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Treatment of pumpkin seeds with silicon: effects on mineral nutrition of seedlings

Tratamento de sementes de abóbora com sílicio: efeitos na nutrição mineral das plântulas

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ABSTRACT
Pumpkins are cultivated worldwide, providing edible pulp and seeds. The use of silicon is a clean technology from the environmental perspective, which may provide several benefits to plants. The aim of this study was to evaluate the effects of the application of silicon derived from Sifol® and kaolin via seed treatment, in pumpkin, on the nutritional quality of seedlings. Five doses of silicon were applied via seed imbibition 0,1, 2, 4 and 5 mL $0.5L^{-1}$ for Sifol® and 0, 50, 100, 200 and 400 $g.L^{-1}$ for kaolin, respectively. The genotype used was the early cultivar menina brasileira. Seedling chemical composition was evaluated using flame atomic absorption spectrometry.

Keywords: *Cucurbita moschata* L., imbibition, aluminum silicate, nutrients.

RESUMO
As abóboras são cultivadas em todo o mundo, fornecem polpa e sementes comestíveis. A utilização de silício é uma tecnologia limpa do ponto de vista ambiental, que pode proporcionar vários benefícios para as plantas. O objetivo do trabalho foi avaliar o efeito da aplicação de silício oriundo de Sifol® e caulim via tratamento de sementes, em abóbora, na qualidade nutricional das plântulas. Aplicando cinco doses de silício via embebição de sementes, 0, 1, 2, 4 e 5 mL.0,5L-1 para Sifol® e 0, 50, 100, 200 e 400 g.L-1 para caulim, respectivamente. O genótipo utilizado foi a cultivar menina brasileira precoce. A composição química das plântulas foi avaliada através de espectrofotometria de absorção atômica em chama.

Palavras-chave: *Cucurbita moschata* L., embebição, silicato de alumínio, nutrientes.

1 INTRODUCTION

The benefits associated with the use of silicates are not limited to increased silicon supply but also due to the effect in soil acidity amendment and as a supply of calcium, magnesium and micronutrients such as copper, iron, manganese and others (QUEIROZ, 2003). Thus, the supply of silicon-rich products through seed coating may be an efficient and low cost approach to increase its availability during initial growth stages, wherein the root system is underdeveloped, which affects the absorption of soil elements (BONNECCARRÉRE et al., 2004). Seed coating with silicon-rich materials is gaining support due to the benefits provided to the crops.

Silicon is not an essential nutrient, however, it may stimulate growth and crop production due to several indirect effects, such as reducing self-shading due to upright leaves, greater tolerance to lodging due to greater structural tissue hardness, the protection against abiotic stresses through the decrease of aluminum, manganese, iron and sodium toxicity, and biotic stresses through

increased protection against pathogens and phytophagous insects (EPSTEIN, 1994; MARSCHNER, 1995).

Macronutrients are found in high concentrations on plant tissues, which are nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. On the other hand, micronutrients are found in small concentrations, which are chlorine, manganese, boron, zinc, iron, copper, nickel and molybdenum (MALAVOLTA, 2006; WARAICH et al., 2011). There are also the beneficial elements, which are only essential for some species or under specific conditions, among which are cobalt (Co), silicon (Si), selenium (Se) and sodium (Na). Micronutrients are required in small quantities by plants, however, the absence of any essential element may limit or derail plant growth, even if other essential nutrients are present under adequate quantities (LOPES, 1989).

The aim of this work was to evaluate the absorption of essential nutrients on pumpkin seedlings due the application of different concentrations of silicon on seed treatment.

2 MATERIAL AND METHODS

The study was performed at the Didactic Laboratory of Seed Analysis, located at the Eliseu Maciel College of Agronomy of the Federal University of Pelotas, and in a greenhouse and an experimental field, from the EMBRAPA Temperate Climate station, both located at the municipality of Capão do Leão (Brazil – RS), 31º52'00'' S and 52º21'24'' W.

The experiment was composed by 30 treatments, involving three factors: Factor A – silicate sources (Sifol® and kaolin) and water (control); Factor B – doses; Factor C – soaking time (30, 60 and 90 minutes). The Split-plot design was used under a factorial scheme (2x5x3), with four repetitions. A pumpkin seed lot from the early cv. "Menina brasileira" was acquired in the Rural Union of Pelotas, which were commercialized by *ISLA sementes* and produced in the 2016/2017 growing season.

