SEED RESERVE MOBILIZATION EVALUATION FOR SELECTION OF HIGH-VIGOR COMMON BEAN CULTIVARS[1]

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ABSTRACT – The efficiency of seed reserve mobilization (SRM) can be affected by genotype characteristics and seed initial physiological quality, which are determinant for the choice of cultivars that present plants with high physiological performances. The objective of this study was to evaluate the SRM in different common bean cultivars with different vigor and determine the differences in this process between seed lots and cultivars. Six common bean cultivars were grown in the 2017-2018 and 2018-2019 crop seasons in Lages, Santa Catarina, Brazil. The physiological quality of the cultivars was defined by germination test, accelerated aging test, seedling length, and vigor index, establishing two vigor groups (high vigor and low vigor). SRM was evaluated based on seed and seedling dry weights, use of seed reserves, use rate of seed reserves, SRM rate to the seedling, and use efficiency of seed reserves. The high-vigor cultivars presented higher use rates of seed reserves, SRM rate to the seedling, and use efficiency of seed reserves, favoring the development of vigorous seedlings. The evaluation of SRM is an alternative to improve control of internal seed quality and selection of high-vigor common bean cultivars.

Keywords: *Phaseolus vulgaris* L. Seedling growth. Germination.

AVALIAÇÃO DA MOBILIZAÇÃO DE RESERVAS EM SEMENTES DE FEIJÃO PARA A SELEÇÃO DE CULTIVARES DE ALTO VIGOR

RESUMO – A eficiência da mobilização de reservas em sementes pode ser afetada pelas características do genótipo e sua qualidade fisiológica inicial, sendo determinantes na escolha de cultivares que apresentem melhor desempenho fisiológico a campo. O estudo teve como objetivo avaliar a mobilização de reservas em diferentes cultivares de feijão com contraste no vigor, buscando determinar como esse processo se diferencia entre esses lotes e cultivares. Foram utilizadas seis cultivares produzidas nas safras 2017/2018 e 2018/2019 em Lages, Santa Catarina, Brasil. A qualidade fisiológica das cultivares foi definida pelo teste de germinação, teste de envelhecimento acelerado, comprimento de plântulas e pelo índice de vigor, sendo determinados dois grupos de vigor (maior e menor vigor). A mobilização de reservas foi avaliada pela massa seca de sementes e de plântulas, utilização de reservas da semente, taxa de utilização de reservas da semente, taxa de mobilização de reservas para a plântula e pela eficiência de uso das reservas da semente. As cultivares caracterizadas como de maior vigor apresentaram maior taxa de utilização de reservas, taxa de mobilização de reservas para a plântula e maior eficiência de uso de reservas, favorecendo a formação de plântulas vigorosas. A avaliação da mobilização de reserva é uma alternativa para o uso em programa de controle de qualidade e seleção de cultivares com maior vigor.

Palavras-chave: *Phaseolus vulgaris* L. Crescimento de plântulas. Germinação.

INTRODUCTION

The use of high-vigor seeds results in a fast, uniform, and complete emergence of seedlings and assists in the competition with weeds and in a uniform plant development, even under adverse conditions (MARCOS-FILHO, 2015a, CHENG et al., 2015).

Common bean (*Phaseolus vulgaris* L.) crops are important in the whole world as source of carbohydrates, proteins, and minerals. Studies on vigor of common bean plants have sought to identify correlations between yield (MONDO; NASCENTE; CARDOSO NETO, 2016), production systems (GINDRI et al., 2017), genetic diversity (GINDRI; COELHO, 2019), biochemistry composition (CASSOL et al., 2016) and enzymatic activity (MORIYA et al., 2015). However, such studies do not consider the dynamics of seed reserve mobilization (SRM) in control of internal seed quality and selection of high-vigor common bean genotypes, which is an important strategy to be explored for this purpose.

