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RESPONSE OF RICE (*ORIZA SATIVA* L.) TO SOME ANTITRANSPIRATIORS UNDER WATER STRESS IN NORTH NILE DELTA, EGYPT

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Abstract

The limited water resources and the remarkable increment in population in Egypt force the research workers to find various ways of saving water without a critical reduction in rice yield. So, this study was conducted to assess the response of rice plants to different irrigation intervals, different types of irrigation water and foliar applications of some antitranspirants and their interactions. For this purpose, three irrigation intervals were applied throughout the period of plant life until crop harvest (starting after first irrigation) as follows; I_1: irrigation every 4 days, I_2: irrigation every 8 days and I_3: irrigation every 12 days. Three types of irrigation water treatments were used as follows; W_1: normal irrigation water (100% canal water), W_2: agricultural drainage water and W_3: alternate irrigation with canal water and agricultural drainage water. Three antitranspirants treatments were sprayed as follows; A_1: Control (without any applications), A_2: KCl at a rate of 7% and A_3: $MgCO_3$ at a rate of 7%. The used experimental design was a split- split plot design with three replicates for each treatment. Plant height (cm), panicle length (cm), 1000 grains weight (g), grain yield (kg fed^{-1}), straw yield (kg fed^{-1}) and No. of filled grains/spike of rice plant were evaluated as well as (SOD) (Unit.g^{-1} F.W) in leaves and protein rice grain (%)were measured. The findings indicated that the best values were recorded when rice plants irrigated every 4 days (I_1) by normal irrigation water (100% canal water) (W_1) and foliar application of $MgCO_3$7 % (A_3). Also, spraying rice plants with $MgCO_3$ or KCl under irrigation by normal water (100% canal water) (W_1) every 8 days (I_2) or 12 days (I_3) gave better results than untreated plants (A_1) under irrigation by normal water (100% canal water) (W_1) every 4 days (I_1). The growth and yield of rice plant under water-stress condition was positively influenced by the application of antitranspirants.

***Keywords*:** Rice plant, irrigation intervals, antitranspiratiors and agricultural drainage water.

Introduction

In Egypt, rice (*Oryza Sativa* L.) is ranked as is one of the most important cereals and it is a crucial food crop because of the shortage in wheat production. Rice crop consumes so much irrigation water as compared with other crops and most of the Egyptian rice genotypes are grown under continuous flooding with almost five cm depth of standing water during the growing season. Due to shortage of water in Egypt, there is an urgent need to use untraditional water sources in irrigation proposes (El-Habet *et al.*, 2019). Agricultural drainage water is referred to as "Degraded Waters" because of their deterioration in biological, physical and chemical properties but it is often considered as a viable option for using as irrigation purposes. Furthermore, it has adverse effects on the growth and yield of plants in several species (Hammad *et al.,* 2018). Antitranspirants are chemicals substances that are sprayed on surfaces of transpiring plants to reduce water use by suppressing transpiration. Several researchers stated that antitranspirants not only alleviate the water loss but also enhance the disease resistance, physiological process, yield and quality aspects in many vegetable crops (Ahmed *et al.*, 2019). There is little published information available on the effect of antitranspirants on rice (*Oryza sativa* L.). Nowadays, due to the scarcity of water, Egypt faces a problem in rice crop productivity. So, the purpose of this study is an attempt to improve rice crop productivity under water stress (different irrigation intervals, *i.e,* irrigation every 4 days, irrigation every 8 days and irrigation every 12 days) as well as different types of irrigation water, *i.e.* normal water, agricultural drainage water and alternative irrigation with canal water and agricultural drainage water) during the rice-growing season using some antitranspirants (*i.e,* KCl 7% and $MgCO_3$ 7%) to reduce water losses through transpiration process under Egyptian aired conditions.

Materials and Methods

Therfor, to achieve the objective of this investigation; a field experiment was carried out at El-Karada Experimental Research Station, Kafr El-Sheikh Governorate, Egypt (31° 6' N latitude, 30° 56' E longitude, with an elevation of about 6 meters above mean sea level) during the summer season of 2019, rice-growing season, to investigate the effect of three irrigation intervals, three types of irrigation water, three foliar applications of antitranspirants and their interactions on growth, yield and yield attributes of rice plants (*Oryza sativa* L.) "Sakha 104 cultivar" as well as chemical constituents and superoxide dismutase (antioxidant enzyme).Twenty-seven treatments (which were the simple possible combination between all studied treatments) were arranged in a split- split plot design. The irrigation intervals represented the main plots and the different types of irrigation water were devoted in sub-plots, while the antitranspirants were allocated in the sub-sub plots. Each treatment was replicated three times. Thus, the total number of experimental units used was 81. The sub-sub plot size was $15m^2$ (3×5). Two ditchers were established among the irrigation treatments to avoid the lateral movement of irrigation water. The three irrigation intervals were applied throughout the period of plant life until crop harvest (starting after first irrigation) as follows; I_1: irrigation every 4 days, I_2: irrigation every 8 days and I_3: irrigation every 12 days. The types of irrigation water treatments were as follows; W_1: normal irrigation water (100% canal water), W_2: agricultural drainage water and W_3: alternate irrigation with canal water and agricultural drainage water. The antitranspirants were sprayed two times (after 35 and 70 days from transplanting).The antitranspirants treatments were as follows; A_1: Control (without any applications), A_2: KCl at a rate of 7% and A_3: $MgCO_3$ at a rate of 7%.

Before transplanting the rice seedlings in the permanent field, soil samples at three successive depths (0-15, 15-30 and 30-45 cm) were taken using an auger and analyzed as a routine work according to Dewis and Fertias (1970) as presented in Table 1. Water samples were collected from both irrigation canal and drainage water and chemically analyzed according to Jackson (1973) as shown in Table 2. The rice was cultivated on 5th Jun in 2019 season. All agricultural operations were performed according to the traditional local agriculture management practices. The experimental sites were prepared (plowed two times and well dry leveled). Seedling age was 28 days which transplanted using spaces 20 × 20 cm between hills and rows. The amounts of fertilizers were applied according to recommendations of Rice Research& Training Center (RRTC), Field Crops Research Institute, Agricultural Research Center (ARC). The weeds were chemically controlled using Saturn 50% 4 to7 days after transplanting as recommended by the Rice Research and Training Center (RRTC). The harvest was done on 18th Sep 2019. Growth characters [*i.e.*plant length (cm) and panicle length (cm)], Yield and its components: [*i.e.* weight of 1000-grain (g), straw and grain yield (kg fed^{-1}), number of filled and unfilled grains/panicle] were determined. Also, superoxide dismutase activity (SOD) of rice plant leaves was determined by measuring inhibition of photochemical reduction of nitrobluetetrazolium (NBT) using method of Beauchamp and Fridovich (1971). Data were statistically analyzed according to Gomez and Gomez (1984) using CoStat (Version 6.303, CoHort, USA, 1998–2004).

Table 1 : Some soil characteristics of the location for rice experiment.

