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Evaluation of some Bread Wheat Promising Lines Against Rust Diseases

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Twenty one wheat genotypes including sixteen bread wheat promising lines, wheat cultivar Morocco (check for rust resistance) as a highly susceptible cultivar for rust diseases and four commercial wheat cultivars, *i.e*. Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1 (checks for agronomic characters) were evaluated against rust diseases, *i.e*. leaf rust (*Puccinia triticina*), stem rust (*Puccinia graminis* f.sp. *tritici*) and stripe rust (*Puccinia striiformis* f.sp. *tritici*) at the farm of the Faculty of Agriculture, Minufiya University, Shibin El-Kom and at Itay El-Baroud Agricultural Research Station, during 2012/13 and 2013/14 growing seasons. Also, some other agronomic traits, *i.e.* days to heading and maturity, plant height, number of spikes per square meter, number of kernel/spike, 1000 kernel weight, straw yield, grain yield and biological yield, were studied. Out of sixteen lines, seven lines, *i.e.* 1, 2, 7, 8, 10, 11 and 15, were found to be resistant to rust diseases and showed acceptable/desirable relative resistance index (RRI) during the two seasons. Meanwhile, wheat lines 3, 6, 9, 11, 12, 13 and 14 showed high yield at the two locations during 2012/13 growing season. Wheat line 11 was not only resistant to rust diseases but also high yielding genotype. So, this line could be recommended to be grown as a commercial cultivar at these locations which was resistant and high yielding genotype.

Keywords: Promising lines, relative resistance index, rust diseases and wheat.

Bread wheat (*Triticum aestivum* L.) is one of the most important field crops in Egypt; it covers less than 60% of local consumption (Anonymous, 2013). An important objective of the Egyptian government is consequently to reduce the dependence on imported wheat by enhancing average grain yield. Increasing wheat productivity has been a national target in Egypt to fill the gap between wheat consumption and production. Yield of wheat can be increased by increasing the cultivated area (horizontally) or by increasing the yield per unit area (vertically). The only alternative method is to obtain higher yield per unit area by growing high yielding cultivars which were resistant to diseases.

Rust diseases of wheat, *i.e.* leaf rust (*Puccinia triticina* Eriks.), stem rust (*Puccinia graminis* Pers. f.sp. *tritici* Eriks. & E. Henn.) and stripe rust (*Puccinia striiformis* Westend. f.sp. *tritici*) are still the most dangerous biotic stress that threaten wheat production in Egypt and in many wheat growing areas of the world. This is mainly due to the appearance of pathogen aggressive races (Singh *et al*., 2005).

Yield losses due to stripe rust range from 10-70% (Chen, 2005), moreover, stripe rust can cause 100% yield loss if infection occurs at very early growth stage and the disease continues its developing during the growing season provided the cultivars are susceptible (Afzal *et al*., 2007). Leaf rust causes severe losses in grain yield which may reach more than 20% on the susceptible cultivars depending on environmental conditions, level of resistance, stage of crop development at the initial stage of infection and the dominant physiologic races (Nazim *et al*., 1983). While, wheat stem rust fungus could affect the entire wheat crop especially during the early growth stages leading to blocking of the vascular system hence stunting and lodging of weak stalks eventually causing yield losses of even 100 % due to shriveled grain and damaged tillers (Boukhatem *et al*., 2002 and Kokhmetova *et al*., 2011). In Egypt, yield losses due to stem rust ranged from 1.96 to 8.21% on the Egyptian wheat cultivars (Ashmawy *et al*., 2013). In most cases, susceptible wheat cultivars were replaced with new resistant ones (Rattu *et al*., 2007).

The aim of this study was to evaluate twenty one wheat genotypes including sixteen bread wheat promising lines against prevalent pathotypes of leaf, stem and stripe rust diseases. Also, to evaluate these lines for yield components and select lines that perform high yield and showing desirable resistance against rust diseases to be grown as commercial cultivars.

Materials and Methods

Twenty one genotypes including sixteen wheat promising lines, the wheat cultivar Morocco (check for rust resistance) as a highly susceptible and four commercial wheat cultivars, *i.e.* Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1 (checks for agronomic characters) were used in this study (Table 1). The wheat promising lines were selected from the preliminary yield trial, National Bread Wheat Research Program season of 2011/12. These experiments were carried out at two locations, *i.e.* the farm of the Fac. Agric., Minufiya Univ., Shibin El-Kom and Itay El-Baroud Agric. Res. Station, during 2012/13 and 2013/14 growing seasons. These experiments were designed in a randomized complete block with 4 replicates. Tested wheat genotypes were planted in plots of 3.5 m × 3 m (10.5 m^2), each plot contained six rows (3.5 m long, 30 cm apart). Each tested entry was planted in rows with seed rate of 350 seeds/m^2 at 30th November broadcast sowing method. The plots were surrounded by spreader area planted with a mixture of highly susceptible wheat genotypes to leaf, stem and stripe rust diseases. These genotypes were belonging to *Triticum spelta sahariensis*, Morocco, Thatcher and Max, to spread rust inoculum. For field inoculation with leaf, stem and stripe rusts, the spreader plants were sprayed with a mist of water and dusted with mixture of aggressive urediniospores of the prevalent and aggressive pathotypes mixed with a talcum powder at a ratio of 1:20 (v/v) (spores : talcum powder). Plants were dusted in the early evening (at sunset) before dew point formation on the leaves. The inoculation of all plants was carried out at booting stage according to the method of Tervet and Cassell (1951). The urediniospores of leaf, stem and stripe rusts was provided from Wheat Res. Dis. Dept., Plant Pathol. Res. Inst., Agric. Res. Centre, Egypt. To maintain crop stand/vigour, normal agronomic practices including recommended fertilization dose and irrigation schedule were followed.

