



Tolerance of Soybean Seeds to Aluminium and Heat Stress During Germination

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Abstract – Stress can be defined as an external factor, which exerts disadvantageous influence on the plant. Osmotic stress and temperature affect crop productivity and also limit the expansion of agriculture in many regions of the world. The objective of the present work was to evaluate the effects of different levels of temperature and aluminum concentrations on germination and vigor of soybean seeds. Soybean (*Glycine max* L.) seeds from two cultivars: 5G770 and 5G830, were submitted to five aluminum concentrations (0, 0.25, 0.50, 1.00 and 1.50 mmolc dm⁻³ of Al⁺³) and three temperatures (20, 25 and 30 °C). It was observed that the temperature influenced germination more than aluminum concentration, reducing the potential of germination of plants, mainly at 30 °C. The higher aluminum concentrations influenced the greater appearance of abnormal seedlings, causing smaller root and shoot size at 20 °C. Germination and vigor of soybean seeds are affected more by temperature than by aluminum concentrations. In the ideal condition at 25 °C, the germination and vigor of both cultivars were not influenced by the aluminum concentration until 1,50 mmolc dm⁻³ of Al⁺³.

Keywords – Temperature, Aluminum, Abiotic Stress

I. INTRODUCTION

According to [1], stress can be defined as an external factor, which exerts disadvantageous influence on the plant. Among the stress conditions that the environment offers, the temperature and the presence of aluminum affect the yield of the crops, and may limit the advance of agriculture in several regions.

The temperature affects the germinative process beginning with the uptake speed of water, later interferes in the biochemical reactions that determine the whole germinative process and, consequently, both the speed and the uniformity of germination, as well as the total germination are altered [3]-[4].

The dissolution of clay minerals and aluminum oxide leads to the appearance of the exchangeable form according to the acidity condition of the soil, that is, the availability of aluminum is favored by soil acidity [5]. The available aluminum limits the productivity of plants, being considered a stress-causing agent that will influence the germination process, because according to [6] besides reducing the germination it still exerts decisive influences on the metabolism of the seeds.

Reference [7] evaluated the germination and vigor of *Coffea arabica* and *Coffea canephora* seeds under different concentrations of aluminum and they realized that the germination was not affected until the

concentration of 60 mg.L⁻¹, however, root growth was higher in the presence of aluminum up to the concentration mentioned above. Reference [8] studied the effect of aluminum on seeds *Coniza canadensis* and *Coniza bonariensis* at concentrations of 0 to 2 cmolc.dm⁻³ aluminum and they observed that the germination decreased proportionally to the increase of aluminum for both species.

Reference [9] investigated the performance of soybean seeds at different concentrations of aluminum, showing that up to the concentration of 1.5 mmolc.dm⁻³ the germination was not affected in the five cultivars studied. Reference [10] selected soybean genotypes by initial root growth for tolerance to oxidative stress by aluminum up to the dose of 2.0 mg.L provided by Al₂(SO₄)₃.

The global climate is causing adverse factors such as high temperatures and increased availability of exchangeable aluminum, so it is necessary to characterize the germination capacity of soybean seeds and the initial development of these seedlings under different combined conditions of stress, considering that few studies about that have been performed. In this approach, the aim of this research was to evaluate the influence in the seed germination and vigor of two soybean cultivars when submitted to different temperatures and concentrations of aluminum.

II. MATERIAL AND METHODS

The experiment was carried out at the Central Laboratory of Seed Analysis, Department of Agriculture, from Federal University of Lavras (UFLA), located in the city of Lavras - MG, Brazil.

Soybean seeds of two cultivars 5G770 and 5G830 were used, a tolerant and susceptible to aluminum toxicity, respectively, donated by Dow Agrosociences.

The seeds of the two cultivars were submitted to different aluminum concentrations (0, 0.25, 0.50, 1.00 and 1.50 mmolc dm⁻³ of Al⁺³) provided by aluminum trichloride (AlCl₃), and the temperatures (20, 25 and 30 °C) providing the stress conditions.

The stress response was assessed by the following tests and evaluations:

Germination test – It consisted of placing four replicates of fifty seeds, wrapped in three sheets of germitest-type paper soaked in 2.5 times their weight with the solutions mentioned above, then they were packed in germinating chambers of the type B.O.D.s, at the temperatures mentioned. The result was expressed as percentage of

normal seedlings on the eighth day [11]. The percentage Length of root and shoot – It was performed according to [12]. At the end of the germination test, 10 normal seedlings were randomly selected and the root and shoot length were measured using a millimeter ruler. The result was expressed as an average of centimeters of root or shoot per seedling.

