Vol. 16(12), pp. 1721-1725, December, 2020
DOI: 10.5897/AJAR2020.14964
Article Number: E7558BB65582
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Foliar and time of application of silicon and the effect on rice yield components, productivity and seed quality

Jucilayne Fernandes Vieira[1*], Michele Nadal[1], Lilian V. M. Tunes[1], Gabriel Duarte[1], Ewerton Gewehr[1], Otávio Oliveira Corrêa[1], Acácio Figueiredo Neto[2] and Marylia de Sousa Costa[2]

[1]Federal University of Pelotas, Post Graduate Course in Seed Science and Technology. 96 001-970, Pelotas, Rio Grande do Sul, Brazil.
[2]Federal University of São Francisco Valley-UNIVASF. Campus Juazeiro - Colegiado de Engenharia Agrícola e Ambiental, Av. Antonio Carlos Magalhães, n.510 - Country Clube. 48.902-300, Juazeiro - Bahia, Brazil.

Received 8 May, 2020; Accepted 4 September, 2020

The application of silicon (Si) has been beneficial to several cultures, mainly those considered Si accumulators, such as rice. Thus, in most cases Si is supplied via soil. However, it has been found that foliar application and small amounts of the element can be a viable alternative for its supply to plants. The objective of the present work was to evaluate the foliar application times of different silicon sources on yield components, productivity and seed quality of irrigated rice. The experiment was conducted in a greenhouse at the Federal University of Pelotas. The experimental design was completely randomized with four replicates. The treatments were: two sources of Si (Caulim®, 50 kg ha^{-1}; and Sifol®, 3 L ha^{-1}), three times of foliar application (tillering, bottling and flowering). Two distinct rice cultivars (IRGA 424 and Puitá Inta CL) were used. The production components evaluated were: Seed yield, number of panicles, and number of seeds per plant. For the evaluation of the physiological quality, the seeds were submitted to the tests of germination and first germination count. Seed health test was performed. To cultivate IRGA 424, the use of Caulim® and Sifol® in the drilling phase increased the number of seeds per panicle. Therefore, for both cultivars the use of silicon provided improvements in seed vigor. We conclude that the application of silica via foliar, through the Caulim® and Sifol®, to the cultivar IRGA 424 in the drilling phase, increases the number of seeds per panicle, and for both cultivars, it improves the vigor of the seeds, in addition to reducing the incidence of fungi.

Key words: *Oryza sativa* L., vigor, germination.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the main cereals produced and consumed worldwide. In Brazil, the national harvest was estimated at 10.8 million tons in 2019/2020 of which about 9.9 million correspond to irrigated cropping areas (CONAB, 2020). Southern Brazil accounts for the highest rice yield, mainly due to the flood

*Corresponding author. E-mail: laynevieira@yahoo.com.br.

irrigation system used in 100% of the cultivated commercial crop areas. This system allows efficient weed control, eliminates crop water deficit, and promotes electrochemical changes in the soil that increase nutrient availability for the crop (SOSBAI, 2016). Besides yield, a constant demand of this crop is the search for sustainable management techniques. In this sense, the use of silicon-based products has increased interest from researchers, technicians, and farmers, as it has potential for the protection of grasses (Pereira et al., 2009; Silva et al., 2013; Oliveira et al., 2016; Oliveira, 2016).

Silicon (Si) is an immobile element in the plant, being deposited on leaf blades and sheaths, stems, bark, and roots (Yoshida et al., 1962). This element participates in the biosynthesis of cell wall components that reduce enzymatic degradation. According to Dayanandam et al. (1983), silicon-accumulating plants such as rice tend to have greater resistance to the action of fungi and insects. These benefits may contribute to increased rice yield, as shown by the studies of Tokura et al. (2007), improved seed vigor (Tunes et al., 2014; Oliveira et al., 2016), and decreased use of toxic products in crop management (Vieira et al., 2011), which may assist in practices as integrated pest and disease control.

