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Effect of Irrigation Intervals and Silicon Sources on the Productivity of Broadcast-Seeded Sakha 107 Rice Cultivar

Mikhael, B. B.; M. M. A. Awad-Allah and E. E. Gewaily
Rice Research and Training Center, Field Crops Research Institute, Agricultural Research Center, Egypt

ABSTRACT

This investigation was carried out during the two summer seasons of 2016 and 2017 at Rice Research Department, Experimental Farm, Sakh, Kafrelsheikh Governorate, Egypt. The purpose was to study the response of Sakha 107 rice cultivar to irrigation intervals and Silicon sources under broadcast-seeded method. A strip-plot design with four replications, was used. The horizontal ports were devoted to the four irrigation interval, i.e. continuous flooding, irrigation every 6 days, irrigation every 9 days and irrigation every 12 days.. While, the different silicon sources; namely, potassium silicate, magnesium silicate and silica gel, as well as, the check treatment (without silicon application) were assigned in the vertical plots. The results cleared that, both continuous flooding and irrigation every 6 days gave the maximum values for number of tillers/m^2, chlorophyll content, number of panicles/m^2 number of grains/panicle, 1000-grain weight and grain yield, as well as, hulling and milling percentages without any significant differences during both seasons. However, the maximum significant values of flag leaf area, filled grains percentage, straw yield and head rice percentage were recorded with continuous flooding and significantly decreased with increasing irrigation intervals. The highest values of water use efficiency were obtained by 6 days interval. On the other side, irrigation every 12 days gave the lowest values of the studied mentioned traits, as well as, the longest vegetative growth period. Potassium silicate gave the highest values of plant height, number of panicles/m^2, number of grains/panicles filled grains parentage and 1000-grain weight, as well as, grain yield and milling percentage. While, the largest area of flag leaf and the highest percentages of hulling and head rice were obtained by either potassium silicate or magnesium silicate, which recorded the highest chlorophyll content in flag leaves comparing to check treatment. Thus, irrigation every 6 days could be the adequate water regime and potassium silicate as source of silicon could be mitigate the harmful effects of water shortage, improve grain yield and water use efficiency for Sakha 107 rice cultivar under broadcast-seeding method.

Keywords: Rice, irrigation intervals, water deficit, water use efficiency, silicon sources, broadcast and direct-seeding.

INTRODUCTION

Rice is a vital food crop for more than half of the world's population. The majority of rice eco-types are semi-aquatic crop adapted to saturated soil conditions (Champoux *et al.,* 1995).

In Egypt, irrigation water considers one of the most important factors limiting the development of agriculture. Furthermore, rice is one of the major water consuming crops and continuous flooding is the only irrigation regime. Irrigation water shortage during critical growth stages of rice are considered one of the most serious constants to rice production (Shehate, 2004 and Abd Allah *et al.,* 2010).

Water deficit stress increase stomata resistance, leaf hydrogen peroxide and proline concentrations, as well as, leaf lipid peroxidation in rice. However, Silicon fertilization improve these factors and alleviated membrane damage due to increasing the content of relative water in leaves. Silicon as an anti-stress agent can reduce cuticle transpiration and increase water use efficiency (Mauad *et al.,* 2016).

Guimaraes *et al.* (2016), mentioned that, the genotypes that exhibit less dense panicles, low sterility and greater 1000-grain weight under water stress should be prioritized, also, Sheng *et al.* (2005), found that, drought stress at tillering stage could enhance water use efficiency (WUE) of rice plant significantly during and treatment.

Low silicon content was reported to be associated with the old soils. In addition, it is common to find depletion of plant available silicon in soils where rice is cultivated for a long time Agostinho *et al.* (2017).

Effects of silicon on rice grain yield are related to the deposition of the element under the leaf epidermis of defense, reduces lodging increases photosynthesis capacity and decreases transpiration losses, so, silicon can be increase the tolerance of cereal crops, especially rice to both biotic and a biotic stress (Ahmad *et al.,* 2013).

