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ECOBREED FARMERS PARTICIPATORY FIELD TRIALS 2021

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IMPROVING CROPS

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1. Introduction

The project ECOBREED (*Increasing the efficiency and competitiveness of organic crop breeding*) is funded by the European Union Horizon 2020 project scheme and brings together 24 partners from 14 different countries. ECOBREED aims to increase the availability of seeds and varieties for the organic and low-input sector, to identify traits and combinations of traits suited to organic and low-input production environment including high nutrient use efficiency and weed competitiveness, and to increase breeding activities for organic and low-input crop production.

Within the ECOBREED Work package 6, the project aims to establish an efficient system for farmer-participatory-selection of new varieties in selected countries, representing different pedoclimatic zones and/or regions that can later be adopted throughout Europe and beyond. This will be achieved via:

- Identification of region-specific traits/trait combinations desired by organic farmers.
- Development and use of a data-recording system for Farmer Participatory Trials.
- Undertaking farmer-participatory breeding in contrasting pedo-climatic zones.
- Allowing farmers/breeders to select lines from evaluation of CCP that are particularly suited to their own environment.

The above-mentioned Farmer Participatory Field Trials, which are performed under Task 6.2, aim to establish on-farm variety evaluation trials in Northern, Central, and Southern European organic production systems/rotation backgrounds. In each country, which is included as partner in the project, 4-6 farmers are included, and each participating farmer established a non-replicated trial to compare the performance of 8-12 genotypes of each species (identified from phenotyping in work packages 2-5, focusing on wheat, potatoes, soybean, and buckwheat). For each country, a standard agronomic and field assessment protocol will be developed and used, but each farmer will be able to include additional parameters/protocols in the trials performed on his/her farm.

The responsible partner for this work package is Naturland Association for Organic Agriculture (NATUR) from Germany with task leader Werner Vogt-Kaute. The partners involved in this task are the University of Newcastle (UNEW) and LC Smales & Son Limited (SMA) from the UK, Agricultural Institute of Slovenia (KIS), Slovenia, University of Natural Resources and Life Sciences (BOKU) from Austria, Poslovni system Global Seed (GS) and Institute of Field and Vegetable Crops (IFVCNS) from Serbia, Crop Research Institute (CRI) and PROBIO sro from the Czech Republic, University of Tuscia (UNITUS) from Italy, Hungarian Academy of Sciences, Centre for Agricultural Research (ATK) and the Hungarian University of Agriculture and Life Sciences (MATE) from Hungary, National Research Institute – Plant Breeding and Acclimatization Institute (IHAR) from Poland, National Agricultural and Food Center (NPPC) and BIOMILA spol. sro from Slovakia, and National Agricultural Research and Development Institute (NARDI) from Romania.

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2. Wheat

2.1. Wheat farmer participatory trials in the UK

All four wheat FPT trials were drilled in the autumn of 2020. Newlands on 30 September at a seed rate of 200 kg/ha (with the exception of the variety Wendelin that had gone on at a lower seed rate by mistake), Nisbet Hill Farm (230 kg/ha) on 7 October 2020, Thornton Farm (220 kg/ha) on 9 October and at Gilchesters on 24 October. At Gilchesters Viki and Liocharls population were drilled at 160 kg/ha which is 400 seeds/m^2 with all other varieties at 210 kg/ha which is ~425 seeds/m^2 this is to take account of the much smaller seeds of Viki and the Liocharls population and drill all at a similar plant population. Plant counts and germination % were recorded on 17 November at Newlands, Nisbet Hill and Thornton and on 2 December at Gilchesters. At Newlands and Nisbet Hill eight varieties were used (Wendelin, Royal, Alessio, Purino, Revelation, Wakelyns Population, Barranco and Roderik), 11 at Thornton Farm (with the addition of Viki, Liocharls Population and KWS Extase) while at Gilchesters, Roderik was not included but both Skagit 1109 and Laurin were additional varieties evaluated. At all four sites the biostimulant seed treatment Sikulo was also included on the variety Revelation while at Thornton Farm the trial also included the biostimulant seed treatment Tiros on the varieties Revelation and Wendelin. At all sites the trials established very well (Figs. 1-3). At both Thornton Farm and Gilchesters the foliar biostimulant Fixio (from ITAKA) was also applied on 26 April at Thornton Farm and 11 May 2021 at Gilchesters.

Figure 1. Farmer Participatory Trial sown at Nisbet Hill Farm on 7October 2020 with photo taken on 17 November 2020

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Figure 2. Farmer Participatory Trial sown at Thornton Farm Berwick on 9 October 2020 with photo taken on 17 November 2020

Figure 3. Farmer Participatory Trial sown at Gilchesters on 24 October 2020 with photo taken on 2 December 2020

The first disease assessment at Gilchesters Organics was carried out on 17 June for leaf blotch and yellow rust while at the other 3 sites, Nisbet Hill Farm, Thornton Farm and Newlands the 1st disease assessment was carried out on 18 June 2021. Further disease assessments were then carried out on 1 and 12 July 2021. Disease data for each site are presented in Tables 4-7. For disease assessments 10 replicate readings were taken from each plot/treatment. *Septoria tritici* was recorded as % leaf coverage on each of leaves 1-3 while for Yellow rust the data is based on a whole plant assessment scale 1-9 (where 1 is no disease present).

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Lodging assessment and plant height were recorded just prior to harvest. All trials were combined with a class Compact plot combine (Newlands 23 August, Thornton Farm 24 August, Nisbet Hill 25 August and Gilchesters 3 September) and all grain yields (Table 1) are presented @15% moisture content.

Figure 4. Wheat FPT being harvested at Nisbet Hill Farm, Duns on 25 August 2021

There was consistency in variety performance across the four sites, but yields were much higher at Thornton Farm than at the other 3 sites. Grain yield was taken from an area of 40 m^2 at Thornton Farm but from a minimum of 75m^2 at the other 3 sites. KWS Extase and Revelation which are both on the UK Recommended List of varieties for conventional production were the best performing varieties across the sites but at Gilchesters the yield of Wendelin was similar to that of Revelation. The grain yield of Wendelin at Newlands was much lower than at the other 3 sites largely due to the fact that it had been drilled at a much lower plant population (about 25 % of the plants/m^2 of other varieties) but considering the very low plant population still produced a grain yield of 4 t/ha (Table 1). There was no effect of the seed treatments Sikulo or Tiros on grain yield at any of the sites.

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Table 1. Grain yield t/ha from all 4 FPT sites presented @15% moisture content

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	9.2	6.29	6.1	5.4
Wendelin	10.5	4.0*	7.1	5.5
Liocharls pop	9.8			5.2
Revelation + Sikulo	11.0	7.3	7.6	5.6
Roderik	9.1	5.8	5.1	
Wendelin + Tiros	10.1			
KWS Extase	11.8	9.5		
Alessio	9.7	6.3	7.1	5.2
Revelation + Tiros	11.1			
Wakelyns pop	9.7	6.2	7.0	5.3
Barranco	9.5	6.2	6.3	3.4
Royal	10.0	5.2	7.1	4.4
Wendelin + Sikulo	10.6			
Revelation	11.7	6.4	7.9	5.4
Viki	9.7			4.6
Skagit 1109				4.0
Laurin				3.8

*Drilled at a lower seed rate by mistake with only 25 % of the plant number compared to other varieties

The grain yields from Thornton Farm are presented in Table 2. In this Fixio applied at 1.5 kg/ha on 26 April was giving a consistent 1 t/ha grain yield increase across all varieties but this was not the case at Gilchesters where no real benefit of Fixio was observed (Table 3). The use of FYM incorporated in the autumn produced no consistent effect on grain yield. At Gilchesters where Fixio had also been applied at a rate of 1.5 kg/ha on 11 May no effect on grain yield was observed.

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Table 2. Grain yields (t/ha @15% moisture content) from Thornton Farm in response to FYM and Fixio application in the 2020-21 season*

	Control	Fixio	FYM
Purino	9.2	10.1	10.0
Wendelin	10.5	11.5	10.1
Liocharls pop	9.8	10.6	9.7
Revelation + Sikulo	11.0	11.1	11.2
Roderik	9.1	10.0	9.4
Wendelin + Tiros	10.1	11.4	10.2
KWS Extase	11.8	12.8	12.1
Alessio	9.7	10.9	9.4
Revelation + Tiros	11.1	12.3	10.4
Wakelyns pop	9.7	11.1	10.1
Barranco	9.5	11.1	9.4
Royal	10.0	11.1	10.7
Wendelin + Sikulo	10.6	11.5	10.4
Revelation	11.7	12.5	11.6
Viki	9.7	11.1	9.6

*Combine yields at Thornton Farm were based on 40.7 m^2 for the Fixio, 51.7m^2 for the control and 47.3m2 for the FYM treatments

Table 3. Grain yields (t/ha) @15 % moisture content from Gilchesters in response to Fixio application in the 2020-21 season*

	Control	Fixio
Viki	4.6	4.3
Liocharls pop	5.3	5.2
1109	4.6	4.0
Wakelyns pop	5.5	5.3
Purino	5.5	5.4
Wendelin	5.2	5.5
Laurin	4.0	3.8
Revelation	5.6	5.4
Revelation + Sikulo	5.9	5.6
Royal	5.4	4.4
Alessio	5.5	5.2
Barranco	4.2	3.4

*Grain yields at Gilchesters were based on 74.8 m^2 for the control and 70.4 m^2 for the Fixio treatment

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Table 4. Septoria leaf blotch and yellow rust disease levels from Nisbet Hill Farm on 18 June, 1 and 12 July in the 2020-21 season

	18 June (GS58-62)		1 July (GS62-65)		12 July (GS75)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust	*S tritici*	Yellow rust
Roderik	0, 0, 0	1	0, 2, 20	2.7	13, 65, 93	1.2
Barranco	0, 0, 2	1	0, 0, 27	1.4	0, 30, 94	2.4
Revelation	0, 0, 22	1	0, 0, 9	1.2	0, 2, 40	1.2
Alessio	0, 0, 50	1	1, 7, 58	1.1	0, 30, 78	1.2
Royal	0, 0, 3	1	0, 0, 14	1.1	0, 27, 76	1.8
Purino	0, 0, 1	1	0, 0, 10	1.2	0, 13, 80	1.7
Wendelin	0, 0, 1	1	0, 0, 24	1	0, 7, 57	1
Wakelyns pop	0, 0, 5	1	0, 0, 22	1	0, 25, 80	2
Revelation + Sikulo	0, 0, 8	1	0, 3, 18	1	0, 5, 35	1

*Septoria tritici % disease recorded on L1, L2 and L3 respectively

**Yellow rust 1-9 scale where 1 = no disease present

Table 5. Septoria leaf blotch and yellow rust disease levels from Newlands Farm on 18 June, 1 and 1 July in the 2020-21 season

	18 June (GS60-63)		1 July (GS65-70)		12 July (GS75)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust	*S tritici*	Yellow rust
Wendelin	0, 0, 0	1	0, 0, 8	1	0, 1, 59	1
Royal	0, 0, 2	1	0, 5, 40	4	0, 42, 82	6
Alessio	0, 0, 22	1	0, 6, 57	1	0, 32, 100	4.8
Purino	0, 0, 50	1	0, 3, 30	3.9	8, 46, 84	4.6
Revelation	0, 0, 3	1	0, 0, 20	1	0, 0, 47	1
Wakelyns pop	0, 0, 1	1	0, 5, 43	2.5	0, 28, 93	2
Barranco	0, 0, 1	1	0, 4, 52	4.5	28, 53, 95	6
Roderik	0, 0, 5	1	0, 6, 33	5.3	53, 71, 77	6
Revelation + Sikulo	0, 0, 8	1	0, 1, 27	1	0, 11, 78	1

*Septoria tritici % disease recorded on L1, L2 and L3 respectively

**Yellow rust 1-9 scale where 1 = no disease present

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Table 6. Septoria leaf blotch and yellow rust disease levels recorded from Thornton Farm on 18 June, 1 and 12 July in the 2020-21 season

	18 June (GS60-64)		1 July (GS65-70)		12 July (GS75)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust	*S tritici*	Yellow rust
Purino	0, 3, 5	4	0, 10, 36	4.7	0, 35, 82	4.6
Wendelin	0, 0, 1	3.5	0, 0, 13	1	0, 3, 28	1
Liocharls	0, 2, 7	1	0, 2, 34	1.5	0, 42, 94	1
Revelation + Sikulo	0, 3, 8	1	0, 2, 5	1	0, 3, 28	1
Roderik	0, 2, 7	1	0, 22,36	5	1, 30, 78	5
Wendelin + Tiros	0, 0, 2	1.5	0, 2, 14	1	0, 5, 40	1
KWS Extase	0, 1, 1	2.6	0, 4, 9	2	0, 16, 71	1
Alessio	0, 4, 8	1.5	0, 7, 44	1.6	0, 30, 90	2.5
Revelation + Tiros	0, 1, 9	1.8	0, 0, 9	1.8	0, 1, 32	1
Wakelyns	0, 1, 7	1.3	0, 5, 25	2.3	0, 20, 67	1
Barranco	0, 1, 9	1	0, 12, 41	5	0, 35, 76	6
Royal	0, 1, 1	3	0, 8, 22	4.6	0, 26, 84	5
Wendelin + Sikulo	0, 1, 2	2	0, 1, 9	1	0, 5, 42	1
Revelation	0, 1, 8	1	0, 3, 10	1.5	0, 2, 38	1
Viki	0, 0, 9	3.5	0, 10, 24	5	0, 41, 91	3.2

*Septoria tritici % disease recorded on L1, L2 and L3 respectively

**Yellow rust 1-9 scale where 1 = no disease present

The lowest disease levels were recorded at Nisbet Hill Farm and the highest at Thornton Farm with earlier signs of yellow rust than at the other three sites. Yellow rust levels showed a significant increase from the 1 of July at Newlands with high levels recorded on Barranco, Royal, Roderik, Alessio and Purino. At Nisbet Hill Barranco was the only variety with a yellow rust disease level >2 on 12 July. At Thornton Farm it was again the varieties Purino, Roderik, Barranco and Royal which showed the highest yellow rust disease levels similar to those at Newlands. At Gilchesters it was royal and Barranco that had the highest yellow rust levels which were similar to those at Newlands and Nisbet Hill. Wendelin was consistent across all sites with no yellow rust recorded and alongside Revelation having the lowest recorded levels of *S. tritici*. Wakelyns population recorded very low levels of yellow rust at all sites but was intermediate in performance against *S. tritici* but better than Liocharls population when grown at Thornton Farm and Gilchesters.

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At Nisbet Hill the variety Alessio (Table 4) showed high levels of *S. tritici* on leaf 3 on 18 June and 1 July but by 12 July Roderik had the highest *S. tritici* levels with disease recorded on Leaf 1. At Newlands (Table 5) Barranco and Roderik had high levels of Septoria leaf blotch on Leaf 1 and Leaf 2 while at Thornton Farm it was only later in the season that *S. tritici* started to take hold on some varieties but the flag leaf of all varieties was still showing very little disease (Table 6).

