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Physiological quality of rice in the function of selenium doses

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ABSTRACT

The aim of this work was to evaluate the effect of the application of elementary selenium and selenite doses on seed germination of rice genotypes. The experiment was conducted in a completely randomized experimental design with four replications. The treatments were arranged in a 2x5x2 factorial scheme, two rice genotypes (BRS - Primavera and BRSMG - Conai), five doses of selenium (0.0, 0.2, 0.4, 0.6 and 0.8 g. L^{-1} in water), applied in two forms of Se (sodium selenite - Na_2SeO_3 and elemental selenium - Se^0). The standard germination and accelerated aging tests were used to verify the effects of the experiment. The germination counts were performed on the fifth and fourteenth day, evaluating the percentage of normal, abnormal seedlings, non-germinated seeds, root and shoot length. The data were transformed into square root and submitted to analysis of variance using the Scott Knott test at the 5% probability level. Regression analysis was performed. A higher phytotoxic effect of selenite was observed, as there was a reduction in the germination and development of the seedlings, noting the infeasibility of the selenium sources when applied via seed.

Palavras-chave: *Orysa sativa* L. Selenite, elemental selenium, application, phytotoxic.

Qualidade fisiológica de arroz em função das doses de selênio

RESUMO

Objetivou-se com este trabalho avaliar o efeito da aplicação de doses de selênio elementar e selenito na germinação de sementes de genótipos de arroz. O experimento foi conduzido em delineamento experimental inteiramente casualizado, com quatro repetições. Os tratamentos foram dispostos em um esquema fatorial 2x5x2, sendo dois genótipos de arroz (BRS – Primavera e BRSMG – Conai), cinco doses de selênio (0,0; 0,2; 0,4; 0,6 e 0,8 g. L^{-1} em água), aplicados em duas formas de Se (selenito de sódio – Na_2SeO_3 e selênio elementar – Se^0). Os testes utilizados foram o padrão de germinação e envelhecimento acelerado. As contagens foram realizadas ao quinto e décimo quarto dia, avaliando a porcentagem de plântulas normais, anormais, sementes não germinadas, comprimento de raiz e parte aérea. Os dados foram transformados em raiz quadrada e submetidos à análise de variância utilizando o teste Scott Knott ao nível de 5% de probabilidade. Foi realizada análise de regressão. Verificou-se maior efeito fitotóxico do selenito, pois ocorreu redução na germinação e desenvolvimento das plântulas, notando-se a inviabilidade das fontes de selênio quando aplicadas via semente.

Key-words: *Orysa sativa* L., selenito, selênio elementar, aplicação, fitotóxico.

1. Introduction

Rice (Orysa sativa L.) is considered as the most important food for food security in the world. It presents excellent nutritional balance, being considered as a rustic crop, and a specie with enormous potential to increase production for the fight against hunger in the world (Fao, 2002). Although food production attempts to keep pace with population growth, nutritional deficiency problems reach almost half of the world population (Graham et al., 2007). The deficiencies caused by lack of iron (Fe), iodine (I), selenium (Se), vitamin A and zinc (Zn) affects human health, especially in under-developed countries (Moraes, 2008). Combs Junior (2001) estimates that there are 0.5 to 1.0 billion people with a possible selenium deficiency.

In Brazil, selenium-rich foods are the Brazilian nut and bovine kidney, followed by beef, chicken, fish and eggs, which are also considered foods with high protein content, consumed by the population worldwide (Cominetti et al., 2011). According to Lucca et al. (2006), many strategies are being adopted to minimize malnutrition, one of which is the nutritional enhancement of rice and other cereals through biofortification through traditional breeding and genetic engineering.

Some studies show low content of Se in foods consumed in Brazil. Ferreira et al. (2002) state that the concentration of Se in plant origin foods consumed in Brazil is considered low, equivalent to 18.3 μg / 100g less in cooked rice, when compared to foods consumed on North America. The low levels of Se in Brazilian soils is considered as the probable factor determining this situation. In Brazil, there is still little work with this element and its influence on the germination of rice, since the germination process is directly related to the development of normal seedlings, in addition to being influenced by internal and external factors. Thus, the importance of selenium to human and animal health, especially when taking into account the economic value of rice cultivation on the world scenery, and the search for new forms of introduction in foods, will help to supply the need for this nutrient by the population.

