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Research Article

Evaluation of some Egyptian Wheat Varieties against Stem Rust at Seedling and Adult Stages

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Abstract:

Stem rust caused by *Puccinia graminis* f. sp. *tritici* (Pgt), has been considered the most common rust disease of wheat. Twenty Egyptian wheat varieties were screened for resistance to stem rust infection at both seedling and adult stages. At the seedling stage, only Misr-3, Misr-4, Gemmeiza-12, and Giza-171 out of twenty wheat varieties had the highest efficacy against the TTTTF and TKTTC races of *P. graminis* f. sp. *tritici.* In contrast, Gemmeiza-9, Gemmeiza-11, Sakha-95, Shandweel-1, Shandweel-2, and Nubaria-2 had the highest efficacy against the second race (TKTTC). Moreover, the Sakha-95 variety was moderately resistant to the TTTTF race, while Gemmeiza-10, Sakha-93, Sakha-94, Giza-168, Sids-13, and Sids-14 were moderately resistant to the TKTTC race. Contrary, Misr-1, Misr-2, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sakha-93, Sakha-94, Giza-168, Sids-12, Sids-13, Sids-14, Shandweel-1, Shandweel-2, Nubaria-2, and Morocco had the lowest efficacy against TTTTF race; while, Misr-1, Misr-2, Sids-12, and Morocco had the lowest efficacy against the TKTTC race. At the adult stage, field reaction of stem rust on twenty wheat varieties was recorded as disease severity (%), and the area under the disease progress curve (AUDPC) during three growing seasons (2020-2022). Based on the correlation analysis, the significance of the chosen disease parameters, particularly final rust severity (FRS%) was validated. FRS% is considered the more suitable indication, rather than the AUDPC for evaluating wheat varieties against stem rust disease.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important grain crops worldwide as a food for humans and animals (Alnusairi *et al.*, 2021; Khedr *et al.*, 2023). Even though Egypt produces about 9.7 million tonnes ($6x10^7$ ardeb) ($0.9 \ x10^9$ Kg) from 3,320,477 fed (1,394,588 he), the country is facing an increasing wheat gap (FAOSTAT, 2023). Egypt produces a lot of bread and imports more wheat than any other nation in the world. More efforts are required by wheat researchers to reduce the growing gap between production and consumption (Abdelmageed *et al.*, 2018). However, researchers face numerous obstacles in their efforts to boost crop productivity in a variety of environmental settings, such as a lack of water (Gui *et al.*, 2024; Li *et al.*, 2024), salinity (Zhang *et al.*, 2024), and rust diseases (Abdelaal *et al.*, 2018; Shahin *et al.*, 2021; Khan *et al.*, 2024; Nazarov *et al.*, 2024).

Stem rust caused by *P. graminis* f. sp. *tritici*, is one of the most dangerous diseases on wheat (Omara *et al.*, 2017; Abdelaal *et al.*, 2018). Rust fungal infections are one of the main stresses that cause a significant loss in wheat production (Belayneh and Emebet, 2005). Disease symptoms resulting from *P. graminis* f. sp. *tritici* mostly appear on stems and leaf sheaths, but they additionally may occasionally be detected on leaf blades and glumes (Leonard and Szabo, 2005). Five different types of spores are involved in the intricate (macrocyclic) life cycles of these plant pathogens: pycniospores, aeciospores, urediniospores, teliospores, and basidiospores requiring alternative hosts to complete their life cycles because they are heteroecious (Martínez-Moreno and Solís 2019). *Mahonia* spp. and various barberry species serve as alternate hosts for the stem rust (Leonard and Szabo, 2005). Under ideal environmental conditions, the fungus can produce new physiological races that attack resistant varieties and spread epidemically, causing yield losses in epidemic years of up to 100% over large areas.

