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Potential of Kaolin and Fulvic Acid Antitranspirant Substances in Suppressing Wheat Leaf Rust and Enhancing Crop Yield under Four Water Irrigation Regime Levels

Minaas E.A. Sallam[1], Enas S. ElRefaay[1], Hamdy A. Emara[2] and Yehia A. Khidr[2]

[1]Wheat Diseases Research Department, Plant Pathology Research Institute, ARC, Giza, Egypt, 12619.
[2]Plant Biotechnology Department, Genetic Engineering and Biotechnology Research Institute, University of Sadat City, Egypt.

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ABSTRACT

Wheat leaf rust caused by the pathogenic fungus, *Puccinia triticina* Eriks, is a serious threat to bread wheat production in many areas of the world. Kaolin and Fulvic acid antitranspirants were used to improve the performance of three wheat cultivars infected by leaf rust (*P. triticina*). The wheat cultivars were grown under four water irrigation regime levels during two successive grown seasons 2015/2016 and 2016/2017 at the Farm of Nubaria Research Station . Spraying Kaolin (Ka) at 6% and Fulvic acid (FA) at 0.06 before one week of inoculation decreased the percentage of final rust severity (FRS%), average coefficent of infection (ACI) and area under disease progress curve (AUDPC) of the treated wheat cultivars compared to infected control. Moreover, foliar appliction of the two antitranspirants reduced the effect of water irrigation regime stress resulted in increasing yield production and yield components of the treated wheat cultivars compared to the infected control. Kaolin followed by Folvic acid recorded the best results in FRS%, ACI and AUDPC of infected wheat cultivars. These results were reflected a postive rsponse of Misr 1 and Sids12 wheat cultivars against leaf rust infection than Gemmmeiza 7. Interaction between the four irrigation regimes, two antitranspirants on the three wheat infected cultivars led to significant improvement in the reaction of cultivars which enhaced yield and yield components.

Keywords: Kaolin, Fulvic acid, Wheat leaf rust, water irrigation regime, antitranspirant, *Puccinia triticina.*

1. Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop in all over the world. Wheat is considered the first strategic food crop in Egypt. Its stable diet for the world population and contributes more calories and protein to the world diet more than any other cereal crop (Hanson *et al*., 1982). In 2022, about 3.6 million feddans (1.512 million hectares) planted with wheat, produced about 9.3 million ton grain yield in Egypt (Economic Affairs Sector, 2022). Globally, it is grown on roughly 200 million hectares with an average production of 766 million tons (FAO, 2022). By the year of 2025 it is predicted that around 1.8 billion people will face complete water deficiency and 65% of the world population will live under water stressed environments (Nezhad Ahmadi *et al*., 2013). In Egypt, high losses in wheat grain yield could be expected due to the dominant environmental conditions favoring disease infection, i.e., rusts, smuts, and powdery mildew. Using resistant varieties seemed to be important to reduce the production losses and obtain economic grain yield.

Cereal rust fungi are amongst the most devastating plant pathogens and their continuously increasing prevalence presents major constraints to *Triticum* spp. Wheat production, posing a serious threat to global food security. Rust diseases are the most important foliar diseases of wheat because of their spore's ability to spread for long distances. Furthermore, their ability to form new physiologic races that can attack resistant cultivars after their release in agriculture, their high potential to develop rapidly under optimal environmental conditions and cause serious losses (El-Daoudi *et al*., 1994).

Corresponding Author: Enas S. ElRefaay, Wheat Diseases Research Department, Plant Pathology Research Institute, ARC, Giza, Egypt, 12619. E-mail: enaselrefaay9@gmail.com

Wheat leaf rust, caused by *Puccinia triticina* Eriks is one of the most common diseases of wheat worldwide. It probably results in higher total annual losses worldwide because of its more frequent and widespread occurrence (Huerta-Espino *et al*., 2011). The fungus *Puccinia triticina* is an obligate parasite that causes leaf rust pustules on wheat. Urediospores of *P. triticina* germinate on the leaf surface and germ tubes enters wheat leaves stoma via appressoria which form at open stomata and colonize the apoplastic space with hyphae within 24 h after germination. The life cycle can be completed in approximately 7 days when new urediospores are formed to initiate a new cycle (Bolton *et al.,* 2008).

According to the mechanism of action, antitranspirants are divided into different groups, which are: film-forming types (that cover leaf surface with thin coat which is unrealizable to water vapor), reflecting materials (which reflect backward a part of the radiation downfall on the upper surface of the leaves), and stomatal closing kinds that influence the metabolic operations in leaf tissues (Conde *et al*., 2016).

They were found antitranspirants to be non-toxic and have a longer period of effectiveness than metabolic types. Kaolin is a non-toxic aluminum silicate spray reduces leaf temperature through rising leaf reflectance which decreases transpiration rate more than the photosynthesis of plants grown at high solar radiation levels (Nakano and Uehara, 1996). Film-forming types: (i) Kaolin that can reflect the radiation falling on the surface of the leaves to reduce leaf temperature and the light needed for signaling during stomatal opening. This is due to that preemptive application of hydrophobic and hydrophilic Kaolin particles which reduce the wheat leaf rust incidence and the transpiration rate in order to minimize the amount of irrigation water and mitigate plant water stress by increasing the leaf resistance and diffusion water vapor (Sallam, 2013).

Fulvic acid (FA) is produced by the biodegradation of organic materials and its activity depends on the organic substance used, in addition to its role as a multifunction growth regulating compound like antitranspirants and Auxins (Anjum et al., 2011 Zhang et al., 2016; Yang *et al*., 2017). Spraying of Fulvic acid has the potential ability to reduce water losses by decreasing leaf stomatal transpiration (Li *et al*., 2005; Calvo *et al*., 2014). FA application on wheat plants increased water uptake by improving root hydrophilic conductance and cell membrane permeability (Delfine *et al*., 2005). Water stress as abiotic agent is one of the main important environmental constraints limiting the productivity of many crops worldwide and causes crop grain yield reduction in most agricultural regions of the world. Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factors (Shao *et al.,* 2009). In Egypt, wheat plants are sometimes exposed to drought stress at different periods of growth. Germination and seedling are the critical stages of the plant, which is seriously disturbed by low water shortage. (Ahmad *et al*., 2015).

Antitranspirants are chemical substances with some biological activities could be applied on the surface of plant to reduce the transpiration rate and mitigate plant water stress by increasing the leaf resistance and diffusion water vapor.

Therefore, the objectives of this research was to evaluate the effect of kaolin and Fulvic acid as antitranspirants on wheat leaf rust severity and enhance the yield and yield components of Gemmeiza 7, Sids 12 and Misr 1 wheat cultivars under deficiency of water irrigation by increasing interval times.

2. Materials and Methods

2.1. Field experiment

2.1.1. Wheat cultivars material

Seeds of Gemmeiza 7, Sids 12, and Misr 1 were kindly obtained from Wheat Research Department, Field Crops Research Institute, ARC, Giza, Egypt.

Table 1: List of the tested wheat cultivars that were used and leaf rust susceptibility.

