ASSESSMENT OF YIELD WITH ALTERED SOYBEAN TRAITS FOR DROUGHT TOLERANCE IN SOUTHERN BRAZIL

BATTISTI, R.[1]; SENTELHAS, P.C.[1]; BOOTE, K.J.[2]; CÂMARA, G.M. de S.[3]; FARIAS, J.R.B.; BASSO, C.J. [1]Department of Biosystems Engineering, USP – ESALQ, Piracicaba, SP, Brazil, r.battisti@hotmail.com; [2]University of Florida; [3]USP – ESALQ; [4]EMBRAPA Soja; [4]UFSM - CESNORS.

Brazil is one the most important soybean producers in the world, representing more than 25% of the soybean market in 2011. In southern Brazil, five states produce around 35 million tons, representing nearly 47% of Brazilian soybean production in 2011 (IBGE, 2013). Crop yield is highly dependent on environmental conditions, being mainly influenced by weather conditions throughout the growing season, especially for rainfed crops. In Brazil, soybean yield gaps are caused mainly by droughts (SENTELHAS et al., 2015).

Crop mitigation can be made by adapting the crop to the environment, adjusting its morphological and physiological characteristics. Genetic variability enables one to identify cultivars with different growth characteristics, which can be used to adapt to adverse climate conditions, such as early reduction of transpiration under mild stress (conservation) (ERT) (SINCLAIR et al., 2008), modified root depth distribution with better soil management (RDD) (BORTOLUZZI et al., 2014) and N_2 fixation drought tolerance (NFI) (SINCLAIR et al., 2007).

Much time is required between identifying a valued trait in a soybean breeding program and applying it in a new cultivar; and in some cases, the traits selected may not show good results under highly variable field conditions. One alternative is to test the traits through crop models to evaluate how these traits can affect yield for specific regions/soils, using historical climatic series, and selected soybean traits based on a probabilistic level applicable to a given region. Following these strategies, the hypothesis of this study is that selection of soybean traits specific to stress conditions can help to improve soybean yield and to develop cultivars for southern Brazil.

The soybean model used was CSM CROPGRO Soybean, present in the software Decision Support System for Agrotechnology Transfer (DSSAT) (JONES et al., 2003). The crop model was calibrated using data of crop development and growth from three sites in southern Brazil, being Frederico Westphalen (RS), Londrina (PR), and Piracicaba (SP). Cultivar BRS 284 was used at all sites, grown under rainfed and irrigated conditions (except for Frederico Westphalen), during 2013/2014 crop season (BATTISTI et al., 2014).

ERT was simulated by penalizing the potential transpiration (EOP) and photosynthesis (P) as a function of the following equation: EP1 = Min (EOP; ((1.0-Exp (-1.527*TRWU/EOP)*EOP), where EP1 is the new potential transpiration, TRWU is the total root water uptake and EOP is the original potential transpiration (after ET equation and partitioning to transpiration, EOP). P was penalized at the same magnitude and way as EOP (Figure 1a). RDD was simulated changing soil root growth factor (SRGF) from the original value obtained from calibration, creating a new root distribution profile with more root length at depth (Figure 1b). NFI was simulated changing the parameter FNFXD (relative effect of plant water deficit on N-fixation), using two values, being 1.0 (drought tolerance in N_2 fixation lower than photosynthesis) and 0.67 (same drought tolerance in N_2 fixation than in photosynthesis) (Figure 1c).

The simulation was made for the eight sites in southern Brazil: Bagé, São Luiz Gonzaga, Cruz Alta and Passo Fundo in the state of Rio Grande do Sul, Londrina, Cascavel and Ponta Grossa in the state of Paraná and Dourados, in the state of Mato Grosso do Sul. In these locations, yields were simulated with new versus original values using 15 Nov as sowing date for the weather from 1961 to 2014, totaling 53 crop seasons. Soils used in the simulations were those occurring in the region. The results were evaluated through difference in yield from original and new trait, computing the number of crop seasons with positive and negative results.

ERT had the largest difference from original traits, when compared with RDD and NFI. Most of crop seasons showed a negative effect, reducing yield at most of the locations (Figure 2a and 3a), except for Bagé, which showed positive results in 60% of crop seasons, with yield increase of 48% for the percentile of 25% (Table 1). Dourados and Ponta Grossa showed an average yield gain of 1.44 and 1.13% in the percentile of 25%, while other locations showed negative result (Table 1). This trait showed a negative effect for most locations and crop seasons, but had advantages only when water deficit was high and sustained as at Bagé site with lower soil water storage and low rainfall. Under these conditions, the crop saved water from the beginning of cycle to use during reproductive growth.

