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Rice Cultivation Adaptation to Water Resources Shortage in Egypt

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CLIMATE change and water resources shortage in Egypt has placed the responsibility on the researchers in the agricultural field to find practical solutions that would confront the environmental constraints that the strategic crops are exposed to them. These solutions are such as creating new varieties that can withstand high temperatures and irrigation water shortages, or adding materials that raise plant resistance to any environmental stress.Egypt's rice cultivation required a large amount of the available water resources for agricultural sector.So, two field experiments on rice cultivation were carried out aiming to assess three irrigation water levels [100% of traditional followed full irrigation (TFI), 80% of TFI and 60 % of TFI] as main plots. While the sub-main plots were assigned by two treatments of DM (applied at a rate of 20.0 Mg ha^{-1} or not), where DM=mixture of zeolite, biochar and rice straw compost.Also, the foliar application of anti-transpirants [kaolin (7%) and magnesium silicate (7%) plus control (without)] were allocated in the sub-sub plots.The main results showed that treatments of 80 and 60 % of TFI caused a raise in the production of enzymatic antioxidants *i.e.,* superoxide dismutase (SOD) and peroxidase enzyme (POD). While the DM addition and both anti-transpirants led to a decline in the values of SOD and POD. The deficit irrigation treatments (80 and 60 % of TFI, respectively) caused a significant decline in the rice growth performance as well as the quantitative and qualitative yield compared to the traditional irrigation (100 % of TFI). Regarding the DM treatment, the plant performance and productivity significantly increased with DM addition compared to the corresponding rice plants grown without DM addition. Concerning the exogenous applications, the best plant growth performance and productivity were realized with magnesium silicate followed by kaolin and lately control. On the other hand, the addition of DM increased the soil water holding capacity at the harvest stage compared to that of the initial soil. Also, it is worth observing that the addition of DM before rice cultivation under 80% of TFI with exogenous application of both anti-transpirants caused growth performance and productivity were better than that recorded with rice plants grown without both DM and anti-transpirants (control) under 100% of TFI. Generally, it can be concluded that DM treatment may hold enough amounts of both water and nutrients and release them as required by the rice plant. Also, anti-transpirants have great potential in raising the water-deficit stress tolerance of rice via increasing leaf reflectance and thereby reducing water loss through the transpiration process. Thus enhancing the growth performance, quantitative and qualitative yield of rice with the limited supply of irrigation water.

Keywords: Biochar, zeolite, compost,kaolin andmagnesium silicate.

1. Introduction

Rice (*Oryza Sativa* L.) is the basic food which the population of Egypt lives on, because of its relatively low price and its efficiency in feeding a large number of people **(Fouda 2021).** Rice is a semi-aquatic plant that grows in highly humid environments **(Mandal and Ghosh 2021).**In other words, the grown rice plants' behavior requires much irrigation water compared to other crops. Egypt's rice cultivation required about 2.0 billion m^3 of irrigation water for transpiration, evaporation and irrigation every year, while people in Egypt are under the water poverty limit **(Elmoghazy and Elshenawy 2018).**

Nowadays, due to the scarcity of water resources (**El-Sherpiny *et al.* 2023**), Egypt is facing a big challenge in rice productivity. A team of experts from the Rice Research Center and Egyptian

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Universities continues their research to produce strains of rice that resist drought and increase productivity, in light of changing climatic and soil nature conditions and the lack of Egypt's share of the Nile water. New varieties with low water consumption developed, including “Sakha 104”, “Sakha 106”, “Sakha 107”, “Sakha 108”, “Sakha Super 300”, and “Egyptian Hybrid 1”**(Khattab 2019; Mehana*et al.* 2021).**Even though the development of rice varieties, the data on rice water consumption did not change in a way that achieves overcoming thewater issue shortage and preserving the cultivation of this strategic crop **(Elbasiouny and Elbehiry 2020).**

Despite the importance of rice as a strategic crop that Egyptians depend on for their daily food, the government forces farmers in some areas not to sow the rice due to its gluttonous consumption of water, where officials expect a future water crisis that threatens this crop. Thus, the Egyptian government work hard to confront this potential danger, through the adoption of agricultural policy officials in Egypt some policies that aim to reduce the cultivated areas of the rice crop, given that the rice crop consumes about 22-25% of the total share of water allocated for crop irrigation. So, there is an urgent need to find practical solutions that would raise the performance efficiency of rice varieties with a limited supply of irrigation water **(Abdelhafez*et al.* 2020).**

The application of irrigation water-absorbent substances (*e.g.,* zeolite, biochar and compost, *etc.*) to soil before rice cultivation as well as the addition of anti-transplants (*e.g.,* kaolin, magnesium silicate, *etc.*) to leaves may be beneficial to improve the plant performance under drought stress.There are many studies indicating that zeolite, biochar and compost increased the soil's ability to retain irrigation water as follows. Zeolite, as a crystalline hydrated aluminosilicate, has the ability to hold irrigation water in its pores, thus it helps in declining infiltration rate of the soil (**Azarpour*et al.* 2011; El Refaey 2021).** Biochar, as a pure carbon product made from organic substances, has the ability to hold irrigation water in its pores, and thereby it helps in the declining infiltration rate of the soil (**Abou Hussien*et al*2020; Mosa*et al.* 2020).**Compost also reduces the irrigation requirements of plants because it retains a large amount of water for a long time**(Elsherpiny and Helmy 2022),** moreover, it provides the soil with nutrients and bacteria which possess multiple essential functions for the higher plant **(Soliman *et al.* 2022).**

One of the options that can help with facing water scarcity is the utilization of anti-transpirants that is considered as a chemical sprayed on plant surfaces to reduce water consumption by reducing transpiration either through stomatal closing, film forming on leaves' surface, or reflectance of sun rays. Anti-transpirants possess some of the ideal characteristics e.g., stable, non-toxic, cheap and long-lasting in their effectiveness and they should have some benefits **(Elmahdy *et al.* 2022).** Several researchers stated that antitranspirants not only lead to decrease water loss but also cause improvement in the physiology of plants and their effects on the quality and yield **(Wissa 2017).** Anti-transpiration such as kaolin (non-toxic aluminosilicate clay mineral) and magnesium silicate (Talc, or talcum) are widely available.

