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Soybean Seeds Submitted to Different Water Deficit Periods after Sowing in Dry Soil

Sementes de Soja Submetidas aos Diferentes Períodos de Déficit Hídrico Após a Semeadura no Solo Seco

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Abstract

Sowing in dry soil aims to alleviate the effects of water restriction, allowing for an earlier start of sowing and maximizing operational productivity in the use of agricultural machinery and implements. Thus, the objective of the present work was to evaluate the physiological quality of soybean seed lots submitted to different periods of water deficit after sowing in dry soil under vegetal cover. The experimental design was completely randomized, in a 2x5x2 factorial scheme (seed lots: high and low vigor; periods of water deficit after sowing in dry soil: 0; 4; 8; 12 and 16 days after sowing (DAS) and soil cover crops: without and with), with four replications. The evaluations were carried out from emergence to the beginning of the crop's reproductive phase. It was verified that there was no triple interaction of the factorial, where each factor individually interfered on the physiological quality of soybean seeds, regardless of their initial vigor. It was concluded that the use of plots with different vigor affects negatively the emergence of soybean seedlings, as well as the different periods of water deficit after sowing in dry soil. However, the presence of vegetation cover on the soil mitigates this effect, allowing greater emergence due to this promoting more favorable environmental conditions.

Keywords: *Glycine max*. Vegetation Ground Cover. Seed Vigor.

Resumo

A semeadura em solo seco visa amenizar os efeitos de restrição hídrica, permitindo o início da semeadura mais precoce e a maximização da produtividade operacional no uso de máquinas e implementos agrícolas. Deste modo, o objetivo do presente trabalho foi avaliar a qualidade fisiológica de lotes de sementes de soja submetidas aos diferentes períodos de déficit hídrico após a semeadura no solo seco sob cobertura vegetal do solo. O delineamento experimental foi conduzido inteiramente casualizado, no esquema fatorial de 2x5x2 (lotes de sementes: alto e baixo vigor; períodos de déficit hídrico após a semeadura no solo seco: 0; 4; 8; 12 e 16 dias após a semeadura (DAS) e coberturas vegetais do solo: sem e com), com quatro repetições. As avaliações foram realizadas a partir da emergência até o início da fase reprodutiva da cultura. Verificou-se que não houve interação tripla do fatorial, onde cada fator individualmente teve interferência sobre a qualidade fisiológica das sementes de soja, independente do seu vigor inicial. Conclui-se que a utilização de lotes com diferença de vigor afeta negativamente a emergência das plântulas de soja, bem como os diferentes períodos de déficit hídrico após a semeadura no solo seco. Todavia, a presença de cobertura vegetal sobre o solo ameniza esse efeito, possibilitando maior emergência em virtude dessa promover condições ambientais mais favoráveis.

Palavras-chaves: *Glycine max. Cobertura Vegetal do Solo. Vigor de Sementes.*

1 Introduction

Soybean (*Glycine max* (L.) Merrill) is the main Brazilian agricultural crop, with Brazil being the world's largest producer. In the 2021/22 national harvest, the sown area corresponded to 43.5 million hectares with a production of 152.7 million tons (CONAB, 2023). Being the establishment of the culture one of the most critical and important phases to ensure the productivity potential of the crop.

In this scenario, the use of seeds with high physiological quality associated with seed treatment helps in the establishment of these in the field. Where seed vigor is directly related to the rate, speed and uniformity of emergence and seedling growth, which may influence final productivity (ROSSI *et al*., 2017).

Sowing in dry soil or "powder sowing" is a practice that has been adopted by several producers in different regions of the country. This practice consists of sowing directly in the soil with low humidity, before the occurrence of rains. In this way, the seeds will remain stored in the soil waiting for moisture conditions to start the germination process (FLETCHER *et al*., 2015). One of the main obstacles to sowing in dry soil is the period in which the seed is exposed to water and thermal restrictions. This can cause negative consequences throughout the germinal process, especially in the phases of the triphasic pattern, which begins with imbibition, followed by the mobilization of reserves until the elongation of the embryonic axis (NONOGAKI *et al*., 2010).

