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Increasing the efficiency and competitiveness of organic crop breeding

PRACTICE ABSTRACT No. 2

Why do we use evolutionary populations?

PROBLEMS:

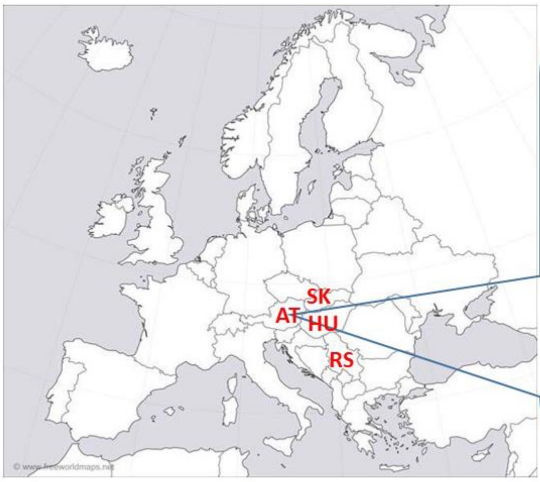
- There are only a limited number of varieties adapted to the environmental variability of low-input organic farming.
- Genetically homogeneous varieties are more susceptible to spatio-temporal changes in biotic/abiotic stresses and therefore have limited adaptability to local growing conditions.
- Environmental variability often affects crop yields more under low-input and organic conditions than in conventional agriculture.

SOLUTIONS:

- Growing genetically diverse populations could improve tolerance to a wide range of environmental stresses and different growing conditions by allowing them to evolve and adapt to changing conditions.
- Composite cross populations (CCPs) are populations of segregating individuals that are crossed with each other (e.g. by bulking the progenies of these crosses) to produce heterogeneous and diverse material. The development of CCPs is an example of evolutionary breeding.
- Many breeders and researchers have developed and tested heterogeneous populations over the past two decades. In ECOBREED, the Hungarian variety 'Mv Elit CCP', produced by crossing seven different parents, was tested in organic field trials in 2020 and 2021 and showed stable grain yields and high protein content. Compared to the variety 'Capo', which is popular with organic farmers and growers, 'Mv Elit CCP' showed a significantly higher protein content with a similar yield.

PRACTICAL RECOMMENDATIONS:

- Based on Regulation (EU) 2018/848 on organic production (**https://eur-lex.europa.eu/eli/reg/2018/848/oj**), organic heterogeneous material (OHM) such as CCPs can now be marketed and used (after listing) by organic farmers/growers, which will improve their development and availability.
- Look for availability of OHM in national or EU organic seed databases (after 1 January 2022) or ask breeders directly.
- Test OHM at your own site. As part of ECOBREED, the Hungarian wheat population (i.e. 'Mv Elit CCP') was evaluated on 14 commercial farms in Central Europe in the 2020-21 season and the initial results showed the competitiveness of the population compared to established organic varieties (Fig. 1).
- Maintain the population and let it regrow each year to allow natural selection for your specific environment. You may weed out plants with undesirable traits, such as individuals that are too tall, before harvesting (i.e., negative selection). Over time, multiplication and (natural) selection of CCPs will increase their adaptation to local growing conditions.



ECOBREED Farmer Participatory field trials of Mv Elit CCP in 2021: 4 countries, 14 farms

Austrian results:

Testing sites	Variety	Yield (t/ha)
Starnwörth	Mv Elit CCP	6.96
	Organic wheat control (Capo)	6.57
Aspersdorf	Mv Elit CCP	7.40
	Organic wheat control (Capo)	7.40
Wallern im Burgenland	Mv Elit CCP	4.20
	Organic wheat control (Capo)	4.10

Fig. 1: ECOBREED trial network of Hungarian winter wheat population 'Mv Elit CCP' by Central European farmers in 2021 and exemplary results from Austria.

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EU Organic Seed Databases (including a complete list of weblinks to the National Organic Seed Databases): **https://www.liveseed.eu/tools-for-practitioners/eu-organic-seed-databases/**

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ECOBREED CONSORTIUM

ABOUT ECOBREED:
ECOBREED is a 5-year (2018-2023) project funded by European Union's Horizon 2020 research and innovation programme that will improve the availability of varieties and seed suitable for organic and low-input production. Activities will focus on four crop species i.e. wheat, potato, soybean and common buckwheat, selected for their potential contribution to increasing the competitiveness of the organic sector.

