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Improve the Lodging Resistance and Grain Yield of Sakha 104 Rice Cultivar Through the Use of Silicon Application

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ABSTRACT

During the two seasons of 2018 and 2019, a field experiment was carried out at The Experimental Farm of Rice Research Department, Sakha, Kafrelsheikh, Field Crops Research Institute, and Agricultural Research Center, Egypt. In order to determine the appropriate stage of potassium silicate application to improve some of morphological, chemical characters related to the lodging resistance and increase the grain yield of Sakha 104 rice cultivar. Four replications of a randomised complete block design were used.. The eight treatments of foliar applications of potassium silicate at the rate of 1.0% were used as follows; (T_1) control (without potassium silicate application); (T_2)at vegetative stage; (T_3)at reproductive stage; (T_4) at maturity stage; (T_5) at vegetative stage+ reproductive stage; (T_6) at vegetative stage+ maturity stage; (T_7) at reproductive stage+ maturity stage; (T_8) at vegetative stage+ reproductive stage+ maturity stage. The results showed that the most studied characters of Sakha 104 rice cultivar were generally increased by the application of (T_5) treatment followed by T_8 treatment, while (T_1) treatment resulted the maximum degree of lodging. According to the previous results and under the same conditions of experiment, it could be summarized that adding potassium silicate as foliar application at the same concentration 1.0% twice at vegetative and reproductive stages (T_5 treatment) was the best treatment for improving morphological, chemical characters related to lodging resistance and obtaining the highest grain yield of Sakha 104 rice cultivar.

Keywords: Potassium Silicate, Lodging Resistance, Rice and Silicon.

INTRODUCTION

In Egypt, rice crop have a vital position in the agricultural economy sector which assumed one of the important main cereal crops which required to improving the yield, grains quality characters and the quality of the applied elements nutrition. In agriculture and crop production one of the important aspects is nutrient management. It involves proper foliar addition of nutrients or fertilizers at the right rate and time. This practice potentially could save the cost of management and minimize the loss of the yield. Rice growth plant is divided and obtained into three basic stages; vegetative, reproductive and maturity as summarized by Yoshida, 1981. It is surely necessary to determine the appreciate and proper stage of application to enhance the productivity and efficiency of nutrient uptake as wrong timing would be an absolute waste of resources and prove costly. Amount of nutrient uptake is dependent upon the uptake pattern of the crop and may differ according to the stage of growth. Moreover, the addition at the appropriate stage would decrease nutrient loss.

the traits which are most commonly associated with and related to the resistance of lodging in rice are height of the plants, diameter of the culm and the strength, thickness of the lower and the upper internodes, the thickness of the stem wall, cellulose and lignin accumulation in the stem wall, and the weight of grains as said by Wang *et al.,* 2011. Silicon absorption is activated in rice plants, so it's not be affected by the ratio of transpiration and this element is accumulated in shoots(stems) and leaf, sclerenchyma, vascular sheaths and vascular tissues, young leaves have less silicon than the old leaves as summed up by Tanaka and Park, 1996. Silicon considered to be accumulated in leaves Elawad and Green, 1979, increase the resistance to the diseases which caused by fungal as abstracted by Datnoff *et al.,* 1997 and caused to increase the percentage of filled seeds and the yield grains Datnoff *et al.,* 2001. Silicon enhance and increase the total number of seeds per panicle, the percentage of filled seeds, 1000-seed weight, grain yield and to decrease the degree of lodging plants as briefed by Chaoming *et al.,* 1999. Silicon boosts vegetative growth, accumulates dry matter, and reduces transpiration, all of which have an impact on grain output and grain quality Agarie *et al.,* 1993. As stated by, silicon is essential for the stability of rice grain production Mauad *et al.,* 2003. According to, the application of silicon directly affected the growth of leaves, stems, and plant sheaths, especially in rice, which increased the canopy's capacity to emit light Savant *et al.,* 1997. When silicon is applied correctly, plants become more resistant to salt, drought, and lodging, as described by Bocharnikova and Matichenkov, 2008. In addition to increasing plant height, inter-node length, fresh weight, bending moment, breaking resistance, and lodging index, silicon improved rice's tolerance for lodging Fallah, 2008.

By making the rice culm stronger mechanically or physically, lodging may be reduced. The properties of silicon (Si) are stiffness and durability Ismail *et al.,* 2017. Lodging is regarded as one of the most affected environmental factors that makes harvesting difficult and results in a significant loss of grain quality and grain

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production, according to Ookawa and Ishihara, 1993 and Liaqat *et al.,* 2019. Lodging mainly happens when the plant's stem is too frail to carry the weight of its grain, and at that point, a small amount of wind can also contribute to lodging. Previous research has demonstrated a selective correlation between lodging resistance in rice and the diameter of the stem and plant height.

