rate, and susceptibility of cultivar and suitability of the environmental conditions. Positive correlation was observed between the Area Under Disease Progressive Curve (AUDPC) and the amount of grains yield loss in wheat cultivars Figure (1). High AUDPC values resulted from high grains yield loss in wheat cultivars. The highest AUDPC in SaberBeg that caused high reduction in grains yield comparing with the resistant genotype Al-124which has the lowest AUDPC vales and grain reduction. This correlation is similar to other scientist findings [3, 5, 6, 35].

Table 4. Effect of *P. striiformis f. sp. tritici* on grain yield of different wheat genotypes under natural epidemic of the disease at Bakrajo Experimental Station

Genotype	Treatment[1]	AUDPC	Grain Yield/m² (g)	Reduction %
SaberBeg	Unprotected	252.0	173.3	35.5
	Protected	0.0	268.5	
	Mean	126.0	220.9	
Araz	Unprotected	129.1	341.93	17.6
	Protected	0.0	415.03	
	Mean	64.6	378.46	
Tamuz 2	Unprotected	79.2	384.2	15.3
	Protected	0.0	453.7	
	Mean	39.6	418.95	
AL-8/70	Unprotected	158.0	354.2	19.2
	Protected	0.0	438.5	
	Mean	79.0	391.2	
AL-84	Unprotected	40.0	377.56	11.9
	Protected	0.0	428.78	
	Mean	20.0	403.17	
AL-8/172	Unprotected	21.6	438.33	6.3
	Protected	0.0	467.8	
	Mean	10.8	453.03	
AL-124	Unprotected	7.9	464.18	3.7
	Protected	0.0	482.5	
	Mean	3.95	473.34	
Mean	Unprotected	98.26	356.1	15.6
	Protected	0.0	422.12	
LSD 0.05	Cultivars	6.5	25.3	
	Treatments	4.7	13.1	
	Interaction	9.1	37.2	

Bayfidan was applied twice for yellow rust control during the season.

resistant genotypes AL-124 and AL-8/172. High significant differences in number of kernels/spike were detected between the genotypes at Plevel despite the disease. The highest number of kernels in each spike was detected in AL-84 (79.15) followed by Tamuz 2 (74.32) which were significantly surpassed all other genotypes in the mean of this trait. While the less value was detected in SaberBeg (39.32). No any significant differences were observed in the mean of kernels number/spike between Al-84, Al-8/172 and Al-124. Significant differences also detected between the cultivars in the presence of the disease. The highest number of kernels/spike was recorded in Al-84 followed by Tamuz 2 and Al-124, while the lowest number (36.57) recorded in SaberBeg. The results show clear significant differences in number of kernels/spike in the presence and absence of the disease table (3). Positive relationship was found between AUDPC and the rate of reduction, the highest AUDPC 252.0 in SaberBeg resulted in 13.0 % reduction and significantly surpassed all other treatments followed by Al-8/70 with 158 AUDPC and 10.7% reduction, while the lowest reduction in number of kernels /spike in Al-124 (2.3%) resulted from the lowest AUDPC value which was 7.9. These results explain how yellow rust affect yield of wheat by decreasing the numbers of kernels/spike, this is similar to the results of other researcher [3, 5] who showed similar effect of yellow and leaf rust diseases on different wheat genotype at different location in Iraq. Number of kernels in each spike depends on the growth and development of pills and ovary of the flowers which depends on translocation of water and nutrient substance between the flowers and among the spikes in each plant. Yellow rust infection causes deficiencies in water, nutrient and hormones balance inside the spikes which lead to decrease number of grain in each spike [17, 33].

