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Amelioration of Rice Productivity under Irrigation Treatment Using Anti-Transpirants Sprays and Amino Acids

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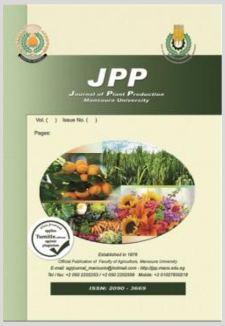

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ABSTRACT

The worsening water crisis in Egypt,aggravated by climate change, has necessitated the exploration of innovative strategies by agricultural scientists. These efforts aim to enhance productivity and optimize of this study was to evaluate the growth, yield, water-use efficiency and grain quality of the Giza 179 rice cultivar under different irrigation treatment,supplemented with anti-transpirants application and amino acids, in order to improve tolerance to water deficiency. A strip-plot experimental design with three replications was utilized for this study.Three irrigation treatments were applied in the vertical plots of 100% AOWU, 90% AOWU,and 80%AOWU. Horizontal plots represented anti-transpirants spray treatments:Control(without spraying), Kaolin, Amino acids and Kaolin+ amino acids.The study demonstrated a significant positive correlation between growth, grain yield and its attributes under well-watered conditions 100% AOWU and moderately reduced irrigation 90% AOWU in compared to the reduced water treatment 80% AOWU. Furthermore, the combination of anti-transpirants spray and amino acid treatment(Kaolin+ amino acids)led to enhanced growth and grain yield compared to the other treatments.Meanwhile, the A1 treatment required the highest amount of irrigation water, and the 80% AOWU treatment utilized the least amount. The 90% AOWU treatment exhibited superior water use efficiency compared to the other treatments. The combined application of kaolin and amino acids and amount irrigation 90% AOWU irrigation level resulted in the highest water use efficiency. Based on the results, the Kaolin+ amino acids and 90%AOWU irrigation regime were identified as the most effective in optimizing growth, yield, grain quality, and water use efficiency of the Giza 179 rice cultivar.

Keywords: Rice, water deficit, amino acids, grain yield, kaolin.

INTRODUCTION

Rice (*Oryza sativa* L.) is a semi-aquatic crop that thrives in environments with high humidity (Gao *et al*., 2021). As a result, rice cultivation requires substantially higher irrigation water inputs than other crops. Rice serves as a primary dietary staple for nearly half of the global population, accounting for 21% of the world's food supply (Meus *et al*., 2022). Irrigation management is a critical factor in ensuring optimal productivity and crop quality within the agricultural sector. In arid regions such as Egypt, where water resources are limited and the majority of water supply comes from the Nile River, agricultural production is constrained more by water availability than by land resources (Abdelhafez *et al*., 2020). As a result, the focus of agricultural production strategies among researchers is shifting from maximizing land productivity to optimizing water productivity. Under Egyptian conditions, implementing effective water management through irrigation scheduling based on weather factors to determine irrigation water requirements has become a crucial task. Timely and sufficient water application, with minimal losses, is essential for enhancing water productivity and mitigating the ongoing water scarcity issues (Muroyiwa *et al*., 2022). Rice is a high-water-demand crop, which has resulted in irrigation practices that involve frequent and excessive water application. Therefore, it is essential to study water-saving techniques to assess their potential in improving water use efficiency and addressing the challenge of water scarcity in Egypt. (Mallareddy *et al*., 2023). Improving plant resistance to stress represents the most cost-effective approach for maintaining agricultural productivity in regions frequently affected by water scarcity. (Liu *et al*., 2023). It is necessary to combine various methods, some of which must focus on water conservation with minimal negative impact. Stomatal control is the primary and most crucial response to stress, as reducing stomatal conductance lowers water loss rates, slows the onset of stress, and mitigates its severity (Arve *et al*., 2011). The potential to reduce transpiration water loss without significantly affecting the photosynthetic rate relies on the assumption that the resistance to carbon dioxide movement within the mesophyll exceeds the stomatal resistance that restricts water loss to the atmosphere (Jeber and Khaeim, 2019). Anti-transpirants, which can be either natural or synthetic materials, have been suggested to reduce water loss and improve the water status of plants. These substances work by reflecting leaf radiation, lowering leaf temperature, and decreasing the transpiration rate (e.g., Titanium dioxide, aluminosilicate (Kaolin)) (El-Din and Mokhtar, 2020). One potential solution to address water scarcity is the use of anti-transpirants, which are applied to plant surfaces to decrease water consumption. This is achieved by reducing transpiration through mechanisms such as stomatal closure, the formation of a film on the leaf surface, or the reflection of sunlight. Anti-transpirants exhibit several desirable characteristics, including stability, non-toxicity, affordability, and long-lasting effectiveness, and they should offer various benefits (Kandi *et al*., 2016). Several studies have indicated that anti-transpirants not only reduce water loss but also enhance plant physiology, thereby improving both the quality and yield of the crops (Patel *et al*., 2019). Anti-transpirants such as kaolin (a non-toxic aluminosilicate clay mineral) However, limited research has been conducted on the combined effects of water-absorbent anti-transpirants, applied foliar during the growth period of plants, under

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conditions of restricted irrigation water availability. Amino acids play a vital role in various biological processes, both in their free form and as constituents of proteins. Amino acids function as the primary building blocks required for protein synthesis. Structurally, they are organic molecules consisting of an amino group (NH_2), a carboxyl group (COOH), and a distinctive side chain (R group) specific to each amino acid. This side chain is bonded to the central (α) carbon atom, which serves as the core structural component. Proteins are composed of 21 distinct types of amino acids, which are broadly categorized into two groups based on their molecular structure and size: peptides and proteins. (Lopez and Mohiuddin, 2024). The importance and functional efficacy of amino acids are manifested across multiple stages of plant development. Amino acids enhance cellular capacity for the uptake of water and nutrient solutions from the growth medium, thereby facilitating vegetative growth. Amino acids also function as precursors in the biosynthesis of various essential compounds, including vitamins, nucleotides, and plant growth regulators, thereby constituting vital components of living tissues and protoplasm. Furthermore, amino acids are integral to the synthesis of enzymes and contribute to the facilitation of enzymatic reactions within plant cells. (Baqir and Al-Naqeeb, 2019). The aim of this study is to examine the effects of irrigation treatments and anti-transpirants, as well as their interactions, on growth, yield, and water relations under Egyptian conditions of.

