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Water Stress Induced by Mannitol and Sodium Chloride in Soybean Cultivars

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ABSTRACT

Four soybean (Glycine max L. Merril.) cultivars were contrasted in relation to germination and vigour of seedlings, when seeds were submitted to water stress induced by mannitol or sodium chloride. Water stress affected seed germination and seedling development, however, seedling development was affect in higher osmotic potential (-0.3MPa) than the necessary to affect germination -1.2MPa when induced by mannitol or -0.6MPa when induced by sodium chloride. 'Pioneira' and 'Xingu' cultivars had high development in low water availability and/or salinity conditions.

Key words: *Glycine max,* tolerance, salinity, germination, vigour

INTRODUCTION

Seeds of high quality, especially in soybeans, are the most important tool to be used in agricultural employment, as over it all other investments will be done (Krzyzanowski et al., 1992). Water availability and movement into the seeds are very important to promote germination, initial root growing and shoot elongation. These factors are highly influenced by the soil matric potential, soil texture and seed/soil contact area (Dasberg and Mendel, 1971; Hadas and Russ, 1974; Hadas, 1976; Bewley and Black, 1994). Only, highly negative water potential, especially in the early germination, may influence the seeds water absorption, making germination not possible (Bansal et al., 1980; Braccini et al., 1996).

To allow germination, there is a minimum moisture that the seed should get and it depends on its chemical composition and of the permeability of the tegument (Popinigis, 1985; Carvalho and Nakagawa, 1988). With water absorption, tissues will be rehydrated and consequently starting an intensification of breathing and of all the other metabolic activities, that culminate in the necessary supply of energy and nutrients to restart the embryonic axis growth (Carvalho and Nakagawa, 1988). In soybean, seeds require at least 50% of moisture. This moisture content could be reached five days after sowing, if soil water tension will keep at least on less than -6.6 bars (-0.66MPa) (Sediyama et al., 1985). According to Peske and Delouche (1985) if any precipitation or irrigation occurs between 5 to 10 days after sowing, seeds will be deteriorated and could not germinate any more, even if low humidity conditions have gone.

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Observing germination and elongation of eight soybean cultivars exposed to water potentials of 0, -0.5, -1.1 and -1.5MPa, and at 15 or 30ºC, Seong et al. (1988) reported that the moisture content and the seedling length decreased when the mannitol concentration increased, concluding that germination in mannitol was useful for the selection of soybean cultivar for emergency capacity under conditions of water deficit. Induced water deficit by polyethylene glycol showed similar values to that observed in the fields (Thill et al., 1979), permitting also vigour evaluation (Santos et al., 1996). In similar potential ranges, germination patterns may be different between species or even between varieties of the same species (McWilliam and Phillips, 1971; Therios, 1982). However, some species, as soybean are very sensitive to sodium chloride during germination (Bourgeais-Chaillov et al., 1992; Santos et al., 1992).
In this paper the effect of the induced water deficit, either by mannitol or by sodium chloride, was evaluated observing the germination and seedling vigour of four soybean cultivars commonly sowed in Brazilian savannah.