Soil depth (cm)	Physical properties							
	Particle size distribution (%)				Texture class	F.C	W.P.	SP.
	C. sand	F. sand	Silt	Clay		%		
0-15	1.99	19.3	25	53.71	Clay	45.18	24.50	10.68
15-30	2.72	16.9	28.2	52.18	Clay	44.01	23.42	2.04
30-45	2.89	18.2	29.1	49.81	Clay	39.2	22.18	17.72
45-60	3.25	19.6	33.2	43.95	Clay	38.41	21.65	17.26
Mean	2.71	18.5	28.87	49.91	Clay	41.83	22.9	11.9

Soil depth (cm)	Chemical properties									
	EC, dS m^{-1}	pH	Soluble ions, meq L^{-1}							
			Cations				Anions			
			Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	Cl^-	SO_4^-
0-15	0.519	7.82	1.40	3.10	3.70	0.14	--	2.30	2.65	3.39
15-30	0.860	7.42	2.10	1.42	7.11	0.12	--	3.72	4.10	2.93
30-45	0.950	8.01	1.92	1.72	8.10	0.10	--	2.05	3.51	6.28
45-60	0.980	8.04	1.40	2.3	7.7	0.08	--	2.5	3.00	5.98
Mean	0.827	7.82	1.705	2.135	6.65	0.11	--	2.64	3.315	4.645

Table 2: Chemical analysis of irrigation water*.

Parameters		Canal water	Agricultural drainage water
pH		7.7040	7.760
EC (dSm^{-1})		0.4406	1.297
SAR		0.8560	2.850
Soluble Cations (meq L^{-1})			
	Ca^{+2}	1.914	4.702
	Mg^{+2}	1.392	2.890
	K^+	1.110	5.750
	Na^+	0.156	0.710
Soluble Anions (meq L^{-1})			
	CO_3^{-2}	0.000	0.000
	HCO_3^-	1.000	5.470
	Cl^-	2.710	3.120
	SO_4^{-2}	0.860	5.430

* The mean values of the number of irrigation during the season

Results and Discussion

1- Growth Characters, Yield and its Components.

Figs (from 1 to 6) and Table (3) show the effect of different irrigation intervals, different irrigation water types, foliar spraying with antitranspirants and their interactions on plant height (cm) and panicle length (cm) of rice plant as well as rice yield characters expressed as 1000 grains weight (g), grain weight (kg fed^{-1}), straw weight (kg fed^{-1}) and No. of filled grains/spike.

Irrigation intervals effect

It is clear from Figs (from 1 to 6) that; plant height (cm), panicle length (cm),1000 grains weight (g), grain weight (kg fed^{-1}), straw weight (kg fed^{-1}) and No. of filled grains/spike of rice plant were pronouncedly affected by different irrigation intervals. Results showed highly significant differences among the three irrigation intervals. All aforementioned traits were increased significantly as irrigation intervals decreased which leads to an increase in water and nutrients availability in the soil. Hence, the highest values were found when rice plants irrigated every 4 days (I_1), followed by irrigation every 8 days (I_2). On the opposite, the lowest plant height and panicle length were obtained at 12 days irrigation regime (I_3). These findings agree with the fact that rice grown under drought conditions normally has slower growth than that grown under flooded conditions particularly in the vegetative growth stage. From another point of view, the increase in growth parameters, yield and yield attributes of rice plants might be enhanced by the availability of sufficient water and nutrients that are necessary for all various biological and physiological processes including cell division and cell elongation of the plant. These findings are in harmony with those obtained by Wan *et al*. (2009) and Sultan *et al*. (2013).

Irrigation water types effect.

Concerning the influence of irrigation water types on plant height (cm), panicle length (cm), 1000 grains weight (g), grain weight (kg fed^{-1}), straw weight (kg fed^{-1}) and No. of filled grains/spike of rice plant, the same Figs (from 1 to 6) showed that different water quality treatments varied in their effect on all aforementioned traits and this was attributed to the differences in their salinity levels. Generally, rice plant growth under W_1 treatment [normal irrigation water (100% canal water)] was better regarding to plant height (cm) and panicle length (cm) followed by W_3 treatment [alternate irrigation with canal water and agricultural drainage water] and lately W_2 treatment [irrigation by agricultural drainage water]. That may be due to high salinity level and Na^+ content of agricultural drainage water as well as hazard anions. Alternate irrigation with canal water and agricultural drainage water in irrigation system decreased the adverse effect of agricultural drainage water alone, however mostly there was a significant difference between the mean values of W_1 and W_3. These results are supported by the findings of El-Sharkawy *et al.* (2006), Gomaa *et al*. (2015) and Mansour *et al*. (2015) who stated that the yield components were restricted under poor quality of water, so it can be inferred that irrigation with drainage water accumulates more Na^+ and increases EC value of soil resulting in unfavorable conditions for optimum rice growth. Besides, the saline irrigation inhabits reduces in dry matter accumulation, lowers assimilation and production and its transformation from stem or sheath to grains, restrict panicle formation and grain filling, and promote the early aging particularly during the grain filling period leading to decrease in rice grain yield.

Antitranspirants forms effect

The Figs (from 1 to 6) illustrated that all studied antitranspirants, *i.e*, KCl and $MgCO_3$ had a significant increase in the plant height (cm), panicle length (cm), 1000 grains weight (g), grain weight (kg fed^{-1}), straw weight (kg fed^{-1}) and No. of filled grains/spike of rice plant as compared to control (untreated plant). Spraying $MgCO_3$7% was superior treatment regarding aforementioned traits of rice plant compared with KCl 7% and untreated plant (control). Generally, sequence of foliar antitranspirants treatments from top to less was the A_3 ($MgCO_3$ 7%) > A_2 (KCl 7%) > A_1 (control). This is due to the role of antitranspirants that curtail water loss. $MgCO_3$ as antiperspirant based on stomata close is active in the water-limited environment which acts on stomatal opening regulation in an ABA-dependent way (Gaballah and Moursy, 2004; Tambussi and Bort, 2007, Koteswara Rao *et al.,* 2018 and Ahmed *et al*., 2019). A similar result was obtained with application of K_2SO_4 and $MgCO_3$ in barley (Hellal *et al.,* 2020).

Interaction effect

Statistical analysis of the data in Table (3) indicated that the interaction effect among irrigation intervals, irrigation water types and foliar spraying applications was significant.