To date, few papers have focused on the joint effect of water-absorbent substances (as soil addition before cultivation) and anti-transpirants (as a foliar application during plants' life period) on the higher plants' behavior under limited supply irrigation water conditions. So, the aim of this investigation was to determine the effect of a mixture of zeolite, biochar and rice straw compost (DM) combined with anti-transpirants (kaolin or magnesium silicate) on the quantitative and qualitative yield of rice plants.

2. Material and Methods

Experimental location and soil sampling

Fieldexperiments were conducted at the Experimental Farm of Agricultural Faculty, Mansoura University, Egypt, (31°22' 59.88" N latitude and 31°05' 31.38 "E longitude) during two successive rice seasons of 2021 and 2022.The climatic circumstances of the studied location according to the Meteorological Authority was presented in Table 1. Table 2 points out the initial soil characteristics before rice cultivation, where the soil sample was analyzed depending on the stander methods reported by **Sparks *et al.* (2020); Dane and Topp (2020).**

Table 1. The climatic circumstances of the studied location (averages).

Months	Rain (mm)		Wind speed,km day^{-1}		Temperature (°C)	
	1stseason	2ndseason	1stseason	2ndseason	1stseason	2ndseason
May	0.20	0.00	241	233	23.10	23.01
June	0.10	0.00	209	199	24.60	24.80
July	0.00	0.00	173	164	26.45	26.60
Augusts	0.00	0.00	163	159	28.74	27.30
September	0.00	0.00	172	162	26.99	26.40

Table 2. Characteristics of Initial Soil before Rice Cultivation.

Soil Parameters			Values	Notes:
	Particle size distribution (%)			This Table shows the combined data over both seasons. The soil samples were taken at depth of 0-30 cm.
Physical characteristics	Sand		21.55	
	Silt		28.45	EC was measured in saturated soil paste extract.
	Clay		50.00	
	Textural class is clayey			Soil pH was measured in soil suspension (1: 2.5).
Hydro physical characteristics	WHC, %		36.00	
	SP		72.00	WHC: water holding capacity
Chemical characteristics	EC dSm^{-1}		2.070	
	pH		8.000	
	$CaCO_3$ %		1.970	SP: Saturation percentage
Fertility criteria	O.M, %		1.300	O.M:Organic matter
	Available nutrients	N, mg kg^{-1}	48.92	EC: Electric conductivity
		P, mg kg^{-1}	8.540	pH: Power of Hydrogen
		K, mg kg^{-1}	231.9	

DM and anti-transpirants preparation

The mixture of zeolite, biochar and rice straw compost was prepared at a ratio of 3.0 zeolite: 1.0 biochar: 7.0 compost). Table 3 points out the attributes of the components of the studied mixture. Zeolite was purchased from the Egyptian commercial market (Alex Zeolite Company). While biochar (rice straw residues +maize stover) was prepared depending on the method reported by **Wang and Wang (2019)** under the temperature of 400-500 °C for 30 minutes without oxygen. Also, a compost of rice straw residues was prepared depending on the method reported by **Inckel*et al.* (2005)** at the experimental site.

Table 3. Characteristics of the Components of the Studied Mixture.

Substance	Parameters	Values	Notes:
Zeolite	**EC, dS m^{-1}**	2.400	The analyses were done depending on the stander methods reported by**Tandon (2005).**
	CEC, cmol$_c$ kg^{-1}	150.0	
	K_2O,%	5.250	
	P_2O_5,%	1.050	
Biochar	**EC, dS m^{-1}**	5.000	
	CEC, cmolc kg^{-1}	67.00	
	pH	8.650	
Compost	**EC, dS m^{-1}**	3.750	
	pH	6.240	
	C:N ratio	11.50	

Both anti-transpirants [kaolin ($Al_2Si_2O_5$ $(OH)_4$) and magnesium silicate (Mg_2 O_2 Si_2)] were was purchased from Egyptian commercial market (Techno green Company). Then the foliar application solutions wereprepared at rate of 7% for both of them.

Experimental design and treatments

The current trial was conducted under a split split-plot design (Table 4) with three replicates. Three irrigation water levels [100% of traditional followed full irrigation (TFI) in most of the delta regions (equivalent 16000 m^3 ha^{-1}), 80% of TFI (equivalent 12800 m^3 ha^{-1})

and 60 % of TFI (equivalent 9600 m^3 ha^{-1})] were evaluated as main plots. While the sub-main plots were assigned by two treatments of DM (applied at a rate of 20.0 Mg ha^{-1} or not), where Mg ″mega gram″=106 g *i.e.,* metric ton. DM=mixture of zeolite, biochar and rice straw compost (at a ratio of 3.0 zeolite: 1.0 biochar: 7.0 compost). Also, the foliar application of anti-transpirants [kaolin (7%) and magnesium silicate (7%) with a volume of 1300 L ha^{-1}plus control (without)] were allocated in the sub-sub plots.

Table 4. The experiment layout.

Treatments			Replicates		
I_1	S_1	F_1	R_2	R_1	R_3
		F_2	R_2	R_3	R_1
		F_3	R_3	R_1	R_1
	S_2	F_1	R_1	R_3	R_2
		F_2	R_3	R_2	R_1
		F_3	R_1	R_2	R_3
I_2	S_1	F_1	R_2	R_1	R_3
		F_2	R_2	R_3	R_1
		F_3	R_3	R_1	R_1
	S_2	F_1	R_1	R_3	R_2
		F_2	R_3	R_2	R_1
		F_3	R_1	R_2	R_3
I_3	S_1	F_1	R_2	R_1	R_3
		F_2	R_1	R_2	R_3
		F_3	R_3	R_1	R_1
	S_2	F_1	R_1	R_3	R_2
		F_2	R_3	R_2	R_1
		F_3	R_1	R_2	R_3

Nursery period

The nursery soil was ploughed and well dry levelled. The nursery soil area was 116.6 m^2. Calcium superphosphate (6.6%P) was applied at a rate of 3.5 kg for the nursery area before ploughing. Ammonium sulphate (20.6 % N) was added after ploughing at a rate of 4.0 kg for the nursery area. Also,zinc sulfate was added at a rate of 0.65 kg for the nursery area, where it was mixed with enough soil dust to make it easy for homogenous distribution. The seeds were soaked in fresh water for 24 hours and incubated for another 48 hours for obtaining early germination. Pre-germinated seeds were broadcasted in the nursery area with 2.0 to 3.0 cm water depth on the 1st of May in the rice seasons of 2021 and 2022. The seeds were sown in the nursery area at a rate of 25.0 kg ha^{-1}. All other cultural practices were executed as recommended for the nursery.Rice seeds "***Oryza Sativa* L. Cv Sakha 108**" were obtained from ARS, Egypt.