The identification and development of resistant varieties are the most effective, economical, and environmentally benign ways to manage this disease (Singh *et al.*, 2011; Admassu *et al.*, 2012; Regasa *et al.*, 2019). Since resistant host plants are the most effective way to prevent rust disease, planting resistant varieties is advised. The resurgence of a highly pathogenic race, commonly referred to as Ug99 and termed TTKSK according to North American nomenclature, poses a threat to wheat production for both small and large-scale farmers (Jin *et al.*, 2008; Chen *et al.*, 2009; Njau *et al.*, 2010). *Sr* genes are present in stem rust-resistant varieties, and at least 60 *Sr* genes are known to exist (Chen *et al.*, 2018). Furthermore, the 1998 discovery of the incredibly virulent race Ug 99 in Uganda cast doubt on stem rust's status as a disease that has been defeated (Singh *et al.*, 2008). Since then, it has been seen in various locations such as Kenya, Ethiopia, Eritrea, Yemen, Iran, Tanzania, South Africa, Sudan, Zimbabwe, Mozambique, and Egypt (Nazari *et al.*, 2009).

The wheat stem rust pathogen, *P. graminis* f. sp. *tritici*, seriously reduces yields on varieties that are susceptible in Egypt, particularly in late sowing dates (Ashmmawy *et al.*, 2013; Abdelaal *et al.*, 2018). Host-genetic resistance is thought to be the most environmentally safe and effective way to stop rust disease because it reduces yield losses from the infection and thus prevents severe epidemics (Singh *et al.*, 2011; Abou-Zeid *et al.*, 2018; Karelov *et al.*, 2022). As a result, some genotypes were previously evaluated in various nations to determine how they responded to the wheat stem rust disease, under field conditions (Kokhmetova *et al.*, 2011; Abdelaal *et al.*, 2018). The primary sources of resistance to the Egyptian breeding programs are the wheat genotypes derived from CIMMYT and ICARDA, in addition to the existing resistant varieties. In various parts of Egypt, commercial wheat varieties have recently demonstrated varying degrees of susceptibility to stem rust infection (Abdelaal *et al.*, 2018).

The objective of this study was to evaluate twenty Egyptian wheat varieties for stem rust resistance by assessing two stem rust resistance parameters; FRS (%) and AUDPC usually used as the criteria for evaluating resistance of slow rusting resistance at seedling and adult stages.

2. Materials and Methods

2.1. Pathological studies

The experiments were conducted using twenty wheat varieties (Table 1) at the sowing date on December 15th during the growing seasons from 2020 to 2022.

For the seedling stage, investigations were conducted in the stem rust greenhouse, Wheat Disease Research Department, Plant Pathology Research Institute (PPRI), Agricultural Research Center (ARC), Giza, Egypt. Additionally at the adult stage, experiments were carried out under field conditions at Itay El-Baroud Agricultural Research Station, Agricultural Research Center (ARC), El-Beheira Governorate (ElEU: 71ft, N: 30*892796^o and E:30*30.639638^o), during (2020-2022) growing seasons.

2.1.1. Seedling stage

The twenty wheat commercial varieties were evaluated at the seedling stage under greenhouse conditions during the 2020 growing season. The disease was assessed according to the scale adopted by Stakman *et al.* (1962) as shown in Table (2).

2.1.2. Adult stage

2.1.2.1. Disease assessment

These varieties were sown in a complete randomized block design with 3 replicates. The experimental unit consisted of 3 rows (3 m long and 30 cm apart and 5g seed rate for each row). The sowing date was on the fifteenth of December during the 2020-2022 growing seasons.

The experiment was surrounded by a 1 m allay and 1.5 m belt, which served as a spreader of stem rust susceptible entries, *i.e.* “Morocco”. The spreader was artificially inoculated using a mixture of physiological races in addition to the natural infection during late tillering and late elongation stages.

Disease severity (DS) was recorded four times, one every 10 days interval, during the three successive seasons expressed as percentage coverage of stems with rust pustules following the method adopted by Peterson *et al.* (1948). Rust reaction was expressed in five types (Stakman *et al.*, 1962), *i.e.* highly resistant = (0), resistant = (R), moderately resistant = (MR), moderately susceptible = (MS), and susceptible = (S). The obtained data served in determining final rust severity (FRS) and the area under the disease progress curve (AUDPC). The observation of the response of stem rust was carried out according to Saari and Wilcoxson (1974) and Afzal *et al.* (2009) as shown in Table 3.