For the plant height (cm), panicle length (cm), 1000 grains weight (g), grain weight (kg fed^{-1}), straw weight (kg fed^{-1}) and No. of filled grains/spike of rice plant, the highest values were recorded when rice plants irrigated every 4 days (I_1) by normal irrigation water (100% canal water) (W_1) and foliar application of $MgCO_3$7 % (A_3), while the lowest values were recorded when rice plants irrigated every 12 days (I_3) by agricultural drainage water (W_2) without any antitranspirants applications (A_1). On the other hand, spraying rice plants with $MgCO_3$ or KCl under irrigation by normal water (100% canal water) (W_1) every 8 days (I_2) or 12 days (I_3) gave better results than untreated plants (A_1) under irrigation by normal water (100% canal water) (W_1) every 4 days (I_1). In general, antitranspirants reduce the transpiration loss of water occurring mainly through closing stomatal pores present on the leaf surface (Patel *et al*. 2019). Also, spraying rice plants with antitranspirants (A_2 and A_3) under irrigation with low-quality water (W_2 and W_3) every 8 days (I_2) or 12 days (I_3) gave better results than untreated plants (A_1) under irrigation with normal water (100% canal water) (W_1) every 4 days (I_1). Generally, the yield of rice crop under water-stress condition ($W_2$and W_3 treatments) was positively influenced by the application of antitranspirants. Because of shortage in water requirements in Egypt, rice could be treated with antitranspirants to save applied water (Patel *et al.*, 2019). Also, alternate irrigation with canal water and agricultural drainage water may be acceptable to save the water needs (Gomaa *et al*. 2015). These results agree with those reported by El-Refaaee *et al.* (2005) who mentioned that plant height, panicle length and yield significantly decreased as irrigation intervals increased to twelve days or nine days as noticed by (El-Refaee *et al.,* 2008) and this might be due to that plant height, panicle length and yield were significantly decreased with the increased salinity stress (Shereen *et al.,* 2005 and Mirza *et al.,* 2009). On the other hand, Gomaa *et al.* (2005) concluded that plant height and panicle length were not significantly affected by different irrigation water types. The obtained increment values of the plant height, panicle length and yield components of rice plant with irrigation every 4 days may be due to that irrigation water is a substantial factor in plant life and water deficit is one of the major abiotic stresses, which adversely affects plant growth and metabolic functions, one of those is either loss or reduced synthesis of photosynthetic pigments and in turn resulting in declined light-harvesting and generation of reducing powers, which are a source of energy for dark reactions of photosynthesis. These changes in the number of photosynthetic pigments are closely associated to plant biomass yield (Wan *et al*, 2009 and Sultan *et al.* (2013). Generally, the positive effect of spraying antitranspirants on plant height, panicle length and yield components of rice plant may be due to reducing the rate of transpiration and alleviate the harmful effect of water stress on metabolic processes in leaves tissue. The application of $MgCO_3$ 7% gained superiority in plant height, panicle length and yield components of rice plant as compared to KCl 7% due to decrease of leaf temperature and increase leaf reflectance, reduce transpiration rate and improve metabolic process in plants grown under water stress, increasing water use efficiency and capacity of $MgCO_3$ to enhance net photosynthesis (Gaballah and Moursy, 2004 and Hellal *et al.,* 2020).

2. SOD (Unit.g^{-1} F.W) and Protein %

Figs (7 and 8) and Table (4) show the effect of different irrigation intervals, different irrigation water types, foliar spraying with antitranspirants and their interactions on SOD (Unit.g^{-1} F.W) and protein % of rice grain.

Irrigation intervals effect

Regarding the individual effect of irrigation intervals, Fig (7) show that the water stress caused marked increases in superoxide dismutase activity (SOD, Unit.g^{-1} F.W) of rice plant leaves, where the increase of irrigation intervals causes increasing self-production of plant from SOD (Unit.g^{-1} F.W) to resist water deficit. In this concern; water stress under irrigation every 12 days gave the highest values of SOD (Unit.g^{-1} F.W). These results are in harmony with those obtained by Goud and Kachole, (2011) and Yi *et al.*, (2014) who stated that plant species have evolved various mechanisms to cope with environmental stresses. On the other hand, Fig (8) illustrates that protein % of rice grain reached to maximum value under I_1 and I_2 treatment respectively, compared with I_3 which gave the lowest value. These results are supported by the findings of El-Refaaee *et al.* (2005); El-Refaee *et al.* (2008); Sultan *et al.* (2013) and Hellal *et al.* (2020).

Irrigation water types effect

Concerning the influence of irrigation water types on SOD (Unit.g^{-1} F.W) in plant leaves and protein % of rice grain, Fig (7) illustrates that the rice plants irrigated with degraded water (W_2 and W_3) produced superoxide dismutase (SOD Unit.g^{-1} F.W) more than plants irrigated with normal water (W_1) to resist the harmful effect of degraded water that leads to production of free radicals or reactive oxygen species (ROS), which damage various macromolecules and cellular structures. To mitigate stress induced damage, plants may up-regulate various scavenging mechanisms like enzymatic antioxidants (superoxide dismutase, peroxidase and catalase) and non-enzymatic metabolites e.g., ascorbic acid and osmoprotectants (Ahmad *et al.*, 2013). On the other hand, Fig (8) shows that protein % of rice grain under W_1 treatment [normal irrigation water (100% canal water)] was better followed by W_3 treatment [alternate irrigation with canal water and agricultural drainage water] and lately W_2 treatment [irrigation by agricultural drainage water]. These results are supported by the findings of El-Sharkawy *et al.* (2006), Gomaa *et al.* (2015) and Mansour *et al.* (2015).

Antitranspirants forms effect

According to Figs (7 and 8), all studied antitranspirants, i.e., KCl and $MgCO_3$ had a significant decrease in the values of SOD (Unit.g^{-1} F.W) in rice plant leaves and a significant increase in the protein (%) of rice grain as compared with control (untreated plant). This trend due to the beneficial role of these antitranspirants in increasing rice plant resistance to environmental stress, thus the plant's requirement from antioxidative enzymes such as SOD reduced. Generally, spraying $MgCO_3$7% was superior treatment regarding the aforementioned traits followed by KCl 7% and lately untreated plant (control) (Hellal *et al.*, 2020).

Interaction effect

The interaction effect among the treatments under study are presented in Table (4).For the protein % of rice grain, the highest values were recorded when rice plants were irrigated every 4 days (I_1) by normal irrigation water (100% canal water) (W_1) and foliar application of $MgCO_3$ 7% (A_3), while the lowest values were recorded when rice plants were irrigated every 12 days (I_3) by agricultural drainage water (W_2) without any antitranspirants applications (A_1).On the contrary, the lowest value of SOD (Unit.g^{-1} F.W) was noticed at [I_1 (irrigation every 4 days) × W_1 (normal water) ×A_3 (foliar application of $MgCO_3$7 %)] treatment, while the highest value was found at [I_3 (irrigation every 12 days) × W_2 (agricultural drainage water) ×A_1 (without any antitranspirants applications)] treatment. As we mentioned before, antitranspirants reduced the transpiration loss of water occurring mainly through closing stomatal pores present on the leaf surface as well as it increases plant resistance to environmental stress and therefore raising the protein % in rice grain with reducing rice plant production from antioxidative enzymes (Goud and Kachole.2011; Ahmad *et al.* 2013; Yi *et al.* 2014 and Patel *et al.* 2019).

Conclusion

From our point of view according to the obtained results in this investigation, because of the limited water supply and fixed water budged in Egypt, rice plants could be treated with antitranspirants to save water, where the growth and yield of rice plant under water-stress condition were positively influenced by the application of antitranspirants. Also, alternate irrigation with canal water and agricultural drainage water may be acceptable to save the water and also minimize the hazard effects on soil properties and environment.