Permanent field period

Seedlings of rice (25 days old) were pulled and transferred to the permanent field and then regularly transplanted at a rate of two seedlings per hill in all plots. The plot size was 9.0 m^2 (3.0 × 3.0) during both seasons.Each irrigation regime was isolated from others by 3.5 meters to prevent irrigation water seepage. Before rice cultivation six days, DM was added to the soil of the permanent field and mixed with a surface layer at a depth of 0.0-30 cm. The exogenous application of anti-transpirants was done after 20 days from transplanting three times at 15 days intervals. All usual cultural practices for rice cultivation were implemented in growing rice fields depending on the recommendation of the Rice Research and Training Center **(RRTC 2010).** The permanent field area received calcium superphosphate (6.6%P)at a rate of 240 kg ha^{-1}before transplanting in the absence of irrigation water. Ammonium sulphate (20.6 % N) was added via two split doses at a265rate of 480 kg ha^{-1}(2/3 as basal, while 1/3 top dressing at one month after transplanting). Also,zinc sulfate was added at a rate of 24.0 kg ha^{-1} before transplanting immediately, where it was mixed with enough soil dust to make it easy for homogenous distribution. Potassium sulphate (39.8 % K) was applied via two split doses at rate of 120 kg ha^{-1}(1/2 as basal and 1/2 top dressing at 45 after transplanting).

The source of irrigation water was the Nile River, where the amount of 16000 m^3 water ha^{-1} represents the amount of irrigation used in most of the North Nile Delta region, Egypt with the most rice cultivars. The irrigation process was executed as continuous flooding using a pump (Honda WB30XT) and the amount of irrigation water was known via the discharge rate of the irrigation water from the pump by the flow meter.Harvest was done after 120 days from transplanting.

Measurement traits

At the period of 30 days after transplanting, rice self-production of enzymatic antioxidants [superoxide dismutase **(SOD)**and peroxidaseenzyme **(POD)]** wasdetermined using the methods reported by **Alici and Arabaci (2016)**. Also, the rice measuredcriteria were plant height (before five days from harvest), chlorophyll in F.W (SPAD, reading) according to **Yan*et al.* (2007)**, (SPAD-502, Minolta Camera, Osaka, Japan)at the booting period. Leafarea index was estimated at the booting period using the method reported by **Watson (1952)** at the booting period**.** Chemical content in rice tissues (straw, D.W) including N, Pand Kwere determinedat the booting period according to the stander methods reported by **Walinga *et al.* (2013),** where the samples of rice straw were digested according to the stander method reported by **Peterburgski (1968),** using the mixture of H_2SO_4 and $HClO_4$ (1:1)**.**Yield and its components *i.e.,* panicle length, panicle weight, No. of grains panicle^{-1}, No. of filled grain, 1000 seed weight and grain yield (Mg ha^{-1}) were measured at the harvest stage. Also,some biochemical traits *i.e.,*total carbohydrates and protein in rice milled grainswere estimated at the harvest stage depending on the stander methods described in **AOAC (2000).** Soil WHC (water holding capacity) was determined after rice harvest as the average of both studied seasons using the method reported by **Dane and Topp (2020).**

Statistical Analyses

Data were statistically analyzed by**CoStat version 6.303 copyright (1998-2004)** using the technique reported by **Gomez and Gomez(1984)**.Treatment means were compared by utilization of the least significant difference (LSD) at a level of 0.05 probability.

2. Results

Rice enzymes

Data of Table 5 show the effect of soil addition of DM (mixture of zeolite, biochar and rice straw compost) solely or in combination with the foliar applications of anti-transpirants[kaolin or magnesium silicate) on rice plant's self-production of enzymatic antioxidants (SOD and POD, min^{-1} mg^{-1}) under three irrigation water levels [100% of traditional followed full irrigation (TFI) in most of the delta regions (equivalent 16000 m^3 ha^{-1}), 80% of TFI (equivalent 12800 m^3 ha^{-1}) and 60 % of TFI (equivalent 9600 m^3 ha^{-1})] at the period of 30 days after transplanting during two successive rice seasons (2021-2022). It is evident from the data in Table 5 that treatments of 80 and 60 % of TFI, respectively caused a raise in the production of enzymatic antioxidants *i.e.,* superoxide dismutase (SOD) and peroxidase enzyme (POD). While the soil of DM conditioner as well as both anti-transpirants led to a decline in the values of SOD and POD. In other words, the highest values of the studied antioxidants content in rice tissues at a period of 30 days from transplanting were realized under deficit water treatment of 60 % of TFI (9600 m^3 ha^{-1}) in the absence of DM conditioner and both studied anti-transparent. The same trend was achieved for both seasons.

Growth criteria and chemical constituents

Data illustrated in Table 6 detected the individual and interaction influences of the studied treatment son the plant's height (cm) before five days from harvest as well as leaf chlorophyll pigment (SPAD), leaf area index and chemical constituents in rice straw tissues *i.e.,* N, P and K(%) at booting period. Findings show that deficit irrigation [80% of TFI and 60 % of TFI, respectively] caused a significant decline in all aforementioned traits compared to the treatment of 100% of TFI. For example, the highest values of plant height (101.18 and 104.35 cm, for 1st and 2nd seasons, respectively), chlorophyll content (39.00 and 39.47 SPAD, for 1st and 2nd seasons, respectively) and nitrogen content (2.84 and 2.98% for 1st and 2nd seasons, respectively) were realized with the irrigation treatment of 100% of TFI (16000 m^3 ha^{-1})followed by the values of plants grown with irrigation treatment of 80% of TFI (12800 m^3 ha^{-1}), while the lowest ones were achieved with the irrigation treatment of 60% of TFI (9600 m^3 ha^{-1}).Regarding the DM treatment, the data of the same Table show that theplant height, leaf chlorophyll pigment, leaf area index, N, P and K contents significantly increased with DM addition compared to the corresponding rice plants grown without DM addition. The same trend was achieved for both seasons.Concerning the exogenous applications of anti-transpirants[kaolin or magnesium silicate), the maximum values of theplant height, leaf chlorophyll pigment, leaf area index, N, P and K contentswere realized with magnesium silicate followed by kaolin and lately control (without anti-transparent).The trend was similar during both studied seasons.

