EFFECT OF SOME PLANT GROWTH REGULATORS AND BIOSTIMULANTS ON THE PRODUCTIVITY OF SAKHA108 RICE PLANT (*ORYZA SATIVA* L.) UNDER DIFFERENT WATER STRESS CONDITIONS

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Abstract. In order to study the effect of biostimulants and growth regulator foliar application (PGRs) under different level of water stress, a field experiment was conducted to find out the role of some plant biostimulants and plant growth regulating substances on a rice cultivar grown under different irrigation intervals in the 2018 and 2019 growing seasons at the farm of Agricultural Research Station, Sakha, Kafrelsheikh, Egypt. The Experiment was conducted using Randomized Complete Block Design with Strip plot arrangements. Main plots consisted of the four irrigation intervals while sub plots contained the different plant biostimulants and plant growth regulators with different concentrations. Some growth characteristics, yield components were recorded. The main results indicated that spraying plant substances during this study increased all studied characters as compared to control treatment. Spraying with Crop plus surpassed and gave the highest value in all the studied characters followed by Cytokinin. Spraying Crop plus under irrigation every 12 days which cause water stress, relieve the harm of stress in the plant and increase the yield by about 2.47 t/ha as compared with control. These results are beneficial for farmers who suffer from shortage of irrigation water in their rice field.
Keywords: *crop plus, cytokinin (CK), abscisic acid (ABA), leaf area index, chlorophyll content, yield*

Introduction

Rice is a major summer crop in Egypt, occupying 10 percent of total crop area. Rice requires a special irrigation regime and its cultivation is largely restricted to the northern part of the Delta. It is often planted on low quality land where the soil is fairly saline and has varying degrees of productivity. Farmers normally exceed the area targeted by the government for rice cultivation despite the prospect of fines (LE 1434/hectare) for those who violate their targeted areas. This is due to the much higher profitability of rice cultivation compared to other traditional summer crops (i.e. corn and cotton) and the higher potent for exporting the crop. The government is trying to restrict the area of rice and increase the area of corn to save water.

Rice is particularly susceptible to soil water deficit, which causes large yield losses in many Asian countries. And drought affects its growth in about 50% of the world production area. More than 50% of the 40 million ha of rain fed lowland rice area in South and Southeast Asia is affected by drought annually, which has contributed to significant yield losses.

Generally, reduction of water content in plant tissues under drought conditions limits their growth. Studies show that the stress caused by water shortage reduces growth and leaf surface area, damages and reduces photosynthetic processes, damages cell

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membranes, damages and reduces proteins and enzymes, hurts pigments and plastids, and reduces chlorophyll and root growth (Levitt, 1980). Water shortage stress can directly affect photosynthesis related biochemical processes while it indirectly reduces CO_2 molecules entering stomata which are closed due to water shortage. As a result, transportation of photosynthetic substances are affected by water shortage and leaves become saturated which in turn may further limit photosynthesis. Limitation in photosynthetic substances under water shortage will obviously reduce plant growth and eventually its photosynthesis and performance (Blum, 1996).

The plant bio-stimulants, include diverse substances and microorganisms that enhance plant growth. The global markets for bio-stimulants has been projected to reach $2.241 million by 2018 and to have a compound annual growth rate of 12.5% from 2013 to 2018 (Anonymous, 2013). The European bio-stimulants industry council (EBIC) reported that in 2012 over 6.2 million hectares were treated with bio-stimulants (European Bio-stimulants Industry Council, 2013). Also, contains macro elements' (e.g.: Ca, K and P) and microelements (Fe, Cu, Zn, B, Mn, Co and Mo) (Craigie, 2011). Seaweed extracts a positive impact of several species of algae (Ascophyllum sp., Laminaria sp. and Ecklonia sp) on growth and development (Sultana et al., 2005). Seaweed extracts are now available commercially under the names, such as Maxi crop (Seaborn), Algifert (Marinure), Goemar GA14, Kelpak66, Crop plus, Seaspray, Seasol, and Seacrop16. Recently researchers proved that seaweed fertilizer are better than other fertilizers and are very economical (Ramya et al., 2011).

Biozyme Crop plus is a commercial formulation of seaweed extract (*Ascophyllum nodosum*), enzymes and hydrolyzed proteins whereas, spic cytozyme contain gibberellic acid, auxins, cytokinins, seaweed extract (*Ascophyllum nodoum*), hydrolysed proteins and trace elements.

Cytokinins (CKs) promote cell division and, acting both in synergy and antagonism with other plant hormones, influence a wide range of events during plant growth. The major portion of CKs is produced in meristematic regions in the root system and transported via the xylem to the shoot. These CKs, along with the locally synthesized CKs, control the development and senescence of the whole plant. CKs promote leaf expansion, accumulation of chlorophyll and conversion of etioplasts into chloroplasts, and delay leaf senescence. The molecular mechanism of CK action is only poorly understood and information on how endogenous CKs are affected under stress is meager (Pospíšilová et al., 2000). Plant responses to CKs are often judged from their responses to exogenously applied CKs. However, when CKs are applied and plant response have been followed, it is necessary to take into consideration that exogenous CKs (natural and synthetic) can increase the content of endogenous CKs by their uptake and by promotion of CK biosynthesis. On the other hand, they can increase cytokinin oxidase activity and CK degradation (Hare et al., 1997; Kamínek et al., 1997). Thus, the composition and concentration of CKs in the site of action might be quite different than in the site of application.

The plant hormone abscisic acid (ABA) plays a major role in plant responses to stress. Although rapid production of ABA in response to drought and salt stresses is essential to define ABA as a stress hormone, an equally rapid catabolism of ABA when such stresses are relieved is also essential in that role. Among these regulated physiological responses, the plant hormone abscisic acid (ABA) plays a central role. ABA is defined as a stress hormone because of its rapid accumulation in response to stresses and its mediation of many stress responses that help plant survival over the

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stresses. How can this substance achieve this purpose? The first prerequisite is that its production should be sensitively and rapidly triggered by the stress to avoid any inhibition of plant growth and functions under unstressed conditions. The second prerequisite is that ABA should be rapidly degraded and deactivated once the stress is relieved such that normal plant growth and functions can resume (Zhang et al., 2006).

Application of CKs can reverse leaf and fruit abscission induced by ABA or water stress, or CKs release seed dormancy in contrasts with ABA inhibition of germination. The antagonism between CKs and ABA may be the result of metabolic interactions. CKs share, at least in part, a common biosynthetic origin with ABA (Cowan et al., 1999).

Various studies show that water stress negatively affects plants including rice and reduce yields in crops. Application of hormones and growth regulators on the other hand, improves growth parameters in the plants under drought stress. Therefore, the present study aimed to investigate the effect of foliar different plant growth regulator and biostimulants on Sakha108 rice variety production under different levels of drought stress under Egyptian conditions.