Some marketed products can be used to supply this element. Caulim® (79% SiO_2) and Sifol® (12% Si), for example, can be used for seed treatment aiming at increased plant yield. Moreover, it is known that the efficiency of agricultural technologies depends on the time of their application (SOSBAI, 2016). It is know that Si is a major constituent in higher plants and the value of Si in crop productivity also has been demonstrated. Nowadays, in many diferent countries, the application of Si fertilizers is very common in crop production systems. Silicon is already recognized as a beneficial element for several crops and may be classified as a quasi-essential element. We need to know if the application in three different moments can also bring benefits to rice plants. These stages of plant development are equally important for rice plants; however, we need to know the total amount of silicon needed and which phases require more of this nutrient. Despite research on the effects of Si on plant growth, much information is still incipient. In this context, further research is needed to address this topic. Thereby, research is needed to study Si application at different times, sources, and doses, exploring all the benefits that this nutrient can bring to rice crop. Given the above, this study evaluated silicon sources and the times for their foliar application in irrigated rice seeds.

MATERIALS AND METHODS

The study was carried out under greenhouse conditions. Seeds of rice cultivars (cv) IRGA 424 (medium cycle) and Puitá Inta CL (medium cycle) were used. These cultivars were selected because they are recommended for all rice-growing regions of Rio Grande do Sul and also for showing higher yield among the cultivars. The seeds were sown in the first 20 days of November and the experimental units were harvested on March 23. They were placed in 10 L buckets filled with sieved and homogenized soil collected from the A1 horizon of a Soil Eutrophic Haplic Planosol (EMBRAPA, 2006) belonging to the Pelotas mapping unit, in Rio Grande do Sul State (RS), Brazil. Nitrogen, phosphate, and potassium fertilization were performed according to the recommended doses for irrigated rice (CQFS – Soil fertility and chemistry commission- RS/SC, 2016). Flooding was carried out when plants had four leaves, maintaining a 10 cm water depth during the experiment. Cultural treatments were performed according to the technical recommendations for irrigated rice cultivation in RS (SOSBAI, 2016). The experimental design was bifactorial, consisting of Si application times (Stage I - full tillering, Stage II - booting, and Stage III - full bloom) and its different sources (Caulim®, at 50 Kg ha^{-1}, and Sifol®, at 3 L ha^{-1}). Four replicates were used for each treatment. Foliar applications were performed with a CO_2-pressurized back-pack sprayer.

Harvesting was carried out and panicles of each plant packed in brown paper envelopes separately and threshed manually. Harvested seeds were dried at the temperature of 42°C. The following characteristics were analyzed: number of seeds per plant, determined by counting the seeds in each plant; number of panicles per plant; and seed yield per plant (g $plant^{-1}$), where seeds were cleaned and moisture was standardized to 13% by drying in an oven with forced air circulation at 32 ± 2°C, followed by weighing on a precision scale. Physiological quality was determined by the germination and first germination count tests, using four replicates of 50 seeds. Seeds were placed between paper sheets and germinated at a temperature of 25 ± 2°C. Counts were performed at 5 and 14 days after sowing (Brasil, 2009). The filter paper method or Blotter Test was used to evaluate seed health. The sample consisted of 200 seeds subdivided into eight subsamples of 25 seeds. The seeds were placed in plastic boxes (gerbox) and incubated at 20°C for seven days (Brasil, 2009). Subsequently, the percentage of fungi-contaminated seeds was determined. Data were subjected to analysis of variance by the F test, and means were compared by the Tukey test at 5% probability, using the Winstat 1.0 software (Machado and Conceição, 2003).

RESULTS AND DISCUSSION

Cultivar IRGA 424 showed no effect between phonological stages and foliarly applied silicon sources for seed yield and number of panicles per plant. For number of seeds per plant, however, there was interaction between treatments (Table 1). The use of Caulim® in the tillering stage differed only from the control, with an average about 20.3% higher. In the booting stage, this source differed from the control and the use of Sifol®. In the flowering stage, Sifol® showed better results for number of seeds per plant, differing from the control and the treatment with Caulim® (Table 1). For cultivar Puitá Inta CL, the application times and silicon sources tested did not affect the number of panicles. Notwithstanding, there was a simple effect of silicon sources for seed yield and number of seeds per plant in the lot with application during the tillering stage, and the use of Sifol® was superior to Caulim® for both variables analyzed (Table 1).