Table 5. Effect of DM and anti-transpirantson rice plant'sself-production from enzymatic antioxidants (superoxide dismutase or SOD and peroxidase enzyme or POD) during successive rice seasons of 2021and 2022.

Treatments			SOD, min^{-1} mg^{-1}		POD, min^{-1} mg^{-1}	
			1st season	2nd season	1st season	2nd season
Irrigation treatments						
I_1			20.35c	20.74c	186.78c	189.75c
I_2			25.43b	25.87b	208.67b	212.21b
I_3			30.75a	31.45a	233.73a	237.10a
LSD at 5%			**0.42**	**0.09**	**2.99**	**2.58**
Soil addition treatments						
S_1			26.70a	27.24b	215.52a	218.84a
S_2			24.32b	24.79a	203.93b	207.20b
LSD at 5%			**0.18**	**0.07**	**2.31**	**1.42**
Foliar aplication treatments						
F_1			26.38a	26.95a	213.62a	216.82a
F_2			25.46b	25.92b	209.52b	212.93b
F_3			24.69c	25.19c	206.04c	209.31c
LSD at 5%			**0.26**	**0.08**	**1.88**	**1.81**
Interactions						
I_1	S_1	F_1	22.42m	22.92m	195.45jk	198.35ij
		F_2	20.81n	21.23n	191.97kl	195.26jk
		F_3	20.56no	20.98o	187.96lm	191.08kl
	S_2	F_1	20.04o	20.40p	184.15mn	187.05lm
		F_2	19.23p	19.55q	180.95n	183.85m
		F_3	19.01p	19.36r	180.19n	182.90m
I_2	S_1	F_1	27.90g	28.50g	217.92de	221.41de
		F_2	27.17h	27.56h	214.08ef	217.69ef
		F_3	25.61i	25.99i	210.20fg	213.46fg
	S_2	F_1	24.81j	25.24j	206.65gh	210.34gh
		F_2	23.95k	24.36k	203.52hi	207.64h
		F_3	23.12l	23.56l	199.66ij	202.72i
I_3	S_1	F_1	32.73a	33.58a	244.78a	247.96a
		F_2	31.98b	32.60b	241.02a	244.45a
		F_3	31.09c	31.84c	236.32b	239.87b
	S_2	F_1	30.34d	31.07d	232.78b	235.81b
		F_2	29.60e	30.24e	225.58c	228.71c
		F_3	28.76f	29.38f	221.89cd	225.80cd
LSD at 5%			**0.63**	**0.19**	**4.62**	**4.44**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level I_1: 100% of TFI; I_2: 80% of TFI; I_3: 60% of TFI; S_1: without soil addition (control); S_2: Zeolite + biochar + compost; F_1: Without anti-transpirants(control); F_2: Kaolin and F_3: Magnesium silicate.

Also, it is worth observing that the addition of DM before rice cultivation under 80% of TFI with exogenous application of both anti-transpirantscaused growth performance were better than that recorded with rice plants grown without both DM and anti-transpirants(control) under 100% of TFI.

Table 6. Effect of DM and Anti-transpirantson Riceplant's Performance under different Irrigation Regimes during Successive Rice Seasons of 2021 and 2022.

Treatments			Plant height (cm)		Chlorophyll (SPADvalue)		Leaf area index	
			1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Irrigation treatments								
I_1			101.18a	104.35a	39.00a	39.47a	7.30a	7.39a
I_2			97.07b	100.16b	38.22b	38.70b	6.93b	7.02b
I_3			87.54c	90.66c	36.42c	36.99c	5.92c	5.99c
LSD at 5%			**0.24**	**0.25**	**0.06**	**0.55**	**0.07**	**0.07**
Soil addition treatments								
S_1			92.14b	95.12b	37.23b	37.69b	6.40b	6.48b
S_2			98.39a	101.67a	38.52a	39.08a	7.02a	7.12a
LSD at 5%			**0.21**	**0.21**	**0.28**	**0.37**	**0.04**	**0.03**
Foliar application treatments								
F_1			94.15c	97.15c	37.64b	38.08	6.58c	6.66c
F_2			95.23b	98.28b	37.88ab	38.33	6.72b	6.81b
F_3			96.41a	99.74a	38.12a	38.74	6.84a	6.93a
Foliar treatments			**0.20**	**0.21**	**0.34**	**0.35**	**0.05**	**0.07**
Interaction								
I_1	**S_1**	**F_1**	96.49i	99.58i	37.95fi	38.35e-h	6.79g	6.88gh
		F_2	97.68h	100.71h	38.20eh	38.62d-g	6.92f	7.02fg
		F_3	98.91g	101.88g	38.42dg	38.83def	7.06e	7.14ef
	S_2	**F_1**	103.57c	106.68c	39.49abc	39.94abc	7.53b	7.62b
		F_2	104.59b	107.52b	39.85ab	40.36ab	7.68a	7.79a
		F_3	105.84a	109.76a	40.09a	40.70a	7.80a	7.90a
I_2	**S_1**	**F_1**	91.70l	94.90l	37.26il	37.72hij	6.41i	6.48j
		F_2	92.97k	95.67k	37.43h-k	37.92ghi	6.56h	6.66i
		F_3	94.11j	96.75j	37.67gj	38.18fgh	6.69j	6.75hi
	S_2	**F_1**	100.10f	103.10f	38.75cf	39.17cde	7.17de	7.26de
		F_2	101.21e	104.65e	38.94cde	39.40cd	7.30cd	7.40cd
		F_3	102.36d	105.88d	39.25bcd	39.80bc	7.41bc	7.53bc
I_3	**S_1**	**F_1**	84.96r	87.43r	35.86o	36.26l	5.61m	5.68o
		F_2	85.66q	89.00q	36.07no	36.48kl	5.72m	5.79no
		F_3	86.75p	90.14p	36.24mno	36.83kl	5.85l	5.92mn
	S_2	**F_1**	88.06o	91.23o	36.50lo	37.04jkl	5.96l	6.06lm
		F_2	89.29n	92.15n	36.80kn	37.20ijk	6.11k	6.20kl
		F_3	90.51m	94.04m	37.02jm	38.12fgh	6.24j	6.31k
LSD at 5%			**0.51**	**0.53**	**0.83**	**0.86**	**0.13**	**0.16**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level.
I_1: 100% of TFI; **I_2:** 80% of TFI; **I_3:** 60% of TFI; **S_1:** without soil addition (control); **S_2:** Zeolite + biochar + compost; **F_1**: Without anti-transpirants(control); **F_2**: Kaolin and **F_3:** Magnesium silicate.

