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BRESOV

Breeding for Resilient, Efficient and Sustainable Organic Vegetable production

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A comprehensive and agricultural practice relevant synthesis of the results of this WP

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1. Introduction

BRESOV is a project focusing on breeding for organic of three important vegetable crops, Broccoli and other brassicas, tomato and beans. Next to the breeding activities, it was essential to involve the main stakeholders in the practice of organic farming, namely the farmers. Furthermore, the project needed a strategy to test the products of the research and validate candidate material under different environments and local practices. The fifth work package of BRESOV (WP5) consisted of a multi-site evaluation of plant genetic material (pre-breeding lines, niche, new, or heirloom varieties) on-farm in crop rotation schemes, agronomic trials with a microorganisms' formulations, and a socio-economic assessment of organic tomato production in the project.

The first two objectives of WP5 were i) to evaluate a shortlist of breeding lines compatible with organic farming for the production of crops of enhanced quality and marketing value and ii) to provide farmers with new materials to be tested alongside commercial organic varieties on farm. These test materials of tomato, broccoli and beans were selected in the trials of task 5.1 and are described in BRESOV Deliverable 5.1. The selection included trained and semi-trained organoleptic assessments as well as untrained public tastings. Tasting forms are available on Organic e-prints and allow farmers to perform simple variety degustation.
The production of the selected varieties was tested under local organic production conditions during two seasons in different European location (fig.1). The one-year prolongation of the project allowed the addition of a season of trials in Portugal (P4-UTAD) and Romania (P11-VRDS).

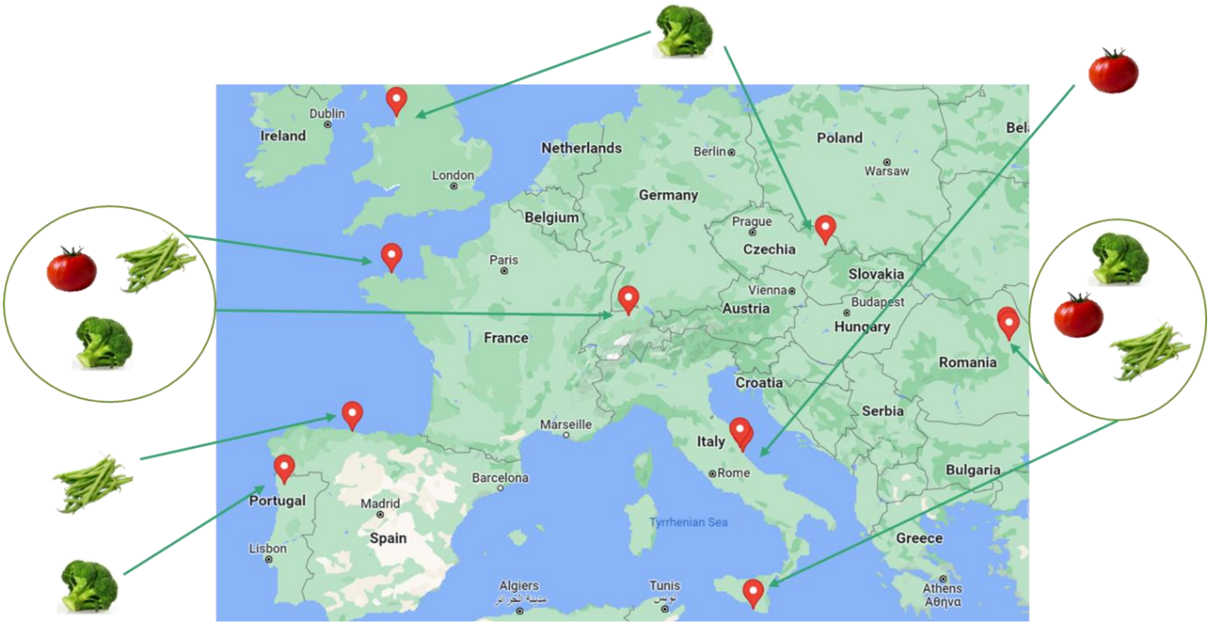

Figure. 1: European locations of the on-farm trials of WP5, along with the tested crop(s) at each location.

