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Effect of Exogenous Application of Salicylic Acid and Proline on Hybrid Rice Productivity under Different Irrigation Intervals

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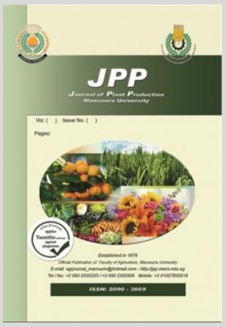

ABSTRACT

Two field experiments were carried out during 2018 and 2019 seasons at the experimental farm of Sakha Agriculture Research Station, Sakha, Kafrelsheikh, Egypt to study the response of three rice varieties namely; EHR1, EHR3 and Giza178 to examine the possible role of exogenous application of SA and P applications under three irrigation intervals; continuous flooding, irrigation every six days and irrigation every nine days. The experiment was performed in a strip split plot design with three replications. Irrigation intervals were subjected in the vertical plots and the rice varieties were allocated in the horizontal plots. The sub-plots were devoted to chemical treatments. The main results of the both seasons were summarized as follows; EHR1 gave the longest heading date and the maximum values of number of tillers m^{-2}, plant height and flag leaf area, EHR3 variety gave the highest values of leaf chlorophyll content, leaf area index, number of total grains $panicle^{-1}$, 1000-grain weight and grain yield as well as hulling and milling percentages. Giza178 inbred rice cultivar recorded the highest percentages of filled grains and head rice, while, it gave the minimum values of growth parameters, yield attributes and grain yield. Irrigation every 6 days recorded high water use efficiency with a little reduction in grain yield and save some of irrigation water when SA or P was exogenously applied. Nine days interval saved water by 19.09 % and 18.86 % with grain yield reduction of 13.52 % and 14.41 % in both seasons, respectively.

Keywords: Egyptian hybrid rice, irrigation intervals, Exogenous, salicylic acid and proline.

INTRODUCTION

Sustainable agricultural production in many parts of the world faces the problem of water shortages (Schewe *et al.,* 2014). Great challenges occur in rice production, which consumes approximately 40% of global water resources in only 18% of the total planting area (Lampayan *et al.*, 2015). Although rice (*Oryza sativa* L.) is the highest water consumer, among all major cereal crops, but it plays an important role in Egyptian food security and economy as well as soil reclamation in the northern parts of River Nile Delta .In Egypt, irrigation water availability is the most limiting factor affecting rice production, especially at the northern parts of River Nile Delta (Abd Allah *et al.,* 2010).

The negative effects of water deficit on mineral nutrition (nutrient uptake and transport) and metabolism lead to a decrease in leaf area and alteration in assimilate partitioning among the organs. Responses to water deficit are complex and various mechanisms are adopted by plants when they encounter water deficit. They include water deficit escape by rapid development allowing plants to finish their cycle before death, water deficit avoidance by, for example, increasing water uptake and reducing transpiration rate by the reduction of stomata conductance and leaf area, water deficit tolerance by maintaining tissue turgor via osmotic adjustment allowing plants to maintain growth, and resisting the severe stress through other survival mechanisms (Jones, 2004).

Improving rice irrigation techniques is considered one of the most important approaches for increasing water use efficiency and water saving. Alternative wetting and drying of rice cultivation save about 15-50 % of irrigation water and increase irrigation water productivity by 5-35 % comparing with the traditional irrigation method of continuous flooding (Romeo *et al.*, 2004 and Naresh *et al.*, 2014).

In order to reduce water-use amount in rice irrigation and to improve water use efficiency, Alternate wetting and drying (AWD) has been developed as a water-saving irrigation regime and adopted in many rice-producing countries (Samoy *et al.,* 2019). AWD is characterized by alternation of soil submergence periods with non-submergence periods during the growing season. However, this irrigation regime is not necessarily suitable for all types of paddy rice, and may reduce yield in some areas. Yang *et al.,* (2017) showed that AWD can reduce water consumption and CH4 emission significantly, but that at the same time rice yield could be compromised.

Breeding inbred and hybrid rice varieties for less requirements and high water use efficiency are also considered another effective way for water saving and alleviating the harmful effect of water shortage.

Rice hybrids can out yield conventional the high yielding inbred rice varieties by about 15: 30 percent under the same conditions (Abo Youssef *et al.*, 2005 and El-Mowafi *et al.*, 2005).Rice hybrids have shown their ability to perform better under adverse conditions of water deficit than inbred varieties (Virmani *et al.*, 1997 and Zayed *et al.*, 2010).

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Therefore, the exogenous proline applications can alleviate the harmful effect of such environmental stress through its function as a molecular chaperone able to protect protein integrity and enhance various enzymes activities (Ashraf and Foolad, 2007 and Verbruggen and Hermans, 2008). Proline plays a major role in the process of osmotic adjustment in many different organisms including higher plants (Hasegawa *et al*., 2000) to increase their water deficit stress tolerance. It increases the concentration of the culture osmotic components in order to equalize the osmotic potential of the cytoplasm (Wated *et al*., 1983). It also acts as a free radical scavenger to alleviate water deficit stress effects (Okuma *et al*., 2000).