Table 7. Septoria leaf blotch and yellow rust disease levels from Gilchesters on 17 June, 1 and 14 July in the 2020-21 season

	17 June (GS57-61)		**1 July (GS69-71)**		**14 July (GS75)**	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust	*S tritici*	Yellow rust
Viki	0, 0.1, 1.6	1.2	0.8, 6.8, 10.6	3	0, 25, 73	3.1
Liocharls	0, 0, 0.1	1	1.2, 3.6, 16.7	1.5	0, 18.5, 70	1.3
Skagit 1109	0, 0, 1.2	1	1.1, 1.0, 9.2	2.2	0, 5.5, 25	1.1
Wakelyns pop	0, 0, 3.7	2	0.2, 0.7, 3.7	1.4	0, 17.5, 43	1.2
Purino	0, 0, 0	1.2	0, 1.7, 3.5	1.8	0, 26.5, 68	2.5
Wendelin	0, 0, 0	1	0, 0.1, 2.1	1.3	0, 4, 21	1
Laurin	0, 0.5, 0.7	1	0, 0.8, 3.3	1.7	0, 4, 38.5	1
Revelation	0, 0.5, 2.0	1	0, 1.1, 0.8	2.0	0, 3.5, 13	1
Revelation + Sikulo	0, 0, 0	1	0.3, 1.5, 4.3	1.6	0, 2.5, 18.5	1
Royal	0, 0, 0.6	1.2	0.1, 1.8, 6.3	2.7	0, 28, 56	6.1
Alessio	0, 0.1, 3.0	1	0.2, 3.6, 9.2	1.9	5.5, 41, 68.5	1.6
Barranco	0, 0.1, 2.0	1	1.0, 9.6, 30	4.7	28, 83, 94	6.2

*Septoria tritici % disease recorded on L1, L2 and L3 respectively

**Yellow rust 1-9 scale where 1 = no disease present

2.1.1. Grain Quality

Grain quality results in terms of protein %, HFN and specific weight are presented in Tables 8-10. Overall grain protein % was higher at Gilchesters and Thornton Farm compared to Newlands and Nisbet Hill. Wendelin produced a consistently high protein content at all four sites as did the Liocharls population and Viki at Thornton Farm and Gilchesters. Surprisingly the Group 2 conventional bread-making variety KWS Extase had a very low grain protein of <10 % at both Thornton Farm and Newlands. The varieties 1109, Laurin and Barber all showed high protein content but were only grown at Gilchesters.

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Table 8. Grain protein (%) from the four FPT sites presented @15% moisture content in the 2020-21 season

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	12.8	11.7	12.6	13.1
Wendelin	13.6	12.9	12.5	13.9
Liocharls pop	13.3	-	-	14.0
Revelation + Sikulo	10.4	10.1	10.7	11.7
Roderik	12.6	12.1	14.4	-
Wendelin + Tiros	12.5	-	-	-
KWS Extase	9.9	9.6	-	-
Alessio	12.6	12.5	12.1	13.8
Revelation + Tiros	10.4	-	-	
Wakelyns pop	11.8	11.0	11.2	12.7
Barranco	10.9	11.1	12.9	13.3
Royal	11.3	11.2	11.3	12.9
Wendelin + Sikulo	13.0	-	-	
Revelation	11.2	10.5	12.1	12.1
Viki	12.5	-	-	14.1
Skagit 1109	-	-	-	14.8
Laurin	-	-	-	14.8
Barber	-	-	-	15.0

Table 9. Grain HFN (s) from all 4 FPT sites in the 2020-21 season

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	271	272	250	324
Wendelin	307	188	203	238
Liocharls pop	315	-	-	255
Revelation + Sikulo	215	215	180	207
Roderik	264	271	227	-
Wendelin + Tiros	234	-	-	-
KWS Extase	247	291	-	-
Alessio	280	310	268	277
Revelation + Tiros	198	-	-	-
Wakelyns pop	234	225	173	241
Barranco	225	253	229	237
Royal	274	317	218	249
Wendelin + Sikulo	246	-	-	-
Revelation	204	224	174	178
Viki	258	-	-	306
Skagit 1109	-	-	-	217
Laurin	-	-	-	273

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Table 10. Grain specific weight (kg/hl) from all 4 FPT sites in the 2020-21 season

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	76.9	74.8	76.8	76.9
Wendelin	80.2	75.2	79.1	78.8
Liocharls pop	80.5	-	-	79.8
Revelation + Sikulo	74.0	71.5	72.8	74.2
Roderik	79.0	74.6	77.1	77.1
Wendelin + Tiros	79.1	-	-	-
KWS Extase	76.3	72.8	-	-
Alessio	79.2	77.7	78.8	79.3
Revelation + Tiros	73.9	-	-	-
Wakelyns pop	77.2	73.7	76.2	76.9
Barranco	75.1	73.2	75.2	76.2
Royal	80.7	78.7	79.7	79.6
Wendelin + Sikulo	79.2	-	-	-
Revelation	74.1	71.7	73.0	73.1
Viki	76.9	-	-	77.7
Skagit 1109	-	-	-	77.6
Laurin	-	-	-	77.7

In terms of HFN there were clear varietal differences between sites. Wendelin had a high HFN of 307s at Thornton Farm but was below 250s at all the other three sites. Allesio showed a great consistency in terms of grain quality with high protein %, HFN and specific weight across all sites. As with grain protein %, specific weight was higher at Thornton Farm and Gilchesters than Newlands and Nisbet Hill Farm. Across all four sites most varieties achieved the UK milling specification of >76 kg/hl except for Revelation which is a UK soft Group 4 conventional variety mostly used for animal feed. Royal and Alessio showed consistently high specific weight across all 4 sites.

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2.2. Wheat farmer participatory trials in Austria

Farmer participatory trials (FPT) with winter wheat (*Triticum aestivum* L.) in Austria were established at four organic farms located in different agroecological zones of Austria.

The first FPT trial was established mid-October 2020 in the production area "Seewinkel" at the farm of Franz Traudtner (Hauptstr. 18, 7151 Wallern im Burgenland; test site: 47.70554, 16.96950; pre-crop: spelt wheat) with a sowing density of 140 kg/ha. The FPT included 17 varieties (i.e. Adamus, Alessio, Arminius, Arnold, Aurelius, Bernstein, Capo, Christoph, Edelmann, Ehogold, Energo, IS Laudis, Izalco CS, Mv Elit, PS Dobromila, Tillsano, Tobias and Wendelin); 14 out of them are also included in the Austrian BioNet trial network with Capo as check variety, replicated 3 times across the FPT.

The second trial was sown on 22 November 2020 in the production area "Hollabrunn-Mistelbacher Gebiet" at the farm of Andreas Patschka (Zeile 85, 2020 Aspersdorf; test site 48.591265, 16.095740; pre-crop: faba bean). The trial included the following 11 varieties: Alessio, Arnold, Capo, Edelmann, Ehogold, Liocharls, Mv Elit, Mv Kolompos, Purino, Wendelin, and Lennox as the farmer's choice.

The third trial was sown on 13 November 2020 in the production area "Herzogenburg-, Tulln-, Stockerauer Gebiet" at the farm of Hermann Schwarzl (Dorfstr. 20, 3463 Starnwörth; test site: 48.43032, 16.03060; pre-crop: oilpumpkin). The trial included the following 7 varieties: Alessio, Capo, Liocharls, Mv-Elite-CCP, PS Dobromila, Wendelin and Arminius as the farmer's choice.

The last trial was sown on 20 October 2020 in the production area "Grieskirchen-Kremsmünster Gebiet" at the farm of Anton Berger (Hinterleiten 1, 4673 Gaspoltshofen; test site: 48.14947, 13.72543; pre-crop: grass-clover ley). The trial included the following 7 varieties: Alessio, Capo, Liocharls, Purino, Viki, Wendelin, and Bernstein as the farmer's choice.

Harvest of the field trials was done in July 2021 by harvesting replicated 1 m² samples from the trials in Gaspoltshofen, Starnwörth and Aspersdorf, whereas in Wallern the whole plots were combine harvested. Grain yield, thousand grain weight, test weight and crude protein content were determined on each sample.

Yield level was highest in Aspersdorf and Starnwörth, followed by Gaspoltshofen and Wallern (Figure 5). The low yield level in Wallern is not astonishing as this location is regularly suffering from water stress. Yield levels in Gaspoltshofen and Wallern are within the long-term range, whereas in the other two sites the yield level is above the long-term yield under organic conditions. This may be explained partly by harvesting only 1 m² samples but both sites are also characterized by a good soil fertility and excellent management.

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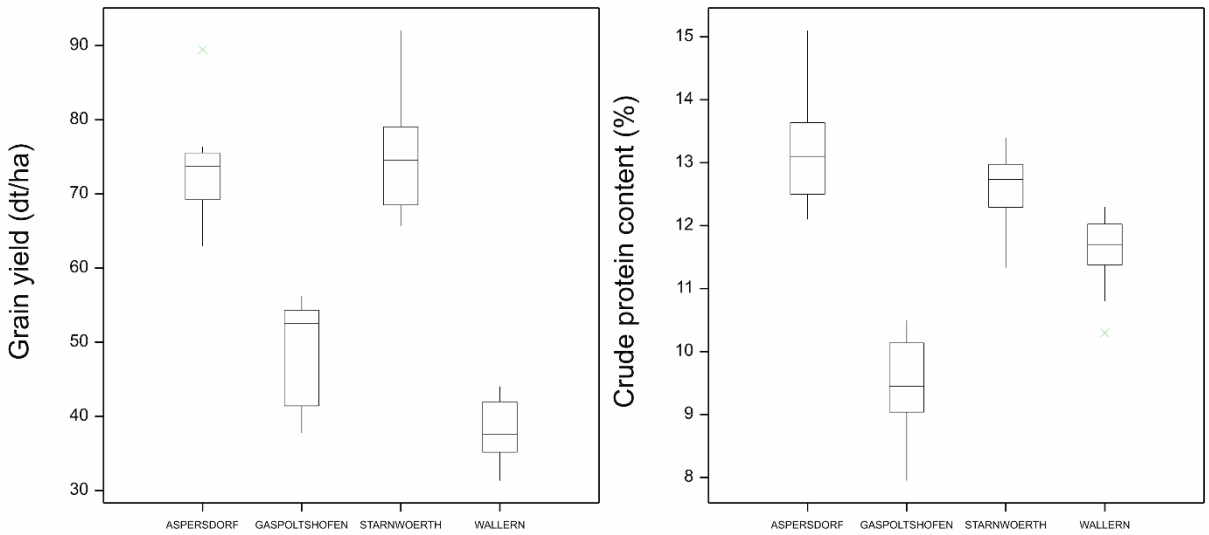

Figure 5. Site specific variation in grain yield and crude protein content of the Austrian winter wheat trials in 2021

It is worth mentioning that the farmer's choice varieties were the highest and lowest yielding varieties in Aspersdorf (i.e. Lennox) and Gaspoltshofen (i.e. Bernstein), respectively, whereas in the two other sites they (i.e., Arminius, Capo) were above average (Table 11). The two included CCPs (i.e. Liocharls and Mv Elit) showed diverse performance. While Mv Elit was medium in yield, Liocharls was medium to low yielding.

With respect to quality traits, in Aspersdorf all varieties reached test weights and crude protein contents required for organic quality wheat, 6 varieties reached even the protein limit of ≥ 13 % required for premium quality wheat (Table 11). In Starnwörth, only PS Dobromila reached a protein content of 13 %, all other varieties except Mv Elit had protein contents ≥ 12 %. Im Gaspoltshofen protein contents and test weights were significantly inferior. All samples were <11% protein content and would, therefore, only traded as feed wheat. In fact, the respective farmer is not interested in quality wheat as he uses his wheat on farm only for feeding chickens. In Wallern, only Adamus, Aurelius and Alessio exhibited protein contents ≥ 12 % and test weights ≥ 80 kg/hL. Two varieties, i.e. Tillsano and Mv Elit did not reach the limit of 11% protein content required at least by the milling industry.

Considering protein yield as measure for nitrogen use efficiency the top performing varieties were Lennox (1141 kg/ha), Mv Elit (1114 kg/ha) and Capo (1045 kg/ha) in Aspersdorf, IS Laudis (1010 kg/ha) and Arminius (999 kg/ha) in Starnwörth, Capo (561 kg/ha) and Alessio (551 kg/ha) in Gaspoltshofen, and Adamus (532 kg/ha) and PS Dobromila (512 kg/ha) in Wallern.

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Table 11. Genotype by location means for grain yield, thousand grain weight, test weight and crude protein content for the Austrian winter wheat trials in 2021

VAR[1]	LOC	GYLD (dt/ha)	TGW (g)	HLW (kg/hL)	PROT (%)
LENNOX	ASPERSDORF	89.45	37.7	81.8	12.8
IS LAUDIS	ASPERSDORF	76.40	37.0	83.9	12.5
EDELMANN	ASPERSDORF	75.75	42.1	85.4	12.7
CAPO	ASPERSDORF	74.90	41.0	84.9	14.0
PURINO	ASPERSDORF	74.75	40.1	83.4	12.1
Mv ELIT	ASPERSDORF	73.75	40.6	85.6	15.1
ALESSIO	ASPERSDORF	71.20	37.8	84.8	13.5
Mv KOLOMPOS	ASPERSDORF	70.95	46.6	80.4	12.2
ARNOLD	ASPERSDORF	68.65	41.2	81.2	13.7
EHOGOLD	ASPERSDORF	64.20	38.9	84.8	13.4
LIOCHARLS	ASPERSDORF	62.95	37.9	83.0	13.1
PS DOBROMILA	STARNWOERTH	92.03	40.0	86.2	13.0
IS LAUDIS	STARNWOERTH	79.30	37.8	85.7	12.7
ALESSIO	STARNWOERTH	78.27	44.3	85.7	12.2
ARMINIUS	STARNWOERTH	74.53	42.9	85.0	13.4
MV ELIT	STARNWOERTH	69.63	36.3	84.3	11.3
LIOCHARLS	STARNWOERTH	68.13	40.2	83.1	12.5
CAPO	STARNWOERTH	65.67	42.4	85.9	12.9
PURINO	GASPOLTSHOFEN	56.25	34.7	75.9	9.0
CAPO	GASPOLTSHOFEN	54.50	42.1	81.5	10.3
VIKI	GASPOLTSHOFEN	53.80	33.6	75.3	9.3
ALESSIO	GASPOLTSHOFEN	52.50	36.8	80.7	10.5
LIOCHARLS	GASPOLTSHOFEN	51.35	40.9	79.0	9.5
IS LAUDIS	GASPOLTSHOFEN	38.10	39.8	78.3	9.7
BERNSTEIN	GASPOLTSHOFEN	37.80	39.3	78.2	8.0
TOBIAS	WALLERN	44.06	34.7	79.3	11.2
ADAMUS	WALLERN	43.93	37.6	80.8	12.1
ARNOLD	WALLERN	42.00	33.8	78.4	11.4
PS DOBROMILA	WALLERN	41.96	35.6	79.6	12.2
MV ELIT	WALLERN	41.96	35.3	79.9	10.8
CAPO	WALLERN	41.19	31.6	79.0	11.9
ENERGO	WALLERN	39.86	35.6	79.1	11.4
ARMINIUS	WALLERN	37.84	35.5	80.2	11.6
IZALCO CS	WALLERN	37.61	34.8	79.4	11.4
CHRISTOPH	WALLERN	35.77	33.8	79.7	12.0
TILLSANO	WALLERN	35.70	37.7	80.3	10.3
EHOGOLD	WALLERN	35.70	35.9	80.8	11.3
EDELMANN	WALLERN	35.70	33.9	79.4	11.8
AURELIUS	WALLERN	33.53	33.7	80.1	12.1
BERNSTEIN	WALLERN	33.50	32.2	79.9	12.3
WENDELIN	WALLERN	31.53	35.9	79.3	11.7
ALESSIO	WALLERN	31.34	35.7	80.3	12.0

1 VAR, variety name; LOC, location; GYLD, grain yield (14% H2O); TGW, thousand grain weight; HLW, test/hectolitre weight; PROT, crude protein content

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2.3. Wheat farmer participatory trials in Serbia

Winter wheat farmers participatory field trials were performed by the Institute of Field and Vegetable Crops (IFVC) on three organic farms located in the north Serbian province Vojvodina (typical Pannonian plain). The aim of these trials was to support farmers in selection of wheat varieties that are suitable for their pedoclimatic region. Furthermore, during the growth season, we trained farmers to select varieties that are most convenient for their environment.