The practice of sowing in dry soil, in the Brazilian Midwest, has been gaining prominence in the soybean-corn crop rotation. Where early sowing, together with the early soybean cycle are essential to enable the rotation of these crops in the same harvest. In the southern region of Brazil, sowing in dry soil becomes an important strategy due to operations at the beginning of the preferential sowing season, seeking to escape the damage caused by water restriction (GARCIA *et al.*, 2018; ZANON *et al*., 2016).

The rate of deterioration is associated with the period and environmental conditions to which the seeds are exposed during storage (SALINAS *et al.*, 2001). During this period, the degradation of proteins and reserve compounds can occur due to seed metabolism, consuming substrates used in respiration during germination (ABBADE; TAKAKI, 2014; SHARMA *et al*., 2007). Thus, such effects can be intensified under stress conditions to which seeds can be exposed in the field.

Soil vegetation cover acts as an insulator and stress reliever, reducing the thermal amplitude of the soil and helping to maintain its moisture. Thus, the increase or decrease in soil temperature depending on the condition of its cover will exert great ecophysiological influence, regulating processes such as seed germination (MARIN *et al*., 2008; GHIMIRE *et al.*, 2018).

Thus, the interaction between ground cover crops and sowing time aim to improve soil microbial community structure and nutrient cycling (MBUTHIA *et al.*, 2015). Thus, the objective of the present work was to evaluate the physiological quality of seed lots submitted to different periods of water deficit after sowing in dry soil under vegetation cover.

2 Material and Methods

The experiment was carried out in 2019 at the Didactic and Research Laboratory with Seeds and in the automated greenhouse at the Department of Plant Science of the Federal University of Santa Maria (UFSM), located in Santa Maria, RS (29°43' S; 53 °43' W and altitude of 95m). The climate in the region is humid subtropical (Cfa), according to the Köppen-Geiger classification, with average annual precipitation of 1,769 mm, average annual temperature close to 19.2 ºC and air humidity around 78.4% (ALVARES *et al.*, 2013).

The experimental design was completely randomized, organized in a 2x5x2 factorial scheme (batches of seeds, periods of water deficit after sowing in dry soil and soil cover), with four replications. The periods of water deficit after sowing in dry soil were 0; 4; 8; 12 and 16 days after sowing (DAS). Soil cover crops were without and with black oat straw (*Avena sativa* L.) in an amount corresponding to 3 t ha^{-1}. The seed batches were with high and low vigor and their initial characterization was determined by the tests mentioned below.

In the laboratory, the initial characterization of seed lots of the soybean cultivar Nidera (NA5909), 2018/2019 harvest, were evaluated by the following tests (Table 1): mass of a thousand seeds, degree of seed moisture and standard germination test (SGT) by the methodology of Brazil (2009). For SGT, four replications of 50 seeds were sown in a paper roll, moistened with distilled water at a rate of 2.5 times the dry paper mass. The rolls were kept in a B.O.D. (Box Organism Development), with a photoperiod of 24 h and a temperature of 25±2ºC. The evaluations of first count (FC) and germination (G) occurred at 5 and 8 DAS and the germination of normal seedlings at 8 DAS, with the results expressed in percentage. Along with this SGT test, the length and dry mass tests of seedlings were carried out. With random selection of ten normal seedlings of each repetition, the length of the hypocotyl and radicle being measured with a millimeter ruler and the determination of the dry mass occurred by drying of this material in a forced ventilation oven at 65±5 ºC for 48 h (NAKAGAWA, 1999).

