INTERRELATIONSHIP OF COMPOUNDS OF SOYBEAN SEEDS PRODUCTION WITH MORPHOLOGIC AND CLIMATOLOGIC ATTRIBUTES

Ivan Ricardo Carvalho[1], José Antonio Gonzalez da Silva[1], Murilo Vieira Loro[1], Danieli Jacoboski Hutra[1], Jaqueline Piesanti Sangiovo[1], Marlon Vinicius da Rosa Sarturi[1], Christian Szambelam Zimmermann[1], Leonardo César Pradebon[1], Aline Danielle Novello da Silva[1]

ABSTRACT – The study was objective of evidencing the interrelationship between the morphological attributes, productivity, climatological and physiological components of soybean seeds. The experiment was conducted in the crop season of 2013/2014 in Santa Rosa-RS, Tenente Portela – RS, Campos Borges - RS and Sarandi – RS in Rio Grande do Sul, Brazil. The experimental design was a randomized complete blocks, with four cultivation environments x 20 soybean genotypes, arranged in three replicates. The analysis canonicals correlations were based in the establishment of the canonical groups with characters were reunid as physiological (Group I), morphological (Group II), yield components (Group III) and climatological (Group IV). Soybean seed yield is potentiated in plants with larger stature and reproductive units in the main stem. The physiological potential of the seeds is determined by the specific interrelationships of the maximum and minimum air temperature intrinsic to the growing environment. Reduced emphasis on assimilate allocation to the formation of lateral branching of soybeans results in more vigorous seeds.

Keywords: *Glycine max.* (L.), production of seeds, selection of traits of importance.

INTERRELAÇÕES DOS COMPONENTES DE PRODUTIVIDADE DE SEMENTES DA SOJA COM ATRIBUTOS MORFOLÓGICOS E CLIMATOLÓGICOS

RESUMO – O estudo teve como objetivo evidenciar a inter-relação entre os atributos morfológicos, produtividade, componentes climatológicos e fisiológicos das sementes da soja. O experimento foi conduzido na safra 2013/2014 em Santa Rosa - RS, Tenente Portela - RS, Campos Borges - RS e Sarandi - RS no Rio Grande do Sul, Brasil. O delineamento experimental foi em blocos casualizados, com quatro ambientes de cultivo x 20 genótipos de soja, dispostos em três repetições. As correlações canônicas das análises foram baseadas no estabelecimento dos grupos canônicos com caracteres reunidos em componentes fisiológicos (Grupo I), morfológicos (Grupo II), de rendimento (Grupo III) e climatológicos (Grupo IV). A produção de sementes da soja é potencializada em plantas com maior estatura e unidades reprodutivas no caule principal. O potencial fisiológico das sementes é determinado pelas inter-relações específicas das temperaturas máxima e mínima do ar intrínsecas ao ambiente de cultivo. A redução da ênfase na alocação de assimilados para a formação da ramificação lateral dos grãos da soja resulta em sementes mais vigorosas.

Palavras chave: Glycine max (L.), produção de sementes, seleção de caracteres de importância.

INTRODUCTION

The soybean (Glycine max. (L.) Merril) is a plant of the Fabaceae family and subfamily Faboideae (Judd et al. 2009), which has its origin center from the central and western regions of China, being one of the main food sources. It is fundamental for the human diet, mostly for people with lactose intolerance (Rigo, 2015), besides its large use in animal nutrition

In the 2020/2021 harvest, Brazil was the largest soybean producer with approximately 135.5 million tons

[1] Northwestern Regional University of the State of Rio Grande do Sul. R. do Comércio, 3000, CEP 98700-000 - Universitário, Ijuí - RS, Brazil. carvalho.irc@gmail.com; jose.gonz@gmail.com; muriloloro@gmail.com; dani_hutra@gmail.com; sarturi.marlon@gmail.com; zimmermann.chris@gmail.com; pradebon.cesar@gmail.com; aline_novello@gmail.com

of grain, in an area of 35.6 million hectares, distributed in several states (CONAB, 2021). In Rio Grande do Sul, the area surpassed 6 million hectares with production exceeding 20.2 million tons of grain (CONAB, 2021). This distribution exposes the culture to different growing environments with varied climatological characteristics (Leite et al. 2015), requiring a great effort of the breeders to obtain new genotypes adapted to the most different environmental conditions.