MATERIAL AND METHODS

Seeds of four soybean cultivars were used, 'Pioneira' (MT/BR 49), 'Conquista' (MG/BR 46), ‘Pintado' (MT/BRS 63) and 'Xingu' (MT/BR 51) used in Mato Grosso state as commercial crop. Seeds were harvested in 98/99, in a seed production field and donated by Sementes Maggi Ltd., placed in the Sapezal - MT (13º32´48" S and 58º48´55" W).
The experiment was carried out during August-September 1999 in the Seed Analysis Laboratory of Universidade do Oeste Paulista - UNOESTE - located in Presidente Prudente - SP. Seeds, after reception, were hand separated, taking off broken, split and wrinkled seeds remaining only pure and externally perfect seeds, that were maintained at 15ºC/20%RH at the storage room. Seeds were submitted to germination, using induced osmotic potentials (0, -0.3, -0.6, -1.2, -2.4 MPa) of sodium chloride (NaCl) and mannitol (Table 1) (Braccini et al., 1996).
Germination test was conducted with four replications per treatment with 50 seeds each. Seeds were rolled in three paper towels, moistened to 2.25 its weight with one of the solutions mentioned before (Table 1) (Krzyzanowski et al., 1991). Rolls were put in polyethylene bags and kept in Mangesldorf chambers at 25ºC. Germination was evaluated at days 5 and 8 after sowing. Only normal seedlings were counted (Brasil, 1992) to determine germination percentage and were classified, for vigour classification test in strong or weak seedlings according to Nakagawa (1999). Percentage of abnormal seedlings was scored at the end of the germination test (Brasil, 1992).
The evaluation of physiological quality was carried out using four repetitions of 10 seeds each, per cultivar and per treatment in Mangesldorf chambers at 25ºC. Seeds rolled in paper were regularly spaced in one row on the first third of the paper towel (Krzyzanowski, 1991). Normally developed seedlings were measured on day 8, computing the hypocotyl and root length(cm), the dry weight(g) of the shoots without the cotyledons and the dry weight of the roots (Nakagawa, 1999).
The experimental design was totally randomised in a factorial arrange of 4 x 5, between cultivars and mannitol or cultivars and sodium chloride, with four replications. The germination values, abnormal seedling and vigour classification were transformed in arcsine $(X/100)^{0,5}$, dry weight of shoot and root, were not transformed. The data were tabulated and analysed statistically with aid of the software SANEST (Zonta et al., 1984), using the test F for variance analysis and the test of Tukey for the average comparison.

Table 1 - Used amounts of sodium chloride and mannitol to obtain different levels of water deficit.

Ψos Level (MPa)	NaCl (gL^{-1} of distilled water)	Mannitol
0	0	0
-0.3	4.20	22.29
- 0.6	8.40	44.58
- 1.2	16.81	89.17
- 2.4	33.62	178.34

RESULTS AND DISCUSSION

There was a significant interaction between cultivars and osmotic treatments for germination and abnormal seedlings, where cultivars ‘Pioneira’, ‘Conquista’ and ‘Xingu’ did not have any decrease in germination ability at water deficit of 0, -0.3, -0.6 and -1.2MPa. However, ‘Pintado’ showed a reduction with an increasing in mannitol induced water deficit (Table 2). According Mayer and Poljakoff-Mayber (1989) results like these could be attributed to absence of energy to start the germination process, as energy was obtained by increments in the respiratory pathway after the imbibition, and in low levels of water potential tax water absorption was processed slowly. At zero potential 'Pintado' cultivar presented a low germination than 'Pioneira'. At -2.4MPa no cultivars showed any normal seedling. Water deficit worked decreasing velocity and seed germination percentage and for each species there was water potential, that under it germination did not occur (Adegbuyi et al., 1981). Germination patterns could be different between species and between different varieties in the same specie (McWilliam and Phillips, 1971, Therios, 1982) and for soybean the water potential was -0.7MPa. According Braga et al. (1999), potentials between -0.4 and -0.6MPa declined all parameters (germination percentage, size and seedling weight), in common bean plants, and seeds with low physiological quality showed higher decrease when submitted to lower water potentials.

For abnormal seedlings (Table 2), there was a significant interaction between cultivars and mannitol induced water deficit. 'Pioneira' at the potentials 0, -0.3, -0.6 and -1.2 MPa showed low number of abnormal seedlings. At -2.4MPa there was a higher number of abnormal seedlings in 'Pioneira', 'Conquista' and 'Xingu', all cultivars tested did not show any normal seedling at -2.4MPa. Germination, in strongly negative water potentials, especially at the beginning of the imbibition could influenciate water absorption by the seeds, and this event could turn not viable the germination process (Bansal et al., 1980).