Table 1 - Initial characterization of lots of soybean seeds (*Glycine max*) of the cultivar Nidera (NA5909) thousand seed weight (TSW), moisture content (MC), first count (FC), germination (G), shoot length (SL), root length (RL), shoot dry mass (SDM) and root dry mass (RDM)

Lots of seeds	TSW (g)	MC (%)	FC (%)	G (%)	SL (cm)	RL (cm)	RDM (g)	SDM (g)
High	153.4	9.5	91	94	10.36	13.39	14.07	32.40
Low	149.8	9.9	77	84	11.07	13.28	11.30	26.07
CV (%)	-	-	3.87	4.19	5.12	13.74	3.10	10.13

Source: resource data.

In the greenhouse, after initial characterization, the seeds were treated with a commercial product Cruiser® (thiamethoxam base) at a dose of 2 mL kg-1 of seeds. Subsequently, sowing was carried out with 20 seeds three centimeters deep in a 10 L black plastic pot, containing dry soil, classified as Argisol Red dystrophic sandstone (EMBRAPA, 2013). The soil was dried in the greenhouse; fertilization and liming were performed according to the soil analysis report (Table 2).

Table 2 - Soil analysis report.

pH water 1:1	Ca	Mg	Al	H + Al	ECEC	Saturation (%)		SMP index	Texture
	$cmol_c\ dm^{-3}$					Al	Bases		
4.7	2.4	0.7	0.9	6.9	4.3	20.9	32.7	5.6	4,0
% MO	% Clay	P-Mehlich	K	CEC pH7	K	Molar relations			
m/v		$mg\ dm^{-3}$	$cmol_c\ dm^{-3}$		$mg\ dm^{-3}$	Ca/Mg	(Ca+Mg)/K	$K/(Ca+Mg)^{1/2}$	
1.7	20.0	34.1	0.225	10.3	88.0	3.2	14.0	0.127	

Source: resource data.

For all periods of water deficit, sowing occurred on the same day with enough irrigation to raise soil moisture to 60% of its retention capacity, following the methodology of Brasil (2009). The maintenance of this soil moisture occurred daily until the beginning of seedling emergence, after which the maintenance occurred every two days.

Evaluations took place in two stages, the first was in the period of 5th and 8th day after initial irrigation (DAI), where the first emergence count (FEC) and emergence (E) were evaluated, respectively, by counting the number of seedlings emerged in the pots (BRASIL, 2009). The dry masses for the aerial part of the seedling were 8 and 36 DAI, and for the dry masses of the root part at 36 DAI, both with ten seedlings for each repetition, determined by drying this material in a forced ventilation oven at 65±5 ºC for 48 h (NAKAGAWA, 1999).

In the second stage, on days: 8; 15; 22; 29 and 36 DAI, three plants per pot were evaluated, the length of shoots of seedlings, and at 36 DAI the root length, with a millimeter ruler. In addition, at 36 DAI, the stem diameter (SD) was measured using a digital caliper (0.01), in the plant stem at 2 cm above the soil surface. Soil temperature was monitored every minute with T-type thermocouples installed at the same depth as the seeds and these were connected to an automated data collection system with an AM25T multiplexer and RL1000 data logger, both Campbell Scientific® equipment.

