

Seed vigor level in association to fertilizer distribution

Nível de vigor da semente em associação com a distribuição de fertilizantes

Nivel de vigor de la semilla asociado a la distribución de fertilizantes

Received: 09/21/2020 | Reviewed: 09/22/2020 | Accept: 10/06/2020 | Published: 11/10/2020

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Abstract

This work aimed at evaluating yielding responses of soybean seeds production fields in response to the association between seed vigor level and fertilizer distribution systems at the sowing line. Experimental design was randomized blocks design, with two growing

environments (Passo Fundo - RS and Ernestina - RS) x three vigor levels (high = 90%, medium = 70% and low = 60%) x three fertilizer distribution systems (absence, conventional and by transshipment), arranged in four replicates, grain yield (GY). For grain yield (GY), it was applied the method genotype main effects and genotype environment interaction (GGE). Seed vigor levels and fertilizer distribution systems influence on seed yield, first pod insertion height, plant height, number of pods in the main stem and ramifications, magnitude and length of ramifications in soybean. The high vigor level in the conventional and by transshipment fertilization systems provided an absolute increase of 10.9 and 5.6% in seed yield, respectively, in Ernestina-RS. The conventional fertilizer distribution system, in Passo Fundo-RS, increased seed yield in 12.5% in plants originated from low vigor seeds.

Keywords: *Glycine max* (L.); GGE; Physiological quality; Yield.

Resumo

Este trabalho teve como objetivo avaliar a produtividade dos campos de produção de sementes de soja em resposta à associação entre o nível de vigor das sementes e sistemas de distribuição de fertilizantes na linha de semeadura. O delineamento experimental foi de blocos ao acaso, com dois ambientes de cultivo (Passo Fundo - RS e Ernestina - RS) x três níveis de vigor (alto = 90%, médio = 70% e baixo = 60%) x três sistemas de distribuição de fertilizantes (ausência, convencional e por transbordo), dispostos em quatro repetições, rendimento de sementes (RS). Para o rendimento de sementes (SY), foram aplicados os principais efeitos genotípicos do método e interação genótipo-ambiente (GGE). Níveis de vigor de sementes e sistemas de distribuição de fertilizantes influenciam no rendimento de sementes, altura de inserção da primeira vagem, altura de planta, número de vagens no colmo principal e ramificações, magnitude e comprimento de ramificações em soja. O alto nível de vigor nos sistemas de adubação convencional e transbordo proporcionou um aumento absoluto de 10,9 e 5,6% no rendimento de sementes, respectivamente, em Ernestina-RS. O sistema convencional de distribuição de fertilizantes, em Passo Fundo- RS, aumentou a produtividade de sementes em 12,5% em plantas oriundas de sementes de baixo vigor.

Palavras-chave: *Glycinemax* (L.); GGE; Qualidade fisiológica; Rendimento.

Resumen

Este trabajo tuvo como objetivo evaluar la productividad de los campos de producción de semilla de soja en respuesta a la asociación entre el nivel de vigor de la semilla y los sistemas de distribución de fertilizantes en la línea de siembra. El diseño experimental fue de bloques

al azar, con dos ambientes de cultivo (Passo Fundo - RS y Ernestina - RS) x tres niveles de vigor (alto = 90%, medio = 70% y bajo = 60%) x tres sistemas de distribución de fertilizantes (ausencia, convencional y por rebosamiento), dispuestos en cuatro repeticiones, rendimiento de semilla (RS). Para el rendimiento de semilla (SY) se aplicaron los principales efectos genotípicos del método y la interacción genotipo-ambiente (GGE). Los niveles de vigor de la semilla y los sistemas de distribución de fertilizantes influyen en el rendimiento de la semilla, la altura de inserción de la primera vaina, la altura de la planta, el número de vainas en el tallo principal y ramas, y la magnitud y longitud de las ramas en la soja. El alto nivel de vigor en los sistemas convencionales de fertilización y rebosamiento proporcionó un aumento absoluto de 10,9 y 5,6% en el rendimiento de semillas, respectivamente, en Ernestina-RS. El sistema de distribución de fertilizantes convencional, en Passo Fundo-RS, incrementó la productividad de semilla en un 12.5% en plantas de semillas de bajo vigor.

Palabras clave: *Glycine max* (L.); GGE; Calidad fisiológica; Rendimiento.

1. Introduction

Soybean (*Glycine max* (L.) Merrill), originating from China, is the Fabaceae with the greatest economic expression in the world, being Brazil the second largest producer. A survey carried out by CONAB (National Food Supply Company) shows how much soybean production in Brazil corresponds to the country's growing area, reaching 35.2 million hectares in the 2017/18 harvest, with production of approximately 117 million tons (CONAB, 2017).