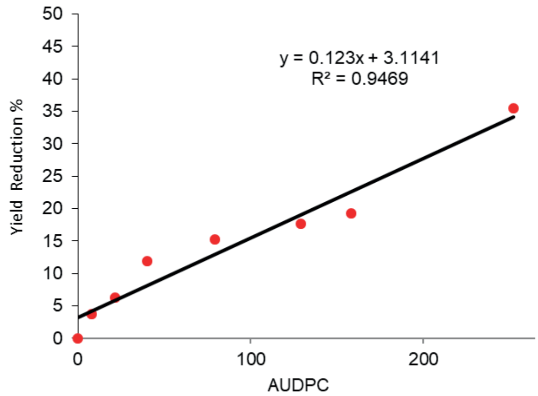

Fig 1. Regressions and correlation relation between AUDPC of *P. striiformis f.sp. tritici* and yield losses on different wheat genotypes at Bakrajo Experimental Station.

Effect of yellow rust on grain quality

Table (5) show some physio- chemical properties of wheat grains of some wheat genotypes protected and infected by yellow rust. It is clear that no significant differences in flour extraction rates between protected and unprotected cultivars. Yellow rust disease significantly decreased protein and gluten content of wheat flour in the un protected treatment comparing with protected ones. The highest reduction was observed on the susceptible wheat cultivar SaberBeg which was 14.7 and 7.6% respectively, followed by AL-8/172. While no significant effect of the disease on gluten and protein content was observed in Al-124 and Al-84.

Chemical quality of flour of all wheat genotypes protected from yellow rust infection was improved, where protein, wet gluten ratio increased significantly compared with the unprotected treatments. The highest protein content (17.7) was detected in SaberBeg significantly surpassed all other genotypes in protein content except Al-84. No significant differences in protein content were observed among other genotypes except Al-8/70. SaberBeg also surpassed all other genotypes in gluten content except Al-8/172. These results were similar to findings of [3, 5], but O´Brien, et al. [31] stated to shriveling of grains increase of the genotypes protein content. Result showed that the yellow rust effects on flour extraction rate, protein content and wet gluten, this effect will increase by increasing susceptibility of wheat cultivars to the disease. Yellow rust disease decrease protein rate in wheat grains due to inhibition the activity of protein synthesis enzymes particularly Nitrate reductase, and increasing the activity of lytic enzyme during seed formation stage in the infected tissue [1]. The total amount of protein in rusted cereal tissues sometimes increases 20-50% on afresh-weight basis, much of the total protein can be assumed to be use in developing the fungus body, especially at sporulation and thereafter, although the total host protein declines, the evidence for accelerated RNA metabolism suggests that synthesis of some host proteins might been enhanced by rust infection, especially before sporulation [13].

Table 5. Effect of *P. striiformis f.sp. tritici* on some chemical and physical properties of different wheat genotypes under natural epidemic of the disease at Bakrajo Experimental Station.

Genotype	Treatment[1]	Flour Extraction %	Reduction %	Protein %	Reduction %	Wet Gluten %	Reduction %
SaberBeg	Unprotected	76.0	2.3	16.3	14.7	36.0	7.6
	Protected	77.8		19.1		39.0	
	Mean	76.9		17.7		37.5	
Araz	Unprotected	78.4	2.1	15.8	7.1	33.1	6.2
	Protected	80.1		17.0		35.3	
	Mean	79.3		16.4		34.2	
Tamuz 2	Unprotected	81.4	+1.7	15.5	6.6	34.0	5.5
	Protected	80.0		16.6		36.0	
	Mean	80.07		16.05		35.0	
AL-8/70	Unprotected	81.1	0.9	15.1	7.4	31.2	6.1
	Protected	81.8		16.3		33.2	
	Mean	81.5		15.7		32.2	
AL-84	Unprotected	79.2	2.3	16.8	5.6	32.1	3.6
	Protected	81.1		17.8		33.3	
	Mean	80.2		17.3		32.7	
AL-8/172	Unprotected	81.4	+0.7	16.1	4.2	35.5	4.0
	Protected	80.8		16.8		37.0	
	Mean	81.1		16.5		36.3	
AL-124	Unprotected	79.8	2.6	16.1	1.2	32.0	3.0
	Protected	81.9		16.3		33.0	
	Mean	80.9		16.2		32.5	
Mean	Unprotected	79.61		15.95	6.9	33.41	
	Protected	80.50		17.13		35.23	5.2
LSD 0.05	Cultivars	N.S		0.6		0.78	
	Treatments	N.S		0.23		0.51	
	Interaction	N.S		0.75		1.21	

Bayfidan was applied twice for yellow rust control during the season.