The aim of this work was to evaluate the physiological quality of rice seeds, with doses elemental selenium and sodium selenite.

2. Material and Methods

The experiment was conducted in the seed analysis laboratory at the Federal University of Tocantins, in the municipality of Gurupi, located at the southern region of the State, at an altitude of 276 m and 11º46 '18 "south latitude and 49º02’35” west longitude. The statistical design adopted was completely randomized (DIC), in a 2x5x2 factorial scheme, being two rice genotypes (BRS - Primavera and BRSMG - Conai) grown in five doses of selenium in water (0.0; 0.2; 0.4; 0.6 e 0.8 g. L-1) under two forms (Selenite - Na2SeO3 and elemental selenium - Se0), with four replicates for the first germination standard tests, Counting and accelerated aging. The quantities from each of the sources used were as follows: 430; 870; 1310; 1750 ppm of selenite and 240; 480; 720; 960 ppm of elemental selenium as sources of selenium.

The seeds were harvested after physiological maturation in the 2012/2013 harvest and stored under controlled conditions ± 6ºC. Subsequently, they were submitted to tests to evaluate the physiological quality. The experiments were conducted in January 2014, using standard germination and first count tests, according to Rules for Seed Analysis (Brasil/Mapa, 2009) and accelerated aging, according to AOSA (1983). The first germination count test was performed together with the germination test where the percentage of normal, abnormal and non-germinated seedlings verified on the fifth day after the test installation was evaluated. To perform the standard germination test, 200 seeds were used, subdivided into 4 samples of 50 seeds each, and the seed distribution was done in paper towel made by means of perforated plates containing 50 holes with size and shape of the seeds. The volume of distilled water used for seed imbibition was the equivalent of 2.5 times the weight of the substrate paper, containing two sheets of paper at the base and one at the top of each sample. Afterwards, the solutions of the respective treatments were sprinkled, and 10 ml of them were used on each repetition (50 seeds) at the time of the germination test. The rolls were then positioned vertically in a Mangelsdorf type germinator, set at a temperature of 24 °C ± 2 °C, and relative humidity around 99%, throughout the test period. Seed counts were performed on the fifth and fourteenth day after the test was installed. After completing the test period, the percentage of normal, abnormal seedlings, non-germinated seeds, primary root length and aerial part were evaluated. For measurements of primary and shoot root length, five random seedlings were used in each replicate. The accelerated aging test was performed using 200 seeds. The samples were placed on the screens and these on gerbox plastic boxes, placing 40 ml of distilled water inside. Afterwards, they were submitted to temperature of 42ºC ± 2ºC and relative humidity around 99%, during 96 hours according to AOSA (1983). Soon after this period, the seeds were submitted to the standard germination test and the selenium was applied in the respective treatments using the same doses that were applied in the standard germination test. Seed counts follow the recommendation for rice cultivation, being carried out on the fifth day after the test, verifying the percentage of normal, abnormal seedlings and non-germinated seeds. The percentage data were transformed into square root √ (x + k) and submitted to analysis of variance. Averages comparisons were made using the Scott Knott test at the 5% probability level. Regression analysis was adopted. The analyzes were performed using the SISVAR statistical program (Ferreira, 2011).

In order to verify the quality of the obtained analyzes, the accuracy was used, since it considers the random and systematic effects, whereas the precision considers the systematic errors. According to Resende (2002), the accuracy is classified as: very high accuracy (rgg'≥90), high (70 ≤ rgg' <90), moderate (50 ≤ rgg' <70), low (rgg' <50). Being calculated by the estimator:

$$r_{gg'} = \sqrt{\left(1 - \frac{1}{Fc}\right)} \times 100.$$

In wich rgg 'represents the accuracy and Fc (Snedecor) is the value of the variance ratio for the effects of treatments, associated with the analysis of variance (Resende e Duarte, 2007).