Salicylic acid is a naturally occurring derivative of phenolic acid compounds group that are distributes in rice crop. It has a regulatory role as an endogenous antioxidant in a range of physiological processes like photosynthesis, transpiration, nutrient uptakes, synthesis of chlorophyll and plant development. SA has been known to positively modulate a series of physiological and biochemical processes, such as photosynthesis, nutrient uptake, antioxidant defense and water status for enhancing plant acclimatization to many a biotic stresses, including salinity and drought (Ahanger *et al*., 2020). It was also recognized as an important signaling molecule that potentially influences plant tolerance for water stress due to it's role in regulation of metabolic and physiological activities during the entire lifespan (Raskin, 1992; Popova *et al*., 1997 and Pal *et al*., 2014). Moreover, Farooq *et al*. (2009) and Khan *et al*. (2015) confirmed positive effect of the exogenous application of salicylic acid on photosynthesis, growth promotion and rice productivity under drought stress.

The current investigation aimed to study the beneficial role of the exogenous application of salicylic acid and proline on growth and productivity of two Egyptian rice hybrids; namely, EHR1 and EHR3 as compared to Giza 178 inbred rice cultivar under the different irrigation intervals.

MATERIALS AND METHODS

Two field experiments were carried out at the experimental farm of Sakha Agriculture Research Station, Sakha, Kafrelsheikh Governorate, Agriculture Research Center, Ministry of Agriculture and Soil Reclamation during 2018 and 2019 summer seasons. This study was performed to investigate the effect of salicylic acid and proline on growth, productivity, water use efficiency of Giza 178, EHR1 and EHR3 rice varieties under different irrigation intervals.

The experiments were laid out in a strip split plot design with three replications. Irrigation intervals were subjected in the vertical plots and the tested rice varieties were allocated in the horizontal plots. The sub-plots were devoted to salicylic acid and proline application. Area of the sub-plot was 15m2 (5m length and 3m width).

Evaluated rice varieties used in this investigation were included two rice hybrids; namely, Egyptian EHR1 and Egyptian EHR3 and one inbred rice cultivar; namely, Giza 178 as a check.

The three irrigation intervals of continuous flooding, irrigation every six days and irrigation every nine days were applied at 10 days after transplanting.

The biochemical treatments were as fallow:

1. Control: water spray at 15, 30 and 45 days after transplanting (DAT).
2. Proline: 20 ppm of proline sprayed at 15, 30 and 45 DAT.
3. Salicylic acid: 400ppm of salicylic acid sprayed at 15, 30 and 45 DAT.

Soil physical and chemical analysis of the experimental sites were done according to Piper (1950) and Black *et al.* (1965), respectively and presented in Table 1.

Table 1. Soil physical and chemical analysis of the experimental sites in 2018 and 2019 seasons.

Soil Characteristics	Season	
	2018	2019
Soil texture	Clayey	Clayey
Silt (%)	22.7	21.6
Sand (%)	25.9	26.4
Clay (%)	51.4	52.0
pH	7.93	8.02
E.C. (dSm^{-1} at 25 C^0)	2.62	2.89
Organic matter (%)	1.61	1.57
Available P(mg kg^{-1})	13.2	12.5
Available (K mg kg^{-1})	339	348
Available NO_3^- (mg kg^{-1})	11.6	12.3
Available NH_4^+ (mg kg^{-1})	13.2	12.9

Barley and Flax were the previous winter crops in the first and the second seasons, respectively. Sowing date was 8th in the first season and 14th in the second season. All other culture practices for inbred and hybrid rice cultivation were undertaken as recommended according to Rice Research Department annual recommendations package.

Studied characters:

1. Growth parameters:

At heading growth stage, the following data of each sub-plot were recorded, days to 50% heading, plant height (cm), number of tillers m^{-2}, leaf chlorophyll content (Minolta Model SPAD 501), flag leaf area (cm^2) (Model LI-3000A) and leaf area index according to IRRI (1996).

2. Grain yield and its components:

At harvesting time, in each sub-plot, panicles number of five guarded hills were counted and adjusted into m^2. Ten random panicles were collected to determine number of total grains panicle^{-1}, filled grains percentage, 1000-grain weight (g) and grain yield of the of the central 10 m^2 recorded and adjusted into tons hectare^{-1} at 14% moisture content.

3. Some of grain quality characters:

According to the method described by Juliano (1971) and Khush *et al.* (1979), hulling, milling and head rice percentages were determined.

4. Water relations:

The amount of total applied water (m^3ha^{-1}) of each irrigation treatment block was measured by using a rectangular sharp crested weir. The discharge was calculated using the following equation as described by (Masoud, 1969), as follows:

$$Q = CL\,(H)^{1.5}$$

Where: **Q = Discharge (m^3s^{-1}), L = Length of the crest (m), H = Head above the weir (m), C = Empirical coefficient determined from discharge measurement. Also water saving (%), grain yield reduction (%) and Water use efficiency (kgm^{-3}) were calculated.**

The collected data were subjected to the standard statistical analysis, according to Gomez and Gomez (1984) by using MSTAT-C computer program, according to Russel (1994). Treatments means were compared by using Duncan's Multiple Rang Test, according To Duncan (1955).

RESULTS AND DISCUSSION

1. Vegetative growth characteristics:

a. Rice varieties performance:

Data in Tables 2 and 3 revealed that the tested rice varieties significantly differed in their vegetative growth period, tillers number m^{-2}, plant height and leaf area index. EHR1 recorded the longest vegetative period, the highest tillers number m^{-2}, the tallest plants, the largest area of flag leaf. While, the highest values of leaf chlorophyll content and leaf area index were recorded by EHR3. The differences between the two tested rice hybrids were not significant in leaf chlorophyll content and flag leaf area. The lowest significant values of studied vegetative growth parameters were obtained by the check inbred rice variety (Giza 178). The superiority of rice hybrids as compared to the inbred variety could mainly be attributed to the high heterosis.

