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Potassium Fertilization and Physiological Soybean Seed Quality

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Abstract

The purpose of this study was to evaluate the influence of increased application rates of potassium on the physiological quality of seeds from different soybean cultivars. Seeds from two locations (São Gotardo, MG and Lavras, MG, Brazil) were used. After harvest, the seeds were sent to the Central Seed Analysis Laboratory of the Federal University of Lavras. We used a randomized design in a 4 × 6 factorial arrangement of four cultivars and six doses of potassium. All tests were performed with two replicates of 50 seeds (300 seeds per treatment). Germination, emergence under controlled conditions, accelerated aging, electrical conductivity, and tetrazolium tests were performed. Data were subjected to analysis of variance. In soybean seed production fields with high potassium content in the soil, higher application rates of potassium do not increase the physiological quality of seeds.

Keywords

***Glycine max* L., Seed Vigor, Seed Production**

1. Introduction

The use of high vigor seeds in soybean is critical in establishing the crop and bringing about high yield. In this context, it should be noted that nutrient availability can influence the chemical composition of seeds and therefore their metabolism. Thus, an adequate supply of nutrients can provide for good plant development and produce metabolites for seed development.

The chemical composition of seeds may be influenced by genetic factors, the environment, and, moreover, the nutrients applied to the soil. Potassium fertilization can influence germination and seed vigor since it is an es-

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sential element for oil synthesis and transport in soybeans [1] [2]. Similar results were obtained by [3], who found that seed vigor was significantly affected by potassium fertilization rates.

Some authors show the evident importance of maintaining high potassium concentration in plant tissue and grain; and a higher potassium level in grain is positively associated with yield and physiological quality [4]. In a study by [5], the author states that the rates of pathogens in seeds increase when less than 120 kg·ha^{-1} is applied, indicating that potassium deficiency may predispose seeds to infection by numerous pathogens.

In general, the literature reports that seed quality is significantly higher when potassium is applied at rates greater than 80 kg·ha^{-1} [5]. However, results are still contradictory [6]. Thus, the aim of this study was to evaluate the influence of potassium application rates on the physiological quality of seeds from different soybean cultivars.

2. Materials and Methods

The study was performed at the Central Seed Analysis Laboratory of the Universidade Federal de Lavras (Federal University of Lavras)—UFLA (Lavras, Minas Gerais [MG], Brazil). We used seeds from Lavras and São Gotardo, MG. Chemical and physical analyses of the field experiments, and rainfall and average temperature results of the sites are shown in **Table 1** and **Figure 1**.

A randomized complete block design with three replications was used in a 4 × 6 factorial arrangement, with four soybean cultivars (TMG 127 RR, TMG 1179 RR, BRS MG 850 GRR, and NA 7255 RR) and six potassium application rates (0, 40, 80, 120, 160, and 200 kg·ha^{-1}). Potassium chloride (KCl^-) with 60% K^+ was used as a source. Each plot consisted of two 5 m rows at a spacing of 0.5 m.

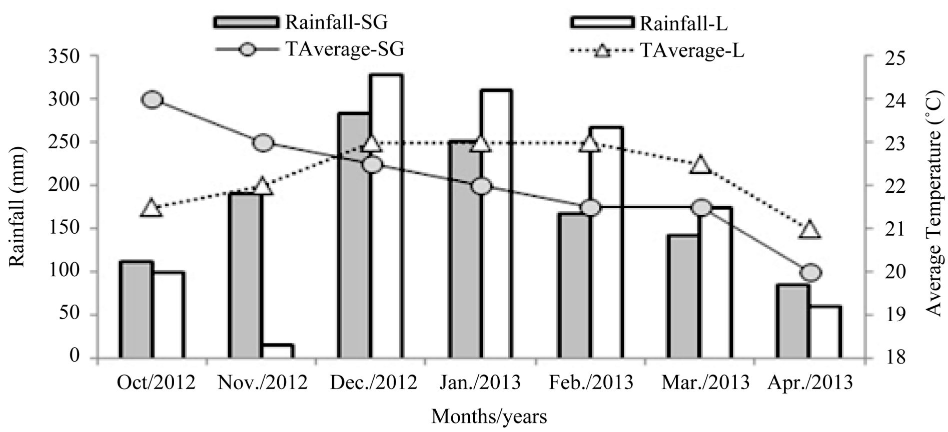

Figure 1. Monthly rainfall and air temperature average in São Gotardo, MG (SG) and Lavras, MG (L) over the 2012/2013 crop season. Source: National Institute of Meteorology (INMET).