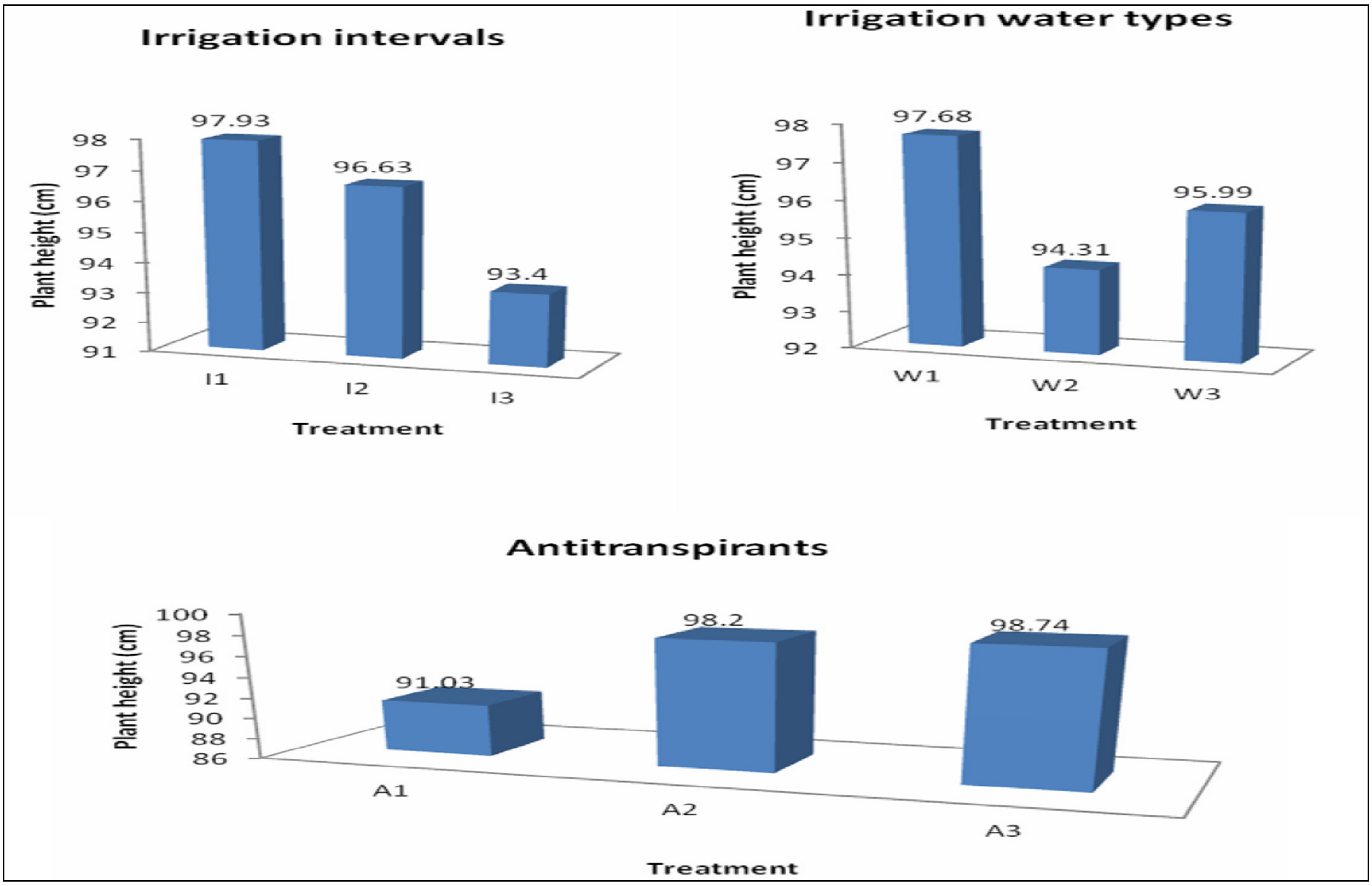

Fig 1. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on plant height (cm) of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

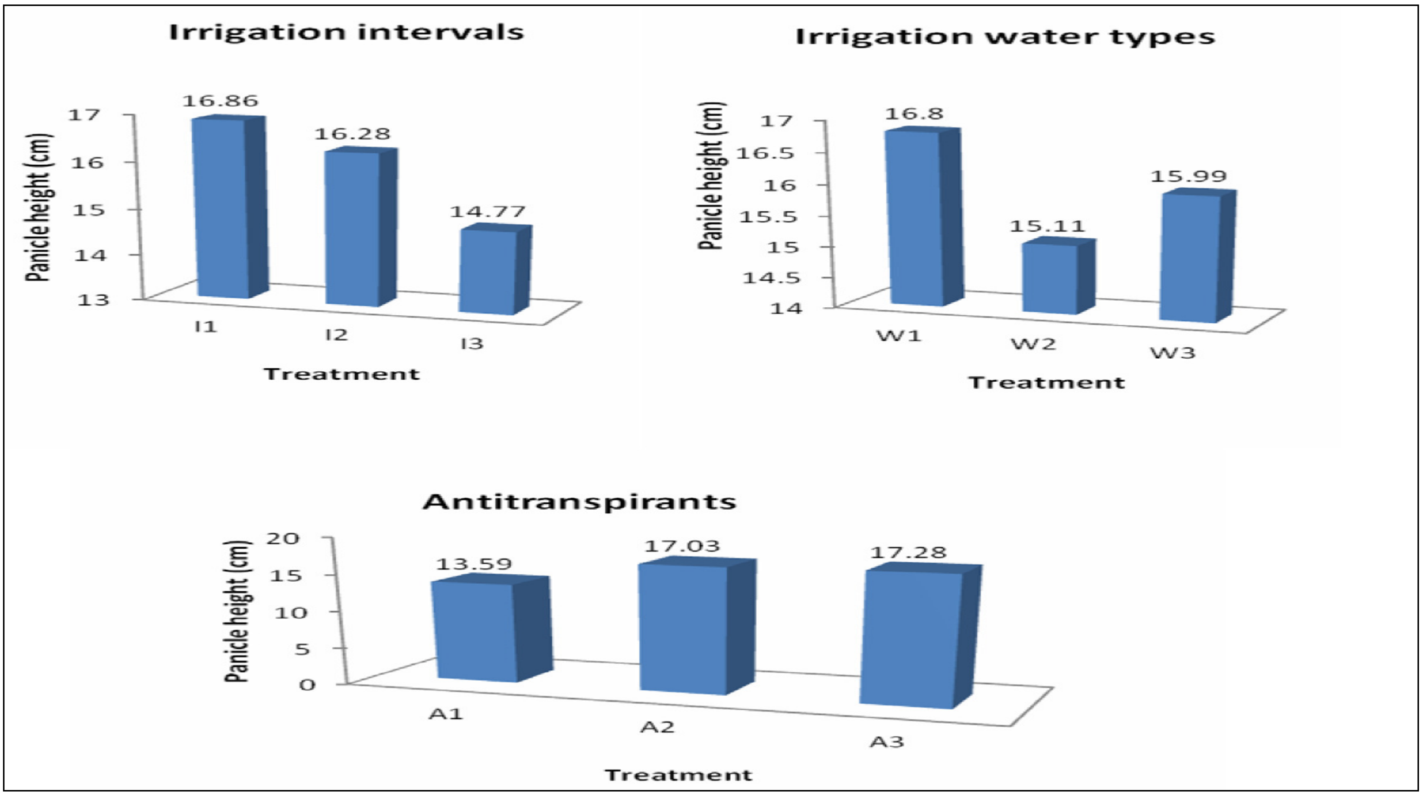

Fig 2. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on panicle length (cm) of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

