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Research Article

Assessment of some Sources of Adult Plant Resistance to Wheat Stem Rust in Egypt

Walid M. El-Orabey[1]*, Fatma A. Mostafa[1], Gomaa A. Abdel-Wahed[1], Mohamed E. Selim[2]

[1]*Plant Pathology Research Institute, ARC, Giza, Egypt;* [2]*Department of Agricultural Botany, Faculty of Agriculture, Menoufia University, Egypt*

ABSTRACT

Stem rust is a devastating disease of wheat in the major wheat-growing regions of the world. Particularly, the stem rust race identified as Ug99 and its mutants initially emerged in Uganda in 1999 had crossed borders of neighboring countries in Africa, Middle East and Asia has become a major threat to the world wheat industry. Therefore, the present study was conducted under field conditions to assess sources of resistance to stem rust. A total of 93 wheat genotypes delivered to Egypt by International Maize and Wheat Improvement Center (CIMMYT) and a susceptible variety; Morocco were evaluated under field conditions at the two locations i.e. Behira and Minufiya governorates during three growing seasons i.e. 2017/2018, 2018/2019 and 2019/2020. Results of the current study showed that 84 wheat genotypes were resistant and had the lowest values of FRS (%), ACI and AUDPC. These genotypes might possess one or more Adult Plant Resistance (APR) gene(s) to stem rust. Therefore, the 84 genotypes can be good sources of durable stem rust resistance genes to be incorporated in the Egyptian wheat improvement breeding programs for stem rust resistance.

Keywords: Wheat; Stem rust; Promising lines

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the three major cereal crops that supply the majority of calories worldwide, with over 600 million tonnes harvested annually [1].

Developing new cultivars carrying effective disease resistance genes is a sustainable and environmentally responsible approach to disease management. However, pathogens can evolve virulence to resistance genes emphasizing the need to identify and utilize new resistance genes that are found within a crop and related species. Wheat stem rust (caused by *Puccinia graminis* f. sp. *tritici* Eriksson & Henning; *Pgt*) is a devastating fungal disease of wheat that has re-emerged as a worldwide threat to wheat production with the evolution of highly virulent races of *Pgt* in Africa, including the Ug99 race group [2].

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 [3]. In Egypt, yield losses due to stem rust ranged from 1.96% to 8.21% on the Egyptian wheat cultivars [4,5]. In most cases susceptible wheat cultivars were replaced with new resistant one [6].

Global wheat production was threatened by stem rust when a highly virulent race known as Ug99 or TTKSK that combined virulence to *Sr31* and various other commonly deployed resistance genes was detected in 1998 in Uganda [7-9]. After its appearance, evaluations of international wheat germplasm and varieties in both field and greenhouse screenings revealed the predominance of wheat susceptibility to race TTKSK [10]. In subsequent years, new variants of Ug99 emerged that carry additional virulence to *Sr24* [8,11,12], *Sr36* [13], and *SrTmp* [14] placing an even greater number of wheat varieties at risk. Races of the Ug99 race group have already spread over a wide geographical area including 13 countries in the East African highlands, Southern Africa, Yemen, Egypt and Iran, and there is a high chance of further spread into large wheat growing belts of Asia and beyond [15]. Consequently, the new variants belonging to Ug99 race group and their geographical spread have further reduced the number of effective genes that can be used by breeding programs.

Sixty wheat stem rust resistance genes have a designated gene symbol and a few more carry temporary designations [16]. Five

***Corresponding to:** Walid M. El-Orabey, Plant Pathology Research Institute, ARC, Giza, Egypt, E-mail: walid_elorabey2014@hotmail.com

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genes, namely *Sr2*, *Sr55* (*Lr67/Yr46/Pm46*), *Sr56*, *Sr57* (*Lr34/Yr18/Pm38*), and *Sr58* (*Lr46/Yr29/Pm39*), confer adult plant resistance. Resistance to wheat rusts is generally categorized into two non-exclusive types, race-specific and race non-specific. Race specific resistance is generally qualitative and usually short lived due to the evolution of potentially virulent pathogens [17,18]. In contrast, adequate levels of race non-specific resistance involve genes which might contribute from minor to intermediate effects. The deployment of rust resistant cultivars is considered the best option to control rust diseases and their development is the major focus of the breeding program at CIMMYT and worldwide.

Hence, this necessitates the need to identify sources of adult plant resistance germplasm to be incorporated in the wheat breeding program. Thus, the aim of this study was to assess and find out resistant sources in available 93 advanced CIMMYT wheat genotypes against stem rust.

MATERIALS AND METHODS

Plant materials

A total of 716 wheat genotypes in four sets were provided to Egypt by International Maize and Wheat Improvement Center (CIMMYT), Mexico, through the website (http://www.cimmyt.org/seed-request/#wheat) including the wheat variety; Morocco (check for rust resistance) as a highly susceptible. The five sets of germplasm evaluated included (1) Elite Spring Wheat Yield Trial (ESWYT), (2) Stem Rust Resistance Screening Nursery (STEMRRSN), (3) International Spring Bread Wheat Screening Nursery (IBWSN) and (4) High Temperature Wheat Yield Trial (HTWYT) consisting of 98, 168, 329 and 121 entries, respectively. A total of 93 *i.e.* 26 genotypes from (ESWYT), 32 (STEMRRSN), 25 (IBWSN) and 10 (HTWYT) wheat germplasm were selected from 716 tested wheat genotypes which were selected according to their response for stem rust resistance under field conditions. The pedigree of the tested genotypes is found (Table 1).

Field testing

The experiments of this study were carried out at two locations *i.e.* Behira governorate (Itay El-Baroud Agricultural Research Station) and Minufiya governorate (Shibin El-Kom) during 2017/2018, 2018/2019 and 2019/2020 growing seasons. These experiments were planted in Randomized Complete Block Design (RCBD) with three replicates. The tested wheat genotypes were planted in

Table 1: Pedigree of wheat genotypes used in this study.