World populational growth is directly related to the demand for food, thus, improved growing techniques for productivity increase are essential. In order to set high yielding fields, plants of high performance are necessary, which come from seeds of high quality that efficiently use the available resources.

Many factors influence soybean yield, among them, the use of high physiological quality and high-vigor seeds are highlighted. These factors provide uniformity in germination, emergence and seedling growth at field conditions, improving grain yield (Marcos Filho et al., 2009; Szareski et al., 2018a; Troyjack et al., 2018; Szareski et al., 2018b; Meneguzzo et al., 2020).

The seek for uniform fields and superior performance of the plants is closely related to seeds of high physiological potential and the uniform amount of fertilizer in the sowing line. These effects may be hampered by peculiarities expressed in some growing environments, such as sharp slopes that may impair the proper functioning of the tractor-sowing set,

especially regarding the correct fertilizer distribution (Pelegrin et al., 2016; Ferrari et al., 2016; Rosa et al., 2019)

The use of high quality seeds is fundamental for the maximum expression of the productive potential of species and variety being cultivated. It occurs because the seed is the vehicle of advances achieved by plant breeding, and its performance is influenced by physical, sanitary and physiological attributes. Among physiological quality attributes of the seeds, vigor stands out for being related to germination, emergence, seedling growth, uniformity rates and uniformities at field, influencing grain yield strongly.

Due to the lack of researches combining seed vigor and the efficient fertilizer distribution, as well as its effects on the main components of soybean yield, this work aimed at evaluating yielding responses of soybean seeds production fields in response to the association between seed vigor level and fertilizer distribution systems at the sowing line.

2. Methodology

The experiment was established in two growing fields (environments) in the agricultural year of 2016/2017, being, Ernestina-RS, located at latitude 28°29'56 "S and longitude 52°34'24" W with altitude of 493 meters, and Passo Fundo- RS, with latitude 28°15'46 "S and longitude 52°24'24"W, and altitude of 687 meters. The soils were classified as typical dystrophic red latosol (Streck et al., 2008), and the climate for both environments was characterized by Köppen as subtropical humid Cfa type.

Experimental design was randomized blocks design, with two growing environments (Passo Fundo - RS and Ernestina - RS) x three vigor levels (high = 90%, medium = 70% and low = 60%) x three fertilizer distribution systems (absence, conventional and by transshipment), arranged in four replicates.

Before sowing, the seeds were stratified in lots of different vigor levels through the accelerated aging method (AOSA, 1983). For this, seeds were distributed in single layers of approximately 250 grams and arranged on an aluminum screen fixed inside a plastic container. 240 mL of water was added to each vessel, which were placed at the aging chamber set at 41 °C. After 48; 84 and 96 hours of exposure, the seeds were submitted to germination test (BRASIL, 2009). This criterion was established to define vigor levels at 90% (high); 70% (medium) and 60% (low).

Three fertilizer distribution systems were used in the sowing machine. The conventional one, which is composed by an endless screw and gravity system; by

transshipment, which is composed by endless screw and transshipment system, where the fertilizer is driven by the impeller (endless) and taken to a damming chamber, occurring the transshipment in uniform and homogeneous volumetric quantities through the level regulator into the nozzle discharge to the soil. There was also a treatment level representing the absence of fertilizer distribution.

Seeding was carried out in the first half of November 2016, using as biologic model the cultivar DM5958RSFIPRO®, with indeterminate growth habit. The sowing density corresponded to 30 seeds m⁻², and the experimental unit was composed by five lines with five meters length, spaced by 0.45.m, totaling 11.25 m². For the evaluations of traits of interest, 3,96m² was collected, which corresponds to the useful area of the experimental unit.

Soil fertility and acidity correction was performed based on the previous soil analysis, following the instructions from the manual of fertilization and liming (CQFS, 2004). It was used 300kgha⁻¹ of NPK fertilizer in formulation 02-20-20, and control of weeds, pest insects and diseases were performed preventively to minimize biotic effects in the experiment's results. The evaluated traits were measured through the random selection of ten plants from the useful area of each experimental unit, being:

First pod insertion height (FP): measured through the distance between soil level and insertion of the first reproductive node with presence of legume, with results expressed in centimeters (cm).

Plant height (PH): measured through the distance between the soil level and the upper end of the main stem. The results were presented in centimeters (cm).

Number of pods on the main stem (NM): measured by counting the total number of viable pods on the main stem, and results are shown in units.