Seeds were treated manually, the treatments used were based in a foliar fertilizer (Sifol® - leaf silicon) with the following physical characteristics: liquid, viscous, nontoxic and odorless, presenting: Si – 12%, K_2O - 15%, saline index – 26, electrical conductivity – 2.93 mS cm^{-1}, density – 1.40 g L^{-1} and pH – 10.96 and, kaolin (white clay) rich in calcium carbonate, composed by kaolinite ($Al_2 O_3.2SiO_2.2H_2 O$), nonflammable, nontoxic and does not present chemical reactivity. For treatment I, seeds were soaked in water during 30, 60 and 90 minutes. For treatment II, seeds were exposed to five doses of Sifol® (0; 1mL; 2mL; 4mL and 5mL), diluted in 500 mL of water, by soaking for 30, 60 and 90 minutes. For treatment III, which used kaolin, seeds were exposed to

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five doses (0, 50, 100, 200 and 400g), diluted in 1000 mL of water and soaked for 0, 30, 60 and 90 minutes.

After treatment, the seeds were sown in completely randomized raised beds and seedlings were collected 21 days after sowing. For each treatment, 20 plants were randomly collected and, after drying (kiln at 60ºC), the samples were ground using a Wiley mill and accommodated in hermetically sealed plastic bottles. Aliquots were taken from each sample for the determination of the macronutrients: phosphorus (P), potassium (K), Calcium (Ca) and magnesium (Mg); and the micronutrients: zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn). Nutrient analyzes were performed at the Analytical Center at EMBRAPA Temperate Climate station located in Pelotas/RS. The methodology used for plant nutrient analysis was carried out according to MALAVOLTA et al. (1997).

Data were subjected to the analysis of variance ($p<0.05$), when significant, the qualitative variables (soaking times) were compared by the Tukey test at the 5% probability level of error and the quantitative variables (doses) were subjected to regression analysis. The statistical analyzes were performed using R, version 3.1.1. and the statistical package "ExpDes.pt" (Banzato & Kronka, 2006; R Core Team, 2014).

3 RESULTS AND DISCUSSION

The analysis of variance for Potassium (K), Phosphorus (P), Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese (Mn) in pumpkin seedlings, derived from seeds subjected to different concentrations and soaking times in a Sifol® solution are presented in Table 1, in which a significant interaction for the variables studied can be observed.

Table 1. Analysis of variance for the variables Potassium (K), Phosphorus (P), Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu) and Mangansese (Mn) in pumpkin seedlings, derived from seeds subjected to different concentrations and soaking times in a Sifol® solution. Pelotas-RS, 2018.

Source of Variation	DF	K	P	Ca	Mg	Fe	Zn	Cu	Mn
Dose (D)	4	*	*	*	*	*	*	*	*
Time (T)	2	*	*	*	*	*	*	*	*
D x T	8	*	*	*	*	*	*	*	*
Residue	30	-	-	-	-	-	-	-	-
Total	44	-	-	-	-	-	-	-	-
CV (%)		1.9	0.9	1.66	0.6	1.35	1.95	3.9	1.44
Average		18.5	8.8	13.6	13.8	104.2	56.74	5.7	84.3

ns Not significant at the 5% probability level; * Significant at the 5% probability level. DF: degrees of freedom; CV: coefficient of variation;

Comparing the soaking times in each dose of Sifol®, a significant variation was observed for all variables, depending on the dose used. Wherein, seeds imbibed for 30 and 90 minutes presented greater concentrations of K when compared to seeds subjected to the solution for 60 minutes (Table 2), presenting a better performance in the doses of 4.0 mL 0.5 L^{-1}.

For phosphorus (P) (Table 2), a significant difference was observed, the soaking time of 30 minutes presented greater accumulation of P compared to the other times tested, when seeds were immersed in the doses of 0, 1.0 and 4.0 mL 0.5L^{-1}, highlighting the dose of 4.0 mL 0.5 L^{-1}, which presented the best performance. For calcium (Ca), the best performance was observed for the soaking time of 90 minutes for the doses 0 and 4.0 mL 0.5L^{-1}, when compared to the others. Similarly, the variable magnesium (Mg) also presented better results at the dose of 4.0 mL 0.5L^{-1}, when compared to the other doses tested, where the soaking times of 30 and 90 minutes can be highlighted. Although silicon is not an essential element, the use via seed treatment intensifies other elements of fundamental importance for plant development.

Almeida et al. (2014) observed an isolated and significant effect of seed treatment in seed vigor for the variables first count of germination and electrical conductivity. Thus, seeds, independently of the lot, which were treated via immersion in distilled water and in solutions containing micronutrients, expressed greater percentages for normal seedlings and lower values for electrical conductivity than those which were not immersed.

Table 2. Potassium (K), Phosphorus (P), Calcium (Ca), Magnesium (Mg), in pumpkin seedlings derived from seeds subjected to different concentrations and soaking times in a Sifol® solution (mL 0.5 L^{-1}). Pelotas-RS, 2018.