Silicon participates in the biosynthesis of cell wall components. Silicon-accumulating plants tend to have a more rigid leaf architecture and thicker cuticle, which enables greater use of solar energy and helps to reduce

Table 1. IRGA 424 and Puitá Inta CL cultivar- Seed yield per plant (g), number of panicles per plant and number of seeds per plant as a function of foliar application with silicon sources (Caulim® and Sifol®) at tillering, booting and flowering.

Silicon sources	**Seed yield per plant (g) – IRGA 424**			
	Leaf application stages			**Average**
	Tillering	**Booting**	**Flowering**	
Control	28.47 ^{ns}	29.43 ^{ns}	29.87 ^{ns}	29.47
Caulim®	29.22	31.34	29.03	29.85
Sifol®	27.85	31.26	29.89	29.66
Average	28.84	30.67	29.46	
C.V. (%)	9.6	7.7	7.3	
	Number of panicles per plant			Average
Control	15.6 ^{ns}	15.1 ^{ns}	15.3 ^{ns}	15.6
Caulim®	17.0	16.1	16.3	16.7
Sifol®	16.6	16	17.3	16.3
Average	16.5	16.2	16.4	
C.V. (%)	9.4	11.8	8.6	
	Number os seeds per plant			Average
Control	182 bA	189^{bA}	178^{bA}	182
Caulim®	218 aA	232^{aA}	183^{bB}	211
Sifol®	219 aA	177^{bB}	217^{aA}	201
Average	206	197	194	
C.V. (%)	9.1	13.7	7.4	
Silicon Sources	Seed yield per plant (g) – Puit Inta CL			
	Foliar silicon application times			Average
	Tillering	Booting	Flowering	
Control	22.31 b	24.36 ^{ns}	24.02 ^{ns}	24.36
Caulim®	20.36 b	24.46	28.42	24.41
Sifol®	30.24 a	24.52	26.64	27.13
Média	24.98	24.44	26.47	
C.V. (%)	7.1	14.1	10.5	
	Number of panicles per plant			Average
Control	13.0 ^{ns}	13.7 ^{ns}	13.2 ^{ns}	13.0
Caulim®	15.2	15.6	15.4	15.4
Sifol®	15.5	15.4	13.5	14.5
Média	14.3	14.3	13.6	
C.V. (%)	7.3	6.7	8.9	
	Number of seeds per plant			Average
Control	245 a	239 ^{ns}	235 ^{ns}	245
Caulim®	164 b	221	211	199
Sifol®	244 a	234	247	242
Average	218	233	234	
C.V. (%)	4.7	14.3	9.4	

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ from each other by the Tukey test at 5% probability.

plant water loss. These characteristics later contribute to a more efficient production of photo assimilates, which are important in seed formation (Taiz and Zeiger, 2015). Silicon supply in the different stages of rice growth and

Table 2. Cultivate Irga 424 and Puitá Inta CL, first germination count test (FGC) and germination test (Germ) on seeds produced as a function of foliar application with silicon sources (Caulim® and Sifol®) at tillering stages, booting and flowering.

Phenological stages of the plants	IRGA 424				Puitá Inta CL			
	FCG (%)		GERM (%)		FCG (%)		GERM (%)	
	Caulim®	Sifol®	Caulim®	Sifol®	Caulim®	Sifol®	Caulim®	Sifol®
Control	77[a]*	74[a]	98[a]	92[a]	71[b]	74[c]	97[a]	92[a]
Growth stage	67[b]	76[a]	95[a]	98[a]	79[b]	69[c]	99[a]	95[a]
Booting	79[a]	71[a]	98[a]	96[a]	84[a]	78[b]	95[a]	97[a]
Flowering	69[b]	71[a]	98[a]	95[a]	87[a]	86[a]	98[a]	98[a]
Average	72	72	95	94	80	77	97	95
C.V.(%)	8.7		6.1		7.4		7.5	

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ from each other by the Tukey test at 5% probability.

development can contribute to increased seed yield and to the formation of more vigorous and healthy seeds.