Table 2 - Germination (%) and abnormal seedlings (%) of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of mannitol during germination. Presid. Prudente, 1999

Mannitol (MPa)	Germination (%)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	88 aA	80 abAB	76 abAB	68 bA	78
-0.3	93 aA	66 bB	80 abA	41 cB	69
-0.6	83 aA	82 aA	72 aAB	44 bB	70
-1.2	87 aA	72 bAB	64 bB	30 cB	63
-2.4	0 aB	0 aC	0 aC	0 aC	13
Average	70	60	58	37	

Mannitol (MPa)	Abnormal Seedlings (%)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	7bB	11abC	19abB	22aB	15
-0.3	7cB	36bB	14cC	56aA	28
-0.6	9bB	17bBC	22bB	42aAB	23
-1.2	11bB	16abBC	20abB	32aB	20
-2.4	89aA	82aA	86aA	30bB	72
Average	22	32	31	37	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

Results of hypocotyl and root length (Table 3) were similarly affected by mannitol induced water deficit. At zero potential, both hypocotyl and root lengths reached their highest values. All other treatments gradually reduced the seedling growing. Hypocotyl length was not efficient to allow differentiation between cultivars; however, root length was superior in 'Xingu'. Kramer (1974) reported that the first effect measurable due to water deficit was the growth reduction, caused by the declining in the cellular expansion. The cellular elongation process and the carbohydrates wall synthesis were very susceptible to water deficit (Wenkert et al., 1978) and the growing decrease was a consequence of the turgescence laying down of those cells (Hsiao, 1973; Shalhevet et al. 1995).

Table 3 - Hypocotyl and root length (cm) of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of mannitol during germination. Presidente Prudente, 1999.

Mannitol (MPa)	Hypocotyl (cm)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	6.41	5.92	6.30	6.90	6.38A
-0.3	3.71	3.13	3.63	3.01	3.37B
-0.6	2.63	2.32	2.17	2.10	2.30C
-1.2	1.12	0.71	0.98	0.60	0.85D
-2.4	0.00	0.00	0.00	0.00	0.00E
Average	2.77a	2.42a	2.62a	2.52a	

Mannitol (MPa)	Root (cm)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	4.50	4.26	5.05	3.95	4.44A
-0.3	2.98	2.82	4.06	3.23	3.27B
-0.6	1.58	1.33	1.62	1.36	1.47C
-1.2	0.63	0.37	0.55	0.28	0.46D
-2.4	0.00	0.00	0.00	0.00	0.00E
Average	1.94ab	1.76b	2.26a	1.76b	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

Torres et al. (1999), working with cucumber, related a gradual reduction in the seedling growth at -0.4MPa.

Dry weight of shoot and root (Table 4) were differently affected by water deficit. Shoot dry weight showed significant interactions between cultivars and treatments, ‘Pioneira’, ‘Conquista’ and ‘Xingu’ did not show any difference till the water potential of -0.6MPa, but there were reductions in the lower potentials (-1.2 and -2.4MPa). These data were in contrast to those exhibited by Braccini et al. (1996, 1998) where a drastic reduction in shoot dry weight was observed in water deficits between -0.6 and -0.9MPa. ‘Pintado’ have its dry weight reduced gradually with the increasing of water deficit. At zero potential ‘Pintado’, ‘Pioneira’ and ‘Conquista’ did not differ. At -0.3MPa there were no difference among the materials. At -0.6MPa ‘Xingu’ had the poorest result. At -1.2MPa ‘Pioneira’ produced a superior shoot dry weight, however without differing of ‘Xingu’, ‘Conquista’ and ‘Pintado’ were inferior for this parameter.

Using shoot dry weight as a parameter (Table 4), there were no significant interaction between cultivars and treatments. Water deficit at -0.3 and -0.6MPa showed higher root dry weight. Braccini et al. (1996) reported that soybean roots exposed to water deficit were well developed than the roots that grew without water deficit. At -1.2 and -2.4MPa there were a significant reduction in root dry weight for all cultivars. According to Marur et al. (1994), water restriction acted slowing physiological and biochemical processes and soybean seedlings at low water deficit showed a weak growing leading to a lower accumulation of dry matter.