Line	Pedigree	Line	Pedigree
1	ROLF07*2/3/PRINIA/PASTOR//HUITES	37	CHIBIA//PRLII/CM65531/3/FISCAL/4/ND643/2*WBLL1
2	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/FH6-1-7	38	DANPHE #1/3/HUW234+LR34/PRINIA//PFAU/WEAVER
3	KACHU #1/KIRITATI//KACHU	39	KACHU/BECARD//WBLL1*2/BRAMBLING
4	WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX	40	PCAFLR/KINGBIRD #1//KIRITATI/2*TRCH
5	ATTILA*2/PBW65*2//MURGA	41	MUU/3/KIRITATI//ATTILA*2/PASTOR/4/MUU
6	ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/ AE.SQUARROSA (213)//PGO/4/HUITES	42	PRINIA/PASTOR//KIRITATI/3/PRL/2*PASTOR
7	ATTILA*2/PBW65*2//W485/HD29	43	OASIS/SKAUZ//4*BCN*2/3/PASTOR/4/HEILO/5/ PAURAQ
8	WBLL1*2/TUKURU//FN/2*PASTOR/3/FRET2/KIRITATI	44	ND643/2*WBLL1//ATTILA*2/PBW65/3/MUNAL
9	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/ KACHU/6/KACHU	45	ND643/2*WBLL1/3/KIRITATI//PRL/2*PASTOR/4/ KIRITATI//PBW65/2*SERI.1B
10	WAXWING/4/BL 1496/MILAN/3/CROC_1/AE.SQUARROSA (205)//KAUZ/5/FRNCLN	46	ND643/2*TRCH//BECARD/3/BECARD
11	WBLL1*2/KURUKU/6/CNDO/R143//ENTE/MEXI_2/3/ AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*JANZ/7/ WBLL1*2/KURUKU	47	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1
12	UP2338*2/VIVITSI/3/FRET2/TUKURU//FRET2/4/MISR 1	48	GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ// PRINIA /3/BAV92
13	TACUPETO F2001*2/BRAMBLING//WBLL1*2/BRAMBLING	49	BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/ CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)// OPATA/7/PASTOR// MILAN/KAUZ/3/BAV92
14	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/FH6-1-7	50	BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/ CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)// OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92
15	FRET2/TUKURU//FRET2/3/MUNAL #1	51	D67.2/PARANA 66.270//AE.SQUARROSA (320)/3/ CUNNINGHAM/4/VORB
16	FRET2/TUKURU//FRET2/3/MUNAL #1	52	D67.2/PARANA 66.270//AE.SQUARROSA (320)/3/ CUNNINGHAM/4/VORB
17	GAN/AE.SQUARROSA (408)//2*OASIS/5*BORL95/3/ TACUPETO F2001*2/BRAMBLING	53	H45/4/KRICHAUFF/FINSI/3/URES/PRL//BAV92
18	KIRITATI//ATTILA*2/PASTOR/3/AKURI	54	EGA BONNIE ROCK/4/MILAN/KAUZ//PRINIA/3/ BAV92

19	KIRITATI//PRL/2*PASTOR/3/FRANCOLIN #1	55	CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*JANZ/6/D67.2/ PARANA 66.270//AE.SQUARROSA (320)/3/CUNNINGHAM
20	BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	56	INQALAB 91*2/KUKUNA/4/TC14/2*HTG// DUCULA/3/ PRINIA
21	WBLL1*2/BRAMBLING/3/KIRITATI//PBW65/2*SERI.1B	57	KANZ/5/CNO79//PF70354/MUS/3/PASTOR/4/ BAV92/6/PRL/SARA//TSI/VEE#5
22	WBLL1*2/KURUKU//SUP152	58	BABAX/KS93U76//BABAX/3/2*SOKOLL
23	WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING	59	ATTILA*2/PBW65*2//KACHU
24	FRET2*2/BRAMBLING/3/FRET2/WBLL1//TACUPETO F2001/4/WBLL1*2/BRAMBLING	60	ROLF07*2/3/PRINIA/PASTOR//HUITES
25	WHEAR*2/3/FRET2/WBLL1//TACUPETO F2001	61	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/FH6-1-7
26	ALTAR 84/AE.SQUARROSA (221)//3*BORL95/3/URES/ JUN//KAUZ/4/WBLL1/5/KACHU/6/KIRITATI// PBW65/2*SERI.1B	62	KACHU #1/KIRITATI//KACHU
27	FRANCOLIN #1*2/MUU	63	PBW343*2/KUKUNA*2//FRTL/PIFED
28	FRANCOLIN #1*2/KINGBIRD #1	64	WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42// BABAX
29	SERI.1B*2/3/KAUZ*2/BOW//KAUZ*2/4/KINGBIRD #1	65	ATTILA*2/PBW65*2//MURGA
30	HUIRIVIS #1/MUU//WBLL1*2/BRAMBLING	66	SUP152/4/BABAX/LR42//BABAX*2/3/KURUKU
31	CROC_1/AE.SQUARROSA (205)//BORL95/3/PRL/SARA//TSI /VEE#5/4/FRET2/5/KINDE	67	QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP// KAUZ
32	KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/5/DANPHE #1	68	TACUPETO F2001*2/BRAMBLING//WBLL1*2/ BRAMBLING
33	THELIN/3/BABAX/LR42//BABAX/4/BABAX/LR42// BABAX/5/BOW/NKT//CBRD/3/CBRD/6/FRET2*2/ BRAMBLING	69	ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/ AE.SQUARROSA (213)//PGO/4/HUITES
34	WBLL1*2/KUKUNA/4/WHEAR/KUKUNA/3/ C80.1/3*BATAVIA//2*WBLL1	70	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/ KACHU/6/KACHU
35	WBLL1/KUKUNA//TACUPETO F2001/4/WHEAR/ KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1	71	WAXWING/4/BL 1496/MILAN/3/CROC_1/AE. SQUARROSA (205)//KAUZ/5/FRNCLN
36	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/4/ QUAIU	72	TACUPETO F2001/BRAMBLING//KACHU
73	SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI	84	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/ KACHU/6/KACHU
74	ALTAR 84/AE.SQUARROSA (221)//3*BORL95/3/ URES/ JUN//KAUZ/4/WBLL1/5/REH/HARE//2*BCN/3/CROC_1/ AE.SQUARROSA (213)//PGO/4/HUITES	85	KACHU #1/6/NG8201/KAUZ/4/SHA7//PRL/VEE# 6/3/ FASAN/5/MILAN/KAUZ/7/KACHU
75	ROLF07*2/3/PRINIA/PASTOR//HUITES	86	ATTILA*2/PBW65*2//MURGA
76	ROLF07*2/4/CROC_1/AE.SQUARROSA (205)// BORL95/3/2*MILAN	87	KBIRD//WH 542/2*PASTOR/3/WBLL1*2/BRAMBLING
77	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311	88	KZA/5/2*WBLL1/3/STAR//KAUZ/STAR/4/BAV92/ RAYON
78	CS/TH.SC//3*PVN/3/MIRLO/BUC/4/URES/JUN//KAUZ/5/ HUITES/6/YANAC/7/CS/TH.SC//3*PVN/3/MIRLO/BUC/4/ MILAN/5/TILHI	89	WBLL1*2/KURUKU/4/BABAX/LR42//BABAX*2/3/ KURUKU
79	PF74354//LD/ALD/4/2*BR12*2/3/JUP//PAR214*6/FB6631/5/ NL750/6/PVN/7/TOBA97/PASTOR	90	BAV92//IRENA/KAUZ/3/HUITES/6/ALD/CEP75630// CEP75234/PT7219/3/BUC/BJY/4/CBRD/5/TNMU/ PF85487
80	BAV92//IRENA/KAUZ/3/HUITES/4/2*ROLF07	91	TACUPETO F2001/6/CNDO/R143//ENTE/MEXI_2/3/ AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/ PASTOR/7/ROLF07
81	FRET2/TUKURU//FRET2/3/MUNIA/CHTO//AMSEL/4/ FRET2/TUKURU//FRET2	92	BAV92//IRENA/KAUZ/3/HUITES*2/6/TURACO/5/ CHIR3/4/SIREN//ALTAR 84/AE.SQUARROSA (205)/3/3*BUC
82	ATTILA*2/PBW65*2/4/BOW/NKT//CBRD/3/CBRD	93	FRANCOLIN #1/KIRITATI
83	BAV92//IRENA/KAUZ/3/HUITES/4/FN/2*PASTOR/5/ BAV92//IRENA/KAUZ/3/HUITES	Morocco	-

