Soybean Research for Sustainable Development

WSRC 11

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Abstracts

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18-23 June 2023, Vienna, Austria

Johann Vollmann · Marjana Vasiljević · Leopold Rittler · Jegor Miladinović · Donal Murphy-Bokern

Editors

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High-throughput phenotyping for temporal screening of soybean canopy cover and height assessed in different environments

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The combined power of remote sensing and photogrammetry can be used to assess significant information about plant development. The canopy cover (CC) and height (HT) are important for defining the growth patterns of the plants and their reaction to different environmental conditions. The objective of this study was to utilize the technology of high-throughput phenotyping (HTPP) for the temporal screening of soybean CC and HT. The trial was set in 2020 and 2021 at the experimental fields of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. In total, 206 soybean genotypes divided into early (ED) and late (LD) were grown in drought simulation environments. As a control, the same set of genotypes (EC and LC) was grown in favorable conditions. The CC and HT were determined from the images collected with the unmanned aerial vehicle (UAV). In both years, the photos were taken four times at approximately 274, 390, 706, and 917 growing degree days (GDDs) after emergence. The results showed that the genotypes grown in drought simulation environments had lower CC compared to the control in both years. This was especially pronounced at 274 and 390 GDDs. In these time points, depending on the year, the CC of genotypes from ED and LD groups was 16%–54% lower than the control. The unfavorable growing conditions also had a negative effect on the soybean HT. The drought reduced the HT of the plants within the ED and LD trial between 12% and 44% compared to the control. The results suggest that some genotypes were more tolerant to unfavorable conditions than others which can be very useful in the selection of drought-tolerant varieties. The study showed that HTPP can be successfully used for collecting important information about soybean development within different environments.

Keywords: Soybean, high-throughput phenotyping, UAV, canopy cover, height

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Soybean phenotyping: ideotypes for organic breeding

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The creation of focused breeding programs for organic farming systems was encouraged by the expanding market for organic farming. Breeding efforts are being stimulated by the rising demand for soybean varieties that are appropriate for organic farming in order to better meet the unique needs of those involved in the organic value chain. Within the ECOBREED project, extensive phenotyping on 200 soybean genotypes is carried out across contrasting environments in three countries, i.e. Austria, Romania and Serbia, which will enable the identification of useful traits (variation) and the level of local adaptation of genotypes. The following traits are assessed: yield and yield supportive traits, crop growth related traits, grain quality traits, plant architecture. Multi-trait genotype-ideotype distance index (MGIDI) implemented for genotypes selection, based on multiple traits. Classical linear multi-trait selection indices are available, but multi-collinearity and arbitrary weighting coefficient selection may erode genetic gains while. MGIDI provide genotype selection based on multiple traits easy to interpret. An ideotype is a genotype that contains a set of favorable traits that enables high performance under organic and low input production. Multi-location data were analyesd by linear-mixed model, and BLUP values were used for calculation of the multivariate genotype-ideotype distance index. Strength and weakness analysis performed, which are accounted for the proportion of each factor to the genotypes' MGIDI index. Factors clearly grouped similar traits and represent main performances (eg. yield supportive, seed quality, plant architecture). MGIDI and affiliated analysis, clearly identified best performance genotypes, with advantages and disadvantages of each genotype, allowing selection of soybean for organic and low input production and future breeding work. The promising usage of MGIDI index is interpretation of genotype performances in context of GxE and factors (trait groups) contribution across different environments.

Keywords: Glycine max, multi-trait genotype-ideotype distance index (MGIDI), organic production

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Exploration of selective genotyping and selective phenotyping for optimization of soybean genomic prediction models