Number of pods in the ramifications (NR): determined by counting the total number of viable pods in the ramifications. Results were expressed in units.

Number of ramifications on the main stem (NRM): determined by counting the ramifications longer than ten centimeters containing pods. The results were presented in units.

Ramification length (RL): measured by the average of three ramifications present in each plant, with results presented in centimeters (cm).

Number of plants per square meter (NP): magnitude of plants present in the useful area of each experimental unit was calculated. The results were presented in units.

Contribution of the number of seeds in the pods: Pods containing one (N1); two (N2); three (N3) and four (N4) seeds were evaluated, counting the number of pods with viable seeds. The results were expressed as percentage (%).

Seed yield (RS): obtained by the ratio of seed mass in the useful area of each experimental unit, which was weighted by the number of plants contained in the experimental unit area, after weighting to 12% of humidity and population density adjusted for hectare. The results were expressed in bags per hectare (bgha^{-1}).

The data were submitted to diagnosis of normality and homogeneity of variances. Then, variance analysis was performed at 5% of probability in order to verify the presence of interaction among growing environments x vigor levels x fertilizer distribution systems. When significant, the factors were sliced into simple effects. In contrast, in the absence of interaction, the variation factors were sliced into principal effects.

For seed yield (SY), it was applied the method genotype main effects and genotype environment interaction (GGE). It allowed to gather the effects attributed to growing environments, tested vigor levels and fertilizer distribution systems. Through this test, it was possible to identify which treatment levels presented higher performance (Yan, 2001; Woyann et al., 2017).

3. Results and Discussion

The analysis of variance revealed significant effect at 5% of probability for interaction among growing environments x vigor levels x fertilizer distribution systems (Table 1), for first pod insertion height (FP), plant height (PH), number of pods in the main stem (NM), number of pods in the ramifications (NR), number of ramifications on the stem (NRM), ramification length (RL), number of plants per square meter (NP).

Table 1. Summary of variance analysis for the 12 components related to soybean yield from two growing environments, three vigor levels and three fertilizer distribution systems.

FV	DF	Mean squares											
		FP	PH	NM	NR	NRM	RL	NP	N1	N2	N3	N4	SY
Environment (E)	1	2039,88*	1073,65*	51073,04*	51073,04*	291,20*	6339,95*	79260649520,00*	4825,10 *	31009,69*	36878,31*	79,03*	3896,82*
Vigor (V)	2	909,79*	1095,21*	7596,99*	7596,99*	275,48*	20141,06*	69493764155,00*	0,31	171,11*	565,34*	4,43*	112,31
E x V	2	31,15	89,59	572,30	572,30	38,47*	1543,04*	3728725052,20	100,54*	572,12*	39,95	3,82	389,02*
System (S)	2	70,23*	131,56*	580,30	580,30	27,77*	695,60	948377523,87	28,16	121,65*	285,71*	0,49	456,48*
E x S	2	0,63	141,62*	97,84	97,84	2,00	990,67	106635660,76	35,13	1,79	93,35	4,76*	20,86
V x S	4	59,44*	141,13*	288,76	288,76	3,66	1358,14*	1514331029,90	59,90*	6,85	98,61	2,50	234,43
E x V x S	4	56,14*	150,07*	922,62*	922,62*	17,03*	2411,92*	8215390020,50*	17,04	55,92	22,35	0,99	281,30*
Bloc	3	33,12*	327,72*	569,84*	569,84*	36,54*	2021,47*	7363530901,10	73,60*	183,97*	44,72	4,13*	90,92
Error	672	13,49	33,55	215,35	215,35	5,7	483,66	2927466536,40	16,9	41,61	59,73	1,45	107,88
CV%		20,05	6,66	32,07	27,05	49,34	57,63	28,45	43,13	21,17	18,54	121,83	13,47

* significant at 5% of probability by the F test.

DF- degrees of freedom; **FV**- Factor of variation; **FP**-First pod insertion height;**PH**- Plant height; **NM**- number of pods in the main stem; **NR**-number of pods in the ramifications; **NRM**- number of ramification in the main stem; **RL**- ramification length; **NP**- number of plants per m²; **N1**- contribution of the number of pods with one seed; **N2**- contribution of the number of pods with two seeds; **N3**-contribution of the number of pods with three seeds; **N4**-contribution of the number of pods with four seeds, and **SY**-seed yield. Source: Authors.

Significant interaction was evidenced between levels of vigor x fertilizer distribution systems for the contribution to seed yield through pods with one seed (N1). Significant interaction between growing environment x fertilizer distribution system was verified for the contribution to seed yield through pods with four seeds (N4). Significant interaction was also expressed between growing environment x levels of vigor for the contribution to seed yield through pods with one (N1) and two seeds (N2).