SRM occurs in a critical time, during the seedling development in the field. This process can be evaluated considering the amount of reserves used by the seed and the efficiency of use of mobilized seed reserves (SOLTANI; GHOLIPOOR; ZEINALI, 2006). The correlations between SRM and seedling development can be affected by intrinsic characteristics of the genotype and seeds, such as biochemical composition (SNIDER et al., 2016), physical properties (PEREIRA; PEREIRA; DIAS, 2013), enzyme production, and enzymatic activity (BEWLEY et al., 2013; CHENG et al., 2015; LAMBERT et al., 2016).

The dynamics of SRM have been evaluated for chickpea (SOLTANI et al., 2002), wheat (SOLTANI; GHOLIPOOR; ZEINALI, 2006), barley, (SHARAFI et al., 2012), rice (CHENG et al., 2015), soybean (PEREIRA; PEREIRA; DIAS, 2015), and maize (CHENG et al., 2018). However, these studies evaluated correlations between genotypes, seed weights, amount of mobilized seed reserves, and the use efficiency of seed reserves for seedling development, but not effectively approached the correlation between seed vigor and SRM dynamics, showing the need to determine such correlation.

Seed physiological quality is affected by several factors, including seed genotype (MICHELS et al., 2014; NERLING; COELHO; BRUMMER, 2018). Vigor is essential for seeds, since high-vigor seeds result in seedlings with high dry weight, long length, and high productive potential (KRZYZANOWSKI; FRANÇA-NETO; HENNING, 2018).

In addition to evaluation of seed vigor, the use of different parameters related to seedling performance assists in assessing the genotype dynamics, thus contributing to programs focused on control of internal seed quality (ANDRADE; COELHO; PADILHA, 2019). Seed vigor can explain differences in SRM capacity and use efficiency of seed reserves during the seedling development process. The determination of differences in initial vigor between seed lots can be used to assess the correlation between genotype and vigor during the seedling heterotrophic growth.

In this context, the objective of this study was to evaluate the SRM and determine the contribution of this process to the vigor of seedlings of different common bean cultivars.

MATERIAL AND METHODS

The experiment was conducted using seeds of six common bean cultivars obtained from the Active Bank of Common Bean Germplasm (BAF) of the Centro of Agro-Veterinary Sciences of the Santa Catarina State University (UDESC-CAV). The cultivars were previously characterized in studies with nine consecutive crop seasons using self-fertilization, which favored the homogeneity and stability of the populations. The cultivars used were determined by their morpho-agronomic characteristics and seed physiological qualities (MICHELS et al., 2014; EHRHARDT-BROCARDO; COELHO, 2016; GINDRI et al., 2017).

The cultivars used were: BAF07, BAF13, BAF23, BAF42, BAF55, and BAF112 (IPR88-Uirapuru). The six cultivars were produced in the 2017-2018 (November 2017 to February of 2018) and 2018-2019 (November 2018 to February of 2019) crop seasons, in the UDESC-CAV experimental area, Lages, Santa Catarina, Brazil (27° 78'S, 50°30'W, and 930 m of altitude).

A randomized block experimental design was used, with three replications. The plots consisted of four 2-meter rows spaced 0.5 m apart, with 12 seeds per meter; the two central rows were used for the evaluations, disregarding 0.30 m from each end. Soil fertilizers were placed in the rows at planting, based on the soil analysis, estimating a production of 4 Mg ha^{-1}. Topdressing was applied when the plants had three trifoliate leaves and at the beginning of the flowering stage, using 28 Kg of nitrogen per hectare in each application.

The seeds were manually harvested when they had approximately 18% moisture. The seeds were then taken to a seed analysis laboratory, where they were dried in a forced air circulation oven at 35 ºC until reaching 13% moisture.

Seed samples of the three replications were

gathered in a single sample and homogenized to form a 1000-gram composite sample. The composite sample was divided into four 250-gram replications, using a sample divider, as done by Coelho et al. (2010). The samples were stored in a dry chamber at 10 ºC and 50% air relative humidity until the analyses of samples from each crop season.

The 1,000-seed weight and moisture degree were determined according to the Rules for Seed Analysis (BRASIL, 2009).