Table 1. Chemical and physical composition of a Distroferric typical Oxisol soil (0 - 20 cm) before setting up the experiments in Lavras, MG and São Gotardo, MG in the 2012/2013 crop season.

Site	pH	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^+ + Al^{3+}$	SB	CEC	P	K	OM	V
	H_2O			$cmol_c·dm^{-3}$				mg·dm^{-3}		dag/kg^{-1}	%
São Gotardo¹	5.27	3.60	1.10	0.08	7.05	4.90	11.90	28.14	103	4.68	40.94
Lavras²	5.90	4.70	1.30	0.00	2.90	6.30	9.20	7.21	118	2.61	68.51
Site	Zn^{2+}	Mn^{2+}	Cu^{2+}	B	Fe^{2+}	S	Clay	Silt	Sand	Textual class	
			mg/dm^3					dag/kg		-	
São Gotardo¹	17.10	14.50	11.30	0.50	-	-	50	28	22	Clayey	
Lavras²	5.31	13.33	0.60	0.33	-	-	64	20	16	Clayey	

$H + Al^{3+}$: potential acidity; SB: sum of bases; CEC: cation exchange capacity at pH 7.0; OM: organic matter; V: base saturation. ¹Experimental area of the Experimental Farm of the Cooperativa Agropecuária do Alto Paranaíba Ltda—COOPADAP. ²Experimental area of the Centro de Desenvolvimento Científico e Tecnológico em Agropecuária of the Universidade Federal de Lavras.

The experiments were harvested manually and then threshed mechanically. Samples from the plots were homogenized and classified by sieving. For the laboratory tests, we used the seeds contained in the 5.5 and 6.0 mm sieves.

The field experiment laboratory evaluations were performed using a randomized design; all tests were performed with two replicates of 50 seeds per replicate, totaling 300 seeds per treatment. Physiological quality was evaluated by the following tests:

Germination: seeds were distributed on *germitest* paper towel with a distilled water volume at the ratio of 2.5 times the dry weight of the substrate. They were then placed in a *Mangelsdorf* model germination chamber at a temperature of 25˚C. Evaluations were performed on the 8th day after sowing, according to the criteria set forth in the Regra de Análises de Sementes (Seed Analysis Guidelines) [7]. The mean results were expressed as a percentage of normal seedlings.

Accelerated Aging: in this test we adopted the criteria established by [8]. We used 42 g of seed samples per treatment. The samples were placed on stainless steel screens adapted to plastic *gerbox* boxes with 40 mL of water at the bottom. The boxes were sealed and taken to a water-jacketed model incubation chamber set at 41˚C for 72 h. Then the seeds were subjected to germination tests and the evaluations as described in the methodology above.

Emergence under controlled conditions: the substrate was composed by mixing soil + sand (2:1) and then placed in plastic trays. Upon sowing, the seeds were covered with a layer of substrate (2 - 3 cm). The trays were kept in a plant growth chamber at 25˚C with daily watering according to plant needs. As of emergence of the first seedling (cotyledon visible), daily evaluations were performed by computing the number of seedlings until stabilization, with final evaluations at 14 days after sowing. The average percentage at the end of emergence (% E) was considered. To calculate the speed of emergence index (ESI) of the seeds, we adopted the equation suggested by [9].

Tetrazolium test: the seeds were placed on moistened *germitest* paper and kept for 16 hours at 25˚C. After this period, the seeds were placed fully submerged in 0.075% tetrazolium salt solution in plastic containers, remaining for three hours at 40˚C in a water-jacketed model incubation chamber. After this period, the seeds were washed in water and again placed in plastic containers with water. Then viability and vigor were determined by classifying each seed in one of the eight groups described by [10].

Electrical conductivity: we used the conductivity of mass method and placed 50 previously weighed seeds/replicates in plastic beakers containing 75 mL of deionized water and then transferred them to an incubator chamber regulated at the temperature of 25˚C for 24 hours [11]. After this period, the containers were removed from the incubator chamber and gently stirred, and the electrical conductivity of the solution was measured with the aid of a conductivity meter (MS TECNOPON®-mCA150). The mean values were expressed as $\mu S \cdot cm^{-1} \cdot g^{-1}$.