First pod insertion height (FP) revealed (Table 2) that in the absence of fertilization, and through conventional fertilizer distribution system, the Ernestina - RS environment increased this trait's magnitudes when plants originated from high and medium vigor levels.

Table 2. First pod insertion height (FP) and plant height (PH) of soybean plants, due to the association of seed vigor levels (high, medium and low), fertilizer distribution systems (Absence, conventional and by transshipment fertilization systems) and growing environments (Ernestina-RS and Passo Fundo-RS).

System	Growing environments					
	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	¹ 23.23 aA α	19.82 aB α	18.88 aB α	19.47 aA β	17.04 aB β	14.84 aC β
Conventional	23.1 abA α	19.05 abB α	16.33 bB α	18.25 abA β	14.97 bB β	15.28 aB α
By transshipment	21.51 bA α	17.76 bB α	20.12 aAB α	17.51 bA β	16.3 abAB α	15.4 aB β
CV%	20,05					
System	Growing environments					
	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	90.98 abA α	89.05 aAB α	87.61 aB α	89.41 aA α	84.84 aB β	83.43 aB β
Conventional	93.01 aA α	87.38 aB α	86.41 aB α	89.03 aA β	84.64 aB β	82.75 aB β
By transshipment	89.11 bA α	84.14 bB α	86.04 aB α	84.63 bA β	87.90 bA β	84.76 aB β
CV%	6,66					

CV- Coefficient of variation.

¹means followed by the same lowercase letter in the column, for fertilizer distribution systems within growing environments and each vigor level, uppercase letter in the line for vigor levels within fertilizer distribution systems in each environment, and Greek letter in the line for growing environments within fertilizer distribution systems at each vigor level, did not differ among themselves by Tukey test (p <0.05). Source: Authors.

For management with by transshipment fertilizer distribution, there was higher first pod insertion height for plants from low vigor seeds. For Passo Fundo-RS, the absence of fertilizer

increased this trait in plants from low vigor seeds. The high level of vigor, for Ernestina - RS, resulted in increased first pod insertion height for all fertilizer distribution systems, while the low vigor level increased this trait in the by transshipment distribution system (Table 2). In Passo Fundo - RS, the high level of vigor increased first pod insertion height in the management compound by absence and conventional fertilizer distribution. For Ernestina - RS, the high and medium vigor levels increased first pod insertion height regardless the fertilizer distribution systems. The low vigor level potentiated this trait in Ernestina - RS when plants were grown in the by transshipment distribution system (Table 2). These results corroborate with Carvalho et al. (2010), which determined that the first pod insertion height does not result in soybean yield loss, as long as its magnitude is close to 10 cm, indicating that soybean plants were ideal for mechanized harvesting, and losses were minimal.

The lowest plant height was obtained through the by transshipment fertilizer distribution system for high and medium vigor levels, and the low vigor did not differ for any of the fertilizer distribution systems for both growing environments (Table 2). Sedyama et al. (1999) reported that taller plants, or whit thinner stem, tend to lodging, which is positively associated with plant height and causes serious damage to soybean seed productivity (Sherrie et al., 2011). Regarding vigor levels, superiority is verified for the high vigor level in the three fertilizer distribution systems for Ernestina-RS. Similar results were expressed for Passo Fundo - RS when the soybean was submitted to absence and conventional fertilizer distribution system. The height of soybean plants should be between 60 and 90 cm in order to potentiate seed production and minimize losses with mechanized harvesting (Garcia et al., 2007). In Ernestina-RS, the highest plant height was verified for medium and low vigor levels, regardless the fertilizer distribution system. According to Rossi et al. (2018), quality and especially the vigor of seeds used may determine the growth of soybean, as well as the insertion of the first pod. Schuch et al. (2009) define that soybean from seeds of high physiological quality present increased stem height, stem diameter and grain yield by 25% when compared to plants from low quality seeds.

For the three fertilizer distribution systems, seeds with high vigor increased the number of pods in the main stem (NM) in Ernestina - RS (Table 3). For Passo Fundo – RS, it was evidenced that high vigor seeds increased the number of pods in the main stem at absence and conventional fertilizer management. Between growing environments, vigor levels do not differ in function of fertilizer distribution systems for number of pods in the main stem. The number of pods from ramifications (NR) was increased with medium seed vigor level in the conventional fertilizer distribution system. For Passo Fundo – RS, it was observed that seeds

of high vigor increased NR. When using low vigor level seeds, better responses were expressed for the by transshipment system (Table 3). Passo Fundo -RS was superior for this trait through the conventional distribution system and by transshipment.