Table 1. List of the tested bread wheat lines, check cultivars, pedigree and origin

Line/Cultivar	Pedigree	Origin
Promising lines		
1	WHEAR/VIVITSI//WHEAR.GCSS03B00069T-099Y-099M-099Y-099M-34WGY-0B-0S	CIMMYT
2	PBW343/4/B4//K134(60)/VEE"S"/3/BANISUEF1.CM9015-1GM-1GM-5GM-0GM	Egypt
3	KIRITATI/2*WBLL1.CGSS02B00118T-099B-099Y-099M-099Y-099M-18WGY-0B-0GM	CIMMYT
4	BECARD.CGSS01B00063T-099Y-099M-099M-0999Y-099M-3WGY-0B-0GM	CIMMYT
5	WHEAR//INQALAB91*2/TUKURU.CGSS04Y00076S-099Y-099M-099Y-099M-5WGY-0B-0NUB	CIMMYT
6	WHEAR/VIVITSI/3/C80.1/3*BATAVIA//2*WBLL1.CGSS03B00079T-099Y-099M-099Y-099M-3WGY-0B-0SD.	CIMMYT
7	CNDO/R143//ENTE/MEXI-2/3/AEGILOPS SQUARROSA(TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001. GMSS04N01331S-0TOPY-099ZTM-099Y-099M-7WGY-0B-0GM	CIMMYT
8	SOKOLL//W15.92/WBLL1.PTSS02B000882-0TOPY-0B-0Y-0B-5Y-0M-0SY-0GM	CIMMYT
9	WAXWING*2//PBW343*2/KUKUNA.CGSS04B00027T-099Y-099ZTM-099Y-099M-3WGY-0B-0EGY	CIMMYT
10	WHEAR/SOKOLL.CMSS04Y00201S-099Y-099ZTM-099Y-099M-11WGY-0B-0EGY	CIMMYT
11	ROLF07*2/KIRITATI.CGSS05B00123T-099TOPY-099M-099NJ-6WGY-0B-0EGY	CIMMYT
12	PASTOR//SITE/MO/3/CHEN/AEGILOPS SQUARROSA(TAUSBCN4/ WBLL1CMA01Y00158S-040POY-040M-030ZTM-040SY26M-0Y-0SY-0S	CIMMYT
13	BABAX/LR42//BABAX*2/4/SNI/TRAP#I/3/KAUZ*2/TRAP//KAUZ.CGSS01B00045T-099Y-099M-099M-099Y-099M-40Y-0B-0ET.	CIMMYT
14	KAMB1*2/BRAMBLING.CGSS01B00069T-099Y-099M-099M-099Y-099M-47Y-0B-0SD.	CIMMYT
15	GIRWILL-13/2*PASTOR-2.ICW03-20004-10AP-2AP/0TS-0AP-0AP-10AP-0AP-0SD.	ICARDA
16	WON-D22/SAFI-1.ICW01-00114-0AP-3AP-0AP-0AP-8AP-11AP-0AP-0SD.	ICARDA
Check cultivars		
Giza 168	MIL/BUC//Seri CM93046-8M-0Y-0M-2Y-0B	Egypt
Gemmeiza 11	B0W"S"/KVZ"S"//7C/SERI82/3/GIZA168/ITAY EL-BAROUD61.GM7892-2GM-1GM-2GM-1GM-0GM.	Egypt
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. (local check)	Egypt
Shandweel 1	SITE//MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC.CMSS93B00567S-72Y-010M-010Y-010M-0HTY-0SH	Egypt
Morocco	-	-

Disease assessment:

Final leaf, stem and stripe rust severities were recorded for each genotype using the modified Cobb's scale (Peterson *et al*., 1948). Plant reaction (infection type) was expressed in five types according to Stakman *et al.* (1962), *i.e.* immune (0), resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S).

Coefficient of infection (CI) was calculated by multiplying rust severity with constant values of infection type (IT). The constant values for infection types were used based on; R= 0.2, MR= 0.4, MS= 0.8 and S= 1 (Stubbs *et al*., 1986). Average coefficient of infection (ACI) was derived from the sum of CI values of each line divided by the number of locations.

After some modifications, a rating scale for disease resistance was adopted in 1982 for use with cereals (Aslam, 1982) based on scale of Doling (1965) for selecting wheat varieties to powdery mildew. The highest ACI of a candidate line is set at 100 and all other lines are adjusted accordingly. This gives the country average relative percentage attack (CARPA). Using 0 to 9 scale previously designated as resistance index (RI) has been re-designated as relative resistance index (RRI). From CARPA the value of RRI is calculated on 0 to 9 scale, where 0 denote most susceptible and 9 highly resistant (Akhtar *et al*., 2001). The relative resistance index (RRI) is calculated according to the following formula:

$$RRI = \frac{100\text{-}CARPA}{100} \times 9$$

The desirable index and acceptable index number for rusts (Aslam, 1982) are shown below:

Disease	Desirable index	Acceptable index
Stripe and stem rust	7 and above	6
Leaf rust	7 and above	6 or 5

Agronomic characters:

The agronomic characters were measured at two locations, *i.e.* the farm of the Fac. Agric., Minufiya Univ., Shibin El-Kom and Itay El-Baroud Agric. Res. Station during 2012/13 growing season. Days to heading and days to maturity were recorded on individual plants of all genotypes. Days to heading was taken at the emergence of 50% of the full spike from each plot, number of days to physiological maturity was recorded when 50% of the most upper internodes (peduncle) turned yellow. At harvest, the guarded plants were selected from each row for subsequent measurements, *i.e.* plant height (cm) was measured as the distance from soil surface to the upper part of the main spike excluding awns (average of ten measurements), number of spikes/m^2, number of kernel per spike, 1000-kernels weigh (g), straw yield (kg), grain yield (kg) and biological yield (kg).