On each farm 9 winter wheat varieties were included, and four of them were varieties from Serbia that are most suitable for organic farming. Plot size was 300 m^2 (3 x 100 m).

Table 12. List of varieties sown on farms

	Variety	Country of origin
1	MV CCP	Hungary
2	IS Laudis	Slovakia
3	PS Dobromila	Slovakia
4	Capo	Austria
5	Alessio	Austria
6	NS 40 S	Serbia
7	NS Obala	Serbia
8	NS Ilina	Serbia
9	NS Mila	Serbia

Below are locations, name of farms, sowing dates and sowing rates:

- Čenej-Nada Letić
- Čurug-Global Seed
- Šuljam-Ignjat Jurišić
- *Sowing dates were:* 01.12.2020 Čenej; 02.12.2020 Šuljam; 04.12.2020 Čurug
- Sowing rate was 600/m^2 as sowing was out from optimum date

Harvest of the WP6 varieties from Serbia (9) was performed with the hand harvester. From each farm, samples were collected, and post-harvest analyses were performed. For sampling, we built a frame size 1 x 1 m and samples were taken from four spots on each plot.

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Figure 6. WP6 sampling with hand harvester taken in Šuljam (05.07.2021).

2.3.1. Results

Values of the examined traits are shown in Table 13. Grain yield varied between varieties and among locations. The highest grain yield (6.3 t/ha) was recorded for the variety Capo at the Šuljam location, while the lowest was recorded for PS Dobromila 1.2 t/ha (Čenej). Furthermore, PS Dobromila had the highest hectolitre weight 90.4 kg/hl (Šuljam), while the lowest hectolitre weight 63.6 kg/hl was recorded for IS Laudis and Alessio (Šuljam). Highest 1000 grain weight 46.2 g was recorded for the variety Alessio (Šuljam). On the other hand, lowest value for 1000 grain weight 34.5 g was recorded in the Slovakian variety IS Laudis (Čurug).

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Table 13. Values of the examined traits

	Yield (t/ha)			Hectolitre weight (kg/hl)			1000 grain weight (g)		
Genotype/ Location	Čenej	Čurug	Šuljam	Čenej	Čurug	Šuljam	Čenej	Čurug	Šuljam
MV CCP	2.8	5.0	3.0	82.5	75.2	73.8	37.9	43.2	42.9
	3.0	4.7	2.5	76.3	82.7	74.0	40.2	41.8	41.6
	3.2	5.3	2.7	77.2	81.4	73.5	41.6	43.4	43.0
	3.4	5.5	3.7	76.1	80.7	74.1	39.5	40.0	42.0
AVERAGE	**3.1**	**5.1**	**3.0**	**78.0**	**80.0**	**73.9**	**39.8**	**42.1**	**42.4**
IS Laudis	1.5	3.6	3.2	78.4	79.3	64.3	38.2	37.2	42.4
	1.9	3.2	3.4	76.0	84.3	65.0	40.0	34.5	42.0
	1.7	3.5	3.0	80.8	85.9	63.6	36.4	36.0	40.8
	2.0	3.8	2.7	83.2	81.5	64.7	39.4	37.5	41.7
AVERAGE	**1.8**	**3.5**	**3.1**	**79.6**	**82.7**	**64.4**	**38.5**	**36.3**	**41.7**
PS Dobromila	1.6	4.9	4.5	84.2	87.8	90.0	38.5	34.6	41.2
	1.4	5.2	5.0	77.9	79.8	88.4	35.9	36.5	40.3
	1.2	5.4	4.4	84.9	86.5	89.6	39.5	35.5	41.6
	1.7	4.7	4.2	83.8	86.0	90.4	37.3	37.8	40.8
AVERAGE	**1.5**	**5.1**	**4.5**	**82.7**	**85.0**	**89.6**	**37.8**	**36.1**	**41.0**
Capo	2.7	4.6	6.0	82.4	87.7	84.6	41.4	46.1	43.0
	3.0	5.0	5.7	83.7	83.3	85.3	38.7	44.1	43.5
	2.4	5.3	5.9	80.8	84.0	84.2	39.1	46.6	42.2
	2.9	4.8	6.3	77.0	82.1	83.6	42.1	43.2	41.9
AVERAGE	**2.8**	**4.9**	**6.0**	**81.0**	**84.3**	**84.4**	**40.3**	**45.0**	**42.7**
Alessio	2.0	3.4	2.2	81.4	78.8	65.0	41.2	41.3	46.2
	2.4	2.8	2.4	78.3	79.2	63.8	39.4	42.3	45.7
	1.9	3.1	2.1	83.7	75.8	64.5	38.2	42.9	45.3
	2.2	3.6	2.9	77.4	82.7	63.6	37.6	39.5	45.9
AVERAGE	**2.1**	**3.2**	**2.4**	**80.2**	**79.1**	**64.2**	**39.1**	**41.5**	**45.8**
NS 40S	2.1	2.7	2.6	79.2	75.3	69.7	37.8	35.9	45.0
	2.5	3.1	2.9	78.1	79.8	68.4	41.5	36.6	44.6
	1.7	2.8	3.1	73.2	77.8	69.1	38.6	39.0	45.2
	1.9	3.4	3.0	78.7	81.9	67.6	39.3	37.6	44.1
AVERAGE	**2.1**	**3.0**	**2.9**	**77.3**	**78.7**	**68.7**	**39.3**	**37.3**	**44.7**
NS Obala	2.7	3.3	3.1	78.4	78.8	73.5	35.5	40.1	43.9
	2.9	3.0	2.6	81.1	74.2	72.1	38.3	38.8	41.7
	3.1	3.6	3.3	76.1	80.5	74.0	37.9	42.1	43.2
	2.5	3.4	3.0	74.8	79.8	72.8	39.1	39.4	42.5
AVERAGE	**2.8**	**3.3**	**3.0**	**77.6**	**78.3**	**73.1**	**37.7**	**40.1**	**42.8**
NS Ilina	3.1	5.0	3.8	79.9	81.3	71.1	38.0	40.2	40.3
	3.5	5.3	3.5	73.1	75.2	70.3	37.2	36.8	38.8
	2.9	4.7	3.7	78.3	77.1	72.3	34.6	37.4	39.4
	3.3	5.6	3.2	75.9	81.6	72.0	36.4	38.3	39.9
AVERAGE	**3.2**	**5.2**	**3.6**	**76.8**	**78.8**	**71.4**	**36.5**	**38.2**	**39.6**
NS Mila	3.6	5.1	5.5	76.7	79.9	85.2	42.7	38.8	45.3
	3.1	5.7	5.3	82.4	81.5	83.6	41.2	42.1	45.7
	2.7	5.3	5.0	82.6	82.5	84.1	38.6	39.8	44.7
	3.1	5.0	5.7	83.8	75.6	84.9	40.7	38.9	43.4
AVERAGE	**3.1**	**5.3**	**5.4**	**81.4**	**79.9**	**84.5**	**40.8**	**39.9**	**44.8**

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2.4. Durum wheat trials in Italy

The durum wheat participatory breeding program of Tuscia University was performed in three organic farms located in central area of Italy with different environments characteristics from seaside to inland, respectively Montalto di Castro at 68 m asl close to the sea, Viterbo at 300 m asl with hill environment, and Rieti at 400 m asl with mountain environment (Figure 7). For each farm were chosen durum wheat accessions developed in Central Europe and in the Mediterranean basin, with the objectives of evaluating and selecting, together with the farmers, the most suitable accession(s) for each location. In the trials of Montalto di Castro and Rieti was included also a population obtained from a mix of different genotypes originated from both Central Europe and Mediterranean basin. The germplasm was evaluated in spring 2021 measuring several traits such as: percentage of ground cover (GCover), growth habit (GHabit), phenological stage using the BBCH scale (Lancashire et al. 1991[1]), and average number of tillers (ATillers); while at the end of the agricultural cycle was measured the seed production and the grain quality with NIR method. The experiment was highly affected by the adverse environmental conditions of 2020/2021 season characterized by an excess of rainfall (at the sowing) and cold stress (at the sowing and late spring period).

2.4.1. Results

The accessions in Montalto di Castro were less affected than the ones grown in Viterbo and Rieti. In Tables 14-16 are reported the measurements taken at the end of March 2021, in Montalto di Castro, Viterbo, and Rieti respectively. Comparing the data collected in the three locations, it's visible how at the same time and phenological stage the plants were under stress conditions; GCover, GHabit and number of tillers values of the accessions grown in Viterbo and Rieti are much lower than the values registered from the accessions grown in Montalto di Castro. Moreover, the accessions in Rieti were totally affected by the severe cold stress, and due to that it was recorded a total loss of production. In Montalto di Castro was registered a lower winter damage which led into a higher production of every accession, in particular the Mediterranean accessions Azeghar 2-1 (56) and Fuego (Figure 8) that however have registered a lower protein content and wet gluten than other accessions (Table 4). Viterbo was moderately affected by the frost events, and the Central Europe accessions, such as Mv-Makaroni and Mv-Pelsodur, have produced more than the Mediterranean ones, exception were Fuego and

[1] Lancashire P D, Bleiholder H, Boom TVD, Langelüddeke P, Stauss R, Weber E, Witzenberger A (1991). A uniform decimal code for growth stages of crops and weeds. Annals of applied Biology, *119*(3), 561-601.

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Azeghar 2-1 (56) which again have produced a good quantity though not statistically different (Figure 9). Unfortunately, the grain production obtained in Viterbo wasn't enough to perform NIR analysis.

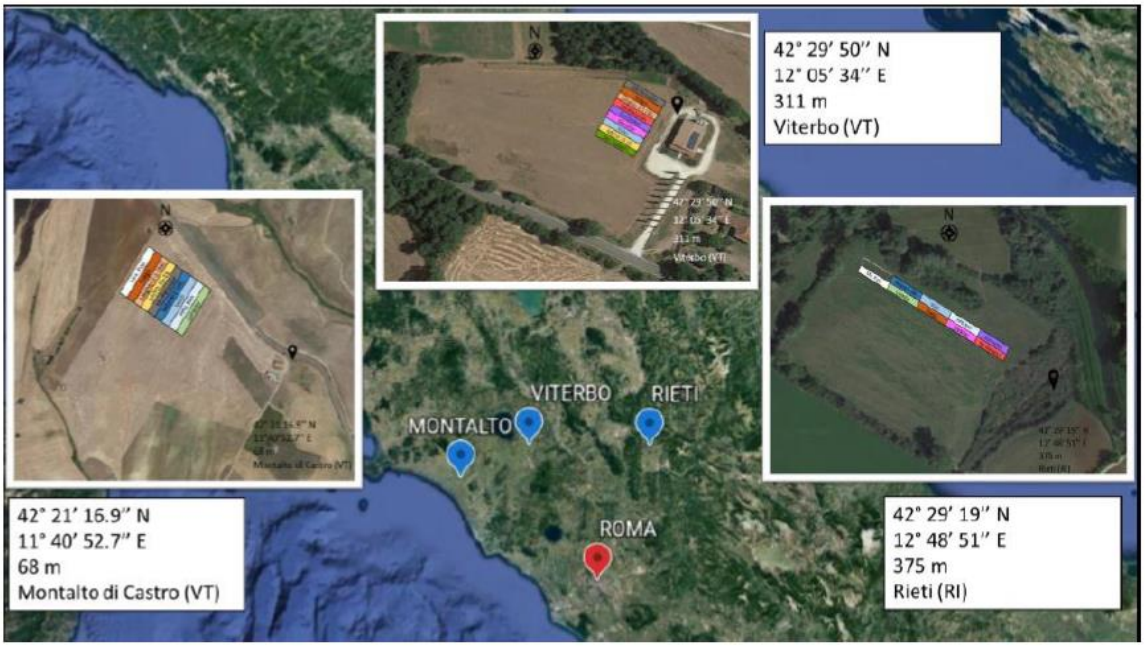

Figure 7. Location map of the three farms

Table 14. Spring measurements of durum wheat accessions located in Montalto di Castro

Accession	Gcover (%)	GHabits	Stage (BBCH)	ATillers
Lunadur	28.13	3.0	29	4.5
HFN 94n	83.10	3.0	31	9.5
Vulci	89.36	1.5	30	9.5
Sebatel2 (45)	81.68	1.5	31	5.5
Mv-Pelsodur	83.15	1.0	29	5.5
MVTD 15-19	80.49	4.0	28	9.5
Azeghar 2-1 (56)	83.41	3.0	31	5.5
Fuego	83.00	1.5	32	3.5
Mix-Population	77.00	2.0	30	3.5
Means	76.59	2.38	30.11	6.28
Standard dev.	18.46	1.03	1.27	2.54

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Table 15. Spring measurements of durum wheat accessions located in Viterbo

Accession	GCover (%)	GHabit	Stage (BBCH)	ATillers
Sen. Cappelli	39.59	1.0	30	1.5
MVTD 15-19	21.56	3.0	28	4.5
Vulci	40.56	1.5	29	2.0
Gibraltar	30.43	1.5	29	1.0
Ousloukos	49.06	1.5	30	3.5
Mv-Makaroni	38.72	3.0	29	4.5
Azeghar 2-1 (56)	30.98	1.5	29	2.5
Fuego	23.80	1.5	30	1.5
Mv-Pelsodur	34.40	1.5	29	1.5
Means	34.34	1.78	29.22	2.50
Standard dev.	8.68	0.71	0.67	1.35