Yield gains are reflex of advances in genetic improvement and more productive varieties obtained for different environments, where the maximum effects of genotype x environment interactions are exploited (Kavalco et al., 2014; Carvalho et al., 2015). In this way, the morphological characteristics of soybean are dependent on climatological factors, on the management of the crop along its cycle and on the genetic characteristics of the genotype (Cruz et al., 2014), thus, it seeks out to understand the interrelationships among these attributes of agronomic interest. In this context, the canonical correlations allow to evaluate the dependency of intrinsic characters to morphologic, physiologic and climatologic groups that are related to compounds of seeds yield (Cruz et al., 2012).

The expression of characters is due to several related factors, and determined by the production, accumulation and partition of assimilates by the plant (Souza et al., 2015; Carvalho et al., 2017). According to Szareski et al. (2015), large fraction of the produced vegetable assimilates are directed to forming the main stem and branches of soybeans, as well as increasing the plant height (Almeida, 2011; Nardino et al., 2015). Plant formation, for high yields, is dependent on productivity components reconciled with morphological attributes associated with environmental conditions (Farias et al., 2007; Setiyomo et al., 2007; Zanon et al., 2016). Thus, this work had the objective of evidencing the interrelationship between the morphological attributes, productivity, climatological and physiological components of soybean seeds.

MATERIAL AND METHODS

The experiment was conducted in the crop season of 2013/2014 in the municipalities of Santa Rosa-RS with latitude of 27°52' S, longitude 54°28' W and altitude of 268 m, Tenente Portela – RS with latitude of 27°22' S, longitude 53°45' W and altitude of 420 m, Campos Borges - RS with latitude of 28°55' S, longitude 53°01' W and altitude of 513 m and Sarandi - RS with latitude of 27°55' S, longitude 53°05' W and altitude of 408 m , being these representative of the main micro-regions producer of soybean of Rio Grande do Sul, Brazil. The climate of the regions studied, according to Köppen, is classified as subtropical *Cfa.*

The experimental design was a randomized complete randomized blocks, with four cultivation environments x 20 soybean genotypes, arranged in three replicates. The genotypes used were: BRS Tordilha RR, FPS Paranapanema RR, Fepagro 37 RR, FPS Solimões RR, Fepagro RR, FPS Netuno RR, FPS Iguaçu RR, FPS Urano RR, FPS Jupiter RR, AMS Tibagi RR, Don Mario 7.0 i RR, A 6411 RR, Don Mario 5.8i RR, BMX Potência RR, Don Mario 5.9i RR, ROOS Camino RR, BMX Ativa RR, NA 5909 RR, BMX Turbo RR and TMG 7161 RR.

The experimental units were comprised of four rows of five meters long and spaced 0.5 meters. Sowing was performed manually in the second half of November 2013, the density of plants was 300 thousand plants per hectare. The base fertilization was performed with N - P - K (02-20-20) at the time of sowing with 300 kg ha^{-1}. The plant management was realized in a preventive way in all production environments. For the measurement of agronomic interest characters, 10 random plants were collected in the central lines of each experimental unit, 0.5 meters of each end being scraped for border effect. The harvest was done manually in the first half of April 2014.

The characters were measured following the methodologies used by Szareski et al. (2015) and Frari et al. (2016), these being: plant height (PH cm), first pod height (FPH cm), number of pods in the main stem (NPMS, units), number of pods in the branches (NPB, units), number of reproductive nodes in the main stem (NRNMS, units), number of reproductive nodes in the branches (NRNB, units), number of branches (NB, units), length of branches (LB, cm), number of pod with one seed (NP1S, units), two seeds (NP2S), three seeds (NP3S), four seeds (NL4S) and mass of seeds per plant (MSP, g). The physiologic parameters evaluated were: first germination counting (FGC, percentage), germination (G, percentage), seedling dry mass (SDM, g), shoot length (SL, cm), radicle length (RL, cm) and emergence in field (EF, percentage). The climatology information were based in air maximum temperature (Tmax, Cº) and minimum temperature (Tmin, Cº), relative air humidity (UR, %), solar radiation (RAD, cal cm^{-1} day) and rainfall (RAIN, mm).