2.1.2.2. Final rust severity (FRS)

Final rust severity (FRS) was recorded as outlined by Das *et al.* (1993) as disease severity (%) when the highly susceptible check variety was severely rusted, and the disease rate reached the highest and final level of stem rust severity.

2.1.2.3. Area under disease progress curve (AUDPC)

The area under the disease progress curve (AUDPC) was estimated to compare different responses of the tested varieties according to Pandey *et al.* (1989) using the following equation:

$$AUDPC = D\,[1/2\,(Y1 + YK) + Y2 + Y3 + \ldots Y\,(K\text{-}1)]$$

Where

D = days between readings

Y1 = first disease record

Yk = last disease record

2.2. Statistical analysis

WASP software was used to conduct an analysis of variance (ANOVA) on the data. To compare treatment means, the least significant difference (L.S.D) at a 5% level of significance was employed.

3. Results

3.1. Pathological studies

The response of twenty wheat varieties against stem rust was studied at the seedling stage in the greenhouse and the adult stage in the field to build up data on the regional performance and disease effects due to stem rust at Itay El-Baroud Agricultural Research Station, Agricultural Research Center (ARC), El-Beheira Governorate, during the 2020-2022 growing seasons.

3.1.1. At the seedling stage

Data presented in Table (4) revealed that the wheat varieties Misr-3, Misr-4, Gemmeiza-12, and Giza-171 had the highest efficacy against the TTTTF race of *P. graminis* f. sp. *tritici*, as the infection type of each variety was zero. Additionally, the wheat variety Sakha-95 was moderately resistant to TTTTF race with infection type 2 (Table 4). On the other hand, the wheat varieties Misr-1, Misr-2, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sakha-93, Sakha-94, Giza-168, Sids-12, Sids-13, Sids-14, Shandweel-1, Shandweel-2, Nubaria-2, and Morocco had the lowest efficacy and highest virulence frequencies against TTTTF race. The infection types were 3 for the ten varieties and 4 for the Morocco variety (Table 4).

Table (1): Pedigree and year of release of the wheat varieties under study

No.	Variety	Pedigree	Year of release
1	Misr-1	OA-SIS/SKAUZ//4*BCN1312*PASTOR.CMSSOOYO1881T-050M-030Y-030M-030WGY-33M-0Y-0S.	2011
2	Misr-2	SKAUZ/BAV92. CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S.	2011
3	Misr-3	ATTILA*2/ABW65*2/KACHU CMSS06Y00258 2T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY	2019
4	Misr-4	NS-732/HER/3/PRL/SARA//TSI/VEE#5/FRET2/5/WHEAR/ SOKOLL.	-
5	Gemmeiza-9	ALD"S"/HUAS//CMH74A.630/SX.GCM4583-5GM-1GM-0GM.	1999
6	Gemmeiza-10	MAYA74"S"/ON / 1160- 147 /3/ BB/ G11/4/ CHAT "S"/5/ CROW "S"GCM 5820- 3GM- 1GM-2GM- 0GM.	2004
7	Gemmeiza-11	BOW"S" /KVZ"S"// 7C/SERI82/3/GIZA168 /SKHA61. GM7892-2GM-1GM-2GM-1GM-0GM.	2011
8	Gemmeiza-12	OTUS/3/SARA/THB//VEECMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM	2011
9	Sakha-93	SAKHA92/TR810328 S.8871-1S-2S-1S-0S	1999
10	Sakha-94	OPATA/RAYON//KAUZ. CMBW90Y3180-OTOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S.	2004
11	Sakha-95	POSTOR//SITE/MO/3/CHEN/AEGILOPS/SQUARROSA(TAUS)	2018
12	Giza-168	MRL/BUC//SERI.CM93046-8M-0Y-0M-2Y-0B-0GZ.	1999
13	Giza-171	SAKHA 93 / GEMMEIZA 9S.6-1GZ-4GZ-1GZ-2GZ-0S	2013
14	Sids-12	BUC//7C/ALD/5/MAYA74/ON//1160147/3/BB/GLL/4/CHAT"S"/6/MAYA/VUL//CMH74A.630//4*SX. SD7096-4SD-1SD-1SD-0SD.	2007
15	Sids-13	AMAZ19=KAUZ"S"//TSI/SNB"S". ICW94-0375-4AP-2AP-030AP-0APS-3AP-0APS-050AP-0AP-0SD.	2010
16	Sids-14	KAUZ"S"//TSI/SNB"S". ICW94-0375-4AP-2AP-030AP-0APS-3AP.	2014
17	Shandweel-1	SITE/MO/4NAC/TH.AC//3*PVN/3/MIRLO/BUC/CMSS93B00567S-72Y-010Y-010M-3Y-0M-0HTY-0SH	2011
18	Shandweel-2	-	-
19	Nubaria-2	FRET2∗2/4/SNI/TRAP#1/3/KAUZ∗2/TRAP//KAUZ∗2/5/BOW/URES//2∗WEAVER/3/CROC_1/ AESQUARROSA (213)//POG.	-
20	Morocco (check)	Highly susceptible check variety.	-