Statistical analysis:

The yield data were subjected to ANOVA by computer using MSTATC statistical package and mean performance of all agronomic characters of the tested genotypes was compared using the least significant difference (LSD) at 5% (Steel and Torrie, 1980).

Results

A total of twenty one genotypes consisting of sixteen promising lines, the wheat cultivar Morocco (check) and four wheat cultivars were tested for adult plant resistance to rust diseases at the farm of the Fac. Agric., Minufiya Univ., Shibin El-Kom and Itay El-Baroud Agric. Res. Station (Tables 2, 3, 4, 5, 6 and 7).

1- Evaluation of wheat genotypes against leaf rust under field conditions:
A) Season 2012/13:

Results presented in Table (2) show that final leaf rust severity of the tested genotypes ranged from 0-50 % at Shibin El-Kom, while at Itay El-Baroud, it ranged from 0-80 %. Wheat genotypes, *i.e.* 1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, Sids 12 and Shandweel 1, showed resistant reaction at the two tested locations. Out of 21 tested genotypes, 18 ones, *i.e.* 6 (9.0), 7 (9.0), 10 (9.0), 8 (8.9), 13 (8.9), 14 (8.9), 1 (8.7), 11 (8.7), Sids 12 (8.7), Shandweel 1 (8.7), 15 (8.6), 9 (8.3), 12 (8.1), 5 (7.8), 2 (7.3), 4 (7.3), 3 (7.2) and Gemmeiza 11 (5.6), showed desirable/acceptable (RRI) to leaf rust.

Table 2. Response of 21 wheat genotypes to leaf rust along with average coefficient of infection (ACI), country average relative percentage attack (CARPA) and relative resistance index (RRI) at Shibin El-Kom and Itay El-Baroud locations during 2012/13 growing season

Line/cultivar	Location / final rust severity (%)*		ACI	CARPA	RRI
	Shibin El-Kom	Itay El-Baroud			
1	0	Tr MR	0.6	3.0	8.7**
2	10 MS	Tr MS	3.9	19.5	7.3**
3	5 S	Tr S	4.0	20.0	7.2**
4	10 MS	Tr MS	3.9	19.5	7.3**
5	10 MR	Tr MR	2.6	13.0	7.8**
6	0	0	0.0	0.0	9.0**
7	0	0	0.0	0.0	9.0**
8	0	Tr R	0.3	1.5	8.9**
9	10 R	Tr MR	1.6	8.0	8.3**
10	0	0	0.0	0.0	9.0**
11	0	Tr MR	0.6	3.0	8.7**
12	0	10 MR	2.0	10.0	8.1**
13	0	Tr R	0.3	1.5	8.9**
14	0	Tr R	0.3	1.5	8.9**
15	10 R	0	1.0	5.0	8.6**
16	30 S	10 S	20.0	100.0	0.0
Giza 168	10 S	20 S	15.0	75.0	2.3
Gemmeiza 11	10 S	10 MS	7.0	35.0	5.9**
Sids 12	0	Tr MR	0.6	3.0	8.7**
Shandweel 1	Tr MR	0	0.6	3.0	8.7**
Morocco (check)	50 S	80 S	65.0	325.0	-20.3

* Final rust severity includes two components: disease severity based on modified Cobb's scale (Peterson *et al*., 1948), where Tr = less than 5% and 5= 5% up to 100= 100%, and host response based on scale described by Stakman *et al.* (1962), whereas: R= resistant, MR= moderately resistant, MS= moderately susceptible and S= susceptible.

** RRI= Relative resistance index (above 5 is acceptable; means the variety is resistant to rusts (Aslam, 1982).

B) Season 2013/14:

Results in Table (3) show that the final leaf rust severity of the tested genotypes ranged from 0-70% at Shibin El-Kom and 0-80% at Itay El-Baroud. Also, wheat genotypes 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, Sids 12 and Shandweel 1 showed resistant reaction at the two tested locations. Moreover, wheat genotypes 1 (9.0), 5 (9.0), 8 (9.0), 15 (9.0), Shandweel 1 (9.0), 14 (8.9), 4 (8.7), 6 (8.7), Sids 12 (8.7) 7 (8.6), 9 (8.3), 10 (8.3), 11 (8.3), 12 (8.3), 13 (8.3), Gemmeiza 11 (7.2), 3 (6.1) and 2 (5.4) showed desirable/acceptable RRI for leaf rust.

Table 3. Response of 21 wheat genotypes to leaf rust along with average coefficient of infection (ACI), country average relative percentage attack (CARPA) and relative resistance index (RRI) at Shibin El-Kom and Itay El-Baroud locations during 2013/14 growing season

Line/cultivar	Location / final rust severity (%)*		ACI	CARPA	RRI
	Shibin El-Kom	Itay El-Baroud			
1	0	0	0.0	0.0	9.0**
2	10 MS	10 S	8.0	40.0	5.4**
3	10 S	5 MS	6.5	32.5	6.1**
4	0	Tr MR	0.6	3.0	8.7**
5	0	0	0.0	0.0	9.0**
6	0	Tr MR	0.6	3.0	8.7**
7	0	5 MR	1.0	5.0	8.6**
8	0	0	0.0	0.0	9.0**
9	Tr MR	5 MR	1.6	8.0	8.3**
10	0	Tr MR	0.6	3.0	8.7**
11	0	Tr MR	0.6	3.0	8.7**
12	0	Tr MR	0.6	3.0	8.7**
13	0	Tr MR	0.6	3.0	8.7**
14	0	Tr R	0.3	1.5	8.9**
15	0	0	0.0	0.0	9.0**
16	20 S	20 S	4.0	20.0	0.0
Giza 168	10 S	10 S	20.0	100.0	0.0
Gemmeiza 11	Tr S	5 S	4.0	20.0	7.2**
Sids 12	0	Tr MR	0.6	3.0	8.7**
Shandweel 1	0	0	0.0	0.0	9.0**
Morocco (check)	70 S	80 S	75.0	375.0	-24.8

* and **: As described in footnote of Table (2).