Materials and methods

A field experiment was carried out in the farm of Agricultural Research Station, Sakha, Kafrelsheikh, Egypt, the latitude and longitude of the field experiment (31°05′17″N, 30°56′44″E) and the experimental conditions of the study have been described in *Table 1* during 2018 and 2019 in rice growing seasons to identify the impact of foliar application of bio-stimulants by different levels of seaweed extracts named commercially [Crop plus at rates 0.5, 1.00 and 1.5 ml/l liter water]. Biozyme Crop plus is a commercial formulation of seaweed extract (*Ascophyllum nodosum*), enzymes and hydrolyzed proteins whereas, spic cytozyme contain gibberellic acid, auxins, cytokinins, seaweed extract (*Ascophyllum nodoum*), hydrolysed proteins and trace elements and plant growth regulator named i.e. [Cytokinin (CK) and Abscisic acid with concentration of 15, 20, 25 ppm] and Trafos K (Trafos K is a registered trademark of products Trade crop nutri-performance, Co., in Spain, it has been obtained from Perfect-Egypt Company, Al-Sadat City. The chemical composition of Trafos K is Phosphorus “P_2O_5” 42% (w/v) and Potassium “K_2O” 28% (w/v), in the form potassium phosphite at rates 1, 1.5 and 2 ml/l liter water) to improve the vegetative and reproductive growth of Sakha108 rice cultivar under different irrigation intervals i.e. irrigation every 3 days (I_1), irrigation every 6 days (I_2), irrigation every 9 days (I_3) and irrigation every 12 days (I_4) (water stress). The field experiments were laid out in a strip design with four replications. The irrigation treatments were applied in the main plots, while the plant growth biostimulating growth regulating substances (PGRs) and Trafos K as shown in *Table 2* were placed in the sub- plots. Rice variety was sprayed with plant bio-stimulated, growth regulators (PGRs) and Trafos-K four time after 15, 30, 45 and 60 DAT. Pre-germinated seeds of rice cultivar at the rate of 120 Kg/ha, were broadcasted manually in the nursery on 10th of May in 2018 and 2019 seasons. Nitrogen (Urea 46% N) was added according to the treatments in two splits. Two thirds added as basal and incorporated in dry soil before flooding. The other 1/3 was applied as top-dress just before panicle initiation (about 30 days after transplanting). Phosphorus as a single super phosphate 15% at the rate of 36.89 kg P_2O_5/ha was added to the soil before tillage and zinc ($ZnSO_4$) was applied as recommended at the rate of 24 kg $ZnSO_4$/ha.

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***Table 1.** Means of climate parameters of the experimental site during 2018 and 2019 seasons*

Years	Climatic condition	May	June	July	August
2018	Air temp (°C)	27.5	28.95	29.8	29.55
	RH (%)	59.75	61.75	66.8	66.9
2019	Air temp (°C)	28.65	30.5	30.95	31.55
	RH (%)	57.15	65.75	69.8	72.65

***Table 2.** Plant bio stimulants and the amount of this component during period of rice plant growing*

No	Growth biostimulants	Dose	No	Growth biostimulants	Dose
1	Crop Plus (T_1)	0.5 ml/1 liter water	8	ABA (T_8)	20 ppm
2	Crop Plus (T_2)	1.0 ml/1 liter water	9	ABA (T_9)	25 ppm
3	Crop Plus (T_3)	1.5 ml/1 liter water	10	Trafos K(T_{10})	1 ml/1 liter water
4	Cytokinin (T_4)	15 ppm	11	Trafos K(T_{11})	1.5 ml/1 liter water
5	Cytokinin (T_5)	20 ppm	12	Trafos K (T_{12})	2 ml/1 liter water
6	Cytokinin (T_6)	25 ppm	13	Tap water (T_{13})	–
7	ABA (T_7)	15 ppm			

Seedlings were manually pulled and transferred to the permanent field and transplanted in 20 × 20 cm between rows and hills. The sub plot size was 12 m^2. The number of seedling/hill was 2-3 seedlings. Seven days after transplanting, the herbicide Saturn 50% [S-(4-Chlorophenol methyl) diethyl carbamothioate] at the rate of 4.8 L ha^{-1} was mixed with enough amount of sand to make it easy for homogenous distribution to control the weeds. Leaf area index, chlorophyll content of flag leaf using (SPAD) chlorophyll meter Minolta camera Co. Ltd., Japan, dry matter, number of tillers/m^2, number of panicles/m^2, number of filled grains/panicle, panicle weight (g), 1000-grain weight (g) and grain yield (t/ha) were estimated.

Representative soil samples were taken from the experimental sites at (0-30 cm) depth from soil surface. Chemical analyses were done and the results are presented in *Table 3* according to Black et al. (1965).

***Table 3.** Soil mechanical and chemical properties of the experimental site*

Seasons of study	Soil texture (%)	pH	EC dS/m	Organic matter (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
2018	Clayed	7.9	1.8	1.65	22.5	14.45	346
2019	Clayed	8.1	1.45	1.68	24.4	14.12	357

Statistical analysis

The collected data were subjected to statistical analysis and were tested at 5% level of significance to interpret the differences among the treatments, which adapted by Waller and Duncan (1969). All the collected data were subjected to statistical analysis according to procedure described by Gomes and Gomes (1984).

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Results and discussion

Leaf area index

Data in *Table 4* clearly assured that, irrigation of rice every 3 days recorded the highest leaf area index followed by irrigation every 6 and 9 days. While irrigation every 12 days significantly reduced the leaf area index. It might be due to the effect of the stress of water shortage caused by irrigation every 12 days which affected rice growth. These results are in harmony with that recorded by Abd Allah et al. (2009), Abdel-Megeed et al. (2017) and Zheng et al. (2020).

From the results presented in *Table 4* it can be easily noticed that spraying high concentration of Crop plus at the rate of 1.5 ml gave the highest leaf area index followed by next concentration of the same regulator 1.00 and 0.5 ml respectively. While the high concentration of Cytokinin (25 ppm) come in the second rank after Crop plus and recorded positive result. Whereas, control gave the lowest value of leaf area index in both seasons. These results are in coincidence with that reported by Gemici et al. (1998, 2002), Houssien et al. (2011), Prajapati and Modi (2012) and Abdel-Megeed et al. (2017).

Table 4. *Leaf area index (LAI), Chlorophyll content, dry matter production (DM) (g/m²) of Sakha108 rice cultivars as affected by different irrigation intervals and growth regulators during 2018 and 2019 season*

Treatments	2018			2019		
	LAI	**Chlorophyll content**	**DM**	**LAI**	**Chlorophyll content**	**DM**
Irrigation interval (A):						
(I_1)	4.20a	43.86a	1574.4a	4.526a	43.124a	1578.8a
(I_2)	3.91ab	42.75b	1421.8b	4.196b	42.013b	1426.2b
(I_3)	3.79b	41.47c	1311.9c	4.104b	40.732c	1316.3c
(I_4)	3.27c	40.94d	1202.0d	3.573c	40.208c	1206.5d
F. Test	**	**	**	**	**	**
Growth regulates treatment (B)						
(T_1)	4.51abc	44.36bc	1553.4a	4.82b	43.63bc	1557.8a
(T_2)	4.67ab	44.90ab	1560.2a	4.99ab	44.17ab	1564.6a
(T_3)	5.05a	45.35a	1573.1a	5.14a	44.62a	1577.5a
(T_4)	3.85cde	42.45e	1408.8d	4.18d	41.71e	1413.2d
(T_5)	4.11bcd	43.41d	1481.8c	4.43c	42.68d	1486.2c
(T_6)	4.22bcd	43.80cd	1510.7b	4.54c	43.07cd	1515.2b
(T_7)	3.30ef	41.18f-h	1299.0e	3.63f	40.45f-h	1303.5e
(T_8)	3.56de	41.38fg	1394.1d	3.90e	40.65fg	1398.5d
(T_9)	3.70de	41.58f	1399.7d	4.03de	40.84f	1404.2d
(T_{10})	3.14ef	40.27i	1165.4gh	3.46f	39.53i	1169.8gh
(T_{11})	3.26ef	40.54hi	1172.5g	3.58f	39.81hi	1176.9g
(T_{12})	3.30ef	40.65ghi	1237.6f	3.62f	39.92ghi	1242.1f
(T_{13})	2.66f	39.43j	1151.6h	2.99g	38.69j	1156.0h
F. Test	**	**	*	**	**	*
Interaction: AXB	**	*	*	**	*	*