The data obtained were submitted to variance analysis where the assumptions of the model were verified, diagnosis of residue normality (Shapiro - Wilk, 1965) and homogeneity of residual variance (Steel et al. 1997). After the canonical correlations were realized to groups of characters previously defined and weighted by the significance of the maximum likelihood ratio (LRT) (Cruz & Regazzi, 1997; Resende & Duarte., 2007; Merchant et al., 2010; Carvalho et al., 2018). In the establishment of the canonical groups the characters were agglomerated as physiological (Group I: FGC, G, SDM, RL, SL and EF), morphological (Group II: PH, HFP, NPMS, NPB, NRNMS, NRNN, NB and LB), yield components (Group III: NP1S, NP2S, NP3S NP4S and MSP) and climatological (Group IV: TMAX, TMIN, UR, RAIN and RAD).

It was established a prediction model based on the *Stepwise* multiple regression in which the considered statistical model was: $\hat{Y} = A+B+C+D+n$. Where, $\hat{Y}$ were considered the dependent characters EF and MSP, the incidence matrix A represents the point of the data source, the matrices of incidence B, C and D represent the multivariate angular coefficients related to the climatological attributes TMAX, TMIN, UR, RAD, RAIN and PH, HFP, NPMS, NPB, NRNMS, NRNN, NB and LB explanatory, respectively.

RESULTS AND DISCUSSION

All the studied characters presented variability and the matrix genotypes x environments was considered together, with the purpose of consolidating the trends in a representative way. The estimates of the coefficients and canonical pairs referring to the morphological (Group II) and physiological (Group I) characteristics of the seeds (Table 1), showed significance with inter-class association of r=0.45. Because, higher SDM, EF and FGC were determined duet to plants with higher FPH, PH, NB and LB. Plants with better development and favorable climatic conditions tend to potentiate the physiological quality of the produced seeds (Marcos-Filho, 2013).

Soybean plants with superiority of NPB, NRNB, NPMS and NRNMS potentiate the production of more seeds. By enhancing the magnitude of reproductive structures in soybean (Table 1), there was partitioning of assimilates produced in greater number of drains or reproductive structures, resulting in decreases in deposition reserves in soybean seeds.

Seedlings with lower SL, RL and G were obtained from seeds formed in plants of lower FPH and PH, inferior magnitude of NB and LB. Plants with lower vegetative development direct their assimilates to the formation of vigorous reproductive structures and seeds (Marcos-Filho,2013). The canonical interrelationships for the components of productivity (Group III) and physiological (Group I) reveal (Table 2) significance for the four canonical pairs, with inter-class correlations of r = 0.59, r = 0.30, r = 0.29 and r = 0.26, respectively.

Table 1 - Estimates of correlations and canonical pairs between physiological characters (Group I) and morphological characters (Group II) in twenty soybean genotypes grown in four environments

Characters	Canonical pair 1
Group I	
FGC [(1)]	0.0402
G	-0.0078
SDM	0.4369
SL	-0.2218
RL	-0.0353
EF	0.0566
Group II	
HFP	0.3271
PH	0.2252
NPMS	-0.0959
NPB	-0.2821
NRNMS	-0.0500
NRNB	-0.2691
NB	0.1017
LB	0.0508
R	0.4540
P	<0.0001

r = canonical correlation.

p = significance.

[1] FGC = first germination counting; G = germination; SDM = seedling dry mass; SL = shoot length; RL = radicle length; EF = emergence in field; HFP = height of insertion of the first pod; PH = plant height; NPMS = number of pods on the main stem; NPB = number of pods in the branches; NRNMS = number of reproductive nodes in the main stem; NRNB = number of reproductive nodes in the branches; NB = number of branches; LB = branches length.