Cultivar	Pedigree and selection history	Susceptibility
Gemmeiza 7	CMH74A.630/SX//SERI82/3/AGENT GM4611-2GM-3GM-1GM-0GM	Highly susceptible
Sids 12	BUS//7C//ALD/5/MAYA74/ON//1160.147/3/BB/GLL/4/CHAT"S"/6/MAYA/VU L//CMH74A.630/4*SX	Moderately susceptible
Misr 1	OASIS/KAUZ//4*BCN/3/2*PASTOR CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S	Resistant

2.1.2. Design of the experiment:

The experiment was conducted using spilt- spilt plot design with three replicates at the experimental farm of EL-Nubaria Agricultural Research Station in two consecutive growing seasons 2015/2016 and 2016/2017. The main plots were 4 irrigation regimes (25, 50, 75 and 100%), the sub-plots were wheat cultivars, while the sub-sub-plots were 2 antitranspirant substances (Kaolin and Fulvic acid). Three replicates were used for each. The experiment consisted of 144 plots, 36 plots for each treatment. Each plot contains six rows, two meter long, twenty cm apart and eight-gram seeds were drilled along each row. These plots were surrounded by one meter width spreader border cultivated with the highly susceptible wheat cultivars (Morocco and Thatcher) to ensure statement of leaf rust disease. Fertilizers were added to the soil as recommended by Agriculture Ministry.

2.2.1. Irrigation regime levels:

The main plot was irrigation water regimes(I_1, I_2, I_3 and I_4) of water hold capacity where : (1) I_1 represent 100% in which the irrigation is applied every fourteen days with total of eight times of irrigation each season, (2) I_2 represent 75% in which the irrigation applied every twenty one days with total of six times of irrigation , (3) I_3 represent 50% in which the irrigation applied every twenty eight days with total of four times of irrigation and (4) I_4 represent 25% in which the irrigation applied every thirty five days with total of three times of irrigation in addition to the irrigation of growing.

2.2.2. Wheat cultivars.

The wheat cultivars, Gemmeiza7, Sids12 and Misr1 were used as sub-treatments.

2.2.3. Application of antitranspirant substances:

Kaolin (Aluminium silicate, $H_2Al_2Si_2O_8.H_2O$) at 6% and the organic fertilizer product fulvic acid at 0.06% concentration were applied as sub-sub- treatment. Also, the fungicide Sumi-8 (0.35 ml/L water) was used which act as healthy control. While, infected control plots were sprayed with water. All treatments were sprayed 24 h. before inoculating the experimental cultivars at booting stage (Large, 1954).

2.2.4. Procedures of wheat Leaf Rust (*Puccinia triticina*) inoculation at adult stage in the open field:

Fresh mixture of aggressive leaf rust urdiospores pathotype in race groups (TT---, TS---, TK---, ST---) of *Puccinia triticina* (Pt) were collected from infected adult highly susceptible wheat plants (Morocco) urediospores in the greenhouse of wheat Dis. Res. Dept., Plant Pathol. Res. Inst., ARC. Urediospores were mixed with talc powder (1:20 v/v) according to Tervet and Cassel (1951) then dusted using baby cyclone in uniformly artificial inoculation at adult plants.

2.2.5 Disease assessment:

The assessment includes the following:

1. **Final rust severity** (FRS%) was carried out onset the rust appearance, and weekly recorded as percentage of disease severity (DS%) as the percentage of leaves covered with rust pustules and contentiously recorded until constancy of reading according to the scale 0 -100 adopted by Peterson *et al.* (1948). The above data were used to calculate the final rust severity (FRS). Average coefficient of infection (ACI) and area under the disease progression curve (AUDPC).
2. **Infection type** of leaf rust was detected according to Long and Kolmer (1989) as follows: Immune (0), Resistant = R, Moderately resistant= MR, Moderately susceptible =MS and Susceptible = S.
3. **Average coefficient of infection (ACI) =** values of rust severity x constant values of infection type (IT) following the method of Saari and Wilcoxson (1974) which: Immune (O) = 0.0, Resistant (R) = 0.2, Moderately resistant (MR)= 0.4, Mixture types (X)= 0.6, Moderately susceptible (MS) =0.8 and Susceptible (S) =1.0.
4. **Area under disease progress curve** (**AUDPC**) parameter was calculated using a simple formula adopted by Pandey *et al.* (1989) as follows:

$$AUDPC = D\,[1/2\,(Y_1+Y_K) + (Y_2+Y_3+......................Y_{K-1})].$$

Whereas D = days between time intervals, Y_1+Y_K = Sum of the first and last disease scores and Y_2+Y_3+.................. Y_{K-1}= Sum of all in between disease scores.

2.1.3. Yield components:

At harvest time, spikes number/m^2, kernels number/spike, spike weight (g), 1000- kernel weight (g), grain yield/plot (g) were determined in both seasons and compared with the healthy protected and infected control wheat plants.

2.1.4. Statistical analysis:

All the detected parameters during the two seasons of study were analyzed using analysis of variance (ANOVA) with Co-Stat (2005) software. The test was arranged and listed using the least significant differences (LSD at 0.01%), as stated by Gomez and Gomez (1984).

Results and Discussion

3.1. Effect of foliar spraying of kaolin and Fulvic acid on disease parameters of leaf rust under four irrigation regime levels:

3.1.1. Final rust severity and Infection type.

Final rust severity and infection type of the three wheat cultivars (Gemmeiza7, Sids12 and Misr1) sprayed with kaolin and Fulvic acid under four irrigation regime levels are shown in Table (2).

The obtained results revealed that, all the treated wheat cultivars by Kaolin and Fulvic acid showed decreases in its responses to leaf rust disease under the four irrigation regime levels compared with the infected controls. The resistant wheat cultivar Misr1 followed by Sids12 were the best, while Gemmeiza7 was the least one in this respect. The best results of final disease severity (FRS) were obtained with the fourth irrigation level (I_4). In general, the fungicide Sumi-8 showed the best results under all the irrigation regime levels, which showed final disease severities ranged from 3.00% (R and R/MR) under 25% (I_4) irrigation regime level to 5.3, 7.60 %(R/MR) response under 100% (I_1) the highest irrigation regime level.

The cultivar Gemmeiza7 showed the highest final disease severity (FRS%) and susceptible infection type (S) with Kaolin releasing 57.00, 33.00 % and 67.00 , 40.00% with Fulvic acid with 100% irrigation regime level (I_1) compared with the infected control ,83.00 , 60.00 % susceptible infection type (S) in 2015/2016 and 206/2017 growing seasons, respectively. However, it showed 46.7, 15.6 % and 53.3, 18.3% with Kaolin and Fulvic acid with 25% irrigation regime level (I_4) compared with the infected control, 70.00, 23.3 % (S) in the two growing seasons, respectively.

On contrast, Sids12 wheat cultivar showed 10.00% moderately susceptible response (MS), 13.3 MR/MS and 6.60MS,13.30 MS with Kaolin and Fulvic acid with 100% irrigation regime level (I_1) compared with the infected control 46.6, 40.00% and susceptible infection type (S) in the two seasons of study. While it gave 5.00 MS, 6.6 MS and 4.3, 5.00 MR/MS when treated by Kaolin and Fulvic acid, respectively compared with 20S, 20MS in the infected control under 25% irrigation regime level (I_4) in the two seasons of study.

Also, Misr1 wheat cultivar gave the lowest final disease severity (FRS) which released 5.00MR, 8.3 R/MR and 5.00 MR, 8.00R/MR when treated by Kaolin and Fulvic acid under 100% irrigation regime level (I_1) compared with infected control 18.30, 18.30 R/MR during the two seasons, respectively. However, it showed the lowest final disease severity, 3.6 % (R/MR) and 3.60, 3.00 % (R/MR) when treated with both of Kaolin and Fulvic acid under 25% irrigation regime level (I_4) compared to the infected control, 8.30, 3.60 % (MR) in the two seasons, respectively.