2- Evaluation of wheat genotypes against stem rust under field conditions:

A) Season 2012/13:

Results presented in Table (4) show that the final stem rust severity of the tested genotypes varied from 0-50% at Shibin El-Kom, while at Itay El-Baroud, it ranged from 0-70% during 2012/13growing season. Wheat genotypes 2, 7, 8 and Shandweel 1 showed resistant reaction at the two tested locations. Wheat genotypes Shandweel 1 (8.9), 2 (8.7), 7 (8.5), 8 (8.5), 15 (8.5), 11 (8.2), Gemmeiza 11 (8.2), 13 (7.8), 16 (7.6), 10 (7.0), 1 (6.8) and Giza 168 (6.5) showed desirable/acceptable RRI for stem rust.

Table 4. Response of 21 wheat genotypes to stem rust along with average coefficient of infection (ACI), country average relative percentage attack (CARPA) and relative resistance index (RRI) at Shibin El-Kom and Itay El-Baroud locations during 2012/13 growing season

Line/cultivar	Location / final rust severity (%)*		ACI	CARPA	RRI
	Shibin El-Kom	Itay El-Baroud			
1	Tr MS	20 S	10.9	24.2	6.8**
2	Tr MR	5 MR	1.6	3.6	8.7**
3	40 S	40 S	40.0	88.9	1.0
4	30 S	60 S	45.0	100.0	0.0
5	10 S	60 S	35.0	77.8	2.0
6	40 S	40 S	40.0	88.9	1.0
7	Tr MR	10 MR	2.6	5.8	8.5**
8	5 MR	0	1.0	2.2	8.8**
9	20 S	70 S	45.0	100.0	0.0
10	10 S	10 S	10.0	22.2	7.0**
11	Tr S	5 S	4.0	8.9	8.2**
12	5 MS	50 S	26.5	58.9	3.7
13	10 MS	10 MS	6.0	13.3	7.8**
14	40 S	50 S	45.0	100.0	0.0
15	Tr MS	5 MS	2.4	5.3	8.5**
16	Tr MS	20 MS	6.9	15.3	7.6**
Giza 168	5 S	70 S	37.5	83.3	1.5
Gemmeiza 11	Tr MS	10 MS	3.9	8.7	8.2**
Sids 12	Tr MS	40 S	20.9	46.4	4.8
Shandweel 1	0	Tr R	0.3	0.7	8.9**
Morocco (check)	50 S	60 S	55.0	122.2	-2.0

* and **: As described in footnote of Table (2).

B) Season 2013/14:

Results in Table (5) show that the final stem rust severity of the tested genotypes ranged from 0-30% at Shibin El-Kom and from 0-50% at Itay El-Baroud. Wheat genotypes 2, 8, 10, 11, 12, 13, 15, 16, Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1 showed resistant reaction at the two tested locations. Out of 21 tested genotypes, 15 genotypes showed desirable/acceptable RRI for stem rust, *i.e.* 2 (9.0), 7 (9.0), 10 (9.0), 11 (9.0), 12 (9.0), 13 (9.0), 15 (9.0), 16 (9.0), Giza 168 (9.0), Gemmeiza 11 (9.0), Sids 12 (9.0), Shandweel 1 (9.0), 8 (8.7), 1 (7.5) and 9 (7.3).

3- Evaluation of wheat genotypes against stripe rust under field conditions:

In spite of artificial inoculation with stripe rust at the two locations, poor stripe rust development was observed.

A) Season 2012/13:

Results presented in Table (6) show that final stripe rust severity of the tested genotypes ranged from 0-30% at Shibin El-Kom, while at Itay El-Baroud, it ranged from 0-50% during 2013/14 growing season. Wheat genotypes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, Giza 168, Gemmeiza 11and Shandweel 1 showed resistant

Table 5. Response of 21 wheat genotypes to stem rust along with average coefficient of infection (ACI), country average relative percentage attack (CARPA) and relative resistance index (RRI) at Shibin El-Kom and Itay El-Baroud locations during 2013/14 growing season

Line/cultivar	Location / final rust severity (%)*		ACI	CARPA	RRI
	Shibin El-Kom	Itay El-Baroud			
1	Tr S	Tr S	3.0	17.1	7.5**
2	0	0	0.0	0.0	9.0**
3	Tr S	10 S	6.5	37.1	5.7
4	Tr S	20 S	11.5	65.7	3.1
5	5 S	30 S	17.5	100.0	0.0
6	Tr S	20 S	11.5	65.7	3.1
7	0	0	0.0	0.0	9.0**
8	Tr MR	0	0.6	3.4	8.7**
9	10 S	30 S	3.4	19.4	7.3**
10	0	0	0.0	0.0	9.0**
11	0	0	0.0	0.0	9.0**
12	0	0	0.0	0.0	9.0**
13	0	0	0.0	0.0	9.0**
14	5 S	10 S	7.5	42.9	5.1
15	0	0	0.0	0.0	9.0**
16	0	0	0.0	0.0	9.0**
Giza 168	0	0	0.0	0.0	9.0**
Gemmeiza 11	0	0	0.0	0.0	9.0**
Sids 12	0	0	0.0	0.0	9.0**
Shandweel 1	0	0	0.0	0.0	9.0**
Morocco (check)	30 S	50 S	40.0	200.0	-9.0

* and **: As described in footnote of Table (2).

reaction at the two tested locations. While, wheat genotypes line 13 and Sids 12 showed susceptible reaction at the two locations. Moreover, wheat genotypes 1 (9.0), 2 (9.0), 3 (9.0), 4 (9.0), 5 (9.0), 6 (9.0), 8 (9.0), 9 (9.0), 11 (9.0), 12 (9.0), 14 (9.0), 15 (9.0), 16 (9.0), Giza 168 (9.0), Gemmeiza 11 (9.0), 7 (8.9), 10 (8.9) and Shandweel 1 (8.7) showed desirable/acceptable RRI for stripe rust.