Table 2 - Estimates of canonical correlations and pairs between physiological characters (Group I) and yield components (Group III) in twenty soybean genotypes grown in four environments

Characters	Canonical pair			
	1	2	3 °	4 °
Group I				
FGC [1]	0.285 0	0.1126	-0.0232	0.1832
G	0.1971	0.0357	0.0644	0.2355
SDM	0.5293	-0.078 0	0.0595	-0.0593
SL	-0.2085	0.0044	-0.034 0	0.1816
RL	-0.1755	0.0583	0.2378	-0.02 00
EF	0.0393	-0.1756	-0.028 0	0.1237
Group III				
NP1S	0.0281	0.0671	0.1403	-0.0182
NP2S	-0.1562	0.0301	0.122 0	0.1836
NP3S	-0.184 0	0.2559	-0.0996	0.0668
NP4S	0.0613	0.0626	-0.2643	0.0669
MSP	0.4585	0.1184	0.0709	0.1036
R	0.5981	0.30219	0.2928	0.2606
P	<0.0001	<0.0001	<0.0001	0.0044

r = canonical correlation.

p = significance.

[1] FGC = first germination counting; G = germination; SDM = seedling dry mass; SL = shoot length; RL = radicle length; EF = emergence in field; NP1S = number of pods with one seed; NP2S = number of pods with two seeds; NP3S = number of pods with three seeds; NP4S = number of pods with four seeds and MSP = mass of seeds per plant.

The superiority of MSP, NP1S and NP4S produced seeds that allowed generate seedlings with larger SDM, on the other hand, inferior dimensions of both SL and RL. The second, third and fourth canonical pairs defined that plants with larger number of pods with one, two, three and four seeds per pod (NP1S, NP2S, NP3S and NP4S) and lower MSP potentiated the FGC, G and FE. Studies indicate that more productive plants, under favorable environmental conditions, result in seeds of higher physiologic potential (Marcos-Filho, 2013).

The canonical associations between the climatic (Group IV) and the physiological attributes of the soybean seeds (Group I) indicate (Table 3) significance for the three canonical pairs, with inter-class relations of r = 1.00, r = 0.52 and r = 0.41, respectively. Higher air Tmax and Tmin, UR and RAIN may presente disadvantages for DM accumulation of seedlings originated from the produced seeds. Seedlings with greater SL and FE were obtained in seeds produced under lower maximum and minimum air temperatures, that is, lower thermal amplitude.

Table 3 - Estimates of correlations and canonical pairs between physiological characters (Group I) and climatological characters (Group IV) in twenty soybean genotypes grown in four environments

Characters	Canonical pair		
	1	2	3 °
Group I			
FGC [1]	-0.0238	0.1325	-0.3485
G	-0.0041	-0.0169	-0.3539
SDM	-0.1402	-0.3642	0.0206
SL	0.1116	0.3115	-0.0493
EF	-0.0079	0.2632	-0.063 0
Group IV			
TMAX	0.9383	-0.1156	-0.0852
TMIN	0.9451	-0.1353	-0.0593
UR	0.8232	0.2148	0.0174
RAD	0.0000	0.0000	0.0000
RAIN	0.8304	-0.0805	0.093 0
R	1	0.5285	0.4185
P	<0.0001	<0.0001	<0.0001

r = canonical correlation.

p = significance.

[1] FGC = first germination counting; G = germination; SDM = seedling dry mass; SL = shoot length; EF = emergence in field; T_MAX = maximum temperature; T_MIN = minimum temperature; UR = relative humidity; RAD = radiation; RAIN = rainfall.

The canonical relations between climatic attributes (Group IV) and morphological (Group II) revealed significance (Table 4) for both canonical pairs, with correlation coefficient of r= 0.45 and r= 0.40, respectively. The first canonical pair evidenced that higher NR is favored by lower air Tmin and larger air Tmax, as well as environments with lower RAIN and RAD. This plasticity is unfavorable for the magnitude of NPMS and NRNMS of soybean plants.