Variables	Soaking Time (min)	Dose of Sifol® (mL 0.5 L^{-1})					
		0	1.0	2.0	4.0	5.0	Average
K	30	18.08 a	19.19 a	18.11 c	20.44 b	18.83 a	18.93
	60	15.80 b	16.83 c	20.90 a	18.41 c	17.08 b	17.80
	90	16.19 b	18.44 b	20.13 b	21.27 a	18.89 a	18.98
P	30	8.11 a	9.70 a	9.10 c	10.74 a	9.09 b	9.35
	60	6.05 c	9.42 b	9.51 a	8.78 c	9.31 a	8.61
	90	6.66 b	8.86 c	9.34 b	9.47 b	8.84 c	8.63
Ca	30	15.15 b	14.79 a	11.91 c	13.70 b	12.35 b	13.58
	60	11.49 c	13.32 b	14.64 a	10.85 c	12.71 b	12.60
	90	16.13 a	12.52 c	13.97 b	16.87 a	13.72 a	14.64
Mg	30	14.08 a	14.74 b	12.45 b	15.26 a	12.85 c	13.88
	60	10.33 c	15.06 a	14.66 a	13.31 c	14.20 a	13.51
	90	12.34 b	13.65 c	14.81 a	15.08 b	13.88 b	13.95

Averages followed by the same letter in the column do not differ statistically between each other by the Tukey Test at the 5% probability level of error. ns: not significant.

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Comparing soaking times for each dose of Sifol®, significant differences for all variables can be observed, except for Cu. For iron (Fe), seedlings derived from seeds imbibed for 60 minutes presented greater content when compared to seeds subjected to the Sifol® solution for 30 and 90 minutes, for the doses 0 and 2.0 mL 0.5 L^{-1}. For Zn, the greater content was observed for the 60 minutes soaking time, in the dose of 2.0 mL 0.5 L^{-1}, differing from the results for the other doses and the 90 minutes soaking time (Table 3).

For the variable Mn (Table 3), significant differences were observed where the soaking time of 60 minutes presented a greater content of Mn when compared to the soaking times of 30 and 90 minutes, presenting the best response in the dose of 2.0 mL 0.5L^{-1}. For Cu, there was no difference in the doses of 2.0 and 4.0 mL 0.5L^{-1}, independently of the soaking time, presenting better results in the dose of 2.0 mL 0.5L^{-1}. Smiderle et al. (2008), studying bean seeds, verified that seeds immersed in water and in solutions with Mo and Zn did not differ regarding the soaking rate for seeds of three cultivars studied.

Table 3. Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese (Mn), in pumpkin seedlings derived from seeds subjected to different concentrations and soaking times in a Sifol® solution (mL 0.5 L^{-1}). Pelotas-RS, 2018.

Variable	Soaking Time (min)	Doses of Sifol® (mL 0.5L^{-1})					
		0	1.0	2.0	4.0	5.0	Average
Fe	30	45.26 c	114.61 a	113.21 b	131.17 a	124.24 a	105.7
	60	132.20 a	74.52 c	126.02 a	120.69 b	90.86 b	108.8
	90	120.14 b	89.83 b	107.63 c	89.94 c	83.70 c	98.2
Zn	30	44.41 b	52.37 a	92.58 b	54.00 a	46.84 a	58.04
	60	40.67 b	48.74 b	103.07 a	48.88 b	48.47 a	57.96
	90	40.41 a	48.07 b	86.40 c	47.51 b	48.72 a	54.22
Cu	30	5.14 a	6.20 a	5.68 b	6.50 a	5.77 a	5.86
	60	4.06 c	6.00 a	6.43 a	6.02 b	5.74 a	5.65
	90	4.58 b	5.52 b	6.11 ab	6.30 ab	5.80 a	5.66
Mn	30	66.38 c	88.57 a	92.58 b	85.66 b	90.69 a	84.77
	60	69.47 b	79.20 c	103.70 a	93.35 a	79.78 c	84.97
	90	74.02 a	84.54 b	86.40 c	85.08 b	86.04 b	83.21

Averages followed by the same letter in the column do not differ statistically between each other by the Tukey Test at the 5% probability level of error. ns: not significant.

Data from minerals fitted the models tested as a result of the doses of Sifol®, as can be seen in Figure 1. Potassium (Figure 1A) increased in seeds treated for 30, 60 and 90 minutes of imbibition, these data were fitted in quadratic models, with increases in the content for the soaking periods of 30 minutes, between the doses zero and 5 mL 0.5L^{-1}, where the point of maximum was 3.91 mL 0.5L^{-1} with a maximum accumulation of 19.43g of K.kg of $seeds^{-1}$. For the periods of 60

and 90 minutes the greater accumulation of potassium occurred at the doses of 2.74 mL $0.5L^{-1}$ and 3.13 mL $0.5L^{-1}$.