B) Season 2013/14:

Results presented in Table (7) show that final stripe rust severity of the tested genotypes ranged from 0-20% at Shibin El-Kom, while at Itay El-Baroud, it ranged from 0-30% during 2013/14. Wheat genotypes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, Giza 168, Gemmeiza 11and Shandweel 1 showed resistant reaction at the two tested locations, while wheat genotypes 13 and Sids 12 showed susceptible reaction at the two tested locations. Moreover, out of 21 tested genotypes, 18 genotypes showed desirable/acceptable RRI for stripe rust, *i.e.* 1 (9.0), 2 (9.0), 3 (9.0), 4 (9.0), 5 (9.0), 6 (9.0), 8 (9.0), 11 (9.0), 12 (9.0), 14 (9.0), 15 (9.0), 16 (9.0), Giza 168 (9.0), 10 (8.9), 9 (8.7), Shandweel 1 (8.7), 7 (8.6) and Gemmeiza 11 (8.5) showed desirable/acceptable RRI for stripe rust.

Table 6. Response of 21 wheat genotypes to stripe rust along with average coefficient of infection (ACI), country average relative percentage attack (CARPA) and relative resistance index (RRI) at Shibin El-Kom and Itay El-Baroud locations during 2012/13 growing season

Line/cultivar	Location / final rust severity (%)*		ACI	CARPA	RRI
	Shibin El-Kom	Itay El-Baroud			
1	0	0	0.0	0.0	9.0**
2	0	0	0.0	0.0	9.0**
3	0	0	0.0	0.0	9.0**
4	0	0	0.0	0.0	9.0**
5	0	0	0.0	0.0	9.0**
6	0	0	0.0	0.0	9.0**
7	Tr R	0	0.3	0.9	8.9**
8	0	0	0.0	0.0	9.0**
9	0	0	0.0	0.0	9.0**
10	0	Tr MR	0.4	1.1	8.9**
11	0	0	0.0	0.0	9.0**
12	0	0	0.0	0.0	9.0**
13	30 S	40 S	35.0	100.0	0.0
14	0	0	0.0	0.0	9.0**
15	0	0	0.0	0.0	9.0**
16	0	0	0.0	0.0	9.0**
Giza 168	0	0	0.0	0.0	9.0**
Gemmeiza 11	Tr R	5 MR	1.3	3.7	8.7**
Sids 12	20 S	40 S	30.0	85.7	1.3
Shandweel 1	0	0	0.0	0.0	9.0**
Morocco (check)	30 S	50 S	40.0	114.3	-1.3

* and **: As described in footnote of Table (2).

Results in Table (8) indicate that only seven candidate lines, *i.e.* 1, 2, 7, 8, 10, 11 and 15, as well as two wheat cultivars, *i.e.* Gemmeiza 11 and Shandweel 1, were resistant to rust diseases at the two tested locations during 2012/13 and 3013/14 growing seasons.

Agronomic characters:

Analysis of variance and mean performance:

Analysis of variance for all characters studied is presented in Tables (9 and 10). Results of mean square for all genotypes under studied showed highly significant for all characters studied at the two locations Shibin El-Kom and Itay El-Baroud.

Mean performance for all genotypes studied for yield and its components in the two locations Shibin El-Kom and Itay El-Baroud are presented in Tables (11 and 12). Results show that grain yield ranged from 10.13 kg for line 13 to 12.31 kg for line 11 in Shibin El-Kom location. While, in Itay El-Baroud the grain yield ranged from 8.30 kg for line 16 to 10.72 kg for line 11. Generally, the wheat lines 4, 5, 11 and 14 gave higher yield at the two locations than the check cultivars Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1. The wheat line 11 gave 12.31 kg as

Table 7. Response of 21 wheat genotypes to stripe rust along with average coefficient of infection (ACI), country average relative percentage attack (CARPA) and relative resistance index (RRI) at Shibin El-Kom and Itay El-Baroud locations during 2013/14 growing season

Line/cultivar	Location / final rust severity (%)*		ACI	CARPA	RRI
	Shibin El-Kom	Itay El-Baroud			
1	0	0	0.0	0.0	9.0**
2	0	0	0.0	0.0	9.0**
3	0	0	0.0	0.0	9.0**
4	0	0	0.0	0.0	9.0**
5	0	0	0.0	0.0	9.0**
6	0	0	0.0	0.0	9.0**
7	0	5 R	0.5	4.0	8.6**
8	0	0	0.0	0.0	9.0**
9	0	Tr MR	0.4	3.2	8.7**
10	0	0	0.0	0.0	9.0**
11	0	0	0.0	0.0	9.0**
12	0	0	0.0	0.0	9.0**
13	5 S	20 S	12.5	100.0	0.0
14	0	0	0.0	0.0	9.0**
15	0	0	0.0	0.0	9.0**
16	0	0	0.0	0.0	9.0**
Giza 168	0	0	0.0	0.0	9.0**
Gemmeiza 11	Tr R	Tr MR	0.7	5.6	8.5**
Sids 12	5 S	10 S	7.5	60.0	3.6
Shandweel 1	0	0	0.0	0.0	9.0**
Morocco (check)	20 S	30 S	25.0	200.0	-9.0

* and **: As described in footnote of Table (2).