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PRACTICE ABSTRACT No. 3

Screening for nitrogen fixation in soybean

PROBLEMS:

- Soybean yield and product quality are highly dependent on nitrogen fixation by symbiotic root bacteria (rhizobia).
- Soybean varieties and breeding lines have different nitrogen fixation efficiencies but measuring fixation rates is complicated and slow.
- Simple and rapid methods are needed to determine the nitrogen fixation capacity of breeding lines in the field.

Fig. 1: Soybean leaflets of genotypes differing in N2 fixation (left: high fixation; right: low fixation).

SOLUTIONS:

- Soybean leaves and the colour intensity of the green biomass are a suitable indicator of biological nitrogen fixation in the field (Fig. 1).
- Measurement of hyperspectral reflectance (visible and infrared wavelengths of light; Fig. 2 gives a good indication of the nitrogen status of the plant during the growing season.
- Soybean protein content can be used as a final parameter to determine nitrogen fixation capacity at the end of the season.
- Seed protein content below 35% is found in lines/varieties with low nitrogen fixation

Fig. 2: Hyperspectral reflectance measurement of soybean breeding lines in the field with a handheld sensor. (Photo credits: J. Vollmann)

capacity. Breeding lines with protein content above 45% are suitable for soybean food production and can be identified by hyperspectral measurements.

PRACTICAL RECOMMENDATIONS:

- Several measurements at different developmental stages between flowering and senescence would be required to fully assess the nitrogen fixation/uptake status of different lines.
- Drones equipped with hyperspectral reflectance cameras could be used for high-throughput screening of breeding material in the field.

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PRACTICE ABSTRACT No. 4

Soybean genotyping for food safety and organic traits

PROBLEMS:

- No synthetic pesticides or fertilisers are used in organic soybean production. Therefore, varieties suitable for organic production particularly require high disease resistance and efficient nutrient uptake.
- The maximum level of cadmium in soybeans was recently reduced to 0.2 mg/kg fresh weight by Commission Regulation (EU) 2021/1323 (**https://eur-lex.europa.eu/eli/reg/2021/1323/oj**).
- Conventional plant breeding based on phenotypic selection for the above traits is time-consuming and expensive, thus limiting yield progress in the smaller organic and low-input sectors.

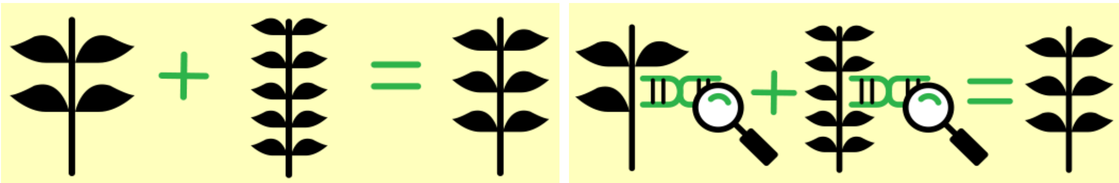

Fig. 1: Schematic representation of phenotypic (left) and marker-assisted (right) selection (MAS): in traditional breeding, the desired traits are identified in the field and combined by crossing; selection for trait combination in the segregating progeny is again performed in the field. Identifying the genes responsible for a trait and a DNA marker near that gene can make breeding more efficient by identifying plants with the desired trait at early stages of development. MAS can also be used to identify (a) genetic diversity in breeding material, (b) varieties with complementary traits for crossing, and (c) plants with a combination of valuable traits (genes) in segregating progeny. (Source: modified after Munday O. & Jung J. (Int. Rice Res. Inst.); see Folger T. (2014), The next Green Revolution, National Geographic Magazine, October 2014 issue; ***https://www.nationalgeographic.com/foodfeatures/green-revolution/****)*

SOLUTIONS:

- The use of soybean varieties suitable for organic farming provides more efficient and sustainable strategies for organic production systems. Genotypes with low cadmium accumulation should be used in organic food production to improve food safety. Selection for supernodulation in soybean could be an important trait showing potential for increased nitrogen fixation. In addition, breeding for disease resistance offers an efficient and sustainable strategy for organic production.