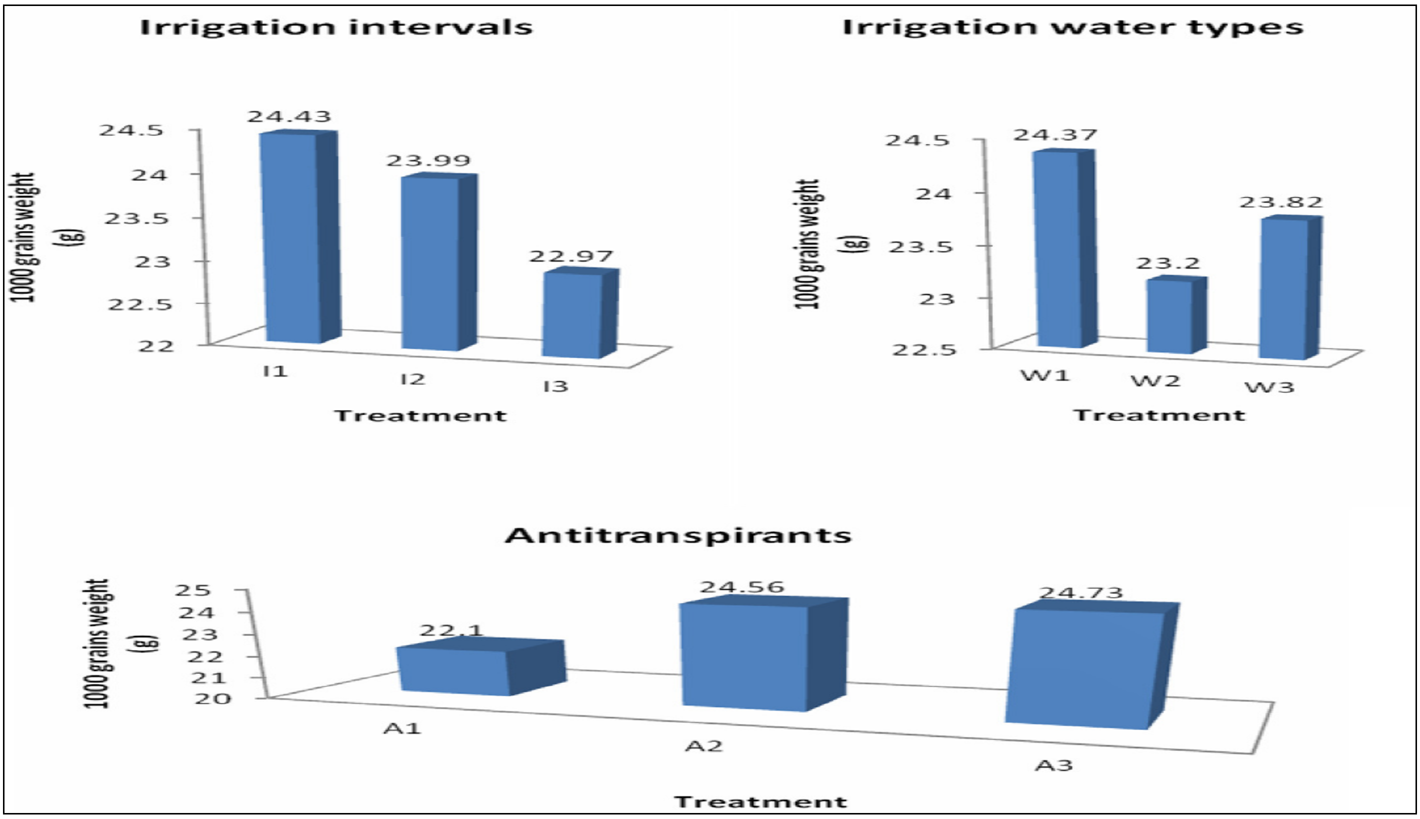

Fig 3. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on 1000 grains weight (g) of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