I1: irrigation every3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

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The interaction between different water intervals and foliar spraying had a significant influence on leaf area index. From the results presented in *Table 5*, it could be concluded that rice plant which treated with any plant growth regulator (PGRs) recorded positive result of leaf area index as value. Where, rice plants treated with high concentration of Crop plus 1.5 ml gave the highest plant height under different time of irrigation even 3, 6, 9 and 12-days and recorded the highest value of leaf area index. It means that tested rice cultivar sprayed by Crop plus led to extending the irrigation interval from 3-days up to every 12-days consequently saving reasonable amount of irrigation water without significant reduction in the sink capacity (leaf area index). While the lowest value of leaf area index was found with irrigation every 12 days under control treatment (without any spray). Such findings had also been pointed out by Bahattacharjee et al. (1973), De Datta et al. (1973) and Kang (1998).

Whereas, spraying with any plant growth regulator gave higher LAI one resulted in producing more photosynthetic metabolites which stored in rice organ up to complete heading and then translocation to sink of rice. These results are in congruence with results obtained by Akita (1989), Abouel-Yazied et al. (2012), Wiatrak (2012b), Nayar and Bott (2014) and Niakan and Ahmadi (2014).

Table 5. *Leaf area index (LAI) of Sakha108 rice cultivars as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	4.68a-e	4.48a-f	4.47a-f	4.41a-f	5.01a-e	4.80a-f	4.79a-f	4.70a-g
(T2)	5.19a-c	4.58a-f	4.47a-f	4.45a-f	5.51ab	4.90a-e	4.80a-f	4.74a-g
(T3)	5.37a	5.33ab	4.81a-d	4.69a-e	5.66a	5.13a-c	5.01a-d	4.77a-g
(T4)	4.22a-f	3.82b-h	3.72c-j	3.65d-j	4.54b-h	4.15c-i	4.04d-i	3.97d-j
(T5)	4.28a-f	4.23a-f	4.10a-g	3.81c-h	4.60b-h	4.56b-h	4.43c-i	4.14c-i
(T6)	4.43a-f	4.37a-f	4.14a-g	3.92a-h	4.76a-g	4.70a-g	4.47c-i	4.24c-i
(T7)	3.78c-i	3.58d-k	3.54d-k	2.30ijk	4.11c-i	3.91e-j	3.87e-j	2.62l
(T8)	3.87a-h	3.76c-j	3.54d-k	3.08f-k	4.20c-i	4.09c-i	3.87e-j	3.41i-l
(T9)	4.11a-g	3.77c-j	3.66d-j	3.27e-k	4.43c-i	4.09c-i	3.98d-j	3.59h-k
(T10)	3.71c-j	3.29e-k	3.28e-k	2.27jk	4.03d-i	3.62h-k	3.61h-k	2.60l
(T11)	3.78c-j	3.40d-k	3.57d-k	2.29ijk	4.10c-i	3.73g-j	3.89e-j	2.62l
(T12)	3.78c-i	3.58d-k	3.53d-k	2.29ijk	4.11c-i	3.91e-j	3.86e-j	2.62l
(T13)	3.46d-k	2.66g-k	2.42h-k	2.12k	3.78f-j	2.99jkl	2.75kl	2.44l

I1: irrigation every3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

Chlorophyll content of flag leaf

Data in *Table 4* indicated that irrigation every 3-days produced the greatest chlorophyll content in the flag leaf followed by the irrigation every 6 and 9-days, while irrigation every 12-days gave the lowest value in this aspect. The decreases in chlorophyll content under the irrigation every 12 days could be attributed to water stress under this treatment which cause a decrease in chlorophyll biosciences inside the plant cell and increase the degradation in chlorophyll under the deficiency of water content. Also, the deficiency of water (water stress) inhibited the specific enzymes that are responsible for the biosynthesis of chlorophyll in chloroplasts resulting in a decrease in

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the content of chlorophyll and cause senescence in rice leaves specially flag leaf. These results are in a line with that obtained by Hossain (2001), El- Refaee et al. (2012) and El-Habet (2014).

Data in the same table indicated that the foliar spray of different plant growth biostimulants or regulators (PGRs) caused an increase in chlorophyll content of flag leaf. The highest values were observed when rice was sprayed with Crop plus followed by Cytokinin and ABA, while the lowest value was recorded when the plants were sprayed without growth regulators (control). The highest value of plant growth regulators were recorded by Crop plus when spraying was carried out at a concentration of 1.5 ml/liter water followed by when spraying by the same component but with a concentration of 1 ml/liter at different growth stage of rice plant. These results are in line with that obtained by Gemici et al. (1998, 2002), Wiatrak (2012b), Nayar and Bott (2014) and Niakan and Ahmadi (2014).

Regarding the interaction effect between different irrigation intervals and plant growth regulators and biostimulants in chlorophyll content of flag leaf (*Table 6*) data showed that spraying with Crop plus at rate 1.5 ml gave the highest chlorophyll content under different water intervals followed by when rice plant treated even with 1 ml, 0.5 ml of Crop plus and 25 ppm Cytokinin which come in the second rank while ABA come in the third rank as plant growth regulator under any irrigation intervals time. In contrast the lowest value was recorded by irrigation every 12 days because of the water deficit (water stress) which cause a reduction in chlorophyll. Also, further water stress usually accelerates leaf senescence. In contrast, Crop plus delays leaf senescence due to improving chlorophyll inside the plant cell. These researchers found that Crop plus increased photosynthetic pigments and leaf chlorophyll contents in the plants under study. These results are in harmony with that recorded by Akita (1989), Abouel-Yazied et al. (2012), Wiatrak (2012b), Nayar and Bott (2014) and Niakan and Ahmadi (2014).

Table 6. *Chlorophyll content of Sakha108 rice cultivars as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	46.47bc	45.67c-f	42.93i-l	42.37k-m	45.74bc	44.94c-f	42.20i-l	41.64k-m
(T2)	47.67b	45.83c-f	43.50g-k	42.60kl	46.94b	45.10c-f	42.77g-k	41.87kl
(T3)	49.07a	46.07c-e	43.63g-k	42.62kl	48.34a	45.34cde	42.90g-k	41.89kl
(T4)	44.37f-j	43.77g-k	40.87m-o	40.77m-o	43.64f-j	43.04g-k	40.14mno	40.04m-o
(T5)	45.00c-g	44.50e-i	42.83j-l	41.30l-n	44.27c-g	43.77e-i	42.10jkl	40.57l-n
(T6)	46.13cd	44.80d-h	42.90i-l	41.37l-n	45.40cd	44.07d-h	42.17i-l	40.64l-n
(T7)	42.57kl	40.83m-o	40.72m-o	40.60no	41.84kl	40.10m-o	39.99m-o	39.87no
(T8)	43.20h-k	40.97mn	40.73m-o	40.63no	42.47h-k	40.24mn	39.99m-o	39.90no
(T9)	43.37h-k	41.47ln	40.73m-o	40.73m-o	42.64h-k	40.74l-n	39.99m-o	39.99m-o
(T10)	40.53no	40.33no	40.17n-p	40.03n-p	39.80no	39.60no	39.44n-p	39.30nop
(T11)	40.90m-o	40.73m-o	40.27n-p	40.27n-p	40.20m-o	39.99m-o	39.54n-p	39.54nop
(T12)	40.93m-o	40.83m-o	40.57no	40.27n-p	40.20m-o	40.10m-o	39.84no	39.54nop
(T13)	39.93n-p	39.90n-p	39.20op	38.67p	39.20n-p	39.20n-p	38.47op	37.94p