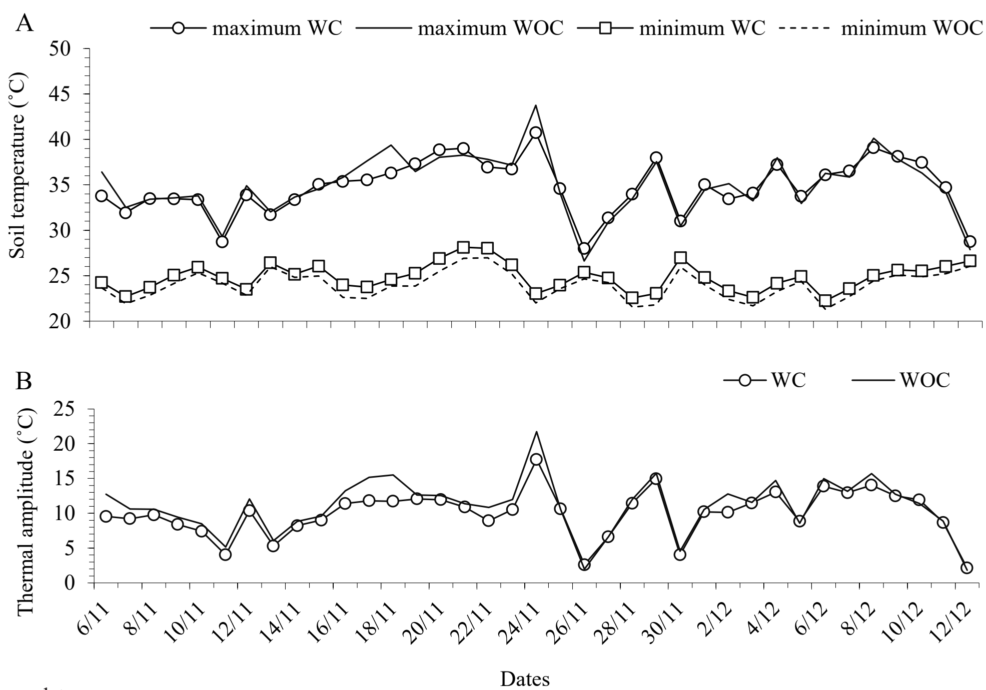
The data expressed as percentages were transformed into arcsine $\sqrt{x/100}$ and the analysis of variance (ANOVA) and the comparison of means by the Scott-Knott test ($p<0.05$) were performed with the aid of the statistical program SISVAR (FERREIRA, 2014).

3 Results and Discussion

From the statistical evaluation of the three factors (five periods of water deficit after sowing in dry soil, two conditions of vegetation cover on the soil and two seed lots), there were no triple and double interactions for the variables analyzed in the present work.

The average soil temperature at seed sowing depth showed maximum and minimum levels of 43.7 and 21.3 °C, respectively, occurring in the absence of soil cover (Figure 1a). In the presence of straw on the soil, there were maximum and minimum thermal levels of 6.8% lower and 4.4% higher in relation to the absence of straw. With this condition, on average, the thermal amplitude at the depth at which the seeds were located in the soil was 9.4% higher in the absence than in the presence of straw (Figure 1b). Such thermal conditions occur under field conditions, similar to those observed by Bortoluzzi and Eltz (2000).

Figure 1 - Soil temperature and thermal amplitude at a depth of 0.03 m in environments with (WC) and without (WOC) soil cover with straw.



Source: resource data.

The ideal temperature for soybean germination is 25 ºC (GARCIA *et al.*, 2007; BRASIL, 2009). As for results found by Lamachhane *et al.* (2020), the optimal temperature for soybeans is 30ºC. This temperature range will provide greater speed and uniformity in emergence. Sowings carried out at lower temperatures will reduce the speed of germination and emergence of the crop. Thus, as the minimum soil temperature on all days of the experimental cycle was lower in the absence of straw than in its presence. There were more adverse conditions for emergence in soil without cover, demonstrating that the presence of covered soil can be an important aspect to successful soy establishment.

Table 3 shows that seeds from high vigor lots present significant statistical differences and better results in relation to the low vigor lot in most of the analyzed variables. According to Marcos Filho (2015), vigorous seeds show greater efficiency in the execution of membrane repair mechanisms and mobilization of reserves for the embryonic axis, resulting in seedlings with a higher growth rate.

Table 3 - Means of first emergence count (FEC, %), emergence (E, %), shoot dry mass (SDM, g pl^{-1}), root dry mass (RDM, g pl^{-1}), stem diameter (SD, cm), shoot length (SL, cm) and root length (RL, cm) of soybean (*Glycine max*) seeds in relation to high and low seed vigor.