At proper height levels, high-yielding rice varieties were created during the Green Revolution, but not nearly enough to handle the current environmental degradation. We should require stronger rice varieties to address this crucial issue. Less energy is expended on stem growth in shorter rice plants, which can enhance stem diameter and improve and boost grain yield and lodging resistance. Internode length and width play a significant role in determining the height of the centre of gravity and the resistance to stem lodging, which in turn determines the height of rice plants. In particular Si-accumulators like rice plants, silicon (Si), which is gaining popularity, is believed to promote plant growth, development, mechanical strength, and disease resistance Ning *et al.* 2014. Deivaseeno *et al,*. (2017) found that all Si-treated plants had more tillers, spikelets per panicle, effective tillers, filled spikelets as a percentage of total spikelets, and weight per panicle than control plants did. Bending characteristics showed that the degree of lodging was higher in Si-containing non-treated plants. The amount of chlorophyll, the area of the flag leaf, and the Si content of the leaves and stems all increased significantly in rice plants that had been treated with silicon. Growth, yield, and lodging resistance of MR219 are influenced by silicon.

Potassium silicate offers a number of potential advantages, thus an adequate supply is necessary for the rice crop to grow healthily, develop productively, and produce the greatest amount of grain. (Kang, 1985) also noted that the silicon foliar spray at 100 to 400 ppm applied twice to the seeding of rice plants at the booting stage increased the capacity of tillering, improved the vegetative growth rate consequently increased the dry matter yield and accelerated heading and photosynthetic efficiency. Silicon hydrated amorphous compounds are advantageous for depositing above and below the cuticle layer in areas of the cell such as the walls, lumens, and intercellular spaces. The goal of the current study was to identify the ideal time to apply potassium silicate in order to enhance the physiological parameters, lodging resistance, and agronomic characteristics of the Sakha 104 rice cultivar.

MATERIALS AND METHODS

In order to improve some morphological and chemical characters related to lodging resistance and increase the grain yield of the Sakha 104 rice cultivar, field experiments were carried out at The Experimental Farm of Rice Research Department, Sakha, Kafrelsheikh, Egypt during the 2018 and 2019 rice growing seasons. The prior crop throughout the two study seasons was barley, and soil samples were taken at random from the experimental site at depths ranging from 0 to 30 centimetres below the soil's surface for both chemical and physical analysis. Following the procedures outlined by Black *et al.,* the chemical and physical examinations of the soil were conducted (1965). The experimental site's soil chemical and physical analyses from the 2018 and 2019 growing seasons are shown in Table 1.

The experimental design:

Randomized complete block design (R.C.B.D.) was the experimental design that was used, with four replications spread across the two seasons. The eight treatments of potassium silicate (10% K_2o and 25% Sio_2) that were allotted for this study experiment's foliar application were distributed as follows: (T_1), control (without potassium silicate application); (T_2), 1.0%potassium silicate were sprayed at vegetative stage; (T_3), 1.0%potassium silicate were sprayed at reproductive stage; (T_4), 1.0%potassium silicate were sprayed at maturity stage; (T_5), 1.0%potassium silicate were sprayed with the same concentration at vegetative stage+ reproductive stage; (T_6), 1.0%potassium silicate were sprayed with the same concentration at vegetative stage+ maturity stage; (T_7), 1.0%potassium silicate were sprayed with the same concentration at reproductive stage+ maturity stage; (T_8), 1.0%potassium silicate were sprayed with the same concentration at vegetative stage+ reproductive stage+ maturity stage.

Nursery preparation:

The nursery area was clarified and identified, ploughed twice and well dry levelled then, before ploughing four kilogram calcium super phosphate (15.5% P_2O_5/175 m^2 land area)was applied, three kilogram urea (46.5% N/175 m^2 land area) was added after ploughing and zinc sulphate ($ZnSO_4$) at the rate one kilogram was applied after buddling (wet leveling). The other all culture practices were applied as recommended for the nursery. In order to expedite early germination, rice seeds were soaked in fresh water for 24 hours and then incubated for another 48 hours at a rate of 50 kg fed^{-1}. In the nursery, pre-germinated seeds were evenly distributed on May 20^{th} and 17^{th} of the 2018 and 2019 growing seasons, respectively, with a water depth of 2 to 3 cm.The weeds controlled in nursery land were chemically controlled using 5 liters/ha of Saturn 50% (85 cm^3 / 175 m^2 nursery land area) applied to sufficient sand to facilitate uniform distribution and it was applied at seven days after sowing into 3 cm water depth. All the other cultural practices were done as the recommendation of the Rice Research Department (R.R.D.).

The permanent field

The permanent field area was prepared well by plowing twice and harrowing fine then, the dry levelled well and carefully made the light wet levelling. Each plot of the experimental site was fertilized by the rate of 36 kg P_2O_5 per ha during soil preparation, in the form of calcium super phosphate (15.5 percent P_2O_5). One inorganic nitrogen 150 kg ha^{-1} (urea 46% N) was applied in two split doses (2/3 as basal, 1/3 top dressing at 30 days after transplanting). The seedling at twenty six days old were pulled and transferred to the permanent field area then, regularly transplanted at 20*20 cm distances between hills and rows (25 hills m^{-2}) in each plot. In both studied seasons four seedlings per hill in all plots were transplanted. The size of each plot was 12 m^2 (3m × 4m). Weeds were chemically controlled using Saturn 50% at a rate of 5 L/ha and combined with sufficient sand to facilitate even distribution. It was applied at four to five days after transplanting into water depth(3 cm) and kept without either flushing or irrigation till all the water in the field reach to the saturation point to increase the efficiency of the herbicide to control weeds. The other usual cultural practices were conducted according to the recommendation of Rice Research Department (R.R.D., 2020).