I1: irrigation every3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

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Dry matter production g/m^2

Results in *Table 4* indicated that dry matter accumulation was significantly higher under different water intervals, whereas the increasing in dry matter content was obtained when rice was irrigated every 3 days followed by irrigation every 6 days, while the lowest value was obtained with the irrigation every 12 days in both seasons of study. Similar results were reported by Islam et al. (1994a, b), Wu et al. (2011) and Li et al. (2015). This result might be due to the increase in number of tillers consequently increased number and area of leaves resulted in increase in photosynthesis which accumulate higher amount of dry matter production.

Data in the same table revealed that spraying by any plant biostimulated and growth regulators caused an increase in dry matter production as compared with control (Tap water). The highest dry matter production was found when rice plants sprayed with any concentration of Crop plus (1.5, 1.00 and 0.5 ml/liter water) and recorded nearly the same value of dry matter production followed by spraying with 25 ppm of Cytokinin as plant regulators which came in second rank after Crop plus. Similar results were observed in the two seasons of the study. These results are mainly attributed to the fact that spraying with growth regulators and biostimulants at various physiological growth stages encourage plant photosynthesis during plant growth through increasing all vegetative growth characters which led finally to raise dry weight accumulation. These results are in a good compatibility with those obtained by Gemici et al. (1998, 2002), Houssien et al. (2011), Prajapati and Modi (2012) and Abdel-Megeed et al. (2017).

Regarding the interaction effect among irrigation treatments and plant growth regulators (PGR) and biostimulants, data in *Table 7* show that foliar application of any biostimulated of plant growth regulators at any different dose of them gave positive result of dry matter production under different water intervals (3, 6, 9 and 12-days) in the two studied seasons. It can be easily observed that Crop plus with 1.5 ml came in the first rank and recorded the highest dry matter production under all different irrigation treatments followed by spraying the same component of crop plus at different concentration 1 ml and 0.5 ml. While Cytokinin at the rate of 25 ppm came in the second rank after Crop plus as plant regulator. It might be due to the role of these substances to help the plant for keeping the water inside the cell longer consequently extending the period of irrigation intervals that led to save reasonable amount of irrigation water. These results are in good agreement with those reported by Akita (1989), Gemici et al. (1998), Abouel-Yazied et al. (2012), Prajapati and Modi (2012) and Abdel-Megeed et al. (2017).

Number of tiller/m^2 at harvest

Data in *Table 8* demonstrated that irrigation every 3-days showed superiority of number of tillers/m^2 than irrigation every 12-days which produced the lowest value in this respect. These results were true in the two seasons of study. It might be due to the decrease in number of tillers as result to water deficiency (water stress) under irrigation every 12-days beside the negative effect of water stress on the growth.

The results are mainly due to the vigor’s of rice variety under this study (genetic background). These results are in line with that reported by Yan et al. (2015), Wu et al. (2018) and Yamaguchi et al. (2019).

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Table 7. *Dry matter production (DM) (g/m^2) of Sakha108 rice cultivars as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				2019 season			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	1715.8ab	1631.5cd	1575.5ef	1290.6k-n	1720.3ab	1635.9cd	1579.9ef	1295.0k-n
(T2)	1716.3ab	1631.7cd	1583.1e	1309.6j-m	1720.8ab	1636.1cd	1587.5e	1314.0j-m
(T3)	1749.5a	1632.2cd	1583.7e	1326.8i-k	1754.0a	1636.7cd	1588.1e	1331.3i-k
(T4)	1628.6cd	1389.2h	1336.9ij	1280.3l-o	1633.0cd	1393.7h	1341.4ij	1284.8l-o
(T5)	1647.7c	1599.1de	1395.6h	1284.7k-n	1652.2c	1603.5de	1400.0h	1289.1k-n
(T6)	1689.1b	1530.1g	1536.9fg	1286.7k-n	1693.5b	1534.5g	1541.4fg	1291.2k-n
(T7)	1584.6e	1363.1hi	1144.7r	1103.7s	1589.0e	1367.5hi	1149.2r	1108.1s
(T8)	1599.3de	1382.0h	1327.4i-k	1267.6m-p	1603.8de	1386.4h	1331.9i-k	1272.1m-p
(T9)	1600.3de	1384.2h	1336.8ij	1277.6l-p	1604.8de	1388.7h	1341.3ij	1282.0l-p
(T10)	1315.7j-l	1235.6pq	1057.8t	1052.5t	1320.1j-l	1240.0pq	1062.3t	1056.9t
(T11)	1338.9ij	1239.3o-q	1058.2t	1053.4t	1343.4ij	1243.8o-q	1062.6t	1057.9t
(T12)	1566.4efg	1246.2n-q	1073.3st	1064.7st	1570.9e-g	1250.6n-q	1077.8st	1069.1st
(T13)	1314.7jkl	1218.9q	1044.7t	1028.2t	1319.1jkl	1223.4q	1049.1t	1032.6t

Table 8. *Number of tiller/m^2, number of panicle/m^2 and number of filled grain/panicle at harvest of Sakha108 rice cultivars as affected by different irrigation intervals and growth regulators during 2018 and 2019 season*

Treatments	**2018**			**2019**		
	No. of tiller/m^2	**No. of panicle/m^2**	**No. of filled grain**	**No. of tiller/m^2**	**No. of panicle/m^2**	**No. of filled grain**
Irrigation interval (A):						
(I_1)	490.77a	466.90a	148.84a	495.36a	471.49a	142.01a
(I_2)	460.19b	429.23b	145.68b	464.78b	433.82b	140.32b
(I_3)	442.94c	414.62c	143.37c	447.53c	419.21c	138.86c
(I_4)	421.40d	402.83c	138.89d	425.99d	407.42d	136.89d
F. Test	**	**	**	**	**	**
Growth regulates treatment (B)						
(T1)	513.13bc	475.00bc	149.24c	517.72bc	479.59bc	144.03c
(T2)	530.00ab	483.75b	152.13b	534.59ab	488.34b	147.08b
(T3)	538.75a	500.00a	155.28a	543.34a	504.59a	148.28a
(T4)	474.56ef	450.00h	144.28e	479.15ef	454.59ef	142.40e
(T5)	488.75de	457.50d	145.82d	493.34de	462.09de	143.00d
(T6)	502.50cd	468.75cd	148.54c	507.09cd	473.34cd	143.33d
(T7)	436.25g	422.44f	141.69f	440.84g	427.03h	137.28l
(T8)	455.00fg	432.50ef	143.25e	459.59fg	437.09gh	140.10g
(T9)	458.75fg	441.25e	143.94e	463.34fg	445.84fg	141.30f
(T10)	372.50h	355.44h	135.89h	377.09h	360.03j	130.95k
(T11)	377.06h	362.50d	139.13g	381.65h	367.09ij	132.63j
(T12)	387.50h	371.25cd	140.18g	392.09h	375.84i	134.63i
(T13)	365.00h	348.75f	135.15h	369.59h	353.34j	128.75l
F. Test	**	**	**	**	**	**
Interaction: AXB	**	**	**	**	**	**

I1: Continuous flooded, I2: irrigation every 3-days, I3: irrigation every 6-days, I4: irrigation every 9-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

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From the result presented in *Table 8* spraying Crop plus recorded the highest number of tillers/m^2 followed by Cytokinin, ABA and Trafos K which came in the last rank. Whereas, control gave the lowest value of number of tillers/m^2 in both seasons. It can be easily noticed that the application of the plant growth regulating substance caused an increase in number of tillers as compared with control treatments (Tap water).