3. Results and Discussion

The analysis of variance with the mean squares and the respective significance of the studied characteristics, normal seedlings, abnormal seedlings and non-germinated seeds, evaluated by the first count test (Table 1). According to the analysis, there was a significant effect on the factors cultivar, dose, source and dose and source interaction for most characteristics evaluated. The different doses tested were highly significant on germination of seedlings for the characteristics evaluated in the different treatments, except for the characteristic non-germinated seeds, which evidences the influence of selenium on seedlings germination.

The quality and precision of the obtained data for all the characteristics evaluated according to the accuracy classification (rgg'%) was considered very high, which makes it possible to affirm that the experiments were well conducted and the data obtained were accurate (Tables 1, 5 and 11).

The different sources of selenium used in the experiment promoted a phytotoxic effect on the seeds (Table 2). Sodium selenite had a higher inhibitory effect than elemental selenium on germination of normal seedlings for both cultivars. Therefore, the average of seed germination, where sodium selenite was used, was 1.7%, while elemental selenium was 4.3%. The average germination percentage of the experiment without the use of selenium (dose 0) was 4.17%. This difference between the sources of selenium can be justified by the different way of assimilation by the seeds, showing that elemental selenium was not expressed as available to them. According to Seixas and Kehrig (2007), selenite (SeO_3^{2-}) is a selenium compound highly soluble in water and has toxic behavior for low-level biological systems, whereas elemental selenium (Se^0) is a compound less soluble in Water and has no toxic behavior.

For the BRS-Primavera cultivar, the interaction of the doses with the selenium sources showed that there was a phytotoxic effect of sodium selenite as it was added in the seeds, so that at the dose of 0.8 g L^{-1} of Se the germination was practically nil, evidencing negative effect on the percentage of normal seedling. This negative effect is due to the high concentration of selenium in those conditions of germination providing the conditions unfavorable to its growth.

Table 1. Analysis of variance for percentage of germination for normal, abnormal seedlings and non-germinated seeds, evaluated by the first counting test.

Sources	GL	Normal. P	Abnormal.P	N. Germinated
Replication	3	1,546**	0,211	0,125
Cultivar (C)	1	0,919	4,260**	4,709**
Dose (D)	4	9,596**	3,386**	0,257
Form (F)	1	132,011**	57,590**	0,487
C x D	4	0,261	0,325	0,196
C x F	1	0,003	0,037	0,012
D x F	4	7,126**	1,722**	0,117
C x D x F	4	0,287	0,040	0,143
Residual	57	0,372	0,335	0,188
$r_{gg'}$ %		99,87	99,75	98,44

*and ** Significant at 5 and 1% by the F test, respectively

Table 2. Average results of normal seedling germination, evaluated by the first count test in different sources of selenium, within each dose and cultivar.

Selenite dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	4,1	3,8
0,2	2,5	1,9
0,4	1,4	0,8
0,6	0,7	0,5
0,8	0,6	1,0
Average	1,8Ba	1,6Bb
Elementar Selenium	Average	Average
0,0	4,7	4,1
0,2	4,5	4,3
0,4	4,3	4,3
0,6	4,2	4,2
0,8	4,3	4,0
Averages	4,4Aa	4,2Aa
Cultivars average	3,1a	2,9a
Selenite average	1,7B	
Elementar selenium average	4,3A	

Averages followed by the same capital letter in the column and lower case in the row belong to the same group by the Skott Knott test (1974) at 5% probability.

The percentage of normal seedlings of the cultivar BRSMG - Conai also shows a negative effect of selenite on germination, that is, the percentage of seedlings decreased as the doses increased. With the dose of 0.6 g.L-^{1} of Se, the germination was almost null, which promoted large amount of the element in the seeds due to its high absorption. For elemental selenium, the same result was not observed due to its lower absorption and assimilation, since it does not present a readily absorbable form, as is the case with selenite.