MATERIALS AND METHODS

The study was carried out at the Experimental Farm of the Sakha Research Station, under the jurisdiction of the Agricultural Research Center in Kafr El-Sheikh, Egypt, during the 2023 and 2024 growing seasons. The objective of the study was to evaluate the effects of different amounts of irrigation water application, the use of foliar anti-transpirants, and their interactions on the performance of rice. The experimental plots were previously cultivated with barley (Hordeum vulgare). Data on monthly mean temperatures and relative humidity (RH) for the study area during the experimental period were obtained from Egypt. www.weather.com

The mechanical and chemical properties of the soil, as determined through laboratory analyses, are summarized in Table 2.

The experiment was designed using a strip plot layout with three replications conducted for each growing season. The vertical plots included three irrigation treatments: 100% AOWU amount of water use of 10.800 m³/ha, 90% AOWU of 9.720 m³/ha, and 80% AOWU of 8.640 m³/ha. The horizontal plots consisted of four fertilization treatments: a control, kaolin, amino acid, and a combination of kaolin and amino acids. Source of kaolin from kaolinite clay ($Al_2O_3.2SiO_2.2H_2O$) applications were administered at two periods: 20 and 40 days after transplanting. Foliar sprays of kaolin rate 2/L. A foliar spray containing free amino acids, each with a purity of 98%, was prepared using amino acid reference standards. The amino acids included: L-aspartic acid (Asp), L-serine (Ser), L-glutamic acid (Glu), L-glutamine (Gln), glycine (Gly), L-histidine (His), L-asparagine (Asn), L-arginine (Arg), L-threonine (Thr), L-alanine (Ala), L-tyrosine (Tyr), L-valine (Val), L-methionine (Met), L-isoleucine (Ile), L-tryptophan (Trp), L-leucine (Leu), L-phenylalanine (Phe), L-hydroxyproline (Hyp), L-lysine (Lys), L-proline (Pro), and L-norleucine (Nor). Foliar applications of amino acids at a concentration of 100 mg/L were administered at two intervals: 20 and 40 days after transplanting. The nursery was thoroughly plowed and leveled. Treatments other cultural practices were applied according to standard recommendations for the nursery. Seeds of the Giza 179 rice cultivar, at a rate of 143 kg/ha, were soaked in water for 24 hours and then incubated for an additional 48 hours to promote germination. The pre-germinated seeds were subsequently broadcast into the nursery after puddling on May 14th and 16th for the first and second seasons, respectively.

Table 1. Average monthly temperature and relative humidity (RH) values recorded at the study site during the 2023 and 2024 growing season.

Month	2023			2024		
	Max.°C	Min.°C	RH%	Max.°C	Min.°C	RH%
May	33	17	76.3	36.5	31.5	77.5
June	34	20.5	82.4	37.3	33.5	82.6
July	35.6	22.3	81	38.5	34.9	81.7
August	37.5	26.2	83.5	38.8	35.2	84.2
September	34	24	80	37	32.4	81.4

Table 2. Mechanical and chemical characterization of the experimental soil.

Soil chemical properties	season	
	2023	2024
pH (1:2.5)	8.3	8.4
Ec (dsm^{-1})	3.1	3.3
Organic matter%	1.35	1.36
Available P, mg/kg	12.4	13.0
Available Ammonium (ppm)	19.3	19.9
Available Nitrate (ppm)	16.6	16.0
Available Potassium (ppm)	300	305
Anions(meq/L)		
CO3-	--	--
HCO3	5.4	5.5
SO4-	11.3	11.5
Cations(meq/L)		
Ca+Mg	13.2	14.6
Na+	16.6	17.1
K+	0.8	0.95

For the permanent field, N P K treatments were applied according to standard recommendations. The plot size for each treatment was 20 m² (4 x 5 m). Each plot was transplanted with 30-day-old seedlings, 3 to 4 plants per hill, spaced 20 cm apart within rows. To minimize lateral movement of irrigation water and improve water management, each main plot was separated by two-meter-wide ditches. Forty days after transplanting, five randomly selected hills per horizontal plot were sampled to assess dry matter accumulation and leaf area index (LAI). At harvest, plant height and the total number of panicles were determined using ten randomly selected hills. Additionally, ten panicles were randomly collected from each plot to evaluate number of grains per panicle, number of unfilled grains, panicle weight(g), 1000-grain weight(g), and grain yield(t/ha). Grain yield was recorded from a randomly selected 12 m² area (3 × 4 m) within each plot and standardized to 14% moisture content before being converted to tons per hectare. Available soil moisture was then determined using soil moisture sensors, which measure the amount of water available to plants in the soil. Plants were harvested at maturity to ensure accurate measurements. To evaluate grain quality, approximately 150 grams of grain were sampled from each treatment, pooled, and submitted to the Grain Quality Laboratory at the Rice Research and Training Center (RRTC) for analysis. The assessment of grain quality parameters was conducted in accordance with the procedures described by Bautista and Siebenmorgen (2002).

Water Management and Use Efficiency:

A calibrated water meter was integrated into the water pumping system to accurately measure water application throughout the experimental period. Water use efficiency was calculated as the grain yield per unit volume of water consumed (kg of grains per m³ of water). Additionally, water savings were determined using the following formula: Water savings as a percentage were calculated by determining the difference between the total water applied under amount of water use 10800

m^3/ha (Tn) and the total water applied under intermittent irrigation treatments (Ts), then dividing this difference by the total water applied under continuous flooding, and multiplying the result by 100. The formula is as follows:

Water saved (%) = ((Tn - Ts) / Tn) × 100.