3.1.2 Average coefficient of infection (ACI)

Average coefficient of infection (ACI) values of the three wheat cultivars as affected by the two antitranspirant substances and four irrigation regime levels in the two growing seasons 2015/2016 and 2016/2017 are presented in Table (3).

In general, the average coefficient of infection (ACI) values of the three wheat cultivars run in a parallel line with those of its final disease severities. The interaction between the used antitranspirants substances and irrigation regime levels led to decreases in ACI values of the three wheat cultivars .Also, the low levels of irrigation regime led to decrease leaf rust severity consequently, showed low values of ACI and vice versa with the high levels of irrigation regime. All the wheat cultivars gave the lowest

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Table 2: Mean of final rust severity (FRS%) and infection type (IT) of three Egyptian wheat cultivars as affected by four irrigation regime levels (I) and two antitranspirants (Kaolin and Fulvic acid).

Irrigation regime levels	Cultivars	2015/2016				2016/2017			
		Kaolin.	Fulvic acid	Protected control	Infected control	Kaolin.	Fulvic acid	Protected control	Infected control
I_1	Gem.7	57 S	67S	5.3MS	83S	33S	40S	7.6R/MR	60S
	Sids12	10MS	6.6MS	3.4MS	46.6S	13.3S	13.3S	7.6R/Mr	40S
	Misr1	5Mr	5Mr	6.3R	18.3R/Mr	8.3R/Mr	8Mr	4.3R/Mr	18.3R/Mr
I_2	Gem.7	56.6S	56.6S	3.6MS	80S	31.6S	33S	5.2R/Mr	46.75S
	Sids12	8.3MS	6.6MS	4.3R/Mr	23.3S	8.3MS	8.3MS	5R/Mr	23.3MS
	Misr1	5MR	5MR	5.3R	15MR	6.6R/Mr	6.6R/Mr	5.6R/Mr	8.3MR
I_3	Gem.7	46.7S	53.3S	3R/Mr	70S	16.3S	21.6S	3R/Mr	23.3S
	Sids12	5.8MS	5MS	4.5R	23.3S	6.6MS	8.3MS	3R/Mr	18.64S
	Misr1	3.6MR	3MR	3R/Mr	8.3MR	5R/Mr	5R/Mr	3.6R/Mr	6.6MR
I_4	Gem.7	46.7S	53.3S	3R/Mr	70S	15.6S	18.3S	3R/Mr	23.3S
	Sids12	5MS	4.3MS	3R/Mr	20S	6.6MS	5R/Mr	3R/Mr	20MS
	Misr1	3.6R/Mr	3.6R/Mr	3R	8.3MR	3.6R/Mr	3R/Mr	3R/Mr	3.6Mr

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Table 3: Average coefficient of infection (ACI) of three Egyptian wheat cultivars as affected by four water irrigation regime levels and two antitranspirants under open field conditions of El-Nubaria Agric. Res. Farm during 2015/2016 and 2016/2017 growing seasons.

Irrigation regime levels	Cultivars	2015/2016					2016/2017				
		Kaolin.	Fulvic acid	Mean	Protected control	Infected control	Kaolin.	Fulvic acid	Mean	Protected control	Infected control
I1	Gem.7	57.00	67.00	62.00	4.20	83.00	33.00	40.00	36.50	2.28	60.0
	Sids12	8.00	5.28	6.64	1.72	46.60	7.98	10.64	9.31	2.28	40
	Misr1	2.00	2.00	2.00	1.29	5.49	2.49	2.40	2.44	1.29	5.49
	Mean	22.33	24.76	23.54			14.49	14.68	16.08		
I2	Gem.7	56.6	56.6	56.60	2.88	80.00	31.60	33.00	32.30	1.54	46.7
	Sids12	6.64	5.28	5.96	1.29	23.30	6.64	6.64	6.64	1.5	18.64
	Misr1	2.00	2.00	2,00	1.06	6.00	1.98	1.98	1.98	1.08	3.32
	Mean	21.74	21.29	21.52			14.40	13.87	13.64		
I3	Gem.7	46.7	53.3	50.00	0.9	70.00	16.30	19.44	17.87	1.08	23.3
	Sids12	4.64	4.00	4.32	0.9	23.30	5.28	4.98	5.13	0.8	18.64
	Misr1	1.44	1.20	1.32	0.9	3.32	1.50	1.50	1.50	0.9	2.64
	Mean	17.59	19.50	18.54			7.69	8.64	8.16		
I4	Gem.7	46.70	53.3	50.00	0.9	70.00	15.60	18.30	16.95	0.9	23.3
	Sids12	4.00	3.44	3.72	0.9	20.00	5.28	3.00	4.14	0.9	16.0
	Misr1	1.08	1.08	1.08	0.6	3.32	1.08	0.90	0.99	0.9	1.44
	Mean	17.26	19.27	18.26			7.32	7.51	7.36		

L.S.D at 0.05 (2015/2016) for A= 2.8 **B** = 2.5 **C** = 1.2 L.S.D at 0.05(2016/2017) for **A**= 2.1, **B** = 1.7, **C** = 1.9
AXB = 2.00 **AXC** = 1.4 **BXC** = 3.2 **AXBXC** = 3.6 **AXB** = 1.4 **AXC** = 1.9 **BXC** = 3.4 **AXBXC**= 2.8

values of ACI with the fourth irrigation regime level (I_4). Misr1, Sids12 cultivars reacted well with the four irrigation regime levels than the susceptible cultivar Gemmeiza7.

The highest values of ACI were obtained by Gemmeiza7 with the first irrigation regime level (I_1) which showed 57.00, 33.00 and 67.00, 40.00 with Kaolin and Fulvic acid, respectively compared with the infected control (83.00, 60.00) in the two seasons of study. However, it showed 46.7, 15.6 and 53.3, 18.3 ACI values when treated by Kaolin and Fulvic acid, respectively with the fourth irrigation level (I_4) compared to the ACI values of the infected control (70, 23.3) in the two seasons of study.

The average coefficient of infection (ACI) of Sids12 recorded values range from 8,7.98 and 5.28, 10.64 with Kaolin, Fulvic acid under 100% (I_1) irrigation regime level compared with its infected control 46.6, 40 in 2016 and 2017 growing seasons, respectively. While, the fourth irrigation regime level (25%) showed the lowest values of ACI, 4, 5.28 and 3.44, 3 when treated by Kaolin and Fulvic acid, respectively during the two seasons. It could be mention that the I_4 irrigation regime level led to decrease the ACI value of the infected control of Sids12 (20.00 and 16.00) compared to those under the other irrigation regime levels in the two seasons of study.

The obtained results of ACI values of Misr1 cultivar were the best in this respect. It showed ACI values ranged from 1.08 when treated with Kaolin and from 1.08, 0.9 with Fulvic acid under 25% irrigation regime level (I_4) in the two seasons of study, respectively. While, the highest ACI values did not exceed 2.00, 5.49 with Kaolin and 2.00, 2.40 with Fulvic acid under 100% irrigation regime level (I_1) compared to 3.32, 1.44 in its infected control during the two seasons, respectively.

3.1.3 Area under disease progress curve (AUDPC)

The AUDPC values of the three wheat cultivars as affected by four irrigation regime levels and two antitranspirant substances at the two growing seasons 2015/2016 and 2016/2017 presented in Table (4).