There was significant interaction in the parameter vigour classification (Table 5). ‘Pioneira’ presented the highest vigour classification at 0MPa, but decreased at water deficits of -0.3 and -0.6MPa. ‘Conquista’ and ‘Pintado’ did not reduce its vigour until -0.3MPa, declining drastically at higher water deficits. ‘Xingu’ exhibited the same vigour from 0 to -0,6MPa when its values drastically falls to zero.

Water deficit, induced by mannitol, affected germination and seedling development. Germination was severely affected at -2.4MPa. Parameters that evaluated seedling development were more affected by water deficit than germination. Beginning at -0.3MPa seedling started hypocotyl and root growth reduction reached zero at -2.4MPa. Dry weight shoot and root, were weakly affected till -0.6MPa and reach zero at -2.4MPa.

Table 4 - Shoot and root dry weight of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of mannitol during germination. Presidente Prudente, 1999

Mannitol (MPa)	Shoot dry weight (g)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	0.180 a A	0.173 ab A	0.135 b A	0.187 a A	0.168
-0.3	0.135 a AB	0.174 a A	0.132 a A	0.148 a AB	0.148
-0.6	0.171 a A	0.155 ab A	0.121 b A	0.132 ab B	0.145
-1.2	0.102 a B	0.050 b B	0.068 ab B	0.047 b C	0.068
-2.4	0.000 a C	0.000 a B	0.000 a C	0.000 a C	0.000
Average	0.118	0.110	0.090	0.104	

Mannitol (MPa)	Root dry weight (g)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	0.035	0.030	0.017	0.022	0.026AB
-0.3	0.028	0.024	0.024	0.030	0.027A
-0.6	0.027	0.022	0.041	0.019	0.027A
-1.2	0.025	0.012	0.015	0.007	0.015B
-2.4	0.000	0.000	0.000	0.000	0.000C
Average	0.023a	0.018a	0.019a	0.016a	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

Table 5 - Vigour classification (% of strong seedlings) of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations mannitol during germination. Presidente Prudente, 1999

Mannitol (MPa)	Vigour classification (% of strong seedlings)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	57 a A	22 b A	25 b A	29 b A	33
-0,3	42 a B	17 c AB	32 ab A	21 bc A	28
-0,6	29 a B	11 b B	30 a A	4 c B	19
-1,2	0 a C	0 a C	0 a B	0 a C	0
-2,4	0 a C	0 a C	0 a B	0 a C	0
Average	26	10	17	11	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

'Pintado' had a low germination at no water deficit (Table 2), it showed a very good performance at shoot dry weight, being equal to 'Pioneira', the cultivar with the best germination score, supporting that developmental parameters, in seedlings, were most effective to verify cultivar tolerance to water deficit.

Germination and abnormal seedlings in water deficit induced by sodium chloride are shown in Table 6. There was significant interaction between cultivars and water deficit treatments. For ‘Pioneira’ and 'Pintado' there were no difference between 0 and -0.6MPa, and ‘Conquista’ and ‘Xingu’ differed in this range. At -1.2 and -2.4MPa no cultivar produced any normal seedling. 'Pintado' exhibited the poorest results in germination.

There was no difference between 0 and -0.6MPa in the abnormal seedlings for all cultivars; however, 'Pintado' showed the highest score. At -1.2MPa, cultivars could be differentiated showing a high number of abnormal seedlings in ‘Pioneira’, ‘Conquista’ and ‘Xingu’. These results could be attributed to the reduction of the osmotic potential. van der Moezel and Bell (1987) related that NaCl could affect germination, as by the ionic effect, as by ion cell reaching toxic levels or for combination of both. At -2.4MPa all cultivars failed to germinate. Santos et al. (1992) reported that soybean seed germination, with high vigour, was null, when germinated in solutions of NaCl at -1.5MPa. However, in cucumber, Torres et al. (2000) reported that water deficits lower than -0.4MPa were harmful to germination, where a reduction in germination and growth of seedlings could be observed.