Table 16. Spring measurements of durum wheat accessions located in Rieti

Accession	Gcover (%)	GHabits	Stage (BBCH)	ATillers
Mv-Makaroni	50.6	1	30	1.5
Ousloukos	40.5	2	30	1.0
Gibraltar	17.8	1	30	1.0
HFN 94n	37.1	2	30	2.0
Fuego	0.0	0	0	0.0
Vulci	4.1	3	28	3.5
Lunadur	3.0	3	27	3.5
Sebatel2 /45)	0.8	5	30	2.0
Mix-Population	10.5	3	28	3.0
Means*	20.55	2.50	29.13	2.19
Standard dev.*	19.46	1.31	1.25	1.03

*Computed without considering Fuego

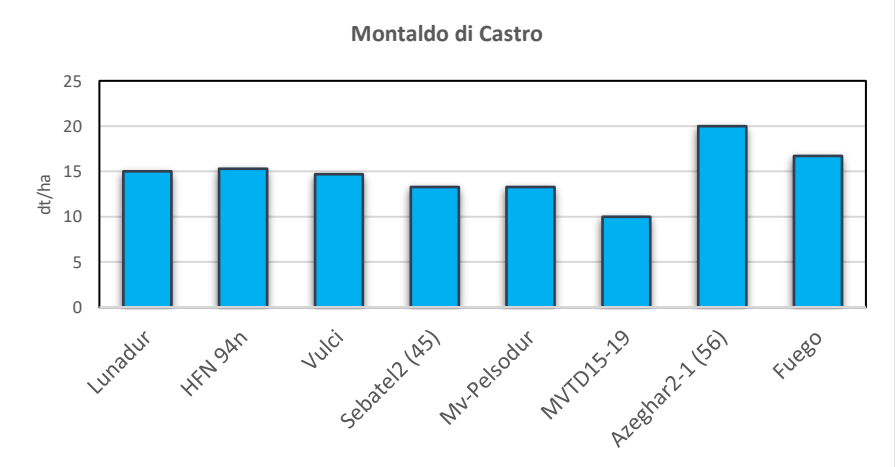

Figure 8. Production in Montalto di Castro

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Table 17. NIR analysis of the accessions grown in Montalto di Castro

Accessions	Humidity (%)	Proteins (%)	Wet gluten (%)	Test weight (Kg/hl)
Lunadur	12.5	12.5	24.9	79.8
HFN 94n	12.4	11.8	23.4	80.4
Vulci	12.4	13.0	26.2	80.5
Sebatel2 (45)	12.3	12.8	25.7	80.2
Mv-Pelsodur	12.5	12.1	24.1	82.4
MVTD15-19	12.4	12.0	23.8	76.8
Azeghar2-1 (56)	12.3	10.3	19.9	81.6
Fuego	12.5	10.5	20.2	81.9
Population	12.3	18.8	21.1	81.1
Means	12.40	12.64	23.26	80.52
Standard deviation	0.09	2.49	2.34	1.64

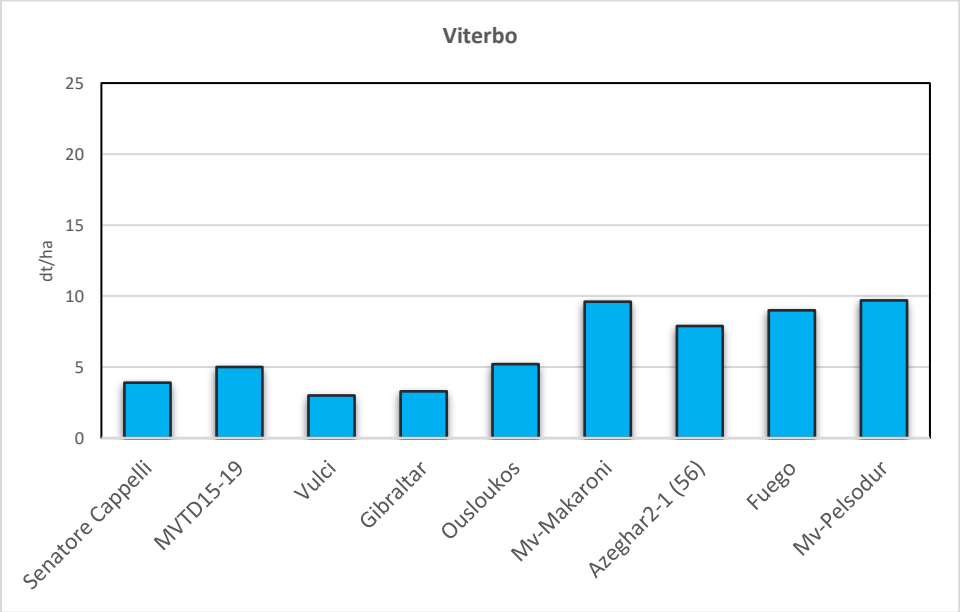

Figure 9. Production in Viterbo

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2.5. Participatory plant breeding in Hungary

Participatory plant breeding is defined as a plant breeding method in which farmers, breeders, and other stakeholders (end-users, traders, processors, etc.) participate together in the development of a new variety. Participatory plant breeding (PPB) was firstly applied in developing countries. In the last decades PPB projects were started in developed countries too, many of them were aimed to develop new varieties for the organic sector. There are two types of participatory programmes, depending on when the participation starts: participatory variety selection (PVS) and participatory plant breeding (PPB). ATK applies both types during the cooperation with organic farmers in the framework of ECOBREED to develop new winter wheat lines/populations.

ATK's composite-cross population (Mv Elit CCP, developed from seven winter bread wheat varieties) was multiplied in the ECOBREED project and distributed among project partners. Testing of Mv Elit CCP has started in season 2020/2021 in four countries (Austria, Slovakia, Serbia, and Hungary) on 14 organic farms with the active participation of farmers.

The Hungarian wheat PPB was started in autumn 2020. Winter wheat varieties and two populations were sent to organic farmers with the aim to start PVS and PPB. Although five farms were planned, due to the unfavourable autumn weather conditions, the sowing was successfully only at two Hungarian and one Slovakian locations: at Szár, Füzesgyarmat and Zselíz (Fig. 10).

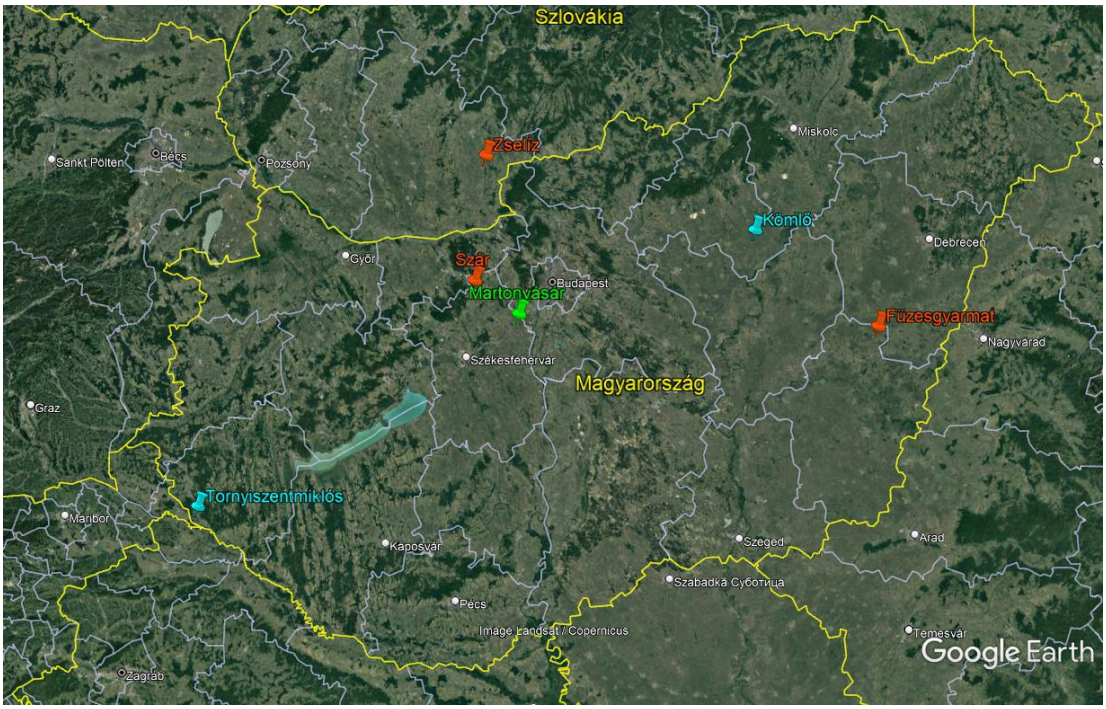

Figure 10. Locations of participatory plant breeding trials organized by ATK. Participating organic farms are in red (2021, 2022) and blue (2022), breeding station (ATK) in green

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PPB trials for testing winter wheat varieties and populations were carried out using medium plots at Zselíz and Füzesgyarmat, and in replicated small plot trial at Szár (Figure 11) Cultivars were evaluated by farmers during the vegetation period: reaction to diseases, plant height, lodging was assessed. Breeders visited the farms, and they discussed the steps of observation, selection, and harvest of trials with farmers. Participatory breeding trial was harvested extremely late at one site (Zselíz) due to the very rainy weather conditions in summer, at this location estimated yield data were determined from harvested samples. Yield and protein content data for the 2021 on-farm trials are shown in Table 20. Yield results of participatory trials cannot be used for comparison, because of the different plot sizes and data types (estimated vs. actual yield), but they are useful to rank the tested cultivars within each farm. The participatory trials continue in season 2021/22 with two additional farms: Kömlő and Tornyiszentmiklós (Figure 10).

Table 18. Yield and protein content results of participatory trials in 2021

Farm	**Szár**		**Füzesgyarmat**		**Zselíz**	
Cultivar	Yield t/ha	Protein %	Yield t/ha	Protein %	Yield t/ha	Protein %
Mv Kolo	7.07	14.00				
Mv Kolompos	7.21	14.55				
Mv Kepe	6.62	13.80				
Mv Káplár	7.04	11.30				
Mv Karéj	7.49	14.70				
Mv Lucilla	7.55	14.45				
Mv Ménrót	6.78	12.30	2.35	14.60	6.00	13.70
Mv Tarsoly	7.61	14.45	2.14	11.80	5.50	12.10
Mv Pántlika	6.50	13.03	2.89	10.10	5.40	13.30
Mv Uncia	7.57	12.98			4.70	13.60
Mv Elit CCP	7.14	15.30	2.22	14.70	5.40	13.70
Mv Bio2020 Pop	8.58	13.65	2.34	14.70	5.60	13.20

Figure 11. Participatory variety selection and participatory plant breeding trials: Füzesgyarmat (left) and Szár (right), 2021

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Our participatory plant breeding program was started based on the two populations (Mv Elit CCP and Mv Bio2020 Pop) sown by farmers. Mv Elit CCP was developed in 2007 and no selection was performed on this population since then. Mv Bio2020 Pop was made in 2020, as a mixture of segregating winter wheat F2 populations which parents were formerly selected in project ECOBREED as appropriate cultivars for organic farming. Positive spike selection was performed on both populations by farmers before harvest and the selected spikes were sent to ATK. Selected spikes were threshed into bulks and 6 new subpopulations were developed based on the population and farm of origin (Fig. 12) The new subpopulations and the unselected ("original") populations were sown at two locations in October 2021: on-station (Martonvásár, ATK) and on-farm (Szár, farmer) in unreplicated, small-plot trial for multiplication and testing.

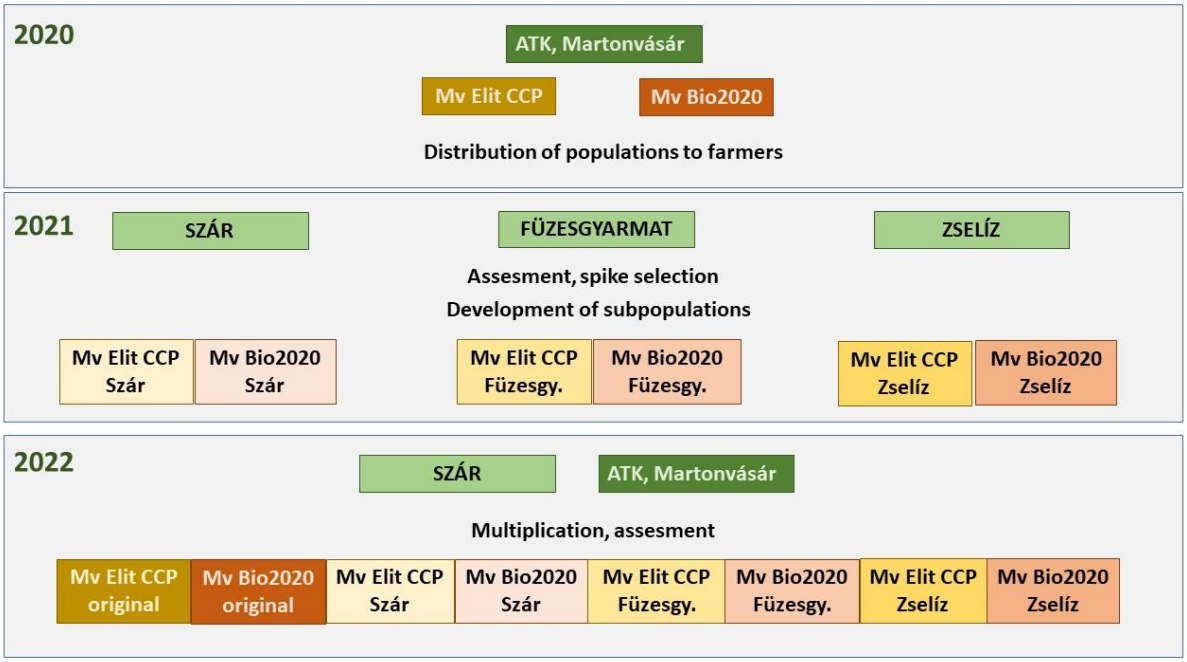

Figure 12. Participatory plant breeding program of ATK based on Mv Elit CCP and Mv Bio2020 Pop populations with the participation of three organic farms (Szár,Füzesgyarmat and Zselíz) and the breeding institute (ATK, Martonvásár)

Our participatory trials and ECOBREED project were presented at the Hungarian Field Day in June 2021 at Szár. The demonstration event was organized by ÖMKi. A workshop dedicated to participatory breeding was organized for interested participants moderated by ATK and ÖMKi.

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Figure 13. Field Day and Participatory Plant Breeding Workshop, Szár, 22 June 2021

2.6. Wheat farmers participatory field trials in Slovenia

2.6.1. Methods

The winter wheat (*Triticum aestivum* L.) farmer participatory field trial in Slovenia was established on organic field at the testing station of the Agricultural Institute of Slovenia, in Jablje (46°08'37.3" N, 14°34'39.2" E; 320 m a.s.l., subalpine climate). The soil type at the trial was Umbrian planosol with a silt loam texture.