In relation to the abnormal seedlings, sodium selenite presented a higher phytotoxic effect (mean 4.5%) when compared to elemental selenium (mean 2.8%), possibly due to the accumulation of the same in a larger quantity and for a longer time In the seeds (Table 3). The cultivars BRS-Primavera obtained a higher average of 3.9% compared to BRSMG-Conai, with 3.4%, indicating a greater susceptibility of the cultivar Primavera to the effect of selenium

For the dead seeds, the BRSMG - Conai cultivar obtained a higher average, 5.0%, with 4.4% of the BRS-Primavera cultivar, that is, presented a higher phytotoxic effect in the seeds, becoming a genotype that absorbs more Selenium, which did not contribute to higher abnormal seedling averages (Table 4). One factor that may be involved and have contributed to this result is the genetic factor, which differentiates the cultivars in the absorption of selenium. Ramos et al. (2010), have developed studies to analyze the differentiated ability of several lettuce cultivars to absorb Se and to note differences between them in order to relate to the distinct expression of the genes involved in the absorption and assimilation of Se / S.

In the dose and source interaction for BRS - Primavera, a high percentage of abnormal seedlings, on average 4.5%, was observed for sodium selenite, when compared to elemental selenium, with a mean of 2.8%. This gives the evidence of the phytotoxic effect of selenite compared with elemental selenium, showing that in addition of diminishing the germination rate, results in a higher abnormal number of plants in the germination of rice genotypes. According to Terry et al. (2000), the selenate and selenite of the available forms are those that present high toxicity, being easily absorbed by plants and readily assimilated into organic forms of Se.

For the cultivar BRSMG - Conai, in the interaction between doses and sources, the superiority of sodium selenite for the characteristic abnormal seedlings was observed, indicating a higher deformation in the seeds at this stage. However, elemental selenium remained constant between the doses, with low seedling accumulation due to its lower absorption by the seeds. It can be observed that the cultivars, through the sources of selenium, were expressed differently, that is, there is a difference between the genotypes when submitted to abnormal germination conditions. According to Ramalho et al. (2012), the influence of the genotype and environment reflects on the particular performance of each genotype in the various environments, that is, the genotypes are differentiated as to their sensitivity to changes in the environment. The analysis of variance with the mean squares and the respective significance of the studied characteristics it's on Table 5.

Table 3. Average results of the germination of abnormal seedlings, evaluated by the first count test in different selenium sources, within each dose and cultivar.

Selenite dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	3,3	3,3
0,2	4,6	4,3
0,4	5,4	4,8
0,6	5,4	4,8
0,8	4,8	4,3
Average	4,7Aa	4,3Ab
Elementar selenium	Average	Average
0,0	2,8	2,5
0,2	3,0	2,6
0,4	3,2	2,6
0,6	3,2	2,6
0,8	3,1	2,4
Averages	3,1Ba	2,5Ba
Cultivars average	3,9a	3,4b
Selenite average	4,5A	
Elementar selenium average	2,8B	

Averages followed by the same capital letter in the column and lower case in the row belong to the same group by the Skott Knott test (1974) at 5% probability.

Table 4. Average results of non - germination of seedlings, evaluated by the first count test in different sources of selenium, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	4,5	4,8
0,2	4,4	4,9
0,4	4,4	5,1
0,6	4,6	5,2
0,8	4,9	5,3
Average	4,5Ab	5,1Aa
Elementar selenium	Average	Average
0,0	4,3	5,0
0,2	4,4	4,8
0,4	4,5	4,8
0,6	4,5	4,8
0,8	4,5	5,1
Average	4,4Ab	4,9Aa
Cultivars average	4,4b	5,0a
Selenite average	4,8A	
Elementar selenium average	4,6A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

Table 5. Analysis of variance for percentage of germination for normal, abnormal seedlings, non-germinated seeds, root and shoot length, evaluated by standard germination test.