CONCLUSIONS

From the present study results we can conclude that yellow rust disease significantly decreases grain yield of wheat in different genotypes by 3.7–35% under natural epidemic of the disease in rain-fed conditions at Sulaimani. The amount of yield loss depends on the susceptibility of the tested cultivars and disease severity on each genotype. Grain yield reduction of wheat attributed mainly to the effect of the disease on grain weight and the number of kernels per spike.

There was positive correlation between grain yield loss and the Area Under Disease Progress Curve (AUDPC) of yellow rust in different genotypes. Moreover, it could be concluded that yellow rust disease significantly decreases gluten and protein content of wheat grains in different genotypes. The advance promising resistant wheat genotype Al-124 explored high yield potential which significantly surpassed all other wheat genotypes under Sulaimani environmental conditions except Al- 8/172.

REFERENCES

[1] Abdul latif, A.R. (1987). Physiology and growth of Agricultural Crop Under arid Zones. Mosul University press. Ministryof higher education, Baghdad, Iraq.

[2] Afzal, S.N., Haque, M., Ahmedani, M., Abdulrauf, M.M., Firdous, S., Rattu, A., and Ahmed, I. (2008). Impact of striperust on kernel weight of wheat varieties sown in rain fed areas of Pakistan. Pak. J. Bot., 40: 23- 929.

[3] AL-Azawi, E. (2005). Epidemiological studied of wheat leaf rust and its effects on quantities and qualities characters of grains, MSC, thesis, University of Baghdad, Collage of Agriculture.

[4] Al-Baldawi, A.A. (1993). Occurrence and importance of wheat and barley diseases in Iraq. Proc. of the work shop on Technology transfer in the production of cereals and legumes. 20-22 Sept.1993, Mosul, Iraq. Pp:106-113.

[5] Al-Maaroof, E. M. (1997). The role of variety mixtures in disease control of wheat rusts caused by Puccinia reconditeand P. striiformis in Iraq. Ph.D thesis , university of agriculture , Baghdad. 1-132.

[6] Al-Maaroof, E.M., Ibrahim, I.F. and Keriabit, A.A. (2001). Response of some bread wheat genotypes to stripe rust disease caused by *Puccinia striiformis* in Iraq. Arab Journal of Plant Protection 19: 12–18.

[7] Al-Maaroof, E.M., Ahmed, M.Y. and Hussein, W.U. (2003). Virulence of wheat yellow rust disease in Iraq. Iraqi J. of Biol. 13: 1–10.

[8] Al-Maaroof, E.M., Nazari, K., Naser,A.H., Razak, A.M., Ali, S.S., Fatteh, S.A., Rasheed N.J., Naef, R.S. and Tufeek,K.K. (2011). Detection of Yr27 virulence in Puccinia striiformis f.sp. triticci populations. Proceeding of the Borlang Global Rust Initiative 2011 Technical work shop (BGRI), St. Paul, Minnesota, USA, 13-16 June, 2011.

[9] Al-Maaroof, E.M., H.A Hadwan, L.O. Mohamed, A.H. Naser, A.M. Abdul Razak, H.M. Naser, S. Ali, S. Fattah, N. Rasheed, M. Laize, R. Naif and K. Tufeek, (2012). Serious outbreak of wheat stripe rust disease in Iraq. Journal of University of Duhok, 15:358-369.

[10] Al-Maaroof, E.M, M. Hovmoler, R. Ali, H. Mohamed, A. Naser, and L. Mohamed (2015). Detection of Yr27 virulence in Puccinia striiformis f.sp. triticci populations. J. of Wheat Res. 7: 39-47

[11] Bartos, P. anzalova, A., and lazkova, V. (2000). Leaf rust resistance of winter wheat cultivars registered in the Czech Republic. So: Acta-Phytopathologica-et- Entomologica- Hungaric)Hungary(. 35: 1-4 p. 149-151.