The second canonical pair showed that the increase in dimensions of the branches of soybean was favored by higher incidence of Tmax and Tmin, UR, RAD and RAIN. Air temperatures, solar radiation and favorable precipitation result in greater LB and NRNB.

Table 4 - Estimates of correlations and canonical pairs between morphological characters (Group II) and climatological characters (Group IV) in twenty soybean genotypes grown in four environments

Characters	Canonical pair 1	Canonical pair 2
Group II		
HFP [(1)]	0.0902	-0.1176
PH	-0.1215	0.0396
NPMS	-0.3086	0.115 0
NPB	0.0329	0.1771
NRNMS	-0.2164	0.0455
NRNB	0.093 0	0.2161
NB	0.2993	-0.1484
LB	0.2146	0.3019
Group IV		
TMAX	-0.2334	0.0593
TMIN	-0.2195	0.0311
UR	0.0371	0.183 0
RAD	-0.1225	0.0759
RAIN	-0.0654	0.1029
R	0.4591	0.4024
P	<0.0001	0.0007

r = canonical correlation.

p = significance.

[1] HFP = height of insertion of the first pod; PH = plant height; NPMS = number of pods on the main stem; NPB = number of pods in the branches; NRNMS = number of reproductive nodes in the main stem; NRNB = number of reproductive nodes in the branches; NB = number of branches; LB = length of branches; T_MAX = maximum temperature; T_MIN = minimum temperature; UR = relative humidity; RAD = radiation; RAIN = rainfall.

Given the canonical correlations between the morphological attributes (Group II) and productivity components (Group III), it is evident that (Table 5) there was significance for the three canonical pairs with coefficients of r = 0.89, r = 0.36 and r = 12.46, respectively. The first canonical pair determines that the number of pulses with one, two and three seeds (SNB1, NB2S and NB3S) were derived from plants with increased PH, NPMS, NRMS, NRNB and LB. Superior soybean yield can be obtained by maximizing the number of plants and seeds per plant (Souza et al. 2013).

Table 5 - Estimates of canonical correlations and pairs between yield components (Group III) and morphological characters (Group II) in twenty soybean genotypes grown in four environments

Characters	Canonical pair 1	Canonical pair 2	Canonical pair 3 °
Group III			
NP1S [(1)]	0.5 000	-0.1974	0.0499
NP2S	0.688 0	-0.2165	0.1307
NP3S	0.6165	0.2705	-0.0952
NP4S	0.2356	0.2765	-0.1425
MSP	0.0944	0.2449	0.3044
Group II			
HFP	-0.1982	0.2048	0.1055
PH	0.0161	0.3083	0.1533
NPMS	0.5177	0.0359	0.1812
NPB	0.7122	-0.1546	-0.0178
NRNMS	0.4671	0.2479	-0.0161
NRNB	0.701 0	-0.0956	-0.0912
NB	-0.1107	-0.0664	-0.0599
LB	0.3708	0.1845	-0.1458
R	0.8910	0.4668	0.3644
P	<0.0001	<0.0001	0.0028

r = canonical correlation.

p = significance.

[1] NP1S = number of pods with one seed; NP2S = number of pods with two seeds; NP3S = number of pods with three seeds; NP4S = number of pods with four seeds and MSP = mass of seeds per plant; HFP = height of insertion of the first pod; PH = plant height; NPMS = number of pods on the main stem; NPB = number of pods in the branches; NRNMS = number of reproductive nodes in the main stem; NRNB = number of reproductive nodes in the branches; NB = number of branches; LB = length of branches.

For the second canonical pair, the plants with the lowest NPB, NB and NRNB favors the number of pods containing four seeds. The third canonical pair showed that the increment of the MSP was due to plants with higher

FPH, PH and NPMS, in counterpart (Table 5), lower NB, LB, NPB and NRNB. For Souza et al. (2013), plants with high performance potentiate the magnitude of seeds and consequently, yield.