A total of 22 cultivars (both domestic and international) were selected for testing by researchers and variety experts. Varieties were selected based on their specific traits for organic cultivation and performance in various organic and low-input trials. The chosen varieties by Slovenian experts were Ingenio, Savinja, Tata mata, Reska, Primorka, Marinka, Illico, Izalco CS, Gorolka, Vulkan and Nexera and the chosen varieties within the ECOBREED project were Liocharls, Arnold, Capo, Aurelious, Albertus, IS Laudis, Purino, Viki, Wendelin, Edelman and Ehogold.

Tillage of the experimental plots was conventional, with a 25 cm deep plough followed by seedbed preparation with cultivation. A three-year rotation of maize, winter wheat or winter spelt, and spring peas is practiced at the site. Prior the seeding, weeds were controlled using the false seedbed method. Two trials were established based on the selection of cultivars (Slovenian or ECOBREED selection). Cultivars were seeded on 28 October 2020 at a density of 400 viable seeds/m2, using the Wintersteiger experimental plot seeder. Design of the experiments was a randomized block with four replications. Size of the plot was 15 m^2 (6 x 2,5 m). During the vegetation a total of 63 kg N/ha was added, using the organic fertilizer Azocor 10.5 % at the tillering and stem elongation phases. No mechanical weed control, fungicides or insecticides were applied during growth.

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The following traits were evaluated to assess the development and agronomic performance of cultivars: date of heading, number of wheat heads, plant height (cm), canopy, lodging susceptibility, identification and scoring of diseases and pests, grain yield (kg/ha), grains moisture at harvest (%) and test weight (kg/hl). Plant height was measured on ten randomly selected individual plants in each plot before harvest. Ground cover (canopy), lodging susceptibility, diseases and pests were assessed using a 1–9 scale (1 meaning low prevalence/susceptibility). Ground cover was estimated at the full flowering stage, while diseases and pests were evaluated at the full flowering stage and late milk stages.

Trials were harvested at the full maturity stage using a Wintersteiger Nursery Master plot harvester. Approximately 1 kg of representative grain samples were used for moisture determination and quality analyses. Contents of moisture, protein, starch and wet gluten were analysed using the Infratec Nova NIR analyser. Sedimentation values were analysed using the Zeleny sedimentation test.

2.6.2. Results

The weather conditions during the vegetation period were generally favourable for growth and development of winter wheat. Only significant deviation from the long-term average weather conditions was observed in May, with a colder climate and higher precipitation prolonging the vegetation period of wheat for about 10–12 days.

Table 19. Mean daily air temperature and cumulative monthly precipitation from sowing to harvest in the 2020/2021 growing season at Jablje

Year	**2015**	
	Temperature (°C)	**Precipitation (mm)**
October	10.1	161.9
November	3.5	38.8
December	1.5	186.9
January	-1.1	143.0
February	3.0	81.2
March	4.0	27.7
April	7.3	58.5
May	11.7	262.5
June	20.7	23.2
July	21.1	105.0
Mean/sum	**8.2**	**1088.7**

The results of plant height are presented in Figure 14. Mean plant height in the first trial was smaller than in the second trial (93.9 cm and 101.8 cm, respectively). The plant height ranged from 76.3 cm (Tata mata) to 113.3 cm (Marinka) in Trial 1 and from 85.0 cm (Arnold) to 117.5 cm (Liocharls) in Trial 2. Cultivars with highest plants s were Liocharls, Ehogold, Marinka, Primorka and Capo.

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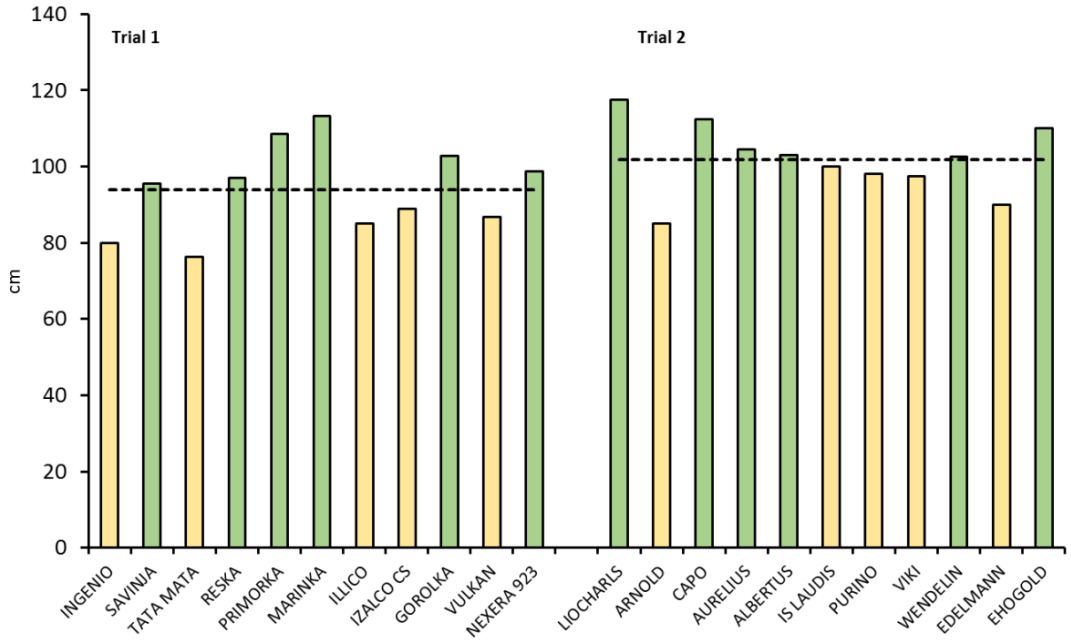

Figure 14. Plant height of the individual cultivars (columns) and trial mean (dotted line) in organic trials at Jablje in growing season 2020/2021. Cultivars marked with green color were higher compared to the mean height of the specific trial

Differences in ground cover between cultivars were also observed, while no differences in lodging tolerance were observed (Table 20). Estimates of ground cover using the 1-9 scale (9 being the highest estimate of ground cover) showed smaller cover for cultivars in Trial 1 (mean estimate 6,2) compared to Trial 2 (mean estimate 7.0). The ground cover of cultivars ranged from 5 (Ingenio) to 7.8 (Reska) in Trial 1 and from 6.3 (Wendelin) to 8.3 cm (Purino) in Trial 2. Nevertheless, observed differences in the ground cover between the cultivars were not reflected with differences in the weed presence in the growing season 2020/2021.

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Table 20. Estimates of ground cover and lodging tolerance of selected cultivars in organic trials at Jablje in growing season 2020/2021 using the 1-9 scale

Cultivar	Ground cover	Lodging	Cultivar	Ground cover	Lodging
Ingenio	5.0	1	Liocharls	7.0	1
Savinja	5.2	1	Arnold	6.8	1
Tata mata	5.5	1	Capo	6.8	1
Reska	7.8	1	Aurelious	7.0	1
Primorka	5.8	1	Albertus	7.0	1
Marinka	6.3	1	IS Laudis	6.8	1
Illico	6.8	1	Purino	8.3	1
Izalco CS	5.5	1	Viki	7.3	1
Gorolka	7.0	1	Wendelin	6.3	1
Vulkan	7.0	1	Edelmann	6.5	1
Nexera 923	5.8	1	Ehogold	7.0	1
Mean	**6.2**	**1**	**Mean**	**7.0**	**1**

Septoria tritici was the most prevalent disease observed in field trials. No difference in the prevalence of the disease between the trials was observed (estimates of 6.8 and 6.7 for Trial 1 and Trial 2, respectively), while individual cultivars were showing differences in tolerance. In Trial 1 estimates of the Septoria ranged from 4.0 (Reska) to 8.0 (Illico, Marinka, Izalco CS, Vulkan) and in Trial 2 estimates ranged from 5.0 (Viki and Wendelin) to 8.0 (Arnold, Capo and Aurelius). Cultivars Reska, Viki and Wendelin appear to have higher tolerance to Septoria. Presence of steam and leaf rust were also noticed in the trials. In Trial 1, estimates for steam rust ranged from 1.0 (Ingenio, Savinja, Tata Mata, Primorka and Izalco) to 4.0 (Reska, Marinka, Illico) and in Trial 2 from 1 (Arnold and Wendelin) to 7.0 (Liocharls, Albertus and Viki). ECOBREED selected cultivars showed to be more susceptible to the specific race of rust fungus that was present in the growing season 2020/2021 at Jablje. Leaf rust was less prevalent at Jablje, with no presence observed in Trials 1, while individual cultivars in Trial 2 showed susceptibility (Albertus, 5.0; Capo, 4.0; Viki, 4.0, and Liocharls, 3.0). The cereal leaf beetle (*Oulema melanopus*) was the most prevalent pest found in trials. Comparing mean estimates of trials showed, that ECOBREED-selected cultivars were showing higher damage to the beetle (mean estimates of 2.1 and 4.1 for Trial 1 and Trial 2, respectively). In Trial 1, the highest estimate of 3 was found for cultivars Tata mata and Vulkan, while in Trial 2, the highest estimate of 7 was found for cultivar Aurelius, followed by Arnold and IS Laudis (estimate 6). Aphids were generally present on all of the cultivars, with only small variation among the cultivars.

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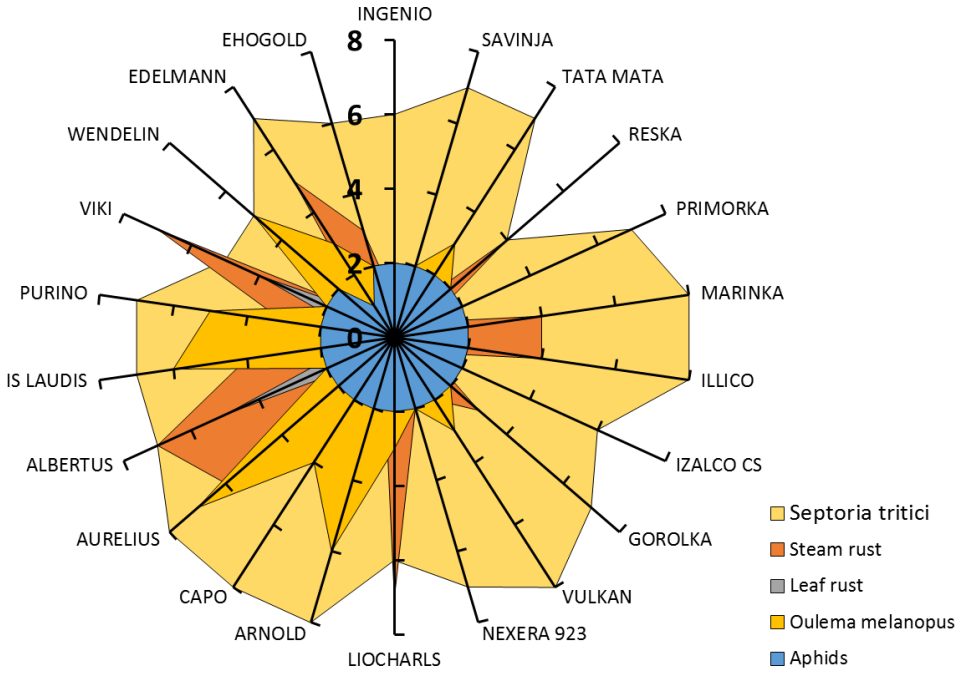

Figure 15. Scorings of disease and pests' prevalence for selected cultivars in organic trials at Jablje in growing season 2020/2021

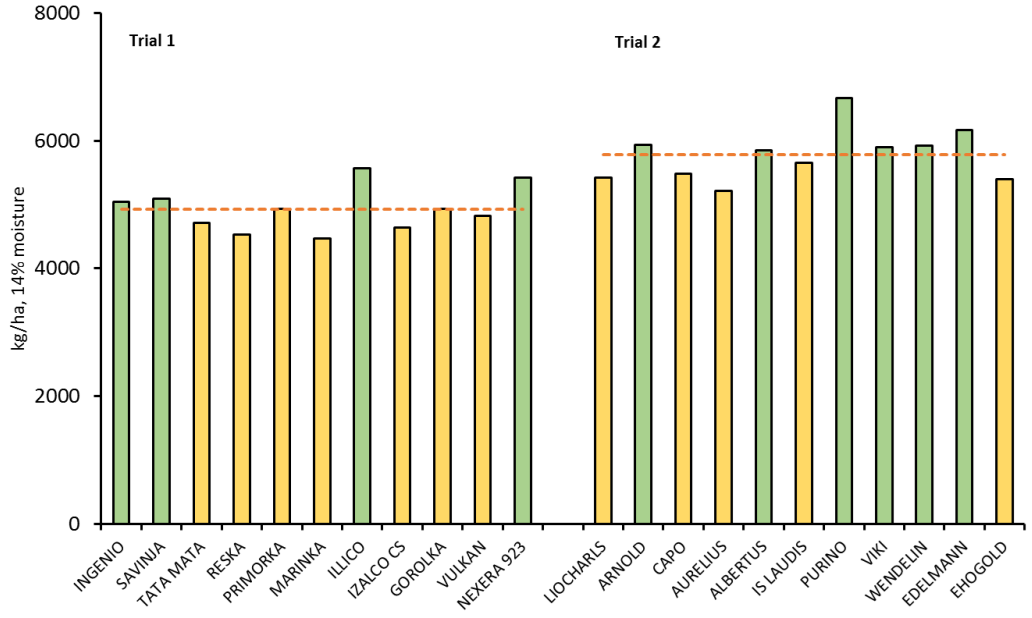

Figure 16. Grain yield of the individual cultivars (columns) and trial mean (dotted line) in organic trials at Jablje in growing season 2020/2021. Yields of cultivars marked with green colour were higher compared to the mean height of the specific trial

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Grain yields calculated to 14% moisture are shown in Figure 16. Cultivars selected in the ECOBREED had higher mean yields in organic production. Mean grain yield in Trial 1 was 4923 kg/ha and mean grain yield in Trial 2 was 5781 kg/ha. There was also smaller variation among the cultivars in Trial 2 compared to cultivars in Trial 1. Comparing cultivars in Trial showed mean grain yields ranging from 4473 kg/ha (Marinka) to 5569 kg/ha (Illico), while in Trial 2 mean grain yields ranged from 5213 kg/ha (Aurelius) to 6670 kg/ha (Purino). The highest yielding cultivars were Purino, Edelman (6170 kg/ha), Arnold (5930 kg/ha), Viki (5895 kg/ha) and Albertus (5847 kg/ha). It is noteworthy that higher grain moistures at harvest were observed for cultivars in Trial 2, although none exceeded 14%.