The above mentioned results are in accordance with those reported by Garba *et al.* (2013), Getachew and Birhan (2015) and Abou-Khalifa and Awad-Allah (2016).

Table 2. Days to heading, number of tillers m^{-2} and plant height of some rice varieties as influenced by irrigation intervals and exogenous application of proline and salicylic acid as well as their interactions in 2018 and 2019 seasons.

Treatments	Days to 50% heading		Plant height (cm)		No. of tillers m^{-2}	
	2018	2019	2018	2019	2018	2019
Rice varieties (v):						
EHR 1	106.3a	105.6a	111.09a	109.34a	623.6a	631.4a
EHR 3	103.5b	101.2b	102.47b	103.06b	608.5b	612.74b
Giza 178	99.4c	96.7c	98.01c	95.63c	536.1c	549.3c
F-test	**	**	**	**	**	**
Irrigation intervals (I):						
Continuous flooding	107.2a	105.8a	108.42a	106.53a	613.3a	623.1a
Irrigation every 6 days.	104.8b	102.4b	105.16b	103.38b	603.3a	615.8a
Irrigation every 9 days.	97.2c	95.3c	97.99c	98.12c	551.6c	554.5b
F-test	**	**	**	**	**	**
Exogenous application (E):						
Control.	101.6b	99.5b	101.28b	99.35b	585.0	589.9
Proline.	103.5a	101.3a	105.38a	104.83a	589.3	597.6
Salicylic acid.	104.1a	102.7a	104.91a	103.84a	593.9	605.9
F-test	**	**	**	**	NS	NS
Interactions:						
V x I	NS	NS	NS	NS	NS	NS
V x E	NS	NS	**	**	NS	NS
I x E	**	**	NS	NS	NS	NS
V x I x E	NS	NS	NS	NS	NS	NS

***, ** and NS. are significant at 0.05 level, significant at 0.01 level and not significantly respectively.**
Means followed by the same letter are not significantly varied, according to DMRT.

b. Effect of irrigation intervals:

Tables 2 and 3, also clarified that irrigation intervals significantly influenced studied growth parameters in both seasons. The peak values of measured growth traits were exhibited by continuous flooding, while the lowest values were recognized when rice plants were irrigated every 9 days. No significant differences between continuous flooding and irrigation every 6 days were found in number of tillers m^{-2}, flag leaf area and leaf area index during the both seasons.

This negative effect of water shortage on growth performance might be due to the deficiency in water with 9 days interval which decrease a chlorophyll biosynthesis inside rice cell chloroplast and, also, the degradation of chlorophyll and leaf senescence, as well as, the reduction in phytochrome hormones. Under prolonged irrigation interval in the terms of water shortage, plant could not absorbed enough water resulted in inhibiting cell elongation, division, metabolism process and development of plant organs. Also, the reduction of water inside plant cell might be affected photosynthesis and assimilate rate resulted in growth inhibition (Yoshida and Shioya, 1976). Similar effects of irrigation intervals on rice vegetative growth were, also, obtained by El-Refaee *et al.* (2012) and El-Habet *et al.* (2019).

c. Impact of proline and salicylic acid applications:

The maximum values of number of days to heading, leaf chlorophyll content and leaf area index were obtained with salicylic acid without significant difference with exogenous proline application regarding days to heading and leaf chlorophyll content. Proline application gave the tallest plants without significant differences with salicylic acid. Both proline and salicylic acid treatments showed no significant effect on number of tillers m^{-2} and flag leaf area (Tables, 2 and 3).

The estimated increase in vegetative growth parameters as a result of proline and salicylic acid applications might be due to the role of proline in osmosis regulation and providing energy for plant growth as a compatible solute regulating and reducing water loss from plant cell during water deficit (Somota *et al.*, 2017). In addition, the exogenous application of salicylic acid enhances growth vigor through increasing photosynthetic rate and it has a great role under water shortage via decrease stomata conductance and transpiration rate (Raskin, 1992).

These results are in harmony with those of Abdel-Megeed *et al.* (2017) and Issak *et al.* (2017).

Table 3. Leaf chlorophyll content, flag leaf area and leaf area index of some rice varieties as influenced by irrigation intervals and exogenous application of proline and salicylic acid as well as their interactions in 2018 and 2019 seasons.

Treatments	Leaf chlorophyll content (SPAD values)		Flag leaf area (cm^2)		Leaf area index	
	2018	2019	2018	2019	2018	2019
Rice varieties (v):						
EHR 1	41.08a	41.73a	35.24a	34.02a	5.35b	5.57b
EHR 3	42.51a	43.81a	33.71a	33.19a	6.13a	6.24a
Giza 178	36.72b	35.51b	31.94b	31.68b	4.69c	4.83c
F-test	**	**	**	**	**	**
Irrigation intervals (I):						
Continuous flooding	43.12a	43.24a	34.70a	33.92a	5.72a	5.92a
Irrigation every 6 days.	40.26b	40.52b	33.98a	33.46a	5.47a	5.66a
Irrigation every 9 days.	36.93c	37.29c	32.21b	31.51b	4.98b	5.06b
F-test	**	**	**	**	**	**
Exogenous application (E):						
Control.	38.33b	37.86b	33.02	32.39	5.21b	5.25b
Proline.	40.71a	40.98a	33.63	32.97	5.35b	5.54b
Salicylic acid.	41.27a	42.21a	34.24	33.53	5.61a	5.86a
F-test	**	**	NS	NS	*	*
Interactions:						
V x I	**	**	NS	NS	NS	NS
V x E	**	**	**	**	**	**
I x E	NS	NS	NS	NS	NS	NS
V x I x E	NS	NS	NS	NS	NS	NS

***, ** and NS. are significant at 0.05 level, significant at 0.01 level and not significantly respectively.**
Means followed by the same letter are not significantly varied, according to DMRT.

d. The interaction effect:

Among all possible interactions, only the interaction between irrigation intervals and exogenous application of proline and salicylic acid had a significant effect on days to heading in both seasons (Table 2).