Seeds of all vigor levels, in Ernestina – RS, showed similarity for fertilizer distribution systems in relation to the number of pods per plant. In this growing environment, it was possible to observe the larger magnitudes of pods in the ramifications, regardless of fertilizer distribution systems and vigor level. For Passo Fundo - RS, the increased number of pods in the ramifications was verified in plants from high vigor seeds cultivated under conventional and by transshipment fertilizer distribution system.

The growing environment of Passo Fundo-RS showed inferiority for number of ramifications in the main stem (NRM) for plants originated from high vigor seeds, regardless of the fertilizer distribution systems used (Table 3). Regarding seeds of medium vigor, the environment Passo Fundo - RS showed similarity for this trait in function of fertilizer distribution systems. According to Peixoto et al. (2008), soybean may express from one to ten ramifications per plant, because this magnitude is due to the spatial arrangement of plants in the canopy, plant population, intraspecific competition and genotype characteristics, as well as edaphoclimatic factors. Regarding the number of ramifications in the main stem (NRM) in the growing environment of Passo Fundo - RS, the conventional fertilizer distribution system resulted in superiority for plants from medium and low vigor level seeds. Otherwise, for by transshipment fertilization system, satisfactory responses were obtained for low vigor seeds. Furthermore, the magnitude of soybean ramifications is determined by intraspecific competition, edaphoclimatic factors, quantity and quality of solar radiation, plant arrangement, sowing time, and genotype characteristics (Martins et al., 1999).

Ramification length (RL) was potentiated in Ernestina - RS when plants were submitted to conventional fertilizer distribution systems and high vigor seeds (Table 3). In Passo Fundo-RS, this trait did not differ in function of fertilizer distribution systems and vigor levels. Regarding growing environments, Passo Fundo - RS was superior when plants came from low vigor seeds, under the by transshipment fertilization system.

Table 3. Number of pods in the main stem (NM), number of pods in the ramification (NR), number of ramification in the main stem (NRM) and average ramification length (RL), due to the association of seed vigor levels (high, medium and low), fertilizer distribution systems (Absence, conventional and by transshipment fertilization systems) and growing environments (Ernestina-RS and Passo Fundo-RS).

NM		Growing environments				
System	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	¹ 42.42 aAβ	38.67 aAβ	37.95 aAβ	67.38 aAα	49.16 bBa	49.96 aBa
Conventional	40.54 aAβ	31.79 bBβ	35.11 abABβ	62.34 abAα	49.63 bBa	47.37 aBa
By transshipment	44.58 aAβ	33.26 abABβ	31.74 bBβ	57.65 bAα	58.54 aAα	48.66 aBa
CV%	32,07					
NR		Growing environments				
System	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	57.57 aAα	61.32 bAα	62.04 bAα	32.61 bBβ	50.83 aAβ	50.03 aAβ
Conventional	59.45 aBa	68.20 aAα	64.88 abABα	37.656 abBβ	50.36 aAβ	52.62 aAβ
By transshipment	55.42 aBa	66.73 abAα	68.25 aAα	42.348 aBβ	41.45 bBβ	51.33 aAβ
CV%	27,05					
NRM		Growing environments				
System	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	2.52 aBβ	4.78 aAβ	4.1 aAβ	3.74 bBa	6.19 aAα	6.00 aAα
Conventional	3.06 aBβ	5.72 aAα	5.1 aAβ	5.00 aAα	5.75 abABα	6.7 aBa
By transshipment	2.1 aBβ	5.3 aAα	5.05 aAα	5.08 aAα	5.16 bAα	5.76 aAα
CV%	49,34					
RL		Growing environments				
System	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	20.46 bBβ	38.22 bAα	37.82 bAβ	30.75 aBa	47.33 aAα	49.28aAα
Conventional	31.84 aBa	49.01 aAβ	36.86 bBβ	29.80 aBa	50.15 aAα	43.94aAα
By transshipment	13.32 bBa	42.82 aBa	46.81 aAα	38.99 aBa	35.60 bBa	45.83aAα
CV%	57,63					

CV- Coefficient of variation.

¹means followed by the same lowercase letter in the column, for fertilizer distribution systems within growing environments and each vigor level, uppercase letter in the line for vigor levels within fertilizer distribution systems in each environment, and Greek letter in the line for growing environments within fertilizer distribution systems at each vigor level, did not differ among themselves by Tukey test (p <0.05). Source: Authors.