Statistical Analysis: Statistical analysis of the collected data was conducted using analysis of variance (ANOVA), following the methodology described by Gomez and Gomez (1984). Treatment means were compared using Duncan's Multiple Range Test (DMRT) as outlined by Duncan (1957). All statistical computations were carried out using the "COSTAT" software package.

RESULTS AND DISCUSSION

1.Growth characteristics:

Table 3 demonstrates that a reduction in irrigation water application led to a statistically significant decrease in Leaf area index (LAI), dry matter (DM), and plant height when compared to the control treatment, which received 100% AOWU of the amount of water use.

Table 3. Means of LAI, dry matter at 40 days after transplanting and plant height at harvest t of Giza 179 rice cultivar as affected by irrigation treatments and anti-transpirants treatments.

Treatment	LAI		Dry matter (g/m2)		Plant height (cm)	
	2023	2024	2023	2024	2023	2024
Irrigation treatments (A)						
100% AOWU	5.61a	6.02a	1142a	1211a	99.00a	102.11a
90% AOWU	5.21b	5.34b	1100b	1164b	95.76a	99.50b
80% AOWU	3.79c	3.90c	875c	933c	86.92b	88.60c
f. test	**	**	**	**	**	**
Anti-transpirants treatments (K)						
Control	3.64d	3.80d	1037d	1101d	89.39d	95.72d
Kaolin	4.31c	4.54c	1038c	1102c	92.55c	96.36c
Amino acids	5.35b	5.59b	1039b	1103b	95.56b	97.01b
Kaolin+amino acids	6.16a	6.40a	1040a	1104a	98.06a	97.85a
f. test	**	**	**	**	**	**
Interactions						
A X K	**	*	NS	NS	*	*

*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS= Not significant. Means having the same letter (s) are not significantly different according to Duncan's multiple range tests. A1= (100% AOWU) amount of water use 10800 m^3/ha,A2= (90% AOWU) of amount of water use and A3= (80% AOWU) of amount of water use .**

The observed decline in growth parameters can primarily be attributed to a reduction in tiller number, total leaf area, and an increase in leaf senescence. It is well-established that restricted water availability, as seen in the 80% AOWU treatment, significantly impedes plant growth. These results align with the findings of previous studies conducted by Toscano and Romano (2021).

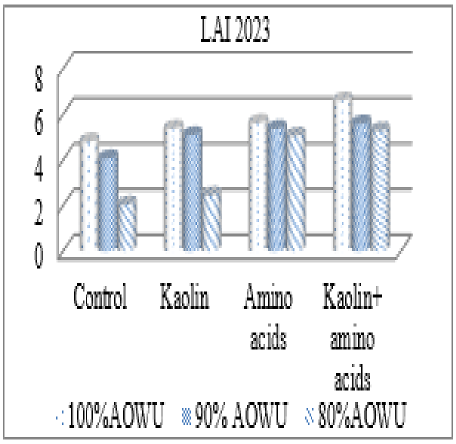
The observed enhancement in Leaf area index, dry matter, and plant height can be attributed to the positive influence of increased water availability on cellular processes such as cell division and elongation. The observed increase in vegetative growth, total dry matter production, and plant height within the 100% AOWU treatment can be partially attributed to enhanced nitrogen availability. This phenomenon is hypothesized to be a result of the treatment stimulating enhanced root development, consequently facilitating improved nitrogen mobility within the soil solution and leading to increased nitrogen uptake by plant roots. These findings corroborate the previous research conducted by Wahab et al. (2022).

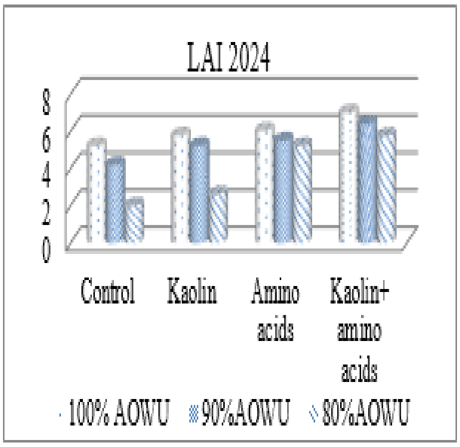
The combined application of kaolin and amino acids led to significantly higher values for Leaf Area Index (LAI), dry matter (DM), and plant height compared to the individual applications of either kaolin or amino acids. The lowest values were observed in the control treatment. Kaolin sprays foliar have been demonstrated to enhance plant water status, water use efficiency (WUE), and photosynthetic activity, particularly under water-limited conditions. Elevated temperatures and high solar radiation significantly increase plant water loss, frequently resulting in leaf burn or wilting due to excessive transpiration and respiration (Sadok *et al*., 2021). Also, reduced leaf water content has been shown to negatively impact leaf area, CO_2 assimilation rates, stomatal conductance, dry matter accumulation, plant height, and ultimately, crop yield (Martínez-Goñi *et al*., 2024). Exogenous application of amino acids has been shown to significantly enhance rice growth and yield (Baqir and Al-Naqeeb, 2019). Specifically, certain amino acids, such as tryptophan, serve as precursors for the biosynthesis of natural auxins, key plant hormones that stimulate root development. This enhanced root system subsequently contributes to increased leaf area index (LAI), dry matter (DM), and plant height.

Conversely, the combination of the 80% AOWU treatment with the control consistently resulted in the lowest LAI values in both seasons.

Fig2. Demonstrates that the combination of irrigation and foliar application of anti-transpirants treatments resulted in the greatest plant height in both growing seasons.