Data in Table 4 showed that at the same irrigation treatment, salicylic acid gave the longest vegetative period under all studied irrigation regimes. In addition, no significant differences were found between continuous flooding and irrigation intervals when salicylic acid was applied.

Table 2 also indicated that number of tillers m^{-2} was not significantly affected by the interactions. However, the interaction between rice varieties and the exogenous proline and salicylic acid application had a significant effect on plant height in both seasons.

Table 5: showed that the tallest plants were recorded by EHR1 rice cultivar when the exogenous proline was applied without any significant differences with salicylic acid application. On the other hand, Giza 178 rice cultivar gave the shortest plants without exogenous proline or salicylic acid applications (Control).

Concerning the effect of the interaction on leaf chlorophyll content, data in Table 3 showed a significant effect of either the interaction between rice varieties and irrigation intervals or the interaction between rice varieties and the exogenous application of proline and salicylic acid.

Table 4. Days to heading as affected by the interaction between irrigation intervals and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Irrigation intervals	Chemical application					
	2018			2019		
	Control	Proline	Salicylic acid	Control	Proline	Salicylic acid
Continuous flooding	107.3a	106.8ab	107.4a	105.6a	105.8a	106.0a
Irrigation every 6 days	102.1c	105.8b	106.6ab	100.4c	102.9b	104.0b
Irrigation every 9 days	95.3e	98.0d	98.3d	92.5f	95.2e	98.1d

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 5. Plant height (cm) as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	107.92b	99.27d	96.64e	105.59b	99.83c	92.62e
Proline	113.04a	104.34c	98.77d	111.54a	105.18b	97.79d
Salicylic acid	112.31a	103.98c	98.62d	110.89a	104.17b	96.47d

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Data listed in Table 6 revealed that EHR3 gave the maximum values of leaf chlorophyll content, dissentingly followed by EHR1and Giza 178 rice varieties under any of irrigation regimes. In addition, leaf chlorophyll content of all tested rice varieties was significantly decreased due to prolonging irrigation intervals.

EHR3 treated with salicylic acid application gave the maximum significant values of leaf chlorophyll content during both seasons, while the lowest values in this regard were obtained by Giza 178 rice cultivar without exogenous applications (Table 7).

It is also clear from data in Table 3 that among all possible interactions only the interaction between rice varieties and exogenous applications had a significant effect on flag leaf area and leaf area index.

The largest area of flag leaves was recorded with EHR1 with salicylic acid application without significant differences with proline under the same variety in the first season only. In contrary, the lowest values of flag leaf area were obtained by Giza 178 rice cultivar with control (no exogenous applications) (Table 8).

Data of Table 9 showed that EHR3 rice variety gave the maximum leaf area index when it was sprayed with salicylic acid in both seasons without significant differences with proline spray for it in the first.

Table 6. Leaf chlorophyll content (SPAD values) as affected by the interaction between rice varieties and Irrigation intervals in 2018 and 2019 seasons.

Irrigation intervals	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Continuous flooding	43.89b	44.92a	40.54d	44.58b	45.96a	39.19d
Irrigation every 6 days	41.73c	43.18b	35.88g	41.49c	44.87b	35.20e
Irrigation every 9 days	37.62f	39.43e	33.74h	39.12d	40.60c	32.15f

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 7. Leaf chlorophyll content (SPAD values) as affected by interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	HER 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	39.63e	40.48d	34.87g	40.02e	40.69e	32.87h
Proline	41.59c	43.17b	37.38f	42.02d	44.79b	36.14g
Salicylic acid	42.02c	43.89a	37.91f	43.16c	45.95a	37.52f

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 8. Flag leaf area (cm^2) as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	HER 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	34.79b	33.26de	31.02g	33.62bc	32.67d	30.88f
Proline	35.23ab	33.68cd	31.97f	33.92b	33.27c	31.73e
Salicylic acid	35.71a	34.19c	32.83e	34.52a	33.63bc	32.43d

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 9. Leaf area index as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	HER 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	5.15de	6.00b	4.48g	5.26e	5.96c	4.52g
Proline	5.29d	6.06ab	4.71fg	5.57d	6.20b	4.85f
Salicylic acid	5.61c	6.33a	4.89ef	5.89c	6.56a	5.13e

Means followed by the same letter(s) are not significantly varied, according to DMRT.

2. Grain yield and its components:

a. Rice varieties performance:

Data related to grain yield and its components in Tables 10 and 11 indicated that EHR3 rice cultivar gave the highest numbers of panicles m^{-2} and number of total grains $panicle^{-1}$ as well as the heaviest 1000-grain weight and the maximum grain yield in both seasons. However, the differences between the two tested rice hybrids were insignificant in number of panicles m^{-2} and grain yield. On the other hand, Giza 178 inbred rice cultivar gave the highest significant percentage of filled grains as well as the lowest significant values of panicles number m^{-2}, number of total grains $panicle^{-1}$, 1000-grain weight and grain yield as compared to the two tested rice hybrids during the both studied seasons. The superiority of hybrid rice varieties in grain yield and its components comparing with the inbred rice variety may be attributed to the hybrid vigor of the F_1 hybridization. Such findings were also revealed by Chen *et al.* (2020), Hasan *et al.* (2020) and Shretha *et al.* (2020).

b. Effect of irrigation intervals:

Both continuous flooding and irrigation every 6 days recorded the maximum values of grain yield its components without any significant differences between them in the two seasons. While, the lowest significant values in this respect were belonged with irrigation every 9 days interval as shown in Tables (10 and 11).