Varieties cultivated at each trial location are listed in BRESOV D5.1. These varieties originate from organic seed producers' breeding programs, BRESOV partners' breeding trials, or from partners previous experiments or tests with other tasks of BRESOV. In the second year of trials, minor changes of varieties were made in some locations to adapt to the result of the first year.

Farmers contributed to the assessment of alternative varieties or breeding lines by hosting trials under usual local organic production conditions, and filling a survey for each material tested in comparison of a standard usual reference variety. This feedback table is available as a tool on organic e-prints and can be used in future on-farm variety trial. They also provided the feedback of their consumers on the material tested, whenever they had direct contact with them, such as in the case of farms working in a direct marketing scheme. Consumers were also involved in this WP in other ways, such as through degustation events (e.g., tastings at UNICT for students and faculty in Q1 of 2019, tastings at fairs in Switzerland at the 2001Gemüse in September 2018, at the "Chant de Marin" festival in France in August 2019) or with farmers in workshops (e.g., in Portugal on bioplastic application in September 2020 and February 2022).

WP5 also included testing alternative fertilizers and/or microorganic formulations under production conditions (T5.3) and analyzing the socio – economic benefits of production under crop rotation schemes (T5.4).

These activities served the other objectives of this WP namely, iii) to Enhance crop performance (i.e., stress tolerance and nutrition) using bioactive products and iv) to promote crop rotations for improved performance of brassicas, snap bean and tomato crops. They were also based on this practice approach to research, by including data collected under production conditions. Task 5.3 included tests with a microorganism formulation and compost in organic production. In this task, a survey to farmers, in several European languages collected their interest and experience with alternative fertilizers and microorganism formulations. Task 5.4 finally looked at the benefits and costs of production of tomato under different crop locations in the different regions where production was tested in task 5.2.

This deliverable summarizes the main results of WP5 that are relevant to the practice of agricultural production.

2. Multi-site variety testing

In advanced breeding lines and varieties, whether old, new or niche, we looked for material bearing characteristics desirable in organic agriculture and where enough seeds could be available for multiple trials. We developed evaluation tables for each of the three crops as well as a simple questionnaire for the farmer to give feedback on specific material, and tables to assess varieties in tastings. These tools can be found in Deliverable 5.2 and in their Excel form on organic e-print and can be used to assess varieties of the three crops in future on-farm production trials.

In broccoli, branching, head shape and homogeneity of heads are important traits in the current market. While the use of CMS (cytoplasmic male sterility) varieties is sometimes still allowed under organic labels, there is a desire from the organic farmers to not use CMS hybrids. FiBL publishes yearly a positive list of cell fusion free varieties (Vieweger et al. 2022) developed with the support of sister project LiveSeed. On the other hand, open pollinated varieties are more genetically diverse and can adapt to changing conditions, which is a useful quality in organic agriculture. We therefore looked for varieties and advanced breeding lines bearing these characteristics and ended-up with 9 genotypes, 8 of them being open pollinated.

We have also evaluated the material from the organoleptic point of view and found that – while big differences in taste between broccoli varieties can exist, especially in terms of sweetness, bitterness and buttery taste – these are very little relevant to the consumer.

In snap beans, we looked at heirloom varieties previously described as robust, and with an intense taste. Characteristics like yield and ease of harvest (visibility of pods, homogeneity of pods maturity, spread of the harvest in time) were the main criteria in the selection of the best material for the on-farm trials. From the BRESOV breeding activities, lines with resistance to important diseases and robust traits were added in the Spanish and Romanian trials. In organoleptic tests, we found large differences between the varieties, with certain being preferred by the majority of tasters. Out of the 10 varieties assessed in task 5.1, two were kept for the production trials.

In tomatoes, we collected material suitable for both greenhouse (GH) and open field (OF) cultivations. Important criteria were: a selection under low-input conditions, a tolerance to drought, tolerance to reduced nutrient supply, resistance against pathogens and observed field resistance against *Phytophthora infestans*. The 12 acquired lines consisted of 7 indeterminate (GH), and 5 determinate (OF), from which 4 were kept for each of the production systems. As expected, the organoleptic quality of tomato differed largely between the different genotypes, and was an important criterium in the selection of the candidates for the on-farm production trials.