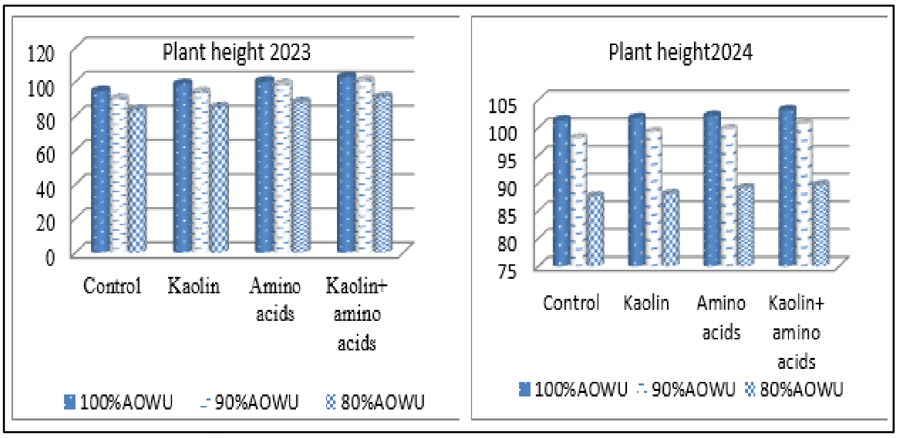
Conversely, the combination of 80% AOWU with the control treatments consistently resulted in the lowest plant height values in both seasons.





100% AOWU amount of water use 10800 m^3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Figure 1 Effect of interaction between water treatments and ant transpiration substances on Leaf Area Index (LAI) in both growing seasons.



(100% AOWU) amount of water use 10800 m^3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 2. Plant height of Giza 179 rice cultivar as affected by the interaction between the studied factors.

2. Grain yield and its attributes:

Table 4 presents the impact of irrigation treatments on key yield attributes, including number of panicle per hill, number of filled and unfilled grain per panicle, across the 2023 and 2024 growing seasons. Notably, the 80% AOWU treatment resulted in a significant reduction in all measured yield components, with the exception of unfilled grains per panicle, which exhibited a significant increase. Data presented in (Table 4) demonstrate that the 100% AOWU treatment consistently yielded the highest values for number of panicle per hill and number of filled grains per panicle in both growing seasons.

Table 4. Effect of Number of panicle/hill, No. of filled grains/panicle and No. of unfilled grains/panicle of Giza 179 rice cultivar as affected by irrigation treatments and anti-transpirant treatmentss.

Treatment	No. of panicle/hill		No. of filled grains/panicle		No. of unfilled grains/panicle	
	2023	2024	2023	2024	2023	2024
Irrigation treatment (A)						
100% AOWU	22.31a	23.11a	135.36a	137.66a	8.05c	10.37c
90% AOWU	20.53b	21.08b	131.08a	133.08a	10.77b	12.83b
80% AOWU	18.17c	18.57c	120.37b	121.93b	16.57a	21.96a
f. test	**	**	**	**	**	**
Anti-transpirants treatments (K)						
Control	18.40d	19.00d	119.56c	121.51c	15.63a	17.17a
Kaolin	20.01c	20.60c	126.63b	128.58b	12.07b	15.96b
Amino acids	21.06b	21.64b	132.34a	134.29a	10.37c	14.32c
Kaolin+amino acids	21.87a	22.45a	137.22a	139.18a	9.11d	12.77d
f. test	**	**	**	**	**	**
Interactions						
A X K	NS	*	*	*	NS	NS

*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS= Not significant. Means having the same letter (s) are not significantly different according to Duncan's multiple range tests. (100% AOWU) amount of water use 10800 m^3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.**

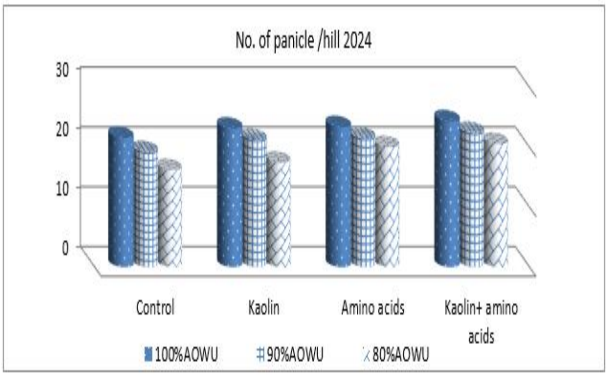
No significant difference was observed between the 100% AOWU and 90% AOWU treatments. This increase in unfilled grains under stress with findings reported by Chakraborty and Sakagami (2024). Conversely, adequate water availability likely facilitated enhanced dry matter production and translocation to the panicles, supporting grain development. This may explain the higher number of panicles per hill and filled grains per panicle observed in well-watered treatments. These findings align with previous research by Gharib *et al.*, (2011) which also demonstrated the positive effects of adequate water availability on key grain yield components. These findings can be attributed to increased soil moisture content during the vegetative growth stage of rice. Enhanced soil moisture is well-documented to positively influence cellular processes such as cell division and elongation within plants (Hu et al., 2024).

Furthermore, adequate water availability may have stimulated various physiological processes, including photosynthesis and enzymatic activity, ultimately enhancing the translocation of dry matter to the developing grains (Hossain *et al.*, 2020). This study demonstrates a positive synergistic effect of the combined application of Kaolin and amino acids on rice growth traits (Table 4). Treatments incorporating both Kaolin and amino acids resulted in the highest values for number of panicle per hill and number of filled grains per panicle in both growing seasons. No statistically significant difference was observed between treatments involving amino acids alone and combined application of Kaolin and amino acids for these parameters (Table4) as compared to control treatment. Conversely, the combined application of Kaolin and amino acids resulted in the lowest number of unfilled grains per panicle. The observed increase in filled grains with the application of Kaolin and amino acids can be attributed to a synergistic enhancement of photosynthetic activity and efficient translocation of photosynthesis to the developing grains. These findings corroborate those reported by De Souza Junior *et al.* (2021). The combined application of Kaolin amino acids likely enhanced rice yield. Firstly, it may have stimulated carbohydrate assimilation, leading to an increase in filled grains. The supplementation of amino acids and kaolin significantly enhanced number of panicle by 21.87% and 22.45%, respectively. Concurrently, number of filled grain increased by 137.22% and 139.18%, respectively. These findings suggest that the treatments stimulated photosynthesis, ultimately leading to a substantial increase in panicle production. Adequate water availability likely facilitated the efficient transportation of photosynthates to the developing panicles, contributing to increased biomass accumulation. This may account for the observed increase in panicle number per hill and grain fill percentage in plants treated with amino acids. These findings corroborate the observations reported by Mahmoud *et al.*, (2021). The control treatment exhibited the lowest values for both panicle number and the number of filled grains, with the exception of unfilled grains per panicle. Conversely, the control treatment displayed the highest values for the number of unfilled grains per panicle.

