BRESOV - Breeding for Resilient, Efficient and Sustainable Organic Vegetable production

POLICY BRIEF ON ORGANIC VEGETABLE PRODUCTION IN EUROPE

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EU H2020 RESEARCH PROJECT BRESOV: SHAPING THE FUTURE OF ORGANIC BREEDING & FARMING

The BRESOV project (www.bresov.eu), that ran from May 2018 until April 2023, aimed to tackle the nutritional challenges of a growing world population and changing climatic conditions by enhancing productivity of different vegetable crops in an organic and sustainable farming infrastructure. BRESOV has worked on broccoli, snap bean and tomato as those staple vegetable crops have significant roles in meeting our global food and nutritional security goal. Under organic conditions they can also contribute to storing carbon and introducing nitrogen for improved organic soil quality. The BRESOV partners have used modern techniques to explore the natural diversity within each crop and then use this to expand the breeding base to select and improve resilience traits in organic farming systems using annual crop rotation schemes. The new breeding lines have been tested for efficiency when grown under water, temperature and nitrogen stresses as well as for resistance to pests and diseases. In addition, desirable traits such as taste, visual appearance and post-harvest performance have been assessed.

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MAIN FINDINGS

- Seed production security: Seed production under organic conditions is challenging due to limited access to plant nutrition and protection products as well as limited options for seed treatment. To reduce the productivity gap under low-input conditions, we identified agronomic practices contributing to increase the quality and quantity of organic seed produced per unit area tested, such as genotype, plant density, nutrition protocol, the use of *Rhizobium* for legumes, grafting, and fruit harvesting time in tomato.
- Genetic and phenotypic diversity and advanced breeding techniques: We screened a wide diversity of around 2000 accessions, of *Brassica*, tomato and snap bean, which were phenotyped and genotyped to look for useful traits for organic farming and unravel their genetic control. We identified sources of resistances to diseases, resilience towards heat, drought, waterlogging, nitrogen-use efficiency, and nutritional, organoleptic, and nutraceutical traits in the three vegetable crops.
- Pedo-climatic adaptation: We tested varieties on-farm in Europe for recommendation of regionally or overall adapted varieties.
- Breeding for low-input conditions: Genetic and phenotypic information was used for breeding: enhance existing varieties to increase resource-use efficiency, stress resistance/tolerance and productivity under organic conditions.

KEY POLICY RECOMMENDATIONS

- High quality seed: Healthy seed are crucial to produce healthy well-performing plants and to contribute to the reduction of crop protection products. This is especially true for organic production.
- End of derogations: For investments in seed production in view of the goal to reach 25% of organic agricultural land by 2030 and 100% use of organic certified seed, clarity on derogations is needed. This includes a clear commitment to end derogations and the development of an EU-wide strategy.
- Advanced breeding methods: Advanced, accessible breeding and selection methods (such as marker assisted breeding, on the basis of genetic information and sources) are needed to adapt varieties to low-input, high-stress conditions while allowing selection for products with increased organoleptic and nutraceutical characteristics. Access to genetic and phenotypic information is key for breeding for sustainable production in a changing climate.
- Breeding for sustainability: Crop production under organic conditions can provide beneficial ecosystem services; however, depending on the species this can be challenging in view of food production security. Plant breeding for sustainability specifically promotes new resistant, tolerant, and resilient varieties and thus contributes to decrease the gap in productivity between a conventional and a low-input, low-impact farming system. Varieties bred for these production systems can serve both conventional and organic farming.

CONTEXT

An agroecological transition to a more sustainable European Agri-Food system is needed to cope with the loss of natural resources and biodiversity. However, this transition must not be achieved at the expense of food safety and security. On the contrary, due to a growing world population we will have to produce 50% more food until 2050[1]. The need to produce "more with less" will be stressed in the European Union as production growth of major agricultural sectors is expected to slow down until 2032[2].

In the European Green Deal and the Farm to Fork Strategy, the European Commission has acknowledged the need for a transition of the European Agri-Food system, setting ambitious goals to reach their targets. These include an increase of land under organic production to 25% and a reduction of pesticides by 50%. To support the development towards a sustainable food system, the Commission has developed an action plan for organic production in the EU to stimulate the demand of organic products and the conversion to organic production systems, and improve the contribution of organic farming to environmental sustainability.

Organic farming provides environmental benefits and eco-system services[3]. To fulfil the goals of a sustainable and secure Agri-Food system, organic farming needs to ensure food security and therefore high and stable productivity. **To reach the above goals in a context of climate change, breeding for environmentally resilient and disease tolerant new varieties appears as a key component in the overall landscape of solutions.** High-quality seed underpins healthy and high-quality food and represents the cornerstone for a sustainable transition of the Agri-Food system. Recent studies have shown that plant-breeding innovation strongly contributes to the economic, social, and environmental sustainability of farming, food production and the entire economy [4],[5]. Climate change, with more extreme and varied weather conditions, together with related new phytosanitary threats, is creating additional challenges to all breeding programmes. Innovative methods and scientific advances will enable breeders to release better, more adapted and climate tolerant plant varieties faster.