The current study aimed to investigate the effect of different irrigation intervals and the silicon sources on the productivity of Sakha 107 rice cultivar under broadcasting method.

MATERIALS AND METHODS

Four irrigation intervals (continuous, flooding, irrigation every 6 days, irrigation every 9 days and irrigation every 12 days) and silicon sources; i.e, control (Without silicon application), potassium silicate, magnesium silicate and silica gel were used to evaluate Sakha 107 rice cultivar under broadcasting method.

Two filed experiments were conducted at the experimental farm of Rice Research and Training Center (RRTC), Sakha, Kafrelsheikh Governorate, Egypt, during the two successive Summer seasons of 2016 and 2017. Wheat was the previous winter crop in both first and second seasons. Soil physical and chemical analysis of the experimental sites, according to Piper (1950) and Black *et al.* (1965) in 2016 and 2017 seasons are presented in Table 1.

Table 1. Soil physical and chemical analysis of the experimental sites during 2016 and 2017 seasons.

Seasons	Physical analysis				Chemical analysis						
	Soil texture	Sand %	Silt %	Clay %	pH.	E.C ds/m	Organic mater %	Available nutrient (ppm) N	P	K	Zn
2016	Clayey	15.2	28.1	56.7	8.0	1.9	1.7	18.2	17.6	318	0.9
2017	Clayey	14.3	26.9	58.8	8.1	2.0	1.5	17.4	17.2	321	0.9

Strip-plot design, with four replications, was used. Irrigation treatments were randomly arranged in the horizontal plots, while the vertical plots were assigned to the three tested silicon sources, as well as, check treatment (without silicon application). Sowing date was 13th and 18th may during 2016 and 2017 seasons, respectively.

Potassium silicate and magnesium silicate were applied with foliar spraying at the concentration of 0.2% at two times 20 and 40 days after sowing while silica gel was added at the rate of 50kg/ha basally. Irrigation regimes was applied at 3 weeks after sowing. The other cultural practices for inbred rice cultivation under broadcast planting method were applied, according to Rice Research and Training Center recommendation.

Data of days to 50% heading, plant height (cm), number of tillers and panicles/m^2, flag leaf chlorophyll content (SPAD value), flag leaf area (cm^2), total number of grains/panicle, fertility percentage, 1000-grain weight (g), grain yield (t/ha.), straw yield (t/ha.) and harvest index, as well as, hulling, milling and head rice percentages were recorded, according to IRRI (1996). Total water applied in each irrigation treatment block was recorded by a calibrated water meter with water Pump, then, water saving and water use efficiency were calculated, according to Michael (1978). Moreover, the total water for main plot was used to estimate the water using efficiency for the sub-plot.

Analysis of variances for collected data were done, using IRRISTAT computer program, according to procedures of Gomez and Gomez (1984) and differences among treatment means were compared, using the revised L.S.D. at 5% probability level of significant, adapted by Duncan (1955).

RESULTS AND DISSCUSSION

I. Growth Parameters:

It could be easily observed from data illustrated in Table 2 that either continuous flooding or irrigation every 6 days recorded the maximum number of tillers/m^2, the largest area of flag leaf and the highest values of flag leaf chlorophyll content without any significant difference between them, expect flag leaf area. On the either side these traits were significantly decreased due to increasing irrigation interval up to 12 days. In addition, the shortest period from sowing up to heading of 50% of plants was recorded with continuous flooding and significantly increased with increasing irrigation intervals. However plant height was significantly decreased by increasing irrigation intervals.