Table 1. lists some of the physical and chemical characteristics of the experimental soil prior to planting in the summers of 2018 and 2019.

Soil properties	2018	2019
Mechanical:		
Clay %	55.0	56.0
Silt %	33.5	35.0
Sand %	12.5	12.0
Texture	Clayey	Clayey
Chemical:		
Organic Matter (O.M)%	1.55	1.68
pH(1:2.5 soil suspension)	8.37	8.44
Ec ($ds.m^{-1}$)	2.98	3.11
Total N (ppm)	477.0	430.5
Available P (ppm)	13.0	12.0
Available K (ppm)	448	462
Available ammonium (ppm)	17.9	18.7
Nitrate concentration (ppm)	13.8	14.2
Soluble anions, $meq.L^{-1}$:		
CO^{--}_3	--	--
HCO^-_3	5.30	6.00
Cl^-	8.50	8.80
$SO^{=}_4$	17.4	17.5
Soluble Cations, $meq.L^{-1}$:		
Ca^{++}	9.7	10.3
Mg^{++}	4.0	4.2
Na^{++}	2.0	2.1
K^+	15.5	15.7
Availabe micronutrients (ppm)		
Fe^{++}	5.1	5.8
Mn^{++}	3.4	3.7
Zn^{++}	1.00	1.10

Studied characters:

Growth characters were; Culm length (cm) at 5 days before harvest which measured from the soil's surface to the panicle's peak, Flag leaf area (cm^2) which estimated at 15 days after completing all treatments. Third internode length and fourth internode length (cm) at 5 days before harvest, culm diameter(mm) at 5 days before harvest measured for the third internode from upward, Visual scoring was used to determine the percentage of plants that lodged at 5 days prior to harvest. items were evaluated on a 1 to 9 point scale where 1 was means totally upright and 9 was means totally lodged (lodging scale: 1 means (no lodging), 3 means (0%–10% lodging), 5 means (11%–25% lodging), 7 means (26%–50% lodging), 9 means (>50% lodging) as described *by* (TTSM 2003), dry matter accumulation ($gm./m^2$) estimated at 15 days after completing all treatments and grain yield(t/fed).

chemical characters were: chlorophyll a & b content(mg/cm^2) Spectrophotometer measurements were made on the flag leaf samples estimated at 15 days after completing all treatments according to Coombs *et al.* (1985).: Total carbohydrates in shoots at 5 days before harvest(mg/g DWT)were determined colorimetrically as described by Dubois *et aI.*(1956).: Soluble sugars in shoots at 5 days before harvest (mg eqv. /glucose g FW), were determined colormetricaly according to Thomas and Dutcher (1924).: Determination of cellulose, hemicellulose and lignin content in shoots at 5 days before harvest using visible and near infrared spectroscopy as described by Hayes, 2012.: Determination of silicon content in shoots at 5 days before harvest was conducted according to the method described by Dai *et al.* (2005).

Statistical data analysis:

The study's data were subjected to the analyses of variance defined by Gomez and Gomez (1984), and according to Russel, all statistical analysis was carried out using the "MSTATC" computer software programme (1986). The Duncan's Multiple Range Test, as described by Duncan (1955) was used to compare the treatment mean values.

RESULTS AND DISCUSSIONS

The obtained results from the present investigation on growth characteristics, yield and chemical characters of Sakha 104 rice cultivar as affected by potassium silicate application of the two growing season 2018 and 2019 were statistically analysed and discussed as follows:

Growth characters:

Results demonstrated in Table(2) observed that sprayed potassium silicate at any stage of the rice stages caused an significant increase in Culm length(cm), flag leaf area(cm^2), third internode length(cm) and fourth internode length(cm) as compared with the control treatment which didn't receive any of the tested potassium silicate treatments. The greatest values of the previously studied growth characters were registered from the sprayed potassium silicate (T_5 treatment), followed by the sprayed potassium silicate at vegetative stage+ reproductive stage+ maturity stage (T_8 treatment) in the two studied seasons, respectively. While the lowest values of the three previously mentioned growth characters were observed with control (T_1 without sprayed potassium silicate). Yoshida *et al.*, (1962) clarified that this increase of the plant height and the internodes may be due to the favourable effect of silicon on cell division, elongation of internodes and on stature of leaves. Silicon increase vegetative growth, and decrease transpiration *(*Agarie *et al.,* 1993). Silicon application boosted light contribution inside of canopy by promoting growth of leaves, stems, and plant sheaths, especially in rice (Savant *et al.,* 1997). Plant height, inter-node length, and fresh weight were all boosted by silicon (Fallah, 2008). Growing in popularity, silicon (Si) is believed to enhance plant growth, development, and mechanical strength, particularly in Si-accumulators like rice plants, which frequently benefit from Si fertilisation (Ning *et al.* 2014). Flag leaf area, chlorophyll content, and Si content all increased significantly in plants that had been treated with Si. silicon's effects on the Malaysian lowland rice variety MR219's development, yield, and resistance to lodging. Potassium silicate has several potential benefits consequently its sufficient supply is required for healthy growth and productive development of the rice crop. (Kang, 1985) also, observed that foliar spray of 100 to 400 ppm silicon applied twice to rice seeding at the booting stage increased tillering capacity, improved vegetative growth consequently increased dry matter yield and hastened heading and photosynthetic efficiency. The superiority of the potassium when applied as foliar spray could mainly be due to its role for increase the potassium supply viability of rice leaves and delayed leaf senescence specially flag leaf as the result of the increase in both protein and chlorophyll synthesis with the reduction in abcisic acid (ABA), also, potassium improve the activity of the enzymes related to biosynthesis of auxinex and growth substances in plants which improve the plant growth consequently the increase in photosynthesis and its products (assimilates) resulted in increased the dry matter accumulation (Randall *et al.,* 2003). By increasing the amount of light that reaches the plant's leaves, potassium silicate enhances the architecture of rice plants, resulting in a rise in both the leaf area index and photosynthetic rate. An increase in photosynthetic rate leads to an increase in NADP and NADPH reducing power, which has the effect of increasing the capacity to assimilate nitrogen and increasing the amount of dry matter accumulation (Taiz and Zeiger, 2010). Interesting silica had favourable effect on rice growth, since it improve photosynthesis, reducing respiration and increased cell division and elongation turn in good canopy resulted in high LAI. Similar findings had been reported by Singh and Singh (2006) and Singh *et al.,* (2006). Dastan *et al.,* (2012) indicated that the application of silicon rates had a significant effect and increased the third internode length (cm) and fourth internode length(cm) and caused an increase in plant height and stem length.

Table 2. Culm length(cm), flag leaf area(cm²), third internode length(cm) and fourth internode length(cm) of Sakha 104 rice cultivar as affected by sprayed potassium silicate at different growth stages in 2018 and 2019 seasons.

Treatments	Characters							
	Culm length (cm)		Flag leaf area (cm²)		Third internode length(cm)		Fourth internode length(cm)	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	115.53d	115.00c	13.39g	12.59f	27.07e	26.00d	25.01g	24.23f
T2	121.27bc	120.37b	15.45e	14.49d	29.00cd	28.30c	26.33e	25.66d
T3	121.90abc	121.93ab	16.18d	14.49d	29.20bcd	28.70bc	27.03d	27.20c
T4	119.67bc	120.30b	14.38f	13.15e	28.30de	28.00c	25.99f	25.05e
T5	125.10a	124.00a	21.15a	19.93a	31.07a	30.33a	28.15a	27.67a
T6	122.00abc	120.13b	19.45c	18.12c	29.50bcd	29.30abc	27.61c	27.25bc
T7	122.03abc	121.73ab	19.49c	18.35b	29.80abc	29.67ab	27.74bc	27.47ab
T8	123.30ab	122.47ab	19.82b	18.35b	30.53ab	30.00ab	27.91ab	27.50ab
F. test	*	*	**	**	**	**	**	**

(T_1), control (without potassium silicate), (T_2) foliar application of potassium silicate at vegetative stage, (T_3) foliar application of potassium silicate at reproductive stage, (T_4) foliar application of potassium silicate at maturity stage, (T_5) foliar application of potassium silicate at vegetative stage+ reproductive stage, (T_6) foliar application of potassium silicate at vegetative stage+ maturity stage, (T_7) foliar application of potassium silicate at reproductive stage+ maturity stage, (T_8) foliar application of potassium silicate at vegetative stage+ reproductive stage+ maturity stage .
***and ** indicate $p < 0.05$, and $p < 0.01$. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

Results associated with Culm diameter (mm), Degree of lodging, Dry matter accumulation (gm/m²) and grain yield (t/fed) of Sakha 104 rice cultivar as affected by spraying potassium silicate at different stages of growth in 2018 and 2019 seasons are listed in Table 3.