The treatments were distributed in the factorial scheme 2 x 5 x 4, composed of two soybean cultivars (5G770 and 5G830), five concentrations of aluminum (0, 0.25, 0.50, 1.00 and 1.50 mmol_c.dm⁻³ of Al³⁺) and three temperatures (20, 25 and 30 ° C). The data were submitted to normality and homogeneity tests, followed by analysis of variance by the F test. The averages were compared by the Tukey test at 5% significance.

III. RESULTS AND DISCUSSION

Table 1 shows the percentage of germination, abnormal

seedlings and dead seeds, root and shoot length, in the different concentrations of aluminum when submitted to 20 °C. It is observed that in the absence of aluminum the germination was low for both cultivars, however in the higher concentration of aluminum there was an increase of the germination. Probably the higher concentration of aluminum induced some mechanism of metabolic activation, thus promoting the increase of the germination associated to lower temperature. However, in spite of favoring the increase in the percentage of germination, the seedlings originated were smaller and less vigorous, according to root and shoot length results, compared to other temperatures (Table 1). Interestingly, the increase in aluminum concentration did not promote the increase in the percentage of abnormal seedlings in the cultivar 5G830. The high percentage of abnormal seedlings of cultivar 407 under high concentrations of aluminum are indicative of the sensitivity of this cultivar to aluminum acidity.

Table 1. Percentage of germination, abnormal seedlings, dead seeds and root and shoot length of two soybean cultivars exposed to different concentrations of aluminum (mmol_c.dm⁻³ of Al³⁺) at 20 °C.

Cultivars	Aluminum (mmol _c .dm ⁻³)				
	0,00	0,25	0,50	1,00	1,50
Germination (%)					
5G830	38 aB	66 aA	04 bD	56 aAB	75 aA
5G770	00 aC	00 bC	28 aB	00 bC	82 aA
Abnormal seedlings (%)					
5G830	62 aC	32 aB	96 bD	42 aB	20 aA
5G770	82 bC	54 bB	64 aB	99 bD	14 aA
Dead seeds (%)					
5G830	00 aA	02 aA	00 aA	02 aA	05 aA
5G770	18 bB	46 bC	08 bA	01 aA	04 aA
Root (cm)					
5G830	3,40 aB	3,07 aB	1,13 bC	3,68 aB	5,86 aA
5G770	00 bC	0,00 bC	3,03 aB	0,00 aC	4,72 bA
Shoot (cm)					
5G830	2,41 aAB	2,81 aA	1,09 bB	2,58 aA	3,35 aA
5G770	0,00 bB	0,00 bB	3,26 aA	0,00 bB	3,07 aA

Means followed by the same lowercase letter in the column and upper case in the row do not differ statistically from each other by the Tukey test at 5% of significance.

It is observed that in each aluminum concentration the highest germination averages were observed in the two cultivars at 25 ° C (Table 2), when compared to the other

temperatures. According to [11], the ideal temperature for germination of soybean seeds is 25 ° C, and in this condition there was a statistical difference between the

two cultivars in the absence of aluminum, with superiority of cultivar 5G830. However, for both lots, the increase in aluminum concentration did not negatively or positively affect the final percentage of germination. Reference [9] obtained similar results for germination in five soybean cultivars at the same aluminum concentrations at 25 °C.

Reference [13] found no effect of concentration of Al^{3+} below 20 $mmol.c.dm^{-3}$ on the germination of *Calopogonium mucunoides* seeds. Reference [14] investigated the germination of melon seeds at Al^{3+} concentrations ranging from 1 to 40 $mg.dm^{-3}$ (0.12 to 4.5 $mmol.c.dm^{-3}$), but there was no effect on germination.

Table 2. Percentage of germination, abnormal seedlings, dead seeds and root and shoot length of two soybean cultivars exposed to different concentrations of aluminum ($mmol.c.dm^{-3}$ of Al^{3+}) at 25°C.

Cultivars	Aluminium ($mmol.c.dm^{-3}$)				
	0,00	0,25	0,50	1,00	1,50
Germination (%)					
5G830	94 aA	87 aA	97 aA	76 aA	96 aA
5G770	75 bA	83 aA	87 aA	88 aA	72 bA
Abnormal seedlings (%)					
5G830	06 aA	10 aAB	03 aA	22 bB	04 aA
5G770	23 bB	05 aA	11 aAB	10 aAB	21 bB
Dead seeds (%)					
5G830	00 aA	03 aA	00 aA	02 aA	00 aA
5G770	02 aA	12 bB	02 bA	02 aA	07 bAB
Root (cm)					
5G830	6,80 aA	5,83 bA	7,09 aA	5,29 aA	6,74 aA
5G770	6,81 aB	9,31 aA	6,30 aB	6,67 aB	5,72 aB
Shoot (cm)					
5G830	6,21 aA	4,26 bB	6,58 aA	6,03 aA	5,88 aA
5G770	6,05 aA	5,72 aA	5,27 bA	6,25 aA	5,93 aA

Means followed by the same lowercase letter in the column and upper case in the row do not differ statistically from each other by the Tukey test at 5% of significance.