Table 2. Plant height, number of tillers/m^2, flag leaf area flag leaf chlorophyll content and days to heading of broadcast-seeded Sakha 107 rice cultivar as affected by irrigation intervals and silicon sources during 2016 and 2017 seasons

Treatment	Days to 50% heading (Day)		Plant height (cm)		Number of Tillers/m^2		Flag leaf area (cm^2)		Flag leaf chlorophyll content (SPAD values)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation intervals (t):										
Continuous flooding	93.9d	94.7d	92.58a	91.76a	596a	579a	32.96a	33.73a	42.75a	41.83a
Irrigation every 6 days	95.8c	96.3c	90.32b	89.03b	585a	558a	31.08b	29.84b	41.63a	40.56a
Irrigation every 9 days	97.3b	97.9b	85.41c	83.69c	439b	472b	23.86c	23.63c	36.06b	35.65b
Irrigation every 12 days	99.4a	99.9a	74.66d	71.86d	366c	383c	13.93d	15.56d	24.38c	26.18c
F-test	**	**	**	**	**	**	**	**	*	*
Silicon sources (s):										
Control (without silicon application)	97.9a	98.4a	82.54c	80.66c	478	484	22.42d	21.92c	31.82d	32.14d
Potassium silicate	95.8b	96.3c	88.61a	87.78a	514	521	28.08a	27.76a	37.26b	36.36b
Magnesium silicate	96.3b	97.5b	85.99b	84.29b	499	502	26.39b	27.45a	40.05a	40.73a
Silica gel	96.4b	96.6c	85.83b	83.61b	495	486	24.94c	25.63b	35.69c	34.99c
F-test	*	*	**	**	NS	NS	**	**	**	**
Interaction (IXS)	NS	NS	**	**	NS	NS	**	**	**	**

Means not sharing the same letter significantly differ using DMRT.
*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS= Not significant.**

These results might be due to the wet and dry cycles enhances air exchange between soil and the atmosphere and may have contributed to more tillers number under both 3 and 6 days irrigation intervals (Singh *et al.,* 2013). In addition water shortage might be affected the root size, elongation and the division of cells which intern reduced plant height and delayed heading. These data go in line with those reported by Pascual and Wang (2016) and Zayed *et al.* (2017).

Potassium silicate gave the tallest plants, maximum number of tillers/m2 and shortest days to heading, while, magnesium silicate recorded the highest values of flag leaf chlorophyll content. The largest area of flag leaf was obtained by potassium silicate. Furthermore, either potassium silicate or magnesium silicate gave the largest flag leave area without significant difference between them in the second season.

The differences of silicon sources on number of tillers/m^2 were insignificant during the both seasons. In general, the lowest values of plant height, number of tillers/m^2, flag leaf area and flag leaf chlorophyll content, as well as, the longest growth period were obtained by control treatment (without silicon application). However, silica gel treatment recorded intermediate values. Yoshid *et al.* (1969) mentioned that the deposition of silicon in cell wall can increase rice plant height by making rice leaves and stems become more erect which decrease mutual shading, thereby increasing photosynthetic rate of the plant due to better high interception and improving vegetative growth. These findings are in harmony with those observed by Ranganathan *et al.* (2006), Ghanbari (2011) and Pati *et al*. (2016).

Plant height, flag leaf area and flag leaf chlorophyll content were significantly affected by the interaction between irrigation intervals and silicon sources, while, number of tillers/m^2 and days to heading were does not affected by the interaction (Table, 2). The tallest plants and largest area of flag leaf were detected with continuous flooding or irrigation every 6 days when potassium silicate was applied. On the other hand, the shortest plants and narrowest area of flag leaf in both seasons were obtained by irrigation every 12 days without silicon application (Tables 3 and 4).

Table 5 revealed that, the highest values of flag leaf chlorophyll content in both first and second seasons were obtained by either continuous flooding or irrigation every 6 days with magnesium silicate, that referred to the important role for magnesium element in the chloroplast structure.

Table 3. Plant height (cm) of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	91.83abc	93.22a	92.79ab	92. 48ab	90.63b	92.94a	91.88ab	91.59ab
Irrigation every 6 days	87.35ef	92.74ab	91.02bc	90.17cd	85.57d	92.37ab	91.72b	87.46c
Irrigation every 9 days	81.96h	88.86de	86.53f	84.29g	79.98f	87.64c	83.78e	83.36e
Irrigation every 12 days	69.02l	79.62i	73.62k	76.38j	66.46i	78.17g	70.78h	72.03h

Means not sharing the same letter(s) significantly differ using DMRT.