Table 7. Effect of DM and anti-transpirantson thechemical constituents in rice straw tissues under different irrigation regimes during successive rice seasons of 2021and 2022.

Treatments			N (%)		P (%)		K (%)	
			1st Season	2nd season	1st Season	2nd season	1st Season	2nd season
Irrigation treatments								
	I1		2.84a	2.89a	0.331a	0.337a	2.73a	2.77a
	I2		2.66b	2.71b	0.309b	0.314b	2.53b	2.56b
	I3		2.13c	2.17c	0.251c	0.256c	2.08c	2.10c
	LSD at 5%		**0.04**	**0.05**	**0.003**	**0.003**	**0.02**	**0.05**
Soil addition treatments								
	S1		2.42b	2.47b	0.284b	0.289b	2.33b	2.35b
	S2		2.66a	2.71a	0.310a	0.316a	2.57a	2.60a
	LSD at 5%		**0.02**	**0.03**	**0.001**	**0.001**	**0.01**	**0.03**
Foliar aplication treatments								
	F1		2.46c	2.51b	0.291c	0.297c	2.39c	2.42c
	F2		2.57b	2.62a	0.298b	0.303b	2.44b	2.47b
	F3		2.60a	2.65a	0.303a	0.308a	2.51a	2.54a
	LSD at 5%		**0.03**	**0.04**	**0.001**	**0.001**	**0.02**	**0.04**
Interaction								
I1	**S1**	**F1**	2.65e	2.70ef	0.313h	0.320h	2.59hi	2.63ef
		F2	2.73d	2.77de	0.317g	0.323gh	2.63gh	2.67ef
		F3	2.77cd	2.83cd	0.319fg	0.325fg	2.67fg	2.70def
	S2	**F1**	2.88b	2.94b	0.342c	0.349c	2.80bc	2.84ab
		F2	2.99a	3.06a	0.346b	0.352b	2.84ab	2.88ab
		F3	3.01a	3.07a	0.349a	0.356a	2.87a	2.90a
I2	**S1**	**F1**	2.21f	2.25g	0.275k	0.280k	2.19jk	2.21gh
		F2	2.59e	2.63f	0.289j	0.292j	2.21j	2.24g
		F3	2.60e	2.65f	0.305i	0.308i	2.57i	2.60f
	S2	**F1**	2.83bc	2.90bc	0.322f	0.328f	2.70ef	2.73cde
		F2	2.84bc	2.91bc	0.331e	0.338e	2.74de	2.77bcd
		F3	2.88b	2.93bc	0.335d	0.341d	2.78cd	2.82abc
I3	**S1**	**F1**	2.05i	2.09i	0.244p	0.249p	2.00o	2.02j
		F2	2.09hi	2.13hi	0.247o	0.252o	2.06mn	2.08ij
		F3	2.12gh	2.16ghi	0.247o	0.252o	2.02no	2.04j
	S2	**F1**	2.14fgh	2.18ghi	0.250n	0.255n	2.08lm	2.11hij
		F2	2.16fg	2.20gh	0.257m	0.262m	2.14kl	2.17ghi
		F3	2.20f	2.25g	0.261l	0.266l	2.16jk	2.19gh
	LSD at 5%		**0.07**	**0.11**	**0.003**	**0.004**	**0.06**	**0.10**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level.
I1: 100% of TFI; **I2:** 80% of TFI; **I3:** 60% of TFI; **S1:** without soil addition (control); **S2:** Zeolite + biochar + compost; **F1**: Without anti-transpirants(control); **F2**: Kaolin and **F3:** Magnesium silicate.

Yield and its components at harvest stage

Tables 8 and 9 point out the effect of soil addition of DM (mixture of zeolite, biochar and rice straw compost) solely or in combination with the foliar applications of anti-transpirants[kaolin or magnesium silicate) under three irrigation water levels on rice quantitative and qualitative yield*i.e.,* panicle length (cm), panicle weight (g), No. of grains panicle^{-1}, No. of filled grain, 1000 seed weight (g), grain yield (Mg ha^{-1})and grain chemical traits in rice milled grains (total carbohydrates and protein, %) at the harvest stage during the two successive rice seasons (2021 and 2022). It is clear that all aforementioned traits of rice quantitative and qualitative yieldwere significantly and pronouncedly affected because of the different irrigation treatments, where the values decreased as irrigation levels were reduced. In other words, the highest values of the aforementioned traits of rice quantitative and qualitative yieldwere recorded with the treatment of 100% of TFI (16000 m^3 ha^{-1}) followed by the deficit irrigation [80% of TFI (12800 m^3 ha^{-1}).

As for soil addition of the DM (mixture of zeolite, biochar and rice straw compost) treatment, the highest values of the aforementioned traits of rice quantitative and qualitative yieldwere recorded with DM addition compared to the corresponding rice plants grown without DM addition. Concerning the exogenous applications, the highest values of the aforementioned traits of rice quantitative and qualitative yield were realized with magnesium silicate followed by kaolin and lately control.Also, it is worth observing that the addition of DM before rice cultivation under 80% of TFI with exogenous application of both anti-transpirantscaused rice quantitative and qualitative yield were better than that recorded with rice plants grown without both DM and anti-transpirants(control) under 100% of TFI.

Table 8. Effect of DM and anti-transpirantson some rice physical traits at harvest stage under different irrigation regimes during successive rice seasons of 2021and 2022.