Table (2): Disease assessment of wheat stem rust at the seedling stage

Host response	Infection type	Disease symptoms
Immune	0	No uredia or other macroscopic signs of infection.
Nearly immune	0	No, uredia but hypersensitive necrotic or chlorotic flecks are present.
Very resistant	1	Small uredia surrounded by necrosis.
Moderately resistant	2	Small to medium uredia surrounded by chlorosis or necrosis.
Moderately susceptible	3	Medium-sized uredia that may be associated with chlorosis.
Very susceptible	4	Large uredia without chlorosis or necrosis or rarely necrosis.
Heterogeneous	X	Random distribution of different variable-sized uredia on a single leaf.

Table (3): The observation of the response of stem rust

Reaction	Observation	Response value
No disease	0	0.0
Resistant	R	0.2
Resistant-Moderately Resistant	R-MR	0.3
Moderately Resistant	MR	0.4
Moderately Resistant-Moderately Susceptible	MR-MS	0.6
Moderately Susceptible	MS	0.8
Moderately Susceptible-Susceptible	MS-S	0.9
Susceptible	S	1.0

Furthermore, the wheat varieties Misr-3, Misr-4, Gemmeiza-9, Gemmeiza-11, Gemmeiza-12, Sakha-95, Giza-171, Shandweel-1, Shandweel-2, and Nubaria-2 had the highest efficacy against the second race TKTTC. The infection types were 0, 0, 1, 0, 0, 1, 1, 0, 0, and 0, respectively (Table 4). Moreover, the wheat varieties Gemmeiza-10, Sakha-93, Sakha-94, Giza-168, Sids-13, and Sids-14 were moderately resistant to TKTTC race with an infection type 2. The wheat varieties Misr-1, Misr-2, Sids-12, and Morocco had the lowest efficacy and highest virulence frequencies against the TKTTC race, as the infection types were 3 for the first three varieties and 4 for the Morocco variety (Table 4).

It can be also observed from Table 4 that the race TTTTF was more aggressive than the race TKTTC, where it was broken resistance to 15 wheat varieties (Figs. 1 and 2).

Table (4): Infection types of some Egyptian wheat varieties against stem rust races at seedling stage

Wheat variety	Stem rust races	
	TTTTF	TKTTC
Misr-1	3	3
Misr-2	3	3
Misr-3	0	0
Misr-4	0	0
Gemmeiza-9	3	1
Gemmeiza-10	3	2
Gemmeiza-11	3	0
Gemmeiza-12	0	0
Sakha-93	3	2
Sakha-94	3	2
Sakha-95	2	1
Giza-168	3	2
Giza-171	0	1
Sids-12	3	3
Sids-13	3	2
Sids-14	3	2
Shandweel-1	3	0
Shandweel-2	3	0
Nubaria-2	3	0
Morocco (check)	4	4
Total susceptible varieties	15	4
Total resistant varieties	5	16
L.S.D $_{0.05}$		
Races (R)	0.30	
Variety (V)	0.95	
R×V	1.34	

0, 0, 1, 2= resistant; 3, 4= susceptible (Stakman *et al.*, 1962).