Table 8. Resistant wheat genotypes with desirable and acceptable relative resistance index (RRI) to rust diseases during 2012/13 and 2013/14 growing seasons at adult plant stage

Line / cultivar	Rust disease / Season / RRI								
	Leaf rust			Stem rust			Stripe rust		
	2012/13	2013/14	Mean	2012/13	2013/14	Mean	2012/13	2013/14	Mean
1	8.7	9.0	8.9	8.6	7.5	8.1	9.0	9.0	9.0
2	7.3	5.4	6.4	8.7	9.0	8.9	9.0	9.0	9.0
7	9.0	8.6	8.8	8.5	9.0	8.8	8.9	8.6	8.8
8	8.9	9.0	9.0	8.8	8.7	8.8	9.0	9.0	9.0
10	9.0	8.7	8.9	7.0	9.0	8.0	8.9	9.0	9.0
11	8.7	8.7	8.7	8.2	9.0	8.6	9.0	9.0	9.0
15	8.6	9.0	8.8	8.5	9.0	8.8	9.0	9.0	9.0
Gemmeiza 11	5.9	7.2	6.6	8.2	9.0	8.6	8.7	8.5	8.6
Shandweel 1	8.7	9.0	8.9	8.9	9.0	9.0	9.0	9.0	9.0

Table 9. Mean square from analysis of variance for days to heading and maturity, plant height (cm), No. of spikes/m^2 and No. of kernel/spike in Shibin El-Kom and Itay El-Baroud locations

Source of variation	Degrees of freedom	Days to heading		Days to maturity		Plant height (cm)		No. of spikes/m^2		No. of kernel/spike	
		Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud
Replicates	3	3.5	14.2	0.1	15.0	14.2	28.6	25.5	42.7	362.7	106.1
Genotypes	19	37.7*	26.7*	17.6*	24.5*	170.0*	158.2*	2337.2*	889.6*	167.4*	86.5*
Error	57	0.84	3.13	0.65	7.33	8.46	11.50	511.01	282.13	4.55	37.16

* Significant at 0.05 probability level.

Table 10. Mean square from analysis of variance for 1000-kernel weight (g), straw yield (kg), grain yield (kg) and biological yield (kg) in Shibin El-Kom and Itay El-Baroud locations

Source of variation	Degrees of freedom	1000-kernel weight (g)		Straw yield (kg)		Grain yield (kg)		Biological yield (kg)	
		Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud
Replicates	3	1.16	22.04	10.50	10.22	1.06	6.08	17.30	28.90
Genotypes	19	33.67*	36.33*	8.87*	4.05*	1.74*	1.47*	18.71*	5.40*
Error	57	4.75	4.27	2.93	0.98	0.48	0.56	5.58	1.95

* Significant at 0.05 probability level.

compared to the check cultivars Giza 168 (11.38 kg), Gemmeiza 11 (11.98 kg), Sids 12 (11.39 kg) and Shandweel 1 (12.14 kg). The wheat line 11 gave 8.2 %, 2.8 %, 8.1 % and 1.4 % higher yield than the check cultivars Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1, respectively, in Shibin El-Kom. While, in Itay El-Baroud the wheat line 11 gave 10.72 kg as compared to the check cultivars, *i.e.* Giza 168 (9.05 kg), Gemmeiza 11 (9.26 kg), Sids 12 (9.74 kg) and Shandweel 1 (9.45 kg). The wheat line 11 gave 18.5 %, 15.8 %, 10.1 % and 13.4 % higher yield than the check cultivars Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1, respectively. Days to heading ranged from 90.75 days for line 13 to 104 days for line 15 in Shibin El-Kom location and from 90.5 days to 101.5 days for the same lines in Itay El-Baroud location. Wide range of variation in days to maturity was also observed. Line 13 which was the earliest entry in days to heading was also the earliest in maturity (135.25 days) in Itay El-Baroud location. The averages of plant height ranged from112.5 cm for line 16 to 136.25 cm for line 1 and from 107.5 cm for line 16 to 131.5cm for line 1 in Shibin El-Kom and Itay El-Baroud locations, respectively.

Table 11. Mean performance of twenty genotypes for days to heading and maturity, plant height (cm), No. of spikes/ m^2 and No. of kernel / spike in Shibin El-Kom and Itay El-Baroud locations during 2012/13 growing season

Line / cultivar	Days to heading		Days to maturity		Plant height (cm)		No. of spikes / m^2		No. of kernel / spike	
	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud
Line 1	99.00	98.00	143.50	140.25	136.25	131.25	197 50	172.75	63.65	50.30
Line 2	92.50	91.75	143.25	140.00	117.50	122.50	157.50	157.25	59.95	59.50
Line 3	97.25	95.50	144.50	139.75	116.25	115.00	192.50	172.00	58.35	63.95
Line 4	98.25	94.50	143.75	139.75	122.50	115.00	212.50	184.00	61.50	52.07
Line 5	93.25	92.50	143.75	138.00	125.00	117.50	223.25	179.00	59.10	52.90
Line 6	95.75	93.25	143.50	139.00	133.75	126.25	242.50	201.25	63.25	57.82
Line 7	97.50	96.50	141.50	140.00	123.75	121.25	207.50	186.25	56.10	57.30
Line 8	97.50	94.75	142.25	137.75	118.75	121.25	176.25	188.00	51.70	52.30
Line 9	101.50	97.00	144.25	140.25	122.50	115.00	203.75	207.00	53.00	52.88
Line 10	96.25	96.00	141.25	136.75	127.50	126.25	200.00	201.25	64.75	49.47
Line 11	95.00	93.25	139.50	139.50	121.25	116.25	200.00	191.75	52.50	57.57
Line 12	98.00	94.50	141.75	139.25	117.50	120.00	198.80	183.50	49.20	51.37
Line 13	90.75	90.50	142.00	135.25	122.50	117.50	187.50	176.75	57.05	63.10
Line 14	95.75	90.50	140.50	136.50	120.00	111.25	140.00	163.25	64.70	56.00
Line 15	104.00	101.50	148.25	146.25	121.25	117.50	162.50	188.25	70.70	53.92
Line 16	94.25	95.00	139.75	139.75	112.50	107.50	222.50	184.75	66.10	52.67
Giza 168 (check)	94.50	94.00	144.25	140.50	112.50	106.25	177.50	181.75	58.30	59.67
Gemmeiza 11 (check)	95.00	93.75	141.50	138.50	117.50	116.25	200.00	159.75	73.10	60.20
Sids 12 (check)	93.50	93.25	141.00	141.00	111.25	110.00	180.00	186.50	64.00	65.15
Shandaweel 1 (check)	95.25	96.25	145.50	144.50	115.00	115.00	177.50	189.25	68.75	58.12
L.S.D $_{0.05}$	1.29	2.51	1.14	3.83	4.11	4.81	32	23.77	3.02	8.62
C.V%	0.94	1.90	0.56	1.90	2.41	2.90	11.7	9.19	3.50	10.80