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The accuracy of genomic selection can be affected by several factors including trait architecture and heritability, marker density, linkage disequilibrium between markers and trait loci, statistical models, training population size, composition, and population structure. The selection of a minimal and optimal marker set with high prediction accuracy as an alternative to reduce genotyping costs, computational time, and multicollinearity for the genomic selection is a challenging task. Furthermore, optimal training population size is mostly determined empirically, by random sampling a whole set of genotypes, which may not reflect the true relationships in the population and may lead to the loss of rare genotypes and alleles. Selective phenotyping could reduce the number of genotypes tested in the field while preserving the genetic diversity of the initial population. This study aimed to evaluate different methods of selective genotyping and phenotyping on the accuracy of genomic prediction for soybean yield. The evaluation was performed on three different populations: recombinant inbred lines, multifamily diverse lines, and germplasm collection. Strategies adopted for marker selection were: SNP pruning, approaches with and without re-estimation of marker effects, randomly selected markers, and genome-wide association study-based strategy. Reduction of the number of genotypes is performed by selecting a core set from the initial population based on marker data. In 10-fold cross-validation and external validation, the average prediction ability using all markers was different among examined populations. Generally, all datasets followed a similar pattern of prediction ability for different marker reduction strategies. The selective phenotyping procedure based on maker data in all cases had higher values compared to minimal values of random sample selection. Overall, obtained results indicate that selective genotyping and phenotyping can be integrated as useful tools that can improve or retain selection accuracy by reducing genotyping or phenotyping costs for genomic selection.

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Phenomic selection in soybean breeding

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Phenomic selection is a promising complement and alternative to genomic selection for improving breeding efficiency. The major advantage of using near-infrared spectroscopy (NIRS) to indirectly capture phenotypic variants and predict complex traits is its high-throughput and low cost. Using NIR spectra to predict individual performances in the context of breeding for yield remains relatively novel. Certain wavelengths of NIR light are absorbed by specific chemical bonds that constitute the components of tissues. The relative proportion of each of these bonds within the tissue quantitatively influence the nature of the absorbance or reflection of light at different wavenumbers. Phenomic selection was tested on 206 soybean genotypes, collecting yield and NIRS data. Spectra were obtained from different tissues, grains and dried, milled leaves, measuring absorbance in range 4000 – 10000 cm−1. RR-BLUP model was used for phenomic predictions, considering NIRS data instead of molecular. Differences between collected plant and seed NIR spectra were observed, causing variation in prediction ability of RR-BLUP models, ranging between 0,6 and 0,7 that was at the level of previously determined genomic prediction. For selection of optimal phenomic prediction model, it was important to elucidate contribution of chemical bonds i.e. macromolecules to the model's prediction power, in order to avoid that the model itself and not selection for yield, affects other traits. In the seed, spectra with the highest prediction values were mostly located at the positions of protein and oil peaks. Therefore, developed prediction model basically predicts protein and oil content in seeds. Due to existing genetic correlations between protein and oil content with the yield, by employing this model one may take the risk of selecting genotypes based on altered chemical composition rather than yield. In terms of specific breeding goals, it is necessary to focus carefully on selection of optimal phenomic prediction model.

Keywords: NIR spectroscopy, phenomic selection, yield, macromolecules

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Soybean nutritional quality: introduction of the winter cover crops in soybean rotations

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Soybean (*Glycine max* L. Merill) is a high-value crop due to its high content of protein and oil, which contribute nutrients to both humans and animals. The objective of this study was to evaluate the effects of the winter cover crops on soybean nutritional quality. For this purpose, near-infrared spectroscopy was used, due it is an extremely potent tool in plant-related field of research for analysis. It is commonly used to estimate characteristics of grain including protein, starch, and oil content. Based on reliable calibration models, the spectral characteristics of the examined sample are related to the content of the component of interest. After mulching of cover crop biomass and conservation tillage, two soybean varieties were sown (NS Mercury, 00 maturity group and NS Altis, 0 maturity group). The field trial was grown under conventional production in agroecological conditions of Southeastern Europe at two sites (Rimski Šančevi and Čurug locations) in 2021. A pure rye crop (1) and mixture of peas and oats (2) were sown as a cover crop, while the control treatment (C) was an area without cover crops (period autumn – spring). Total protein and oil content of soybean, were analysed by Antaris II Thermo Scientific FT-NIR, while OMNICTM software was used for data processing and calibration. The relation between the seed quality parameters and use of cover crops was seen through obtained results. The average protein content of different genotypes was in the range of 35.67 to 44.30, while the oil content ranged between 18.78 and 23.22 % of dry matter. The obtained results indicate that there is a statistically significant difference between the average protein and oil content within the cultivars and within the locations.