As depicted in Figure 3, the concurrent application of 100% AOWU irrigation and a combination of Kaolin and amino acids resulted in the highest number of panicle per hill. In contrast, the combination of 80% AOWU irrigation and the control treatment consistently exhibited the lowest number of panicle per hill during the second season.

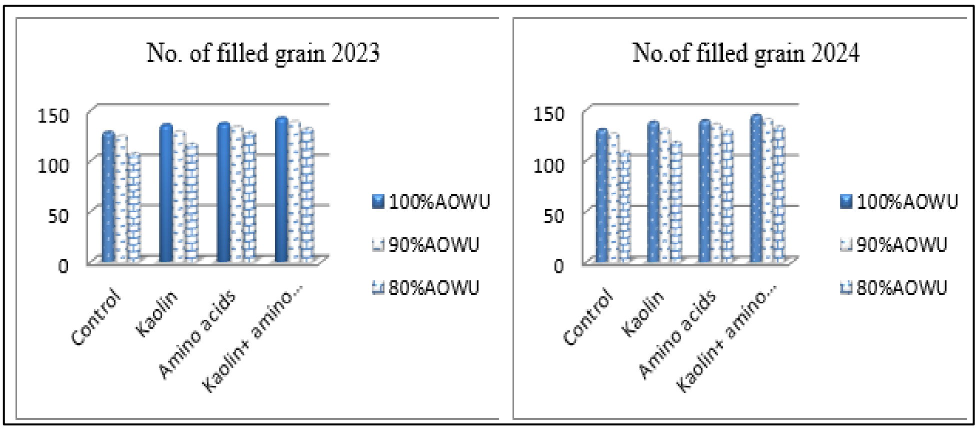
As illustrated in Figure 4, the simultaneous application of 100% AOWU irrigation and a combination of Kaolin and amino acids resulted in the highest number of filled grains. Conversely, the combination of 80% AOWU irrigation and the control treatment consistently exhibited the lowest number of filled grains during both the first and second seasons.

As presented in Table 5, the irrigation treatment at 100% AOWU consistently yielded the highest values across all measured yield components during both growing seasons. These components encompass panicle weight (3.44 and 3.82 g), 1000-grain weight (24.68 and 25.31 g), and grain yield (10.37 and 10.66 t/ha). The 90% AOWU treatment exhibited yield comparable to that of the 100% AOWU treatment. In contrast, stress induced by the 80% AOWU treatment resulted in a significant decline in yield components. These findings are consistent with those reported by Patel *et al*., (2019).



(100% AOWU) amount of water use 10800 m³/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 3. Number of panicle /hill of Giza 179 rice cultivar as affected by the interaction between the studied factors.



A1= (100% AOWU) amount of water use 10800 m3/ha,A2= (90% AOWU) of amount of water use and A3= (80% AOWU) of amount of water use.

Fig 4. Number of filled grain of Giza 179 rice cultivar as affected by the interaction between the study factors.

Table 5. Influence of irrigation regimes and anti-transpirants applications on panicle weight, 1000-grain weight, and grain yield of the Giza 179 rice cultivar.

Treatment	Panicle weight (g)		1000-grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2023	2024	2023	2024	2023	2024	2023	2024
Irrigation treatments (A)								
100% AOWU	3.44a	3.82a	24.68a	25.31a	10.37a	10.66a	12.70a	13.33a
90% AOWU	3.07b	3.45b	24.17b	24.57b	9.96a	10.26a	12.52a	12.97b
80% AOWU	2.16c	2.41c	23.00c	23.35c	8.42c	8.90c	11.04b	11.37c
f. test	**	**	**	**	**	**	**	**
Anti-transpirants treatments (K)								
Control	1.85d	2.13d	22.45d	23.10d	8.56d	8.82d	10.77d	11.28d
Kaolin	2.51c	2.84c	23.66c	23.88c	9.21c	9.58c	11.55c	12.06c
Amino acids	3.18b	3.55b	24.39b	24.92b	9.86b	10.22b	12.60b	13.10b
Kaolin+amino acids	4.01a	4.38a	25.28a	25.73a	10.70a	11.14a	13.41a	13.78a
f. test	**	**	**	**	**	**	**	**
Interactions								
A X K	*	*	**	**	*	**	NS	NS

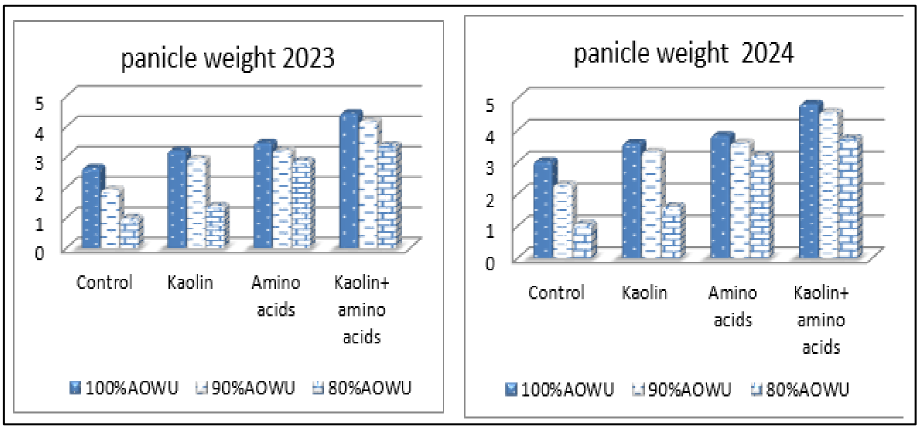
*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS= Not significant. Means having the same letter (s) are not significantly different according to Duncan's multiple range tests. (100% AOWU) amount of water use 10800 m³/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.**

This reduction in yield can be attributed to tiller mortality under stress, consequently diminishing the number of panicles per unit area. Conversely, the well-watered 100% AOWU treatment ensured adequate nutrient availability, fostering tiller development and ultimately resulting in a higher number of panicles with filled grains. These results are in agreement with the findings reported by Jarin *et al*., (2024).