When RDD was changed toward deeper rooting, most of crop seasons had a positive result (Figure 3b), with a yield gain reaching 200 kg ha^{-1} (Figure 2b), especially for the lower yielding sites, which can be verified by yield increase for the percentile 25% and 50% (Table 1). There were only a few cases of minor yield losses, thus making RDD an interesting trait to improve yield. Bagé showed an inverse result compared to the other sites (Figure 1b), which can be associated with lower root density in the first soil layer, which diminish water uptake from lower rainfall patterns and reduce nitrogen uptake in the first layer, where organic matter is present on higher concentration.

NFI showed most of crop seasons with positive or neutral results (Figure 3c), which is associated with improved nitrogen fixation under water stress. A few cases of negative values are present, but with small yield reductions, which is associated with minor interactions in the model between total grain mass and nitrogen concentration in the seed. This trait had yield gain with differences ranging along sites, but with yield increase reaching 300 kg ha^{-1}. Bagé and Ponta Grossa had a higher increase with better nitrogen fixation under water deficit, while Cruz Alta and S. L. Gonzaga had lower response (Figure 2c).

These crop simulations showed an interaction between traits and environment (climate and soil), showing that ERT did not have advantage in most of locations, except under high water deficit, while RDD and NFI, although having small yield benefits, had consistent advantages for yield increase. So, this type of study with other additional traits can help to define guidelines for breeding programs, aiming to improve soybean yield in distinct environmental conditions.

References

BATTISTI, R.; SENTELHAS, P. C.; BOOTE, K. J. Assessment of yield with altered soybean traits under climate change in Southern Brazil: Performance of the crop model and genotype trait. In: AGU Fall Meeting, San Francisco, CA, USA, 2014.

BORTOLUZZI, E.C.; PARIZE, G.L.; KORCHAGIN, J.; SILVA, V.R. da; RHEINHEIMER, D. dos S.; KAMINSKI, J. Soybean root growth and crop yield in response to liming at the beginning of a no-tillage system. **Revista Brasileira de Ciência do Solo**, v. 36, p. 262-271, 2014.

IBGE. (2013). Produção Agrícola Municipal. Source: http://www.sidra.ibge.gov.br.

JONES, J. W.; HOOGENBOOM, G.; PORTER, C.H.; BOOTE, K.J.; BATCHELOR, W.D.; HUNT, L.A.; WILKENS, P.W.; SINGH, U.; GIJSMAN, A.J.; RITCHIE, J.T. The DSSAT cropping system model. **European Journal Agronomy,** v.18, p.234-265, 2003.

SENTELHAS, P.C.; BATTISTI, R.**;** CÂMARA, G.M.S.; FARIAS, J.R.B.; HAMPF, A.; NENDEL, C. The Soybean Yield Gap in Brazil - Magnitude, Causes and Possible Solutions for a Sustainable Production. **Journal of Agriculture Science**, Online First View, 18 p. 2015.

SINCLAIR, T.R.; PURCELL, L.C.; KING, C.A.; SNELLER, C.H.; CHEN, P.; VADEZ, V. Drought tolerance and yield increase of soybean resulting from improved symbiotic N2 fixation. **Field Crops Research**, v.101, p.68–71, 2007.

SINCLAIR, T.R.; ZWIENIECKI, M.A.; HOLBROOK, N.M. Low leaf hydraulic conductance associated with drought tolerance in soybean. **Physiology Plant**, v. 132, p. 446–451, 2008.

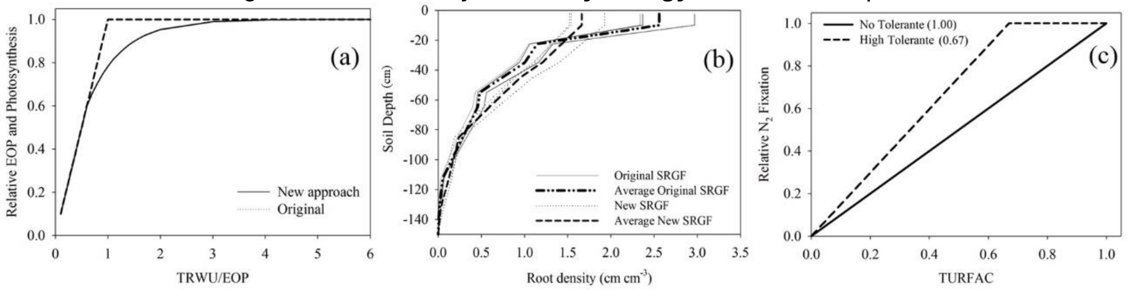

Figure 1. Original and new coefficients used to simulate early reduction of transpiration under mild stress (ERT, a), deeper root depth distribution (RDD, b) and greater N_2 fixation drought tolerance (NFI, c). EOP is the potential transpiration, TRWU is the total root water uptake, SRGF is the soil root growth factor and TURFAC is the turgor-based water stress index.