In the studied seasons the sprayed of potassium silicate at the tested stages caused a significant increase in the studied characters listed in table 3 as compared with control treatment. The lowest values of these characters were found when the tested cultivar didn't receive potassium silicate (control). The greatest values of the three previously mentioned characters were recorded when the tested rice cultivar sprayed by potassium silicate (T_5) treatment, followed by T_8 treatment which received potassium silicate at (vegetative stage+ reproductive stage+ maturity stage). These increases of grain yield might be owing to the foliar of potassium silicate to the rice which is more beneficial and increase the amount and translocation of carbohydrates from stems, leaf sheathes and other storage organs to grain, leading to high sink capacity and subsequently, higher grain yield as a result to the role of potassium for enhancing the activity of enzymes related to the biosynthesis of carbohydrate. This corroborated of findings by Korndörfer *et al.* (2004), Prakash *et al.,* (2011), Wattanapayapkul *et al.,* (2011) and (Gholami and Falah, 2013) reported that sprayed potassium silicate increased grain yield by about two – fourteen percentage(2-14%) over the control. The effects of silicon and potassium, in the form of potassium silicate, on grain yield are due to the elements being deposited under the leaf epidermis, which produces a physical defense mechanism, lowers lodging, boosts photosynthesis capacity, and lowers transpiration losses, all of which lead to a decrease in the rate of unfilled grains and an increase in grain yield (ton/ha). The outcomes support Nagarathna and Prakasha's findings (2007). The addition of potassium silicate to the soil boosted the photosynthetic efficiency, which may have aided plant growth. This effect was seen in the proportion of filled grains, the length of the panicle, and the number of productive tillers. The addition of potassium silicate to the soil boosted the photosynthetic efficiency, which may have aided plant growth. This effect was seen in the proportion of filled grains, the length of the panicle, and the number of productive tillers. Also, because of the role of silicon in increase the strength of cell wall by precipitate the cuticle layer resulted in more erect leaves which gave the chance of light to penetrate most of the leaves that increase the photosynthesis and its products consequently increase filling rate and percentage which lead to increase grain yield. The deposition of the elements under the leaves' epidermis produced a physical defensive mechanism, increased photosynthetic capacity, decreased transpiration losses, and decreased lodging, all of which are positively correlated with silicon's impacts on yield (Korndörfer *et al.,* 2004). Zhang *et al.,* (2014) indicated that divides the fertilizers into rates decreased the breaking strength of culms and decreased the section modulus. Dastan *et al,.* (2012) clarified that applied nitrogen and silicon into doses caused a significant increase in morphological and growth characters in rice. Silicon enhanced the plant height, bending moment, inter-node length, breaking resistance, fresh weight, rice with a higher tolerance for lodging and a lodging index (Fallah, 2008).

Table (4) shows the impact of Sakha 104 rice cultivar potassium silicate timings on the number of panicles per square metre, the number of grains per panicle, the percentage of filled grains, and the weight (gm) of 1000 grains in the 2018 and 2019 growing seasons.

Table 3. Culm diameter(mm), Degree of lodging, Dry matter accumulation (gm/m^2) and grain yield (t/fed) of Sakha 104 rice cultivar as affected by sprayed potassium silicate at different growth stages in 2018 and 2019 seasons.

Treatments	Characters							
	Culm diameter (mm)		Degree of lodging		Dry matter accumulation (gm/m^2)		Grain yield (T/fed)	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	4.157d	4.018d	7a	7a	890.4e	817.6h	3.991e	3.983d
T2	5.146c	5.033c	5b	5b	930.8d	883.3f	4.264d	4.201c
T3	5.462b	5.281b	5b	5b	987.3c	909.1e	4.586c	4.545b
T4	5.097c	4.984c	7a	7a	921.3de	865.5g	4.224d	4.188c
T5	5.674a	5.592a	3c	3c	1156.0a	1072.2a	4.789a	4.735a
T6	5.538ab	5.400ab	5b	5b	1010.0c	947.3d	4.6310c	4.585ab
T7	5.602ab	5.461ab	3c	3c	1096.0b	1013.1c	4.683bc	4.628ab
T8	5.643a	5.553a	3c	3c	1109.0ab	1029.5b	4.718ab	4.645ab
F. test	**	**	**	**	**	**	**	**

(T_1), control (without potassium silicate), (T_2) foliar application of potassium silicate at vegetative stage, (T_3) foliar application of potassium silicate at reproductive stage, (T_4) foliar application of potassium silicate at maturity stage, (T_5) foliar application of potassium silicate at vegetative stage+ reproductive stage, (T_6) foliar application of potassium silicate at vegetative stage+ maturity stage, (T_7) foliar application of potassium silicate at reproductive stage+ maturity stage, (T_8) foliar application of potassium silicate at vegetative stage+ reproductive stage+ maturity stage .
***and ** indicate p< 0.05, and p<0.01. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

Table 4. Number of panicles /m^2, Number of grains /panicle, Filled grains (%)) and 1000-grain weight (gm) of Sakha 104 rice cultivar as affected by sprayed potassium silicate at different stages of growth in 2018 and 2019 seasons.