This reduction in rice grain yield with increasing irrigation intervals up to 9 days could mainly be due to the reduction in grain yield components as a result to water imbalance inside rice plants and water shortage around root zone which decrease photosynthesis products, net assimilation, plant organs development, assimilates translocation and grain filling process (Wang *et al.*, 2018).

These findings were supported by those obtained by Sultan *et al.* (2013) and Abou El-Darag *et al.* (2017).

c. Impact of proline and salicylic acid applications:

Data listed in Tables 10 and 11 indicated significant and positive effect of the exogenous application of salicylic acid and proline on grain yield and its components. The maximum values of number of panicles m^{-2}, total grains $panicle^{-1}$ and filled grains percentage were obtained by salicylic acid application compared with proline application or the control treatment. In addition, salicylic acid gave the highest values of 1000-gain weight and grain yield without any significant differences with proline application in both seasons. The control treatment (without exogenous application) gave the lowest values of grain yield and its components.

This advantage in grain yield and its component with the application of exogenous salicylic acid might be attributed to increase mobilization of reserve food material to rice grains during gain filling process through increasing the activity of hydrolyzing and oxidation enzymes (Singh *et al.*, 2015). These findings are in line with those of Neeraj *et al.* (2013) and Tabssum *et al.* (2019).

d. The interaction effect:

Table 10 showed that all possible interactions had no significant effect on panicles number m^{-2} except for the interaction between irrigation intervals and the exogenous applications in both seasons.

Table 10. Number of panicles m^{-2}, Number of total grins $panicle^{-1}$ and filled grains percentage of some rice varieties as influenced by irrigation intervals and exogenous application of proline and salicylic acid as well as their interactions in 2018 and 2019 seasons.

Treatments	No. of panicles m^{-2}		No. of total grains $panicle^{-1}$		Filled grains (%)	
	2018	2019	2018	2019	2018	2019
Rice varieties (v):						
EHR 1	594.4a	587.5a	187.1b	192.7b	90.27c	91.11c
EHR 3	601.9a	598.7a	229.4a	231.5a	93.86b	94.48b
Giza 178	527.6b	513.8b	164.7c	168.9c	95.78a	96.92a
F-test	**	**	**	**	**	**
Irrigation intervals (I):						
Continuous flooding	594.1a	585.6a	212.4a	220.5a	96.72a	97.02a
Irrigation every 6 days.	585.3a	576.3a	203.2a	209.9a	94.51a	95.69a
Irrigation every 9 days.	544.5b	538.1b	165.6b	162.7b	88.68b	89.80b
F-test	**	**	**	**	**	**
Exogenous application (E):						
Control.	567.4c	559.4b	184.0b	190.7b	91.31b	91.94b
Proline.	574.3b	568.2a	191.9b	195.8b	92.77b	93.82b
Salicylic acid.	582.2a	572.4a	205.3a	206.6a	95.83a	96.75a
F-test	**	**	**	**	**	**
Interactions:						
V x I	NS	NS	**	**	NS	NS
V x E	NS	NS	**	**	**	**
I x E	**	**	NS	NS	NS	NS
V x I x E	NS	NS	NS	NS	NS	NS

***, ** and NS. are significant at 0.05 level, significant at 0.01 level and not significantly respectively.**
Means followed by the same letter are not significantly varied, according to DMRT.

Table 11. 1000-grain weight and grain yield of some rice varieties as influenced by irrigation intervals and exogenous application of proline and salicylic acid as well as their interactions in 2018 and 2019 seasons.

Treatments	1000-grain weight (g)		Grain yield (t/ha.)	
	2018	2019	2018	2019
Rice varieties (v):				
EHR 1	25.18b	24.83b	10.46a	10.63a
EHR 3	26.79a	27.02a	10.73a	10.81a
Giza 178	21.47c	21.39c	8.90b	8.96b
F-test	**	**	**	**
Irrigation intervals (I):				
Continuous flooding	25.08a	25.15a	10.59a	10.76a
Irrigation every 6 days.	24.64a	24.49a	10.34a	10.43a
Irrigation every 9 days.	23.72b	23.61b	9.16b	9.21b
F-test	**	**	**	**
Exogenous application (E):				
Control.	23.87b	23.64b	9.64b	9.68b
Proline.	24.66a	24.58a	10.07a	10.16a
Salicylic acid.	24.91a	25.03a	10.38a	10.56a
F-test	**	**	**	**
Interactions:				
V x I	**	**	**	**
V x E	NS	NS	NS	NS
I x E	NS	NS	NS	NS
V x I x E	NS	NS	NS	NS

***, ** and NS. are significant at 0.05 level, significant at 0.01 level and not significantly respectively.**
Means followed by the same letter are not significantly varied, according to DMRT.

As shown in Table 12, the differences among the exogenous treatments were not significant under continuous flooding with respect to panicles number m^{-2}. In addition, there were no significant differences in panicles number m^{-2} between continuous flooding and irrigation every 6 days when proline or salicylic acid was applied. The lowest values were obtained by irrigation every 9 days and no exogenous application (Control). Interestingly, under prolonging irrigation interval of 9 days the foliar application of salicylic acid significantly alleviated the hazard effect of water shortage and increased panicles number as comparing to other treatments.