Table 4. Flag leaf area (cm^2) of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	33.06a	33.43a	32.63a	32.72a	33.54ab	34.14a	33.92a	33.31ab
Irrigation every 6 days	27.81b	32.48a	32.17a	31.36a	34.87f	31.65cd	32.28bc	30.56d
Irrigation every 9 days	19.54d	27.31b	24.92c	23.67c	17.93g	26.86e	24.76f	24.97f
Irrigation every 12 days	9.28g	18.59d	15.84e	12.01f	11.34i	18.39g	18.84g	13.68h

Means not sharing the same letter(s) significantly differ using DMRT.

Table 5. Flag leaf chlorophyll content (SPAD values) of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	40.18de	43.51abc	45.05ab	42.26bcd	37.52ef	41.63bc	46.14a	42.03b
Irrigation every 6 days	38.49ef	42.04cd	46.17a	39.82de	36.98fg	40.71bcd	45.86a	38.69def
Irrigation every 9 days	29.28g	37.62ef	40.44de	36.90f	31.27h	36.94fg	39.58cde	34.81g
Irrigation every12 days	19.33i	25.87h	28.54g	23.78h	22.79j	26.16i	31.34h	24.43ij

Means not sharing the same letter(s) significantly differ using DMRT.

II. Grain yield Components:

It is clear from data tabulated in Table 6 that, both continuous flooding and irrigation every 6 days treatments gave the maximum significant for number of panicles/m^2 and grains/panicle, as well as, the heaviest 1000-grain weight without significant differences between them dissentingly followed by irrigation every 9 and 12 days. In addition, continuous flooding recorded the maximum percentage of filled grains, then, significantly decreased by increasing irrigation intervals up to 12 days.

These findings might be due to water availability with continuous flooding and irrigation every 6 days treatments during crop growth stages which increased dry matter production and grain filling rate (Kamoshita *et al.,* 2008). Such results had, also, been pointed out by several researchers, such as Gaballah (2009) and El-Degwy and El-Banna (2010).

It was clear from Table 6 that potassium silicate gave the maximum significant number of panicles/m^2 and number of total grains/panicle followed by either magnesium silicate or silica gel without any significant differences. Moreover, the maximum significant values of filled grains percentage and 1000-grain weight were recorded with potassium silicate, dissentingly followed by magnesium silicate and silica gel. On contrast, the lowest values of these characters were obtained by control (without silicon application) during the both seasons. This enhancement of yield components by the application of potassium silicate might be due to the effectiveness of silicon in promoting the assimilation of carbohydrates in rice panicles, which leads to improved grain filling rate (Jawahar *et al.,* 2015). Similar findings were, also, obtained by Arab *et al.* (2011) Gholami and Falah (2013) and Dallagnol *et al.* (2014).

At the same irrigation treatment and potassium silicate gave the highest values of filled grains percentage and 1000-grain weight during both seasons, while, the lowest values were recorded without silicon applied (control treatment) (Tables 7 and 8). On the other side, the interaction between irrigation intervals and silicon sources failed to exert any significant effect on both number of panicles/m^2 and number of grains/panicle (Table 6).

Table 6. Number of panicles/m^2, number of total grains/panicle, filled grains percentage and 1000-grain weight of broadcast-seeded Sakha 107 rice cultivar as affected by irrigation intervals and silicon sources during 2016 and 2017 seasons.

Treatment	Number of panicles/m^2		Number of total grains/panicle		Filled grains percentage		1000-grain weight (g)	
	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation intervals (t):								
Continuous flooding	582a	571a	143.8a	146.1a	95.13a	94.87a	29.81a	29.19a
Irrigation every 6 days	545a	528a	136.5a	134.9a	93.61b	91.99b	29.32a	28.83a
Irrigation every 9 days	421b	443b	124.6b	16.5b	86.37c	87.54c	27.94b	27.59b
Irrigation every 12 days	325c	351c	93.0c	89.7c	79.09d	81.05d	24.29c	23.86c
F-test	**	**	**	**	**	**	**	**
Silicon sources (s):								
Control (without silicon application)	417c	429c	112.7c	110.8c	83.41d	83.96d	26.46d	25.97d
Potassium silicate	523a	512a	136.1a	133.5a	92.33a	92.18a	29.11a	28.69a
Magnesium silicate	474b	486b	125.2b	124.2b	90.52b	91.01b	28.27b	27.82b
Silica gel	459b	465b	123.9b	118.7b	87.94c	88.30c	27.53c	26.99c
F-test	**	**	**	**	**	**	**	**
Interaction (IXS)	NS	NS	NS	NS	**	**	**	**