Fertilizer distribution systems, for both environments, revealed similar trends for number of plants per square meter (NP) for all vigor levels (Table 4). In Ernestina-RS, high vigor seeds increased this trait's magnitude even in the absence of fertilizer. Seed yield (SY) showed similar tendencies between high and medium vigor level of the seeds, independently of the fertilizer distribution system used in Ernestina - RS (Table 4). For Passo Fundo - RS, vigor levels expressed tendency to increase SY, similar for all fertilizer distribution systems. However, it can be observed that the high vigor level, in association to conventional and by transshipment fertilization system, provided an absolute increase of 10.9 and 5.6% in the yield of seeds, respectively, for Ernestina-RS. The conventional fertilizer distribution system, in Passo Fundo - RS, increased seed yield in 12.5%, when plants originate from low vigor seeds.

Table 4. Number of plants per m² (NP) and seed yield (SY), due to the association of seed vigor levels (high, medium and low), fertilizer distribution systems (Absence, conventional and by transshipment fertilization systems) and growing environments (Ernestina-RS and Passo Fundo-RS).

NP		Growing environments				
System	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	¹ 28,28 aAα	19,19 aBα	20,95 aABβ	25,25 aAα	12,87 aBα	10,47 aBα
Conventional	23,73 aAα	23,61 aAα	20,95 aAα	24,11 aAα	13,25 aBβ	9,72 aBβ
By transshipment	30,93 aAα	16,28 aBα	17,04 aBα	18,30 aAβ	17,04 aAα	10,22 aAα
CV%	28,45					
SY		Growing environments				
System	Ernestina-RS			Passo Fundo-RS		
	Vigor level			Vigor level		
	High	Medium	Low	High	Medium	Low
Fertilizer absence	82,1 aAα	81,82 aAα	96,74 aAα	69,01 aAα	68,91 bAα	74,3 aAβ
Conventional	93,33 aAα	83,68 aAα	84,14 aAα	59,83 aBβ	90,76 aAα	72,45 aBα
By transshipment	84,36 aAα	76,5 aAα	79,83 bAα	62,1 aAβ	61,79 bAβ	69,62 aAα
CV%	13,47					

CV- Coefficient of variation.

¹means followed by the same lowercase letter in the column, for fertilizer distribution systems within growing environments and each vigor level, uppercase letter in the line for vigor levels within fertilizer distribution systems in each environment, and Greek letter in the line for growing environments within fertilizer distribution systems at each vigor level, did not differ among themselves by Tukey test (p <0.05). Source: Authors.

The employment of high quality seeds is fundamental for expressing the maximum productive potential of the species and variety being growth. Seeds are the carriers of

advances brought by plant breeding, expressed by genetic attributes, and has its performance influenced by physical, sanitary and physiological features. Among the attributes of seed physiological quality, vigor is highlighted as relevant because it relates to germination, emergence, seedling growth, uniformity rates at field with the possibility of influencing grain yield in different crops (RossI et al., 2018). Research from França Neto (1984) revealed increases of 20-35% in grain yield when using high-vigor seeds. Kolchinski et al. (2005) determined that the use of high vigor seeds increased soybean yield by 35%, while Rossi et al. (2018) evidenced that lots of high vigor seeds are closely related to high yields in this crop. Therefore, the importance of seed vigor level and its effects on soybean growth and development is confirmed, being essential to yield components and seed productivity (Table 5).

Table 5. Contribution of pods with one (N1), two (N2) and four grains (N4) for soybean yield due to the association of seed vigor levels (high, medium and low) and growing environments (Ernestina-RS and Passo Fundo-RS).

N1		Growing environments	
Vigor level	Ernestina-RS	Passo Fundo-RS	
High	¹ 6.26 bB	12.99 aA	
Medium	7.51 aB	11.65 bA	
Low	7.05 abB	12.06 abA	
CV%	43,13		
N2		Growing environments	
Vigor level	Ernestina-RS	Passo Fundo-RS	
High	21.11 bB	38.12 aA	
Medium	25.34 aB	36.61 aA	
Low	25.25 aB	37.17 aA	
CV%	21,17		
N4		Growing environments	
Vigor level	Ernestina-RS	Passo Fundo-RS	
High	0.59 aB	1.11 bA	
Medium	0.74 aB	1.29 bA	
Low	0.64 aB	1.62 aA	
CV%	121,83		

CV- Coefficient of variation.

¹Means followed by the same lowercase letter in the column of each growing environment within vigor levels, and uppercaseletter in lines for each vigor level within growing environments do not differ by Tukey test (p <0.05). Source: Authors.