Results of analysis on test weight, protein content, sedimentation value, gluten and starch are shown in Table 21. Mean test weight was higher in Trial 1 (75.7 kg/hl) and ranged from 70.4 kg/hl (Ingenio) to 80.3 kg/hl (Gorolka). In Trial 2, test weight ranged from 70.7 kg/hl (Viki) to 78.1 (Capo). Cultivars with the highest test weight were Gorolka and Tata mata (80.2). Protein content showed no differences between both trials. In Trial 1 content ranged from 8.6% (Illico) to 11.5% (Izalco CS) while in Trial 2 content ranged from 8.9% (Purino) to 10.6% (Albertus). The dilution effect of protein content with higher dry matter production can be noticed with the highest yielding cultivars showing the lowest protein content. Sedimentation values also showed no difference between the mean values of both trials. Value ranged from 21 ml (Illico) to 35 m (Izalco CS) in Trial 1 and from 23 ml (Purino and Ehogold) to 34 ml (Albertus) in Trial 2. Cultivars with the highest sedimentation value were Izalco CS, Albertus, Tata Mata, and Edelman (both 31 ml), while the cultivars with the higher grain yield were generally showing the smallest sedimentation value. Percentage of wet gluten ranged from 15.6% (Illico) to 23.5% (Izalco CS) in Trial 1, and from 15.6% (Purino) to 20.4% (Albertus). Percentage of starch generally showed smaller variation than other quality traits and ranged from 70.9% (Ingenio) to 73.5% (Nexera 923) in Trial 1, and from 69.3% (Viki) to 72.9% (Ehogold).

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Table 21. Test weight, content of protein, sedimentation value, percentage of wet gluten, and percentage of starch in grains of selected cultivars in organic trials at Jablje in growing season 2020/2021

Cultivar	Test weight kg	Protein content %, DM	Sedimentation value ml	Wet gluten %	Starch %, DM
Ingenio	70.4	9.8	26	18.5	70.9
Savinja	76.0	10.0	29	19.3	72.2
Tata Mata	80.2	10.6	31	21.5	72.7
Reska	76.8	10.5	29	20.6	72.4
Primorka	75.5	9.3	26	17.4	71.9
Marinka	74.7	9.5	27	17.9	71.9
Illico	72.3	8.6	21	15.6	72.5
Izalco CS	77.1	11.5	35	23.5	72.1
Gorolka	80.3	10.1	25	19.7	72.7
Vulkan	73.9	9.9	27	18.8	72.3
Nexera 923	76.0	9.4	26	18.7	73.5
Mean	**75.7**	**9.9**	**28**	**19.2**	**72.3**
Liocharls	72.4	9.4	25	17.2	72.1
Arnold	73.3	10.2	28	18.4	70.3
Capo	78.1	10.1	27	20.2	72.8
Aurelious	73.9	9.5	27	18.6	72.5
Albertus	76.1	10.6	34	20.4	72.2
IS Laudis	74.3	10.4	29	20.1	71.1
Purino	72.3	8.9	23	15.6	72.3
Viki	70.7	10.4	29	18.8	69.3
Wendelin	72.9	9.9	26	17.3	70.1
Edelmann	75.2	10.4	31	19.5	72.5
Ehogold	76.1	9.4	23	17.7	72.9
Mean	**74.1**	**9.9**	**28**	**18.5**	**71.6**

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2.7. Wheat participatory field trials in the Slovak Republic

The participatory field trials were performed on four organic farms located in Slovakia (Table 22 and Figure 17).

Table 22. List of organic farms with participatory field trials in Slovakia

Name of farm	Farm address	GPS latitude	GPS longitude	MSL (m)	Area of farm site
BIOMILA spol. s r.o.	Rudník 428	48,760822	17,638586	325	135,07 ha
Vladimír Zeman SHR	Polianka 115	48,721571	17,595196	416	179,87 ha
Martin Kolárik SHR	Horná Polianka 203	48,72704	17,58127	416	64,84 ha
SEMA HŠ s.r.o.	Nový Dvor 1862	48,214648	17,597916	121	1313 ha
Note: GPS - global positioning system; MSL - mean sea level					

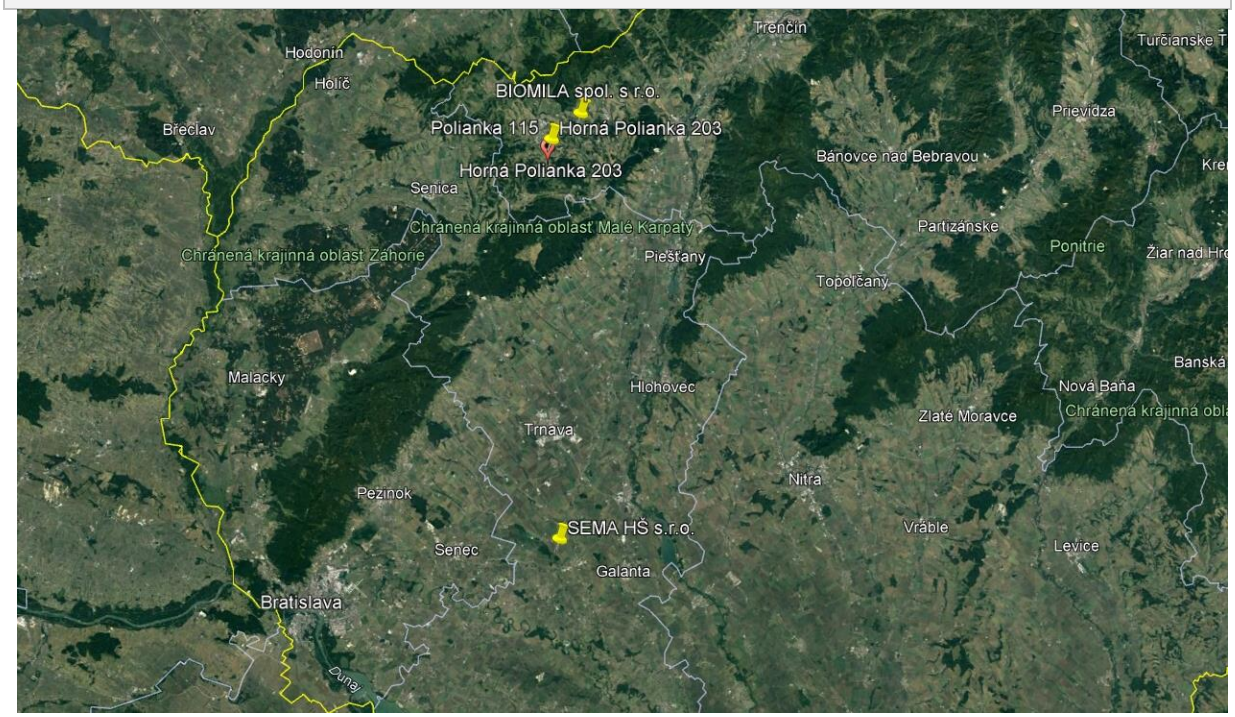

Figure 17. Location map of the four farms in Slovakia

A total of eight wheat varieties (both domestic and international) were sown in autumn 2020 in plots with a minimum plot size of 300 m^2 (Table 23). Selected varieties were chosen for their specific traits for organic cultivation and low-input trials. The sowing dates and conditions were different. Prior to the seedling, weeds were controlled using the false seedbed method. The sowing density was 450 plants per m^2 at each location. Inter-row cultivation was performed three times during the growing season and weed infestation was low.

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Table 23. The list of varieties with their 1000 grain weight (TGW)

Variety name	TGW (g)	Seeding rate (g/m^2)
Arnold	36.50	22.50
Aurelius	31.74	18.00
IS Laudis	36.20	18.00
Viki	34.19	18.00
Wendelin	35.76	20.25
PS Dobromila	46.90	18.00
Ehogold	38.99	20.25
Hungary population	37.09	20.25

Cultivars were evaluated during the vegetation period on all farms: reaction to diseases and pests, plant height, lodging, and yield. Ground cover, lodging susceptibility, diseases, and pests were assessed using a 1-9 scale (1 meaning low prevalence).

The weather conditions during the vegetation period on all farms were generally good for the vegetation and development of wheat. The highest precipitation was recorded during May 92.7 mm. The summer was too hot followed by high temperatures, and heavy rainfalls during July signed particularly on the quality of postharvest wheat. The harvest in the year 2021 can characterize as wet and it was slowed by rainfalls and high humidity of wheat.

Participatory field trials were harvested at the end of July 2021 according to the full maturity stage with moisture at 14 %. Approximately 1 kg of representative grain sample was used for moisture determination and quality analyses (proteins, moisture, starch, volume weight, sedimentation index, falling number, dry matter and nitrogen).

Generally, wheat had no significant issues with diseases and pests. *Tilletia caries* and *T. controversa* were the most prevalent diseases observed in field trials, but the occurrence was very low (Table 24). All varieties appear to have good tolerance to the diseases. The yield report in Figure 18 was in the range of 6.29 - 7.15 t/ha. The lowest yield recorded PS Dobromila 6.29 t/ha, and the best yield reached the variety IS Laudis 7.15 t/ha.

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Table 24. Disease evaluation Tilletia caries and Tilletia controversa and agronomic characters varieties of plant height, lodging, and grain yield levels in the 2020-21 season from farm SEMA HŠ s.r.o. in Sládkovičovo

Variety name	*Tilletia caries*	*Tilletia controversa*	Plant height (cm)	Lodging	Grain yield (t/ha)
Aurelius	1	1	114	1	6.36
Hungary population	1	1	108	1	6.65
Ehogold	1	1	118	1	6.71
Viki	1	1	104	1	6.54
Wendelin	1	1	106	1	6.57
Dobromila	1	1	106	1	6.29
IS Laudis	1	1	103	1	7.15
Arnold	1	1	100	1	6.33

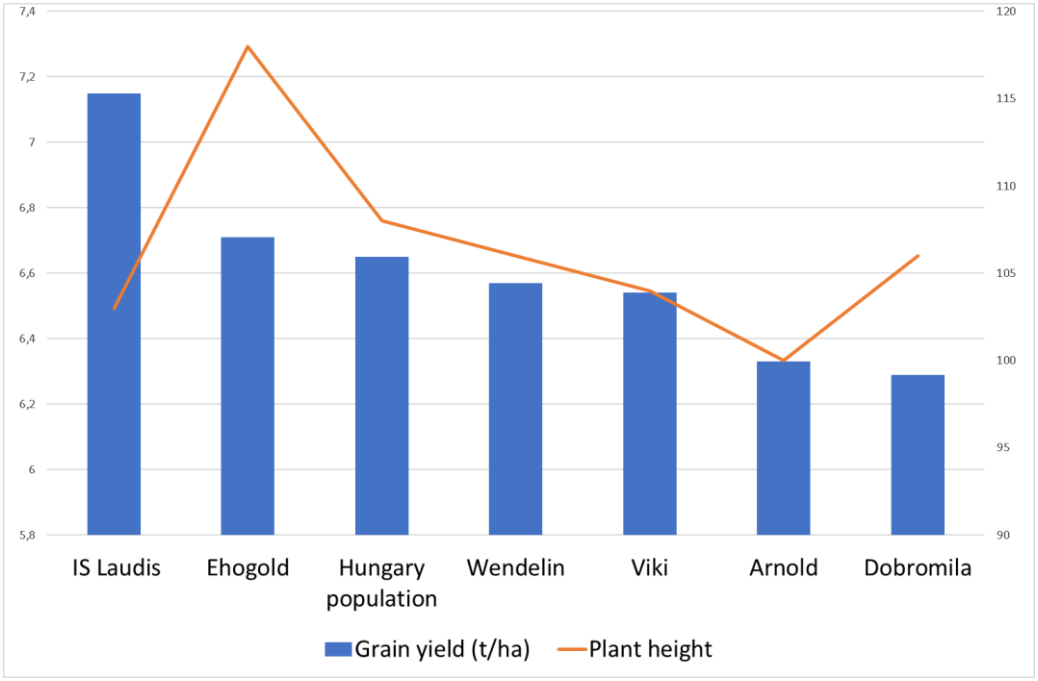

Figure 18. Evaluation of plant height and grain yield of varieties in the season 2020-21 from the farm SEMA HŠ s.r.o. in Sládkovičovo

Results of the analysis on starch, wet gluten, sedimentation index, volume weight, falling number, and proteins are shown in table 25 and figure 19.

Protein content showed no differences between trials. The content ranged from 10.64 to 12.07 % while the highest was reached by Aurelius and the lowest by Ehogold. The percentage of wet gluten ranged from 21. 8% (Ehogold) to 26.4 % (Wendelin) which corresponds to quality class A. The value of the falling number was not a problematic parameter for any of the varieties. All of them reached a high value the number and

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exceeded the value 200. The average sedimentation index was reached in the Wendelin and PS Dobromila, when they reached the value of min. 40 ml. The lowest average value if the sedimentation index of 34 ml was reached by the Ehogold variety.

Table 25. Values of indicators of quality characteristics of selected varieties in organic trials at farm SEMA HŠ s.r.o. Sladkovičovo in growing season 2020/2021

Variety name	Starch (%)	Wet gluten (%)	Sedimentation index	Volume weight (kg/hl)	Falling number	Protein (%)
Aurelius	61.5	25.4	39	81.1	408	12.07
Hungary population	61.2	24.6	39	82.5	393	11.83
Ehogold	62.3	21.8	34	81.2	400	10.64
Viki	58.9	25.9	38	75.3	388	12.80
Wendelin	60.6	26.4	43	80.6	391	12.81
Dobromila	61.5	25.5	41	82.5	421	11.96
IS Laudis	61.3	23.3	35	79.7	402	11.49
Arnold	60.2	24.0	35	77.4	437	11.52

Note: Starch [%] calibrated by IS0 10520; Wet gluten [%] calibrated by ICC 155; Sedimentation index, calibrated by ISO 5529:2007; Volume weight (kg/hl) – bulk density ISO 7971-3: 2009; Falling number (s) ISO 3093: 2009; Proteins (Nx5,7 %) in dry matter (%), Dumas method

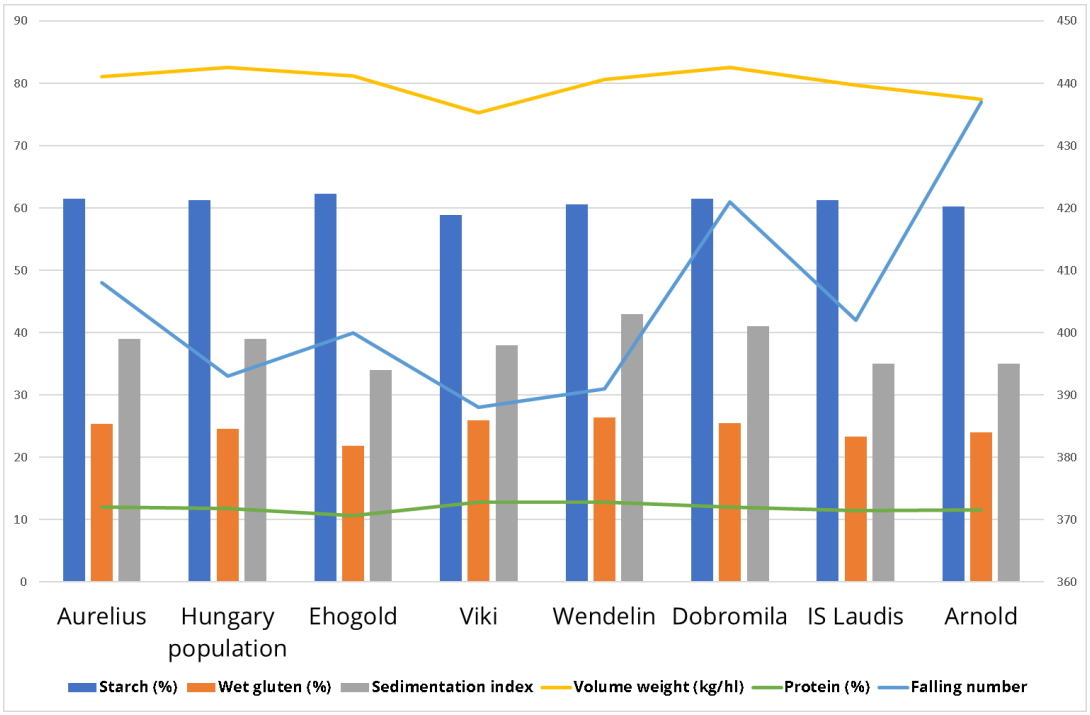

Figure 19. Graphic characteristics of quality traits of the varieties in organic trials at farm SEMA HŠ s.r.o. Sladkovičovo

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Figure 20. Participatory field trials and Field Day in Slovakia

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3. Soybean

3.1. Soybean participatory trials in Serbia

On-farm variety evaluation trials for organic soybean were set up in Serbia as part of the ECOBREED project. The goal of these trials was to support farmers in selecting new varieties for their respective pedo-climatic zones and locations. Organic farmers typically have extensive knowledge of crop features required for optimal agronomic performance. These trials served as a baseline for the following production season. During the trial observations, organic farmers were actively involved, and they were trained to be able to select soybean varieties that are better suited to their specific area and growth conditions.