Sources	GL	Normal.P	Abnormal. P	N. Germinated	Root L	Aereal P
Repetition	3	1,553**	0,102	0,244	0,062	0,030
Cultivar (C)	1	0,949	4,103**	5,193**	0,131	0,901**
Dose (D)	4	9,687**	2,582**	0,373	6,695**	0,944**
Form (F)	1	131,661**	54,833**	0,463	52,056**	13,198**
C x D	4	0,268	0,466	0,215	0,100	0,038
C x F	1	0,002	0,022	0,016	0,0006	0,007
D x F	4	7,206**	1,462**	0,127	5,123**	0,714**
C x D x F	4	0,283	0,067	0,164	0,106	0,050*
Residue	57	0,368	0,351	0,229	0,096	0,016
$r_{gg'}$ %		99,87	99,72	98,23	99,92	99,94

*and ** Significant at 5 and 1% by the F test, respectively.

There was a significant effect for the factors of cultivar, dose, source and interaction between dose and source for most of the characteristics studied, evidencing the influence of selenium on germination and the development of those characteristics, showing that it is an element that needs many studies so that its best application ways on Agricultural crops can be defined.Those results (Table 5) demonstrate a lower phytotoxic effect of elemental selenium, a fact that can be justified by its lower solubility than selenite. It is observed that in the second count of normal seedlings similar results to those of the first count occurred, where sodium selenite (1.7%) was the source of selenium that presented the highest phytotoxic effect against (4.3%) Elemental selenium, since it was absorbed in larger quantities in the seeds because it was readily available for absorption by the seedlings. Unlike selenite, elemental selenium is slightly less soluble, leading to its minimal absorption, behaving in a stable way, which reflects in higher percentages of germination (Table 6). Li et al. (2008) suggest that when plants are treated with Se in the form of selenite it remains in the roots and that the active process, being partially interceded by the phosphate transporters, controls its absorption.

In the second germination count of normal seedlings, sodium selenite was highly toxic as the doses were increased, presenting minimal germination at the dose 0.8 gL-1 of Se in water, that is, there is a great accumulation of selenium in the seeds under those conditions. For elemental selenium a slight decline was observed in the germination of normal plants, however, always remaining constant between the doses. As already mentioned, the phytotoxic effect of selenium on seedlings depends on the form used and its ease in absorption and assimilation by plants. There are studies that indicate the negative effect of selenite lettuce (Rios et al., 2008). However, there are no works with elemental selenium that express their negative effect on the cultures, proving not to be toxic, but when applied via seed the same presents a slight toxicity, as demonstrated in the present study. It was also observed that there was no significant difference between the genotypes, which indicates similarity in the selenium assimilation, that is, there was no genetic influence among the cultivars.

It was verified that in the second count of abnormal seedlings there was an increase both among the cultivars and between sources, compared with the first count (Table 7). In the case of the sources, the selenite remained the most phytotoxic, with a mean of 4.6%, while the average elemental selenium was 3.0%, proving to be among the sources used the most absorbed and accumulated by the seeds. Reflecting the lower percentage of normal seedlings and the higher percentage of abnormal seedlings in the two counts. Among the genotypes, BRS - Primavera continued to present greater susceptibility with the effect of selenium for this characteristic.

Table 6. Average results of germination of normal seedlings, evaluated by standard germination test in different selenium sources, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
$g.\ L^{-1}$	Average	Average
0,0	4,1	3,8
0,2	2,4	1,9
0,4	1,3	0,8
0,6	0,7	0,5
0,8	0,6	1,0
Average	1,8Ba	1,6Ba
Elementar selenium	Average	Average
0,0	4,7	4,2
0,2	4,5	4,3
0,4	4,3	4,3
0,6	4,2	4,2
0,8	4,3	4,0
Average	4,4Aa	4,2Aa
Cultivars average	3,1a	2,9ª
Selenite average	1,7B	
Elementar selenium average	4,3A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

The genotypes BRS – Primavera, despite its susceptibility, presents a higher mean of normal seedlings and less sensitivity to the characteristic of dead seedlings when compared to Cultivar BRSMG - Conai. The interaction between dose and source for the characteristic abnormal seedlings for the cultivar BRS - Primavera showed the susceptibility of the cultivar with increasing doses of selenite, with the rise of 2.0% of damaged seedlings between dose 0 and 0.6 g L- [1] of Se, against 0.4% of elemental selenium.