Treatments			Panicle length (cm)		Panicle weight (g)		No. of grains panicle^{-1}		No. of filled grain		1000 seed weight (g)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation treatments												
I1			25.29a	25.74a	2.79a	2.84a	142.11a	143.94a	99.50a	103.67a	28.26a	28.70a
I2			24.02b	24.47b	2.61b	2.66b	133.39b	135.33b	93.22b	97.44b	26.94b	27.40b
I3			20.98c	21.36c	2.15c	2.19c	114.67c	115.83c	79.33c	83.17c	23.84c	24.18c
LSD at 5%			**0.33**	**0.07**	**0.04**	**0.03**	**0.22**	**2.6**	**1.62**	**1.99**	**0.10**	**0.09**
Soil addition treatments												
S1			22.50b	22.92b	2.37b	2.42b	123.59b	125.37b	85.74b	89.56b	25.31b	25.70b
S2			24.36a	24.79a	2.66a	2.71a	136.52a	138.04a	95.63a	99.96a	27.38a	27.82a
LSD at 5%			**0.15**	**0.03**	**0.05**	**0.02**	**1.89**	**1.62**	**1.07**	**1.29**	**0.04**	**0.07**
Foliar application treatments												
F1			23.08c	23.50c	2.46c	2.51c	128.06b	129.78b	88.78c	92.72c	25.95c	26.33c
F2			23.43b	23.81b	2.51b	2.57b	129.89ab	131.33b	90.67b	94.67b	26.35b	26.77b
F3			23.78a	24.25a	2.57a	2.62a	132.22a	134.00a	92.61a	96.89a	26.73a	27.18a
LSD at 5%			**0.24**	**0.08**	**0.04**	**0.02**	**2.34**	**2.29**	**1.55**	**1.58**	**0.08**	**0.08**
Interaction												
I1	S1	F1	23.94g	24.39i	2.59e	2.65f	132.00f	134.00f	92.00fg	96.00ef	26.78i	27.17h
		F2	24.31fg	24.69h	2.64e	2.69ef	134.67ef	136.67ef	93.67ef	97.67de	27.13h	27.58g
		F3	24.60f	25.09g	2.68de	2.73e	138.67de	141.00de	96.00de	100.00cd	27.53g	28.04f
	S2	F1	25.97bc	26.44c	2.90ab	2.95b	147.67ab	149.67ab	103.67a	107.67b	28.98c	29.37c
		F2	26.31ab	26.73b	2.94a	2.99b	149.00a	149.67ab	104.67a	108.67ab	29.38b	29.84b
		F3	26.60a	27.09a	2.99a	3.06a	150.67a	152.67a	107.00a	112.00a	29.75a	30.21a
I2	S1	F1	22.43ij	22.85l	2.38gh	2.44h	122.00gh	124.00gh	86.00hij	89.67ghi	25.23l	25.64k
		F2	22.82hi	23.25k	2.43fg	2.48h	124.00g	126.00gh	87.00hi	91.00gh	25.62k	26.01j
		F3	23.19h	23.68j	2.49f	2.54g	125.00g	126.67g	89.00gh	92.67fg	26.01j	26.39i
	S2	F1	24.87ef	25.35f	2.74cd	2.80d	141.67cd	144.00cd	97.00de	102.00c	27.91f	28.39e
		F2	25.23de	25.73e	2.78c	2.84cd	142.67bcd	144.67bcd	98.67cd	102.67c	28.29e	28.80d
		F3	25.57cd	25.95d	2.84bc	2.89c	145.00abc	146.67bc	101.67b	106.67b	28.59d	29.19c
I3	S1	F1	20.14o	20.51q	1.96m	2.01n	110.00k	111.00k	73.00n	76.00m	22.65r	22.94q
		F2	20.33no	20.69q	2.05lm	2.09m	112.00jk	113.00jk	77.00m	81.00l	23.20q	23.52p
		F3	20.75mn	21.15p	2.12kl	2.16l	114.00jk	116.00ijk	78.00lm	82.00kl	23.68p	24.05o
	S2	F1	21.13lm	21.48o	2.19jk	2.23k	115.00ijk	116.00ijk	81.00kl	85.00jk	24.15o	24.48n
		F2	21.56kl	21.79n	2.25ij	2.30j	117.00hij	118.00ij	83.00jk	87.00hij	24.52n	24.86m
		F3	22.00jk	22.54m	2.31hi	2.36i	120.00ghi	121.00hi	84.00ijk	88.00ghi	24.83m	25.22l
LSD at 5%			**0.59**	**0.18**	**0.10**	**0.05**	**5.74**	**5.61**	**3.80**	**3.89**	**0.19**	**0.19**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level.

I1: 100% of TFI; **I2:** 80% of TFI; **I3:** 60% of TFI; **S1:** without soil addition (control); **S2:** Zeolite + biochar + compost; **F1**: Without anti-transpirants(control); **F2**: Kaolin and **F3:** Magnesium silicate.

Table 9. Effect of DM and anti-transpirantson rice milled grains quality and rice yield at harvest stage under different irrigation regimes during successive rice seasons of 2021and 2022.