rows of 3 m long. The experiments were surrounded by spreader area planted with a mixture of highly susceptible wheat genotypes to leaf, stem and stripe rusts. These genotypes were Morocco and Max to spread rust inoculum. For field inoculation with stem rust, 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 stem rust received from Wheat Research Diseases Department, Plant Pathology Research Institute, Agricultural Research Center, Egypt. To maintain crop stand/vigor normal agronomic practices including recommended fertilization dose and irrigation schedule were followed.

Disease assessment

Final stem rust severities were recorded for each genotype using the modified Cobb's scale [19]. Plant reaction (infection type) was expressed in five types [20]; 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 [21]. 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 [22] based on scale by 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 [23]. The relative resistance index is calculated according to the following formula:

$$RRI = \frac{(100 - CARPA)}{100} X\, 9$$

The desirable index and acceptable index number for rusts are as below [22].

Disease	Desirable index	Acceptable index
Stem rust	7 and above	6

Area under disease progress curve (AUDPC) was calculated by using the formula suggested by Pandey et al. [24].

$$AUDPC = D\left[\frac{1}{2}(Y_1 + Y_k) + (Y_2 + Y_3 + \ldots\ldots + Y_{k-1})\right]$$

Where:

D = days between two consecutive records (time intervals)

$Y_1 + Y_k$ = Sum of the first and last disease scores.

$Y_2 + Y_3 + \ldots\ldots + Y_{k-1}$ = Sum of all in between disease scores.

Statistical analysis

The data were subjected to ANOVA by computer using MSTATC statistical package and mean performance of all resistance characters of the tested genotypes was compared using the Least Significant Difference (LSD) at 5% [25].

RESULTS

Evaluation of wheat genotypes against stem rust under field conditions

Season 2017/18

Data presented in Table 2 showed that, final stem rust severity of the tested genotypes ranged from 0-100% at Minufiya and Behira.

Table 2: Response of 94 wheat genotypes to stem rust along with Average Coefficient of Infection (ACI), Country Average Relative Percentage Attack (CARPA) and Relative Resistance Index (RRI) at Minufiya and Behira locations during 2017/18 growing season.

Line	2017/18		ACI	CARPA	RRI[b]
	Location / Final rust severity (%)[a]				
	Minufiya	Behira			
1	5 S	10 S	7.5	7.5	8.33
2	Tr S	5 S	4	4	8.64
3	10 S	10 S	10	10	8.1
4	0	0	0	0	9
5	20 S	40 S	30	30	6.3
6	0	0	0	0	9
7	30 S	10 S	20	20	7.2
8	0	0	0	0	9
9	30 S	40 S	35	35	5.85
10	40 S	50 S	45	45	4.95
11	0	0	0	0	9
12	0	0	0	0	9
13	20 S	30 S	25	25	6.75
14	0	0	0	0	9
15	40 S	40 S	40	40	5.4
16	20 S	10 S	15	15	7.65
17	0	0	0	0	9