Canonic estimates between the climatological attributes (Group IV) and yield components (Group III) determined (Table 6) significance for three canonical pairs, with coefficients r= 0.52, r= 0.44 and r= 0.34 inter-groups. The first and second canonical pair demonstrate that Tmax and Tmin, RAIN and RAD when lower, can favor the formation of pods with three and four seeds. The third canonical pair evidence that the increase in Tmax and Tmin, UR, RAD and PREC favors the production of pods with two seeds.

Table 6 - Estimates of canonical correlations and pairs between yield components (Group II I) and climatological characteristics (Group IV) in twenty soybean genotypes grown in four environments

Group III			
Characters	Canonical pair		
	1	2	3 °
NP1S [1]	-0.2149	-0.0132	0.0875
NP2S	-0.0764	0.2029	0.1831
NP3S	0.1356	0.3463	0.089 0
NP4S	0.2555	0.2699	-0.2038
MSP	-0.4174	0.2275	-0.0748
Group IV			
TMAX	-0.1787	-0.034 0	0.2313
TMIN	-0.1795	-0.0704	0.234 0
UR	0.1918	0.0042	0.2097
RAD	-0.0499	-0.0664	0.293 0
RAIN	-0.0425	-0.0948	0.1694
R	0.5242	0.4489	0.3472
P	<0.0001	<0.0001	0.0002

r = canonical correlation.

p = significance.

[1] NP1S = number of pods with one seed; NP2S = number of pods with two seeds; NP3S = number of pods with three seeds; NP4S = number of pods with four seeds and MSP = mass of seeds per plant; T_MAX = maximum temperature; T_MIN = minimum temperature; UR = relative humidity; RAD = radiation; RAIN = rainfall.

The construction of the multivariate predictor model has the purpose of presenting which explanatory characteristics are decisive for the emergence in field and seed mass per plant. Through the field emergence, it was possible (Table 7) to establish that favorable climatic conditions, for the intensification of this dependent character, occurs when environments with higher thermal amplitudes are obtained (increase of Tmax and reduction of Tmin, as well as increase of relative humidity). The morphological features and productivity components that enhance field emergence are disclosed by plants with increased LB and NP2S, in contrast, smaller emphases of NP1S and NP3S. The MSP was favored by increase of the thermal amplitude and smaller effects of the radiation incident on the canopy. The morphological components that increase the seed mass per plant were emphasized by increasing the HFP, PH, NPMS, in contrast, smaller expressions of the magnitude of NB.

Table 7 - Predictive model based on multiple linear regression for emergence field and seed mass characteristics per plant in twenty soybean genotypes grown in four environments

Characters	Dependent characters for physiological, morphological, climatological and performance aspects	
EF	Climatological	EF = - 12.15872 + 9.08557 (TMAX) - 10.06981 (TMIN) + 0.52823 (UR)
	Yield	EF = 26.07404 + 0.14625 (CR) - 0.90917 (NP1S) + 0.23758 (NP2S) - 0.38772 (NP3S)
MSP	Climatological	MSP = 5.92785 + 2.76929 (TMAX) - 2.36071 (TMIN) - 0.17727 (UR)
	Morphological	MSP = 1.73908 + 0.04031 (FPH) + 0.01782 (PH) + 0.03627 (NPMS) - 0.02291 (NB)

* significant at 5% by *t*-test.

EF = emergence in field; MSP = mass of seed per plant; LB = length of branches; NP1S = number of pods with one seed; NP2S = number of pods with two seeds; NP3S = number of pods with three seeds; T_MAX = maximum temperature; T_MIN = minimum temperature; UR = relative humidity; FPH = insertion of the first pod; PH = plant height; NPMS = number of pods on main stem; NB = number of branches.

CONCLUSIONS

Soybean seed yield is potentiated in plants with larger stature and reproductive units in the main stem.

The physiological potential of the seeds is determined by the specific interrelationships of the maximum and minimum air temperature intrinsic to the growing environment.

Reduced emphasis on assimilate allocation to the formation of lateral branching of soybeans results in more vigorous seeds.