Table 12. Mean performance of twenty genotypes for 1000-kernel weight (g), straw yield (kg), grain yield (kg) and biological yield (kg) in Shibin El-Kom and Itay El-Baroud locations during 2012/13 growing season

Line/cultivar	1000-kernel weight (g)		Straw yield (kg)		Grain yield (kg)		Biological yield (kg)	
	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud	Shibin El-Kom	Itay El-Baroud
Line 1	51.44	45.28	30.25	14.57	10.33	9.26	40.75	23.82
Line 2	60.63	52.83	32.00	13.95	11.53	9.18	43.50	23.12
Line 3	50.75	44.73	32.75	13.62	11.96	10.00	44.50	23.62
Line 4	52.16	46.45	33.50	12.60	12.14	9.75	45.75	22.35
Line 5	51.19	47.03	34.50	13.74	12.20	9.51	47.00	23.25
Line 6	50.92	45.63	31.50	14.17	11.02	10.43	42.50	24.60
Line 7	50.93	43.23	29.25	13.19	10.31	9.21	39.50	22.40
Line 8	51.61	47.68	30.00	14.31	10.63	9.81	41.00	24.12
Line 9	50.69	42.60	32.50	14.37	11.78	10.25	44.50	24.62
Line 10	53.16	45.70	32.25	16.49	11.33	9.69	43.50	26.17
Line 11	52.13	46.93	31.50	14.41	12.31	10.72	42.75	25.12
Line 12	52.82	46.00	31.75	14.19	11.30	10.43	43.00	24.62
Line 13	55.35	47.68	29.50	12.63	10.13	10.07	39.50	22.70
Line 14	53.16	46.40	33.75	12.48	12.04	10.32	46.00	22.80
Line 15	47.35	41.15	32.75	14.45	11.60	8.92	44.25	23.37
Line 16	49.65	43.73	33.00	14.15	12.16	8.30	45.25	22.45
Giza 168 (check)	50.72	40.60	31.00	12.60	11.38	9.05	42.75	21.65
Gemmeiza11 (check)	55.34	47.33	33.25	13.27	11.98	9.26	45.50	22.52
Sids 12 (check)	50.73	44.60	32.50	12.79	11.39	9.74	43.50	22.52
Shandaweel 1 (check)	47.23	39.18	34.00	15.20	12.14	9.45	46.25	24.65
L.S.D $_{0.05}$	3.08	2.93	2.42	1.41	0.98	1.06	3.34	1.98
C.V%	4.18	4.60	5.33	7.20	6.04	7.80	5.42	5.90

Also, results indicated that there was variation in the number of spikes per square meter ranged from 157.5 m^2 for line 2 to 242.5 m^2 in Shibin El-Kom, while in Itay El-Baroud ranged from 157.25 m^2 for line 6 and 207.0 m^2 for line 9. Concerning, No. of kernel per spike it ranged from 49.2 for line 12 to 70.7 for line 15 in Shibin El-Kom location and from 51.37 for line 12 to 63 95 for line 3 in Itay El-Baroud location. Weight of 1000-kernel showed variation ranged of 50.7 g for line 3 to 60.63 g for line 2 in Shibin El-Kom location and in Itay El-Baroud location ranged for 41.15 g for line 15 to 52.83 g for line 2. As for straw yield, a narrow variation ranged from 34.5 kg for line 5 to 33.75 kg for line 14 in Shibin El-Kom location and ranged from 16.49 kg for line 10 to 12.04 kg for line 14 in Itay El-Baroud location. Concerning, biological yield ranged from 47 kg for line 5 to 39.5 kg for line 13 in Shibin El-Kom location but ranged from 26.17 kg for line 10 to 22.35 kg for line 4 in Itay El-Baroud location.

Discussion

Using resistant wheat cultivars will protect wheat plants from disease infection and consequently from yield loss. In this study, 21 wheat genotypes; 16 promising lines and the wheat cultivar Morocco (check for rust resistance) and four commercial wheat cultivars (checks for agronomic characters) were tested. The tested genotypes were grown at two locations, *i.e.* Shibin El-Kom and Itay El-Baroud for two growing seasons, *i.e.* 2012/13 and 2013/14.

In case of rust incidence, results were recorded as final rust severity (%), infection type, average coefficient of infection (ACI) and relative resistance index (RRI). According to the scale of Aslam (1982), RRI = 0 means the genotype is highly susceptible and RRI = 9 means the genotype is highly resistant. Moreover, for leaf rust, RRI = 5 or 6 means the genotype is acceptable in its resistant, while RRI = 7 and above means the genotype is desirable in its resistant. For stripe and stem rust, RRI = 6 means the genotype is acceptable in its resistant, while RRI = 7 and above means the genotype is desirable in its resistant.