Lots of seeds	**FEC 8**	**E**	**SDM (DAI)**		**RDM (DAI)**		**SD**
		36		**36**			
High vigor	70 a*	87 a*	0.062 a*	2.766 ^{ns}	1.426 ^{ns}		4.33 ^{ns}
Low vigor	50 b	66 b	0.049 b	2.568	1.341		4.14
CV (%)	23.37	14.48	12.52	18.21	31.95		11.10

	SL (DAI)					RL
	8	15	22	29	36	
High vigor	9.68 a*	12.53 a*	16.32 a*	22.70 a*	25.75 ^{ns}	40.90 ^{ns}
Low vigor	8.74 b	11.68 b	15.27 b	21.08 b	24.84	40.57
CV (%)	10.50	7.05	7.48	10.95	11.63	13.92

DAI: days after irrigation. *significant effect and ^{ns} non-significant effect to the F test ($p<0.05$). Means not followed by the same letter in the column differ from each other by the Scott Knott test ($p<0.05$).
Source: resource data.

It was found that the means of the first emergence count (FCE) and emergence (E) showed differences between the lots, following the parameters of first count and germination, which distinguishes the lots. Our results corroborate the results found by Rossi *et al.* (2017), for soybean cultivars BRS 232, BRS 282 and BRS 243RR, where the high vigor lots showed greater emergence in the field.

In non-optimal conditions, low vigor lots present a more expressive reduction in the evaluated parameters in relation to high vigor lots. According to Wendt *et al.* (2017), sensitivity and adversities are greater in relation to the degree of seed deterioration, which can be identified with vigor tests.

The parameters of shoot (SDM) and root (RDM) dry masses, stem diameter (SD), shoot lengths (SL), at 36 DAI, and SD, there were no significant differences between the lots. Only SDM at 8 DAI and SL at 8; 15; 22 and 29 DAI, showed significant differences between batches. It was verified that the vigor effects are more expressive in the initial stages of germination and seedling establishment, and less evident as the phenological stages advance.

For Meneguzzo *et al.* (2021), when analyzing seedling growth at 12 h intervals, observed that high vigor seeds tend to express higher initial growth velocity due to rapid metabolic activation and degradation of reserves. While low vigor seeds take longer to reach the growth peak, due to their reduced ability to take advantage of the reserves present in the cotyledons, having their growth rate slower. According to Menegaes *et al.* (2022), the difference in the seedling growth rate is inserted in the physiology quality, which can be expressed by the coincidence of the emergence frequency peaks.

Table 4 shows the parameters related to soybean sowing and the periods of water deficit after sowing in dry soil, it was found that only the emergence parameter showed a statistical difference, thus indicating the sensitivity of the seed in relation to the water deficit caused. Rezende *et al.* (2003) observed that there was a reduction in the emergence potential of seeds treated with fungicides and exposed to periods of drought after sowing at 0, 7, 14 and 21 days.

For Marcos Filho (2015), the germination process is triggered in favorable environmental conditions in the presence of water, characterized by the protrusion of the radicle. However, the water deficit period after sowing in dry soil may have interfered with the three-phase pattern proposed by Bewley and Black (1978), still in Phase I, which is characterized by the period of water transfer from the soil to the seeds, due to the difference of potentials. Following the other phases, Phase II, moment of reorganization and mobilization of reserves and preparation for cell elongation, and Phase III, with the resumption of the embryo identified with the protrusion of the radicle. Our results indicate that during the zero period of water deficit, the emergence occurred due to minimum conditions of humidity around the seed, however, for the other periods there was an energy expenditure of the mobilization of the reserves and the lack of humidity stopped the complete mobilization.