The obtained AUDPC values affected gradually with the four irrigation regime levels, which decreased either on the treated cultivars or the infected controls. Also, AUDPC values run in a parallel line with the recorded leaf rust severities and the ACI values.

Concerning the treated cultivar Gemmeia7, the lowest values of AUDPC were obtained with the fourth level of irrigation regime (I_4). It showed AUDPC values 372, 155 and 424,193when treated by Kaolin and Fulvic acid, respectively compared to 700, 398 on its infected control in 2015/2016 and 2016/2017growing seasons. However, increasing the irrigation regime level up-to the normal level (I_1), led to increase the AUDPC values to 507, 332 and 613, 364 when treated by Kaolin and Fulvic acid, respectively in the two seasons of study. Also, area under disease progress curve of the infected control of Gemmeiza7 increased to 857 and 685 under the normal irrigation regime level (I_1). The other two irrigation levels (I_2 and I_3) were in between concerning with AUDPC values.

Area under disease progress curve (AUDPC) values of Sids12 cultivar, showed gradually decreases ranging from 126, 130 to 80,115; 72,107 and 62, 103 when treated by Kaolin under irrigation regime levels 100, 75, 50 and 25%, respectively during 2015/2016 and 2016/2017 growing seasons. Also, the AUDPC values of Sids12 decreased from 80,148 to 78.4, 121; 68.4,101 and 57.8, 68 when treated by Fulvic acid under these four irrigation regime levels, respectively during the two growing seasons. While, the AUDPC values of the infected control of Sids12 decreased from 482, 444 to 332, 245; 295, 225and 264, 207 under the fourth irrigation levels.

Misr1showed the same manner of AUDPC values which, it ranged from 32.4, 35 to 30.8, 32; 23.8, 28 and 18.3, 20.3 when treated by Kaolin under I_1, I_2, I_3 and I_4 levels of irrigation regime, respectively during 2015/2016 and 2016/2017 growing seasons. Also, treating Misr1 cultivar by Fulvic acid under the previous levels of irrigation regime recorded decrease in AUDPC values ranged from 33.6,33 to 25.8,30;21.9,23.8 and 17.9, 21, respectively during the two seasons of study. Also, the AUDPC of the infected control of Misr1affected by the fourth irrigation regime levels and showed decreases ranging from 74, 48 to 58, 40; 48, 40 and 37, 27during the two seasons, respectively.

Two antitranspirant products (kaolin and Fulvic acid) were used as foliar spray which serve as an alternative materials to protect wheat plants against leaf rust disease caused by *Puccinia triticina*. Final rust disease severity (FRS), average coefficient of infection (ACI) and area under disease progress curve (AUDPC) parameters were used to evaluate the effect of both antitranspirant products under four irrigation regime levels 100, 75, 50 and 50% on development the performance of Gemmeiza7, Sids12 and MIsr1 against leaf rust disease. All The treatments decreased significantly leaf rust severity (FRS),

Table 4: Area under disease progress curve (AUDPC) of three Egyptian wheat cultivars as affected by four water irrigation regime levels and two antitranspirants under open field conditions of El-Nubaria Agric. Res. Farm during 2015/2016 and 2016/2017 growing seasons.

Irrigation regime levels	Cultivars	2015/2016					2016/2017				
		Kaolin.	Fulvic acid	Mean	Protected control	Infected control	Kaolin.	Fulvic acid	Mean	Protected control	Infected control
I_1	Gem.7	507.00	613.00	560.00	40.80	857.00	332.00	364.00	348.00	19.80	685.00
	Sids12	126.00	80.00	103.00	19.50	482.00	130.00	148.00	139.00	22.30	444.00
	Misr1	32.40	33.60	33.00	18.50	74.00	35.00	33.00	34.00	22.00	48.00
	Mean	221.80	242.20	232.00			165.66	181.66	173.66		
I_2	Gem.7	485.00	510.00	497.50	25.40	785.00	293.00	337.00	315.00	28.30	582.00
	Sids12	80.00	78.40	79.20	18.30	332.00	115.00	121.00	118.00	25.30	245.00
	Misr1	30.80	25.80	28.30	16.50	58.00	32.00	30.00	31.00	20.00	40.00
	Mean	198.60	204.73	201.66			146.66	162.66	154.66		
I_3	Gem.7	423.00	490.00	456.50	11.90	747.00	189.00	227.00	208.00	26.00	432.00
	Sids12	72.00	68.40	70.20	12.50	295.00	107.00	101.00	104.00	16.50	225.00
	Misr1	23.80	21.90	22.85	11.90	48.00	28.00	23.80	25.90	20.00	40.00
	Mean	172.93	193.43	183.18			108.00	117.26	112.63		
I_4	Gem.7	372.00	424.00	398.00	11.90	700.00	155.00	193.00	174.00	19.00	398.00
	Sids12	62.00	57.80	59.90	10.50	264.00	103.00	68.00	85.50	18.00	207.00
	Misr1	18.30	17.90	18.10	7.70	37.00	20.30	21.00	20.65	19.00	27.00
	Mean	150.76	166.56	158.66			92.76	94.00	93.38		

L.S.D at 0.05 (2015/2016) for A= 30.7 **B** = 19.7 **C** = 18.6 **L.S.D at 0.05(2016/2017) for A**= 24.5, **B** = 16.7, **C** = 14.2
AXB = 39.5 **AXC** = 36.4 **BXC** = 32.5 **AXBXC** = 30.8 **AXB** = 33.4 **AXC** = 32.4 **BXC** = 33.6 **AXBXC**= 30.6

area under disease progress curve (AUDPC) and average coefficient of infection (ACI) compared to the infected controls. But, the two products recorded the best results of the previous mentioned parameters under the fourth irrigation level (I_4). Antitranspirant substance films formed on wheat leaf surface capable to prevent physical contact between leaf and germ tube of the pathogen urediospores acting as physical factor against their penetration through stomata into leaf tissues (Nasraoui, 1996). Reduction in final rust severity of wheat leaf rust may be due to that pre-emptive application of hydrophobic and hydrophilic Kaolin particles depending on creating a low water potential at infection sites which is very important to present free water to pathogen germ tube germination that explanation was in agreement with the result obtained by (Zekaria *et al* .,1991; Hsieh and Huang, 1997; Galenn *et al*., 2001; Haggag, 2002, Gaballah and Moursy , 2004). In the same trend, Sallam (2013) detected that area under disease progress curve (AUDPC) was reduced by application of these antitranspirants due to their physical effect. Also, Haggag (2002) sprayed Kaolin as epidermal coating protected film against the pathogen in controlling cucumber downy mildew under greenhouse condition. Similarly, Velez and Zapata (2005) used Fulvic acid for the management of diseases caused by *Mycosphaerella* spp. Fulvic acid antitranspirant product showed the highest values in reducing disease incidence, possibly due to the high potassium content in the used solution (Escobar and Castano, 2005 and Li *et al*., 2005). Fulvic acid contains high potassium content which makes the leaf cellular walls more resistant and as a result, the germination of spores became more difficult. Also, Fulvic acid increased the nitrate reductase activity free proline content, chlorophyll content and water content of winter wheat leaves, thus drought stress can be mitigated. Li *et al.*, (2005) indicated that Fulvic acid increased photosynthesis, reduced stomatal opening status and transpiration rate, thus led to growth stimulation and water loss reduction. According to the obtained data herein, reduction of wheat leaf rust by treatment with Kaolin and Fulvic acid are inexpensive, nontoxic, environmentally safe, and applicable in organic agriculture. Differences between tested wheat cultivars may be due to genetic makeup and environmental factors. These results were in harmony with those by obtained Maqsood *et al.* (2009).