The treatments which had not received any plant growth regulator produced the lowest values in this aspect. These might be due to the encouraging of the emergence of more number of tillers from up ground nodes to when the rice plant treated by PGRs at different growth date of rice plant. These results could be mainly attributed to the fact that spraying with any PGRs improved the number of tillers/m^2 as compared with control treatments (Tap water only). These results are in a good coincidence with that obtained by Gemici et al. (1998, 2002), Craigie (2011), Abubakar (2012), Canady (2012) and Bhattacharya (2019).

The interaction between different irrigation intervals and different PGRs had a significant influence on number of tiller/m^2. From the results presented in *Table 9*, it could be concluded that plants which treated by Crop plus produced the highest number of tillers/m^2 under different water irrigation every 3, 6, 9 and 12 days, followed by Cytokinin and ABA treatments, while Trafos K treatment came in the last rank of plant growth regulator. While the lowest number of tillers were obtained when rice plant was treated by tap water under irrigation every 12 days.

Table 9. *Number of tiller/m^2, number of panicle/m^2 and number of filled grain/panicle at harvest as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	565.00a	512.50bc	500.00b-f	475.00e-h	569.59a	517.09b-e	504.59b-f	479.59e-h
(T2)	570.00a	550.00ab	515.00b-e	485.00d-g	574.59a	554.59ab	519.59be	489.59d-g
(T3)	575.00a	570.00a	515.00b-e	495.00c-f	579.59a	574.59a	519.59be	499.59c-f
(T4)	495.00c-f	480.00d-h	478.25d-h	445.00f-j	499.59c-f	484.59d-h	482.84d-h	449.59f-j
(T5)	530.00a-d	495.00c-f	485.00d-g	445.00f-j	534.59a-d	499.59c-f	489.59d-g	449.59f-j
(T6)	540.00a-c	500.00b-f	500.00b-f	470.00e-h	544.59a-c	504.59d-f	504.59b-f	474.59e-h
(T7)	460.00e-h	450.00f-i	430.00gj	405.00i-k	464.59e-h	454.59f-i	434.59g-j	409.59i-k
(T8)	470.00e-h	470.00e-h	455.00f-i	425.00h-j	474.59e-h	474.59e-h	459.59f-i	429.59h-j
(T9)	475.00e-h	470.00e-h	465.00eh	425.00h-j	479.59e-h	474.59e-h	469.59e-h	429.59h-j
(T10)	425.00h-j	365.00kl	350.00l	350.00l	429.59h-j	369.59kl	354.59l	354.59l
(T11)	435.00g-j	365.00kl	355.00kl	353.25kl	439.59g-j	369.59kl	359.59kl	357.84kl
(T12)	435.00g-j	395.00jkl	360.00kl	360.00kl	439.59g-j	399.59jkl	364.59kl	364.59kl
(T13)	405.00i-k	360.00kl	350.00l	345.00l	409.59i-k	364.59kl	354.59l	349.59l

I1: irrigation every 3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

Also, data in the same table showed that rice plants which irrigated every 3 days and treated with different dose of Crop plus and 25 ppm of Cytokinin recorded nearly equal number of tillers/m^2. Nearly of the same values of number of tillers/m^2 were recorded when rice plants were irrigated every 8 days and sprayed by the rate of 1.5, 1.0 and 0.5 ppm of Crop plus and 25 ppm Cytokinin without any significant difference between

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them. It means that tested rice sprayed by Crop plus led to extend the irrigation interval from 3-days up to every 9 days consequently saving reasonable amount of irrigation water without significant reduction in the sink capacity (No. of tiller). While the lowest value of number of tillers/m^2 were found with irrigation every 12 days under control treatment (without any spray). Such findings had also been pointed out by Gemici (1993, 1998, 2002), Craigie (2011), Abubakar (2012), Canady (2012) and Bhattacharya (2019).

No. of panicles/m^2

Data in *Table 8* clarified that irrigation every 3-days showed superiority of number of panicle/m^2 than irrigation every 12-days which produced the lowest value in this respect. These results were true in both seasons of study. This might be due to the decrease in number of panicle as result to water deficiency (water stress) under irrigation every 12-days beside the negative effect of water stress on the growth and initiation of panicles as a result to the reduction in phytochrome hormones that responsible for flowering. Also, Hossain (2001), El- Refaee et al. (2012), El-Habet (2014) and Abdel-Megeed et al. (2017) found significant reductions in panicle numbers when rice imposed to water stress at tillering stage. The results are mainly due to the vigor of Sakha108 rice variety under this study (genetic background).

From the result presented in *Table 8* spraying Crop plus recorded the highest number of panicle/m^2 followed by Cytokinin, ABA and Trafos K which came in the last rank. Whereas, control gave the lowest value of number of panicle/m^2 in both seasons. It can be easily noticed that the application of the plant growth regulating substance caused an increase in number of panicle as compared with control treatments (Tap water).

The treatments which did not involve plant growth regulators produced the lowest values in this aspect. These might be due to the encouraging of the emergence of more number of panicle from up ground nodes to when the rice plant treated by PGRs at different growth date of rice plant. These results could be mainly attributed to the fact that spraying with any PGRs improved the number of panicle/m^2 as compared with control treatments (Tap water only). These results are in line with that obtained by Akita (1989), Abouel-Yazied et al. (2012), Pospíšilová et al. (1993, 2000), Karimi et al. (2012) and Abdel-Megeed et al. (2017).

The interaction between different irrigation intervals and different PGRs had a significant influence on number of panicle/m^2. From the results presented in *Table 10*, it could be concluded that plants which were treated by Crop plus produced the highest number of panicle/m^2 under different water irrigation every 3, 6, 9 and 12 days, followed by those treated by Cytokinin and ABA, while those treated by Trafos K came in the last rank of plant growth regulators. While the lowest number of panicle were obtained when rice plant was treated by tap water under irrigation every 12 days.

Data in the same table showed also, that rice plants which were irrigated every 3 days and treated with different dose of Crop plus and 25 ppm of Cytokinin recoded the same number of panicle/m^2. Nearly the same values of number of panicle/m^2 were recorded when rice plants were irrigated every 8 days and sprayed with 1.5, 1.0 and 0.5 ppm of Crop plus and 25 ppm Cytokinin without any significant difference between them. It means that tested rice sprayed by Crop plus led to extend the irrigation interval from 3-days up to every 9 days consequently saving reasonable amount of irrigation water without significant reduction in the sink capacity (No. of panicle). While the lowest value of number of panicle/m^2 were found with irrigation every 12 days under

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control treatment (without any spray). Such findings had also been pointed out by Pospíšilová et al. (1993, 2000), Karimi et al. (2012) and Abdel-Megeed et al. (2017).