Number of total grains $panicle^{-1}$ was significantly affected by the interaction between rice varieties and irrigation intervals and the interaction between rice varieties and the exogenous application of salicylic acid and proline in both seasons (Table, 10).

Table 12. Number of panicles m^{-2} as affected by the interaction between irrigation intervals and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Irrigation intervals	Chemical application					
	2018			2019		
	Control	Proline	Salicylic acid	Control	Proline	Salicylic acid
Continuous flooding	591.1a	594.4a	596.7a	580.7ab	586.1a	590.1a
Irrigation every 6 days	575.4b	586.0ab	594.6a	571.2b	576.3ab	581.4a
Irrigation every 9 days	535.7d	542.5d	555.3c	526.3d	542.2c	545.8c

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Under continuous flooding, EHR3 recorded the maximum number of total grains $panicle^{-1}$. Moreover, number of total grains $panicle^{-1}$ of the three tested rice varieties were significantly decreased as irrigation interval is prolonged (Table, 13).

Table 14 revealed that the maximum number of total grains $panicle^{-1}$ was recorded by EHR3 rice variety with salicylic acid application during both seasons.

The interaction between rice varieties and the exogenous application of salicylic acid and proline also had a significant effect on filled grain percentage (Table, 10). The maximum significant filled grain percentage was obtained by Giza 178 rice variety with salicylic acid application without significant difference with EHR3 and the salicylic acid application in both seasons (Table, 15).

Table 13. Number of total grains $planicle^{-1}$,as affected by the interaction between rice varieties and irrigation intervals in 2018 and 2019 seasons.

Irrigation intervals	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Continuous flooding	207.1c	248.6a	181.5e	218.4c	253.8a	189.4e
Irrigation every 6 days	197.8d	239.1b	172.7f	206.9d	247.6b	175.2f
Irrigation every 9 days	156.4g	200.5d	139.9h	152.8g	193.1e	142.1h

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 14. Number of total grains $planicle^{-1}$ as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	179.6de	219.8b	152.7g	185.2d	223.8b	163.1f
Proline	183.4d	226.0b	166.2f	192.1d	229.4b	165.95f
Salicylic acid	198.3c	242.4a	175.1e	200.8c	241.4a	177.6e

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 15. Filled grains percentage as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	88.38f	91.43e	94.11d	88.53g	91.48e	95.81c
Proline	89.37f	93.55d	95.40c	89.80f	94.67d	96.98b
Salicylic acid	93.06d	96.59b	97.83a	95.00cd	97.29ab	97.97a

Means followed by the same letter(s) are not significantly varied, according to DMRT.

As for the effect of the interactions on 1000- grain weight data presented in Table 11 indicated that only the interaction between rice varieties and irrigation intervals had a appositive effect in both seasons.

Table 16 showed that the maximum significant values of 1000-grain weight were obtained by EHR3 rice variety under continuous flooding followed by irrigation every 6 days without any significant differences between them with the same variety. In addition, under the same irrigation interval, Giza 178 inbred rice cultivar recorded the lowest values with respect to the 1000- grain weight.

Among all possible interactions, the interaction between rice varieties and irrigation intervals had a significant effect on grain yield during both seasons (Table, 11).

Table 17 revealed that under continuous flooding irrigation regime, EHR3 rice variety gave the maximum grain yield values in both seasons without significant differences with EHR1 rice variety. However, under irrigation every 6 days interval the highest significant grain yield was obtained by EHR3 rice cultivar. In addition, grain yield of all tested

Table 16. 1000-grain weight (g) as affected by the interaction between rice varieties and irrigation intervals in 2018 and 2019 seasons.

Irrigation intervals	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Continuous flooding	25.68b	27.52a	22.04d	25.42c	27.68a	22.35e
Irrigation every 6 days	25.49b	27.04a	21.39e	24.98c	27.22a	21.27f
Irrigation every 9 days	24.37c	25.81b	20.98e	24.09d	26.17b	20.56g

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 17. Grain Yield (t/ha.) as affected by the interaction between rice varieties and irrigation intervals in 2018 and 2019 seasons.

Irrigation intervals	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Continuous flooding	10.98ab	11.36a	9.43cd	11.18ab	11.43a	9.67cd
Irrigation every 6 days	10.76b	11.02ab	9.24d	10.92b	11.14ab	9.23d
Irrigation every 9 days	9.64cd	9.81c	8.03e	9.79c	9.86c	7.98e

Means followed by the same letter(s) are not significantly varied, according to DMRT.

3.Some of grains quality characters:

a. Rice varieties performance:

The three tested rice varieties were significantly varied in their grain quality characteristics. Moreover, EHR3 rice cultivar gave maximum significance percentages of hulling and milling. Giza 178 inbred rice cultivar gave the highest significant head rice percentage. On the other side, EHR1 cultivar recorded the lowest significant percentages of hulling, milling and head rice in the both studied seasons (Table, 18).

These varietals variation in studied grain quality characters might be due the genetic background of the tested rice verities.

Similar varietals variations were also reported by El-Mowafi *et al.* (2019) and Polidoro *et al.* (2020).

Table 18. Hulling, milling and head rice percentages of some rice varieties as influenced by irrigation intervals and exogenous application of proline and salicylic acid as well as their interactions in 2018 and 2019 seasons.