Treatments	Characters							
	Number of panicles /m^2		Number of grains /panicle		Filled grains (%)		Thousand grain weight (gm)	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	409.85h	402.80h	144.9g	140.2e	94.74f	93.001 h	26.09e	26.03f
T2	435.41f	430.20f	159.0e	154.0d	95.95d	93.490f	26.66d	26.61def
T3	446.59e	443.10e	165.6d	160.1c	96.23c	93.922 e	28.20c	26.86cde
T4	429.01g	425.08g	155.7f	151.6d	95.67e	93.293 g	26.15e	26.29ef
T5	496.61a	490.80a	182.4a	176.8a	96.98a	95.110 a	28.56a	27.91a
T6	460.29d	455.30d	166.9d	161.0c	96.61b	94.259 d	28.25bc	27.11bcd
T7	470.10c	468.25c	171.4c	167.7b	96.67b	94.518 c	28.47ab	27.45abc
T8	480.21b	480.00b	176.9b	172.3ab	96.78b	94.857 b	28.50ab	27.63ab
F. test	**	**	**	*	**	**	**	*

(T_1), control (without potassium silicate), (T_2) foliar application of potassium silicate at vegetative stage, (T_3) foliar application of potassium silicate at reproductive stage, (T_4) foliar application of potassium silicate at maturity stage, (T_5) foliar application of potassium silicate at vegetative stage+ reproductive stage, (T_6) foliar application of potassium silicate at vegetative stage+ maturity stage, (T_7) foliar application of potassium silicate at reproductive stage+ maturity stage, (T_8) foliar application of potassium silicate at vegetative stage+ reproductive stage+ maturity stage .
***and ** indicate p< 0.05, and p<0.01. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

As for times treatments of potassium silicate application, Table (4) revealed that during both 1st and 2nd seasons adding (T_5 treatment) registered the highest ratio of panicles to square metres, number of grains per panicle, percentage of filled grains, and weight of 1000 grains (gm) followed by (T_8 treatment). On contrast, the unfertilized treatment by potassium silicate (T_1 treatment) gave the lowest values of the four tested characters in both seasons, respectively. The superiority of T_5 and T_8 treatments could mainly be due to their capability on produce more effective tillers. Also, this might be owing to the continuous supply of potassium silicate to the crop at the period when it is growing, which is more advantageous and increases the overall number of panicles. Also, it could be concluded that the increase in number of panicles per m^2 resulted from increase in tillers per square metre as a result of the stimulation from branches which gave more panicles per square metre, number of grains per panicle, percentage of filled grains, and weight of 1,000 grains (gm). The superiority of potassium silicate application could mainly be due to their capability on produce more effective tillers (number of panicles) as a result to enhancement the nods and buds to emerge early tillers that mostly productive tillers or number of panicles and the buds emerge leaves. The increase in both productive tillers and leaves led to increase the canopy of the tested rice cultivar consequently increase the photosynthesis and its products. In this case potassium as a cofactors in most of the transferring enzymes cause improving in the activity of these enzymes consequently increase in the translocation of metabolites from source (especially flag leaf) to the sink (panicles and spikelets) that increase the filling rate and percentage resulted in increase the weight of panicles and number of filled grains. Such results were observed by Ebaid and Ghanem (2001) and

Omer (2002). Adding potassium silicate as foliar sprays ensures and promotes panicle differentiation and primordia formation resulted high panicles number. The favorable impact of magnesium silicate application might be attributed to increase leaf water potential, bioavailability of nutrient, increasing antioxidant, elevated growth hormones and regulators, reducing transpiration rate, increasing photosynthesis rate, improving cell membrane stability, increasing energy compound and encourage cell division and elongation. Furthermore, silica contractors the abundant of ABA release which inhibited panicle exertion by reducing panicle peduncle elongation and division. Applying silica might increase IAA and GA3 formation that reduce ABA formation. The current findings and those published by Arab *et al.*, (2011) and Dastan *et al*,. (2011) are in good accord. Application of potassium silicate improved photosynthesis, fasten and properized assimilates production and translocation, optimizing current photosynthesis and maximizing catabolism against anabolism. The current findings are in a good association with those reported by Singh and Singh (2006*)* and Singh *et al.,* (2006).

The same Table (5)'s data showed that the Sakha 104 rice cultivar's chlorophyll a (mg/cm^2), chlorophyll b (mg/cm^2), total carbs, and soluble sugars all increased when potassium silicate was applied as a foliar spray in comparison to the control (without potassium silicate application). The highest values of Chlorophyll a content (mg/cm^2), chlorophyll b content(mg/cm^2), total carbohydrates and soluble sugars were obtained from the treatment number (5) and T_8 treatment which nearly gave the same values of Chlorophyll a content (mg/cm^2), chlorophyll b content(mg/cm^2), total carbohydrates and soluble sugars. The (T_1) unsprayed treatments by potassium silicate, however, generated the lowest values of chlorophyll a content (mg/cm^2), chlorophyll b content (mg/cm^2), total carbs, and soluble sugars (control). The increase in Chlorophyll a content (mg/cm^2), chlorophyll b content(mg/cm^2)by potassium silicate application could mainly be due to its role for increase the potassium supply viability of rice leaves and delayed leaf senescence specially flag leaf as the result of the increase in both protein and chlorophyll synthesis with the reduction in abcisic acid (ABA), also, potassium improve the activity of the enzymes related to biosynthesis of auxinex and growth substances in plants which improve the plant growth consequently the increase in photosynthesis(Randall *et al.,* 2003). Interesting silica had favorable effect on rice growth, since it improve photosynthesis, reducing respiration and increased cell division and elongation turn in good canopy resulted in high LAI. Similar findings had been reported by Singh and Singh (2006) *and* Singh *et al., (*2006). Potassium and silicon enhances the architecture of rice plants through increasing leaves light penetration of the plants, which produced an increase of both LAI (leaf area index) and photosynthetic rate. The increases of photosynthetic ratio causes an increase in Nicotinamide adenine dinucleotide phosphate NADP, NADPH(produced from NADP) reducing the power, and consequently more nitrogen assimilation capacity and higher dry matter accumulation, total carbohydrates and sugars (Taiz and Zeiger, 2010). Deivaseeno *et al.,* (2020) clarified that applied silicon at different growth stages caused a significant increase in Chlorophyll a content (mg/cm^2), chlorophyll b content (mg/cm^2) and photosynthetic rate consequently increased total carbohydrates in rice.