18	5 S	10 S	7.5	7.5	8.33
19	10 S	30 S	20	20	7.2
20	Tr S	Tr S	3	3	8.73
21	20 S	40 S	30	30	6.3
22	10 S	20 S	15	15	7.65
23	Tr S	5 S	4	4	8.64
24	Tr S	5 S	4	4	8.64
25	10 S	20 S	15	15	7.65
26	5 S	Tr S	4	4	8.64
27	10 S	20 S	15	15	7.65
28	0	0	0	0	9
29	10 S	20 S	15	15	7.65
30	5 S	30 S	17.5	17.5	7.43
31	Tr S	10 S	6.5	6.5	8.42
32	20 S	5 S	12.5	12.5	7.88
33	0	0	0	0	9
34	0	0	0	0	9
35	5 S	10 S	7.5	7.5	8.33
36	10 S	20 S	15	15	7.65
37	5 S	10 S	7.5	7.5	8.33
38	Tr S	5 S	4	4	8.64
39	5 S	10 S	7.5	7.5	8.33
40	Tr S	10 S	6.5	6.5	8.42
41	0	0	0	0	9
42	Tr S	20 S	11.5	11.5	7.97
43	5 S	10 S	7.5	7.5	8.33
44	Tr S	20 S	11.5	11.5	7.97
45	Tr S	20 S	11.5	11.5	7.97
46	Tr S	5 S	4	4	8.64
47	10 S	20 S	15	15	7.65
48	0	0	0	0	9
49	0	0	0	0	9
50	0	0	0	0	9
51	30 S	50 S	40	40	5.4
52	40 S	30 S	35	35	5.85
53	20 S	10 S	15	15	7.65
54	10 S	20 S	15	15	7.65
55	0	0	0	0	9
56	60 S	70 S	65	65	3.15
57	20 S	30 S	25	25	6.75
58	10 S	Tr S	6.5	6.5	8.42
59	0	0	0	0	9
60	10 S	20 S	15	15	7.65
61	30 S	50 S	40	40	5.4
62	20 S	10 S	15	15	7.65
63	0	0	0	0	9
64	0	0	0	0	9
65	50 S	30 S	40	40	5.4
66	0	0	0	0	9
67	0	0	0	0	9
68	Tr S	5 S	4	4	8.64
69	20 S	30 S	25	25	6.75
70	50 S	60 S	55	55	4.05

71	5 S	10 S	7.5	7.5	8.33
72	10 S	20 S	15	15	7.65
73	30 S	20 S	25	25	6.75
74	0	0	0	0	9
75	0	0	0	0	9
76	5 MS	Tr MS	3.2	3.2	8.71
77	20 S	30 S	25	25	6.75
78	30 MS	40 MS	28	28	6.48
79	50 S	60 S	55	55	4.05
80	40 S	30 S	35	35	5.85
81	30 S	20 S	25	25	6.75
82	50 S	60 S	55	55	4.05
83	10 S	20 S	15	15	7.65
84	5 MR	Tr MR	1.6	1.6	8.86
85	Tr S	5 S	4	4	8.64
86	10 MR	5 MR	3	3	8.73
87	0	0	0	0	9
88	30 S	40 S	35	35	5.85
89	0	0	0	0	9
90	0	0	0	0	9
91	20 S	30 S	25	25	6.75
92	10 S	20 S	15	15	7.65
93	40 S	60 S	50	50	4.5
Morocco	100 S	100 S	100	100	0
L.S.D. at 5%					0.841

a). Final rust severity includes two components: disease severity based on modified Cobb's scale [19],
where Tr=less than 5% and 5=5% up to 100=100%, and host response based on scale described by Stakman et al. [20], where R=Resistant, MR=Moderately Resistant, MS=Moderately Susceptible and S=Susceptible.
b). RRI=Relative Resistance Index (above 6 is acceptable; means the variety is resistant to stem rust [22].

The wheat genotypes *i.e.* 4, 6, 8, 11, 12, 14, 17, 28, 33, 34, 41, 48, 49, 50, 55, 59, 63, 64, 66, 67, 74, 75, 84, 86, 87, 89 and 90 showed resistant reaction at the two locations (Table 2). Moreover, all of the tested wheat genotypes showed desirable/acceptable (RRI) to stem rust ranged from 9.00 to 6.30 except 14 wheat genotypes *i.e.* 9 (5.85), 15 (5.40), 51 (5.40), 52 (5.85), 56 (3.15), 61 (5.40), 65 (5.40), 70 (4.05), 79 (4.05), 80 (5.85), 82 (4.05), 88 (5.85), 93 (4.50) and Morocco (0.00) (Table 2) at the two locations during 2017/18 growing season.

Season 2018/19

Data presented in Table 3 showed that, final stem rust severity of the tested genotypes ranged from 0-90% at Minufiya and Behira. The wheat genotypes *i.e.* 4, 6, 8, 11, 12, 14, 17, 28, 33, 34, 41, 48, 49, 50, 55, 59, 63, 64, 66, 67, 74, 75, 84, 86, 87, 89 and 90 showed resistant reaction at the two locations (Table 3). Moreover, all of the tested wheat genotypes showed desirable/acceptable (RRI) to stem rust ranged from 9.00 to 6.00 except 19 wheat genotypes *i.e.* 16 (5.50), 19 (5.00), 21 (5.00), 36 (5.00), 47 (5.50), 51 (4.00), 52 (5.50), 56 (5.00), 61 (4.00), 65 (4.00), 79 (5.50), 80 (3.00), 81 (5.50), 82 (5.50), 88 (5.50), 91 (3.50), 92 (4.50), 93 (3.00) and Morocco (0.00) (Table 3) at the two locations during 2018/19 growing season.

Season 2019/20

Data presented in Table 4 showed that, final stem rust severity of the tested genotypes ranged from 0-60% at Minufiya and 0-70% at Behira. The wheat genotypes *i.e.* 4, 6, 8, 11, 12, 14, 17, 28, 33, 34, 41, 48, 49, 50, 55, 59, 63, 64, 66, 67, 74, 75, 84, 86, 87, 89 and 90 showed resistant reaction at the two locations (Table 4). Moreover, all of the tested wheat genotypes showed desirable/acceptable (RRI) to stem rust ranged from 9.00 to 6.23 except 5 wheat genotypes *i.e.* 65 (5.54), 80 (5.54), 81 (5.54), 82 (3.46) and Morocco (0.00) (Table 4) at the two locations during 2019/20 growing season.