In the three years of task 5.2, a total of 47 trials were conducted in 8 countries of Europe using the selected materials of broccoli, beans and tomato.

In broccoli, the two selected genotypes performed well in the different locations. The non-CMS variety CN-Bro-09 performed well in most trials and obtained results similar to F1 references. It is a good alternative to CMS varieties. The open pollinated variety Rasmus was also appreciated in several locations, with high yields (sometimes similar or higher to CN-bro-09) and yield in general exceeding other tested lines (other than the F1 references). It was especially appreciated by the farmer in Portugal for its ability to produce secondary heads. Under certain conditions, Rasmus had less homogeneous heads and a higher proportion of unmarketable yield compared to CN-Bro-09. Both test varieties are recommendable for organic production of broccoli. Rasmus and CN-bro-09 performed differently depending on location. In Italy and France, these varieties were evaluated as less good than available standard varieties on the market. In general, CN-Bro-09 was the most appreciated. The status of CN-Bro-09 needs clarification at the moment. We know that it is free of cytoplasmic male sterility but have no additional information from the seed provider. The results show, that even within the current strict market requirements, good alternatives to CMS-varieties exist.

Crown, green open pollinated (OP) variety. Very good performance especially compared to most OP. Rasmus obtained a good yield, scored high on the production of first quality heads, with good shape comparable to F1. It is suitable for both spring and autumn cultivation, has a good ability to produce secondary sprouts, and can have an appreciable very slight bitter note. It was registered in 2018 and is available from Sativa Rheinau.

Crown, CMS-free variety. Very good performance in trials, with good production rate. Its shape and short branches were similar to F1 standards. Suitable for both spring and autumn cultivation. This variety was found among the sweetest in tastings. Its varietal status still needs clarification.

Figure. 2: Rasmus (top) and CN-bro-09 (bottom) were tested alongside commercial and local materials. Photo: Sebastian Nigro, Itaka, IT.

Slenderwax and la Victoire, the two bean varieties selected in task 5.1 performed generally very good in the on-farm production trials. In the second year of trials, both commonly tested varieties gave good results and high yields, comparable to or better than standard references. Both varieties are therefore recommended for organic cultivation in all regions. Depending on the location, one or the other variety was preferred. In some trials, Slenderwax outperformed La Victoire. In others, it was the opposite. Regional visual appreciation of the varieties also differed, such as for Slenderwax whose yellow pods were not appreciated in Italy. Other tested BRESOV lines gave good result, in particularly SPB240-

Prennel, which was among the best in Romania and Spain. These trials confirm the good performance of Slenderwax and La Victoire under most organic productions of snap beans.

Wax bean type with yellow pods and an elliptic round pod section. Rather low bush bean with moderately good steadfastness compared to the other varieties in test.
Among the best agronomic performance and yield and fast manual harvest due to the good visibility of the yellow pods. Relatively uniform in shape and length of pods with average weight. Among the two most popular varieties in the tasting despite its appearance rated as the least attractive. It has a spicy odour, is very sweet and nutty compared to the other varieties.

Bush bean with green pods and an elliptic round pod section. It is a robust and early ripening variety of low to medium height and a good steadfastness compared to the other varieties. Among the best agronomic performance and yield in the trials. It has rather large and long pods with relatively high fruit weight. Relatively uniform in shape and colour. La Victoire was the most popular variety during tasting, favourite variety of 50% of tasters, and second favourite to 20%. It was found sweet, spicy and nutty in taste with a pronounced spicy smell compared to the other varieties. La Victoire is known for its susceptibility to anthracnose. However, in our trials this was not outstanding.

Figure. 3: Slenderwax (left) and La Victoire (right) were tested alongside commercial and local materials. Photo: FiBL, CH.

In the case of tomato, the acquired and tested material could in most cases not compete with the current high-quality requirements of commercial tomato varieties. In greenhouse trials, not one of the tested materials gained the unanimity of partners and farmers. They all performed below the commercial organic variety references that can currently be found on the market. Organic tomato is under high market quality requirement, usually the same as for conventional varieties. In our trials, fruit heterogeneity and quality (tendency to bursting, thick skin, physiological diseases, etc.) were disqualifying factors that reduced marketable yield. Interesting material with good quality and special type of fruits were however found, such as Brad’s atomic grape - despite a susceptibility to bursting as well as to pests and diseases - and Valenciana d’el Perelló (BRESOV BT04260). However, due to the high market requirements, this material would be only be suitable for alternative markets such as direct marketing to the consumers.