Table 4 - Means of first emergence count (FEC, %), emergence (E, %), shoot dry mass (SDM, g pl^{-1}), root dry mass (RDM, g pl^{-1}) and stem diameter (SD, cm), shoot length (SL, cm) and root length (RL, cm) obtained with soybean seeds (*Glycine max*) in relation to periods of water deficit after sowing in the soil

Periods of water deficit after sowing in dry soil	FEC	E	SDM (DAI)		RDM (DAI)	SD
			8	36	36	
0	62 ^{ns}	80 a*	0.056 ^{ns}	2.676 ^{ns}	1.452 ^{ns}	4.14 ^{ns}
4	65	81 a	0.056	2.707	1.485	4.24
8	58	72 b	0.056	2.681	1.267	4.30
12	57	74 b	0.054	2.615	1.424	4.27
16	56	74 b	0.055	2.656	1.291	4.23
CV (%)	23.37	14.48	12.52	18.21	31.95	11.10
	SL (DAI)					RL
	8	15	22	29	36	
0	9.05 ^{ns}	12.00 ^{ns}	15.86 ^{ns}	22.01 ^{ns}	25.46 ^{ns}	40.81 ^{ns}
4	9.60	12.35	15.75	22.23	25.52	42.34
8	9.25	12.22	15.85	21.59	25.10	38.45
12	8.94	12.12	15.78	21.50	24.76	41.75
16	9.21	11.86	15.73	22.10	25.64	40.31
CV (%)	10.50	7.05	7.48	10.95	11.63	13.92

DAI: days after irrigation. *significant effect and ^{ns} non-significant effect to the F test (p<0.05). Means not followed by the same letter in the column differ from each other by the Scott Knott test (p<0.05).
Source: resource data.

In Table 5, it was observed that there were greater emergences in the soil with vegetal cover in relation to the bare soil, indicating that the vegetal cover promotes favorable environmental conditions for the emergence of seedlings, especially as verified in the thermal conditions of the soil (Figure 1). Our results are in agreement with those of Bortoluzzi and Eltz (2000), in which they also found a higher rate of emergence speed in soils with vegetation cover containing black oat compared to bare soils.

Table 5 - Means of first emergence count (FEC, %), emergence (E, %), shoot dry mass (SDM, g pl^{-1}), root dry mass (RDM, g pl^{-1}), length of shoot (SL, cm), root length (RL, cm) and stem diameter (SD, cm) of soybean seeds (*Glycine max*) in relation to cultivation without and with soil cover with black oat straw (*Avena sativa* L.)

Vegetation ground cover	FEC	E	SDM (DAI)		RDM(DAI)	SD
			8	36	36	
With	63 a*	79 a*	0.056 ^{ns}	2.698 ^{ns}	1.379 ^{ns}	4.01 b*
Without	56 b	74 b	0.055	2.636	1.389	4.46 a
CV (%)	23.37	14.48	12.52	18.21	31.95	11.10
	SL (DAI)					RL
	8	15	22	29	36	
With	10.92 a*	13.29 a*	16.72 a*	22.51 a*	25.01 ^{ns}	40.05 ^{ns}
Without	7.50 b	10.92 b	14.87 b	21.26 b	25.58	41.41
CV (%)	10.50	7.05	7.48	10.95	11.63	13.92

DAI: days after irrigation. *significant effect and ^{ns} non-significant effect to the F test (p<0.05). Means not followed by the same letter in the column differ from each other by the Scott Knott test (p<0.05).
Source: resource data.

Covering the soil with straw helps to maintain soil moisture after irrigation, which at the time of emergence is essential to trigger the three-phase pattern, especially Phase I. For Kader *et al.* (2017), soil cover with straw stored a greater amount of soil moisture at depths of 5 to 15 cm, in addition to promoting a temperature reduction of 2 °C at a depth of 5 cm.

4 Conclusion

The use of lots with high vigor soybean seeds leads to greater emergence and faster establishment in dry soil sowing conditions. The vigor effects are more expressive in the initial stages of emergence and establishment and less evident as the phenological stages advance. The periods of water deficit after sowing in dry soil, under these experimental conditions, up to four days before the ideal soil moisture condition does not interfere with emergence, which is reduced from this period onwards. Soil cover with black oat straw allows for a greater emergence and initial growth in relation to bare soil, improving the establishment and stand of plants.

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