Data as shown in Table 5 indicated that all of the tested wheat genotypes were resistant to stem rust and showed desirable/acceptable (RRI) at the two locations during the three growing seasons of the study except 25 wheat genotypes *i.e.* 5, 9, 15, 16, 19, 21, 25, 36, 47, 51, 52, 56, 61, 65, 70, 77, 79, 80, 81, 82, 88, 91, 92, 93 and Morocco.

AREA UNDER DISEASE PROGRESS CURVE (AUDPC)

The AUDPC values during the 2017/18 growing season ranged from 0.0 to 1260.0 at the two locations. While during the 2018/19 growing seasons, AUDPC values ranged from 0.0 to 1220.0. Also, during the 2019/20 growing seasons, AUDPC values ranged from 0.0 to 840.0. Moreover, during the three growing seasons of the study at the two locations, AUDPC values ranged from 0.0 to 1038.3 (Table 6). Also, during the three growing seasons of the study at the two locations, the tested wheat genotypes divided into two groups depending on the values of AUDPC. The first group is

Table 3: Response of 94 wheat genotypes to stem rust along with Average Coefficient of Infection (ACI), Country Average Relative Percentage Attack (CARPA) and Relative Resistance Index (RRI) at Minufiya and Behira locations during 2018/19 growing season.

Line	2018/19		ACI	CARPA	RRI[b]
	Location / Final rust severity (%)[a]				
	Minufiya	Behira			
1	Tr S	20 S	11.5	12.78	7.85
2	5 S	Tr S	4	4.44	8.6
3	20 S	20 S	20	22.22	7
4	0	0	0	0	9
5	30 S	40 S	35	38.89	5.5
6	0	0	0	0	9
7	10 S	5 S	7.5	8.33	8.25
8	0	0	0	0	9
9	20 S	10 S	15	16.67	7.5
10	20 S	40 S	30	33.33	6
11	0	0	0	0	9
12	0	0	0	0	9
13	10 S	20 S	15	16.67	7.5
14	0	0	0	0	9
15	20 S	30 S	25	27.78	6.5
16	30 S	40 S	35	38.89	5.5
17	0	0	0	0	9
18	20 S	30 S	25	27.78	6.5
19	30 S	50 S	40	44.44	5
20	5 S	10 S	7.5	8.33	8.25
21	30 S	50 S	40	44.44	5
22	20 S	5 S	12.5	13.89	7.75
23	5 S	10 S	7.5	8.33	8.25
24	10 S	20 S	15	16.67	7.5
25	30 S	40 S	35	38.89	5.5
26	10 S	20 S	15	16.67	7.5
27	5 S	20 S	12.5	13.89	7.75
28	0	0	0	0	9
29	20 S	40 S	30	33.33	6
30	10 S	20 S	15	16.67	7.5
31	5 S	30 S	17.5	19.44	7.25
32	10 S	30 S	20	22.22	7
33	0	0	0	0	9
34	0	0	0	0	9
35	20 S	30 S	25	27.78	6.5
36	30 S	50 S	40	44.44	5
37	10 S	30 S	20	22.22	7
38	20 S	30	25	27.78	6.5
39	5 S	10 S	7.5	8.33	8.25
40	5 S	5 S	5	5.56	8.5
41	0	0	0	0	9
42	10 S	30 S	20	22.22	7
43	20 S	40 S	30	33.33	6
44	5 S	10 S	7.5	8.33	8.25
45	Tr S	5 S	4	4.44	8.6
46	10 S	20 S	15	16.67	7.5

47	20 S	50 S	35	38.89	5.5
48	0	0	0	0	9
49	0	0	0	0	9
50	0	0	0	0	9
51	40 S	60 S	50	55.56	4
52	20 S	50 S	35	38.89	5.5
53	Tr S	20 S	11.5	12.78	7.85
54	Tr S	Tr S	3	3.33	8.7
55	0	0	0	0	9
56	30 S	50 S	40	44.44	5
57	5 S	10 S	7.5	8.33	8.25
58	5 S	10 S	7.5	8.33	8.25
59	0	0	0	0	9
60	20 S	30 S	25	27.78	6.5
61	40 S	60 S	50	55.56	4
62	5 S	20 S	12.5	13.89	7.75
63	0	0	0	0	9
64	0	0	0	0	9
65	40 S	60 S	50	55.56	4
66	0	0	0	0	9
67	0	0	0	0	9
68	10 S	20 S	15	16.67	7.5
69	10 S	40 S	25	27.78	6.5
70	20 S	40 S	30	33.33	6
71	Tr S	Tr S	3	3.33	8.7
72	20 S	10 S	15	16.67	7.5
73	20 S	30 S	25	27.78	6.5
74	0	0	0	0	9
75	0	0	0	0	9
76	Tr S	5 S	4	4.44	8.6
77	40 S	50 S	45	50	4.5
78	10 S	30 S	20	22.22	7
79	30 S	40 S	35	38.89	5.5
80	50 S	70 S	60	66.67	3
81	20 S	50 S	35	38.89	5.5
82	30 S	40 S	35	38.89	5.5
83	Tr S	5 S	4	4.44	8.6
84	0	0	0	0	9
85	5 S	10 S	7.5	8.33	8.25
86	5 MR	10 MR	3	3.33	8.7
87	0	0	0	0	9
88	30 S	50 S	40	44.44	5
89	0	0	0	0	9
90	5 R	0	0.5	0.56	8.95
91	50 S	60 S	55	61.11	3.5
92	40 S	50 S	45	50	4.5
93	50 S	70 S	60	66.67	3
Morocco	90 S	90 S	90	100	0
L.S.D. at 5%					0.795

a). Final rust severity includes two components: disease severity based on modified Cobb,s scale [19],
where Tr=less than 5% and 5=5% up to 100=100%, and host response based on scale described by Stakman et al. [20], where R=Resistant, MR=Moderately Resistant, MS=Moderately Susceptible and S=Susceptible.
b). RRI=Relative resistance index (above 6 is acceptable; means the variety is resistant to stem rust [22].