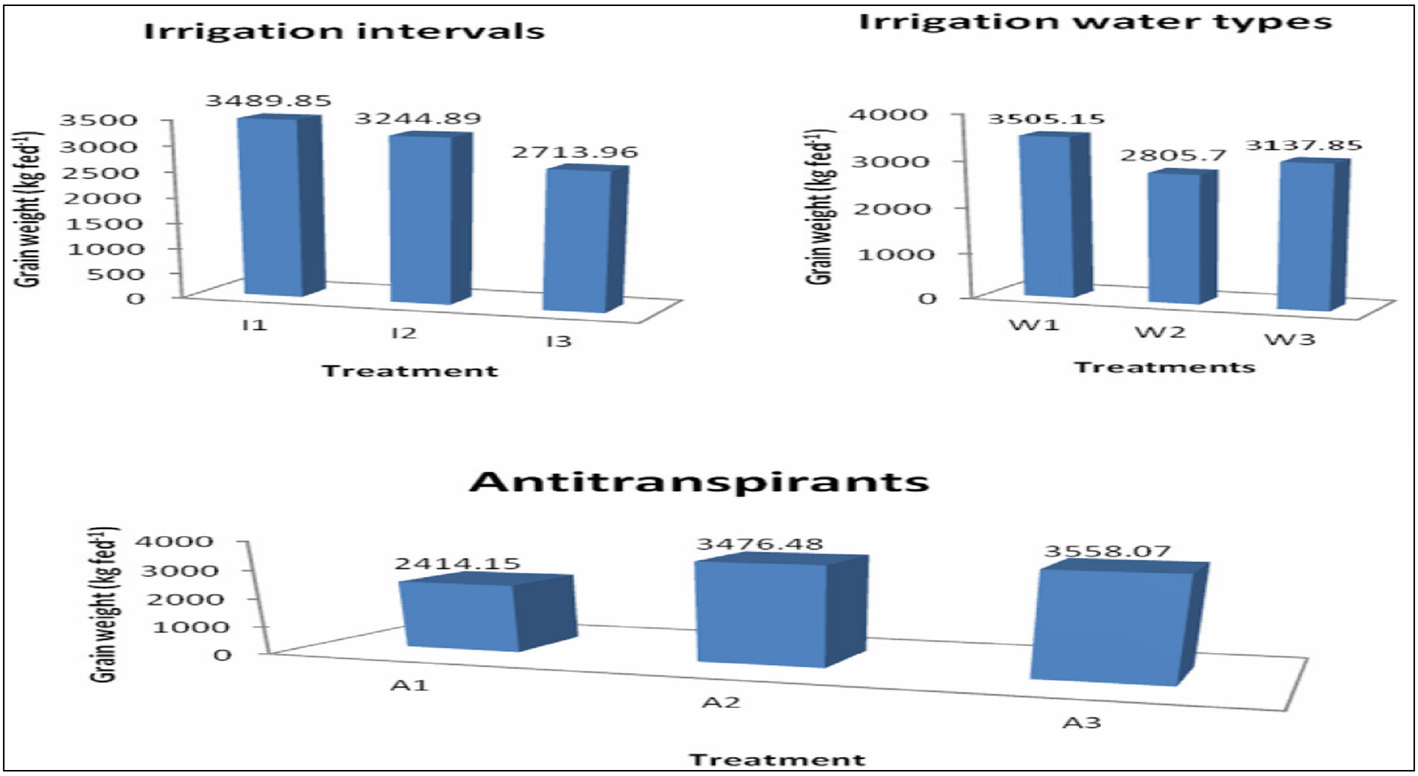

Fig4. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on grain weight (kg fed^{-1}) of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

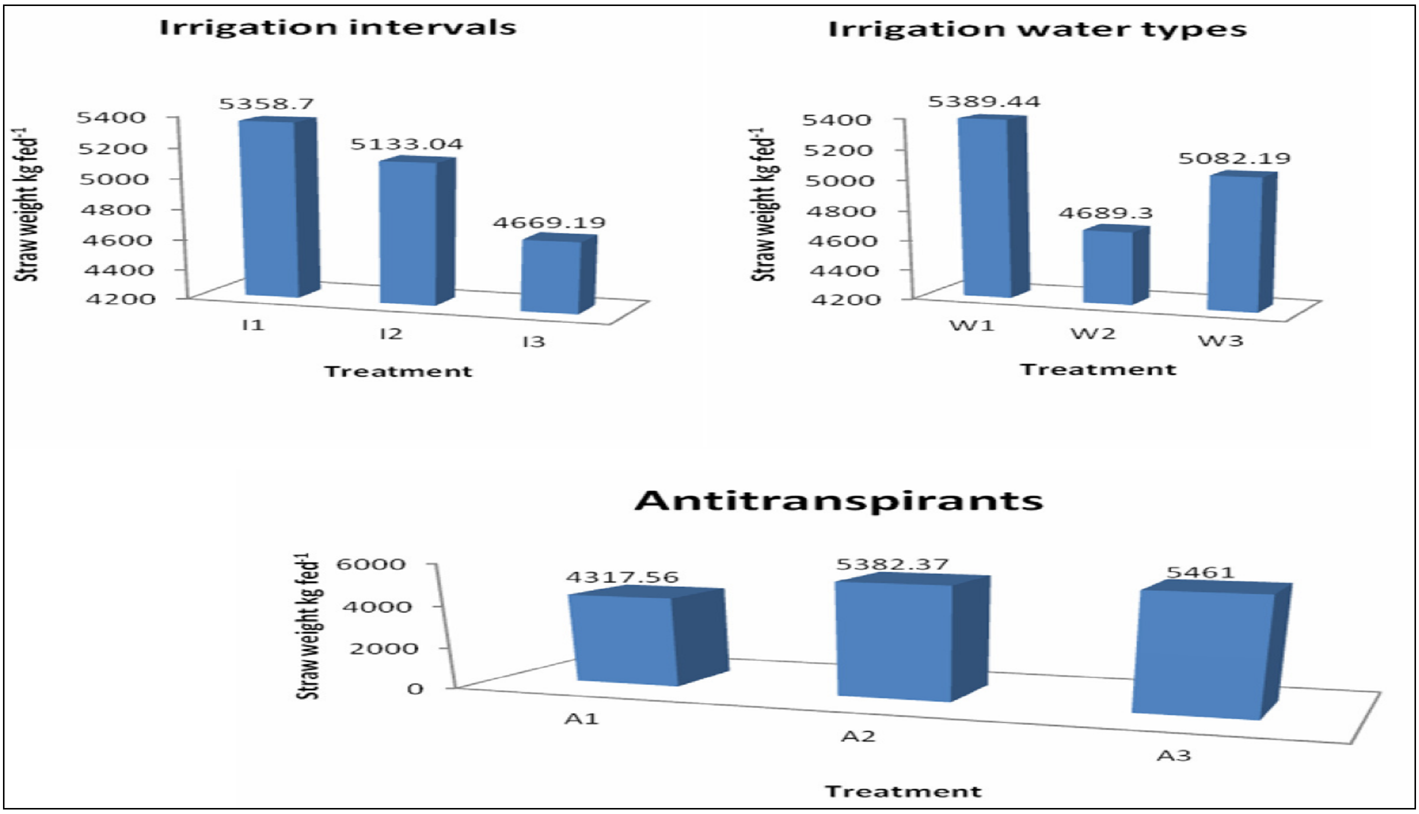

Fig5. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on straw weight (kg fed^{-1}) of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