For phosphorus content (Figure 1B), the soaking times of 30 and 90 minutes were fitted to quadratic models with maximum recommended doses of 3.13 and 3.10 mL $0.5L^{-1}$ and maximum accumulations of 10.16 and 9.87 g of P kg^{-1}, respetively. When the soaking period of 60 minutes is evaluated, a cubic model is fitted with points of maximum of at the doses of 1.85 and 4.09 mL $0.5L^{-1}$, with higher accumulation in the former, reaching 9.78 g of P kg^{-1}.

However, when the variables Calcium and Magnesium are evaluated, the quadratic model presented the best fit for calcium at 30 minutes of imbibition where the greater content was observed at dose 0 (mL $0.5L^{-1}$), for the soaking times of 60 and 90 minutes, which were fitted using the cubic model, the best result was obtained at the dose of 3.94 mL 0.5 L^{-1}, for the 90 minutes soaking time, reaching 16.95 g of Ca kg^{-1},. The results for magnesium (Figure 1D) presented a cubic behaviour for the soaking times of 30 and 60 minutes, oscilating between doses, wherein the best result was observed at the dose 3.41 mL 0.5 L^{-1} for the 30 minute soaking time, with a content of 15.04 g of Mg kg^{-1}. For the 90 minutes soaking period, the data was fitted to a quadratic model, wherein the greater content was of 15.16 g of Mg kg^{-1}, at the maximum dose of 3.06 mL 0.5 L^{-1}.

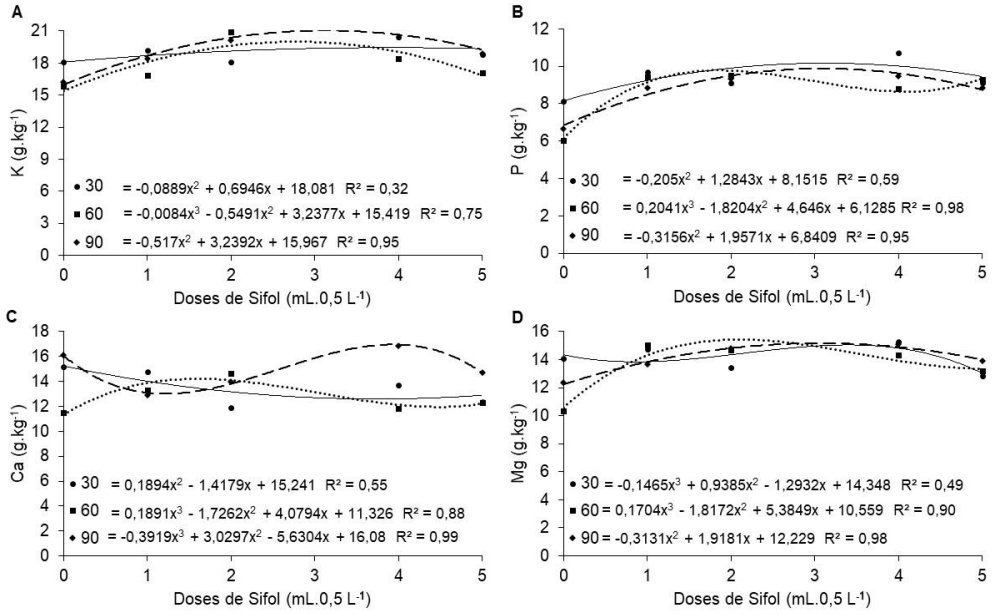

Figure 1: Macronutrients (K – A; P – B; Ca – C; Mg – D) in seedlings derived from pumpkin seeds subjected to different concentrations of Sifol® (mL 0.5 L^{-1}). Pelotas, 2018.

For the variable Iron (Figure 2A), the results presented distinct behaviors for each soaking period, where for 30 and 90 minutes the best model was the quadratic. For the 30 minutes soaking time the curve presents a trend of increase until the point of maximum at the dose of 3.44 mL 0.5 L^{-}

^{1} with a maximum content of 137.77 mg of Fe kg^{-1}, then decreases up to the higher dose. For the 90 minutes soaking time the curve presented a trend of decreasing according to the dose and the greater weight was observed at dose 0 mL 0.5 L^{-1}. For the 60 minutes soaking time, the results were fitted to a cubic model, oscillating between doses, with similar results to the 30 minutes soaking period, with the maximum accumulation at the dose of 3.64 mL 0.5 L^{-1}, with 133.62 mg of Fe kg^{-1}.

For Zinc (Figure 2B), the three soaking times presented similar behaviors wherein the zinc content increased up to a point of maximum of 78.22, 71.20 and 81.75 mg of Zn kg^{-1}, at the doses of 2.50, 2.57, and 2.53 mL 0.5L^{-1}.