Table 4: Response of 94 wheat genotypes to stem rust along with Average Coefficient of Infection (ACI), Country Average Relative Percentage Attack (CARPA) and Relative Resistance Index (RRI) at Minufiya and Behira locations during 2019/20 growing season.

Line	2019/20		CI	CARPA	RRI[b]
	Location / Final rust severity (%)[a]				
	Minufiya	Behira			
1	10 S	10 S	10	15.38	7.62
2	Tr S	10 S	6.5	10	8.1
3	5 S	10 S	7.5	11.54	7.96
4	0	0	0	0	9
5	30 S	10 S	20	30.77	6.23
6	0	0	0	0	9
7	10 S	20 S	15	23.08	6.92
8	0	0	0	0	9
9	5 S	20 S	12.5	19.23	7.27
10	10 S	5 S	7.5	11.54	7.96
11	0	0	0	0	9
12	0	0	0	0	9
13	10 S	5 S	7.5	11.54	7.96
14	0	0	0	0	9
15	10 S	Tr S	6.5	10	8.1
16	5 S	10 S	7.5	11.54	7.96
17	0	0	0	0	9
18	10 S	20 S	15	23.08	6.92
19	10 S	20 S	15	23.08	6.92
20	Tr S	5 S	4	6.15	8.45
21	20 S	10 S	15	23.08	6.92
22	Tr S	Tr S	3	4.62	8.58
23	10 S	5 S	7.5	11.54	7.96
24	10 S	10 S	10	15.38	7.62
25	5 S	5 S	5	7.69	8.31
26	5 S	10 S	7.5	11.54	7.96
27	10 S	10 S	10	15.38	7.62
28	0	0	0	0	9
29	10 S	5 S	7.5	11.54	7.96
30	10 S	10 S	10	15.38	7.62
31	10 S	10 S	10	15.38	7.62
32	20 S	10 S	15	23.08	6.92
33	0	0	0	0	9
34	0	0	0	0	9
35	5 S	Tr S	4	6.15	8.45
36	10 S	20 S	15	23.08	6.92
37	5 S	5 S	5	7.69	8.31
38	10 S	10 S	10	15.38	7.62
39	5 S	Tr S	4	6.15	8.45
40	10 S	Tr S	6.5	10	8.1
41	0	0	0	0	9
42	10 S	Tr S	6.5	10	8.1
43	5 S	10 S	7.5	11.54	7.96
44	10 S	5 S	7.5	11.54	7.96
45	5 S	10 S	7.5	11.54	7.96
46	5 S	Tr S	4	6.15	8.45

47	10 S	5 S	7.5	11.54	7.96
48	0	0	0	0	9
49	0	0	0	0	9
50	0	0	0	0	9
51	10 S	5 S	7.5	11.54	7.96
52	5 S	10 S	7.5	11.54	7.96
53	5 S	5 S	5	7.69	8.31
54	5 S	10 S	7.5	11.54	7.96
55	0	0	0	0	9
56	10 S	20 S	15	23.08	6.92
57	5 S	5 S	5	7.69	8.31
58	Tr S	5 S	4	6.15	8.45
59	0	0	0	0	9
60	5 S	10 S	7.5	11.54	7.96
61	20 S	20 S	20	30.77	6.23
62	Tr S	5 S	4	6.15	8.45
63	0	0	0	0	9
64	0	0	0	0	9
65	20 S	30 S	25	38.46	5.54
66	0	0	0	0	9
67	0	0	0	0	9
68	Tr S	Tr S	3	4.62	8.58
69	5 MS	Tr MS	3.2	4.92	8.56
70	10 S	20 S	15	23.08	6.92
71	5 S	0	2.5	3.85	8.65
72	Tr S	5 S	4	6.15	8.45
73	5 S	Tr S	4	6.15	8.45
74	0	0	0	0	9
75	0	0	0	0	9
76	Tr S	5 S	4	6.15	8.45
77	5 S	5 S	5	7.69	8.31
78	20 S	10 S	15	23.08	6.92
79	10 S	20 S	15	23.08	6.92
80	20 S	30 S	25	38.46	5.54
81	20 S	30 S	25	38.46	5.54
82	30 S	50 S	40	61.54	3.46
83	Tr S	Tr S	3	4.62	8.58
84	0	0	0	0	9
85	Tr S	Tr S	3	4.62	8.58
86	0	0	0	0	9
87	0	0	0	0	9
88	5 S	5 S	5	7.69	8.31
89	Tr R	0	0.3	0.46	8.96
90	0	5 MR	1	1.54	8.86
91	20 S	20 S	20	30.77	6.23
92	5 S	10 S	7.5	11.54	7.96
93	10 S	20 S	15	23.08	6.92
Morocco	60 S	70 S	65	100	0
L.S.D. at 5%					0.799

a). Final rust severity includes two components: disease severity based on modified Cobb,s scale [19], where Tr=less than 5% and 5=5% up to 100=100%, and host response based on scale described by Stakman et al. [20], where R=Resistant, MR=Moderately Resistant, MS=Moderately Susceptible and S=Susceptible.
b). RRI=Relative resistance index (above 6 is acceptable; means the variety is resistant to stem rust [22].

Table 5: Resistant wheat genotypes with desirable and acceptable relative resistance index (RRI) to stem rust disease at Minufiya and Behira during 2017/18, 2018/19 and 2019/20 growing seasons.