3.1.4. Effects of irrigation regimes, wheat cultivars and antitranspirant substances

Data in Table (5) cleared the effect of irrigation levels (main treatments), wheat cultivars (sub-treatments) and antitranspirants (sub-sub treatments) on ACI and AUDPC Values as following:

Significant differences were found between all the irrigation levels as main treatments on average coefficient of infection but no differences found between I_1 (100%) and I_2 (75%) and between I_3 (50%)and I_4 (25%) . I_4 and I_3 showed the lowest ACI values (18.26, 18.54) and (7.36, 8.16), in 2015/2016 and 2016/2017 growing seasons, respectively. Also, the same irrigation levels showed the lowest AUDPC values (158.66, 93.38) and (183.18, 112.63) in the two seasons of study, respectively.

Highly significant differences were found between the tested wheat cultivars. The wheat cultivars Misr1 and Sids12 showed the lowest ACI values 1.60, 1.73 and 5.16, 6.30 as well as the AUDPC values 24.94, 27, 89 and 78.07, 11,62 in 2015/2016 and 2016/2017 growing seasons, respectively.

Also, significant differences were found between the two tested antitranspirants reducing disease severity consequently the ACI and AUDPC values. Kaolin was more effective than Fulvic acid which showed the lowest ACI values 19.73, 10.97 in the two seasons of study, respectively. On contrast, Fulvic acid showed the lowest AUDPC values which gave 151.73, 138.85 while Kaolin showed 186.02, 128.27, respectively in 2015/2016 and 2016/2017 growing seasons.

3.1.5. Interaction between Irrigation regime levels, Wheat cultivars and Antitranspirant substances treatments.

Data in Table (6) clear the interaction between irrigation levels as main treatment and the wheat cultivars (sub-treatment). Highly significant differences were found between the three wheat cultivars in their ACI and AUDPC values under the four irrigation levels in the two seasons of study. The wheat cultivar Misr1 followed by Sids12 showed the best and lowest ACI and AUDPC values under the four irrigation levels on contrast of Gemmeiza7.

Table 5: Effect of irrigation levels (main treatments), wheat cultivars (sub- treatments) and antitranspirants (sub-sub treatments) on ACI and AUDPC values.

	ACI		AUDPC	
	2015/2016	**2016/2017**	**2015/2016**	**2016/2017**
		Irrigation regime levels		
I_1	23.54	16.08	232.00	173.66
I_2	21.52	13.64	201.66	154.66
I_3	18.54	8.16	183.18	112.63
I_4	18.26	7.36	158.66	93.38
LSD at 0.05%	**2.8**	**2.1**	**30.7**	**24.5**
		Wheat cultivars		
Gemmeiza7	54.65	25.90	352.00	261.25
Sids12	5.16	6.30	78.07	111.62
Misr1	1.60**	1.73	24.94	27.89
LSD at 0.05%	**2.5**	**1.7**	**19.7**	**16.7**
		Antitranspirants		
Kaolin	19.73	10.97	186.02	128.27
Fulvic acid	21.20	11.17	151.73	138.85
LSD at 0.05%	**1.2**	**1.9**	**18.6**	**14.2**

Irrigation levels: **I_1** (100%), **I_2** (75%), **I_3** (50%), **I_4** (25%).

Table 6: Interaction between Irrigation levels and the wheat cultivars on average coefficient of infection (ACI) and area under disease progress curve (AUDPC) values in 2015/2016 and 206/2017 growing seasons.

Cultivars / Irrigation levels	ACI					
	2015/2016			2016/2017		
	Gemmeiza7	Sids12	Misr1	Gemmeiza7	Sids12	Misr1
I_1	62.00	6.64	2.00	36.56	9.31	2.00
I_2	56.00	5.56	2.00	32.30	6.64	1.98
I_3	50.00	4.32	1.32	17.87	5.13	1.50
I_4	50.00	3.72	1.08	16.95	4.14	0.99
Mean	54.50	5.06	1.60	25.92	5.30	1.61
L.S.D.at 0.05%		**2.00**			**1.40**	
				AUDPC		
I_1	560.00	103.00	33.00	348.00	139.00	34.00
I_2	497.50	79.20	28.30	315.00	118.00	31.00
I_3	456.50	70.20	22.85	208.00	104.00	25.90
I_4	398.00	59.90	18.10	174.00	85.50	20.65
Mean	478.00	78.07	25.56	261.25	111.62	27.88
L.S.D.at 0.05%		**39.5**			**33.4**	

Irrigation levels: **I_1** (100%), **I_2** (75%), **I_3** (50%), **I_4** (25%)

Table (7) reveal the interaction between the irrigation levels (main treatment) and the antitranspirant substances (sub-sub treatment) on ACI and AUDPC values. Significant differences were detected between Kaolin and Fulvic acid in reducing ACI an AUDPC values under the four irrigation levels. Kaolin was more effective more than Fulvic acid in this respect. In general, Both of Kaolin and Fulvic acid Kaolin and Fulvic acid showed the lowest values of ACI an AUDPC under the I_3 (50%) and I_4 (25%) in 2015/2016 and 2016/2017 growing seasons.

Data in Table (8) show the interaction between the wheat cultivars (sub-treatment) and the Antitranspirants substances (sub- sub treatment) on average coefficient of infection (ACI) and area under disease progress curve (AUDPC) values. Significant differences were detected between Kaolin and Fulvic acid in reducing ACI an AUDPC values when sprayed on the wheat cultivars. The lowest values of ACI and AUDPC detected on Misr1 followed by Sids12 with both of Kaolin and Fulvic acid, respectively in the two seasons of study.

Table 7: Interaction between Irrigation levels and the Antitranspirants on average coefficient of infection (ACI) and area under disease progress curve (AUDPC) values in 2015/2016 and 206/2017 growing seasons.

Irrigation levels/ antitranspirants	ACI			
	2015/2016		2016/2017	
	Kaolin	Fulvic acid	Kaolin	Fulvic acid
I_1	22.33	23.54	14.49	14.69
I_2	21.74	21.52	14.40	13.87
I_3	17.59	18.54	7.69	8.64
I_4	17.26	18.26	7.32	7.51
Mean	19.73	20.46	10.97	11.17
L.S.D. at 0.05%	**1.4**		**1.9**	
	AUDPC			
I_1	221.80	242.20	165.66	181.66
I_2	198.60	204.73	146.66	162.66
I_3	172.93	193.43	108.00	117.26
I_4	150.76	166.56	92.76	94.00
Mean	186.02	201.73	128.27	138.89
L.S.D. at 0.05%	**36.4**		**32.4**	

Irrigation levels: **I_1** (100%), **I_2** (75%), **I_3** (50%),

Table 8: Interaction between wheat cultivars and antitranspirants on average coefficient of infection (ACI) and area under disease progress curve (AUDPC) values in 2015/2016 and 2016/2017 growing seasons.