3.1.2. At the adult stage

Disease assessment

Rust incidence on twenty wheat varieties was recorded as rust severity (%) starting from appearance until the dough stage during three seasons (2020-2022). The final rust severity (FRS), and the area under disease progress curve (AUDPC) were studied.

Field reaction of stem rust (*P. graminis* f. sp. *tritici* Eriks & Henn.) on twenty wheat varieties was recorded as disease severity (%), starting from the first rust appearance in each variety until the dough stage. Two epidemiological parameters; final rust severity percentage (FRS) and area under disease progress curve (AUDPC) were estimated during the three growing seasons of the study. In the growing season 2020, the obtained results showed that wheat varieties: Misr-1, Misr-2, Gemmeiza-10, Gemmeiza-11, and Sids-12 were highly susceptible and exhibited high percentages of FRS (69.50, 62.00, 62.50, 49.00, and 49.00 %) respectively. Moreover, these varieties recorded high values of AUDPC (2150.00, 1870.00, 1920.00, 1520.00, and 1520.00 respectively. Contrarily, the varieties, Misr-4, Giza-171, Shandweel-2, and Nubaria-2 showed high resistance to stem rust as they recorded (6.65, 6.65, 10.65% and 10.65%) and (183.00, 163.00, 263.00, and 303.00) for the FRS and AUDPC respectively. In seasons 2021 and 2022, the results were parallel to those obtained in the previous season (Table 5 and Figs. 3 and 4).

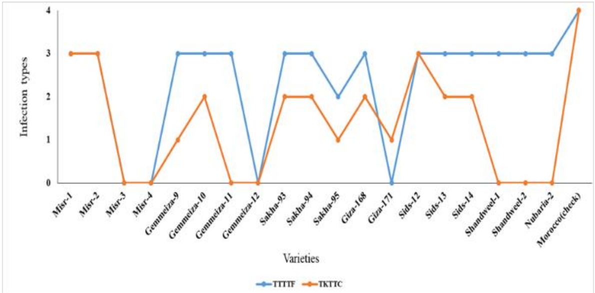

Fig. 1. Infection types of some Egyptian wheat varieties against two stem rust races of *P. graminis* f. sp. *tritici* at the seedling stage to different races.

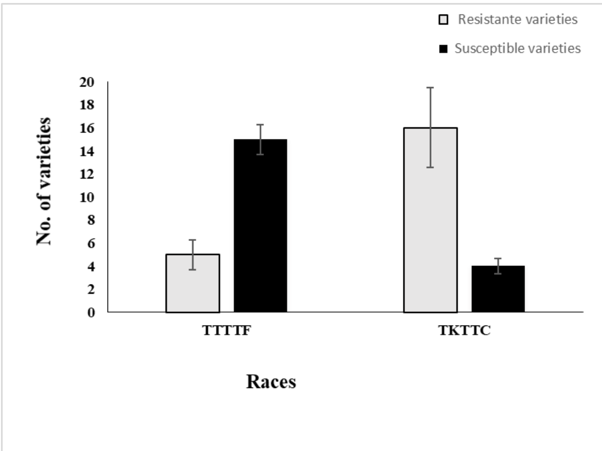

Fig. 2. Number of resistance and susceptible varieties, to TTTTF and TKTTC races of *P. graminis* f. sp. *tritici* at seedling stage

Table 5. Final rust severity (%) and AUDPC for twenty Egyptian wheat varieties during 2020-2022 growing seasons