After collecting and tabulating the data, all the evaluated parameters were analyzed. Mean values were compared according to [12] at 5% probability. Statistical analysis was performed with the aid of the statistical package [13].

3. Results and Discussion

From combined analysis, a significant difference was detected in all the parameters evaluated for cultivars. This was expected since the cultivars have different growth habits and genetic backgrounds, leading to such variation. Several reports in the literature show that genotype influences the physiological quality of soybean seeds [6].

There was a significant effect of the production site on the quality of seed lots. The effect of environment on the expression of physiological quality is often highlighted in the literature [6] [14] and this supports the reports obtained in this study. We also found a significant interaction between cultivars and locations, *i.e.*, the cultivars showed no consistent performance irrespective of environment. These results confirm the reports presented by [15]-[17] for physiological quality in different environments. Significant interactions between cultivars and locations have been frequently reported in the literature for physiological seed quality [6] [16] [18]. In fact, this occurred because the two sites were different in altitude and latitude which are essential factors for seed production.

Additionally, we should also highlight the unpredictable environmental factors, such as precipitation and temperature (**Figure 1**). Considering the period of the field test, it is evident that in December, January, and

February (Lavras) we have a greater accumulation of rainfall and higher average temperature. This fact may be related to the lower vigor and germination percentage observed in this location compared to São Gotardo.

The main objective of this study concerns the influence of potassium levels on seed quality. However, no significant difference was found for the application rates in the tests carried out. This allows us to infer that the physiological quality of soybean seeds, on average, is not dependent on the potassium application rate used.

There are several reports in the literature that confirm this fact. For [2], increasing potassium application rates did not affect germination and vigor. However, according to [19], potassium promoted higher germination percentage and vigor.

One possible explanation for the doses used not having an effect on the physiological quality of seeds is the high content of potassium in the soil. There are several reports in the literature showing that the effect of potassium on physiological quality, yield, and chemical composition is due to the natural content of the nutrient in the experimental area. According to [1], it is necessary to carry out experiments in areas of low natural nutrient content.

The mean values from individual site analyses are shown in **Table 2**. Clearly, the São Gotardo environment provided high physiological quality. For germination percentage, for example, the São Gotardo environment had 15.5% greater germination than Lavras. In this study, seeds from São Gotardo surpassed those produced in Lavras by 31.11% in the tetrazolium/vigor test. This may be related to the climatic conditions observed in Lavras, especially at harvest time. Excess rainfall provides a favorable microclimate for the occurrence of pathogens and also compromises the physiological quality of seeds.

The average of the cultivars and combined analysis involving all the quality tests shown in **Table 2** allow us to infer that BRS MG 850 GRR showed better performance for all tests; however, it did not differ from NA 7255 RR for viability determined by tetrazolium. For germination, the best performance was from BRS MG 850 GRR, at about 81.44%. The other cultivars obtained a germination percentage below that required for the marketing of seeds in Brazil, which is 80% [20].

One of the factors that contributed to low germination was the high percentage of dead and infected seeds observed in the germination test (**Figure 2**). Germination percentage was inversely proportional to the percentage of dead and infected seeds observed in seed lots with different cultivars. The seeds are susceptible to contamination from numerous pathogens [21]. The pathogens cause contamination of the seeds, which, because of an increase in the degree of deterioration, resulted in decreased germination and seed vigor [22].

Estimates of higher magnitude were obtained for emergence percentage compared to germination percentage obtained in the laboratory. BRS MG 850 GRR had the highest emergence rate (90%).

The superiority of the emergence test in relation to the germination test was previously observed by [23] and

Table 2. Mean values of individual and combined analysis per site for germination (G-%), Emergence (E-%), emergence speed index (ESI), accelerated aging (AA-%), electrical conductivity (EC), vigor index (VIG), and seed viability (VIA) tetrazolium, for soybean cultivars evaluated, from Lavras-MG and São Gotardo-MG in the 2012/2013 crop.