The trials were set up in 2021 on five locations (Rimski Šančevi 45°30'59.5"N 19°59'26.3"E, Šuljam 45°05'20.2"N 19°40'14.5"E, Bela Crkva 44°57'27.1"N 21°19'11.2"E, Čurug 50°36'71.3"N 42°06'20"E, Banatsko Karađorđevo 45°35'26.5"N 20°33'42.2"E).

APPLICABILITY
Theme: Crop management, variety testing
For: All soybean growers
Where: selected locations
Timing of main activities: April/May/September
Equipment: Pneumatic seeding machine, inter row cultivator, harvester
Follow-up: Manual weed control, monitoring of pests and diseases
Impact: High crop yield and protein content

Figure 21. Trials locations in Serbia and applicability

Six soybean varieties (00, 0, I, II maturity groups) were evaluated in a network of large-plot trials. Varieties from two breeding companies were tested (Xonia, Saatgut Gleisdorf, Austria; NS Mercury, NS Altis, Zora, NS Apolo, and Rubin, Institute of Field and Vegetable Crops, Novi Sad, Serbia). Crops were sown in early April and harvested in September. The experiment was set up in the form of strips on an area of 300 m^2 per variety. During vegetation inter-row cultivation was performed twice during the growing season (May), manual weed control, and harvest in September, according to the maturity groups. On all farms, field emergence, sowing density, growth development, ground cover, height and lodging was evaluated as well as occurrence of diseases and pests.

Soybean varieties (00-II maturity groups) showed different adaptability to specific farm site conditions (Figure 22).

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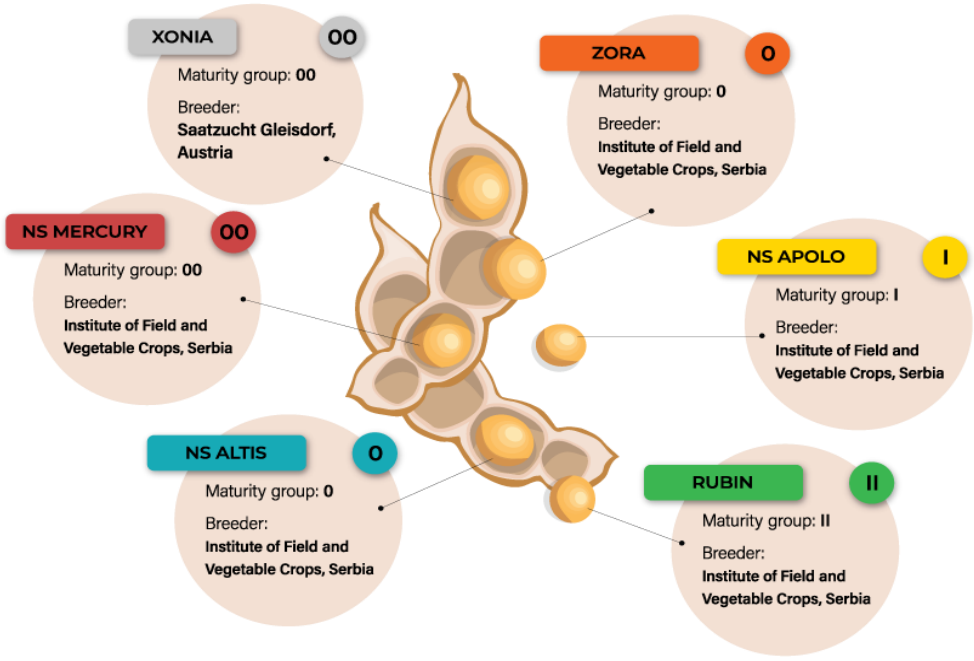

Figure 22. Soybean varieties used in Serbian trials.

Yield was in the range 1.96 - 4.61 t/ha (Figure 23), while protein content was in the range 33 - 44% of dry matter (dm) (Figure 24). The lowest yield (range 1.96 - 2.88 t/ha) for all varieties was recorded at the Bela Crkva site due to the fact that this is not a preferable soybean growing region. Also, overall, at the Čurug site, all varieties had the highest yield (range 3.48 - 4.53 t/ha).

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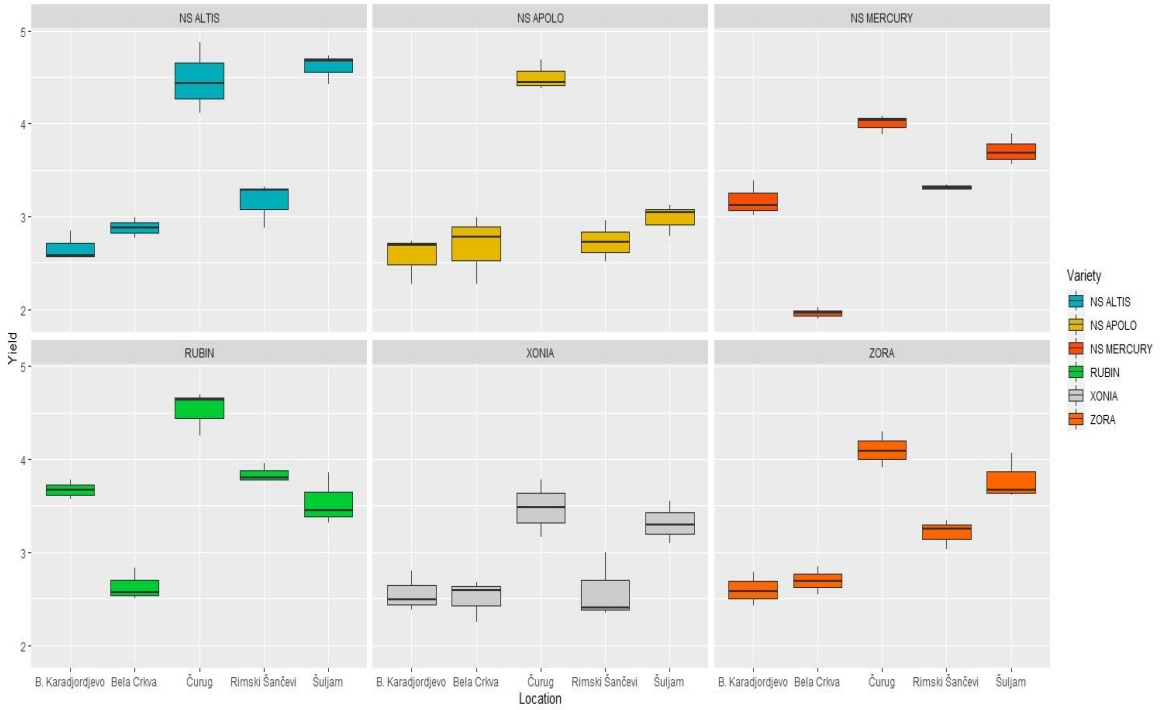

Figure 23. Soybean yield (t/ha). Data for yield are presented as median of 6 varieties per location in 2021, boxes represent the interquartile range

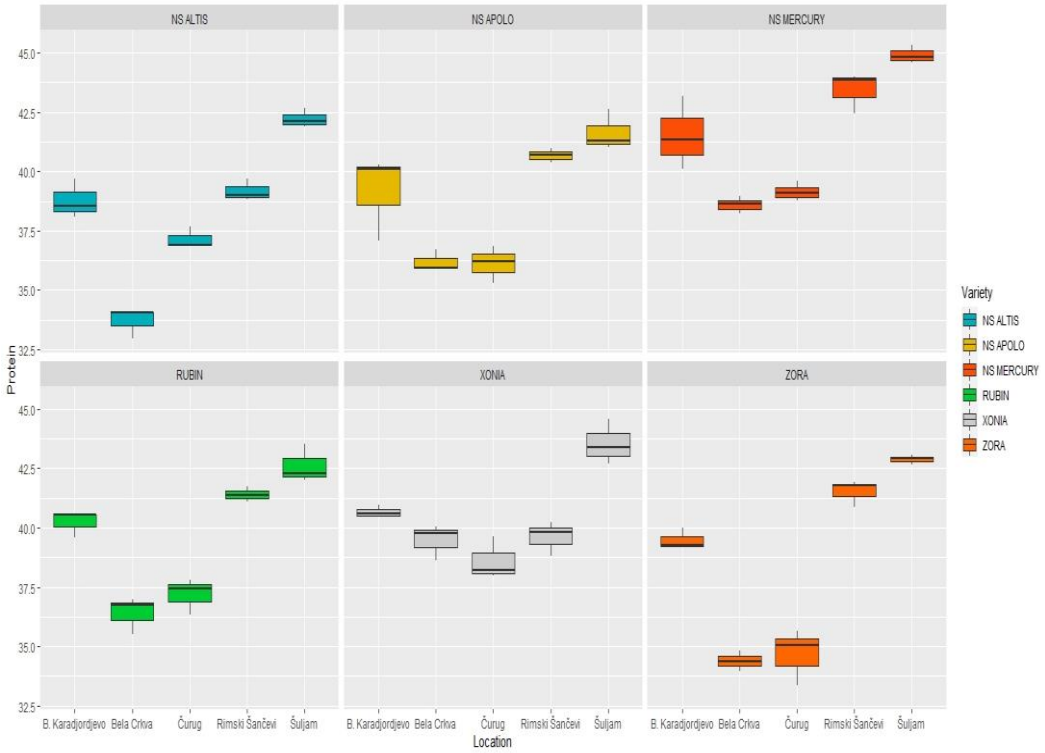

Figure 24. Soybean protein content. Data for protein content are presented as median of 6 varieties per location in 2021, boxes represent the interquartile range

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3.2. Soybean trials in Germany and Austria

The 2021 soybean trials were sown on six organic farms in Germany and two organic farms in Austria.[2] Five of the six German farms were located in Bavaria. The climatic conditions on the farms varied. While some farms can grow 00 varieties without problems, some farms are limited to varieties of maturity group 000. The sowing dates were very different. While the Endres farm sowed on April 20, the Schalk farm could not sow until June 4 due to wet weather. The subsequent cool weather brought uncertainty as to whether harvesting could take place on time this year. However, the stands matured nicely in September and could be harvested well by early October at the latest. Yields were very encouraging. Only at the Jobst and Neder farms did yields fall off somewhat. At the Jobst farm, a hailstorm at the end of June was responsible for this.

The varieties were selected partly by researchers from the project and partly by the farmers/consultants. The variety NS Mercury was the only variety from Serbia that matched in maturity. The cultivars Lenka, Xonia, Obelix and GL Melanie originated from Saatzucht Gleisdorf and were either bred there (GL Melanie) or conservation breeding takes place there. On most farms, field emergence, juvenile development, ground cover, growth height, lodging and maturity were evaluated. Diseases and pests did not occur.

The Serbian variety NS Mercury was sown on three farms and was weak in yield everywhere.

The 00 variety Lenka, which is important for growing edibles, was grown on four farms in Germany and one farm in Austria. It showed average to good yields.

The 00 variety Xonia is the first variety in this maturity group with low trypsin inhibitor content. These varieties have previously been said to have weaker yields. In our trials, the variety did not disappoint.

While the 000 variety GL Melanie was grown at all locations and showed only good results, the 000 variety Obelix had mixed results.

In Germany, popular varieties such as ES Commandor, ES Compositor, RGT Sphinxa showed unstable or weak yields. In Austria, ES Director and Altona varieties were ahead in yield.

Crude protein contents are so far only available from the Güssing location. Here, the breeding lines of Saatzucht Gleisdorf were ahead.

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[2] Many thanks to our colleagues Alexander Kögel, Manuel Mühlbauer and Wolfgang Kober for their support during the trials.

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In protein content the well-known tofu varieties Lenka and Tofina had the best and stabile results. Also, Aurelia, Aurelina and the new breeding lines EGZ19111 und GL08 showed interesting results. The popular varieties ES Comandor and ES Compositor were not so good as expected. The varieties for feed like GL Melanie, Obelix and Xonia showed protein contents under average.

Table 26. Yield in dt/ha. Varieties with yields clearly above average are marked in green, and those clearly below average in red.

Variety/Farmer	Sölch	Endres	Hopf	Binder	Jobst	Neder	Güssing	Schalk
NS Mercury		39.3			12.8			34.2
Lenka		49.7	44.4	32.2	22.4		26.0	
Xonia				49.1	30.0		28.0	34.4
Obelix	33.6	43.2	42.2	37.5	17.0	17.2	23.0	
GL Melanie	47.6	46.2	36.3	31.4	21.4	15.7	48.0	36..7
ES Commandor	38.1	40.4	27.5		20.5	12.3		
Adelfia	21.9							
Aurelia				29.8	24.5			
Tofina	37.7	41.3	39.4	28.2	24.1			
RGT Sphinxa			34.6	23.0				
ES Compositor	42.3	59.0		20.8		12.0	32.0	42.1
Aurelina	40.2	53.2						
Arcardia	44.4		38.0		18.2			
ES Mentor	40.3			26.2	22.4		35.0	38.8
Alicia	47.0							
Yakari		59.3						
Achillea			42.6					39.8
SY Livius			41.2					
Primus				29.0				
Xena						27.4		
22517						23.6		
EGZ19111						19.8		
ES Director							36.0	44.1
Alvesta							27.0	42.6
GL 08							26.0	
GL 20							27.0	
Altona							37.0	43.3
Durchschnitt	**39.3**	**48.0**	**38.5**	**30.7**	**21.3**	**18.3**	**31.4**	**39.6**

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Table 27. Protein %. Varieties with clearly above average values are marked in green, and those clearly below average in red.