Variety	Final stem rust severity (FRS%)				Area under disease progress curve (AUDPC)			
	2020	2021	2022	Mean	2020	2021	2022	Mean
Misr-1	69.50	79.00	67.50	72.00	2150.00	2340.00	2070.00	2186.67
Misr-2	62.00	58.50	69.50	63.33	1870.00	1770.00	2150.00	1930.00
Misr-3	20.00	19.50	29.50	23.00	580.00	570.00	860.00	670.00
Misr-4	6.65	10.65	10.65	9.32	183.00	303.00	303.00	263.00
Gemmeiza-9	40.00	38.00	30.00	36.00	1200.00	1210.00	870.00	1093.33
Gemmeiza-10	62.50	49.00	48.50	53.33	1920.00	1520.00	1550.00	1663.33
Gemmeiza-11	49.00	67.50	69.50	62.00	1520.00	2070.00	2150.00	1913.33
Gemmeiza-12	29.50	49.00	40.00	39.50	860.00	1520.00	1200.00	1193.33
Sakha-93	29.50	20.00	30.00	26.50	860.00	580.00	870.00	770.00
Sakha-94	19.50	30.00	20.00	23.17	570.00	870.00	590.00	676.67
Sakha-95	22.00	19.50	20.00	20.50	620.00	570.00	540.00	576.67
Giza-168	49.00	41.00	40.00	43.33	1520.00	1270.00	1200.00	1330.00
Giza-171	6.65	15.15	10.65	10.82	163.00	463.00	303.00	309.67
Sids-12	49.00	49.00	40.00	46.00	1520.00	1520.00	1200.00	1413.33
Sids-13	40.00	49.00	40.00	43.00	1200.00	1520.00	1200.00	1306.67
Sids-14	31.50	30.00	20.00	27.17	990.00	880.00	540.00	803.33
Shandweel-1	20.00	59.50	40.00	39.83	580.00	1860.00	1200.00	1213.33
Shandweel-2	10.65	10.65	10.65	10.65	263.00	303.00	303.00	289.67
Nubaria-2	10.65	10.65	11.15	10.82	303.00	303.00	323.00	309.67
Morocco (check)	90.50	79.00	79.00	82.83	2760.00	2340.00	2340.00	2480.00
L.S.D $_{0.05}$ for:								
Variety (V)		1.753				136.601		
Year (Y)		0.680				52.903		
V×Y		3.045				236.607		

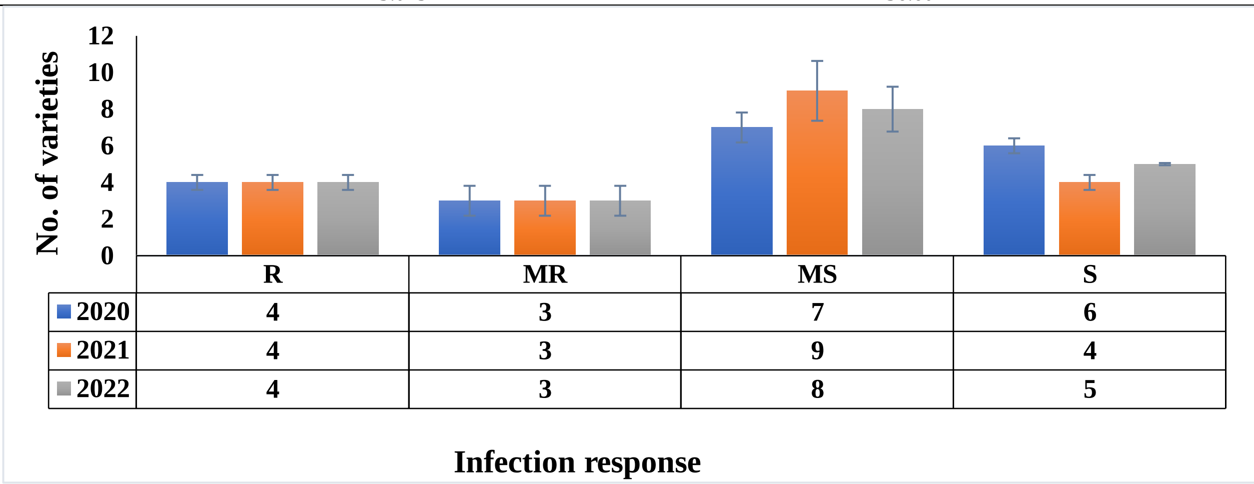

Fig. 3. Final rust severity (%) for twenty Egyptian wheat varieties during the 2020-2022 growing seasons