Table 6 - Germination (%) and abnormal seedlings (%) of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of Sodium chloride during germination. Presidente Prudente, 1999

Sodium chloride (MPa)	Germination (%)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	90 a A	93 a A	87 a A	74 b A	86
-0.3	94 a A	88 ab AB	85 b AB	67 c A	84
-0.6	91 a A	85 ab B	76 bc B	66 c A	80
-1.2	0 a B	0 a C	0 a C	0 a B	0
-2.4	0 a B	0 a C	0 a C	0 a B	0
Average	55	53	50	41	

Sodium chloride (MPa)	Abnormal seedlings (%)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	9 b B	6 b B	10 b B	25 a A	13
-0.3	4 c B	11 bc B	14 b B	30 a A	15
-0.6	9 b B	12 b B	17 ab B	26 a A	16
-1.2	88 a A	60 b A	45 b A	5 c B	50
-2.4	0 a C	0 a C	0 a C	0 a C	0
Average	22	18	17	17	

Different letters, capital letter in the columns and lower case in the lines, indicate significant diffe rence at 5% Tukey test.

Hypocotyl and root length of seedlings exposed to different NaCl induced water deficits can be seen in Table 7. Treatments interfered differently in hypocotyl and root length. For hypocotyl length, cultivars showed the best result at no water deficit, decaying till zero at -1.2MPa, what was according the obtained data of Torres et al. (2000), where the increase in water deficit represented a reduction in seedling. Root growth presents its best result at water deficits between 0 and -0.3MPa, reducing the growth above this mark. There was no difference between cultivars for hypocotyl length, but for root length 'Xingu' was superior not differing from 'Pioneira' but differing from 'Conquista' and 'Pintado'. Shalhevet et al. (1995) showed that, in soybean and maize, elongation of roots, a process direct linked to cell elongation, was more sensible.

There was significance in the interactions between cultivars and NaCl induced water deficit. Shoot dry weight gradually decreased with water deficit increase. Similar results were obtained by Santos et al. (1992), Santos et al. (1996) and Braga et al. (1999). 'Xingu' followed by 'Conquista' and 'Pintado' were more sensible and had the lowest shoot. Root dry weight did not suffer any decrease until -0.6MPa, and 'Conquista' presented the lowest results (Table 8).

Table 7 - Hypocotyl and root length of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of Sodium chloride during germination. Presidente Prudente, 1999.

Sodium chloride (MPa)	**Hypocotyl length (cm)**				
	Cultivar				
	Pioneira	**Conquista**	**Xingu**	**Pintado**	**Average**
0	5.69	5.34	6.40	5.70	5.78A
-0.3	3.49	2.74	3.11	2.70	3.01B
-0.6	1.56	1.59	1.39	1.54	1.52C
-1.2	0.00	0.00	0.00	0.00	0.00D
-2.4	0.00	0.00	0.00	0.00	0.00D
Average	2.15a	1.93a	2.18a	1.99a	

Sodium chloride (MPa)	**Root length (cm)**				
	Cultivar				
	Pioneira	**Conquista**	**Xingu**	**Pintado**	**Average**
0	3.86	3.32	5.31	3.50	4.00A
-0.3	4.32	3.58	4.66	3.64	4.05A
-0.6	3.49	2.55	2.59	2.25	2.72B
-1.2	0.00	0.00	0.00	0.00	0.00C
-2.4	0.00	0.00	0.00	0.00	0.00C
Average	2.34ab	1.89b	2.51a	1.88b	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

Table 8 - Shoot and root dry weight of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of Sodium chloride during germination. Presidente Prudente, 1999

Sodium chloride (MPa)	**Shoot dry weight (g)**				
	Cultivar				
	Pioneira	**Conquista**	**Xingu**	**Pintado**	**Average**
0	0.210a A	0.169bc A	0.156c A	0.183b A	0.179
-0.3	0.140a B	0.123ab B	0.114b B	0.133ab B	0.127
-0.6	0.081a C	0.071a C	0.068a C	0.074a C	0.073
-1.2	0.000a D	0.000a D	0.000a D	0.000a D	0.000
-2.4	0.000a D	0.000a D	0.000a D	0.000a D	0.000
Average	0.086	0.072	0.068	0.077	