The combined application of kaolin and amino acids likely played a role in enhancing rice yield. Specifically, the supplementation with amino acids and kaolin resulted in significant increases in panicle weight (4.01 and 4.38 g), 1000-grain weight (25.28 and 25.73 g), and grain yield (10.70 and 11.14 t/ha) during the two respective growing seasons. Kaolin application has been employed as a strategy to alleviate the detrimental effects of water and heat stress on plant physiological functions and productivity. This intervention has led to various outcomes, including improvements in yield and alterations in photosynthetic activity. While an increase in albedo results in a reduction of leaf temperature and alleviates heat stress, potentially counteracting the beneficial effects of lower temperatures. These findings are consistent with those reported by Rosati *et al*., (2006). The application of amino acids led to an increase in chlorophyll content, which enhanced photosynthetic efficiency and subsequently resulted in a significant improvement in grain yield. These results are in agreement with those reported by Guo *et al*., (2021).

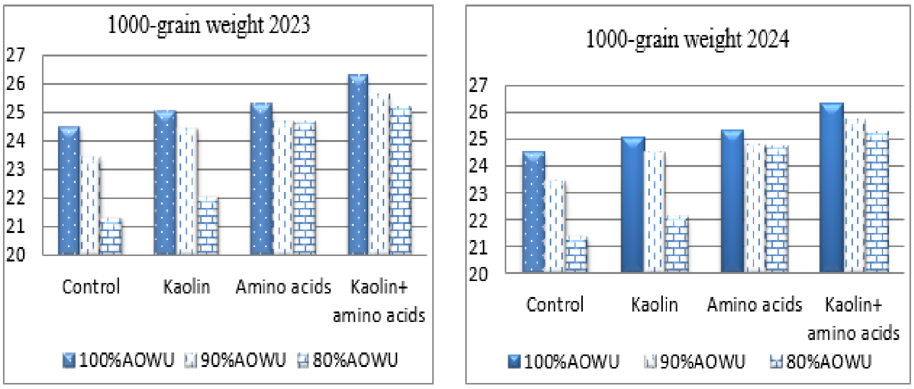
As illustrated in Figure 5, the simultaneous application of 100% AOWU irrigation and a combination of Kaolin and amino acids resulted in the highest panicle weight. In contrast, the combination of 80% AOWU irrigation and the control treatment consistently exhibited the lowest panicle weight during both seasons.

Figure 6 demonstrates that the concurrent application of 100% AOWU irrigation in conjunction with a combination of Kaolin and amino acids resulted in the highest 1000-grain weight. Conversely, the combination of 80% AOWU irrigation and the control treatment consistently yielded the lowest 1000-grain weight in both growing seasons.



(100% AOWU) amount of water use 10800 m3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

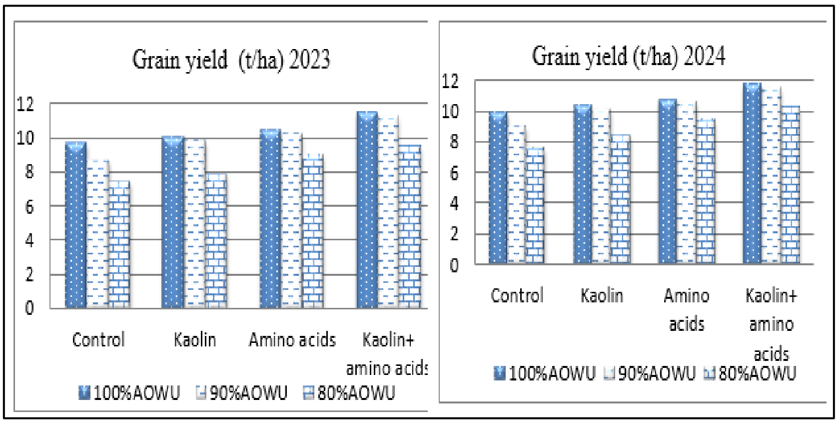
Fig 5. Panicle weight(g) of Giza 179 rice cultivar as affected by the interaction between the study factors.



(100% AOWU) amount of water use 10800 m^3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 6. 1000-grain weight(g) of Giza 179 rice cultivar as affected by the interaction between the study factors.

Figure 7 demonstrates that the highest grain yield was achieved through the concurrent application of 100% AOWU irrigation in conjunction with a combination of Kaolin and amino acids. Conversely, the combination of 80% AOWU irrigation and the control treatment consistently resulted in the lowest grain yield across both growing seasons. Shows water availability likely enhanced the efficiency of dry matter production and its subsequent translocation to the developing panicles, thereby optimizing grain development. These findings suggest that adequate water availability likely contributed to increased panicle number per hill, filled grains per panicle, and grain yield in well-watered treatments.



(100% AOWU) amount of water use 10800 m^3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 7. Grain yield(t/ha) of Giza 179 rice cultivar as affected by the interaction between the study factors.

The application of kaolin effectively mitigates the adverse effects of extreme heat and ultraviolet radiation by increasing leaf reflectance and reducing transpiration rates, thereby facilitating the cooling of plant tissues. Additionally, the application of amino acids led to an increase in chlorophyll content, which enhanced photosynthetic activity and subsequently contributed to a significant improvement in grain yield.