Cultivars / antitranspirants	ACI			
	2015/2016		2016/2017	
	Kaolin	Fulvic acid	Kaolin	Fulvic acid
Gemmeiza7	51.75	55.90	24.12	27.68
Sids12	5.82	4.50	6.29	6.31
Misr1	1.63	1.57	1.64	1.69
Mean	19.73	20.65	10.68	11.89
LSD at 0.05%	**3.2**		**3.4**	
	AUDPC			
Gemmeiza7	446.75	242.25	509.25	280.25
Sids12	72.95	113.75	72.15	109.50
Misr1	26.32	28.82	24.80	26.95
Mean	182.00	128.27	202.06	138.90
LSD at 0.05%	**32.5**		**33.6**	

Data in Table (9) shows the interaction between the irrigation levels (main treatment), the wheat cultivars (sub-treatment) and the Antitranspirants substances (sub- sub treatment) on average coefficient of infection (ACI) and area under disease progress curve (AUDPC) values. The lowest values of ACI and AUDPC were detected when applied Kaolin and Fulvic acid on the wheat cultivars Misr1 and Sids12 under the irrigation levels I_3 (50%) and I_4 (25%) in the two seasons of study.

Antitranspirant substances play enormous roles in improving various physiological traits, reduced the disease incidence and raising the drought tolerance during the early stages of growth by enhancing photosynthetic pigments that improve qualitative characteristics and improve the grain yield of different cereal crops (Guleria and Shweta, 2020). Foliar spraying of antitranspirants can increase water use efficacy, reduce the free water on leaves that may altered the infection process and produce a high grain yield while requiring less irrigation (Gomaa *et al*., 2021).The results indicated that treatments of cereals with antitranspirants reduce the negative impact of water shortage which resulted in reducing the disease incidence, and improve the interaction between the host and the pathogen that reduced the disease severity, these results are in agreement with those obtained by (Kociecka and Liberacki, 2021).

Table 9: Interaction between irrigation levels, wheat cultivars and antitranspirants on average coefficient of infection (ACI) and area under disease progress curve (AUDPC) values in 2015/2016 and 2016/2017 growing seasons.

Irrigation/ cultivars	Antitranspirants	ACI					
		2015/2016			2016/2017		
		Gemmeiza7	Sids12	Misr1	Gemmeiza7	Sids12	Misr1
I_1	Kaolin	57.00	8.00	2.00	33.00	7.98	2.49
	Fulvic acid	67.00	5.28	2.00	40.00	10.64	2.40
I_2	Kaolin	56.6	6.64	2.00	31.60	6.64	1.98
	Fulvic acid	56.60	6.46	2.00	33.00	6.64	1.98
I_3	Kaolin	46.70	4.64	1.44	16.30	5.28	1.50
	Fulvic acid	53.30	4.00	1.20	19.44	4.98	1.50
I_4	Kaolin	46.70	4.00	1.08	45.60	5.28	1.08
	Fulvic acid	53.30	3.44	1.08	18.30	3.00	0.90
L.S.D at 0.05%		3.6			2.8		
		AUDPC					
I_1	Kaolin	507.00	126.00	32.00	332.00	130.00	35.00
	Fulvic acid	613.00	80.00	33.00	364.00	148.00	33.00
I_2	Kaolin	485.00	80.00	30.00	293.00	115.00	32.00
	Fulvic acid	510.00	78.40	25.80	337.00	121.00	30.00
I_3	Kaolin	423.00	72.00	25.80	189.00	107.00	28.00
	Fulvic acid	490.00	68.40	21.90	227.00	101.00	23.80
I_4	Kaolin	327.00	62.00	18.30	155.00	103.00	20.30
	Fulvic acid	424.00	57.80	17.90	193.00	68.00	21.00
L.S.D at 0.05%		30.80			30.60		

3.1.6. Yield Components

Results in Table (10) revealed the effect of four irrigation regime intervals, foliar application of two antitranspirant substances and their interaction on leaf rust infected three wheat cultivars on the number of spike /m^2, number of grains/spike, spike weight (g), 1000- grain weight (g), and grain yield/plot (g) compared with the infected control during the two growing seasons 2015/2016and 2016/2017.

Results showed that leaf rust infected wheat cultivars differed in all yield components in the two seasons where the highest value of spikes number/ m ^{2} was given by Misr1 wheat cultivar in the two seasons (286.9, 268.4), respectively. While Sids12 cultivar recorded the highest number of grain /spike and spike weight (61.6, 62.9 and 2.7, 2.7g.), respectively. However, Gemmieza7 recorded the highest value of 1000 grain weight and grain yield/plot (46.9, 46.3and 1298, 1247.8g.), respectively, in both seasons. These differences among the three tested infected wheat cultivars may be due to their genetic background against leaf rust infection and environmental factors during growing seasons.

The genotypic correlations across trials among grain yield, and yield-determining traits in the non-protected treatment were higher compared to the correlations in the fungicide-protected treatment. ACI and AUDPC were negatively correlated with grain yield and all yield traits which reflected higher positive correlation with yield losses. The results are in agreement with Herrera *et al*. (2006) who illustrated that negative correlation between disease parameters ACI and AUDPC was particularly high with biomass and spikes per square meter. On the other hand, the non-protected treatments, grain yield was positively correlated with biomass, harvest index, grain weight, grains per square meter, grains per spike, spikes per square meter, and test weight.

Results of study also revealed that the highest mean values were obtained in the both seasons by application of water interval regime I_1 (100%, normal) in the number of spike/m^2 (292.9, 275.5), spike weight (3.0, 2.9) and Grain yield/ plot (1235.1, 1234.6), respectively. While I_4 (25%) water regime resulted in the lowest ones in all studied traits in both seasons (247.6, 208.9 - 41.1, 34.02-2.2, 2.3-40.5, 39.1 and 1045.4, 933.6), respectively. This variation may be due to water shortage and leaf rust stresses. The obtained results are in harmony with Sambroski *et al.* (1960) who stated that plants respond to inoculation with energy-demanding physiological processes, probably defense reactions, using stored host energy that otherwise would go to growth and seed production.

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Table 10: Wheat yield attributes of the three cultivars as affected by four water regime levels, two antitranspirants and their interactions at open field conditions of El-Nubaria Agric. Res. Farm during 2015/2016 and 2016/2017 growing seasons.

Treatments	Number of spike/m^2		Number of kernel/spike		Spike weight (g)		1000- kernel weight (g)		Grain yield/plot (g)	
	Seasons									
	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017
Water regimes (A)										
I_1	292.9	275.5	45.5	48.8	3.0	2.9	47.8	47.0	1235.1	1234.6
I_2	269.2	266.0	51.8	50.9	2.5	2.9	48.3	46.4	1093.4	1042.3
I_3	248.8	254.9	68.3	69.9	2.5	2.5	44.7	42.5	1093.7	1038.5
I_4	247.6	208.9	41.1	34.02	2.2	2.3	40.5	39.1	1045.4	933.6
LSD for A at 0.05	19.3	17.6	7.2	4.2	0.3	0.2	1.4	2.0	31.2	26.5
Antitranspirant substances (B)										
Kaolin	253.4	251.2	57.3	54.3	2.7	2.5	46.0	43.9	1125.3	1045.2
Fulvic acid	261.3	254.5	59.7	57.8	2.7	2.5	47.3	46.4	1135.4	1049.8
protected	274.5	250.3	55.9	58.4	2.8	2.7	50.4	46.7	1152.9	1106.9
control	185.2	197.4	43.7	46.6	2.0	2.2	37.6	38.0	832.6	886.9
LSD for B at 0.05	12.9	11.3	3.1	3.9	0.2	0.1	1.2	1.3	32.9	26.6
Wheat cultivars (C)										
Gemmeiza7	252.5	248.4	56.6	53.6	2.6	2.5	46.9	46.3	1298	1247.8
Sids12	263.4	237.2	61.6	62.9	2.7	2.7	44.2	42.9	1095.7	1049.4
Misr1	286.9	268.4	51.9	54.6	2.3	2.3	44.9	41.9	1030.4	1008.6
LSD for C at 0.05	12.8	9.4	3.4	3.1	0.2	0.1	1.4	1.2	22.2	18.6
Interactions										
A x B	*	*	*	*	*	*	*	*	*	*
A x C	*	*	*	*	*	*	*	*	*	*
B x C	*	*	*	*	*	*	*	*	*	*
A x B x C	*	*	*	*	*	*	*	*	*	*