Cultivars	G	E	ESI	AA	EC	VIG	VIA
TMG127 RR	48.92 c[1]	73.08 b	45.39 b	53.92 c	114.52 a	76.06 b	85.19 b
NA 7255 RR	56.81 b	76.78 b	49.11 b	54.25 c	109.11 a	80.86 b	88.11 a
BRS MG 850 GRR	81.44 a	90.08 a	59.75 a	81.67 a	72.80 b	86.22 a	91.97 a
TMG 1179 RR	62.42 b	76.25 b	48.06 b	60.92 b	117.18 a	66.25 c	80.06 c
Overall mean ± SE	62.40 ± 2.61	50.58 ± 2.56	79.05 ± 1.48	62.69 ± 3.88	77.35 ± 6.19	86.33 ± 3.35	103.40 ± 2.17
CV (%)	22.00	14.00	11.00	22.00	15.00	10.00	19.00
São Gotardo, MG							
Overall mean	70.15 a	92.51 a	58.28 a	80.74 a	74.70 b	92.90 a	95.99 a
CV (%)	16.00	4.00	8.00	14.00	13.00	4.00	5.00
Lavras, MG							
Overall mean	54.64 b	65.58 b	42.87 b	44.64 b	132.11a	61.79 b	76.68 b
CV (%)	29.00	18.00	20.00	26.00	20.00	25.00	15.00

[1/]Values followed by the same letter belong to the same group by the Scott & Knott (1974) test at 5% probability. SE—standard error mean.

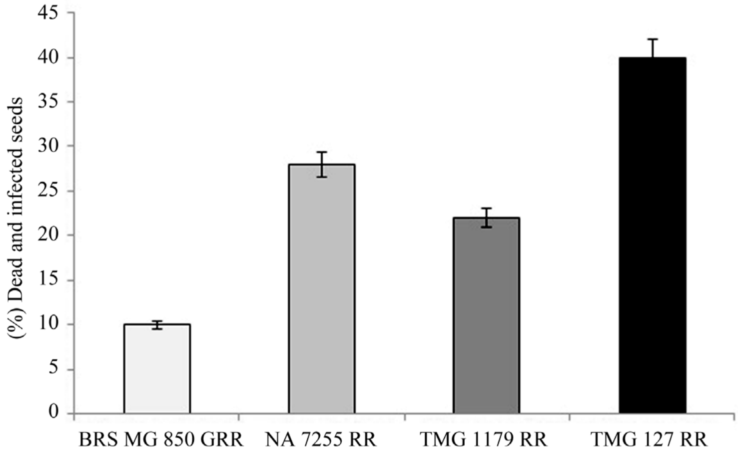

Figure 2. Combined analysis of the total percentage of dead and infected seeds observed in the germination test for each cultivar from Lavras, MG and São Gotardo, MG in the 2012/2013 crop season. Each column represents the mean of three replicates (±standard deviation).

[24]. According to these same authors, this fact can be explained by the escape mechanism in which the seedling releases the infected seed coat to the ground in order to emerge, while in the germination test in the laboratory under roll paper the seed coat remains associated with the cotyledons and the associated fungi cause seed deterioration.

The emergence speed index (ESI) varied among cultivars, with the highest estimate observed for seedlings of the cultivar BRS MG 850 GRR. The speed index is associated with emergence vigor of soybean seeds because seeds with higher ESI tend to perform better and therefore have higher speed of emergence in the field, better resisting the stresses that may occur during emergence [25]. It should also be noted that seeds with higher ESI develop a closed canopy more quickly, which results in efficient weed control [26].

In the accelerated aging test (AA), upon analyzing the mean values of each cultivar, it was observed that the TMG 1179 RR and TMG 127 RR cultivars followed cultivar NA 7255 RR, showing greater sensitivity to conditions of high relative humidity and air temperature.

Accelerated aging is simulation of adverse environmental factors, temperature, and high relative humidity, which are factors seen as causing seed deterioration [8] [27]. Under these conditions, seeds with low physiological quality deteriorate faster than more vigorous seeds, establishing differences in physiological potential [28]. Thus, high vigor seed lots must maintain their viability when subjected to such conditions. Low vigor seeds will bring about reduced viability [29].