Treatments			Protein		Carbohydrates		Grain yield ($Mg\ ha^{-1}$)	
			(%)					
			1st	2nd	1st	2nd	1st	2nd
Irrigation treatments								
I_1			8.32a	8.48a	70.11a	71.20a	9.13a	9.16a
I_2			7.63b	7.75b	68.79b	69.76b	8.09b	8.13b
I_3			6.07c	6.20c	65.50c	66.42c	5.35c	5.37c
LSD at 5%			**0.09**	**0.06**	**0.75**	**0.47**	**0.05**	**0.09**
Soil addition treatments								
S_1			6.83b	6.96b	67.04b	67.93b	6.67b	6.69b
S_2			7.86a	8.00a	69.22a	70.31a	8.38a	8.42a
LSD at 5%			**0.06**	**0.03**	**0.40**	**0.28**	**0.04**	**0.04**
Foliar aplication treatments								
F_1			7.15c	7.29c	67.56b	7.20c	7.23c	7.15c
F_2			7.34b	7.46b	68.23a	7.53b	7.57b	7.34b
F_3			7.54a	7.68a	68.61a	7.83a	7.87a	7.54a
LSD at 5%			**0.06**	**0.04**	**0.53**	**0.08**	**0.02**	**0.06**
Interaction								
I_1	**S_1**	**F_1**	7.57i	7.74i	68.62fgh	69.56ef	7.93i	7.94i
		F_2	7.74h	7.89h	69.06efg	70.14de	8.24h	8.26h
		F_3	7.94g	8.11g	69.33def	70.58d	8.60g	8.63g
	S_2	**F_1**	8.68c	8.83c	70.88abc	71.87ab	9.72c	9.77c
		F_2	8.89b	9.04b	71.19ab	72.42a	10.00b	10.05b
		F_3	9.11a	9.27a	71.57a	72.62a	10.27a	10.30a
I_2	**S_1**	**F_1**	6.73l	6.87l	67.11ijk	68.12gh	6.66l	6.67l
		F_2	6.95k	7.04k	67.44hij	67.58fg	6.99k	7.02k
		F_3	7.18j	7.28j	67.90ghi	68.88ef	7.26j	7.29j
	S_2	**F_1**	8.10f	8.23f	69.69c-f	70.91cd	8.92f	8.96f
		F_2	8.30e	8.43e	70.14b-e	71.51bc	9.22e	9.28e
		F_3	8.50d	8.67d	70.46a-d	71.54bc	9.49d	9.54d
I_3	**S_1**	**F_1**	5.66q	5.80q	63.11n	63.96l	4.44r	4.46r
		F_2	5.75pq	5.86q	65.19m	66.06k	4.81q	4.82q
		F_3	5.90p	6.04p	65.63lm	66.54jk	5.06p	5.09p
	S_2	**F_1**	6.16o	6.30o	65.96klm	66.87ijk	5.53o	5.55o
		F_2	6.37n	6.51n	66.34j-m	67.29hij	5.94n	5.98n
		F_3	6.57m	6.70m	66.74i-l	67.80hi	6.31m	6.34m
LSD at 5%			**0.15**	**0.10**	**1.30**	**0.86**	**0.19**	**0.06**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level.

I_1: 100% of TFI; I_2: 80% of TFI; I_3: 60% of TFI; S_1: without soil addition (control); S_2: Zeolite + biochar + compost; F_1: Without anti-transpirants(control); F_2: Kaolin and F_3: Magnesium silicate.

SoilWHC at postharvest

Fig1 illustrates the impact of (mixture of zeolite, biochar and rice straw compost) and anti-transpirants[kaolin or magnesium silicate) under different irrigation regimes on the water holding capacity of the studied (WHC) after harvest during successive rice seasons of 2021and 2022 (combined data over both seasons).

Irrigation regimes andant transparent treatments possessed an unclear impact on thisparameter, while the most effective factor was MD substance. It is evident from Fig 1 that the addition of (a mixture of zeolite, biochar and rice straw compost) increased the soil water holding capacity at the harvest stage compared to that of the initial soil.

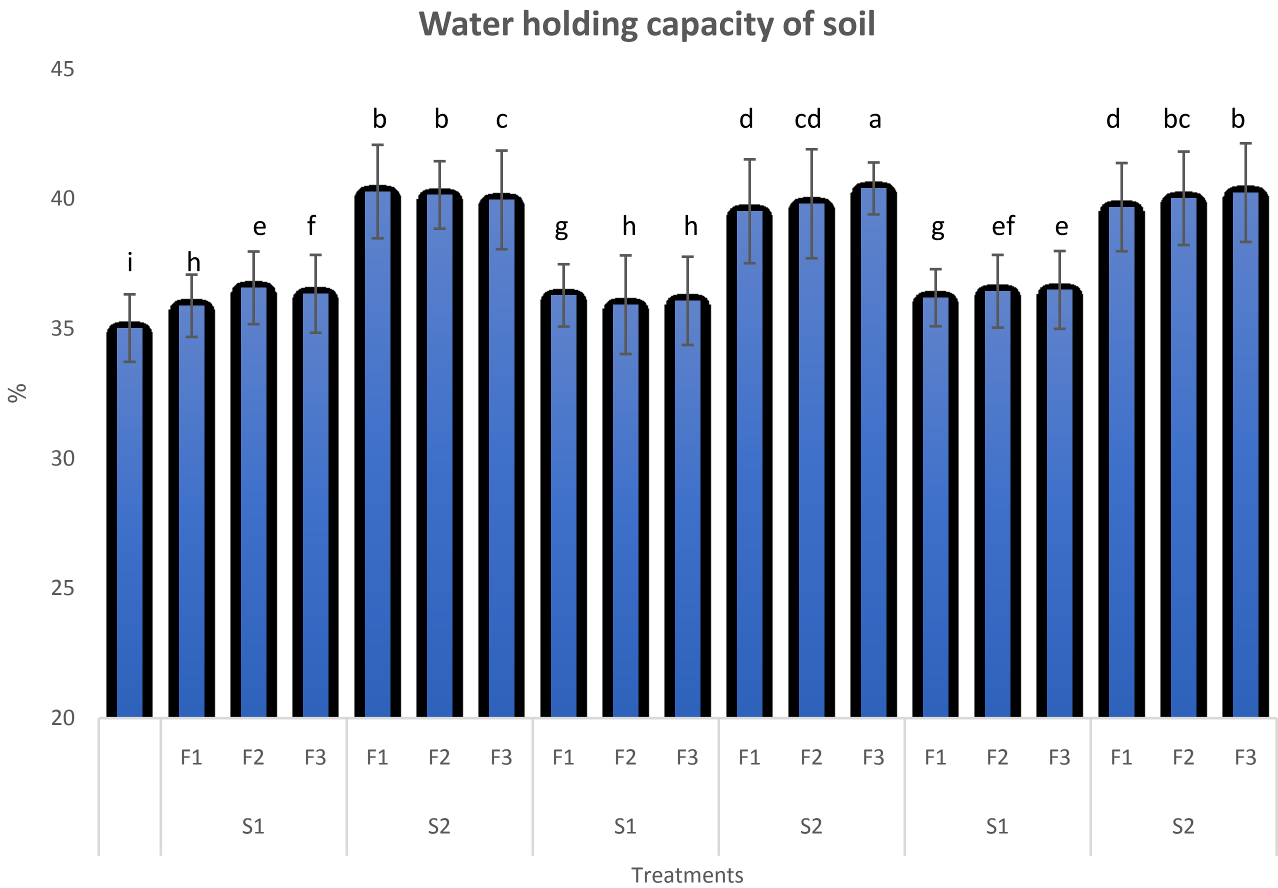

Fig. 1. Effect of DM and anti-transpirantsunder different irrigation regimes on soil water holding capacity (WHC) after harvest during successive rice seasons of 2021and 2022 (combined data over both seasons).