Table 10. *Number of panicle/m^2 at harvest as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	520.00bc	470.00d-h	460.00f-i	450.00g-k	524.59bc	474.59d-h	464.59f-i	454.59g-k
(T2)	545.00ab	470.00d-h	465.00e-i	455.00g-j	549.59ab	474.59d-h	469.59e-i	459.59g-j
(T3)	550.00a	495.00cde	490.00c-f	465.00e-i	554.59a	499.59cde	494.59c-f	469.59e-i
(T4)	475.00d-g	460.00f-i	440.00s	425.00j-m	479.59d-f	464.59f-i	444.59h-k	429.59j-m
(T5)	500.00cd	465.00e-i	440.00h-k	425.00j-m	504.59cd	469.59e-i	444.59h-k	429.59j-m
(T6)	500.00cd	470.00d-i	460.00f-i	445.00g-k	504.59cd	474.59d-h	464.59f-i	449.59g-k
(T7)	454.75g-j	435.00i-l	405.00l-n	395.00mn	459.34g-j	439.59i-l	409.59l-n	399.59mn
(T8)	455.00g-j	435.00i-l	420.00k-m	420.00k-m	459.59g-j	439.59i-l	424.59k-m	424.59k-m
(T9)	460.00f-i	445.00g-k	435.00i-l	425.00j-m	464.59f-i	449.59g-k	439.59i-l	429.59j-m
(T10)	405.00l-n	350.00o-q	340.00p-r	326.75qr	409.59l-n	354.59o-q	344.59p-r	331.34qr
(T11)	405.00l-n	360.00op	345.00o-r	340.00s	409.59l-n	364.59op	349.59o-r	344.59pqr
(T12)	405.00l-n	375.00no	355.00o-q	350.00opq	409.59l-n	379.59no	359.59o-q	354.59opq
(T13)	395.00mn	350.00opq	335.00pqr	315.00r	399.59mn	354.59opq	339.59pqr	319.59r

I1: irrigation every 3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

Number of filled grains/panicle

Within irrigation intervals, data in *Table 8* clarified that irrigation every 3 days produced the greatest number of filled grains/panicle followed by irrigation every 6 days while irrigation every 12 days gave the least because of the injury of water stress under this treatment. The results showed that the number of filled grains per panicle decreased under lower soil moisture level but the degree of reduction in different genotypes did not indicate the tolerance level of the genotypes. Decreased filled grains per panicle under lower soil moisture levels might be due to inhibition of translocation of assimilate to the grains due to moisture stress. These results agree with RRDI (1999), Niakan and Ahmadi (2014), Sokoto and Muhammad (2014), Shao et al. (2015) and Zheng et al. (2020).

Data presented in *Table 8* assert that significant differences were found among the tested PGRs and biostimulants on number of filled grains/panicle in both seasons of the study. Within various PGR and biostimulant applications, plants sprayed with 1.5 ml/1 liter Crop plus gave the highest value of number of filled grains/panicle followed by spraying also with 1 ml/1 liter of Crop plus while spraying with 25 ppm Cytokinin came in next rank without significance when plants sprayed with 0.5 ml/1 liter of Crop plus in the two seasons under study. The lowest number of filled grains was obtained when rice did not receive any of PGR (control). These results are in line with that reported by Gemici et al. (1998, 2002), Wiatrak (2012b), Nayar and Bott (2014) and Niakan and Ahmadi (2014).

For the interaction of number of filled grain/panicle clarified in *Table 11* that application of Crop plus under irrigation every 3-days produced the highest value of number of filled grains followed by irrigation every 9 days and surpassed both Cytokinin and ABA which perform the same trend. It can be also, noticed that the

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application of any of PGR to the tested cultivar caused an increase in number of filled grains as compared with control. The promoting effect of PGRs under irrigation intervals on number of filled grain/panicle were reported by Akita (1989), Gemici et al. (2002), Wiatrak (2012b), Nayar and Bott (2014) and Niakan and Ahmadi (2014).

Table 11. *Number of filled grain/panicle at harvest as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	154.90c	149.26d	148.00d-f	144.80f-i	146.50d	144.20e	143.60e	141.80g
(T2)	157.60abc	155.60bc	149.50d	145.80e-i	147.50c	147.50c	146.70d	146.63d
(T3)	160.10a	158.50ab	156.20bc	146.30d-i	149.00a	148.50ab	147.90bc	147.70c
(T4)	148.00d-f	145.50f-i	144.20h-j	139.40l-n	144.00e	143.70e	141.40h	140.50ij
(T5)	149.50d	148.87de	144.90f-i	140.00lm	146.20d	143.70e	141.50gh	140.60ij
(T6)	154.50c	149.00de	147.30d-h	143.37i-k	146.20d	144.00e	141.70g	141.40gh
(T7)	144.80f-i	144.37g-j	141.40j-l	136.20no	141.40gh	137.10l	137.00l	133.60n
(T8)	147.30d-h	145.00f-i	144.00h-j	136.70no	141.50gh	140.80hi	140.00j	138.10k
(T9)	147.80d-g	145.00f-i	144.00h-j	138.97l-n	143.70e	142.90f	140.30ij	138.30k
(T10)	141.40jkl	135.10o-q	134.66o-q	132.40qr	133.10no	132.30p	131.10q	127.30t
(T11)	144.00h-j	140.40kl	137.00m-o	135.10o-q	136.20m	133.20no	131.50q	129.60s
(T12)	144.30h-j	140.70kl	140.00lm	135.70op	140.40ij	135.80m	132.50op	129.80rs
(T13)	140.70kl	136.50no	132.60p-r	130.80r	130.40r	130.40r	130.00rs	124.20u

I1: irrigation every 3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

Panicle weight/g

Data in *Table 12* indicated that the highest weight of panicle was obtained when rice was irrigated every 3 days followed by irrigation every 6 days, while the lowest value was obtained with irrigation every 12 days in both seasons of the study. Similar results were reported by Islam et al. (1994b), Wu et al. (2011), Abouel-Yazied et al. (2012), Li et al. (2015) and Zheng et al. (2020).

Data in the same table revealed that Plant growth regulators caused an increase in panicle weight as compared with control. The highest panicle weight (g) was found when rice plants were sprayed with Crop plus at 1.5 ml/1liter followed by spraying at a concentration of 1 ml/1 liter while spraying by Crop plus by 0.5 ml/1liter water and Cytokinin with 25 and 20 ppm recorded nearly the same value followed by ABA which came in the third rank gave nearly the same value under different concentration of ABA in this aspect. Similar results were observed in the two seasons of the study.

Regarding the interaction effect among irrigation treatments and plant growth regulators (PGR) and biostimulants, data demonstrated that using any plant growth regulator recorded positive results under this study. Data in *Table 13* show that foliar application of Crop plus by 1.5 or 1 ml/1 liter under either the irrigation every 3-days or 6-days recorded nearly the highest values of panicle weight in the two studied seasons. It can be easily observed that there was any significant difference between the irrigation every 3-days and 6-days intervals in panicle weight when rice was treated by 1.5 or 1.00 ml/1 liter of Crop plus. It might be due to the role of these substances to help the plant for keeping the water inside the cell longer consequently extending the period of

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irrigation intervals that led to save reasonable amount of irrigation water. These results are in good agreement with those reported by Pospíšilová et al. (1993, 2000), Pospíšilová, and Rulcová (1999), Karimi et al. (2012) and Abdel-Megeed et al. (2017).