The data presented in Table 5 demonstrate that irrigation treatments significantly influenced straw yield in both growing seasons. Specifically, the 100% AOWU irrigation treatment consistently resulted in the highest values for all evaluated yield components across both seasons, including straw yield, although the differences between 100% AOWU and 90% AOWU were not statistically significant. In contrast, the 80% AOWU treatment induced stress conditions, leading to a marked reduction in the measured yield components. The reduction in yield is primarily attributed to tiller mortality induced by stress, which consequently decreased the number of tillers per unit area. In contrast, the well-irrigated treatment receiving 100% of the applied optimal water use (AOWU) ensured adequate nutrient availability, thereby supporting tiller development and resulting in a higher number of panicles and increased straw yield. These findings are consistent with those reported by Jarin *et al*., (2024).

Kaolin application has been utilized to alleviate the adverse effects of water stress on plant physiological processes and overall productivity, resulting in a range of outcomes such as both increases and decreases in yield, along with modifications in photosynthetic activity. These results are consistent with the findings of Sotelo *et al.* (2011). Moreover, the application of amino acids enhanced chlorophyll content, which in turn improved photosynthetic efficiency and resulted in a significant increase in straw yield. These outcomes are consistent with the findings of Popko *et al.* (2018).

3. Grain quality

Milling characteristics:

The results presented in Table 6 indicate that irrigation treatments had a significant effect on milling characteristics across both growing seasons. Extending the irrigation interval from 100% AOWU to 80% AOWU led to notable improvements in these characteristics. The 100% AOWU treatment consistently produced the highest values for hulling, milling, and head rice percentages during both seasons. In contrast, the 80% AOWU treatment yielded the lowest values for all milling characteristics across both growing seasons. This decline in milling recovery is likely due to the increased water deficit associated with this treatment, which tends to shorten the grain-filling duration and reduce grain weight. These results are in agreement with those reported by. Gewaily *et al.* (2019).

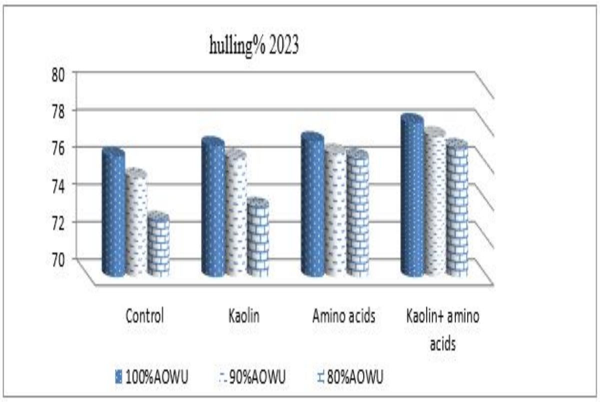
Table 6. Means of hulling, milling and head rice of Giza 179 rice cultivar as affected by irrigation treatments and anti-transpirants treatments.

Treatment	Hulling (%)		Milling (%)		Head rice (%)	
	2023	2024	2023	2024	2023	2024
Irrigation treatments (A)						
100% AOWU	77.24a	78.46a	69.68a	70.86a	62.75a	63.80a
90% AOWU	76.46b	77.60b	68.52b	70.22b	61.86b	62.34b
80% AOWU	75.02c	76.23c	66.43c	67.74c	60.49c	61.27c
f. test	**	**	**	**	**	**
Anti-transpirants treatments (K)						
Control	74.93d	76.48d	66.90d	68.29d	60.39d	61.16d
Kaolin	75.71c	76.90c	67.68c	69.07c	61.17c	61.94c
Amino acids	76.75b	77.94b	68.72b	70.12b	62.21b	62.98b
Kaolin+ amino acids	77.56a	78.39a	69.53a	70.93a	63.03a	63.79a
f. test	**	**	**	**	**	**
Interactions						
A X K	**	NS	NS	NS	**	NS

*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS= Not significant. Means having the same letter (s) are not significantly different according to Duncan's multiple range tests. (100% AOWU) amount of water use 10800 m³/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.**

The data presented in Table 7 demonstrate that anti-transpirants treatments had a significant effect on hulling, milling, and head rice percentages during both growing seasons. Notably, the combined application of kaolin and amino acids substantially improved these parameters, indicating a favorable influence on rice yield relative to the control treatment. Kaolin application has been employed as a strategy to mitigate the detrimental effects of water and heat stress on plant physiological functions and productivity, leading to a range of outcomes such as enhanced yield and improved grain quality. These results are consistent with those reported by Sotelo *et al*. (2011). The application of amino acids has been shown to enhance chlorophyll content, thereby increasing photosynthetic activity and resulting in a significant rise in grain yield. These findings are consistent with those reported by Popko *et al.* (2018).

The data depicted in Figure 8 demonstrate that the interaction of irrigation treatments significantly influenced the hulling percentage during the first growing season. This finding research indicating that varying irrigation intervals can significantly affect hulling percentages in rice.

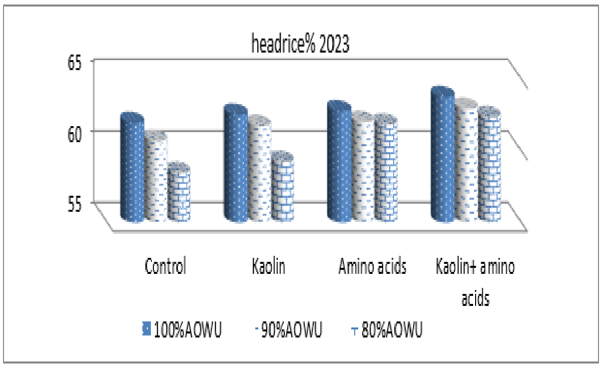


(100% AOWU) amount of water use 10800 m³/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 8. Hulling % of Giza 179 rice cultivar as affected by the interaction between the study factors.