In the evaluations regarding physiological quality, there was a simple effect for silicon sources, with statistical differences for both IRGA 424 and Puitá Inta CL. For the first germination count of cultivar IRGA 424, Sifol® differed statistically from Caulim®, showing the highest average in the harvested lots with application during the vegetative and flowering stages (Table 2). For the first germination count of cultivar Puitá Inta CL, Sifol® showed better results for the lot with application at booting stage. For the lot with Si application at flowering stage there were no statistical differences between Sifol® and Caulim® (Table 2). Regarding the germination percentage, there were no differences between treatments for both cultivars. Germination percentage was above 90% in all cases (Table 2).

Studying seeds treated with different silicon sources and doses, Oliveira et al. (2016) observed an increased vigor in the treatment with Caulim® at 30, 60, 90, and 120 g 100 kg seeds^{-1}. In addition, studying the same cultivars but with aluminum silicate and ground rice husk ash as silicon sources, Tunes et al. (2014) observed an increased seed vigor through the results of root length and field emergence. Study using silicon sources for seed coating have shown that the expression of some important enzymes differs in the germination process (Tunes et al., 2014), which suggests that silicon influences this process. These results corroborate those found in the present study, where silicon treatments promoted increased physiological and sanitary quality of seeds of both cultivars.

Overall averages show that the seeds treated with silicon sources had lower incidence of fungi after harvest compared to the control (Table 3).

Studying the effect of calcium silicate and rice husk ash on fungal spots in irrigated rice seeds, Roma-Almeida et al. (2016) did not observe the reduction of this fungus by applying Si sources. However, Datnoff et al. (2007) provided Si to plants via soil and leaf, observing satisfactory results in the control of various diseases, both in mono- and dicotyledonous plants. According to Figueiredo and Rodrigues (2007), silicon is linked to the induction of a series of metabolic reactions in plants, resulting in the formation of compounds such as phytoalexins and lignins, which confers increased resistance to attack by phytopathogens and pests.

With increasing doses of silicon in rice, Berni and Pradhu (2003) observed a significant decrease in the severity of blast disease caused by the fungus *Pyricularia oryzae*. This fungus was not found in the present study. However, other pathogens found in both treated and untreated seed samples cause spots in grains and seeds (*Phoma* sp., *Curvularia lunata*, *Nigroppora oryzae*, *Alternaria* sp., *Fusarium* sp.). The high incidence of these pathogens has been of concern to producers, as they lead to sterility and decreased seed weight (Malavolta et al., 2007). The use of Sifol® and Caulim®, regardless of application time, proved to be important in this study, minimizing fungal levels in the seeds produced compared to the control average.

Conclusion

Foliar application of silicon through Caulim® and Sifol® proved to be beneficial, contributing to crop seed production. In general, foliar applications of silicon at tillering and boosting stages were efficient to increase the number of seeds produced in cultivar IRGA 424. The use of silicon through Sifol® and Caulim® improved seed quality in both cultivars, which was observed through the first germination count. Moreover, their application minimized fungal levels in harvested seeds. For cultivar IRGA 424, Caulim® can be applied at boosting stage, and Sifol® can be applied at tillering and flowering stages.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Table 3. Cultivate IRGA 424 and Puitá Inta CL - Seed health test for seeds produced as a function of foliar application with silicon sources (Caulim® and Sifol®) at tillering, booting and flowering stages.

Silicon applicatio times	Silicon sources	Health seed test (%) IRGA 424						
		Clad.	**Nig.**	**Alte.**	**Cur.**	**Fusa.**	**Bipo.**	**Pho.**
	Control	83	78	21	5	19	3	0
Tillering	Caulim®	50	50	24	6	25	0	1
	Sifol®	53	32	24	5	25	3	0
Booting	Caulim®	58	60	18	5	12	3	0
	Sifol®	49	50	27	1	14	1	0
Flowering	Caulim®	40	38	22	2	12	1	1
	Sifol®	41	36	29	7	18	1	3
		Health seed test (%) Puitá Inta CL						
	Control	41	36	29	7	18	1	3
Tillering	Caulim®	36	66	22	7	8	2	0
	Sifol®	30	71	23	4	11	1	0
Booting	Caulim®	30	42	24	6	25	3	0
	Sifol®	38	35	21	6	14	0	0
Flowering	Caulim®	34	49	24	3	14	0	0
	Sifol®	31	31	16	5	11	1	1

* Fungi identified in health test: *Cladosporium* sp., *Nigrospora* sp., *Alternaria* sp., *Curvularia* sp., *Fusarium* sp., *Bipolaris oryzae* e *Phoma* sp.