Means not sharing the same letter significantly differ using DMRT.
*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS =Not significant.**

Table 7. Filled grains percentage of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	92.71cd	97.06a	96.27ab	94.48abc	92.18de	98.12a	95.91ab	93.27cd
Irrigation every 6 days	89.34e	96.34a	95.18abc	93.53bcd	87.83f	94.96bc	93.38cd	91.79de
Irrigation every 9 days	78.43h	91.64de	89.02e	86.39f	81.47h	90.21e	91.86de	86.62fg
Irrigation every 12 days	73.16i	84.23f	81.61g	77.36h	74.36i	85.43g	82.89h	81.52h

Means not sharing the same letter(s) significantly differ using DMRT.

Table 8. 1000-grain weight (g) of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	28.56cd	31.04a	30.38a	29.26bc	28.14de	30.59a	29.27bc	28.76cd
Irrigation every 6 days	27.44ef	30.97a	30.13ab	28.74c	27.06f	30.18a	29.46b	28.62cd
Irrigation every 9 days	27.06f	28.78c	28.29cde	27.63def	25.99g	28.68cd	28.13de	27.56ef
Irrigation every 12 days	22.74i	25.65g	24.28g	24.49h	22.69j	25.31h	24.42i	23.01j

Means not sharing the same letter(s) significantly differ using DMRT.

III. Grain yield, straw yield and harvest index:

Data in Table 9 showed that the maximum values of grain yield, straw yield and harvest index during both seasons were obtained by continuous flooding and irrigation every 6 days and the differences were insignificant except for straw yield in the second season. The lowest values in this regard were given by irrigation every 12 days treatment, moreover, the same trained for grain yield was found, that may be the soil fertility was similar in the two seasons, as shown in Table 1.

These results suggest that, rice does not need to be continuously submerged to produce high grain yield if the adequate water is provided at critical growth stages (Kima *et al.,* 2014). Such findings were, also, reported by El-Refaee *et al.* (2005), Sadeghi and Danesh (2011) and Sultan *et al.* (2013).

Data in Table 9, also, indicated that, potassium silicate gave the maximum significant values for grain and straw yields, as will as, harvest index as compared with control (without silicon application) which recorded the lowest values for the studied characters. However, magnesium silicate and silica gel recorded intermediate values. This positive response of grain yield to silicon application might be due to an enhanced growth, yield components, nutrients uptake by rice plants and improved pollen viability and photosynthetic activity (Cuong *et al.,* 2017). In addition, potassium silicate as, also, source of potassium which has an important role in increasing photosynthesis rate and increase stored carbohydrates and grain filling (Szczerba *et al.,* 2009). Such positive effects of silicon application in improving rice grain yield were, also, obtained by Hakim *et al.* (2012) and Manal Emam *et al.* (2014).

Table 9. Grain and straw yields as well as harvest index of broadcast-seeded Sakha 107 rice cultivar as affected by irrigation intervals and silicon sources during 2016 and 2017 seasons.