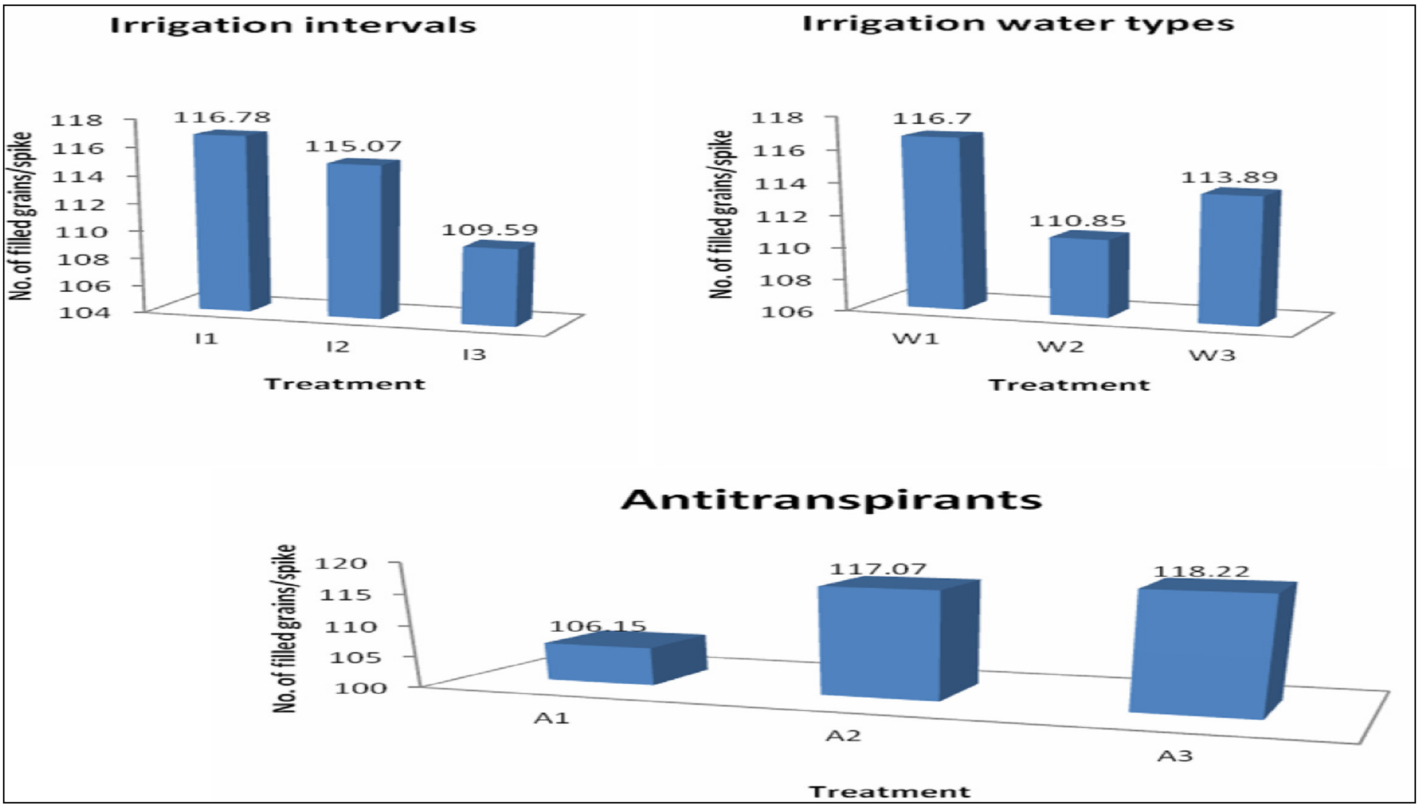

Fig6. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on No. of filled grains/spike of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

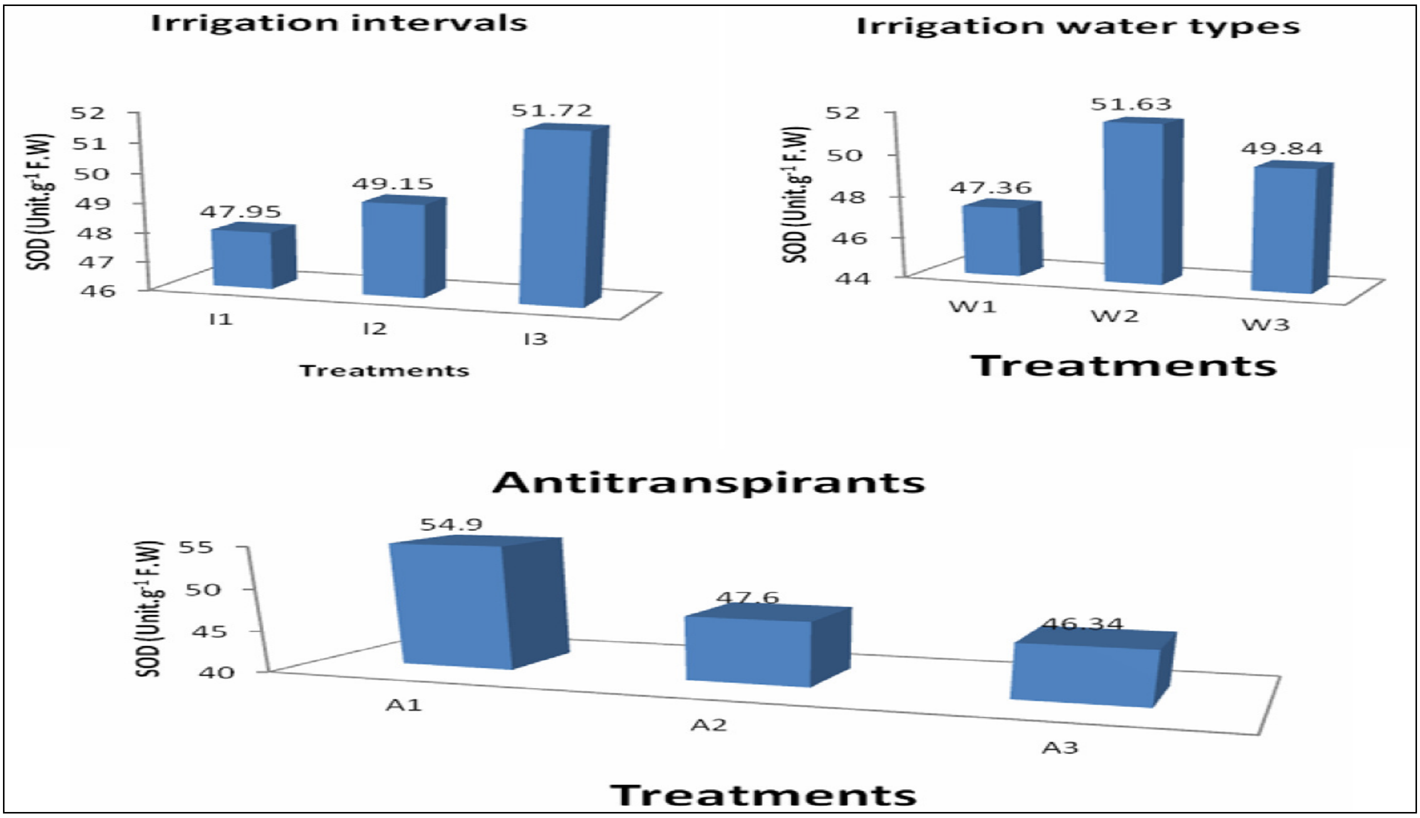

Fig7. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on SOD (Unit.g^{-1} F.W) of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