Table 12. *Panicle weight/g, 1000-grain weight/g and grain yield t/ha of Sakha108 rice cultivars as affected by different irrigation intervals and growth regulators during 2018 and 2019 season*

Treatments	2018			2019		
	Panicle weight/g	**1000-grain weight/g**	**Grain yield t/ha**	**Panicle weight/g**	**1000-grain weight/g**	**Grain yield t/ha**
Irrigation interval (A):						
(I_1)	5.51a	28.54a	10.79a	4.87a	27.32a	10.94a
(I_2)	5.08b	27.63ab	10.46a	4.64b	26.92b	10.62a
(I_3)	4.43c	27.10b	10.02b	4.5bc	26.62b	10.17b
(I_4)	3.55d	25.60c	9.59b	4.44c	25.91c	9.75b
F. Test	**	**	**	**	**	**
Growth regulates treatment (B)						
(T_1)	5.34bc	28.65abc	11.00ab	5.05bc	27.80c	11.16ab
(T_2)	5.51ab	29.23ab	11.13ab	5.16b	28.18b	11.28ab
(T_3)	5.71a	29.70a	11.38a	5.49a	28.79a	11.53a
(T_4)	4.82ef	27.17b-e	10.76bc	4.67d-f	27.00e	10.91bc
(T_5)	4.98de	27.45b-e	10.82bc	4.85cde	27.38d	10.97bc
(T_6)	5.17cd	28.18a-d	10.99abc	4.90cd	27.63cd	11.14a-c
(T_7)	4.44h	26.58cde	10.08d	4.46fgh	26.00g	10.19d
(T_8)	4.55gh	26.88cde	10.53c	4.50fg	26.25fg	10.68c
(T_9)	4.69fg	27.10b-e	10.74bc	4.61efg	26.50f	10.89bc
(T_{10})	3.68jk	25.78e	8.80ef	3.95i	25.28ij	8.96ef
(T_{11})	3.89ij	25.90de	8.94ef	4.25h	25.53hi	9.09ef
(T_{12})	4.11i	26.00de	9.13e	4.39gh	25.68h	9.28e
(T_{13})	3.49k	25.25e	8.55f	3.66j	25.00j	8.69f
F. Test	**	*	**	**	*	**
Interaction: AXB	**	ns	*	**	ns	*

I1: irrigation every 3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

1000-grain weight (g)

The influence of different water intervals on the 1000-grain weight was significant in both season of the study. Data in *Table 12* showed that the highest 1000-grain weight was obtained when rice plant was irrigated every 3-days without any significance under irrigation every 6-days which gave nearly the same value when rice plant was irrigated every 9-day. While the lowest weight was recorded in case of irrigation every 12-days. It could be attributed to the suitable geometric structure of rice plant which allow optimal penetration of light resulting in reasonable photosynthesis during both growth and filling periods consequently increase in metabolites stream translocated from source to sink resulting increase in filling percentage when rice plant irrigation every even 3, 6 and 9-days. The results showed that 1000 grain weight was reduced with reduced soil moisture levels. Lower soil moisture might decrease translocation of assimilates to the grain which lowered grain size. Islam et al. (1994a, b), Abd Allah et al. (2009), Wu et al. (2011), Li et

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al. (2015), Abdel-Megeed et al. (2017) and Zheng et al. (2020) also stated that water stress reduced grain weight.

Table 13. *Panicle weight/g as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	6.160bc	5.940cde	5.510d-i	3.760p-t	5.430bc	5.060b-h	4.920c-j	4.780d-m
(T2)	6.510ab	6.040bcd	5.660c-i	3.810o-s	5.570ab	5.080b-g	5.000c-i	4.990c-i
(T3)	6.750a	6.520ab	5.720c-i	3.840o-r	5.970a	5.560ab	5.310b-d	5.100b-g
(T4)	5.750c-h	5.490e-i	4.400l-n	3.620p-t	4.700e-n	4.680e-n	4.670e-n	4.630f-n
(T5)	5.780c-g	5.650c-i	4.790k-m	3.710p-t	5.150b-f	4.830d-l	4.710e-n	4.680e-n
(T6)	5.870c-f	5.850c-f	5.210i-k	3.760p-t	5.210b-e	4.900c-k	4.770d-m	4.730e-n
(T7)	5.220h-k	4.900jkl	4.120n-q	3.500r-v	4.570g-o	4.510h-p	4.400j-q	4.350k-q
(T8)	5.290g-k	5.200ijk	4.150n-p	3.540r-u	4.640f-n	4.520h-p	4.440i-p	4.410j-q
(T9)	5.540d-i	5.360fj	4.280mno	3.570r-u	4.680e-n	4.600f-o	4.600f-o	4.550g-p
(T10)	4.580l-n	3.610q-u	3.280s-v	3.240tuv	4.250m-s	3.880q-t	3.880q-t	3.770r-u
(T11)	4.770k-m	3.810o-i	3.660p-t	3.350r-v	4.470i-p	4.460i-p	4.070o-s	4.010p-s
(T12)	4.890jkl	4.290mno	3.750p-t	3.490r-v	4.490i-p	4.480i-p	4.300l-q	4.280l-r
(T13)	4.500lmn	3.410r-v	3.080uv	3.000v	4.170n-s	3.750stu	3.410tu	3.320u

I1: irrigation every 3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

From the result presented in *Table 12* spraying Crop plus with different concentrations and 25 ppm concentration of Cytokinin recorded nearly equal value of the highest 1000-grain weight/g followed by spraying with concentration of 20 and 15 ppm of Cytokinin while spraying of ABA and Trafos K came in the last rank. Whereas, control gave the lowest value of 1000-grain weight in both seasons. It can be easily noticed that the application of the plant growth regulating substance caused an increase in 1000-grain weight/g as compared with control treatments (Tap water). The treatments which did not involve plant growth regulator produced the lowest values in this aspect.

Grain yield t/ha

Data indicated that there was significant effect on rice grain yield due to the effect of different water intervals in both seasons of study as shown in *Table 12*. Irrigation every 3 and 6-days gave the highest grain yield in the two seasons of study followed by and 9-days which came in the second rank while irrigation every 12-days recorded the lowest grain yield in both seasons of the study. This mean irrigation every 6-days gave yield almost equal to irrigation every 3-days with saving more water for irrigation every 6-days. On the other side the reduction in grain yield under irrigation every 12 days could be attributed to the water stress which cause a decrease in both number of tillers and panicles, LAI, chlorophyll content, water and nutrient uptake as well as the shrinking in cell protoplasm, cell division and elongation consequently cause a reduction in the morphological and physiological process in the plant such as photosynthesis and its assimilates resulted in a decrease in filling percentage and rates which produced low panicle and 1000-grain weight that cause a significant reduction in the grain yield. There was a linear relationship between available water and yield, where reduction in available water limits evapotranspiration and

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consequently reduced yield, as reported by several researchers Hossain (2001), El- Refaee et al. (2012) and El-Habet (2014) reported that water stress at filling grains period with acceleration in ripening time, casing to a decreasing growth duration period which led to a reduction in grain filling. So, it was observed that grain yield per hill decreased in decreasing soil moisture level. Reduced grain yield under lower soil moisture levels might be due to inhibition of photosynthesis and less translocation of assimilates towards grain due to soil moisture stress. The results also agree with Akita (1989), Abouel-Yazied et al. (2012), Pospíšilová et al. (2000) and Hossain (2001).