[12] Brown, J.K. and Hovmøller, M.S. (2002). Aerial dispersal of pathogens on the global and continental scales and its impact on plant disease. Science, 297: 537 -541.

[13] Bushnell, W. R. and Roelfs, A. P. (1984). The cereal rusts vol I "Origins, specifity, structure and physiology." Academic press. London, 546 p.

[14] Chen, X. (2005). Epidemiology and control of stripe rust *Puccinia striiformis* f. sp *tritici* on wheat. Plant Pathology, 27: 314- 337.

[15] Chen, X.M., and Penman, L. (2006). Stripe rust epidemic and races of Puccinia striiformis in the United States in 2005. Phytopathology, 96: S23.

[16] Cooke BM, Jones DG and Kaye B (2006). The epidemiology of plant diseases. Springer, Netherland 576p.

[17] Cottrell, J.E., Dale, J.E., and Jeffcoat, B. (1982). Endogenous control of spikelet initiation and development in barley. In "Opportunities for Manipulation of crop Productivity "eds. A. F. Hawkins and B. Jeffcott. British plant growth regulator group monograph 7: 130- 139.

[18] Doling, D. A. and Dadson, J. K. (1968). The effect of yellow rust on the yield of spring and winter wheat. Trans. Br. Mycol. Soc. 51: 427- 434.

[19] Ervin, W., Larry, J. (1999). Major Foliar Fungal Diseases of Wheat in Oklahoma. http://pearl.agcomm.okstate.edu/plantdisease/ f- 7661. Pdf

[20] Hovmøller, M.S. (2001). Disease severity and pathotype dynamics of *Puccinia striiformis* f.sp. *tritici* in Denmark. Plant Pathology, 50:181-189.

[21] Karakas, O., Hasancebi, S., Ertugrul, F.,Akan, K., Mert, Z., Cetin, L., Bolat, N. and Uncuoglu, A.A. (2009). Est-Based multiplex gene expression in yellow rust infected wheat using genome lab Gexp genetic analysis system. Proceed of 12th international cereal rust and powdery mildews in Antalya, Turkey in (13-16) October, 2009. P:46.

[22] Knott, D. R. (1989). The wheat rusts- Breeding for resistance. Springer-Verlag. Berlin, New York, London. Paris, Tokyo 201Pp.

[23] Leclerg, E.L., Leonard, W.H. and Clark, A.G. (1982). Field plot technique. Burgess publishing company Minneapolis. Minnesota.

[24[Lewellen, R.T., Sharp, E. and Hehn, E.R. (1967). Major and minor genes in the wheat for resistance of *Puccinia Striiformis* and their response to temperature changes. Can. J. Botany, 45: 2155-2172.

[25] Marasas, C.N. Smale, M. Singh, R.P. and Pingali, P. (2001). The global economic impact of nonspecific leaf rust resistance in modern CIMMYT-derived spring bread wheat: a preliminary report. CIMMYT. http://www. cimmyt .org research/wheat/index html

[26] Markell, S.G. and Milus, E.A. (2008). Emergence of a novel population of *Puccinia* f. sp. *tritici* in eastern United States. Phytopathology, 98:632-639.

[27] Marsalis, M.A. and Goldberg, N.P. (2006). Leaf, stem and stripe rust disease of wheat. New Mexico state university, Guide A-415.P:1-8.

[28] McIntosh, R.A. (2009). History and status of the wheat rusts. Borlaug Global Rust Initiative, Technical Workshop Cd. Obregon, Sonora, Mexico, March 17- 20,2009. Pp 1-16.

[29] Messmer, M.M. Seyfarth, R. Keller, M. Schachermayr ,G. Winzeler, M. Zanetti, S. Feuillet, C. and Keller ,B. (2000).Genetic analysis of durable leaf rust resistance in winter wheat. Theor. Appl. Genet. 100: 419 – 431. Murray , G., Wellings, C., Simpfendorfer, S., and Cole, C. 2005. Stripe rust: understanding the disease in wheat .NSW Department of primary industries. P:1-12.