For Ernestina-RS, there was an increase in the contribution of pods with one seed (N1) to yield, occurring for all levels of vigor, positive effects on productivity. For the contribution of pods with two seeds (N2), there was superiority for plants originated from seeds of low and medium vigor level when the growing environment was Ernestina – RS. In contrast, for Passo Fundo – RS, there was no difference regarding this trait (Table 6, 7 and 8).

Table 6. Contribution of pods with one grain (N1) for seed yield due to the association of fertilizer distribution systems (absence, conventional and by transshipment fertilization system) and seed vigor levels (high, medium and low).

N1	Vigor level		
	High	Medium	Low
System			
Fertilizer absence	¹ 10.10aA	9.05 bA	9.57 aA
Conventional	9.90 aA	10.89 aA	9.07 aA
By transshipment	8.90aA	8.81 bA	10.05 aA
CV%	43,13		

CV- Coefficient of variation.

¹Means followed by the same lowercase letter in the column of each vigor level within fertilizer distribution systems, and uppercase letter in lines of each fertilizer distribution systems within vigor levels, do not differ by Tukey test (p <0.05). Source: Authors.

Table 7. Contribution for seed yield of pods with three grains (N3), due to the association of fertilizer distribution systems (Absence of fertilizer, conventional and by transshipment) and growing environments (Ernestina-RS and Passo Fundo-RS) .

N3	Growing environments	
	Ernestina-RS	Passo Fundo-RS
System		
Fertilizer absence	¹ 33.21 bB	49. 24 abA
Conventional	34.41 abB	47.98 bA
By transshipment	36.01 aB	50.32 aA
CV%	18,54	

CV- Coefficient of variation.

¹Means followed by the same lowercase letter in the column of each growing environment within fertilizer distribution systems, and uppercase letter in lines of each fertilizer distribution system within growing environments do not differ by Tukey test (p <0.05). Source: Authors.

Table 8. Means of the contribution forseed yield of pods with two (N2) and three grains (N3) due to seed vigor levels (high, medium and low).

Vigor levels	N2	N3
High	¹ 29.59 b	40.11 b
Medium	30.87 a	42.72 a
Low	30.93 a	42.19 a

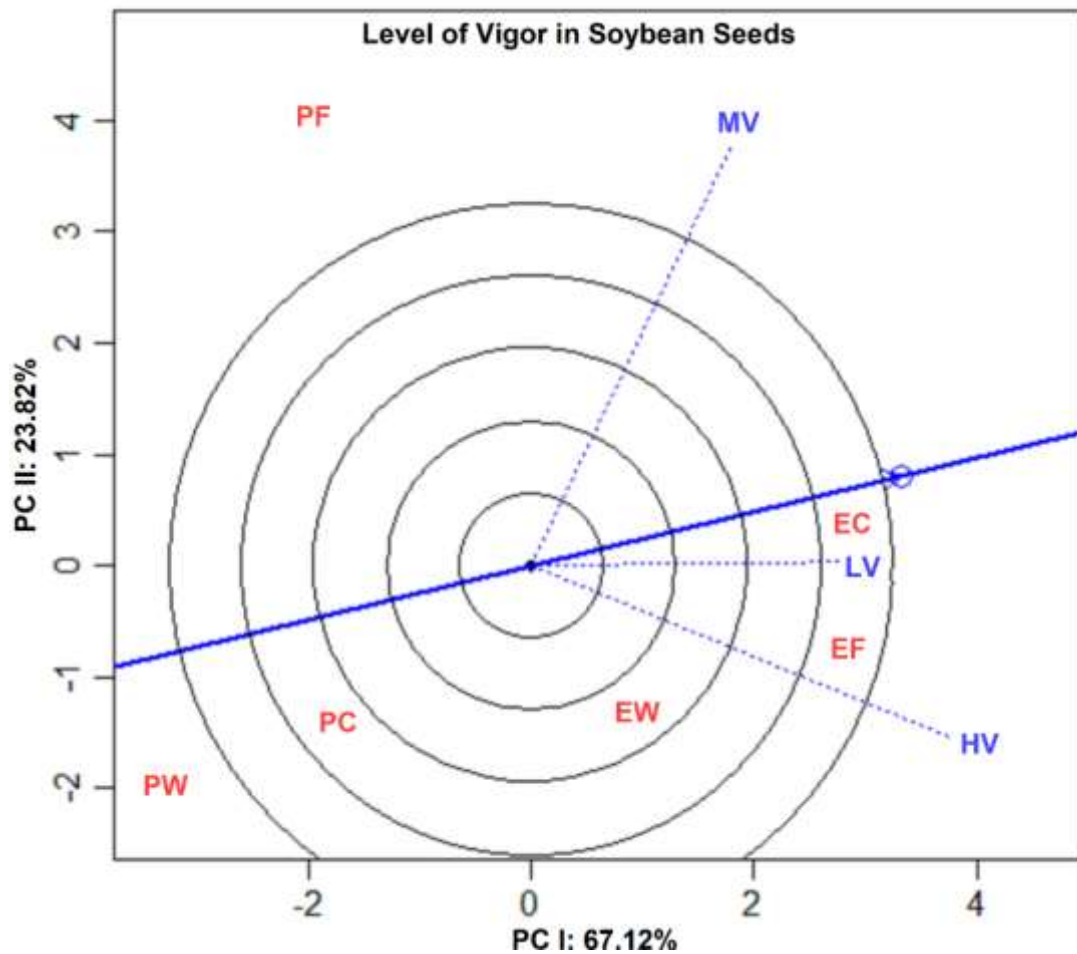
¹Means followed by the same lowercase letter in the column do not differ from each other by the duncan test ($p < 0.05$). Source: Authors.