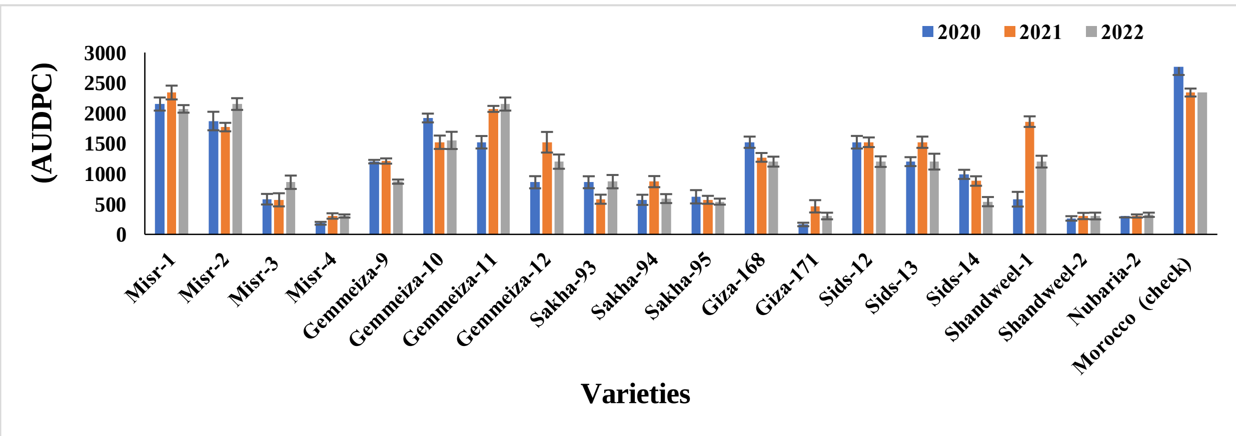

Fig. 4. Area under disease progress curve (AUDPC) for twenty Egyptian wheat varieties during the 2020-2022 growing seasons

4. Discussion

P. graminis f. sp. *tritici* Eriks & Henn, the cause of stem rust, is a devastating wheat disease that affects wheat both in Egypt and globally (El-Naggar *et al.*, 2020). Because of the ideal climate, the stem rust disease affects susceptible varieties more severely when they are sown later (Park *et al.*, 2007) causing 100 % loss, based on the wheat genotype resistance level and crop development stage at the time of the first infection.

Although all of the slow rusting resistance varieties and the highly susceptible ones in the current study were inoculated with the same *P. graminis* f. sp. *tritici* races in a greenhouse with ideal environmental conditions, a considerable amount of variation was discovered between them.

Among the tested varieties and artificial infection with the races TTTTF and TKTTC, Misr-3, Misr-4, Gemmeiza-12, and Giza-171 had the highest efficacy against the TTTTF race of *P. graminis* f. sp. *tritici*. The wheat varieties Misr-3, Misr-4, Gemmeiza-9, Gemmeiza-11, Gemmeiza-12, Sakha-95, Giza-171, Shandweel-1, Shandweel-2, and Nubaria-2 had the highest efficacy against the second race (TKTTC). These varieties were immune to wheat stem rust, as they showed no signs of infection, necrosis, or chlorosis, and they had no uredia.

While the wheat variety Sakha-95 was moderately resistant to the TTTTF race, the wheat varieties Gemmeiza-10, Sakha-93, Sakha-94, Giza-168, Sids-13, and Sids-14 were moderately resistant to the TKTTC race. These moderately resistant varieties exhibit a high degree of slow rusting resistance against stem rust.

On the other hand, the Egyptian wheat varieties, Misr-1, Misr-2, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sakha-93, Sakha-94, Giza-168, Sids-12, Sids-13, Sids-14, Shandweel-1, Shandweel-2, Nubaria-2, and Morocco had the lowest efficacy and highest virulence frequencies against the TTTTF race. The wheat varieties Misr-1, Misr-2, Sids-12, and Morocco had the lowest efficacy and highest virulence frequencies against the TKTTC race. These varieties could be classified as extremely susceptible or quickly rusting stem varieties. These results are in agreement with those reported by Kaur and Bariana (2010); El-Nagar *et al.* (2013) and Mabrouk *et al.* (2019).