Data listed in *Table 12* substantiated that, highly significant differences were found among different plant growth regulators (PGRs) and biostimulated grain yield in both seasons of study. Data indicated that Crop plus treatments of plant growth biostimulated at all tested growth stages with different concentrations and Cytokinin when rice plant was treated by 25 ppm concentration surpassed the other plant growth regulator recorded nearly the same value of grain yield and came in the first rank followed by when rice plant was treated by 15 and 20 ppm of Cytokinin came in the second rank in the two seasons of the study without any significant differences among them. The lowest value of grain yield was recorded when rice plant was not treated by any of plant growth regulator (Tap water only).

Data listed in *Table 14* revealed that statistical differences were found in grain yield due to the interaction between different irrigation intervals and various plant growth regulators in both seasons. Spraying Crop plus with different concentration even 1.5, 1.00 and 0.5 ml/1 liter water gave the highest grain yield under irrigation every 3, 6 and 9-days without any significant difference between them. For Cytokinin data showed also spraying with 25 ppm recorded the highest grain yield under irrigation 3 and 6-days and come in the second rank after Crop plus. Data revealed also Crop plus recorded superiority and recorded the highest grain yield under irrigation every 12-days than another plant growth regulator which recorded positive result under irrigation every 12 day and came in the second rank after Crop plus.

Table 14. *Grain yield t/ha as affected by the interaction between different irrigation intervals and growth regulators in 2018 and 2019 seasons*

	2018 season				**2019 season**			
	I1	**I2**	**I3**	**I4**	**I1**	**I2**	**I3**	**I4**
(T1)	11.540a-c	11.180a-e	10.860b-f	10.430d-h	11.693a-c	11.333a-e	11.013d-f	10.583d-h
(T2)	11.710ab	11.270a-d	11.090a-e	10.440d-h	11.863ab	11.423a-d	11.243a-e	10.593d-h
(T3)	12.080a	11.490abc	11.200a-e	10.730b-f	12.233a	11.643a-c	11.353a-e	10.883b-f
(T4)	11.150a-e	10.840b-f	10.700b-f	10.340d-j	11.303a-e	10.993d-f	10.853b-f	10.493d-j
(T5)	11.180a-e	11.010b-e	10.720d-j	10.370d-j	11.333a-e	11.163b-e	10.873b-f	10.523d-j
(T6)	11.540abc	11.160a-e	10.850d-j	10.410d-i	11.693a-c	11.313a-e	11.003b-f	10.563d-i
(T7)	10.850b-f	10.600c-g	10.200d-i	8.500mo	11.003b-f	10.753c-g	10.353e-j	8.653m-o
(T8)	11.130a-e	10.510c-h	10.230m-o	10.230d-j	11.283a-e	10.663c-h	10.383d-j	10.383d-j
(T9)	11.130a-e	10.800b-f	10.690d-j	10.340d-j	11.283a-e	10.953b-f	10.843b-f	10.493d-j
(T10)	9.400j-m	9.170k-n	8.350no	8.290no	9.553j-m	9.323k-n	8.503no	8.443no
(T11)	9.630g-l	9.410i-m	8.380no	8.330no	9.783g-l	9.563i-m	8.533no	8.483no
(T12)	9.890f-k	9.560h-l	8.730no	8.330no	10.043f-k	9.713h-l	8.883l-o	8.483no
(T13)	9.010k-n	9.000k-n	8.190no	7.980o	9.163k-n	9.153k-n	8.343no	8.133o

I1: irrigation every 3-days, I2: irrigation every 6-days, I3: irrigation every 9-days, I4: irrigation every 12-days, T_1: 0.5 ml Crop plus, T_2: 1.00 ml Crop plus, T_3: 1.5 ml Crop plus, T_4: 15 ppm Cytokinin, T_5: 20 ppm Cytokinin, T_6: 25 ppm Cytokinin, T_7: 15 ppm ABA, T_8: 20 ppm ABA, T_9: 25 ppm ABA, T_{10}: 1 ml Trafos K, T_{11}: 1.5 ml Trafos K, T_{12}: 2 ml Trafos K, T_{13}: Tap water

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The high concentration of any plant growth regulator under this study recorded the highest grain yield under irrigation every 3, 6, 9 and 12-days as compared with control (Tap water). While the lowest grain yield was recorded under irrigation every 12 days when rice plant was not treated with any plant growth regulator. From the previous studies, spraying with biozyme Crop plus, a commercial formulation of seaweed extract (Ascophyllum nodosum), enzymes and hydrolyzed proteins whereas, Spic cytozyme contain gibberellic acid, auxins, Cytokinins, seaweed extract (Ascophyllum nodosum), hydrolyzed proteins and trace elements. Also, spraying of Cytokinin (CK) on the grains during the growth stage leads to increase in Cytokinin (CK) in these organs. Increased Cytokinin (CK) concentration in seeds during cell division caused increase in the number of endospermic cells which had positive correlation with the increase in grain yield (Morris et al., 1993). The same trend was observed with high concentration of ABA (25 ppm) in the two studied seasons. It can be observed that under irrigation every 3 and 6-days there were not any significant differences among the tested PGRs Crop plus and Cytokinin. It is important to observe that Crop plus relieves the harm of water stress under irrigation every 12 days followed by Cytokinin and ABA as compared with control in the two studied seasons. Crop plus is synthetised in rice roots and directly increase the root depth and volume and its viability as a result to free amino acid metabolism. The Crop plus translocated to the rice shoots and indirectly controlled protein metabolism and chlorophyll biosynthesis as well as increased cell division and elongation, also, the Crop plus inhibited the senescence of leaves and increased the viability of leaves especially flag leaf and both the second and third leaves which caused an increase in photosynthesis and its product (assimilates) resulted in increased filling % that produced the heavier grains. Also, Cytokinin concentration was high in the spikelets during filling period and caused an increase in cell division and elongation in the spikelets and then reached to the minimum concentration at the end of the filling period. According to the findings of Kermode et al. (1989) and Yang et al. (2003) they found that the increase in ABA concentration at the beginning of cell division decreased it significantly. Also, ABA, contrary to CK, can reduce the grain filling period via stimulation of aging (Nooden, 1988) resulting in grain yield loss. The results also agree with Ashikari et al. (2005), Wiatrak (2012a, b), Nayar and Bott (2014) and Niakan and Ahmadi (2014).

Conclusion

Irrigation every 3 days gave the highest grain yield without any significant differences with irrigation every 6 days followed by 9 days while irrigation every 12 days recorded the lowest grain yield. According to the previous results, it can be concluded that sprayed Sakha 108 rice cultivar by Crop plus and cytokinin under water stress increase the rice grain yield. Also, Sakha 108 rice cultivar responded to Crop plus application compared to other regulator growth under water stress. Spraying with crop plus 1.5 ml/l prolonged the irrigation interval from 3 days up to 9 days without any significant difference in grain yield.

These results are very important for the farmers whose have shortage of water in rice fields. Finally, this study is needed to be extended to reach the best results about utilization of different growth regulators under different levels of water stress. Further studies are required to determine the amount of water irrigation under Egyptian condition.

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