Treatments	Grain yield (t/ha.)		Straw yield (t/ha.)		Harvest Index	
	2016	2017	2016	2017	2016	2017
Irrigation intervals (I):						
Continuous flooding	10.07a	9.92a	13.19a	13.37a	43.29a	42.80a
Irrigation every 6 days	9.68a	9.71a	12.79a	12.97b	43.08a	42.91a
Irrigation every 9 days	8.33b	8.18b	11.38b	11.43c	42.20b	41.71b
Irrigation every 12 days	6.59c	6.64c	9.43c	9.29d	41.15c	41.61b
F-test	**	**	**	**	**	**
Silicon sources (S):						
Control (without silicon application)	8.07d	7.99d	11.15c	11.11d	41.84c	41.65c
Potassium silicate	9.38a	9.25a	12.17a	12.35a	43.40a	43.00a
Magnesium silicate	8.79b	8.84b	11.99a	12.02b	42.24b	42.35b
Silica gel	8.43c	8.37c	11.47b	11.58c	42.23b	42.04bc
F-test	**	**	**	**	*	*
Interaction (IXS)	**	**	NS	NS	NS	NS

Means not sharing the same letter(s) significantly differ using DMRT.
*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS = Not significant.**

The maximum grain yield in both seasons was recorded by potassium silicate with either continuous flooding or irrigation every 6 days. On contrary the lowest grain yield was recorded by irrigation every 12 days without silicon application (control) (Table 10).

Table 10. Grain yield (t/ha.) of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	9.63cd	10.48a	10.27ab	9.89bc	9.54bc	10.39a	10.13a	9.62bc
Irrigation every 6 days	9.28d	10.19ab	9.73cd	9.52cd	9.19cd	10.28a	9.96ab	9.41cd
Irrigation every 9 days	7.45f	9.67cd	8.31e	7.89e	7.58fg	8.97d	8.23e	7.94ef
Irrigation every 12 days	5.92i	7.16fg	6.86g	6.42h	5.65j	7.34gh	7.04h	6.52i

Means not sharing the same letter(s) significantly differ using DMRT.
The interaction had no significant effect on neither straw yield nor harvest index in both seasons (Table 9).

IV: Some of grain quality characters:

Either continuous flooding or irrigation every 6 days gave the highest significant percentages of hulling and milling. In addition, the maximum significant percentage of head rice was obtained by continuous flooding alone. On the contrary, the lowest percentages in this respect were obtained with 12 days irrigation interval (Table, 11). The obtained results are in agreement with those of Lee *et al.* (1996) and Kumawat *et al.* (2017).

Table 11. Hulling, milling and head rice percentages of broadcast-seeded Sakha 107 rice cultivar as affected by irrigation intervals and silicon sources during 2016 and 2017 seasons.

Treatments	Hulling (%)		Milling (%)		Head rice (%)	
	2016	2017	2016	2017	2016	2017
Irrigation intervals (I):						
Continuous flooding	84.48a	83.14a	72.39a	72.88a	62.97a	62.84a
Irrigation every 6 days	83.01ab	82.33ab	72.17a	72.68a	62.15b	92.57b
Irrigation every 9 days	82.39b	81.52b	71.56b	71.34b	61.36c	61.78c
Irrigation every 12 days	80.54c	79.95c	70.28c	69.85c	60.18d	60.13d
F-test	**	**	**	**	**	**
Silicon sources (S):						
Control (without silicon application)	81.58b	80.93b	70.46d	70.59d	60.97c	61.03c
Potassium silicate	83.17a	82.66a	72.58a	72.76a	62.31a	62.54a
Magnesium silicate	82.46ab	81.87ab	72.04b	72.11b	62.04a	62.11a
Silica gel	82.21ab	81.48b	71.32c	71.28c	61.52b	61.65b
F-test	*	**	**	**	**	**
Interaction (IXS):	NS	NS	**	**	NS	*

Means not sharing the same letter(s) significantly differ using DMRT.
*** = Significant at 0.05 level, ** = Significant at 0.01 level and NS= Not significant.**

Data of both seasons in Table 11, also, showed that potassium silicate treatment gave the highest significant percentages of hulling, milling and head rice. Interestingly, the differences between potassium and magnesium silicate were not significant in hulling and head rice percentages. On the other hand, control treatment (without silicon application) gave the lowest values in this regard. imilar results were reported by Seebold *et al.* (2000).