I_1: 100% of TFI; **I_2:** 80% of TFI; **I_3:** 60% of TFI; **S_1:** without soil addition (control); **S_2:** Zeolite + biochar + compost; **F_1**: Without anti-transpirants(control); **F_2**: Kaolin and **F_3:** Magnesium silicate.

4. Discussion

4.1 Harmful effect of water stress

Understanding the role of water in the growth and development of the rice plant is important for producing a high yield. Water is essential for the rice seeds' germination. Germination occurs when the root and feather begin to unfold from the bean. In order to germinate, a grain of rice needs to absorb water about 25% of its weight, so that the percentage of water becomes 40-45%.Water has various functions regarding rice plants *e.g.,* maintaining cell turgidity; transporting nutrients and organic compounds inside the plant. In addition to its vital role in the photosynthesis process **(Mosa and Ramadan2011).** So, it was found that the water deficit treatments [80% of TFI (12800 m^3 ha^{-1}) and 60 % of TFI (9600 m^3 ha^{-1})] caused in declining the growth performance, quantitative and qualitative yield of rice, respectively compared to the traditional full irrigation followed [100% of TFI (16000 m^3 ha^{-1})] due to an imbalance in the vital functions performed by water inside the rice plant as a result of the limited supply of irrigation water. On the contrary, the growing rice under water scarcity [80% of TFI (12800 m^3 ha^{-1}) and 60 % of TFI (9600 m^3 ha^{-1}), respectively] led to a raise in Reactive Oxygen Species (ROS) content in rice tissues. On other hand, the rice self-production of enzymatic antioxidants *i.e.,* SOD and POD also raise at the booting period to scavenge the ROS, which was produced due to the water deficit stress from protoplasm.

Rice's ability to self-produce enzymatic and non-enzymatic antioxidants may be reduced at the advanced stages of plant life and it is accompanied by an increase in ROS content which might occur physiological disorders in rice tissues and negatively affect growth performance, quantitative and qualitative yield of rice**(Ghazi and El-Sherpiny 2021).** in other words, the water scarcity [80% of TFI (12800 m^3 ha^{-1}) and 60 % of TFI (9600 m^3 ha^{-1}), respectively] may negatively influence the stomata opening, photosynthesis process and stomatal conductance of rice plants and these negative influences reflected on the rice performance, quantitative and qualitative yield. The improvement of the rice performance, quantitative and qualitative yield with the traditional full irrigation followed [100% of TFI (16000 m^3 ha^{-1})] could be due to sufficient nutrients and water at the rice root zone, thus biological & physiological processes inside Positive effect of the studied soil addition rice plant exactly done *e.g.,* cell division and elongation**(Ouda*et al*. 2016).**

The superiority of DM [mixture of zeolite, biochar and rice straw compost (at a ratio of 3.0 zeolite: 1.0 biochar: 7.0 compost)] as water-absorbent substances may be due to the different abilities of the components to retain a large number of nutrients and irrigation water for a long time in the rice root zone. In other words, zeolite, biochar and rice straw compost mighthold irrigation water in their pores, thus they helped in the declining infiltration rate of the soil.Also, one of the reasons for the superiority of this mixture may be the ability of biochar to hold and sequester heavy elements Also, the superiority may be attributed to the ability of zeolite to raise mineral nitrogen fertilizers via holding the added N **(El-Sherpiny*et al.* 2020).** In addition, the recognized benefits of compost *e.g.,* providing the soil with nutrients and growth regulators, increasing soil fertility and nutrients availability, and improving soil physical and biological attributes(Hussein et al 2020). Generally, it can be noticed that the vital role of this mixture manifested in raising the water-holding capacity of the soil. Due to the advantages of this mixture, it can be said that it makes the rice plant more able to tolerate water stress.These results are in accordance with those obtained by**EI-Maghraby*et al*. (2011); Fischer *et al.* (2019); Bassouny and Abbas (2019); Ch'ng*et al.* (2019); Ding *et al*. (2021).**

4.2 Positive effect of studied anti-transpirants

On the other hand, the superiority of anti-transpirants(kaolin and magnesium silicate) compared to the control treatment may be due to their ability to reduce water consumption by reducing transpiration rate either through stomatal closing, film forming on leaves' surface, or reflex the sun rays. This in turn led to keeping higher water content inside the rice plant tissues and hence might enhance the carbohydrate metabolism, physiological processes, photosynthetic rate and many other essential functions that directly affected the rice performance, quantitative and qualitative yield. These results are in agreement with those **of El-Hadidi*et al.*(2020).**

The superiority of magnesium silicate compared to kaolin may be due to it not only leading to decrease water loss but also causing improvement in the physiology of rice plants and its effects reflected on the quality and yield. Talc substance might be improved the membrane functioning of the rice cells and integrity as well as it may be allowed better light transmittance, thus enhancing the photosynthesis process. Moreover, talc may superior to kaolin due to the magnesium element, which is a Co-enzyme with enzymes which build fats in addition to its role in the photosynthesis process. The findings are in harmony with those of **Wissa (2017)** who reported that talc improved the photosynthesis process with rice plants, where it allowed better light transmittance via plant canopies, consequently, the foliar application of talc increased rice grain yield.

5. Conclusion

It can be concluded that the addition of DM before rice cultivation increased the soil water holding capacity. Thus, its addition under 80% of TFI with exogenous application of both anti-transpirantsimproved growth performance and productivity. Generally, it can be said that DM treatment may hold enough amounts of both water and different nutrients and release them as required by the rice plant. Also, anti-transpirants have great potential in raising the water-deficit stress tolerance of rice via increasing leaf reflectance and thereby reducing water loss through the transpiration process. Thus enhancing the growth performance, quantitative and qualitative yield of rice with the limited supply of irrigation water.

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Authors' contribution:

Mohamed A. El-Sherpinydesigned and conducted the field experiment as well as wrote the result section and send the paper to the journal.

Dina A. Ghazi designed and conducted the field experiment as well as wrote the material and introduction section.

Soad H. Hafez designed and conducted the field experiment as well as analyzed the data and wrote the remainder of the manuscript.

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