Copper (Figure 2C) and Manganese (Figure 2D) presented similar behaviors in the different doses of Sifol® in relation to soaking times. For copper, the soaking times of 30 and 90 minutes fitted a quadratic model with greater content at the doses of 3.12 and 3.21 mL 0.5L^{-1}, with concentrations of 6.28 and 6.38 mg of Cu kg^{-1}, respectively. For the 60 minutes soaking time, Cu content oscillated according to the doses of silicon with a point of maximum at 2.23 mL 0.5 L^{-1}, with a concentration of 6.53 mg of Cu kg^{-1}.

Manganese also presented results that fitted the quadratic model for the soaking periods of 30 and 90 minutes, with the curves increasing up to the dose of 3.17 mL 0.5 L^{-1} and 3.25 mL 0.5 L^{-1} with concentrations of 94.64 and 88.24 mg of Mn kg^{-1}, respectively. On the other hand, for the soaking period of 60 minutes the curve presented a cubic behavior, with point of maximum at the dose of 2.99 mL 0.5 mL^{-1}, reaching 101.70 mg of Mn kg^{-1}.

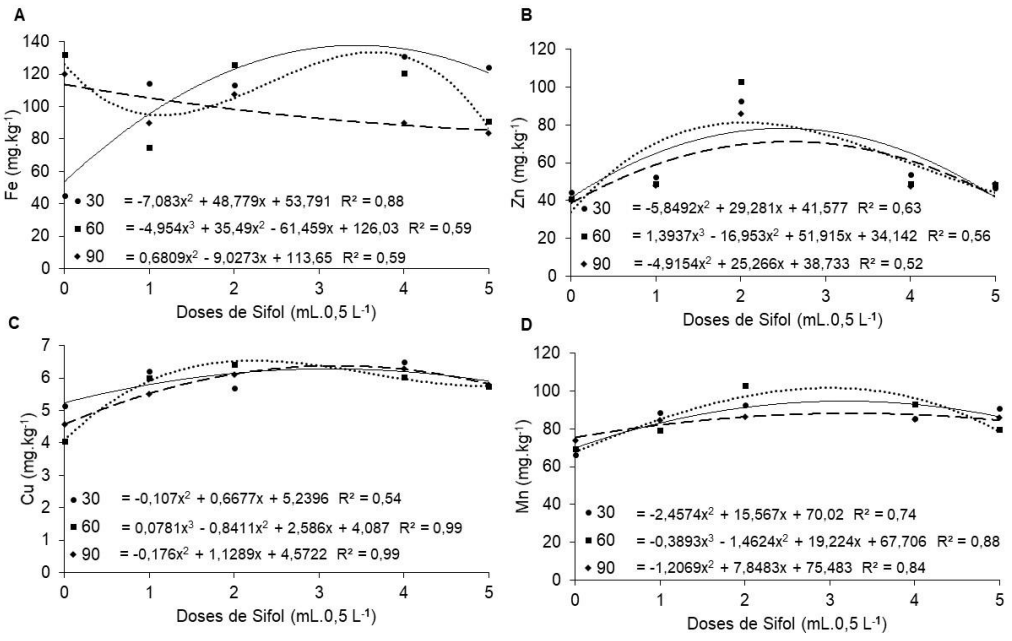

Figure 2: Micronutrients (Fe – A; Zn – B; Cu – C; Mn – D) in seedlings derived from pumpkin seeds subjected to different concentrations of Sifol® (mL 0.5 L^{-1}). Pelotas, 2018.

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Table 4 presents the summary of the analysis of variance for the variables Potassium (K), Phosphorus (P), Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zi), Copper (Cu) and Manganese (Mn) in pumpkin seedlings, derived from seeds subjected to different concentrations and soaking times in a Kaolin solution. A significant interaction was observed among the factors studied for all variables, except for Copper (Cu), where a significant difference was observed for the factor time.

Table 4. Analysis of variance for the variables Potassium (K), Phosphorus (P), Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu) and Mangansese (Mn) in pumpkin seedlings, derived from seeds subjected to different concentrations and soaking times in a kaolin solution. Pelotas-RS, 2018.