REFERENCES

Brasil (2009). Ministério da Agricultura, Pecuária e Abastecimento. Regras para análise de sementes. Brasília: Mapa/ACS, 399p.

Companhia Nacional de Abastecimento (CONAB) (2020). Monitoring of the Brazilian Grain Harvest. Harvest Brazilian Grain. - Harvest 2019/20 – Tenth survey, Brasília 7:1-31. Avaliable at: www.file:///C:/Users/User/Downloads/BoletimZdeZMonitoramentoZVeraoZInvernoZJulZ2020.pdf<

Comissão Química e Fertilidade do Solo - RS/SC (CQFS) (2016). Manual de adubação e calagem para os Estados do Rio Grande do Sul e de Santa Catarina. Sociedade Brasileira de Ciência dos Solos 376 p.

Dayanandam P, Kaufman PB, Frakin CI (1983). Detection of silica in plants. American Journal of Botany 70:1079-1084.

Embrapa- Empresa Brasileira de Pesquisa Agropecuária (2006). Sistema brasileiro de classificação de solos. Centro Nacional de Pesquisa de Solos 2:306.

Machado AA, Conceição AR (2003). Sistema de análise estatística para Windows. WinStat. Versão 1.0. Pelotas: UFPel.

Oliveira S, Brunes AP, Lemes E, Tavares LC, Meneghello G, Leitzke ID, Mendonça AO (2016). Rice seed treatment with silicon and seed quality. Revista de Ciências Agrária 39(2):202-209.

Oliveira RS (2016). Silício na indução de resistência à *Sitobion avenae* (Fabricius, 1775) (Hemiptera: Aphididae), na produtividade do trigo e na produção de voláteis. Tese de Doutoramento. Universidade Federal de Uberlândia, Uberlândia 90 p. Available at: https://repositorio.ufu.br/handle/123456789/18352.

Pereira SC, Rodrigues FA, Carré-Missio V, Oliveira MGA, Zambolim L (2009). Effect of foliar application of silicon on soybean resistance against soybean rust and on the activity of defense enzymes. Tropical Plant Pathology 34:164-170.

Silva MLS, Resende JTV, Trevisam A, Figueiredo ALT, Schwarz K (2013). Influência do silício na produção e na qualidade de frutos do morangueiro. Semina 34:3411-3424.

Sociedade Sul-brasileira de arroz Irrigado (SOSBAI) (2016). Recomendações da pesquisa para o Sul do Brasil. SOSBAI 200 p.

Roma-Almeida RCCOLP, Dias DCFS, Prabhu AS, Filippi MCC, Duarte HSS, Rodrigues FA (2016). Efeito da aplicação de silicato de cálcio e de cinza de casca de arroz sobre a incidência de fungos associados a manchas em sementes de arroz irrigado. Summa Phytopathologic 42:73-78.

Tokura AM, Furtini N, Curi NAE, Carneiro LF, Alves AA (2007). Silício e fósforo em diferentes solos cultivados com arroz de sequeiro. Acta Scientiarum Agronomy 29:9-16.

Tunes LVde, Fonseca DAR, Meneghello GE, Reis BBdos, Brasil VD, Rufino CA, Vilella FA (2014). Qualidade fisiológica, sanitária e enzimática de sementes de arroz irrigado recobertas com silício. Revista Ceres 61:675-685.

Vieira AR, Oliveira JA, Guimarães RM, Carvalho MLM, Pereira EM, Carvalho BO (2011). Qualidade de sementes de arroz irrigado produzidas com diferentes doses de silício. Revista Brasileira de Sementes 33:490-500.

Yoshida S, Ohnishi Y, Kitagishi K (1962). Chemical forms, mobility and deposition of silicon in rice plant. Soil Science and Plant Nutrition 8:15-21.