Table 5. Chlorophyll A content (mg/cm^2), chlorophyll B content (mg/cm^2), total carbohydrates (mg/g DWT) and soluble sugars (mg eqv. /glucose g FW), of Sakha 104 rice cultivar as affected by potassium silicate as foliar application at different stages of growth in 2018 and 2019 seasons.

Treatments	Characters							
	Chlorophyll A content(mg/cm^2)		Chlorophyll Bcontent(mg/cm^2)		Total carbohydrates (mg/g DWT)		Soluble sugars(mg eqv. /glucose g FW),	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	2.579f	2.085e	0.218h	0.220h	48.84h	41.89h	4.73g	3.29e
T2	3.111d	2.610d	0.268f	0.278f	52.57f	43.52f	5.68e	3.55d
T3	3.411c	2.985c	0.283e	0.293e	52.79e	45.17e	7.93d	5.22c
T4	2.915e	2.459de	0.252g	0.261g	49.91g	42.95g	5.04f	3.41d
T5	3.981a	3.779a	0.341a	0.357a	58.38a	49.96a	9.83a	6.16a
T6	3.454c	3.060c	0.299d	0.309d	54.01d	45.99d	8.02d	5.29c
T7	3.617b	3.468b	0.317c	0.326c	54.65c	46.44c	8.60c	5.81b
T8	3.707b	3.527b	0.329b	0.340b	55.56b	47.97b	9.36b	6.11a
F. test	**	**	**	**	**	**	**	**

(T_1), control (without potassium silicate), (T_2) foliar application of potassium silicate at vegetative stage, (T_3) foliar application of potassium silicate at reproductive stage, (T_4) foliar application of potassium silicate at maturity stage, (T_5) foliar application of potassium silicate at vegetative stage+ reproductive stage, (T_6) foliar application of potassium silicate at vegetative stage+ maturity stage, (T_7) foliar application of potassium silicate at reproductive stage+ maturity stage, (T_8) foliar application of potassium silicate at vegetative stage+ reproductive stage+ maturity stage .

***and ** indicate $p< 0.05$, and $p<0.01$. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

Data related to the percentage of cellulose content, percentage of hemi-cellulose content, percentage of lignin content and percentage of silicon content of the tested Sakha 104 rice cultivar as affected by the sprayed application of potassium silicate at different growth stages in 2018 and 2019 seasons.in Table (6).

Results in Table (6) showed that application of potassium silicate had a markedly increase on cellulose content, hemi-cellulose content, lignin content and silicon content in the two seasons. Application of potassium silicate at any of the tested stages significantly increased cellulose content, hemi-cellulose content, lignin content and silicon content in both seasons. The highest values of cellulose content, hemi-cellulose content, lignin content were produced by the T5 treatment followed by T_8. In contrast, the lowest values of cellulose content, hemi-cellulose content, lignin content were obtained from control treatment (without potassium silicate application) during both seasons. Concerning the effect of potassium silicate application on silicon content, data in Table (4) also, revealed that silicon content was significantly increased with all potassium silicate application at all stages under study. The highest values were obtained when potassium silicate was applied at vegetative stage+ reproductive stage+ maturity stage T_8 treatment (23.45 and 22.13), followed by T_5 treatment (23.06 and 21.42), while, the lowest values were found with T_1 treatment (control) (7.80 and 8.97). The characteristics of rice that are most frequently linked to lodging resistance are culm thickness and diameter, upper and lower internode strength, stem wall thickness, lignin and cellulose accumulation in the stem wall, and silicon content (Wang *et al.,* 2011). Similar findings were published by Dastan *et al.*, (2012) who found that silicon application significantly enhanced cellulose, hemicellulose, and lignin content.

Table 6. Cellulose content (%), hemi-cellulose content (%), lignin content (%) and silicon content (%) of Sakha 104 rice cultivar as affected by the addition foliar potassium silicate at the tested different growth stages in 2018 and 2019 seasons.