LITERATURE CITED

ALMEIDA, R.D.A.; PELUZIO, J.M.; AFÉRRI, F.S. Divergência genética entre cultivares de soja, sob condições de várzea irrigada, no sul do Estado do Tocantins. *Revista Ciência Agronômica,* v.42, p.108-115. 2011. DOI: https://doi.org/10.1590/S1806-66902011000100014

CARVALHO, I.R.; SOUZA, V.Q.; NARDINO, M.; FOLLMANN, D.N.; DEMARI, G.; SCHMIDT, D.; SZARESKI, V.J.; PELEGRIN, A.J.; FERRARI, M.: PAVAN, M.; OLIVOTO, T. Efeitos de fungicidas na soja com hábito de crescimento determinado. *Revista SODEBRAS*, v.10, p.30-34, 2015.

CARVALHO, I.R.; NARDINO, M.; SOUZA, V.Q. *Melhoramento e cultivo da soja*, 1. Porto Alegre: Cidadela, 2017. 288p. ISBN: 9788579783074

CARVALHO, I.R.; SZARESKI, V.J.; DEMARI, G.H.; BARBOSA, M.H.; CONTE, G.G.; LIMA, L.F.S.; MARTINS, T.S.; ULIANA, A.S.; PADILHA, M.T.; SOUZA, V.Q.; AUMONDE, T.Z.; VILLELA, F.A.; PEDO, T. Artificial Neural Network and Multivariate Models Applied to Morphological Traits and Seeds of Common Beans Genotypes. *Journal of Agricultural Science*, v.10, p.572, 2018. DOI: 10.5539/jas.v10n11p572

CONAB - Companhia Nacional De Abastecimento - Acompanhamento da safra brasileira de grãos. V.8, safra 2020/2021, n.7, sétimo levantamento, 2021.

CRUZ, C.D.; REGAZZI, A. *Modelos biométricos aplicados ao melhoramento genético*. 2.ed. Viçosa: UFV, 1997. 390p.

CRUZ, C.D.; REGAZZI, A.J.; CARNEIRO, P.C.S. *Modelos biométricos aplicados ao melhoramento genético*. 4.ed. Viçosa: Editora UFV, 2012. 514p.

CRUZ, C.D.; CARNEIRO, P.C.S.; REGAZZI, A.J. *Modelos biométricos aplicados ao melhoramento de plantas*, v.2, 3.ed. Viçosa: Ed. UFV, 2014. ISBN: 8572691510

FARIAS, J.R.B.; NEPOMUCENO, A.L.; NEUMAIER, N. *Ecofisiologia da soja*. Londrina: Embrapa Soja (Circular Técnica, 48), 2007. 9p.

FERRARI, M.; PELEGRIN, A.J.; NARDINO, M.; CARVALHO, I.R.; SZARESKI, V.J.; OLIVOTO, T.; BELLE, R.; OLIVEIRA, A.C.; MAIA, L.C.; SOUZA, V.Q. Evaluation of soybeans genotypes in field environments of Rio Grande do Sul state, Brazil. *International Journal of Current Research,* v.8, p.38383-38392, 2016.

JUDD, W.S.; CAMPBELL, C.S.; KELLOGG, E.A.; DONOGHUE, M.J. *Sistemática vegetal, um enfoque filogenético*. 3.ed. Porto Alegre: Artmed, 2009. 632p.

KAVALCO, S.A.F.; SOUZA, V.Q.; FOLLMANN, D.N.; CARVALHO, I.R.; NARDINO, M.; DEMARI, G. Desenvolvimento da soja com aplicações de hormônios em diferentes densidades de cultivo. *Revista Brasileira de Agropecuária Sustentável (RBAS)*, v.4, p.112-116, 2014. DOI: 10.21206/rbas.v4i2.265

LEITE, W.D.S.; PAVAN, C.H.A.; MATOS FILHO, F.S.; FEITOSA, C.B.; DE OLIVEIRA. Estimativas de parâmetros genéticos e correlações entre caracteres agronômicos em genótipos de soja. *Nativa*, v.3, n.4, p.241-245, 2015. DOI: 10.14583/2318-7670.v03n04a03