The germination was tested in a Mangelsdorf germinator at 25±2 °C; the seeds were sowed in paper rolls (Germitest®) moistened with a water volume of 2.5-fold the dry paper weight (BRASIL, 2009), using four replications of 50 seeds.

The accelerated aging (AA) test was done with four replications of 50 seeds distributed in a suspended stainless-steel screen inside acrylic boxes (Gerbox®; 10.5×10.5×3.0 cm), containing 40 mL of distilled water. The boxes were sealed and maintained in an aging chamber at 42 ºC for 72 hours (MARCOS-FILHO, 1999). These conditions were determined in previous studies as the most favorable for the segregation of seed lots for seed vigor. The germination test was then conducted as previously described.

The seedling lengths (SL) were evaluated using normal seedlings, i.e., those that had all essential structures (primary root; hypocotyl; epicotyl; cotyledons; and plumule) and were not disturbed or damaged. The evaluation was conducted with four replications of 20 seeds; after five days, seedling lengths were measured with a digital caliper. The results were expressed as centimeters per seedling.

The cotyledons and axis of the seedlings were then separated and dried at 80 ºC for 24 hours to determine the remaining dry weight in the cotyledons (RDWC) and the seedling dry weight (SLDW) (NAKAGAWA, 1999).

The vigor index (VI) was calculated as proposed by Abdul-Baki and Anderson (1973), according to Equation 1:

$$VI = \text{germination } (\%) \times \text{seedling length (cm)} \qquad (1)$$

Seed reserve mobilization (SRM) was evaluated using the integument of 20 seeds with four replications; the seeds were dried in an oven at 105 ºC for 24 hours to obtain the seed dry weight (SDW).

The use of seed reserves (USR) was determined by the difference between SDW and RDWC, as done by Soltani, Gholipoor, and Zeinali (2006), and the result was expressed as mg seed^{-1},

according to Equation 2:

$$USR = SDW - RDWC \qquad (2)$$

The use efficiency of seed reserves (UESR) was determined by the ratio between SLDW and USR, as proposed by Soltani, Gholipoor, and Zeinali (2006), and the result was expressed as mg mg^{-1}, according to Equation 3:

$$UESR = \frac{SLDW}{USR} \qquad (3)$$

The use rate of seed reserves (URSR) was calculated by the ratio between USR and SDW and expressed as percentage (SOLTANI; GHOLIPOOR; ZEINALI, 2006; PEREIRA; PEREIRA; DIAS, 2015), according to Equation 4:

$$URSR = \left(\frac{USR}{SDW} \right) \times 100 \qquad (4)$$

The amount of mobilized seed reserves to the seedling was represented by the seed reserve mobilization rate (SRMR), determined by the ratio between SLDW and SDW and expressed as percentage, according to Equation 5:

$$SRMR = \left(\frac{SLDW}{SDW} \right) \times 100 \qquad (5)$$

The data were subjected to analysis of variance (F test), using the Sisvar 5.6 program (FERREIRA, 2011). The means were compared by the Scott-Knott test at 5% probability. The data of both crop seasons were subjected to Pearson's correlation analysis, indicating significances of 1% and 5% probability. Principal Component Analysis (PCA) was used to identify and describe the correlation between the vigor groups and the parameters evaluated. The Pearson's correlation analysis and PCA were done using the R program (R CORE TEAM, 2019).

RESULTS AND DISCUSSION

The cultivars presented significant difference in 1,000-seed weight (1000SW), varying from 203.66 g (BAF42) to 379.98 g (BAF23) in the 2017-2018 crop season, and from 203.47 g (BAF07) to 332.06 g (BAF23) in the 2018-2019 crop season (Table 1). The 1000SW was used to determine differences between cultivars, as done in previous studies (MICHELS et al., 2014), showing the homogeneity and stability of the populations.

Table 1. Moisture degree (MD), 1.000-seed weight (1000SW), germination percentage (G), accelerated aging (AA), seedling length (SL), and vigor index (VI) of common bean cultivars evaluated in two crop seasons (2017-2018 and 2018-2019).