Treatment	Characters							
	Cellulose content%		Hemi-cellulose content%		Lignin content%		Silicon content%	
	2018	2019	2018	2019	2018	2019	2018	2019
T1	33.10e	30.33e	13.20c	12.28c	10.10e	10.03c	7.80e	8.97f
T2	39.61c	37.37d	16.38ab	15.17ab	12.53d	11.58bc	17.97c	19.37c
T3	41.00c	39.53c	16.47ab	15.20ab	12.61cd	11.90bc	16.69d	15.95d
T4	35.63d	36.39d	15.90bc	14.40bc	12.40d	11.47bc	16.39d	15.77d
T5	47.07a	46.10a	17.18a	15.80a	13.91a	13.38a	23.06ab	21.42ab
T6	45.13ab	43.77b	16.55ab	15.40ab	12.90bcd	11.93bc	17.98c	19.66c
T7	45.32ab	44.57ab	16.63ab	15.47ab	13.50abc	12.11abc	19.46b	21.16b
T8	46.30ab	44.60ab	16.78ab	15.73ab	13.80ab	12.68ab	23.45a	22.13a
F. test	**	**	*	*	**	*	**	**

(T_1), control (without potassium silicate), (T_2) foliar application of potassium silicate at vegetative stage, (T_3) foliar application of potassium silicate at reproductive stage, (T_4) foliar application of potassium silicate at maturity stage, (T_5) foliar application of potassium silicate at vegetative stage+ reproductive stage, (T_6) foliar application of potassium silicate at vegetative stage+ maturity stage, (T_7) foliar application of potassium silicate at reproductive stage+ maturity stage, (T_8) foliar application of potassium silicate at vegetative stage+ reproductive stage+ maturity stage .
***and ** indicate $p< 0.05$, and $p<0.01$. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's multiple range test.**

The application of foliar potassium silicate obtained greater accumulation of the percentage of Si content in rice plants. Higher Si content in the straw than in the paddy grains could be associated with the less silicon translocation from the source to the sink because the silicon is constituent of cell wall in the rice shoots (culms and leaves) to increase the strength of the rice internodes that minimized the lodging and also, minimize the angle between the leaves and the culms that cause an increase in erectness of the leaves which gave the chance to light to penetrate most of the rice leaves consequently increase the photosynthesis and the other biological process resulted in the improvement of plant growth and yield, so the silicon must be accumulated in the straw than in grains reported by (Jugal and Ramani, 2016). Singh *et al,.* (2002). reported essential limit for optimum growth and productivity of rice was achieved as 3.7 percent Si content in harvest rice straw, which clarified that the proportion of silicon content in the harvested straw was more than 11 percent. Similar findings were reported by Deivaseeno *et al.,* (2020), who concluded that fertilizing rice plants with silicon at various growth stages led to significantly higher silicon content in the plants than did not fertilize them.

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تحسين مقاومة الرقاد ومحصول الحبوب لصنف الأرز سخا 104 من خلال استخدام الرش بالسيليكون.

مريم طلعت ويصا ، هبة عبدالحميد الشربيني و داليا السيد الشرنوبي
قسم بحوث الارز- معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية- الجيزة - مصر

الملخص

أجريت تجربه حقليه في المزرعة البحثية لقسم بحوث الأرز ، سخا ، كفر الشيخ ، معهد بحوث المحاصيل الحقلية ، مركز البحوث الزراعية، مصر خلال موسمي 2018 و 2019. من أجل تحديد المرحلة المناسبة لإضافة سيليكات البوتاسيوم لتحسين بعض الصفات المورفولوجية والكيميائية المتعلقة بمقاومة الرقاد وزيادة محصول الحبوب لصنف الأرز سخا 104. تم استخدام تصميم القطاعات الكاملة العشوائية في أربعة مكررات في الموسمين. كانت المعاملات الثمانية للرش بسيليكات البوتاسيوم هي: (م1) الكنترول (بدون إضافة سيليكات البوتاسيوم) , (م2) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في المرحلة الخضرية, (م3) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في مرحلة الإكثار, (م4) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في مرحلة النضج, (م5) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في المرحلة الخضرية+ مرحلة الإكثار, (م6) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في المرحلة الخضرية+ مرحلة النضج, (م7) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في مرحلة الإكثار+ مرحلة النضج و(م8) الرش بسيليكات البوتاسيوم بمعدل 1.0٪ في المرحلة الخضرية+ مرحلة الإكثار+ مرحلة النضج. أظهرت النتائج أن أغلبية الصفات المدروسة في صنف الأرز سخا 104 زادت بشكل عام بإضافة المعاملة (م5) متبوعًا بالمعاملة(م8) بينما ينتج عن المعاملة (م1) اعلي درجة من الرقاد. وبناءً على النتائج السابقة وتحت نفس ظروف التجارب يمكن الاستنتاج أن الرش بسيليكات البوتاسيوم مرتين وبنفس التركيز 1.0٪ في المرحله الخضرية +مرحلة الاكثار (م5) كانت أفضل معاملة لتحسين الصفات المورفولوجية والكيميائية المتعلقة بمقاومة الرقاد والحصول على أعلي محصول حبوب لصنف الارز سخا 104.

الكلمات المفتاحية: سيليكات البوتاسيوم ومقاومة الرقاد و الأرز والسيليكون.