Treatments	Hulling %		Milling %		Head rice %	
	2018	2019	2018	2019	2018	2019
Rice varieties (v):						
EHR 1	77.26c	79.04c	69.24c	69.41c	60.81c	61.17c
EHR 3	82.69a	83.11a	72.78a	71.93a	62.96b	63.12b
Giza 178	80.94b	81.38b	71.31b	70.56b	65.04a	64.28a
F-test	**	**	**	**	**	**
Irrigation intervals (I):						
Continuous flooding	81.44a	82.39a	72.02a	71.42a	63.68a	63.92a
Irrigation every 6 days.	80.38b	81.63b	71.38a	70.97a	63.29a	63.18a
Irrigation every 9 days.	79.07c	79.51c	69.93b	69.51b	61.84b	61.47b
F-test	**	**	**	**	**	**
Exogenous application (E):						
Control.	80.09	80.88	70.53c	70.08c	62.05c	62.14c
Proline.	80.54	81.22	71.12b	70.63b	62.79b	62.86b
Salicylic acid.	80.26	81.43	71.68a	71.19a	63.97a	63.57a
F-test	NS	NS	*	*	**	**
Interactions:						
V x I	NS	NS	NS	NS	NS	NS
V x E	NS	NS	**	**	**	**
I x E	NS	NS	**	**	**	**
V x I x E	NS	NS	NS	NS	NS	NS

***, ** and NS. are significant at 0.05 level, significant at 0.01 level and not significantly respectively.**

Means followed by the same letter are not significantly varied, according to DMRT.

b. Effect of irrigation intervals:

The studied irrigation intervals significantly affected the measured grain quality traits in both seasons. Data of Table 18 revealed that hulling percentage was significantly decreased due to increasing irrigation intervals up to 9 days. The maximum milling and head rice percentages were obtained by continuous flooding treatment which was not significantly different with irrigation every 6 days interval during the both seasons of study. On contrary, the lowest significant values of studied grain quality were recorded with irrigation every 9 days.

Prolonging irrigation intervals might be declined photosynthesis rate restricting carbohydrate production and its translocation to grain resulted low starch cell filling leading to poor grain quality including milling and head rice%. These results are in agreement with those obtained by Ibrahim et al, (2017) and Gewaily *et al.* (2019).

c. Impact of proline and salicylic acid application:

Analysis variance of data showed that the exogenous application of salicylic acid and proline significantly influenced milling and head rice percentages in both seasons (Table, 18). The maximum significant percentages of milling and head rice in the first and the second seasons were obtained by salicylic acid, dissentingly followed by proline application and control treatment (without exogenous applications).

Either proline or salicylic acid applications improved hulling percentage, but, the differences between the two treatments were not significant as shown in Table 19. The positive effect of applying the current biochemical materials mainly attributed to its vital role on enhancing growth, enzymes formation , photosynthesis rate , carbohydrate assimilates during pre and post heading brought highly rate of starch to move to rice grain and well filled of starch grain cell induced clear grain quality improvement.

Similar effects have been reported by Okasha *et al.* (2019) and Luo *et al.* (2020).

d. The interaction effect:

Hulling percentage was not significantly affected by all possible interactions in both seasons, while, milling and head rice percentages were significantly affected by the interaction between rice varieties and the exogenous application of salicylic acid and proline and the interaction between irrigation intervals and the exogenous application of salicylic acid and proline in the first and the second seasons as shown in Table 18.

Data listed in Table 19 clarified that the maximum milling percentage was recorded with EHR3 rice variety with salicylic acid application, while the lowest percentage was obtained by EHR1 rice variety with control (no exogenous proline or salicylic acid application) in both seasons.

Under continuous flooding regime the highest milling percentage was obtained when the exogenous salicylic acid was applied without significant deference with proline application. The lowest milling percentage in the two seasons was recorded with irrigation every 9 days without any exogenous application (Control) as shown in Table 20.

The maximum significant head rice percentage was obtained by Giza 178 inbred rice cultivar with salicylic acid application, while the lowest percentage was recorded by EHR1 rice cultivar with the control treatment (without proline or salicylic acid application), as presented in Table 21.

Table 22 showed that the highest head rice percentages were recorded under continuous flooding irrigation regimes with salicylic acid application in the first season and with proline or salicylic acid application in the second season. The differences between continuous flooding and irrigation every 6 days interval in head rice percentage was insignificant when salicylic acid was applied.

Table 19. Milling percentage as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	68.53g	72.25b	70.81d	68.89e	71.16c	70.19d
Proline	69.29f	72.87a	71.20c	69.30e	71.98b	70.61cd
Salicylic acid	69.91e	73.21a	71.92b	70.04d	72.65a	70.88c

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 20. Milling percentage as affected by the interaction between rice varieties and irrigation intervals and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Irrigation intervals	Chemical application					
	2018			2019		
	Control	Proline	Salicylic acid	Control	Proline	Salicylic acid
Continuous flooding	71.42b	72.27a	72.37a	70.89bc	71.42ab	71.95a
Irrigation every 6 days	70.82c	71.26b	72.07a	70.42cd	70.92bc	71.57a
Irrigation every 9 days	69.35e	69.83d	70.60c	68.93f	69.55e	70.05de

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 21. Head rice percentage as affected by the interaction between rice varieties and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Chemical application	Rice varieties					
	2018			2019		
	EHR 1	EHR 3	Giza 178	EHR 1	EHR 3	Giza 178
Control	60.06g	62.27d	63.83c	60.18f	62.42d	63.82b
Proline	60.65f	62.60d	65.12b	61.17e	63.08c	64.33ab
Salicylic acid	61.72e	64.02c	66.17a	62.16d	63.86b	64.69a

Means followed by the same letter(s) are not significantly varied, according to DMRT.