Keywords: Glycine max, protein content, oil content

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Organic and low input soybean production: role of winter cover crops in production systems and its effect on yield parameters

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Cover crops are being used as a tool to reflect agro-ecosystem services. Cover crops differ in the traits by which they capture resources and influence the local agro-ecosystem. The aim of the research was to examine the effects of the winter cover crops in soybean production through the analysis of yield in the two sustainable cultivation systems (organic and low input) during 2021. The experiments were set up according to the block system method with random plots in four replications at two locations Čurug and Rimski šančevi, Serbia. Winter cover crops were following: pure rye crop (R) and a mixture of peas and oats (P+O) (85:15), while the control treatment (C) was an area without cover crops. It was assumed that soybean will respond positively to the selected treatments, which resulted in an increase in grain yield. Yield and yield parameters positively reacted on mixture (P+O) as a pre crop. The beneficial effect of P+O cover crop is mainly associated with rapid growth during autumn and the ability to scavenge large amounts of residual N from deep soil layers with its large tap root and through process nitrogen fixation. Yield was in the range 2.8 – 3.6t/ha. The lowest yield 2.1 t/ha were recorded at the control plot for NS Mercury variety. Average height of NS Mercury variety was 73cm in low input production (Rimski šančevi), whereas NS Mercury in organic production (Čurug) was 92.5 cm. Also, differences in the number of soybean pods and 1,000 grain mass were noted. Agronomic practices which include the introduction of cover crops in soybean production, could significantly contribute to increasing the sustainability of agricultural production systems and to offer the practical solutions that are profitable long term investments in crop production.

Keywords: Glycine max, sustainable cropping systems

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ECOBREED participatory trials as valuable tool for farmer involvement in soybean breeding process

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As a part of the ECOBREED project, farmer participatory trials for organic soybean production were set up in Serbia, Germany, Romania, Austria and Slovenia (seasons 2021 and 2022). By setting up trials direct with organic producers, it was enabled that farmers assess the adaptability of the soybean varieties for organic production in specific agro-ecological conditions at their farm locations. This is one practical tool that enables organic producers to contribute and to be involved in the process of creating new soybean varieties, especially in crops composite population (CCPs) observations together with breeders. ECOBREED farmer participatory trials for organic soybean comprised field testings of soybean varieties from three breeding institutions from Serbia, Austria and Romania (Serbia-Institute of Field and Vegetable Crops, Austria-Saatzucht Gleisdorf, Romania-NARDI-Funduela). The network of organic participatory farms was established in 2021 at 17 locations in 5 European countries. Soybean varieties were selected according to agro-ecological conditions in each country. On all farms same trials observations and assessments were performed: emergence, canopy closure, growth development, height, lodging and yield were evaluated as well as occurrence of diseases and pests. Trial results have big variations among countries, within countries and specific locations (different variety responses). After two years of setting up participatory trials for organic production the farmers got a solid foundation and a direction for selecting a soybean variety for specific agro-ecological conditions that is in line with the farmers' requirements and the established production goal. Farmer participatory trials are a crucial milestone to define local criteria for variety selection and for increased adoption of new and improved soybean varieties to low input and organic production.

Keywords: Trial network, organic production, soybean producers

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Competition between different soybean varieties and selected broadleaf invasive weeds

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The goal of our research was to examine the competitive ability of selected soybean varieties and invasive weeds, and opportunity to select the most competitive soybean varieties based on the loss of crop grain yield. Field trials with competition between three soybean varieties (NS Apolo, Fortuna, NS Zmaj) and three invasive weeds (*Abutilon theophrasti*, *Ambrosia artemisiifolia* and *Xanthium strumarium*) were conducted in 2020 and 2021 at location Novi Sad. The additive design with four replications were used. Soybean was sown at a density of 450,000 seeds ha^{-1} and six rows per plot with inter-row spacing of 50 cm. Weeds were sown at the same time with densities of 0.5, 1, 5 and 10 weeds per m^{-1} of soybean row. The three central rows of the plot were used to calculate the soybean grain yield. Lower densities of *X. strumarium* (0.5 and 1 m^{-1}) in NS Apolo variety caused 35 and 69% yield losses, 33 and 68% in Fortuna and 36 and 72% in NS Zmaj. Higher densities (5 and 10 m-1) caused yield losses in NS Apolo 89 and 96%, in Fortuna 90 and 95% and in NS Zmaj variety 94%. At the lowest density of *A. theophrasti* (0.5 m^{-1}), the yield losses in all three varieties were 15, 26 and 16%, while at a density of 1 m^{-1}, yield losses were 53, 55 and 61%. In the treatments with densities of 5 and 10 m^{-1}, yield losses of all three varieties were about 90 and 95%. The lowest density of *A. artemisiifolia* caused yield losses of 17, 21 and 24%, while at a density of 1 m^{-1} a yield losses were 47, 46 and 54%. Densities of 5 and 10 m^{-1} caused similar yield losses of around 85 and 94% for NS Apolo and Fortuna, and 94 and 96% for NS Zmaj.