- *: significant difference at the 0.05 level of probability

The results in Table (10) showed that spraying of fulvic acid (FA) recorded the highest values of spike number/m^2 (261.3, 254.5) grain number/spike (59.7, 57.8) spike weight (g) (2.7,2.5), 1000- grain weight (g) (47.3, 46.4) and grain yield/plot (g) (1135.4, 1049.8). Followed by kaolin treatment in both seasons compared to infected control which gave the lowest values (185.2, 197.4- 43.7, 46.6-2.0, 2.2-37.6, 38.0 and 832.6, 886.9), respectively.

The results exhibited that foliar application of antitranspirants reduce the harmful effect of water shortage stress. The obtained results are consistent with the most previous investigations, which pointed out the same role of foliar application of antitranspirants, either Fulvic acid (FA) or Kaolin (Ka) for yield improvement (Abdullah *et al*., 2015; Desoky *et al*., 2013; Kandil *et al*., 2020). On the same sequence, application of Fulic acid (FA) increased chlorophyll content and intensity of photosynthesis, and may increase the drought-resistance capacity of the plant (Fu *et al*., 1994). Likewise, Tworkoski *et al.* (2002) reported that using antitranspirant as particle-film-type improved chlorophyll biosynthesis and increased the chlorophyll content of bean leaves. In this respect, Jifon and Syvertsen (2003) stated that spraying of kaolin on grape fruit tree increased leaf reflectance and reduced midday leaf temperature leading to an increase of photochemical activity and CO_2 assimilation which was reflected in increasing biomass and yield. They also pointed out that the increase water absorption in xylem tissue due to antitranspirants may help plants in obtaining its requirement from water by increasing water use efficiency, so increased plant growth and yield of wheat plant. In another study on tomato plants, Kaolin was applied to improve yield and plant production (Cantore *et al.,* 2009). The use of antitranspiration on maize increased the growth traits, i.e., the number of leaves, leaf area, leaf area index, plant dry matter, and crop growth, which might help in increasing the grain yield (Ulameer and Ahmed, 2018; Abdulameer and Ahmed, 2021).

It is likely to mention that the antitranspirants under water shortage conditions had the adverse effect of water stress and generally gained positive effect on yield components with corresponding untreated plants.

4. Conclusion

Plants have acquired sophisticated stress response systems to adapt to changing environments. It is important to understand plants stress response mechanisms in the effort to improve its productivity under stressful conditions**.** The results of field՝s experiment in 2015/2016 and 2016/2017 growing seasons concluded that kaolin (Ka) and fulvic acid (FA) ameliorate the adverse effects of water shortage stress, enhanced wheat plant growth and decreased disease severity of wheat cultivars infected by leaf rust. Significant differences were found between irrigation regime levels, the wheat cultivars as well as between the antitranspirants substances in reducing ACI and AUDPC values. Also, significant differences were found in the interaction between all irrigation regime levels, the wheat cultivars and the antitranspirants substances in reducing ACI and AUDPC values. On the other side, Misr1 and Sids12 gave the best values of ACI and AUDPC with application of antitranspirant substances under water stress at all irrigation regime levels (I_1, I_2, I_3 and I_4)during two growing seasons 2015/2016 and 2016/2017 in El-Nubaria Region. Water shortage stress caused a significant reduction in all the studied agronomic traits such as spike number/m^2, grain number/spike, spike weight (g), 1000- grain weight (g), and grain yield/plot (g) of the three wheat cultivars. On the other hand, application of foliar antitranspirant substances such as Kaolin (Ka) and fulvic acid (FA) reduced the bad effects of water stress on yield components and disease severity under four water irrigation regime levels, which resulted in reducing the severity of leaf rust in the three wheat cultivars and reduced about 50-75 % of water consumption. The type of infection varied according to the used substance. Finally, it's interestingly to mention that reduction of wheat leaf rust by treatment with Kaolin, Fulvic acid are inexpensive, nontoxic, environmentally safe, and applicable in organic agriculture.

References

Abdulameer, O.Q., and S.A. Ahmed, 2021. The effect of anti-transpiration on grain yield, yield component and water use efficiency of corn under water stress. Al-Muthanna J. Agric. Sci., 8(4):139–155.

Abdullah, A.S., M.M. Aziz, K.H.M. Siddique, and K.C. Flower, 2015. Film antitranspirants increase yield in drought stressed wheat plants by maintaining high grain number. Agricultural Water Management, 159: 11-18.

Ahmad, I., I. Khaliq, N. Mahmood, N. Khan, and E.F. Secretariat, 2015. Morphological and physiological criteria for drought tolerance at seedling stage in wheat. J. Anim. Plant Sci., 25(4): 1041-1048.

Anjum, S.A., L. Wang, M. Farooq, L. Xue, and S. Ali, 2011. Fulvic acid application improves the maize performance under well-watered and drought conditions. Journal of Agronomy and Crop Science, 197:409- 417.

Bolton, M.D., J.A. Kolmer, and D.F. Garvin, 2008. Wheat leaf rust caused by *Puccinia triticina*. Mol. Plant Pathol. 9: 563–575.

Calvo, P., L. Nelson, and J.W. Kloepper, 2014. Agricultural uses of plant biostimulants Plant and Soil, 383:33- 41.

Cantore, V., B. Pace, and R. Albrizio, 2009. Kaolin-based particle film technology affects tomato physiology, yield and quality. Environmental and Experimental Botany, 66(2): 279-288.

Conde A, D Pimentel, A Neves, L-T Dinis, S Bernardo, CM Correia, H. Gerós and J Moutinho-Pereira 2016. Kaolin foliar application has a stimulatory effect on phenylpropanoid and flavonoid pathways in grape berries. Front Plant Sci, 7: 1150-1156.

CoStat-Cohort Software, 2005. CoStat User Manual, version 3 Cohort Tucson, Arizona, USA.

Delfine, S., R. Tongnetti, E. Desiderio, and A. Alvino, 2005. Effect of foliar application of N and humic acids on growth and yield of durum wheat. Agronomy for Sustainable Development, 25: 183-191.

Desoky, E.S.M., M.R.A. Tohamy, G.S.A. Eisa, and N.M. El-Sarkassy, 2013. Effect of some antitranspirant substances on growth, yield and flag leaf structure of wheat plant (*Triticum aestivum* L.) grown under water stress conditions. Zagazig J. Agric. Res., 40: 223-233.

Economic Affairs Sector, 2022. Annual report of Agricultural and Land Reclamation Ministry, Egypt.

