The Science of Organic Agriculture in Canada

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Development of Breeding Strategies for Organic Soybean Production Systems in Canada

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The main objective of this project was to build knowledge on how to efficiently develop, through plant breeding, new soybean cultivars for organic growers to maximize competitiveness, efficiency, and volume of production. This was achieved by growing breeding populations of soybean that have been developed from bi-parental crosses between food grade soybean parents and selected in the following generations on contrasting organic (O) and conventional (C) farms.

For the first time, a detailed description of comparative performance of soybean cultivars grown on O vs. C production systems over several years and locations is available to the O agriculture sector specifically for Canada.

Objectives:

1. Grow F7, F8, and F9 soybean breeding lines from breeding populations (crosses) that are the result of selection on organic and conventional farms in replicated yield trials using two organic field locations in Ontario.

2. Grow selected early maturing soybean breeding lines and cultivars from the Guelph and Manitoba programs in several organic locations in Manitoba.

3. Evaluate weed competitiveness, root morphology and other agronomic traits including yield in the above trials to determine the “winners” in O vs. C production systems.

4. Characterize the phenotypic traits that lead to the winning genotypes in contrasting production systems. Isolate the DNA and perform molecular analysis using single nucleotide polymorphism (SNP) markers by genotyping-by-sequencing (GBS) to characterize the genomic regions associated with yield, agronomic, morphological, and physiological traits between the O and C production systems.

Results:

The cultivar trials were grown in Ontario in 2019, 2020 and 2021 at O and C field sites as described below. They consisted of 52 cultivars in the maturity groups 0 and 1.

In 2019, the cultivar trials were grown on conventional sites in Elora and Woodstock and on organic sites in New Hamburg and Arthur, ON. In 2020, fifty-two cultivars from the 00 to 1 maturity groups were grown in C and O environments. The field samples from the 2020 field trials were processed and analyzed. The purpose of these trials was to access root surface area, nodule dry mass, and yield. Root samples of each cultivar were taken using a soil core device.

Seed yield of the 52 cultivars depended on the production system. Some cultivars performed better in O and others in C production systems.

In 2021, field experiments in Manitoba were planted in the eastern (Glenlea) and western (Carman) Red River Valley in Manitoba's soybean heartland. Both locations were in O production as resources, including seed source, were limited, and prevented having them in both O and C field trials. Despite extreme drought and heat, the experiments were carried out successfully, providing an excellent opportunity to evaluate soybeans under water/heat stress conditions.

In 2021, in Ontario, the cultivar trial consisting of 52 soybean cultivars was planted at two O field locations at New Hamburg and Rockwood and two C locations at Elora and Woodstock, Ontario.

The 2021 field results showed that there was significant effect ($p<0.01$) of production type (O vs. C) for the following traits:

- Leaf tissue nitrogen (N) content: The cultivars differed in their N content among themselves as well as between O vs. C environments.

- Leaf tissue phosphorus (P) content: Cultivars significantly differed among themselves, but overall, they accumulated less P in O than in C systems.

- Leaf potassium (K) content: While the production type was significantly different between O and C, the cultivars did not differ among themselves in K content.

- Linkage maps have been generated using DNA markers produced by Genotyping-by-Sequencing (GBS) to be used for Quantitative Trait Loci (QTL) analysis. QTL are genomic regions on soybean chromosomes that are associated with plant performance for different traits under observation between the O vs. C environments. It is anticipated that we will discover some O specific QTL, some C-specific and some universal QTL for yield and other traits in comparison between the O and C environments.

The yield between the O and C environments significantly differed between the cultivars studied. Some cultivars seemed particularly adapted to O (OAC Acclaim, OAC Strive, DH4173, Panorama, and Tala) and others to C (OAC Prodigy, OAC Ginty, S05-T6, OAC 13-05C, OAC 13-61C-ChCdn and OAC Malory). However,

there were several cultivars that showed stable adaption and superior performance in both O and C, such as: OAC Wallace, DH530, OAC Drayton, OAC Bounty, OAC Eve and OAC Prescott. These results suggest that testing cultivars and breeding populations on organic sites may lead to the development of new soybean cultivars specifically adapted for organic production systems which can be grown by organic farmers.

The recombinant inbred line (RIL) populations consisted of two F7 RIL populations as follows: Pop 1: 131 with RIL from the cross OAC Sunny x S05-T6, and Pop 2 with 146 RIL from the cross OAC Calypso x DH618. These populations were developed by crossing pairs of food grade soybean parents, OAC Sunny x S05-T6 and, OAC Calypso x DH618, respectively. The purpose of the crosses that were made under a previous project was to expose them to O and C environments during selection, rather than looking at finished cultivars that were only selected and developed under a C environment. This has allowed us to study comparatively the impact of selection under O vs. C, to determine if the production system affected the selections made and, furthermore, what underlying genetics in terms of QTL were responsible for differential selection.

In 2021, the two RIL populations were grown at the same Ontario field locations in O and C production systems as the cultivar trials, organic at New Hamburg and Rockwood and conventional at Elora and Woodstock. The issues experienced at the O locations (dropping Rockwood) were the same as described above for the cultivar trials. However, all data was able to be collected except for yield from the New Hamburg O location, whereas both C locations provided data for all traits under observation.

The DNA samples were sent to Laval University for Genotyping-by-Sequencing (GBS) in fall 2022 and marker data were received in January 2023. GBS data were filtered for all 285 genotypes from Pop 1 and Pop 2, including the four parental genotypes. The GBS data will be used to map QTL for yield, agronomic and physiological traits, including root traits. We expect that many QTL for yield, agronomic and physiological traits will differ in the RIL populations between O and C.

Impacts:

1. Results provide organic soybean growers with valuable information on the adaptation of current commercial soybean cultivars to the organic soybean production system in their fields in two provinces, Ontario, and Manitoba.

2. New knowledge of the comparative genetic control of yield and agronomic traits in conventional and organic production systems. Plant breeders will benefit from knowing which regions (QTL) of soybean chromosomes determine high yield under O vs. C production systems.

For more information visit the OSC3 Activity 2 webpage and/or DAL.CA/OACC/OSCIII & https://organicfederation.ca/organic-science-clusters/

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