Source of Variation	DF	K	P	Ca	Mg	Fe	Zn	Cu	Mn
Dose (D)	4	*	*	*	*	*	*	*	*
Time (T)	2	*	*	*	*	*	*	ns	*
D x T	8	*	*	*	*	*	*	*	*
Residue	30	-	-	-	-	-	-	-	-
Total	44	-	-	-	-	-	-	-	-
CV (%)		0.25	1.08	1.88	0.56	0.72	1.49	5.64	1.06
Average		17.9	8.7	13.8	13.8	100.2	46.89	5.7	82.4

ns Not significant at the 5% probability level; * Significant at the 5% probability level. DF: degrees of freedom; CV: coefficient of variation;

When comparing the soaking times in each dose of Kaolin, significant differences are observed for all variables, varying according to the dose of Kaolin and soaking time used. For the variable Potassium (K), seeds imbibed for 30 minutes, presented greater contents at the doses of 0 and 400 $g.L^{-1}$, when compared to seeds subjected other doses of Kaolin. For the variables Phosphorus (P) and Magnesium (Mg) (Table 5), the best response was obtained in the dose 400 g L^{-1}, with 30 minutes of imbibition, when compared to the other doses. For Calcium (Ca), the doses of 0, 100 and 200 $g.L^{-1}$, with a soaking time of 90 minutes, presented the best response when compared to the other soaking times, however, the other doses did not differ between each other.

According to Kano et al., (2010) which evaluated the macronutrient content in seeds, there was no significant effect of doses of potassium, verified by the F test of the analysis of variance, for all nutrients evaluated.

Table 5. Potassium (K), Phosphorus (P), Calcium (Ca), Magnesium (Mg) in pumpkin seedlings derived from seeds subjected to different concentrations and soaking times in a Kaolin solution ($g.L^{-1}$). Pelotas-RS, 2018

Variable	Soaking Time (min)	Doses of Kaolin ($g.L^{-1}$)					
		0	100	200	300	400	Average

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	30	18.08 a	17.89 b	17.85 b	19.21 b	20.37 a	18.68
K	60	15.80 c	17.91 b	17.03 c	19.52 a	17.34 b	17.52
	90	16.19 b	18.51 a	20.23 a	16.58 c	16.58 c	17.62
	30	8.11 a	8.24 c	8.52 b	10.28 a	11.31 a	9.29
P	60	6.05 c	9.58 a	8.31 c	8.73 b	10.03 b	8.54
	90	6.66 b	9.36 b	9.08 a	8.10 c	8.10 c	8.26
	30	15.15 b	14.40 b	13.88 b	14.49 a	13.42 a	14.27
Ca	60	11.49 c	13.72 c	14.18 b	14.65 a	11.88 b	13.18
	90	16.13 a	15.46 a	14.99 a	12.30 b	11.49 b	14.07
	30	14.08 a	14.41 b	14.60 a	14.76 a	15.59 a	14.69
Mg	60	10.33 c	14.34 b	14.53 a	14.53 b	14.43 b	13.63
	90	12.34 b	15.38 a	14.62 a	13.50 c	10.33 c	13.24

Averages followed by the same letter in the column do not differ statistically between each other by the Tukey Test at the 5% probability level of error. ns: not significant.

For the soaking times in each dose of Kaolin, a significant difference was observed for all variables, related to the dose of Kaolin and soaking time used. For the variable iron (Fe), seeds imbibed for 90 minutes, presented greater contents when compared to seeds subjected to soaking for 30 and 60 minutes, where the best dose is 300 $g.L^{-1}$ (Table 6), when compared to the other soaking times.

For Zn (Table 6), significant differences were observed when comparing soaking times, with the best response for 30 minutes, in the dose of 4.0 $g.L^{-1}$, presenting greater content of the nutrient when compared to the times of 60 and 90 minutes, which did not differ between each other, independently of the dose of Kaolin used. However, for the variable Cupper (Cu), the best results were observed for the soaking time of 60 minutes for all doses, highlighting the doses of 100 and 400 g L^{-1}. On the other hand, for the variable Manganese (Mn), the best performance was observed in the dose of 300 $g.L^{-1}$ and soaking time of 90 minutes, differing from the other times.

Teixeira et al., (2005), while working with bean seeds under the application of different doses of Mn and Zn, observed that even in the cases where a decrease in the content of N, P, B and Cu was detected, the contents of these nutrients remained near the amounts considered adequate for the crop.

Table 6. Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese (Mn) in pumpkin seedlings derived from seeds subjected to different concentrations and soaking times in a Kaolin solution ($g.L^{-1}$). Pelotas-RS, 2018

Variable	Soaking Time (min)	Doses of Kaolin ($g.L^{-1}$)					
		0	100	200	300	400	Average
	30	45.26 c	105.92 b	97.81 b	66.41 c	83.7 c	79.82
Fe	60	132.20 a	111.38 a	104.73 a	102.94 b	119.7 a	114.1
	90	120.14 b	79.92 c	80.73 c	145.58 a	104.4 b	106.1
Zn	30	44.14 a	44.27 c	47.19 a	50.40 a	55.14 a	48.28

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	60	40.67 b	49.10 a	44.80 a	46.57 b	50.01 b	46.24
	90	40.41 b	47.11 b	47.10 b	47.80 b	48.32 c	46.15
Cu	30	5.14 b	5.89 ab	5.46 ab	6.56 a	5.80 b	5.77
	60	4.06 a	6.28 a	5.16 b	5.98 a	6.76 a	5.65
	90	4.58 ab	5.50 b	5.99 a	6.33 a	6.15 ab	5.71
Mn	30	66.38 c	88.69 b	83.48 a	78.78 c	90.00 a	81.46
	60	69.47 b	91.37 a	76.77 c	80.58 b	82.00 b	80.04
	90	74.02 a	86.08 c	80.74 b	106.94 a	81.04 b	85.76

Averages followed by the same letter in the column do not differ statistically between each other by the Tukey Test at the 5% probability level of error. ns: not significant.