Cultivar	MD (%)	1000SW (g)	G (%)	AA (%)	SL (cm)	VI
			2017/2018			
BAF07	13.3	206.62 e	84 b	74 b	20.39 d	1718 c
BAF13	13.6	248.06 c	85 b	79 a	26.11 b	2207 b
BAF23	13.7	379.98 a	84 b	67 b	22.33 c	1874 c
BAF42	13.4	203.66 e	86 b	84 a	25.95 b	2216 b
BAF55	13.5	223.80 d	91 a	86 a	29.11 a	2635 a
BAF112	13.1	266.32 b	87 b	84 a	26.05 b	2253 b
Mean	13.4	254.74	86	79	24.99	2.150
CV	-	2.88	3.39	6.34	4.32	5.21
			2018/2019			
Cultivar	MD (%)	1000SW (g)	G (%)	AA (%)	SL (cm)	VI
BAF07	12.1	203.47 e	85 c	78 c	18.63 e	1573 d
BAF13	13.4	233.28 c	93 a	85 b	25.09 c	2321 b
BAF23	13.2	332.06 a	90 b	73 c	23.46 d	2101 c
BAF42	12.3	205.73 e	89 b	79 c	25.49 c	2267 b
BAF55	12.7	224.46 d	94 a	91 a	28.28 a	2644 a
BAF112	12.4	261.57 b	85 c	83 b	26.38 b	2229 b
Mean	12.7	243.43	89	81	26.20	2.189
CV	-	1.48	3.03	5.74	2.62	3.76

Means followed by the same letter in the columns are not different by the Scott-Knott test at 5% probability. CV = Coefficient of variation (%).

The germination percentages found for the crop seasons were 84% to 94%, which are above the minimum percentage (80%) acceptable to commercialization of common bean seeds in Brazil (BRASIL, 2013). However, the germination percentage was not correlated to percentage of seedling emergence in the field due to the occurrence of adverse conditions during the emergence. Thus, the use of vigor tests to determine the physiological potential of a seed lot is necessary (MARCOS-FILHO, 2015b).

The cultivars BAF13, BAF42, BAF55, and BAF112 presented higher vigor than the cultivars BAF07 and BAF23 in both crop seasons (Table 1), considering the vigor parameters (AA, SL, and VI). Similar physiological quality results were obtained for the same cultivars in previous studies, with BAF13, BAF42, BAF55, and BAF112 presenting higher potential for production of high-vigor seeds than the cultivars BAF07 and BAF23 (MICHELS et al., 2014; EHRHARDT-BROCARDO; COELHO, 2016; GINDRI et al., 2017). Thus, differences in seed vigor were found even when the cultivars presented germination percentages higher than 80%.

Therefore, the use of more than one evaluation method is needed to correctly characterize the seed vigor and avoid errors in segregation of seed lots (KRZYZANOWSKI; FRANÇA-NETO; HENNING, 2018). Thus, the use of seed segregation methods based on the seed vigor (AA, SL, and VI) enabled the determination of a high-vigor group which includes the cultivars BAF13, BAF42,

BAF55, and BAF112; and a low-vigor group which included the cultivars BAF07 and BAF23.

The highest SLDW were found for the cultivars BAF23, BAF55, and BAF112 in the 2017-2018 crop season, and for BAF23 in the 2018-2019 crop season (Table 2). SLDW is commonly used for evaluation of vigor, since seeds with lower vigor produce seedlings with lower dry weights; however, it can be affected by the seed weight, resulting in errors in segregation of seed lots (NAKAGAWA, 1999). The correlation between high seed dry weight and development of seedlings with high dry weights explains the higher SLDW found for the cultivar BAF23, which presented low vigor (Table 1). Effects of seed dry weight on results were found for cotton (SNIDER et al., 2016) and soybean (PEREIRA; PEREIRA; DIAS, 2013) seeds: seeds with higher weights originated seedlings with higher dry weights. The cultivars BAF23, BAF55, and BAF112 presented no significant differences in SLDW in the 2017-2018 crop season, indicating the effect of vigor on seedling development (Table 2).