Rather large and slender plant, dark colour, with curled leaves at the bottom. Variety very appreciated by consumers and farmers in direct marketing for its special colour and good taste. Small elliptical purple (like aubergine) fruits, turning partially to green, yellow and orange when ripe. Bigger calibre than cherry type.

Rather small and vigorous plant, well aerated, inflorescence with leaf ends. Heart shaped tomato, with large very fleshy fruits.

Figure. 4: Brad's Atomic grape (left) and Valenciana d'el Perelló (BRESOV BT04260; right) were among the most appreciated indeterminate tomatoes tested alongside commercial and local materials. Photo: FiBL, CH.

Among the material tested in open fields, some local materials and advanced breeding lines were found of interest for some markets (e.g., Malareto, a local Spanish variety and the line HF1-17, the Sativa Rheinau advanced breeding lines for industrial production FiBL9_PVB8 (Ti03), and under low input conditions FiBL13-PVB66 and FiBL14- PVB82, as well as FiBL8_To65_Mauro Rosso and FiBL12-PL10 Bacau (VRDS material). In Romania, local lines Buzau47 and PL 15 BACAU performed among the best. The third year of trials carried in Romania showed that seeds from the same varieties but resulting from two different seed multiplications result in plants with very different performance in production trials, hence the importance of propagation conditions. Overall, not one of the tested materials of tomato in open field gained the unanimity of partners and farmers.

All tomato material tested, whether under greenhouse or in open fields, performed below the organic commercial varieties that can be currently found on the market and that were used as references in our trials. A rethinking of the consumers' expectation, and therefore of market requirements for organic varieties with more focus on tolerance to diseases and stresses and taste rather than uniformity, as well as the development of alternative marketing schemes with short supply chains, can support an increase and diversification of available organic tomato varieties.

Medium early line, good tolerance to the most common pathogens. Spherical, easily flattened fruits of average weight, uniformly red at physiological maturity.

Medium early line with spherical, easily flattened fruits of variable above average weight (100-170g), uniformly bright red at physiological maturity.

Medium late line, with spherical, fruits of average weight, uniformly red at physiological maturity.

Figure. 5: Starting from the left, Buzau 47 and PL 15 BACAU are a local variety and line from P11-VRDS, respectively, which produced a performance among the best in the Romanian open field trials. Another P11-VRDS line, PL10 Bacau was appreciated in the Italian trials of P12-CREA. Photo: VRDS, Romania.

The data collected at each on-farm trial, per location and year, has been homogenized, cleaned and deposited in the database repository KIBANA, part of the BRESOV phenotypic metadata. This data will be ideally used in future publications. The questionnaires and data templates are available in Deliverable 5.2 on the organic e-prints repository. To allow for an easier exploitation of these templates in future variety trials, they were submitted as Excel files as practice tool on organic e-print (Herforth-Rahmé J., 2020; *submission still processing at the time of submission of this report*). These tables allow farmers and/or researchers to collect measurements in a production variety trial of tomato, beans or broccoli. Three files allow for the agronomic assessment, one file contains a simple form to acquire feedback regarding general performance and ease of production with the variety and the last file allows for simple organoleptic evaluation of the varieties during an untrained degustation session.

Sources of interesting vegetable varieties include the variety finder of P17-PSR Pro Specie Rara (in German), organic and open source seeds of Culinaris Saatgut and organic seeds of Sativa Rheinau, among others. Practical recommendations on trait selection, multiplication, seed production and treatment, etc. can be found in the BRESOV Practice Abstracts. Additional practical tools can be found on the Organic Farm Knowledge Platform.