Concerning the effect of the interaction between irrigation intervals and silicon sources on milling percentage. Data in Table 12 clarified that, during both investigated seasons, at the same silicon source either continuous flooding or irrigation every 6 days gave the highest significant percentage of milling without any significant differences. Moreover, under the same irrigation treatment, potassium silicate recorded the maximum milling percentage. The interaction had a significant effect on head rice percentage only in the second season (Table 11). Continuous flooding with potassium silicate gave the maximum percentage of head rice, while, the minimum percentage was obtained by 12 days irrigation interval with control (without silicon addition) (Table 13).

Table 12. Milling percentage of broadcast -seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	71.56cd	73.18a	72.79a	72.03bc	72.06de	73.69a	73.21ab	72.54cd
Irrigation every 6 days	71.29cd	72.85a	72.58ab	71.96bc	71.83e	73.48ab	72.94bc	72.47cd
Irrigation every 9 days	70.38ef	72.57ab	71.86bc	71.43cd	70.15g	72.86bc	71.72e	70.63fg
Irrigation every 12 days	68.61g	71.72c	70.93de	69.87f	68.32i	71.01f	70.59fg	69.48h

Means not sharing the same letter(s) significantly differ using DMRT.

Table 13. Head rice percentage of broadcast-seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	2017			
	Silicon sources			
	Control (without silicon application)	Potassium silicate	Silicate	Silica gel
Continuous flooding	62.38d	63.48a	62.93c	62.57d
Irrigation every 6 days	61.79fg	63.25b	62.81c	62.43d
Irrigation every 9 days	61.41h	62.04e	61.99ef	61.68g
Irrigation every 12 days	58.52k	61.39h	60.71i	59.90j

Means not sharing the same letter(s) significantly differ using DMRT.

V. Water relations:

It is obvious from Table 14 that, total applied water was decreased with increasing irrigation intervals up to 12 days. Irrigation every 6 days recorded the highest water use efficiency dissendingly followed by irrigation every 9 days and continuous flooding, while, the lowest efficiency use of water was obtained by 12 days irrigation treatment.

Table 14. Total applied water, water saved, grain yield reduction and water use efficiency of broadcast-seeded Sakha 107 rice cultivar as affected by irrigation intervals during 2016 and 2017 seasons.

Irrigation intervals	Total applied water (m^3/ha.)		Water saved (%)		Grain yield reduction (%)		Water use efficiency (kg/m^3)	
	2016	2017	2016	2017	2016	2017	2016	2017
Continuous flooding	13843.9	14018.6	-	-	-	-	0.727	0.708
Irrigation every 6 days	12276.3	12559.4	11.32	10.41	2.12	3.39	0.789	0.773
Irrigation every 9 days	11139.8	11385.7	19.14	18.78	17.54	16.87	0.748	0.719
Irrigation every 12 days	9874.1	10241.5	28.68	26.94	33.07	34.23	0.667	0.648

Irrigation every 12 days save more amount of irrigation water, but, yield reduction increased to the highest level. Furthermore, the irrigation interval at (6 days) gave the lowest reduction percentage of grain yield and save a suitable amount of irrigation water.

In the similar results obtained by Eliba (2017), found that, the highest values of water use efficiency wee produced by using irrigation every 4 days in the two seasons, while the lowest mean values were obtained by using irrigation every to days respectively.

So 6 days irrigation interval could be the optimum treatment for achieving the high water use efficiency and saving moderate amount of irrigation water with minimizing the reduction of grain yield. Such findings were found by Ashouri (2014).

Potassium silicate with irrigation at 6 or 9 days gave the maximum water use efficiency (Table 15), while, the lowest values were obtained by the control (without silicon application) with irrigation every 12 days.

Table 15. Water use efficiency (kg/m^3) of broadcast -seeded Sakha 107 rice cultivar as affected by the interaction between irrigation intervals and silicon sources during 2016 and 2017 seasons.