Two groups of slow stem rusting resistance were formed from the tested wheat varieties based on the studied parameters (stem rust severity percentage and infection response). Slow stem rusting resistance and high and moderate levels of partial resistance ranged from 1-30 and greater than 30% severity of rust. Response of twenty Egyptian wheat varieties *i.e.* Misr-1, Misr-2, Misr-3, Misr-4, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Gemmeiza-12, Sakha-93, Sakha-94, Sakha-95, Giza-168, Giza-171, Sids-12, Sids-13, Sids-14, Shandweel-1, Shandweel-2, and Nubaria-2 in addition to entry, Morocco was assessed in the field for stem rust disease susceptibility in chicks at Itay El-Baroud Agricultural Research Station, Agricultural Research Center (ARC), El-Beheira Governorate, for three successive growing seasons (2020-2022).

It can be concluded that group I: The first group includes the partial resistant varieties, such as Misr-3, Misr-4, Sakha-93, Sakha-94, Sakha-95, Giza-171, Sids-14, Shandweel-2, and Nubaria-2 for three growing seasons 2020, 2021 and 2022, respectively that were described as being crucial to successful breeding for slow stem rust resistance (Nzuve *et al.,* 2012 and Mabrouk *et al.,* 2019). On the other hand, group II: The second group includes the susceptible varieties such as Misr-1, Misr-2, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Gemmeiza-12, Giza-168, Sids-12, Sids-13, Shandweel-1, and Morocco for three growing seasons 2020, 2021 and 2022, respectively where final stem rust severity ranged from 60 to 80 % with susceptible (S) responses. To improve the adopted but highly susceptible wheat varieties, an appropriate breeding strategy could be used, such as the use of inter-specific and remote crosses or even the direct transfer of these resistances through backcrosses (Bartos *et al.*, 2002).

Due to the different response components that eventually result in the expression of slow rusting, the wheat varieties may differ in their capacity to delay the disease's development (Parlevliet and Kuiper 1977). Furthermore, partial resistance manifested as a susceptible host response but a slower rate of disease development, suggesting that it may be more resilient than hypersensitive resistance (Marais *et al.* 2003).

The second parameter is the area under disease progress curve (AUDPC). It was measured during the three growing seasons under study. The disease parameter, AUDPC is an important indicator of disease progression over the lifespan of the host (Van der Plank 1963). Field observations showed that the evaluation of stem rust in growing season 2021was higher in severity than in the 2020 and 2022 growing seasons and Misr-1, Misr-2, Sids-12 and Sids-13 varieties recorded the highest values of AUDPC compared to the highly susceptible check variety, Morocco, followed by Gemmeiza-9 and Gemmeiza-12 which recorded moderate values of the disease parameter AUDPC and considered moderately susceptible varieties. On the other hand, Misr-4, Giza-171, Shandweel-2, and Nubaria-2 recorded the lowest values of AUDPC and had high levels of resistance in the three growing seasons similar results were found for rusts of wheat (Ali *et al.,* 2008; Safavi *et al.,* 2010 and Mabrouk *et al.,* 2019). The distinction between the type of infection and the disease is reflected in the variations in the genetic background of resistance. This is because new virulent races are entering pathogen populations, which means that over time, some varieties' infections may change in type (Omara *et al.,* 2021). For many years some varieties can maintain resistance but become susceptible after some time (Al-Maaroof, 1997). Due to the effects of biotic stress on wheat plants (*Triticum aestivum* L.), the degree of rust infection has an inverse relationship with grain yield. To develop disease control strategies, particularly through disease-resistant breeding programs, it is necessary to assess the damage caused by disease (Simmmonds 1988). The ability of any variety to reduce grain loss due to infection can be used to characterize its resistance to rust. Therefore, even though the yield of the protected varieties was higher than that of the infected ones, it can be said that the fungus utilizes the nutrients that lead to grain wilting instead of providing them to the grain, especially in the flag leaves (Subba Rao *et al.,* 1989).

5. Conclusion

The timing of sowing is crucial for controlling rust and increasing wheat grain yield. Based on the present results, on late sowing date (the fifteenth of December) Maximum rust severity and area under disease progress curve (AUDPC) were recorded on sowing date 15-Des it is concluded that there is no variety belonging to the group of resistant varieties. In addition to, most of varieties under study belonging to the group of susceptible varieties for three growing seasons 2020, 2021 and 2022, respectively at adult plant stage.

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