3. Evaluation of natural bioactive products and microorganisms to increase crop performance

In this task, Maxy Soil® a microorganism formulation provided by ITAKA was used in on-farm and on-station trials to see whether it could improve crop performance. Trials in Switzerland and France, under production conditions, with or without compost, under drought stress or without it, showed no differences between the treatments, and therefore no improvement of the crop performance when the microorganism formulation was applied. In Italy on the other hand, trials were the microbial based product Maxy Soil® (at the doses of 0.5 g m^{-2}) was tested on tomato and beans showed a better crop performance of plants treated with the microorganism formulations. The effect of Betaine - a natural compound that functions to protect plants from abiotic stress – was also tested with or without the microorganism formulation. Both the microorganisms and betaine had a positive effect on snap bean production when no drought stress was applied. Under drought stress, a small effect was observed with the microorganism formulation. These results were presented at the ''III International Organic

Fruit Symposium and I International Organic Vegetable Symposium'' under the title: Effects of microbial consortia and betaines on snap bean grown under water stress conditions (Malgioglio et al., 2021) and also published in "Use of Bioinoculants Affects Variation in Snap Bean Yield Grown under Deficit Irrigation" (Rizzo et al., 2023). On tomato, there was a trend for less nematode damage when Betaine or the microorganism formulation was applied, however non-significant.

The formulation of microorganisms used in all the trials of task 5.3 was selected based on results obtained by ITAKA prior to BRESOV. With the limited time at hand, a pre-test with several formulations in the different regions could not be carried. Instead, a scientific review on the factors that may influence the efficacy of Plant Growth Promoting Microorganisms application was published within this task (Malgioglio et al, 2022). Dealing with soil health and its numerous interlinked variables, makes it difficult to give clear recommendations to the farming community on the use of microorganism formulations based on a set of trials over the short project period. Trials with different microorganisms and in the specific context where they will be used, are needed as the result will depend on various factors such as the crop variety, soil organic content, nutrients' availability, biotic and abiotic pressure etc. As described in the review, variability is introduced by the soil itself with its microbiome and by the environment. These factors affect the microorganism survival or speed of development, and consequently the possible impact on plants. BRESOV Practice Abstracts N°10 and 11 give practical recommendation on how to test whether your crop can benefit from a specific microorganism formulation.

With the help of a farmer survey, conducted in 5 European languages, we could learn about the farmers' interest for the use of microorganism formulations as well as alternative fertilizers, and collect their experiences with their use. It showed that compost and manure are the main alternative fertilizers used by the farmers responding to our survey, but that sheep wool pellets, shrimp meal, digestate, and horn meal are also used. Sixty one percent of the participants confirmed using alternative fertilizers as the only source of nutrition, mainly to cover Nitrogen needs. Recycled fertilizers are mostly used in open field production and motivated by residue reduction. 69% percent of the respondents were either satisfied or very satisfied with the use of alternative fertilizers and 93% of all participants recommend their use. The majority of survey participants are aware of the use of microorganisms in crop production. From those, 76% have already tested or used such products. Sixty percent of soil applications use Mycorrhizae and Trichoderma. According to our survey, farmers use microorganisms on all crops, in open field and greenhouses. Fifty nine percent of respondents recommended the use of microorganisms. The survey provided testimonials on the successful use of alternative fertilizers and microorganism formulations, confirming that it is possible to rely on alternative fertilizers and that there is a space for microorganism application in agriculture. Specific recommendations need however further trials. The survey has been featured on the EIP-Agri website and the latest newsletter dedicated to the sustainable use of pesticides in agriculture. This article is also available on organic e-prints.

More information about task 5.3 and its results can be found in Deliverable 5.3. The European Inputs list of the FiBL allows the search for fertilizers and plant strengtheners among others, with are allowed under European or national specific organic regulations.

4. Socio-economical study on the influence of crop rotation on crop performance

In task 5.4, data on the inputs, and all agricultural operations in the crop production trials of task 5.2 was used to perform a socio-economic assessment of each trial. All trials of task 5.2 were inserted in the usual crop rotation followed by the farmers. Farmers who were not cultivating in rotation tested the rotation proposed by the partner in T5.2 and adopted crop rotation for their production. Life Cycle