In regard to the results for electrical conductivity, the highest values were observed for the cultivars TMG 1179 RR, TMG 127 RR, and NA 7255 RR, differing from BRS MG 850 GRR. According to [30] soybean seed lots with high vigor may have electrical conductivity values of at most 70 - 80 $\mu S \cdot cm^{-1} \cdot g^{-1}$. In this study, the results obtained show that only BRS MG 850 GRR exhibited values considered ideal for electrical conductivity (72.80 $mS\mu S \cdot cm^{-1} \cdot g^{-1}$), thereby leading to production of seeds with high to medium vigor for the cultivar concerned.

For seed vigor and viability, both determined by the tetrazolium test, best performance was observed for BRS MG 850 GRR with 86.22% and 91.97%, respectively, although the cultivar NA 7255 RR did not differ in regard to viability.

Among the methods of quality control adopted by seed companies in Brazil, the tetrazolium test stands out for soybean due to the speed, accuracy, and large amount of information provided by the test. In addition, in assessing the viability and vigor of seed lots, it provides possible causes responsible for the reduction in soybean quality that can come from mechanical damage, damage caused by moisture, and damage from stink bug attack, which are the problems that most affect the physiological quality of soybean seeds [10].

It is evident that, on average, the most damage leading to reduction in vigor and viability, assessed by the tetrazolium test, was caused by stink bug attack (48.3%), moisture content (32%), and mechanical factors (19.7%).

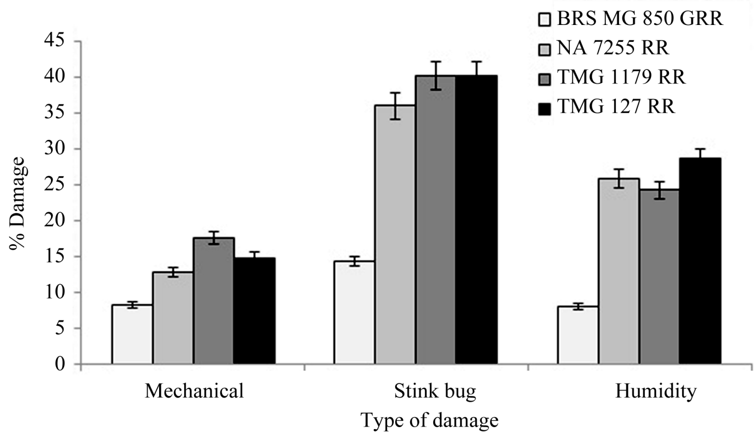

Figure 3. Combined analysis of the damage caused and the respective % of damage observed in the tetrazolium test for each cultivar from Lavras, MG and São Gotardo, MG in the 2012/2013 crop season. Each column represents the mean of three replicates (±standard deviation).

The main damage observed in the tetrazolium test was that caused by the attack of stink bugs. BRS MG 850 GRR showed 14.3% damage caused by this insect; the other cultivars showed damage ranging from 35.9% to 40.2% (**Figure 3**).

In the incidence of stink bug, the site of the lesion is more important than the number of bites because damage to the hypocotyl prevents germination, while multiple lesions on cotyledons reduce vigor and emergence, but not germination [31]. Stink bugs can also cause delayed maturation from leaf retention, hampering harvest [32], due to the excessive amount of water present in the plant.

In assessing damage caused by stink bugs in soybean, [33] observed results similar to those found in the present study. They also found correlation between the intensity of the attack of bugs and leaf retention.

The data related to damage caused by moisture show that BRS MG 850 GRR exhibited 8% damage. The other cultivars exhibited values ranging from 24.3% to 28.6%, while the cultivar that showed the greatest magnitude was TMG 127 RR. This may be related to the maturity group of each cultivar. BRS MG 850 GRR had samples taken in a period with less rainfall. Thus, the operation was performed when the seeds had lower moisture content, leading to greater vigor and viability compared with other cultivars.

In respect to mechanical damage, 8.2% injury was noted in BRS MG 850 GRR. The other cultivars showed damage ranging from 12.8% to 17.5%. Such damage may have been aggravated by mechanical threshing, which favors its occurrence. In a study by [17], evaluating different genotypes in three distinct environments, the authors observed that mechanical damage and damage caused by moisture were responsible for the loss of vigor and viability of seeds in all environments.

4. Conclusion

In soybean seed production fields with high potassium content in the soil, the application of differing rates of potassium did not have immediate effects on seed quality.

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