For Potassium (Figure 3A), an increase in the content was observed in seedlings derived from treated seeds using the soaking time of 30 minutes, results were fitted to a quadratic model, with an increase of 13.45% from dose 0 to 400 g L^{-1}. For the soaking times of 60 and 90 minutes a quadratic behavior was observed, presenting points of maximum at 278.00 g L^{-1} and 307.00 g L^{-1} and reaching the contents of 19.76 g kg^{-1} and 21.54 g kg^{-1}, respectively.

For Phosphorus (Figure 3B) and Magnesium (Figure 3D), the behavior was similar to the observed for potassium. Comparing the soaking times in relation to the doses of Kaolin, the responses fitted the models studied. For the soaking time of 30 minutes a quadratic behavior was observed with increases of 44.49% and 9.61% for both nutrients. The soaking periods of 60 and 90 minutes were also fitted in quadratic models. For the soaking time of 60 minutes a point of maximum of 236.00 g L^{-1} was observed, reaching a phosphorus content of 9.86 g kg^{-1}, while for 90 minutes the point of maximum was of 237.00 g of Kaolin L^{-1} reaching a phosphorus content of 10.28 g kg^{-1}, with further increases in the dose resulting in gradual decreases in the phosphorus content. For the variable Magnesium (Figure 3D) the soaking times of 60 and 90 minutes were fitted in quadratic models with increases up to the doses of 334.00 and 172.00 g of kaolin L^{-1} with contents of 16.99 and 14.79 g of Mg kg^{-1}, with further increases in the doses resulting in decreases of the magnesium content.

On the other hand, for Calcium (Figure 3C) the soaking times were fitted in quadratic models with a decreasing trend to a point of minimum for the times of 30 and 90 minutes and increasing to a point of maximum for 60 minutes. For the time of 30 minutes, calcium content decreases gradually according to the dose, with a total decrease of 11.51% between the minimum and maximum doses evaluated. For 90 minutes, the greater content of calcium was observed for the control treatment (0 g of kaolin L^{-1}) with 16.53 g of Ca kg^{-1}. However, for the soaking time of 60 minutes a point of maximum was observed at the dose of 236.00 g L^{-1} and a calcium content of 14.65 g kg^{-1}.

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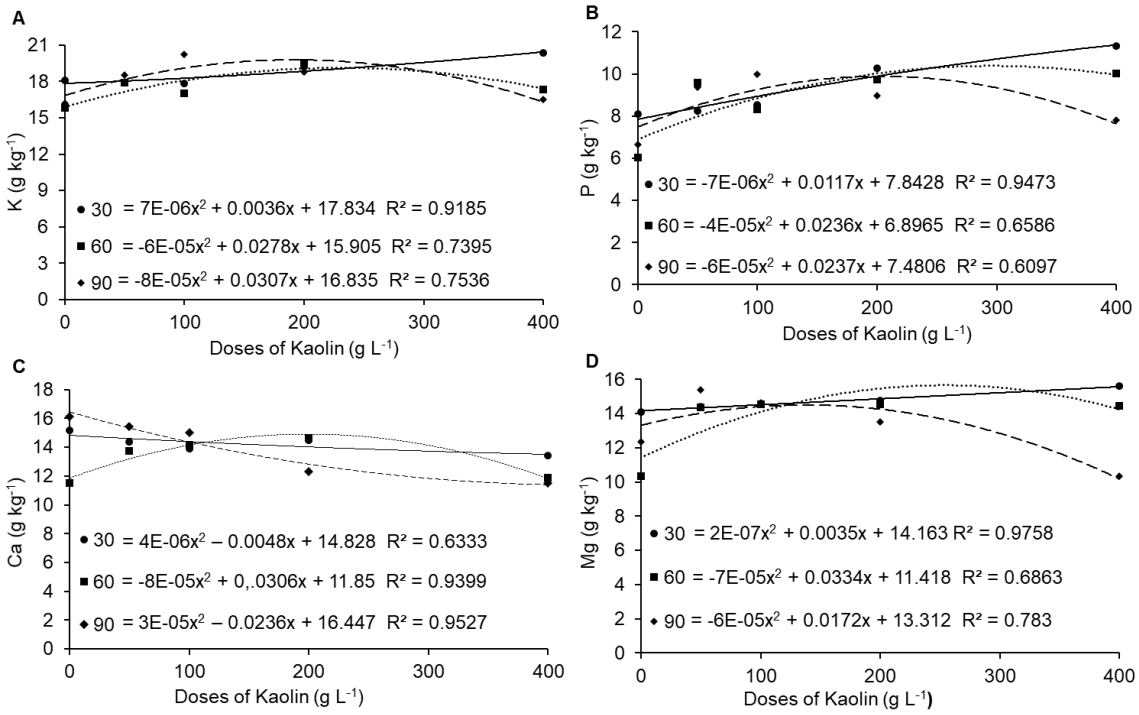