Sodium chloride (MPa)	**Root dry weight (g)**				
	Cultivar				
	Pioneira	**Conquista**	**Xingu**	**Pintado**	**Average**
0	0.031 a A	0.018 b A	0.025 ab A	0.016 b B	0.023
-0.3	0.027 ab A	0.017 b A	0.028 a A	0.031 a A	0.025
-0.6	0.025 a A	0.015 b A	0.019 ab A	0.017 ab B	0.019
-1.2	0.000 a B	0.000 a B	0.000 a B	0.000 a C	0.000
-2.4	0.000 a B	0.000 a B	0.000 a B	0.000 a C	0.000
Average	0.017	0.010	0.014	0.013	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

There was significance interaction between cultivars and NaCl induced water deficit, which led to reduction in vigour classification, especially at -1.2 and -2.4MPa. Cultivars could be differentiated, and ‘Pioneira’ showed to be superior, not only in seedling classification but also in root dry weight (Table 9). Although, 'Conquista' and 'Xingu' showed very good germination at zero (Table 6) they were more sensible than the previous to salt imposed water deficit and 'Pintado' showed as for shoot dry weight, less sensible than 'Conquista' and 'Xingu'. However, the results obtained with NaCl did not match with the one observed for mannitol, meaning that there was another kind of factor acting in this case.

Sodium chloride can be a strong osmotic agent, but it affects the development just by increasing the sodium concentration in the growing medium. Sodium is a small ion that can pass easily throughout cellular membranes, and cells must pump it out expending energy to do that, otherwise the water activity decrease and all the metabolic pathways can be disturbed or disrupted, causing some misbalance in the energy production - consumption, that can be observed by abnormal seedling increase at -1.2MPa (Table 6).

Table 9 - Vigour classification (% of strong seedlings) of 4 soybean cultivars (*Glycine max* (L.) Merrill) exposed to different water deficits induced by different concentrations of Sodium chloride during germination. Presidente Prudente, 1999

Sodium chloride (MPa)	Vigour classification (% of strong seedlings)				
	Cultivar				
	Pioneira	Conquista	Xingu	Pintado	Average
0	42 a A	16 b A	28 ab A	9 c A	15
-0.3	30 a B	17 c A	28 b A	10 d A	23
-0.6	10 a C	17 bc A	22 ab A	12 c A	20
-1.2	0 a D	0 a B	0 a B	0 a B	0
-2.4	0 a D	0 a B	0 a B	0 a B	0
Average	16	10	16	6	

Different letters, capital letter in the columns and lower case in the lines, indicate significant difference at 5% Tukey test.

Results showed that NaCl water deficit affected germination just below -0.6MPa, however, seedling development parameters exhibited these effects below -0.3MPa, specially in relation to hypocotyl and root length and shoot dry weight. ‘Pioneira’ and ‘Xingu’ were the more resistant to low water disposition and/or salinity.

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RESUMO

A disponibilidade hídrica e o movimento de água para as sementes são muito importantes para a ocorrência da germinação, crescimento inicial do sistema radicular e emergência das plântulas, sendo estes fatores influenciados pelo potencial mátrico do solo, textura do solo e área de contato solo - semente. Objetivou-se a avaliação do efeito do estresse hídrico, em quatro cultivares, induzido por soluções de manitol e cloreto de sódio, sobre a germinação e vigor de plântulas de soja. O estresse hídrico induzido por manitol e NaCl afetou a germinação e o desenvolvimento das plântulas, porém o desenvolvimento das plântulas foi prejudicado em potenciais osmóticos maiores (0,3MPa) que o necessário para afetar a germinação ou seja, -1,2 MPa para estresse hídrico induzido por manitol e -0,6MPa para estresse hídrico induzido por NaCl. Os cultivares ‘Pioneira’ e ‘Xingu’ mostraram maior desenvolvimento em condições de baixa disponibilidade hídrica e/ou condições de salinidade.

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