Specifically, the concurrent application of 100% AOUWU irrigation, in conjunction with a combination of kaolin and amino acids, resulted in the highest hulling percentage. Conversely, the combination of 80% AOUWU irrigation and the control treatment consistently yielded the lowest hulling percentage across the first growing season.

The data presented in Figure 9 indicate that the interaction of irrigation treatments significantly influenced the head rice percentage during the first growing season. Specifically, the combination of 100% AOWU irrigation with kaolin and amino acids resulted in the highest head rice percentage.



(100% AOWU) amount of water use 10800 m³/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 9. Head rice percentage of Giza 179 rice cultivar as affected by the interaction between the study factors.

In contrast, the 80% AOWU irrigation coupled with the control treatment consistently produced the lowest head rice percentage. These findings are consistent with previous research demonstrating that varying irrigation intervals can significantly affect head rice percentages in rice.

4. Effective water management strategies are essential for reducing water input in agricultural practices.

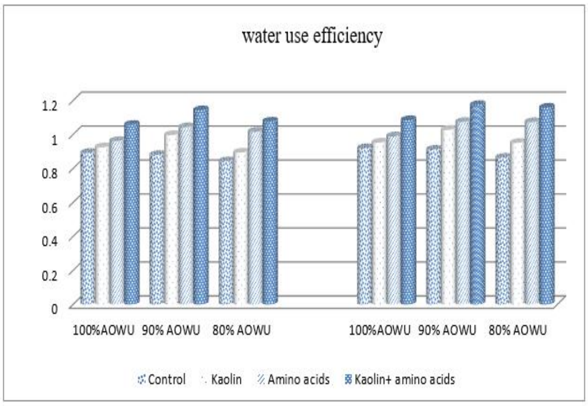
Table 7 presents data on total water consumption, water savings, and water use efficiency for the 2023 and 2024 growing seasons. The 100% AOWU irrigation treatment recorded the highest total water usage, amounting to 10,800 m^3/ha per season, whereas the 80% AOWU treatment applied the lowest amount, totaling 8,640 m^3/ha per season.

Table 7.Total water used, water saved, and water use efficiency as affected by irrigation treatments.

Irrigation treatment	Total water use (m^3/ha)	Grain yield (t/ha)		Water saved (%)	water use efficiency(kg/m^3)	
	2023 or 2024	2023	2024	2023 or 2024	2023	2024
100% AOWU	10800	10.37	10.66	-	0.96	0.987
90% AOWU	9720	9.96	10.26	9.25	1.016	1.046
80% AOWU	8640	8.42	8.90	18.51	0.956	1.011

The percentage of water savings achieved with the 90% AOWU treatment was 9.25% in the first season and 18.51% in the second season, followed by the 80% AOWU treatment. The 90% RAOW irrigation treatment recorded the highest water use efficiency, followed by the 80% AOWU treatment in both growing seasons. Although the 100% AOWU treatment resulted in high grain yield, it was associated with increased water input compared to other treatments. These findings are consistent with those reported by El-Refaee *et al*., (2021).

Figure 10 illustrates that water use efficiency was highest under the 90% AOWU irrigation treatment combined with kaolin and amino acids in both growing seasons. This was followed by the 80% AOWU treatment with kaolin and amino acids. Conversely, the lowest water use efficiency was observed with the 80% AOWU treatment combined with the control in both seasons.



(100% AOWU) amount of water use 10800 m^3/ha, (90% AOWU) of amount of water use and (80% AOWU) of amount of water use.

Fig 10. Water use efficiency of Giza 179 rice cultivar as affected by the interaction between the study factors.

CONCLUSION

The irrigation of 100% amount of water use (AOWU) treatment combined with kaolin and amino acids has a high grain yield and low water inputs with 80% AOWU irrigation treatment. A combination of kaolin and amino acids spraying increases the ability to tolerate high- water shortage.

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تحسين انتاجية الأرز المنزرع تحت معاملات الرى والأحماض الأمينية والرش بمضادات النتح

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الملخص

لقد ادا تفاقم أزمة المياه في مصر بسبب تغير المناخ واستلزم الأمر استكشاف استراتيجيات مبتكرة من قبل العلماء الزراعيين. ويتمثل الهدف الرئيسي لهذه الجهود في التحقيق في استجابات النمو والمحصول وعلاقة المياه لصنف الأرز جيزة ١٧٩ لمعاملات الري المختلفة ومضادات النتح، بهدف تعزيز قدرته على تحمل مواجهة الإجهاد وندرة المياه. تم استخدام تصميم الشرائح المتعامدة بثلاثة مكررات لهذه الدراسة. تم تطبيق معاملات الري على الشرائح الرأسية، ثلاث معاملات ري (١٠٠٪AOWU و ٩٠٪AOWU و ٨٠٪ AOWU). تمثل الشرائح الأفقية معاملات مضادة للنتح: الكنترول، والكاؤلين ، والأحماض الأمينية ، والكاؤلين والأحماض الأمينية. أظهرت الدراسة وجود ارتباط إيجابي كبير بين النمو ومحصول الحبوب ومكوناته في ظل ظروف الري الجيد (١٠٠٪ AOWU) والري المخفض بشكل معتدل (٩٠٪ AOWU) مقارنة بمعاملة المياه المخفضة (٨٠٪ AOWU). علاوة على ذلك، أدى تطبيق الرش بمضادات النتح مع الأحماض الأمينية إلى تعزيز النمو ومحصول الحبوب والجودة مقارنة بالمعاملات الأخرى. في حين أن معاملة ١٠٠٪ AOWU تتطلب أكبر كمية مياه الري مستخدمة، فإن معاملة ٨٠٪ AOWU ، كما كان متوقعًا، استخدمت أقل كمية. بناءً على هذه النتائج، يبدو أن الجمع بين التسميد والرش بمضاد النتح الكاؤلين والأحماض الأمينية مع الري ٩٠٪ AOWU هو الأمثل لتعظيم النمو والمحصول وجودة الحبوب وإنتاجية المياه في صنف الأرز جيزة ١٧٩.