Table 22. Head rice percentage as affected by the interaction between irrigation intervals and the exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Irrigation intervals	Chemical application					
	2018			2019		
	Control	Proline	Salicylic acid	Control	Proline	Salicylic acid
Continuous flooding	63.05cd	63.71b	64.28a	63.77ab	64.00a	63.98a
Irrigation every 6 days	62.72d	63.22c	63.93ab	62.28d	63.33b	63.92a
Irrigation every 9 days	60.38f	61.44e	63.70b	60.36f	61.24e	62.80c

Means followed by the same letter(s) are not significantly varied, according to DMRT.

4. Water relations:

Data in Table 23 indicated that total applied water was decreased with increasing irrigation intervals from continuous flooding up to irrigation every 9 days. Moreover, irrigation every 6 days recorded the highest water use efficiency in the both seasons. Meanwhile, the lowest water use efficiency values were belonged with continuous flooding. Irrigation every 9 days intervals save more irrigation water amount with the maximum values of grain yield reduction. However, 6 days irrigation interval is considered the best irrigation regime for obtaining the highest water use efficiency with less grain yield reduction and reasonable saving amount of water.

Table 23. Total applied water, water saved, grain yield reduction and water use efficiency as affected irrigation intervals in 2018 and 2019 seasons.

Irrigation intervals	Total water applied (m^3/ha.)		Water saved (%)		Grain yield reduction (%)		Water use efficiency (kg/m^3)	
	2018	2019	2018	2019	2018	2019	2018	2019
Continuous flooding	14089.1	13883.9	-	-	-	-	0.752	0.775
Irrigation every 6 days	12458.7	12427.2	11.57	10.49	2.36	3.07	0.830	0.839
Irrigation every 9 days	11399.4	11265.6	19.09	18.86	13.52	14.41	0.804	0.818

Table 24 indicated that under 9 days interval the maximum values of water use efficiency in both seasons was recorded with salicylic acid application. By the way, the interaction effect showed that the exogenous application of proline and salicylic acid improved water use efficiency under prolonged irrigation interval gave the highest values of water use efficiency. From the previous results it could be recommended that rice watering could be prolonged up to 6 days interval with exogenous application of salicylic acid or proline with using EHR1 or EHR3 under the conditions of this study.

Table 24. Water use efficiency (kg/m^3) as affected by the interaction between irrigation intervals and exogenous application of proline and salicylic acid in 2018 and 2019 seasons.

Irrigation intervals	Chemical application					
	2018			2019		
	Control	Proline	Salicylic acid	Control	Proline	Salicylic acid
Continuous flooding	0.745	0.753	0.757	0.764	0.777	0.783
Irrigation every 6 days	0.807	0.834	0.848	0.826	0.835	0.856
Irrigation every 9 days	0.735	0.805	0.870	0.724	0.827	0.898

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تأثير المعاملة بحمض السلسيلك والبرولين على إنتاجية الأرز الهجين تحت فترات رى مختلفه

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أقيمت تجربتان حقليتان خلال موسمى صيف ٢٠١٨م و ٢٠١٩م بالمزرعة البحثية لمحطة البحوث الزراعية بسخا - محافظة كفرالشيخ - مصر ، بهدف دراسة إستجابة ثلاثة أصناف من الأرز هى : هجين مصرى ١ ، وهجين مصرى ٣ ، و جيزه ١٧٨ (صنف مربى ذاتيا) لثلاث فترات رى وهى: الغمر المستمر ، والرى كل ستة أيام ، والرى كل تسعة أيام وأيضا المعاملة بحمض السلسلك والبرولين.أجريت الدراسه بإستخدام تصميم الشرائح المنشقه مرتين لثلاث مكررات حيث وزعت فترات الرى على الشرائح الرأسيه بينما وزعت أصناف الأرز على الشرائح الأفقيه ووزعت إضافات البرولين وحمض السلسليك على القطع المنشقه الثانيه.أوضحت أهم النتائج المتحصل عليها فى كلا الموسمين أن أعلى القيم لصفات عدد الأيام حتى التزهير، وعدد الفروع/م٢، وإرتفاع النباتات قد سجلت مع صنف الأرز هجين مصرى ١ ،فى حين حقق صنف الأرز هجين مصرى ٣ أعلى القيم لمحتوى الأوراق من الكلوروفيل ودليل مساحة الأوراق وعدد الحبوب الكلية/الدالية ووزن الألف حبة ومحصول الحبوب كما أعطى أعلى النسب المئوية لصفتى التقشير والتبييض. حقق صنف المقارنة تحت الدراسة المربى ذاتيا جيزه ١٧٨ أعلى نسبة مئوية للحبوب الممتلئة والتدريج لكنه سجل أقل القيم معنويا لصفات النمو الخضرى و محصول الحبوب ومكوناته.أظهرت النتائج أيضا أن الرى كل ستة أيام قد سجل أعلى كفائه لإستخدام المياه مع توفير كميه من مياة الرى دون إنخفاض معنوى فى محصول الحبوب عند رش النباتات بحمض السلسيلك أو البرولين فى حين أدى الرى كل تسعة أيام إلى توفير ١٩,٠٩ % ، و ١٨,٨٦ % من مياة الرى مع إنخفاض قدره ١٣,٥٢ % , و١٤,١٤ % فى محصول الحبوب خلال موسمى ٢٠١٨م ، و ٢٠١٩م على الترتيب.