For the cultivar BRSMG - Conai, the interaction showed a greater deformation of seedlings when using selenite, indicating that it influences both germination and formation of seedlings capable of germinating in the field. The difference between the BRSMG - Conai cultivars and the BRS - Primavera cultivar showed lower susceptibility of the BRS - Primavera cultivar, showing a 1.2% increase in deformed seedlings between the 0 and 0.6 g L - [1] doses of Se, Against 0.1% of elemental selenium.

In the characteristic non - germinated seeds, a significant difference occurred only for the cultivar factor, showing that this difference is due to the genetics of each cultivar when submitted to a stressful selenium condition, indicating that the BRSMG - Conai cultivar is more sensitive to this treatment, presenting a mean of 5.0% versus 4.4% of BRS - Primavera (Table 8). This is a characteristic of the cultivar, expressed in both the first and second germination counts.

For the characteristic root length (Table 9), a high phytotoxicity effect was observed when sodium selenite 1,7% was used, against 3,4% presented by elemental selenium. This difference is in accordance with the different mode of absorption by the roots, since the selenite is readily absorbed. According to Hopper and Parker (1999), the cause of selenite toxicity is its rapid conversion into organic forms of Se, which are incorporated into proteins substituting of S. The main reason for selenium toxicity is due to the inclusion of selenium in the analogues amino acids selenomethionine and seleniocysteine instead of equivalent sulfur amino acids. Among selenium and sulfur there are physical and chemical differences, which results in small expressive changes in the biological properties of the proteins in which sulfur has been replaced by selenium (Brown and Shrift, 1982).

By analyzing the average length of roots of the seedlings for the cultivar BRS - Primavera, a phytotoxic effect is observed as the doses increase, demonstrating its negative effect on both germination and root development and its phytotoxic superiority in relation to elemental selenium.

For the cultivar BRSMG - Conai, the phytotoxic superiority of selenite was observed for root length, where in larger doses root development was reduced drastically, demonstrating that under those conditions germination and the development of seedlings turns out very difficult for a possible quantification of selenium in rice grains. It was observed that there was a difference between the cultivars, where the cultivar BRS - Primavera obtained a longer length of the seedling aerial part, being noticed a low effect of the applied doses. There was also a difference between sources in which elemental selenium had a lower phytotoxic effect and was stable, while sodium selenite had a higher toxic effect (Table 10).

Table 7. Average results of the germination of abnormal seedlings, evaluated by standard germination test in different sources of selenium, within each dose and cultivar.

Selenite dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	3,5	3,6
0,2	4,8	4,4
0,4	5,4	4,8
0,6	5,5	4,8
0,8	5,0	4,4
Average	4,8Aa	4,4Ab
Elementar selenium	Average	Average
0,0	2,9	2,7
0,2	3,2	2,8
0,4	3,3	2,8
0,6	3,3	2,7
0,8	3,2	2,5
Average	3,2Ba	2,7Ba
Cultivars average	4,0a	3,5b
Selenite average	4,6A	
Elementar selenium average	3,0B	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

Table 8. Mean results of the non - germination of seeds, evaluated by the standard germination test in different selenium sources, within each dose and cultivar.