Figure 3. Macronutrients (K – A; P – B; Ca – C; Mg – D) in seedlings derived from pumpkin seeds subjected to different concentrations of Kaolin (mL 0.5 L^{-1}). Pelotas, 2018.

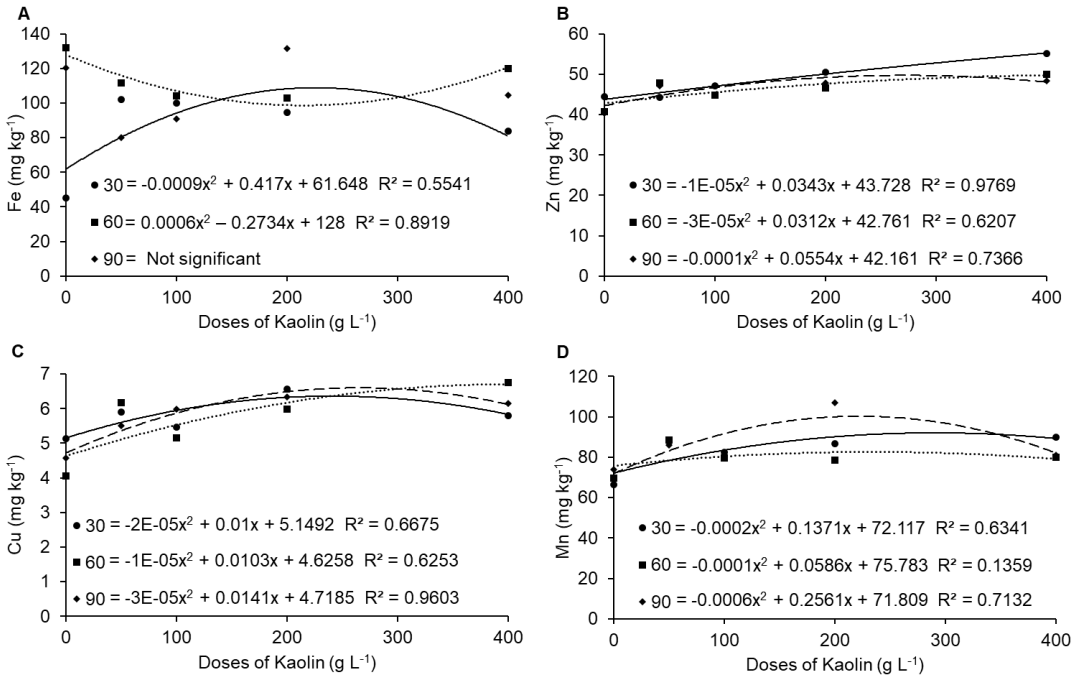

Figure 4. Micronutrients (Fe – A; Zn – B; Cu – C; Mn – D) in seedlings derived from pumpkin seeds subjected to different concentrations of Kaolin (mL 0.5 L^{-1}). Pelotas, 2018.

Despite the relative small quantities of nutrients from fertilizers which are required by plants in the initial stages growth, studies show that the availability of nutrients influences production and

quality, affecting the formation of the embryo and reserve organs, as well as the chemical composition and, consequently, the metabolism and seed vigor (OLIVEIRA et al., 2006; TEIXEIRA et al., 2005).

The dynamic of nutrients which are found on seed tissues is highly variable and additional studies specifically designed to evaluate seed production are necessary. Previous studies on plant nutrition were mostly focused on higher yields. The particularities of each nutrient in seeds are of major importance for modern agricultural production due to the possibility of a direct relationship with physiological quality and seedling performance in the field.

4 CONCLUSIONS

Pumpkin seeds treated with Sifol® present better performance at the dose of 4.0mL 0.5 L^{-1}, for 30 minutes. For pumpkin seeds treated with Kaolin, the best response is obtained with the dose of 400 $g.L^{-1}$ and 30 minutes of imbibition.

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