The BRESOV project tackled these challenges by exploring underutilised genetic and phenotypic diversity of three of the economically most significant vegetable crops in Europe (broccoli, snap bean, and tomato) and improving their competitiveness in an organic environment.

[1] Searchinger et al. 2019.
[2] EU agricultural outlook for markets and income 2020-2030 2020.
[3] Smith et al. 2019
[4] Noleppa 2016.
[5] Wasja und García-Valero 2022.

KEY PROJECT RESULTS

The BRESOV consortium's overall aim was to increase the plants' tolerance to biotic and abiotic stresses and to increase the sensorial and nutraceutical traits of the products by providing new sources of genetic variation together with derived improved breeding materials suited to low-input organic growing systems. A multi-actor approach ensured the necessary cross-disciplinary interactions between researchers, businesses, farmers/producers, food industries, consumers, NGOs, advisors, and end-users.

Photo credit: ITAKA, 2019

1. SEED PRODUCTION SECURITY

Seed production under certified organic conditions is especially challenging due to limited access to plant protection products. To reduce the productivity gap under low-input conditions, we identified agronomic practices contributing to increase the quantity of organic seed produced per area and to ensure high quality seed. We tested the effect of different agronomic practices on organic seed production and germination across different pedo-climatic environments using different contrasting varieties. Our research showed that the choice of varieties and region of cultivation play an important role in successful seed production. Regarding the effect of agronomic practices, plant density and application of microorganisms in combination with amino acids are relevant factors influencing seed production. In addition, *Rhizobium* inoculation can increase snap bean seed production and grafting positively affects seeds production in tomato (see BRESOV Practice Abstracts[6], Protocol and guidelines to maximize organic seed production for broccoli, tomato and snap bean)

[6] BRESOV Practice Abstracts, https://bresov.eu/publications/practice-abstracts

Since competition with weeds is high in organic production and contamination of seed lots with weed seeds is an important issue, the genetic purity of seed lots is a key quality component of organic seed quality. Based on genotyping data from a large collection of varieties and accessions, we set up a methodology to determine the optimal marker sets that enables the detection of genetic contamination of seeds lots for each crop.

Regarding seed heath, molecular-based detection tools have been validated or developed to identify the presence of major seed-borne pathogens in seed lots. In addition, several organically suitable seed treatments against these main pathogens were evaluated and compared. These included natural compounds, formulations of microorganisms as well as a physical method with promising results to reduce bacterial and fungal pathogen titre and disease severity. The development of effective seed treatments against bacterial and fungal diseases should be done complementary to the selection of resistant genotypes/ breeding of resistant varieties.

2. GENOMIC AND PHENOTYPIC DIVERSITY AND ADVANCED BREEDING TECHNIQUES

We extensively screened around 2000 accessions of *Brassica*, tomato, and snap bean to characterise genetic and phenotypic diversity. They were represented by crop wild relatives, landraces, inbred lines, pre-breeding, and breeding materials, recombinant inbreed lines (RILs), organic heterogenous materials (OHMs) and commercial cultivars. We identified 179 sources of disease resistance, resilience towards heat, drought, salinity, waterlogging and nitrogen-use efficiency in the three crops. In addition, organoleptic traits (soluble solid, acidity, firmness, colour, aroma) and nutraceutical (antioxidant capacity, polyphenols, glucosinolates, volatile compounds, vitamins) of the products were evaluated.

Photo credit: SERIDA, 2020

Through new knowledge acquired on genome structure and function relevant for organic farming traits, marker-trait associations could be identified. These molecular tools greatly improve the efficiency of breeding and the success rate of getting the target ideotype or variety. Through BRESOV research, we identified 275 new genetic regions (bean 133, broccoli 84, and tomato 58) associated with traits relevant in organic production. Our results show that interesting traits can be found both in landraces and modern varieties. Phenotyping and genotyping results will be made publicly available via KIBANA and ZENODO open-source web portals.

3. PEDO-CLIMATIC ADAPTATION

Advanced breeding lines, niche, heirloom, and new varieties were evaluated under organic production conditions on-farm in multiple locations with different soil and climatic conditions. This provided farmers with new materials to test alongside commercial organic varieties. In each trial location, the cultivation was carried out according to the usual practices of the organic farmer hosting the trial, with all trials evaluated according to a common protocol. As a result of the trials, different materials were identified as suitable for organic farming production, some were found as better adapted to certain regions, climate, and inputs. While production of broccoli and beans using the test material was often successful, most of the tomato material tested couldn't compete with the commercially available reference organic varieties.

Photo credit: UPV, 2020

4. BREEDING FOR LOW-INPUT CONDITIONS



Photo credit: UNIVPM, 2020; UPV, 2020; VRDS, 2021

Utilizing genetic and phenotypic information, breeding programmes were implemented to enhance existing varieties and to increase resource-use efficiency and productivity under organic conditions and with improved organoleptic and nutritional quality.