Selenite dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	4,4	4,6
0,2	4,3	4,8
0,4	4,4	5,0
0,6	4,5	5,2
0,8	4,8	5,3
Average	4,5Ab	5,0Aa
Elementar selenium	Average	Average
0,0	4,2	4,8
0,2	4,3	4,7
0,4	4,4	4,7
0,6	4,4	4,8
0,8	4,4	5,0
Average	4,3Aa	4,8Aa
Cultivars average	4,4b	5,0a
Selenite average	4,7A	
Elementar selenium average	4,5A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

Table 9. Mean results of seedling root length (cm), evaluated by standard germination test in different selenium sources, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
g. L-1	Average	Average
0,0	3,8	3,5
0,2	2,4	2,2
0,4	1,4	1,3
0,6	0,8	0,9
0,8	0,7	0,8
Average	1,8Ba	1,7Bb
Elementar selenium	Average	Average
0,0	3,7	3,3
0,2	3,5	3,4
0,4	3,4	3,5
0,6	3,3	3,4
0,8	3,4	3,3
Average	3,5Aa	3,4Aa
Cultivars average	2,6a	2,5ª
Selenite average	1,7B	
Elementar selenium average	3,4A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

Table 10. Mean results of seedling shoot length, evaluated by germination pattern in different selenium sources, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
g. L-1	Average	Average
0,0	3,0	2,7
0,2	2,5	2,2
0,4	2,1	1,8
0,6	1,9	1,7
0,8	1,8	1,7
Average	2,3Ba	2,0Ba
Elementar selenium	Average	Average
0,0	3,1	2,9
0,2	3,1	2,9
0,4	3,1	2,9
0,6	3,0	2,8
0,8	3,0	2,8
Average	3,1Aa	2,9Aa
Cultivars average	2,7a	2,4b
Selenite average	2,1B	
Elementar selenium average	3,0A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

The average shoot length results for BRS - Primavera showed a reduction as selenite doses increase, promoting phytotoxicity effect with the translocation of selenite to shoot. The same did not occur with elemental selenium, which remained constant with the increase of the doses, indicating low or no translocation.

The results for the cultivar BRSMG - Conai indicate that selenite provides a reduction in shoot length up to the dose 0.6 g.L- 1 of Se, remaining constant thereafter. The elemental selenium is constant throughout the doses, showing low phytotoxic power, indicating that selenite in these germination conditions is not recommended due to its rapid absorption and translocation by the seeds causing high toxicity.

In the triple interaction (cultivars, doses and sources), a well differentiated behavior in the aerial part of the seedlings characteristic is observed. That is, the phytotoxic effect of selenite is significantly higher than the effect caused by elemental selenium, noting that the phytotoxic effect of elemental selenium was lower in both cultivars and at the same time this effect was very similar between them (Table 5). The analysis of variance with the mean squares and the respective significances of the characteristics of normal seedlings, abnormal seedlings and non-germinated seeds, evaluated by the accelerated aging test, in rice seeds, with five days after the test installation is found in (Table 11). It was observed that there was a significant effect for dose and source factors for normal seedlings, dose for abnormal seedlings and cultivar for non-germinated seeds. This shows the influence of selenium up to a certain dose on accelerated aging for rice seeds.

It was possible to observe that there was no significant difference for the cultivars when submitted to the conditions of accelerated aging stress. It is observed that the number of normal seedlings was influenced by the doses and sources of selenium, noting that elemental selenium promoted a reduction in the number of normal seedlings, when compared with selenite in those conditions, and that the two selenium compounds contributed In the process of accelerated aging until a certain dose (Table 12).

The normal seedling characteristics of the BRS - Primavera cultivar were influenced by the selenite, contributing to the aging of the seeds with the increment of the selenium compound with a peak at the dose of 0.4 g. L-1. The elemental selenium also contributed to the aging of the seeds, but at a slower rate than the selenite, up to the dose 0.4 g. L-1 (Table 13). The use of selenite, despite its phytotoxic effect, showed a better behavior in the stress condition of the test, even promoting greater aging of the seeds up to a certain dose. According to Marcos Filho (2005), the accumulation of water by the seeds during the accelerated aging may compromise the results.

The superiority of the selenite was maintained to cultivate BRSMG -Conai, contributing to a larger number of normal seedlings. The use of elemental selenium did not have an effect on the reduction of germination, since it remained constant until a certain dose, with little increase later; its behavior, when compared to selenite in these conditions, showed a reduction in germination, because although it is a less soluble compound than selenite, when the direct application to the seed is taken into consideration, it can present a contrary effect, interfering In the process of imbibition, besides becoming toxic under these conditions.