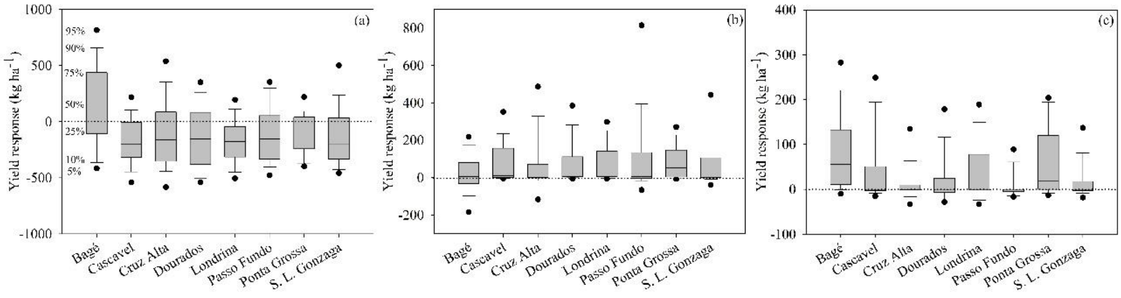

Figure 2. Yield response for the percentile 5, 10, 25, 50, 75, 90 and 95% using the new coefficients for the early reduction of transpiration under mild stress (ERT, a), deeper root depth distribution (RDD, b) and greater N_2 fixation drought tolerance (NFI, c) for eight sites in southern Brazil.

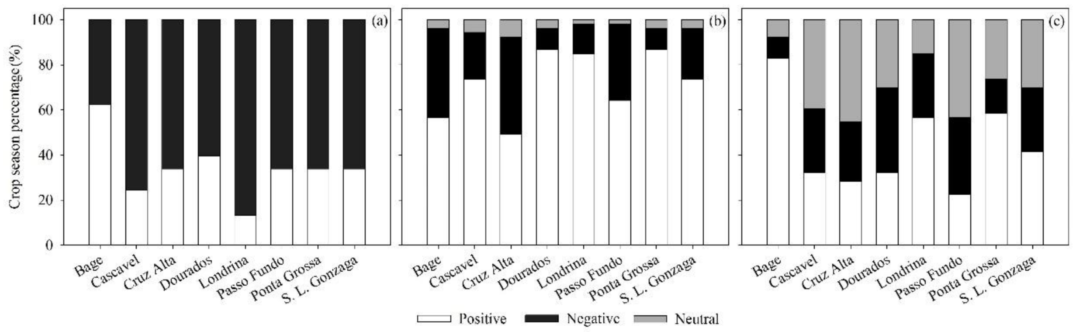

Figure 3. Percent distribution of positive, negative and neutral results for 53 crop seasons for soybean when using the new coefficients in the simulations for the early reduction of transpiration under mild stress (ERT, a), deeper root depth distribution (RDD, b) and greater N_2 fixation drought tolerance (NFI, c) for eight sites in southern Brazil.

Table 1. Percent yield response in the percentile distribution (25, 50 and 75%) for early reduction of transpiration under mild stress (ERT), deeper root depth distribution (RDD) and greater N_2 fixation drought tolerance (NFI) for eight sites in southern Brazil.

Sites	ERT			RDD			NFI		
	25	50	75	25	50	75	25	50	75
Bagé	48.37	9.65	-5.46	-5.58	-0.42	2.28	5.02	7.89	3.70
Cascavel	-7.59	-5.72	-4.54	1.37	2.53	0.79	1.42	0.71	0.77
Cruz Alta	-6.67	-6.05	-4.05	8.45	0.66	0.46	-0.08	0.00	0.00
Dourados	1.44	-7.34	-4.95	0.66	1.57	0.37	5.23	-0.17	0.05
Londrina	-5.13	-6.86	-7.53	6.34	1.14	0.60	4.03	1.09	0.58
Passo Fundo	-2.01	-4.73	-6.15	4.82	2.70	0.63	-0.36	0.59	0.16
Ponta Grossa	1.13	-6.78	-2.80	7.36	2.40	0.08	2.17	2.01	0.20
S. L. Gonzaga	-9.04	-5.37	-5.77	3.05	1.74	1.20	-0.06	0.00	0.00