Keywords: Soybean, competition, *A. theophrasti*, *A. artemisiifolia*, *X. strumarium*

Acknowledgments: This research was supported by the European Union's Horizon 2020 Project *ECOBREED - Increasing the efficiency and competitiveness of organic crop breeding* under grant agreement number 771367.

The influence of different densities of invasive weeds on the dry plant biomass of soybean

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The goal of our research was to examine the competitive ability of selected soybean varieties and invasive weeds, and opportunity to select the most competitive soybean varieties based on their dry plant biomass. Field trials were conducted in 2020 and 2021 at location Novi Sad. Three varieties of soybeans with different morphological traits from the same maturity group (NS Apolo, Fortuna, NS Zmaj) and three very harmful and difficult to control invasive weeds (*Abutilon theophrasti*, *Ambrosia artemisiifolia* and *Xanthium strumarium*) were selected for the tests. The additive design with four replications were used. Soybean was sown at a density of 450,000 seeds ha-1 and six rows per plot with inter-row spacing of 50 cm. After soybean sowing, all weeds were sowed on the same time in four densities by hand (0.5, 1, 5 and 10 weeds per m^{-1}). Average dry biomass of aboveground part of plants was obtained 8 and 12 weeks after soybean emergence, from a sample of plants from $1m^{-1}$ of the fifth row after drying to constant weight and compared with weed free plots. In both years, the variety in which weeds at all densities had the least effect on the reduction of dry biomass was Fortuna. In 2020 and 12 weeks after Fortuna variety emergence, *A. theophrasti* caused a decrease of dry biomass by 7, 23, 50 and 62%, *A. artemisiifolia* decreased it by 18, 21, 49 and 56%, while *X. strumarium* affected a decrease of 15, 41, 70 and 74 %. In 2021 with dry and unfavorable weather for soybean production, *A. theophrasti* with four densities caused 9, 7, 33 and 52% reduction of Fortuna, while *A. artemisiifolia* contributed with 21, 24, 45 and 63%. In the same year, *X. strumarium* caused the least reduction of dry biomass in NS Zmaj variety (19, 39, 68 and 71%).

Keywords: Soybean, weeds, *A. theophrasti*, *A. artemisiifolia*, *X. strumarium*

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ECOBREED

Increasing the efficiency and competitiveness of organic crop breeding

ECOBREED is a 6-year research project coordinated by the Agricultural Institute of Slovenia and involves 24 partners from 12 European countries and partners from the USA and China. Within the project there is cooperation between universities, research institutions, private companies and associations.

ECOBREED intends to improve the availability of seed and varieties suitable for organic and low- input production. Project activities focus on four crop species (wheat, potato, soybean and buckwheat), selected for their potential contribution to increase competitiveness of the organic sector.

The project will develop (a) methods, strategies and infrastructures for organic breeding, (b) varieties with improved stress resistance, resource use efficiency and quality and (c) improved methods for the production of high-quality organic seed.

ECOBREED will increase the competitiveness of the organic and low-input breeding and farming sectors by:

- Identifying genetic and phenotypic variation in morphological, abiotic/biotic tolerance/resistance and nutritional quality traits that can be used in organic breeding
- Evaluation of the potential of genetic variation for enhanced nutrient acquisition
- Evaluation of the potential for increased weed competitiveness and control
- Optimisation of seed production/multiplication via improved agronomic and seed treatment protocols
- Developing efficient, ready-to-use farmer participatory breeding systems
- Pre-breeding of elite varieties for improved agronomic performance, biotic/abiotic stress resistance/tolerance and nutritional quality
- Development of training programmes in (a) genomic tools/techniques, (b) PPB and (c) use and application of improved phenotyping capabilities.
- Ensuring optimum and rapid utilisation and exploitation of project deliverables and innovations by relevant industry and other user/stakeholder groups.