Table 11. Analysis of variance for percentage of germination for normal, abnormal seedlings and non-germinated seeds, evaluated by accelerated aging test.

Sources	GL	Normal P	Abnormal P	N. Germinated
Replicates	3	0,245	0,056	0,091
Cultivar (C)	1	0,346	0,300	0,595**
Dose (D)	4	0,453*	0,524*	0,075
Form (F)	1	0,724*	0,522	0,123
C x D	4	0,301	0,260	0,095
C x F	1	0,001	0,130	0,037
D x F	4	0,212	0,325	0,084
C x D x F	4	0,006	0,191	0,044
Residual	57	0,173	0,176	0,085
$r_{gg'}$ %		95,67	95,99	95,87

*and ** Significant at 5 and 1% by the F test, respectively.

Table 12. Average results of germination of normal seedlings, evaluated by the accelerated aging test in different sources of selenium, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	4,7	4,3
0,2	4,3	4,0
0,4	4,0	4,0
0,6	4,0	4,0
0,8	4,2	4,3
Médias	4,2Aa	4,1Aa
Elementar selenium	Average	Average
0,0	4,3	3,8
0,2	4,1	3,8
0,4	4,0	3,8
0,6	4,0	4,0
0,8	4,0	4,2
Average	4,1Ba	3,9Ba
Cultivars average	4,1a	4,0a
Selenite average	4,2A	
Elementar selenium average	4,0B	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

The abnormal seedling characteristics had a significant effect on the dose factor, which expresses the influence of the different selenium doses independent of the sources used and their interference on the percentage of abnormal seedlings. As the doses were increased, the number of deformed seedlings increased to the 0.4 g dose. L-^{1} of selenium, showing a later slight decline. In the case of non - germinated seeds (Table 14), there was a significant effect for the cultivar factor, with BRSMG – Conai.

Table 13. Average results of the germination of abnormal seedlings, evaluated by the accelerated aging test in different sources of selenium, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	1,3	1,6
0,2	1,9	2,0
0,4	2,2	2,2
0,6	2,3	2,1
0,8	2,2	1,7
Average	2,0Aa	2,0Aa
Elementar selenium	Average	Average
0,0	2,1	2,0
0,2	2,3	2,1
0,4	2,4	2,1
0,6	2,3	2,0
0,8	2,0	2,0
Average	2,2Aa	2,0Aa
Cultivars average	2,1a	2,0a
Selenite average	2,0A	
Elementar selenium average	2,1A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability.

Table 14. Average results of the non - germination of seeds, evaluated by the accelerated aging test in different sources of selenium, within each dose and cultivar.

Selenite Dose	BRS Primavera	BRSMG Conai
g. L^{-1}	Average	Average
0,0	5,1	5,3
0,2	5,2	5,4
0,4	5,3	5,4
0,6	5,3	5,4
0,8	5,2	5,3
Average	5,2Aa	5,4Aa
Elementar selenium	Average	Average
0,0	5,0	5,5
0,2	5,2	5,5
0,4	5,3	5,5
0,6	5,3	5,4
0,8	5,4	5,3
Average	5,2Aa	5,4Aa
Cultivars average	5,2b	5,4a
Selenite average	5,3A	
Elementar selenium average	5,3A	

Averages followed by the same capital letter in the column and lowercase in the row belong to the same group by the Skott Knott (1974) test at 5% probability

That cultivar (Table 14) presented a higher number of non - germinated seeds, with an average of 5.4%, showing its genetic sensitivity to selenium assimilation and to the stress provided by the test, on the other hand the cultivar BRS - Primavera presented an average of 5.2%. There is still a need for many studies with these selenium compounds, since in the germination test the selenite inferred the percentage of normal seedlings when compared to elemental selenium, and in the accelerated aging test, the seeds were aged up to the dose 0.4 G. L-[1.]

4. Conclusions

Both sources influenced the germination and development of the seedlings, promoting phytotoxic effect in them, being the selenite superior to elemental selenium.

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