The cultivars BAF13, BAF42, BAF55, and BAF112 (high vigor) presented higher URSR (Table 2), since high-vigor seeds have higher amount of reserves for seedling development, resulting in high-vigor seedlings (ANDRADE; COELHO; PADILHA, 2019). The cultivars BAF55 (high vigor) and BAF07 (low vigor) presented similar SDW; BAF55 seedlings had higher URSR, favoring the development of seedlings with longer lengths (Table 1) and dry weights (Table 2).

Table 2. Seedling dry weight (SLDW), seed dry weight (SDW), remaining dry weight in the cotyledons (RDWC), use of seed reserves (USR), use rate of seed reserves (URSR), seed reserve mobilization rate (SRMR), and use efficiency of seed reserves (UESR) of common bean cultivars evaluated in two crop seasons (2017-2018 and 2018-2019).

	2017/2018						
Cultivar	SLDW	SDW	RDWC	USR	URSR	SRMR	UESR
	-------------------- mg --------------------				------- % -------		mg mg^{-1}
BAF07	38,06 c	176.93 e	112.50 c	64.43 d	36.39 b	21.47 b	0.59 a
BAF13	49.55 b	202.91 c	110.00 c	92.91 b	45.82 a	24.55 b	0.54 a
BAF23	68.86 a	308.82 a	198.00 a	110.82 a	35.89 b	20.97 b	0.62 a
BAF42	49.84 b	163.67 f	88.50 d	75.17 c	45.89 a	30.27 a	0.66 a
BAF55	57.84 a	187.16 d	93.25 d	93.91 b	50.17 a	30.83 a	0.61 a
BAF112	62.78 a	219.78 b	123.25 b	96.53 b	43.89 a	27.02 a	0.65 a
Mean	54.49	209.87	120.91	88.96	43.01	25.98	0.61
CV	11.29	1.99	5.01	6.83	6.87	10.36	11.39
	2018/2019						
Cultivar	SLDW	SDW	RDWC	USR	URSR	SRMR	UESR
	-------------------- mg --------------------				------- % -------		mg mg^{-1}
BAF07	37.46 d	171.96 c	113.50 b	58.45 e	34.09 c	21.79 e	0.64 b
BAF13	56.02 c	179.65 c	103.62 c	76.02 d	42.31 b	31.18 c	0.74 a
BAF23	73.14 a	271.77 a	170.42 a	101.34 a	37.30 c	26.91 d	0.72 a
BAF42	55.67 c	165.46 c	85.78 d	79.68 d	48.16 a	33.64 b	0.69 a
BAF55	66.98 b	178.83 c	88.79 d	90.04 b	50.38 a	37.50 a	0.74 a
BAF112	64.26 b	206.18 b	121.17 b	85.01 c	41.22 b	31.16 c	0.75 a
Mean	58.92	195.64	113.88	81.75	42.24	30.36	0.72
CV	4.07	4.08	6.67	5.11	5.46	3.38	5.37

Means followed by the same letter in the columns are not different by the Scott-Knott test at 5% probability. CV = Coefficient of variation (%).

The cultivars BAF13, BAF42, BAF55 and BAF112 had the highest SRMR. Similar result was also found in other study (EHRHARDT-BROCARDO; COELHO, 2016), which highlighted that high-vigor seeds have higher capacity for seed reserve mobilization (SRM) to the seedling. This characteristic is, in general, associated to seed vigor, which favors the seedling development (DELGADO; COELHO; BUBA, 2015). The cultivars BAF07 and BAF23 presented the lowest vigor and, consequently, lowest capacity for seed reserve mobilization to the seedling (Table 2), resulting in seedlings with shorter lengths (Table 1) in both crop seasons.