Irrigation intervals	Silicon sources							
	2016				2017			
	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel	Control (without silicon application)	Potassium silicate	Magnesium silicate	Silica gel
Continuous flooding	0.696	0.757	0.742	0.714	0.681	0.741	0.723	0.686
Irrigation every 6 days	0.756	0.830	0.793	0.776	0.732	0.819	0.793	0.749
Irrigation every 9 days	0.669	0.868	0.745	0.708	0.666	0.788	0.723	0.697
Irrigation every 12 days	0.599	0.725	0.694	0.649	0.552	0.718	0.687	0.636

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تأثير فترات الرى ومصادر السليكون على إنتاجية صنف الأرز سخا 107 المنزرع بطريقة البدار

بطرس بشرى ميخائيل ، ممدوح محمد أحمد إبراهيم عوض الله و السيد السيد جويلى

مركز البحوث والتدريب فى الأرز ـ معهد بحوث المحاصيل الحقلية ـ مركز البحوث الزراعية ـ مصر

أجريت هذه الدراسة خلال موسمى صيف 2016 ، 2017م فى المزرعة البحثية لقسم بحوث الأرز بسخا ، محافظة كفرالشيخ ، مصر ، بهدف دراسة إستجابة صنف الأرز سخا 107 المنزرع بطريقة البدار لفترات الرى ومصادر السليكون. استخدم تصميم الشرائح المتعامدة فى أربعة مكررات. حيث وزعت فترات الرى (الغمر المستمر ، الرى كل 6 أيام ، الرى كل 9 أيام ، والرى كل 12 يوم) على الشرائح الأفقية ، بينما وزعت الثلاث مصادر المستخدمة لعنصر السليكون (سليكات البوتاسيوم ، سليكات الماغنسيوم والسليكا جيل) بالإضافة إلى معاملة المقارنة (بدون إضافة السليكون) على الشرائح الرأسية. أظهرت نتائج موسمى الدراسة أن كل من الغمر المستمر والرى كل 6 أيام أعطى أعلى القيم المعنوية من عدد الفروع/م^2 ، محتوى الورقة العلم من الكلوروفيل ، عدد الداليات/م^2 ، عدد الحبوب/الدالية ، وزن الألف حبة ، محصول الحبوب والنسبة المئوية للتبييض بدون أى اختلاف معنوى بينهما. فى حين سجلت أعلى القيم المعنوية لمساحة الورقة العلم ، النسبة المئوية للحبوب الممتلئة ، محصول القش ، والنسبة المئوية للتدريج مع الغمر المستمر ثم انخفضت قيم هذه الصفات معنويا بزيادة فترات الرى. حقق الرى كل 6 أيام أعلى كفاءة لاستخدام المياه. على النقيض من ذلك فإن الرى كل 12 يوم أعطى أقل القيم المعنوية للصفات المدروسة إلى جانب أطول فترة للنمو الخضرى. بينت النتائج أيضا أن سليكات البوتاسيوم حققت أعلى القيم المعنوية لارتفاع النبات ، عدد الداليات/م^2 ، عدد الحبوب/الدالية ، وزن الألف حبة ، محصول الحبوب ، والنسبة المئوية للتبييض ، علاوة على ذلك فإن أكبر مساحة للورقة العلم وأعلى النسب المئوية للتقشير والتدريج قد لوحظت مع كل من سليكات البوتاسيوم وسليكات الماغنسيوم بدون فروق معنوية بينهما. كما أظهرت النتائج أيضا أن سليكات الماغنسيوم سجلت أعلى محتوى معنوى من الكلوروفيل فى الورقة العلم. أوضحت النتائج أيضا أن معاملة المقارنة (بدون إضافة السليكون) أعطت أقل القيم المعنوية للصفات المدروسة وأيضا أطول فترة من النمو الخضرى. لم تتأثر صفة عدد الفروع/م^2 معنويا بأى من مصادر السليكون. فى ضوء النتائج المتحصل عليها فإن الرى كل 6 أيام يعتبر أفضل نظام للرى ، علاوة على ذلك فإن سليكات البوتاسيوم كمصدر للسليكون مفيدة فى تقليل الآثار الضارة لنقص المياه وتحسين محصول الحبوب وكفاءة استخدام المياه لصنف الأرز سخا 107 تحت طريقة الزراعة البدار.