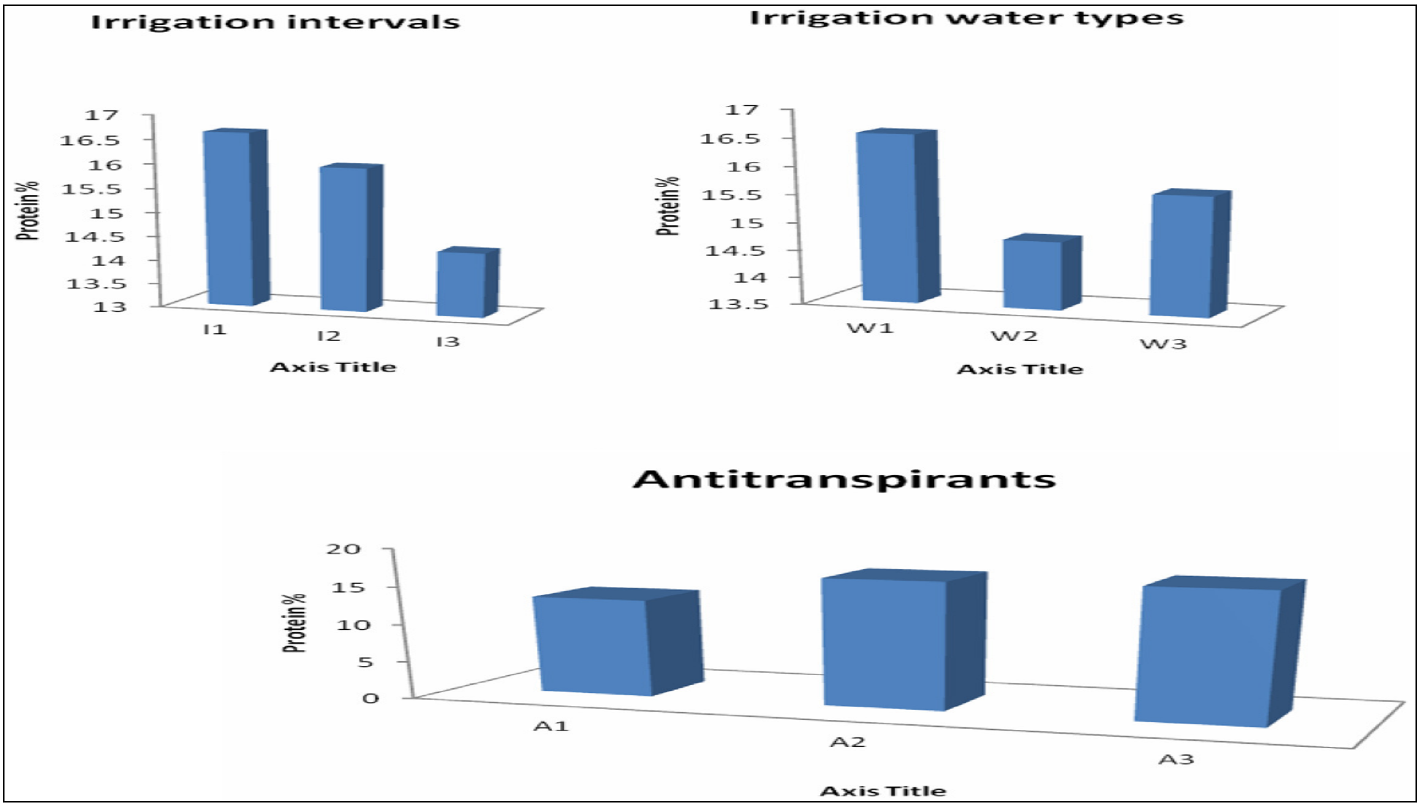

Fig8. Individual effect of irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on protein (%) in grains of rice plant.

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

Table 3 : Interaction effects among irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on vegetative growth parameters of rice plant as well as yield and its components.

Treatments			Vegetative growth parameters		Yield and its components			
			Plant height	Panicle length	1000 grains weight	Grain yield	Straw yield	No. of filled grains /spike
			(cm)		(g)	Kg fed^{-1}		
I_1	W_1	A_1	93.23	14.62	22.91	2733.33	4605.00	110.33
		A_2	102.53	19.14	25.82	4403.67	6310.33	124.33
		A_3	103.10	19.41	26.18	4496.00	6406.33	124.67
	W_2	A_1	92.07	13.52	22.10	2380.00	4221.67	106.33
		A_2	98.20	17.02	24.77	3422.33	5328.00	117.00
		A_3	98.70	17.30	24.68	3495.67	5341.33	117.67
	W_3	A_1	92.07	14.26	22.45	2614.00	4643.00	108.00
		A_2	100.37	18.09	25.42	3798.00	5675.67	121.00
		A_3	101.13	18.35	25.51	4065.67	6006.33	121.67
I_2	W_1	A_1	92.67	14.35	22.68	2693.00	4524.33	108.67
		A_2	101.40	18.63	25.61	4152.67	6064.00	122.33
		A_3	102.13	18.78	25.73	4203.67	6082.33	124.33
	W_2	A_1	90.40	13.32	21.84	2310.67	4177.33	105.33
		A_2	96.03	15.97	23.73	3002.33	4911.33	113.67
		A_3	96.40	16.24	23.99	3013.33	4923.00	115.00
	W_3	A_1	91.57	13.84	22.36	2419.00	4333.67	107.33
		A_2	99.27	17.56	24.87	3683.33	5596.33	118.67
		A_3	99.83	17.84	25.13	3726.00	5625.33	120.33
I_3	W_1	A_1	89.03	13.04	21.63	2274.00	4102.67	104.33
		A_2	97.37	16.50	24.37	3274.33	5183.33	115.00
		A_3	97.63	16.74	24.41	3315.67	5226.67	116.33
	W_2	A_1	89.15	12.59	21.61	2114.50	3957.00	103.00
		A_2	93.73	14.91	23.00	2748.00	4663.67	110.00
		A_3	94.30	15.17	23.28	2773.00	4680.33	110.67
	W_3	A_1	89.30	12.84	21.56	2197.33	4293.33	103.00
		A_2	94.93	15.43	23.48	2803.67	4708.67	111.67
		A_3	95.40	15.70	23.63	2933.67	4857.33	113.33
LSD at 5%			**1.07**	**0.09**	**0.88**	**35.05**	**40.47**	**1.85**

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

Table 4. Interaction effects between irrigation intervals, irrigation water types and foliar spraying with some antitranspirants on SOD (Unit.g^{-1} F.W) and Protein % of rice grain.

Treatments			SOD	Protein
			Unit.g^{-1} F.W	%
I_1	W_1	A_1	52.74	14.11
		A_2	43.02	19.09
		A_3	42.51	19.32
	W_2	A_1	54.75	13.03
		A_2	47.56	17.02
		A_3	47.15	17.10
	W_3	A_1	53.87	13.63
		A_2	45.36	18.04
		A_3	44.64	18.27
I_2	W_1	A_1	53.30	13.95
		A_2	44.30	18.44
		A_3	43.61	18.76
	W_2	A_1	55.45	12.78
		A_2	49.80	15.60
		A_3	49.14	16.00

	W_3	**A_1**	54.37	13.36
		A_2	46.51	17.35
		A_3	45.90	17.56
I_3	**W_1**	**A_1**	56.02	12.55
		A_2	48.68	16.18
		A_3	42.05	16.54
	W_2	**A_1**	57.03	11.82
		A_2	52.12	14.47
		A_3	51.61	14.61
	W_3	**A_1**	56.50	12.15
		A_2	51.01	15.10
		A_3	50.40	15.41
LSD $_{at\ 5\%}$			**0.73**	**0.39**

I_1: irrigation every 4 days; **I_2:** irrigation every 8 days; **I_3:** irrigation every 12 days; **W_1:** normal irrigation water (100% canal water); **W_2:** Agricultural drainage water; **W_3:** Alternate irrigation with canal water and agricultural drainage water; **A_1:** Control (without any applications); **A_2:** KCl 7% and **A_3:** $MgCO_3$ 7%.

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