[30] Nazari. K. (2011). Status of Wheat Stripe in CWANA: Analysis of Current Outbreaks. International Wheat Stripe Rust Symposium, ICARDA, Aleppo, Syria, 18-20, April 2011.

[31] O´Brien, L., Brown, J.S., Panozzo, J.F. and Archer, M.J.(1990). The effect of stripe rust on the quality of Australian wheatvarieties , Aust. J. Agric . Res. 1990. 41. 8:27-33.

[32] Peterson, R.F., Campbell, A.B. and Hanna. (1949).

A diagrammatic scale for estimating rust severity on leaves and stems of cereal Canadian J.Res.Sec. C. 26:249-500.

[33] Radley, M.E. (1982). Some factors affecting grain set in wheat. In "Opportunities for Manipulation of Cereal Productivity" British Plant growth regulation group monograph No. 7. Eds. A.F. Hawkins and B. Jeffcoat. P: 140-150.

[34] Roelfs, A.D., and Bushnell, W.R. (1985). The cereal rust. volII. Disease, distribution, epidemiology and control. Academic press, Newyourk, London , Orlando,p:282 Pp.

[35] Roelfs, A.P., Singh, R.P., and Saari, E.E. (1992). Rust disease of wheat, Concepts and methods of disease management. Mexico,D.F: CIMMYT.P81.

[36] Salman, A., Khan, M. and Hussain M. (2006). Prediction of yield losses in wheat varieties / lines due to leaf rust in Faisalabad . Pak. J. Phytopathol. 18:178- 182.

[37] Schnurbusch, T., Paillard, S., Schori, A., Messmer, M., Schachermayr, G.Winzeler, M., and Keller, B. (2004). Dissection of quantitative and durable leaf rusts resistance in Swiss winter wheat reveals a major resistance QTL in the Lr34 chromosomal region. Theor. Appl. Genet. 108: 477 – 484.

[38] Sharma R.C, Kumarse N, Amir A, Zafar Z and Anwar U J. (2016). Reduction of Winter Wheat Yield Losses Caused by Stripe Rust through Fungicide Management. Journal of Phytopathology 164: 671-677.

[39] Siddiqui, Z.S. and Ahmed, S. (2002). Effects of systemic Fungicides on protein, carbohydrate, Amino Acid, and Phenolic contents of susceptible (Mexipak) and resistant (Povan) varieties of *Triticum aestivum* L. Turk. J. Bot. 26: 127- 136.

[40] Smith, R., Heritage, A., Stapper, M. and Barrs, H. (1986) . Effect of stripe rust *Puccinia striiformis* and irrigation on the yield folage temperature of wheat. Field Crops Research Paises Bajosl . 14: 39- 51 .

[41] Synman, J.E., Welling, C.R. and Roake, (2009). A new pathotype of stripe rust affecting triticale in Australia. Proceeding of 12thinternational cereal rust and powdery mildews conference abstract book. Antalya. Turkey. (13-16) October 2009.

[42] Tariq,A.H. Ahmad, Muhammad, S., Hussain A, Ziaullah M, Akhtar H, and Siddiqi S. (2002). Identifying sources of resistance to wheat leaf rust under induced and natural conditions. Annual Wheat Newsletter, 49.P:79-81. Thorne, G. N. 1965. Photosynthesis of area and flag leaves of wheat and barley. Ann. Appl. Bot. 27: 155- 174.

[43] Thorne, G. N. 1965. Photosynthesis of area and flag leaves of wheat and barley. Ann. Appl. Bot. 27: 155- 174.

[44] Torabi, M., Mardoukhi, V., Nazari, K., Afshari, F., Forotan, A.R., Ramai, M.A., Golzar, H., and Kashani, H.S. (1995)Effectiveness of wheat yellow rust resistance genes in different part of Iran. Cereal rust and powdery mildews bulletin, 23:9-12.

[45] Wan, A.M., Chen, X.M., and He, Z.H. (2007). Wheat stripe rust in china. Aust. J. Agric. Res. 58: 619-695.