The cultivars presented no difference in UESR in the 2017-2018 crop season. However, the cultivars BAF13, BAF23, BAF42, BAF55, and BAF112 presented higher UESR than the cultivar BAF07 in the 2018-2019 crop season. Studies have highlighted that UESR is dependent on the cultivar (PEREIRA; PEREIRA; DIAS, 2015). According to Cheng et al. (2013), UESR shows the conversion efficiency of seed reserves for seedling development and assists in the development of seedlings with high dry weights. The results indicated lower use efficiency for the cultivar BAF07, resulting in lower SLDW (Table 2).

The effects of the correlation between the vigor parameters (AA, VI, and SL) were not significant for the 2017/2018 crop season, therefore, the Pearson's correlation analysis was applied using the data of both crop seasons. The correlation analysis showed that SLDW, SDW, and USR were positively correlated (Table 3). It was also found by Pereira, Pereira, and Dias (2015) for soybean seeds, denoting that seeds with high dry weights tend to produce seedlings with high dry weights due to their high availability of reserves (Table 3). This correlation was found for BAF23, which presented the highest SDW, USR, and SLDW in both crop seasons (Table 2).

USR represents the amount of dry weight mobilized and used; the higher the quantity of soluble compounds available for the growth points, the higher the seedling dry weight (Table 3). According to Soltani, Gholipoor, and Zeinali (2006), low seedling dry weights occur due to low use of seed reserves. Moreover, Cheng et al. (2015) defined the USR as the first determinant factor for the development of high-vigor seedlings.

High use of seed reserves may be related to the activity of proteases, lipases (MARCOS-FILHO, 2015a), and amylases (SHAIK et al., 2014; CHENG et al., 2018), which hydrolyzes reserve compounds and enables the use of soluble compounds that are mobilized and used in the embryonic axis (BEWLEY; NONOGAKI, 2017). According to Lambert et al. (2016), stored globulins are used

during the common bean seedling development, providing reduced nitrogen to be used during the seedling development process. After the proteolysis of stored globulins in the cotyledons, the amino acids are reused and mobilized in the embryonic axis for the synthesis of new proteins (BEWLEY et al., 2013). Cheng et al. (2015) found similar results for stored starch when evaluating the correlation between enzymatic activity and seed reserve use in rice; they reported that the highest activity of alfa amylase was positively correlated to the supplying of soluble sugars to the embryonic axis, resulting in seedlings with better performance.

Table 3. Coefficients of the Pearson's correlation analysis (r) for the parameters evaluated.

	SL	AA	1000SW	SLDW	SDW	RDWC	USR	UESR	URSR	SRMR	VI
G	0.40	0.38	-0.13	0.29	-0.17	-0.29	0.15	0.28	0.47*	0.54*	0.66*
SL	-	0.56*	-0.10	0.48*	-0.15	-0.39**	0.42**	0.24	0.81*	0.75*	0.95*
AA	-	-	-0.51*	0.03	-0.55*	-0.66*	-0.11	0.21	0.64*	0.61*	0.59*
1000SW	-	-	-	0.67*	0.98*	0.93*	0.77*	0.03	-0.38	-0.30	-0.13
SLDW	-	-	-	-	0.62*	0.43**	0.80*	0.52*	0.21	0.47*	0.48*
SDW	-	-	-	-	-	0.95*	0.76*	-0.05	-0.42**	-0.39**	-0.19
RDWC	-	-	-	-	-	-	0.53*	-0.03	-0.67*	-0.55*	-0.42**
USR	-	-	-	-	-	-	-	-0.09	0.27	0.10	0.39**
UESR	-	-	-	-	-	-	-	-	-0.02	0.65*	0.29
URSR	-	-	-	-	-	-	-	-	-	0.73*	0.82*
SRMR	-	-	-	-	-	-	-	-	-	-	0.79*
VI	-	-	-	-	-	-	-	-	-	-	-

* = significant at 5% probability by the t test; ** = significant at 1% probability by the t test. G = germination; SL = seedling length; AA = accelerated aging; 1000SW = 1.000-seed weight; SLDW = seedling dry weight; SDW = seed dry weight; RDWC = remaining dry weight in the cotyledons; USR - use of seed reserves; UESR = use efficiency of seed reserves; URSR = use rate of seed reserves; SRMR = seed reserve mobilization rate; VI = vigor index; number of observations = 48 (2017-2018 and 2018-2019 crop seasons).