El-Daoudi, Y.H., O.F. Mamluk, E. Bekele, Ghanem, Enayat, H., M.B. Solf, and Shafik, Ikhlas, E.H. 1994. Preliminary results for leaf and stem rust of wheat, their prevalence and resistance in the Nile Valley countries and Yemen. Fifth Arab Cong. Plant. Prot., Fez Morocco, Nov. 27-Dec. Abst., 2.

Escobar, Vetez, J.H. and J. Castano, Zapato, 2005. Fulvic acid application for the management of disease caused by *Mycosphaerella* spp. Info. Musa, 14(2):15-17.

FAO 2022. Wheat cultivated area and production. Food and Agriculture Organization of the United Nation.

Fu, Q.L., C.F. Meng and Y.W. Wu,1994. Effects of Fulvic acid on the physiology and yield of rape (*Brassica campestris* L.). Oil Crops of China, 16 (2): 29-31.

Gaballah, M.S. and M. Moursy, 2004. Reflectants application for increasing wheat plant tolerant against se lf stress. Pakistan J. Biol.Sci., 7(6):956-962.

Galenn, D.M., T. Ven der Zwet, G. Puterka, P. Gundrum, and E. Brown, 2001. Efficacy of kaolin-based particle film to control apple diseases. Plant Health progress.

Gomaa, M.A., E.E. Kandil, A.A.M. Zen El‑Dein, M.E.M. Abou‑Donia, H.M. Ali, and N.R. Abdelsalam, 2021. Increase maize productivity and water use efficiency through application of potassium silicate under water stress. Scientifc Reports, 11:224.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedure for Agriculture Research. 2nd Ed. John Wily and Sons Editor Inc., USA.

Guleria1, V. and Shweta, 2020. Antitranspirants: An Effective Approach to Mitigate the Stress in Field Crops. Int. J. Curr. Microbiol. App. Sci., 9(5): 1671-1678.

Haggag, W.M., 2002. Application of epidermal coating antitranspirants for controlling cucumber downy mildew in greenhouse. Plant Pathol. Bull., 11: 69-78.

Hanson, H., N.E. Borlaug, and R.G. Anderson, 1982. Wheat in the third world. West view press.

Herrera-Foessel, S.A., R.P. Singh, J. Huerta Espino, J. Grossa and A. Djurle, 2006. Effect of leaf rust on grain yield and yield traits of durum wheat with race- specific and slow-rusting resistance to leaf rust. The American phytopathological society, 90(80):1065-1072.

Hsieh, T.F. and J.W. Huang, 1997. Applications of film forming antitranspirants for control of plant diseases. Plant Pathol. Bull., 6:89-94.

Huerta-Espino, J., R.P. Singh, S. German, B.D. Mccallum, R.F. Park, W.Q. Chen, S.C. Bhardwaj and H. Goyeau, 2011. Global status of wheat leaf rust caused by *Puccinia triticina*. Euphytica, 179:143-160.

Jifon, J.L. and J.P. Syvertsen, 2003. Kaolin particle film application can increase photosynthesis and water use efficiency of 'ruby red' grapefruit leaves." J. Amer. Soc. Hort. Sci., 128: 107- 112.

Kandil, E.E., N.R. Abdelsalam, A.A.A. EL Aziz, H.M. Ali, and M.H. Siddiqui, 2020. Efficacy of nanofertilizer, fulvic acid and boron fertilizer on sugar beet (*Beta vulgaris* L.) yield and quality. Sugar Tech., 22: 782-791.

Kocięcka, J., and D. Liberacki, 2021. The potential of using chitosan on cereal crops in the face of climate change. Plants, 10 (6) (1160):1–27.

Large, E.C. 1954. Grow stage in cereals; Illustration of the freaks scales. Plant Pathol., 3:128-129.

Li, M.S., S. Li, S.Y. Zhang, and B.L. Chi, 2005. Physiological effect of new FA antitranspirant on winter wheat at ear filling stage. Scientia Agricultura Sinica, 38(4): 703-708.

Long, D.L. and J.A. Kolmer, 1989. A North American system of nomenclature for *Puccinia recondite* f.sp.*tritici*. Phytopathology, 79:525-529.

Maqsood, Q., M.Y. Mujahid, M.A. Khan, R.E. Niks, and M. Asif, 2009. Evaluation of levels of non-hypersensitive resistance in different spring wheat cultivars to leaf rust. Sarhad J. Agric., 25(2): 233-241.

Nakano A. and Y. Uehara, 1996. The effect of kaolin clay on cuticle transpiration in tomato. Acta Hortic., 440:233–238.

Nasraoui, B., 1996. Rôle des films antitranspirants dans la phytoprotection contre les maladies fongiques. Ann. INRAT, 66: 125-133.

Nezhadahmadi, A., Z.H. Prodhan and G. Frouq, 2013. Drought tolerance in wheat. Sci. World J. Article ID 610721 1-12.

Pandey, H.N., T.C.M. Menon, and M.V. Rao, 1989. A simple formula for calculating Area under Disease Progress Curve. Rachis, 8(2):38-39.

Peterson, R.F., A.B. Campbell, and A.E. Hannah, 1948. A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. Canadian Journal of Research, 26(5): 496-500.

Saari, E.E. and R.D. Wilcoxson, 1974. Plant disease situation of high-yielding dwarf wheat in Asia and Africa. Annual Review of Phytopathology, 12**:**49-68.

Sallam, E.A. Minaas. 2013. Application of some epidermal coating antitranspirant products for controlling wheat leaf rust caused by *Puccinia triticin*. Egyptian Journal of Phytopathology, 41(2): 15-33.

Samborski, D.J., and B. Peturson, 1960. Effect of leaf rust on the yield of resistant wheat. Can. J. Plant Sci., 40:620-22.

Shao, H.B., L.Y. Chu, C.A. Jaleel, P. Manivannan, R. Panneer selvam, and M.A. Shao, 2009. Understanding water deficit stress-induced changes in the basic metabolism of higher plants biotechnologically and sustainably improving agriculture and the Eco environment in arid regions of the globe. Crit. Rev. Biotechnol., 29:131-151.

Tervet, I. and R.C. Cassel, 1951. The use of cyclon separation in race identification of cereal rusts, phytopathology, 41: 282-285.

Tworkoski, T.J., D.M. Glenn and G.J. Puterka, 2002. Response of bean to application of hydrophobic mineral particles. Can. J. Plant Sci., 82: 217-219.

Ulameer, O.Q.A. and S.A.A.H. Ahmed, 2018. Antitranspirant role in improving the morphological growth traits of maize plants subjected to water stress. Res. Crop, 19:593–603.

Velez, J.E. and J.C. Zapata, 2005. Fulvic acid applications for the management of diseases caused by *Mycosphaerella* spp. Info. Musa, 14:15-17.

Yang, W., P.F. Li, S.W. Guo, B.Q. Fan, R.Q. Song, and J. Yu, 2017. Compensating effect of fulvic acid and super absorbent polymer on leaf gas exchange and water use efficiency of maize under moderate water deficit conditions. Plant Growth Regulation, 83:451-460.

Zekaria, Oren J., Z. Eyal, and O. Ziv, 1991. Effect of film-forming compounds on the development of leaf rust on wheat seedling. Plant Dis., 75:231-234.

Zhang, X.Y., X.Y. Zhang, X.W. Liu, L.W. Shao, H.Y. Sun, and S.Y. Chen, 2016. Improving winter wheat performance by foliar spray of ABA and FA under water deficit conditions. Journal of Plant Growth Regulation, 35:83-96.