Line	Season / RRI		
	2017/18	2018/19	2019/20
1	8.33	7.85	7.62
2	8.64	8.6	8.1
3	8.1	7	7.96
4	9	9	9
6	9	9	9
7	7.2	8.25	6.92
8	9	9	9
11	9	9	9
12	9	9	9
13	6.75	7.5	7.96
14	9	9	9
17	9	9	9
18	8.33	6.5	6.92
20	8.73	8.25	8.45
22	7.65	7.75	8.58
23	8.64	8.25	7.96
24	8.64	7.5	7.62
26	8.64	7.5	7.96
27	7.65	7.75	7.62
28	9	9	9
29	7.65	6	7.96
30	7.43	7.5	7.62
31	8.42	7.25	7.62
32	7.88	7	6.92
33	9	9	9
34	9	9	9
35	8.33	6.5	8.45
37	8.33	7	8.31
38	8.64	6.5	7.62
39	8.33	8.25	8.45
40	8.42	8.5	8.1
41	9	9	9
42	7.97	7	8.1
43	8.33	6	7.96
44	7.97	8.25	7.96
45	7.97	8.6	7.96
46	8.64	7.5	8.45
48	9	9	9
49	9	9	9
50	9	9	9
53	7.65	7.85	8.31
54	7.65	8.7	7.96
55	9	9	9
57	6.75	8.25	8.31
58	8.42	8.25	8.45
59	9	9	9
60	7.65	6.5	7.96
62	7.65	7.75	8.45
63	9	9	9

64	9	9	9
66	9	9	9
67	9	9	9
68	8.64	7.5	8.58
69	6.75	6.5	8.56
71	8.33	8.7	8.65
72	7.65	7.5	8.45
73	6.75	6.5	8.45
74	9	9	9
75	9	9	9
76	8.71	8.6	8.45
78	6.48	7	6.92
83	7.65	8.6	8.58
84	8.86	9	9
85	8.64	8.25	8.58
86	8.73	8.7	9
87	9	9	9
89	9	9	8.96
90	9	8.95	8.86

Table 6: Area under disease progress curve (AUDPC) of 94 wheat genotypes to stem rust at Minufiya and Behira locations during 2017/18 to 2019/20 growing season.

Line	Location / Season / AUDPC						Mean
	Minufiya			Behira			
	2017/18	2018/19	2019/20	2017/18	2018/19	2019/20	
1	42	42	80.5	80.5	157.5	80.5	80.5
2	42	49	42	49	42	80.5	50.8
3	80.5	157.5	49	80.5	157.5	80.5	100.9
4	0	0	0	0	0	0	0
5	157.5	280	280	420	420	80.5	273
6	0	0	0	0	0	0	0
7	280	80.5	80.5	80.5	49	157.5	121.3
8	0	0	0	0	0	0	0
9	280	157.5	49	420	80.5	157.5	190.8
10	420	157.5	80.5	525	420	49	275.3
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	157.5	80.5	80.5	280	157.5	49	134.2
14	0	0	0	0	0	0	0
15	420	157.5	80.5	420	280	42	233.3
16	157.5	280	49	80.5	420	80.5	177.9
17	0	0	0	0	0	0	0
18	49	157.5	80.5	80.5	280	157.5	134.2
19	80.5	280	80.5	280	525	157.5	233.9
20	42	49	42	42	80.5	49	50.8
21	157.5	280	157.5	420	525	80.5	270.1
22	80.5	157.5	42	157.5	49	42	88.1
23	42	49	80.5	49	80.5	49	58.3
24	42	80.5	80.5	49	157.5	80.5	81.7
25	80.5	280	49	157.5	420	49	172.7
26	49	80.5	49	42	157.5	80.5	76.4
27	80.5	49	80.5	157.5	157.5	80.5	100.9
28	0	0	0	0	0	0	0

29	80.5	157.5	80.5	157.5	420	49	157.5
30	49	80.5	80.5	280	157.5	80.5	121.3
31	42	49	80.5	80.5	280	80.5	102.1
32	157.5	80.5	157.5	49	280	80.5	134.2
33	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0
35	49	157.5	49	80.5	280	42	109.7
36	80.5	280	80.5	157.5	525	157.5	213.5
37	49	80.5	49	80.5	280	49	98
38	42	157.5	80.5	49	30	80.5	73.3
39	49	49	49	80.5	80.5	42	58.3
40	42	49	80.5	80.5	49	42	57.2
41	0	0	0	0	0	0	0
42	42	80.5	80.5	157.5	280	42	113.8
43	49	157.5	49	80.5	420	80.5	139.4
44	42	49	80.5	157.5	80.5	49	76.4
45	42	42	49	157.5	49	80.5	70
46	42	80.5	49	49	157.5	42	70
47	80.5	157.5	80.5	157.5	525	49	175
48	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0
51	280	420	80.5	525	630	49	330.8
52	420	157.5	49	280	525	80.5	252
53	157.5	42	49	80.5	157.5	49	89.3
54	80.5	42	49	157.5	42	80.5	75.3
55	0	0	0	0	0	0	0
56	630	280	80.5	840	525	157.5	418.8
57	157.5	49	49	280	80.5	49	110.8
58	80.5	49	42	42	80.5	49	57.2
59	0	0	0	0	0	0	0
60	80.5	157.5	49	157.5	280	80.5	134.2
61	280	420	157.5	525	630	157.5	361.7
62	157.5	49	42	80.5	157.5	49	89.3
63	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0
65	525	420	157.5	280	630	280	382.1
66	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0
68	42	80.5	42	49	157.5	42	68.8
69	157.5	80.5	49	280	420	42	171.5
70	525	157.5	80.5	630	420	157.5	328.4
71	49	42	49	80.5	42	0	43.8
72	80.5	157.5	42	157.5	80.5	49	94.5
73	280	157.5	49	157.5	280	42	161
74	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0
76	49	42	42	42	49	49	45.5
77	157.5	420	49	280	525	49	246.8
78	280	80.5	157.5	420	280	80.5	216.4
79	525	280	80.5	630	420	157.5	348.8
80	420	525	157.5	280	840	280	417.1
81	280	157.5	157.5	157.5	525	280	259.6