URSR was positively correlated to SRMR (r = +0.73). SRMR shows the seed reserve mobilization capacity for seedling development and is dependent on URSR; the higher the URSR, the higher the SRM to the seedling (Table 3). However, according to Pereira, Pereira, and Dias (2015), the amount of mobilized reserves is dependent on the UESR, i.e., seeds presenting high URSR do not necessarily have their reserves mobilized to the embryonic axis. Seed reserves can be used for metabolism during the seedling development process.

URSR and SRMR were positively correlated to vigor (AA, SL, and VI), indicating that they can be used as parameters for selection of high-vigor cultivars (Table 3). High-vigor cultivars have high URSR and SRMR, as shown by the results found for the cultivar BAF55 (Table 2). Ehrhardt-Brocardo and Coelho (2016) found correlation between SRMR and vigor. Moreover, the present study showed that SRMR is dependent on URSR, and URSR and SRMR are affected by seed vigor.

The correlation between SRMR and SDW was negative (r = -0.39), indicating that SRMR is not dependent on SDW. Seeds with high SDW may present low SRMR (low mobilization). This correlation was found for the cultivar BAF23, which presented lower SRMR and URSR than the others high-vigor cultivars, even presenting the highest SDW among the cultivars evaluated (Table 2).

UESR showed positive correlation with SRMR, indicating that high-UESR seeds have higher capacity to mobilize dry weight to the seedling. UESR indicates the action of metabolism of seeds during the SRM process (SOLTANI; GHOLIPOOR; ZEINALI, 2006). High-UESR seeds result in a higher SRM to the seedling, presenting lower energy cost during the metabolism (e.g. respiration) (CHENG et al., 2015); this result was shown by the positive correlation between UESR and SLDW (r = +0.52) (Table 3). UESR is determinant to ensure that the reserves are used for seedling development.

The association of parameters related to seed reserve dynamics and formation of groups of seed vigor was shown by the PCA. The PCA also included data of both crop seasons. The two first principal components explained 78.18% of the variance of the variables; 45.18% was explained by principal component 1 (PC1), and 33.00% by principal component 2 (PC2) (Figure 1).
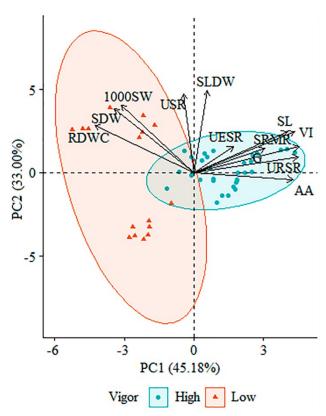
Figure 1. Principal component analysis (PC1 and PC2) for seed reserve mobilization parameters and seed vigor groups.

Considering the results of the variables determined by PCA, PC1 showed that SRMR, URSR, and UESR are associated to the high-vigor group (BAF13, BAF42, BAF55, and BAF112), and SDW, 1000SW, and RDWC presented no positive association with this group. The results found in PCA reinforce that high-vigor seeds present higher SRM and reserve use efficiency capacity during seedling development. These parameters are important for studies related to SRM and for determinations of differences in vigor between seed lots and common bean cultivars.

CONCLUSIONS

High-vigor seeds present higher use rates of seed reserves, seed reserve mobilization, and use efficiency of seed reserves, favoring the development of seedlings with higher performances, longer lengths, and higher dry weight accumulations.

The mobilization rates and use rates of seed reserves can be used for control of internal seed quality and selection of common bean genotypes with high vigor potential.

Seeds with high dry weights have higher use of seed reserves and potential to develop seedlings with high dry weights.

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