The major contributions of pods with three seeds (N3) were verified in plants grown under conventional and by transshipment fertilization systems, both for Ernestina - RS and Passo Fundo - RS (Table 7). Regardless of seed vigor level and fertilizer distribution system, the highest contributions to soybean yield in both environments were achieved through pods with two and three seeds (Table 8).

The contribution of pods containing four seeds (N4) was higher in Passo Fundo - RS for plants originated from low vigor seeds. It may be related to problems in the initial establishment of soybean, resulting in a smaller population per unit area, smaller intraspecific competition and consequently greater possibilities of directing assimilates for filling more seeds per legume.

The detailed visualization of the multivariate trend of seed yield and the effects of vigor levels, growing environments and fertilizer distribution system (Figure 1) was possible through the method of genotype main effects and genotype environment interaction (GGE). Under these conditions, the biplot graph shows the average trend and represents 90.94% of the total variation involved in soybean seed yield.

Figure 1. Plotting of principal components scores regarding the classification of high (HV), medium (MV) and low (LV) vigor levels, and growing environments according to the fertilizer distribution systems. Ernestina-RS/Absence of fertilizer (EW), Ernestina-RS/conventional (EC) and Ernestina-RS/By transshipment (EF), Passo Fundo-RS/Absence of fertilizer (PW),Passo Fundo- RS/By transshipment (PF), based on its performance, according to the GGE Biplot model, for the variable seed yield



Source: Authors.

The data originis located at the central point. It allowed to evidence that greater seed yield variation was due to the growing environment of Ernestina – RS, in the absence of fertilizer distribution (EW). In general, Ernestina-RS potentiated seed yield. For Passo Fundo-RS, lower mean values were verified, and the lowest performances were obtained in Passo Fundo - RS under no fertilization system (PW). The ideal seed production point can be obtained through the use of high vigor (HV) and medium vigor (MV) seeds, similar and satisfactory conditions, followed by the effects of Ernestina-RS, under conventional system, and Ernestina-RS, under by transshipment fertilization system.

The effects attributed to seed vigor levels (Figure 1) show that high (HV) and medium vigor (MV) provide high performance for grain yield, because they are distant from the origin axis. Close relationship was verified between conventional distribution systems (EC) and by transshipment (EC), attributing similar trends to plants produced from low vigor seeds.

In view of the scenarios expressed in this study, it was verified that high vigor seeds, in association to conventional distribution system, potentiated grain yield, number of pods in the main stem, plant height and first pod insertion height. When medium vigor seeds are used in association to conventional fertilization system, the benefited traits are length and magnitude of ramifications, as well as the contribution of pods with one seed for grain yield. In general, low vigor seeds reduced the phenotypic expression of most measured traits, mainly in the absence of fertilizer. As reported in this study, high vigor seeds are fundamental for achieving high-performance plants, which have the ability to better use the available environment's resources, and consequently increase yields.

4. Final Considerations

Seed vigor levels and fertilizer distribution systems influence on seed yield, first pod insertion height, plant height, number of pods in the main stem and ramifications, magnitude and length of ramifications in soybean.

The high vigor level in the conventional and by transshipment fertilization systems provided an absolute increase of 10.9 and 5.6% in seed yield, respectively, in Ernestina-RS. The conventional fertilizer distribution system, in Passo Fundo-RS, increased seed yield in 12.5% in plants originated from low vigor seeds.

In view of the results of this work, it is necessary to carry out further studies in order to verify the real influence of biotic and abiotic factors on seed vigor.

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