For *Brassica*, the BRESOV breeding set was assembled to capture the variation in vegetable crop morphology (broccoli, cabbage, Brussels sprouts, kohlrabi, kale, tronchuda cabbage and kale) and type e.g., autumn and summer cauliflower; heading and sprouting broccoli; white through to purple cabbage. For tomato, the breeding set included different types of population material from worldwide origins, type of material (e.g., landraces and hybrids) and with different fruit shape and characteristics. In addition, a focus laid on improved tomato rootstock breeding. For bean, the breeding sets were chosen to represent the diversity in pod phenotypes, determinacy, photoperiod sensitivity, resistance genes and consumption traits. In multi-field trial experiments (different localities and years) the incidence of pest/diseases of these set of materials was evaluated under organic farming conditions.

In total, 179 genotypes/sources of important traits to organic production (89 for *Brassica oleracea* L. crops and their crop wild relatives, 53 for bean and 37 for tomato) were listed for their resistance to specific biotic and abiotic stresses, and their interesting organoleptic and nutraceutical traits. Utilizing the knowledge gained through the identification of marker-trait associations and detailed characterization of material, pre-breeding and breeding took place to integrate important traits of organic production. For these new materials interaction with the environmental conditions of several European countries was evaluated to allow the improvement and recommendation of crop agronomic performances and production quality.

KEY POLICY RECOMMENDATIONS

1. HIGH QUALITY SEED

Seed production bears risks of production losses due to long production cycles, which are longer than in crop production for food or feed. High quality seed comprises high germination rate, varietal identity, genetic purity, and absence of seed-borne pathogens.

High germination rates and genetic purity contribute to yield, food security and therefore sustainability. High standards need to be retained to protect seed quality and to reach the goal of a sustainable and secure food production system in Europe. This includes investment in plant breeding for the improvement of seed production performance, spread of best practices for seed production, research/spread in methods for ensuring seed quality and the availability of organically compatible seed treatments with high efficacy. In addition to seed treatments with high efficacy, seed dressing may provide an additional solution to compensate for or to complement resistant/tolerant genetic traits together with nutrition to optimize juvenile plantlet development. This includes the need for further research and investment in interaction between seeds and microorganisms. **Indeed, healthy seeds are crucial to produce healthy plants and to provide the basis for reduced need of crop protection.**

Photo credit: FiBL, 2020

3. PREPARATIONS FOR THE END OF DEROGATIONS

Photo credit: Vegenov, 2022

In view of the goal to reach 25% of organic agricultural land by 2030 and 100% use of organic certified seed, the goal is also to supply organic farmers with seeds produced under organic conditions. Consequently, more land needs to be dedicated to organic seed production.

For investments and further development in market share of organic seed production, clarity on derogations is needed. This includes a strong commitment to end derogations and to define clear milestones with the needed steps to reach this goal. This is true for both major and specialty crops. To define clear milestones active involvement of the organic seed suppliers in the decision-making process is important.

Although derogations will be granted on national level depending on specific national circumstances and are currently discussed on a national level (national organic expert group meetings), an EU-wide strategy is needed to define clear milestones and to avoid conflicting regulations across borders to increase organic seed production.

3. ADVANCED BREEDING METHODS

Plant genetic resources, landraces and modern varieties hold a precious potential to develop new, resilient and adapted varieties that will contribute to a sustainable farming system. With advanced DNA analytics, genotypic characteristics can be linked to phenotypic characteristics such as yield, resistance to biotic and abiotic stresses, resource use efficiency and nutritional characteristics. **Genetic information and use of advanced breeding methods such as marker assisted breeding are a crucial tool to gain efficiency in the creation of varieties adapted to low input conditions and to a changing climate; therefore, access to high quality genomic and phenotypic data is key for breeding.**

4. BREEDING FOR SUSTAINABILITY

Farmers need varieties suited to their specific farming systems and pedo-climatic conditions to contribute to economic welfare and sustainability goals. In 2020, organic farming represented 9.2% of EU farmland, meeting the demands of a growing market[7]. Around 54% of utilized agricultural area (UAA) under organic production is managed by holdings focusing on organic production only, whereas around 46% of UAA under organic production is managed by farms producing conventional and organic food[8]. Moreover, breeding benefits from traits and varieties developed for conventional and organic management systems, as breeding companies usually have the same breeding lines for both systems.

Crop production under organic conditions can provide beneficial ecosystem services but can be challenging in view of food production security. Plant breeding for sustainability contributes with resistant and resilient varieties to decrease the gap in productivity in a low-input and low-impact farming system. This is in line with the Farm to Fork strategy's objective of 50% reduction of pesticide use and several of the United Nation's Sustainable Development Goals. **Facing increasing energy, fertilizer and plant protection prices, varieties bred for low-input production systems can serve both conventional and organic farming.**

Photo credit: SERIDA, 2019

[7] Willer et al. 2022.
[8] Eurostat, the Statistical Office of the European Union 2022.

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