- The use of improved and more efficient breeding approaches such as marker-assisted selection (MAS) reduces costs and can be used directly in breeding for organic and low-input production (Fig. 1). This has the potential to shorten the breeding cycle and increase the precision of selection. With better varieties, farmers are likely to achieve greater yield stability and more sustainable production, which means lower risks in the organic production process.

PRACTICAL RECOMMENDATIONS:

Molecular markers were used to screen ECOBREED breeding material harbouring traits relevant to organic farming:

- *Cadmium accumulation*: by using two different marker strategies 11 soybean cultivars (Kamianetz, Novosadska Rana, NS Albus, NS Kraljica, Tajfun, Xonia, Columna, Larisa, NS Maximus, Ovidiu F and Steara) were identified containing an allele for low Cd accumulation, which is particularly suitable for soybean food production. The first six genotypes also showed high grain yields in ECOBREED field trials.
- *Supernodulation*: a molecular marker linked to the gene controlling the autoregulation of nodulation allows rapid screening at early developmental stages without inoculation. However, no supernodulating genotypes were identified in the ECOBREED soybean nursery.
- *Disease resistance*: using multiple molecular markers, soybean cultivars were identified that carry a high number of loci that confer tolerance to: (i) *Sclerotinia sclerotiorum* (i.e., Astafor, Favorit, Fortuna, Gracia, NS Kaca, NS Maximus, Pando, Rubin, Tajfun, Venera and Zita,), (ii) resistance to northern stem canker caused by *Diaporthe caulivora* (i.e. Favorit and Jelica') and (iii) against southern stem canker caused by *Diaporthe aspalathi* (i.e. Astafor, Becejka, Belka, Isidor, Jelica, NS Kraljica, NS Sirius, Pando, Zita and Zlata).

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PRACTICE ABSTRACT No. 5

Wheat resistance to bunt

PROBLEMS:

- Common bunt (caused by *Tilletia caries* (DC.) Tul. & Tul. (syn. *T. tritici* (Bjerk.) G. Winter in Rabenh.) and *T. foetida* (Wallr.) Liro (syn. *T. laevis* Kühn in Rabenh.)) and dwarf bunt (caused by *T. controversa* J.G. Kühn) can cause yield losses of over 80%.
- Bunt sori ('bunt balls') (Fig. 1) contain considerable amounts of trimethylamine, which smells like rotting fish. Therefore, the quality of the grain can be affected even by a very small infestation.
- Bunt diseases threaten farming systems whenever the routine use of chemical seed treatment is not possible. Organic wheat production therefore requires alternative methods of controlling common bunt and dwarf bunt.
- Many control methods used in organic farming have low efficacy against soil-borne pathogens, which is typical for dwarf bunt but may also be important for common bunt.

Fig. 1: Common bunt in wheat: infected spikes (left) with bunt sori (right top) and healthy seeds (right bottom) (Photo credit: V. Dumalasova and H. Grausgruber)

SOLUTIONS:

- Breeding for bunt resistance offers an efficient and sustainable protection strategy, especially for low-input organic production systems.
- To date, sixteen race-specific bunt resistance genes (*Bt1* to *Bt15* and *BtP*) have been identified in wheat, and additional sources of resistance have been reported. In addition, 24 non-race specific quantitative trait loci (QTL) have been identified.
- Marker-assisted selection (MAS) enables breeding and selection for improved and durable bunt resistance by pyramiding and combining multiple race-specific *Bt* genes.

PRACTICAL RECOMMENDATIONS:

- Measures to reduce fungal infections in organic farming include costly seed analysis, seed cleaning, seed treatments approved in organic farming, and the use of varieties with low susceptibility to bunt diseases.
- Some varieties listed in the CPVO (Community Plant Variety Office) database (Agricultural plant species; **https://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases/search/public/index.cfm**) have showen high resistance to common bunt in tests with artificial inoculation in Austria and the Czech Republic: Aristaro (0-0.5% bunt incidence), Genius (0-9%), Spontan (6.6-9.5%), SW Magnifi' (tested only in 2019 and 2020 in the Czech Republic).
- Some commercial varieties carry resistance genes against some pathotypes but seem to be susceptible to some emerging races: Tilliko (0-24%), Tillsano (8.7-28%; only tested in Austria in 2021), Butaro (0-29.5%), Tillstop (0-48%), Graziaro (0-59%), Tillexus (0.3-67.5%).

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