Results of this study showed that only the wheat lines 1, 2, 7, 8, 10, 11 and 15 showed desirable RRI of 9 for stripe rust, more than 7 for leaf rust and acceptable RRI for stem rust. These wheat lines were resistant to rust diseases and could be safely released as commercial cultivars under Egyptian conditions. These results are in harmony with those of many researches (Akhtar *et al*., 2002; Rattu *et al*., 2009; Hussain *et al*., 2010 a, b and c and Hussain *et al*., 2013). Also, obtained results are agree with those of Mahmood *et al*. (2013) who reported that the rust score of Chakwal-50 varied from 5 MR/MS to 30 MS for leaf rust and 5 MS to 30 MS for yellow rust. Moreover, cv. Chakwal-50 gave RRI value of 7 to 8.6 and 8 to 8.3 for leaf and yellow rust, respectively. Also, cv. Chakwal-50 has the potential to be approved and released as a new variety. Also, results of this research are in conformity with those of Tariq *et al*. (2013) who observed that the rust score of cv. Dharabi-11 varied from 0 to 5 S for yellow rust as compared to 80 S to 90 S for yellow rust of the check cultivar Morocco. Meanwhile, cv. Dharabi-11 gave RRI value of 8.8 for yellow rust. Also, cv. Dharabi-11 was adapted at different locations, and it has the potential to be approved and released as a new variety.

Concerning the agronomic studies, high significant variability was found among the studied genotypes. these results implied that this population of wheat promising lines and cultivars would respond positively to be select. Based on the results of this study, differences were found between locations for all traits studied, indicating wide variation among two locations, *i.e.* Shibin El-Kom and Itay El-Baroud. These results cleared that most of the promising lines studied showed the best results compared to check cultivars, *i.e.* Giza 168, Gemmeiza 11, Sids 12 and Shandweel 1. However, the variation in grain yield and other characters studied in the two locations might be due to the wide changes in weather conditions between the two tested locations and the variance of genotypes for promising lines tested in this investigation. Wheat lines 4, 5, 11 and 14 gave high yield; meanwhile, only line 11 was resistant to rust diseases. These due to the wheat lines 4, 5 and 14 possesses high tolerance against rust diseases (Patterson, 1958 and Roberts *et al*., 1984).

To increase the wheat production much more under the Egyptian conditions, the breeding programs must be selected for yield and its components as the traits studied in this investigation. Earliness of days to heading and maturity in wheat are important traits in breeding programs for many reasons. Early maturity cultivars are needed to allow farmers to grow some other crops (*e.g.* soybean or cotton) in summer season after wheat which maximize the net return for farmer. On the other hand, earliness of maturity is also important in resistant to rust diseases especially stem rust. Therefore, selection for these traits should be effective and satisfactory for successful breeding program. These results are in harmony with those of many researches (Hendawy *et al*., 2007; Dawwam *et al*., 2010; El-Shaarawy and Morad, 2011 and Tolba and Saleh, 2012).

Obtained results in these investigation showed that wheat line 11 could be used as a source of resistance and high yielding variety and grown in rust areas for diversification of the genetic basis of resistance in wheat growing areas of Egypt. The promising wheat line 11 is not only resistant to rust diseases but also high yielding genotype. It has a potential to be register as a new cultivar, also, it must be identify the rust resistance genes presented in this line by molecular marker to know the number of genes.

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تم تقييم ٢١ تركيب وراثى متضمنة ١٦ سلالة قمح خبز مبشرة ، صنف القمح موروكو (صنف مقارن للمقاومة للصدأ) كصنف عالى الإصابة بأمراض الصدأ و أربعة أصناف قمح تجاريه وهى جيزة ١٦٨ ، جميزة ١١ ،سدس ١٢ و شندويل ١ (أصناف مقارنة للصفات المحصولية) ضد أمراض الصدأ وهى صدأ الأوراق (*Puccinia graminis* f.sp. *tritici*) ، صدأ الساق (*Puccinia triticina*) والصدأ الأصفر (*Puccinia striiformis* f.sp. *tritici*) فى مزرعة كلية الزراعة - جامعة المنوفية - شبين الكوم ومحطة البحوث الزراعية فى إيتاى البارود خلال الموسمين الزراعيين ٢٠١٢/٢٠١٣ و ٢٠١٣/٢٠١٤.

كذلك تم دراسة بعض الصفات المحصولية الأخرى للسلالات والأصناف المختبرة مثل عدد الأيام حتى التزهير ، عدد الأيام حتى النضج ، طول النبات ، عدد السنابل فى المتر المربع ، عدد الحبوب فى السنبلة ، وزن الألف حبة، وزن القش ، محصول الحبوب والمحصول البيولوجى. وجد أن سبعة سلالات من الستة عشر سلالة المختبرة وهى السلالات ١ ، ٢ ، ٧ ، ٨ ، ١٠ ، ١١ و ١٥ كانت مقاومة وأظهرت معامل المقاومة النسبى مقبول/مرغوب خلال موسمى الدراسة. أما السلالات ٣ ، ٦ ، ٩ ، ١١ ، ١٢ ، ١٣ و ١٤ كانت ذات محصول عالى فى الموقعين خلال الموسم الزراعى ٢٠١٢/٢٠١٣. أظهرت سلالة القمح ١١ أنها ليست فقط مقاومة لأمراض الصدأ بل أيضاً عالية المحصول ولذا يمكن التوصية بزراعة هذه السلالة كصنف تجارى فى هذه المواقع حيث أنها مقاومة وعالية المحصول.