MARCOS-FILHO, J. Importância do potencial fisiológico da semente de soja. *Informativo Abrates*, v.23, p.21-24, 2013. https://www.esalq.usp.br/visaoagricola/sites/default/files/va05-sementes01.pdf

MERCANTE, E.; LAMPARELLI, R.A.C.; URIBE-OPAZO, M.A.; ROCHA, J.V. Modelos de regressão lineares para estimativa de produtividade da soja no oeste do paraná, utilizando dados espectrais. *Engenharia Agrícola*, Jaboticabal, v.30, n.3, p.504-517, 2010. https://doi.org/10.1590/S0100-69162010000300014

NARDINO, M.; SOUZA, V.Q.; BUSANELLO, C.; BAHRY, C.A.; CARON, B.O.; ZIMMER, P.D.; SCHMIDT, D. Desfolha artificial em estádios vegetativos e suas implicações a cultura da soja. *Revista Magistra,* v.27, p.209-217, 2015. ISSN 2236 - 4420

RESENDE, M.D.V.; DUARTE, J.B. Precisão e controle de qualidade em experimentos de avaliação de cultivares. *Pesquisa Agropecuária Tropical*, v.37, n.3, p.182-194, 2007.

RIGO, A.A. *Obtenção e caracterização de farinhas de soja das cultivares BRS 267, BRS 257 e VMAX*. Erechim: Universidade Regional Integrada do Alto Uruguai e das Missões, 89p. Dissertação Mestrado, 2015.

SETIYONO, T.D.; WEISS, A.; SPECHT, J.; BASTIDAS, A.M.; CASSMAN, K.G.; DOBERMANN, A. Understanding and modeling the effect of temperature and daylenght on soybean phenology under high-yield conditions. *Field Crops Research*, v.100, p.257-271, 2007. DOI: https://doi.org/10.1016/j.fcr.2006.07.011

SHAPIRO, S.S.; WILK, M.B. An Analysis of variance test for normality (complete samples). *Biometrika*. v.52, n.3, p.1-25, 1965. DOI: https://doi.org/10.2307/2333709

SOUZA, C.A.; FIGUEIREDO, B.P.; COELHO, C.M.M.; CASA, R.T.; SANGOI, L. Arquitetura de plantas e produtividade da soja decorrente do uso de redutores de crescimento. Plant architecture and productivity of soybean affected by plant growth retardants. *Bioscience Journal,* Uberlândia, v.29, n.3, 2013.

SOUZA, V.Q.; BELLÉ, R.; FERRARI, M.; PELEGRIN, A.J.; CARON, B.O.; NARDINO, M.; FOLLMANN, D.N.; CARVALHO, I.R. Componentes de Rendimento em Combinações de Fungicidas e Inseticidas e Análise de Trilha em Soja. *Global Science and Technology*, v.8, p.167-176, 2015. DOI: 10.14688/1984-3801/gst.v8n1p167-176

STEEL, R.G.D.; TORRIE, J.H.; DICKEY, D.A. *Principles and procedures of statistics: a biometrical approach*. 3.ed. New York: McGraw Hill Book, 1997. 666p.

SZARESKI, V.J.; SOUZA, V.Q.; CARVALHO, I.R.; NARDINO, M.; FOLLMANN, D. M.; DEMARI, G.H.; FERRARI, M.; OLIVOTO, T. Ambiente de cultivo e seus efeitos aos caracteres morfológicos e bromatológicos da soja. *Revista Brasileira de Agropecuária Sustentável (RBAS),* v.5, p.79/2-88, 2015. DOI: DOI: 10.21206/rbas.v5i2.247

ZANON, A.J.; STRECK, N.A.; GRASSINI, P. Climate and management factors influence soybean yield potential in a subtropical enviroment. *Agronomy Journal,* v.108, p.1447-1454, 2016. DOI: https://doi.org/10.2134/agronj2015.0535

Recebido para publicação em 05/03/2021, aprovado em 11/05/2021 e publicado em 13/05/2021.