The root length at each aluminum concentration was higher at 25 °C when compared to the other temperatures (Table 2). For the cultivar 5G830 there was no effect of the aluminum on the root length, while for the cultivar 5G770 the lower aluminum concentration provided a longer root length. Reference [9] found that the aluminum concentration of 1.0 $mmol.c.dm^{-3}$ was the one that produced the highest root length in the five soybean cultivars studied. According to [15] and [16] the most easily recognized symptom of aluminum toxicity is inhibition of root growth, which is used as an indication of plant stress to this element. However, when cultivar 5G880 is in ideal temperature conditions, growth is not affected by the concentration of aluminum.

The shoot length was higher at 25 °C when compared to the other temperatures (Table 2). Similar to root length results, shoot length was not influenced by aluminum concentration, except for cultivar 5G830 at 0.25 $mmol.c.dm^{-3}$, which had a lower response than the others (Table 2). These results differ from those obtained by [9], who observed that the largest shoot length was at the concentration of 0.25 $mmol.c.dm^{-3}$. Reference [14] observed that at concentrations of Al^{3+} in the range of 1 to

5 $mg.dm^{-3}$, i. e. 0.12 to 0.5 $mmol.c.dm^{-3}$, melon seedlings growth was stimulated, causing no abnormalities, which diverges from the results observed in this research, where the aluminum concentration did not affect the shoot length at 25 °C.

Table 3 shows the percentage of germination, abnormal seedlings, dead seeds, root and shoot length, in the different concentrations of aluminum when the seeds were submitted to 30 °C.

The percentage of germination was lower at 30 °C (Table 3) at all concentrations of aluminum. Still at this temperature, most of the seedlings obtained were abnormal presenting the primary root undeveloped and short epicotyl. In most cases, heat stress delays the development of the germination process and can suppress it in quiescent seeds or those who had already started their germination [17]. According to [13], the temperature affects both the capacity and the speed of germination. Seeds have the ability to germinate in a specific temperature range, characteristic for each species, but the time required to obtain the maximum germination percentage is dependent of temperature. Temperatures below or above optimum temperature tend to reduce the

speed of the germination process, exposing the seedlings for a longer period to adverse factors, which may lead to a reduction in the total percentage of germination [4].

IV. CONCLUSIONS

Germination and vigor of soybean seeds are affected

more by temperature than by aluminum concentrations. At the temperature of 20 °C there was a reduction in seed vigor. The temperature of 30 °C reduced the germination potential.

In the ideal condition at 25 °C, the germination and vigor of both cultivars were not influenced by the concentration of aluminum.

Table 3. Percentage of germination, abnormal seedlings, dead seeds and root and shoot length of two soybean cultivars exposed to different concentrations of aluminum (mmol.c.dm⁻³ of Al³⁺) at 30°C.

Cultivars	Aluminium (mmol.c.dm ⁻³)				
	0,00	0,25	0,50	1,00	1,50
Germination (%)					
5G830	00 aA	12 aA	00 bA	09 bA	00 aA
5G770	01 aB	10 bB	34 aA	35 aA	16 aAB
Abnormal seedlings (%)					
5G830	95 aA	85 aA	97 bA	89 bA	98 aA
5G770	91 aB	87 bB	63 aA	59 aA	80 bB
Dead seeds (%)					
5G830	05 aA	03 aA	03 aA	02 aA	02 aA
5G770	08 aA	03 aA	03 aA	06 aA	04 aA
Root (cm)					
5G830	0,00 aC	5,52 aA	0,00 bC	2,78 bB	0,00 bC
5G770	0,48 aD	3,07 bBC	4,73 aA	4,52 aAB	2,83 aC
Shoot (cm)					
5G830	0,00 aC	4,10 aA	0,00 bC	2,65 bB	0,00 bC
5G770	1,02 aA	2,94 bB	4,18 aAB	4,85 aA	3,91 aAB

Means followed by the same lowercase letter in the column and upper case in the row do not differ statistically from each other by the Tukey test at 5% of significance.

ACKNOWLEDGEMENT

To the Laboratory of Seed Analysis of the Federal University of Lavras - UFLA for kindly collaborating with equipment and materials, and DOW AGROSCIENCES, for the concession of seeds.

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