82	525	280	280	630	420	525	443.3
83	80.5	42	42	157.5	49	42	68.8
84	49	0	0	42	0	0	15.2
85	42	49	42	49	80.5	42	50.8
86	80.5	49	0	49	80.5	0	43.2
87	0	0	0	0	0	0	0
88	280	280	49	420	525	49	267.2
89	0	0	42	0	0	0	7
90	0	49	0	0	0	49	16.3
91	157.5	525	157.5	280	630	157.5	317.9
92	80.5	420	49	157.5	525	80.5	218.8
93	420	525	80.5	630	840	157.5	442.2
Morocco	1260	1120	630	1260	1120	840	1038.3
L.S.D. at 5%	39.724	40.968	40.8734	41.614	40.998	41.192	-

genotypes with partial resistance which showed the lowest values of AUDPC (less than 300). This group included 84 wheat genotypes which showed AUDPC values ranged from 0 to 275.3. On the other hand, the second group included ten wheat genotypes *i.e.* 51 (330.8), 56 (418.7), 61 (361.7), 65 (382.1), 70 (328.4), 79 (348.8), 82 (417.1), 91 (317.0), 93 (442.2) and Morocco (1038.3) (Table 6).

DISCUSSION

New sources of resistance are essential to effectively protect wheat production against continuously and rapidly evolving rust pathogens. Little is known about the genetic resistance to stem rust in Egyptian bread wheat varieties. Thus, there is an urgent need to search for new sources and donors of stem rust resistance genes.

The present study was conducted to assess resistance in 93 CIMMYT wheat genotypes to select new sources of adult plant resistance to stem rust. The results from field studies revealed that 84 out of 94 tested wheat genotypes were resistant and showed the lowest values of FRS (%), ACI and AUDPC. A total of 27 out of 84 genotypes were resistant at the two locations during the three growing seasons of the study genotypes. These genotypes are 4, 6, 8, 11, 12, 14, 17, 28, 33, 34, 41, 48, 49, 50, 55, 59, 63, 64, 66, 67, 74, 75, 84, 86, 87, 89 and 90. While, 57 out of 84 showed partial resistance. These genotypes are 1, 2, 3, 5, 7, 9, 10, 13, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 35, 36, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 52, 53, 54, 57, 58, 60, 62, 68, 69, 71, 72, 73, 76, 77, 78, 80, 81, 83, 85, 88 and 92. These 84 genotypes had source of adult plant resistance character to stem rust since they showed comparably low AUDPC values. Debebe [26] reported that selection of genotypes having low AUDPC values with terminal disease score of less than 20S is normally accepted for practical purposes where the aim is to utilize slow rusting resistance as one of the durable resistance strategies.

Moreover, these 84 wheat genotypes showed the highest values of RRI. According to the scale of 0-9 of Aslam [22] to select resistant wheat genotypes for rust diseases, where 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. The RRI assessment is used for study the selection of wheat genotypes to rust diseases in Egypt [27-29]. These results of this study are in agreement with Akhtar et al. [23], Rattu et al. [30] Hussain et al. [31]. Moreover, the results are in line with the work done by Mahmood et al. [32] who reported that the rust score of Chakwal-50 varied from 5 MR/MS to 30 MS for leaf rust. Also, the cv. Chakwal-50 gave RRI value of 7 to 8.6 for leaf rust. The cv. Chakwal-50 has the potential to be approved and released as a new variety. Our results are in conformity with those of El-Orabey et al. [27] who found that out of sixteen CIMMYT promising 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 RRI during the two seasons 2012/13 and 2013/14. Bansal et al. [33] indicated that presence of a single or couple of APR genes in a cultivar may not provide sufficient resistance levels in high disease pressure areas, however, they mentioned that cultivars with high levels of resistance were developed by pyramiding 3-5 APR genes. Durable resistance can be explained that a consistent resistance reaction of a plant displayed across locations/environments for several years of cultivation under favorable condition to a disease development [34]. Durable resistance to rusts can be achieved through a combination of both APR and ASR genes deployed to a single commercial cultivar [33].

In general, the wheat genotypes that exhibited field resistance to stem rust at both locations they can be good sources of APR genes. Therefore, these genotypes have to be selected as donor parent for incorporating durable resistance in bread wheat improvement program. For effective and precise breeding outcome knowledge of identity of the APR genes present in these genotypes is essential; hence, genotyping/screening of these 84 genotypes with the already known molecular markers of the APR genes; *Sr* 2, *Sr* 55, *Sr* 56, *Sr* 57 and *Sr* 58 is imperative. The outcome of these studies could be used as a preliminary source of information to develop high yielding stem rust resistant bread wheat cultivars for future breeding program particularly for durable resistance wheat breeding through gene pyramiding approaches using molecular marker assisted selection [35].

The 84 wheat promising lines should be tested for grain yield and other agronomic characters i.e. Days to heading and maturity, plant height (cm), biological yield (kg), straw yield and also flour extraction (%) and rheological properties to be registered as a new commercial cultivar, also, it must be identify the rust resistance genes present in these lines by molecular marker to know the leaf rust resistance genes and the number of genes present in these lines [36].

CONCLUSION

Wheat stem rust in Egypt has caused significant crop loss. It can be anticipated that control measures will be largely based on the development and release of resistant cultivars. Breeding for resistance will continue to be based on current awareness of variability in *Puccinia graminis* f. sp. *tritici*, the search for and commercial development of new and effective resistance combinations, and the resolve of industry to adopt best management practices that minimize disease risk. Results of this study were promising and some immune, resistant, and moderately resistant genotypes to *Puccinia graminis* f. sp. *tritici* were identified and they may be used as a resistance genetic source for management of the disease in national programs. This study indicated that 84 genotypes out of 94 had source of only adult plant resistance character to stem rust. Therefore, these genotypes have to be selected as donor parent for incorporating durable resistance in bread wheat improvement program.

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