Assessment to evaluate Environmental sustainability; Production Cost Analysis to assess Economic sustainability and Activity Degree Analysis to assess Social sustainability were the methods used in this task. Tomato production in crop rotation was shown to have a significant impact on crop sustainability and was therefore chosen as the selected model crop. Due to the lack of possible comparison with a tomato monoculture production under the same conditions at every trial location, the trials were compared to an Italian monoculture production. Setting up trials to show the effect of particular crop rotation schemes are complex and require many years. Nevertheless, the compromise made here, allowed to measure the production impact at every location on the different environmental indicators. A significantly lower impact of organic tomato cultivation in rotation compared to conventional monoculture was measured in terms of global warming, soil health, water ecotoxicity and consumption among others, in all locations and years. Production costs were barely higher in the Italian trials of T5.2 compared to the monoculture. The much higher cost in the case of France and Switzerland and lower cost in the case of Romania, are only a reflection of the difference in labour and material costs between the countries. This result indicates that within the same country, organic tomato can be in theory produced in a crop rotation scheme with only a small increase of costs. From an economic perspective, the reduced yield compared to conventional tomatoes in monoculture is not a negative aspect for farmers considering that the market in almost all countries recognises a premium price for organic product.

Table 1 Percentage differences in costs and gross marketable production per ha (organic vs. monoculture)

Partner	Difference between organic & IT monoculture costs [%]	Difference between gross marketable production of organic & IT monoculture [%]
P12-CREA, IT	5,2	4,2
P18-ITAKA, IT	3	12,5
P6-FiBL, CH	49,2	36,8
P21-SECL, FR	22,8	31,1
P11-VRDS, RO	-65,9	-17,1

Table 1 shows that for P12-CREA and P18-ITAKA, the production costs of organic cultivation are 5.2 and 3% higher, respectively, than monoculture in the same country. This cost increase is not negative for farmers as the Gross marketable Production given by the yield per hectare and the sale price is 4.2% and 12.5% higher than monoculture. Differences are larges in France and Switzerland due to the higher cost of living. In the case of P6-FiBL, organic production costs are 49.2% higher than monoculture and Gross Marketable Production exceeds that of monoculture by 36.8%. This is also confirmed for P21-SECL where organic production costs are 22.8% higher and Gross Saleable Production 31.1% higher than conventional. The results are reversed in the case of P11-VRDS whereby organic production costs are 65.9% lower than monoculture and Gross Marketable Production is reduced by 17.1% due to a lower cost of living in Romania, and a lower yield per ha than monoculture despite the higher organic selling price.

In terms of labour hours, as expected, organic cultivation in rotation requires more operations and a higher amount of manual labour. This number depends however on the different locations and their needs as well as the requirements of the local organic certification body. The increased number of working hours translates into an increase in the human resources used for cultivation, which consequently leads to more jobs in the agricultural sector. The detailed results of this task can be found in Deliverable 5.5.

5. Conclusions

The tasks of this WP benefited of a great collaboration between multiple actors: the researchers, the farmers, the industry and even the consumers. The trials allowed farmers to test new products and experience first- hand their conditions of use, their effects and their limits, like in the case of microorganism formulations. Above all, they provided farmers with new varieties to grow, some of which were great discoveries. On-farm trials and living labs are more and more common in research projects, because despite being sometimes difficult to assess (data heterogeneity as one of the problems), they can validate or show the limit of a method or a material. In BRESOV, they allowed us to validate varieties of beans and broccoli in specific regions, to identify material with interesting features that can be used in future breeding, and establish tools for variety testing. The assessment of the material at each location is in Deliverable 5.4.

The variety trials of task 5.2 show the difficulty of finding new tomato varieties that are compatible with the current high market requirements. Different market requirements for organic vs conventional tomato with a focus on tolerance and taste and the suitability to short supply chains would allow an increase of the availability of varieties more adapted to organic agriculture or low inputs conditions. The assessment made in task 5.4 also showed that a farm transition to organic production does not necessarily come with a significantly higher cost. The surveys and trials of task 5.3 show that there is a potential for microorganism use to enhance crop production, especially in poorer, less structure soils, but that more complex studies considering all factors are needed.

In addition to summarizing the work and results of WP5 in BRESOV list practical tools that allow farmers to:

- Perform their own variety trials, and tastings
- Have access to organic varieties of vegetables
- Find products/inputs that are compatible with an organic production in their country
- Make their own trials and improvements of their production and marketing

and researchers to:

- Test new lines or varieties of tomato, broccoli and beans under production conditions
- build on the research regarding the use of microorganisms to enhance crop performance and the benefits of organic production

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