Variety/farmer	Sölch	Endres	Hopf	Binder	Jobst	Neder	Güssing	Schalk
NS Mercury		412			426			425
Lenka		458	464	422	460		425	
Xonia				401	407		403	412
Obelix	422	400	410	408	401	452	390	
GL Melanie	414	413	407	401	424	414	422	424
ES Commandor	419	409	416		411	412		
Adelfia	422							
Aurelia				443	423			
Tofina	445	432	438	438	436			
RGT Sphinxa			429	435				
ES Compositor	425	415		407		419	417	435
Aurelina	445	441						
Arcardia	420		396		396			
ES Mentor	422			427	427		400	434
Alicia	412							
Yakari		429						
Achillea			409				423	441
SY Livius			430					
Primus			-					
Xena						-		
22517						433		
EGZ19111						441		
ES Director							416	423
Alvesta								442
GL 08							444	
GL 20							397	
Altona							407	424

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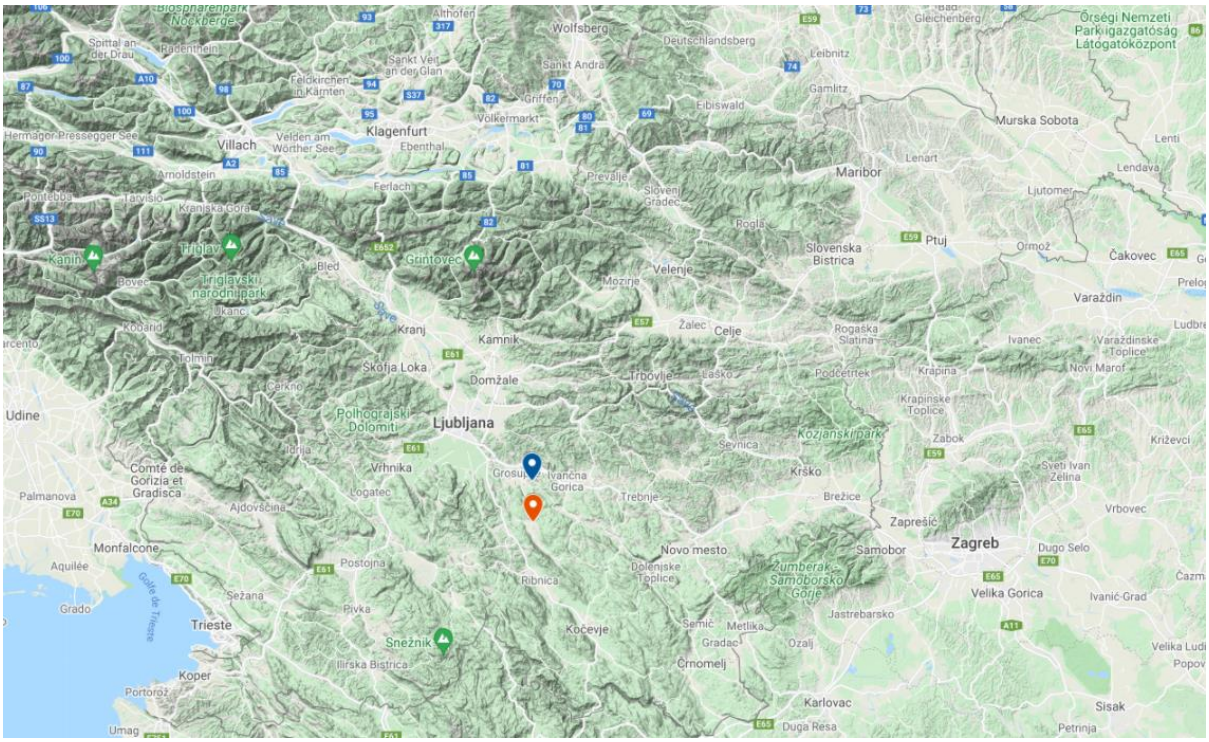
3.3. Soybean farmers participatory field trials in Slovenia

3.3.1. Methods

In Slovenia, soybean farmer participatory trials within the ECOBREED project were established in 2021 on two organic farms located in Dolenjska region (Figure 25). Soil texture at Grosuplje was silt and at Videm Dobrepolje clay silt. The climate at both locations is continental.



Name place	Farm Elevation	Type of landscape	Pedo-climatic zones/regions	Farm size	Farm type	Organic since (years)
Grosuplje	335	Valley	Continental temperate climate	12	Mixed	**+20**
Videm Dobrepolje	441	Valley / "plateau"	Continental temperate climate	24	Mixed	**+12**

Figure 25. Locations of soybean trials and main characteristics

A total of eight soybean cultivars (GL MELANIE, EZRA, OBELIX, XONIA LENKA, NS MERCURY, NS ATLAS And GALINA) were selected for testing by researchers and variety experts. Selected cultivars differed in maturity rating, growth type (determinant and semi-determinant type) and in various other morphological and quality traits (Table 28).

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Table 28. List of soybean varieties and their maturing ratings selected for farmers participatory trials in Slovenia

Variety	Earliness group	Definition
GL Melanie	000	Very Early
Obelix	000	Very Early
NS Mercury	00	Early
Lenka	00	Early
Xonia	00	Early
Ezra	0	Mid Early
NS Atlas	0	Mid Early
Galina	0	0 Mid Early

Tillage of the trials was minimal tillage without ploughing on the Grosuplje location and intensive conventional with a 25 cm deep plough followed by seedbed preparation with cultivation on the Videm Dobrepolje location. Soybean was not present in farms crop rotation before these trials. Trials were established with the farm available seeders on 11 and 21 May at a density of 57 and 48 seeds / m², respectively. Row spacing was 70 cm at both locations. Seeds were not inoculated.

The following traits were evaluated to assess the development and agronomic performance of cultivars: date of emergence, plant height (cm), height of the lowest pods, canopy, lodging susceptibility, identification and scoring of diseases and pests, grain yield (kg/ha) and grains moisture at harvest (%). The yields were estimated by manual sampling of 0.7 m2 with four repetitions for each variety on the 1 October (130 and 140 days after sowing). Samples of collected grains were taken for the analysis of protein content. The previous crops before soybean trial were different in each farm (Table 29).

Table 29. Crop rotation before soybean trial at 4 locations ("1st crop /2nd crop": 1st crop following by a 2nd crop in a same year)

	2018	2019	2020	2021
Grosuplje	spelt / buckwheat	wheat / buckwheat	millet / buckwheat	soybean trial
Videm Dobrepolje	buckwheat	potato	wheat	soybean trial

3.3.2. Results

The basic weather conditions during the vegetation period are presented in Table 30. Conditions were variable, with cold and wet May delaying the emergence and early development, followed by hot and dry conditions in August and September accelerating maturing of cultivars.

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Table 30. Mean daily air temperature and cumulative monthly precipitation from sowing to harvest of soybeans in the 2021 growing season at Novo Mesto weather station

Year	2021	
	Temperature (°C)	**Precipitation (mm)**
April	8.9	76.7
May	13.6	173.5
June	22.5	54.3
July	22.8	144.7
August	20.2	76.4
September	16.3	64.4
October	9.4	66.8
Mean/sum	**16.2**	**656.8**

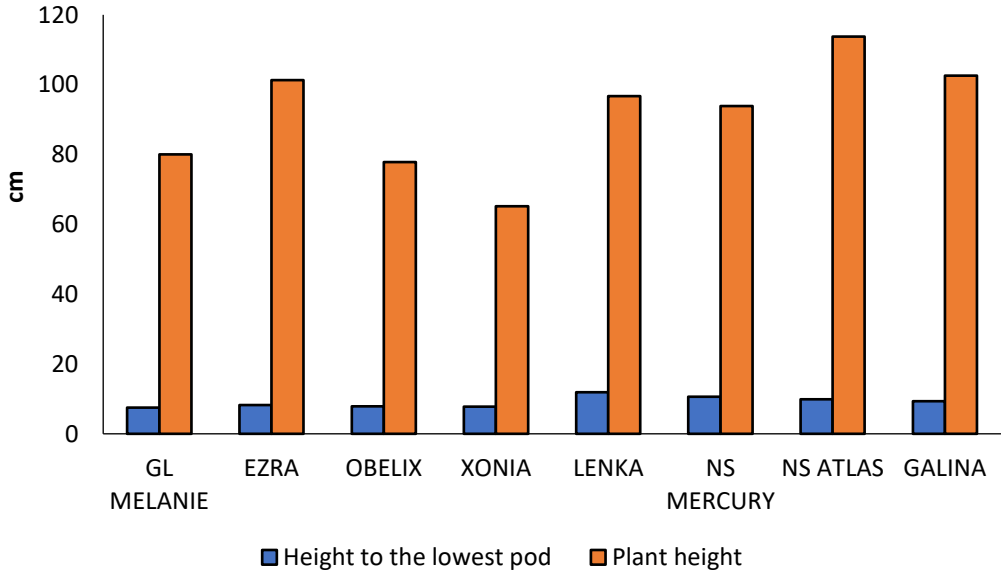

Figure 26. Mean heights of soybean plants and the lowest pod for each variety in Grosuplje

In Grosuplje plants emerged 12 days after sowing, followed by normal development of plants. At Videm Dobrepolje soil compaction affected and delayed plant emergence and development, resulting in small plants with small aboveground biomass. No damage from pests or diseases was reported by farmers.

The variety NS ATLAS was the highest and the variety XONIA was the smallest at both locations. The heights of the lowest pod were between 7,5 cm and 12 cm for Grosuplje and between 9 cm and 17 cm for Videm Dobrepolje. The highest pods at Grosuplje were found for Lenka and at Videm Dobrepolje for NS Mercury and NS Atlas (Figure 26 and 27).

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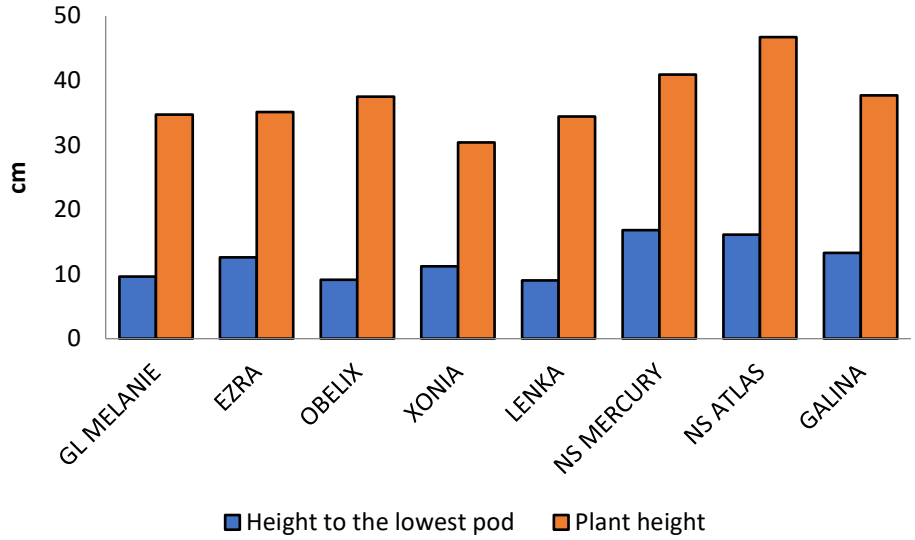

Figure 27. Mean heights of soybean plants and the lowest pod for each variety in Videm Dobrepolje

Differences between the maturity groups were noticeable at both locations and were affecting the time of the harvest and related grain losses. At the time of the harvest, highest grain losses due to opening of pods were observed with the earliest varieties, which were overripe. On the contrary, no losses at that time were observed for later maturing groups. Due to soil compaction affecting soybean development at the Videm Dobrepolje, yields were low (Table 31). Here the highest yielding varieties were Obelix (6.2 dt/ha) and Lenka (7.9 dt/ha). On the contrary, yields at Grosuplje were generally high and ranged between 24.8 dt/ha (NS Mercury, maturity group 00) and 41.1 dt/ha (EZRA, maturity group 0). Yields, which are 20% above average, are marked in green, while yields that are 20% below average are marked in red. Chemical analyses are in progress.

Table 31. Grain yields of the soybean cultivars at the locations Grosuplje and Videm Dobrepolje

Yield (dt/ha)	Grosuplje	Videm Dobrepolje
GL MELANIE	32.8	4.5
EZRA	41.1	4.2
OBELIX	26.5	6.2
XONIA	32.6	3.9
LENKA	33.5	7.9
NS MERCURY	24.8	2.2
NS ATLAS	30.3	3.2
GALINA	37.7	4.6
Average	**32.4**	**4.6**

3.4. Soybean farmer participatory trials in Romania

Farmer participatory trial 2021 was established at four Romanian organic farms: Organic field of SCDA Valu lui Traian/county Constanța, ECO-VIAL Ștefan cel Mare/county Călărași, Agroecologic Research&Innovation Center NARDI Fundulea/county Călărași and Organic Green Cooperativa Agricola Negrași, county Argeș. According to the Map of Romanian ECOBREED Soybean DEMO Farms and information on Table 32, the Romanian organic soybean DEMO farms are located in the Development regions South-Muntenia (3) and in South – East (1), at different altitudes and geographical coordinates and are located on different soil types – cernozems and luvisol.

Table 32. Geographical settlement and soil types of the soybean FPTs

Nr.	Farm Demo (FPTs) Name	Altitude	Position	Development regions	Soil types
1	Organic field SCDA Valul lui Traian	55	44°10'49.1"N 28°30'50.9"E	South - East	Chernozem
2	ECO-VIAL Ștefan cel Mare	33	44°25'14.2"N 27°38'27.6"E	South - Muntenia	Chernozem
3	Agroecological Research& Innovation Center NARDI Fundulea	63	44°26'46.8"N 26°30'52.0"E	South - Muntenia	Chernozem
4	Organic Green Cooperativa Agricola Negrași	199	44°35'23.6"N 25°07'39.4"E	South - Muntenia	Luvisol

Figure 28. Map of Romanian ECOBREEED Soybean Demo Farms

Climatic data collected and recorded in the period September 2020 – August 2021 shows that, everywhere, the air temperature (Fig. 29) was higher than the multiannual average values of the last 60 years. The exception that confirms climate change was the month

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of April 2021 whose average air temperature was significantly lower than the multi-year average, but soybeans had excellent thermal conditions for emergence, growth and development in all vegetation phases.

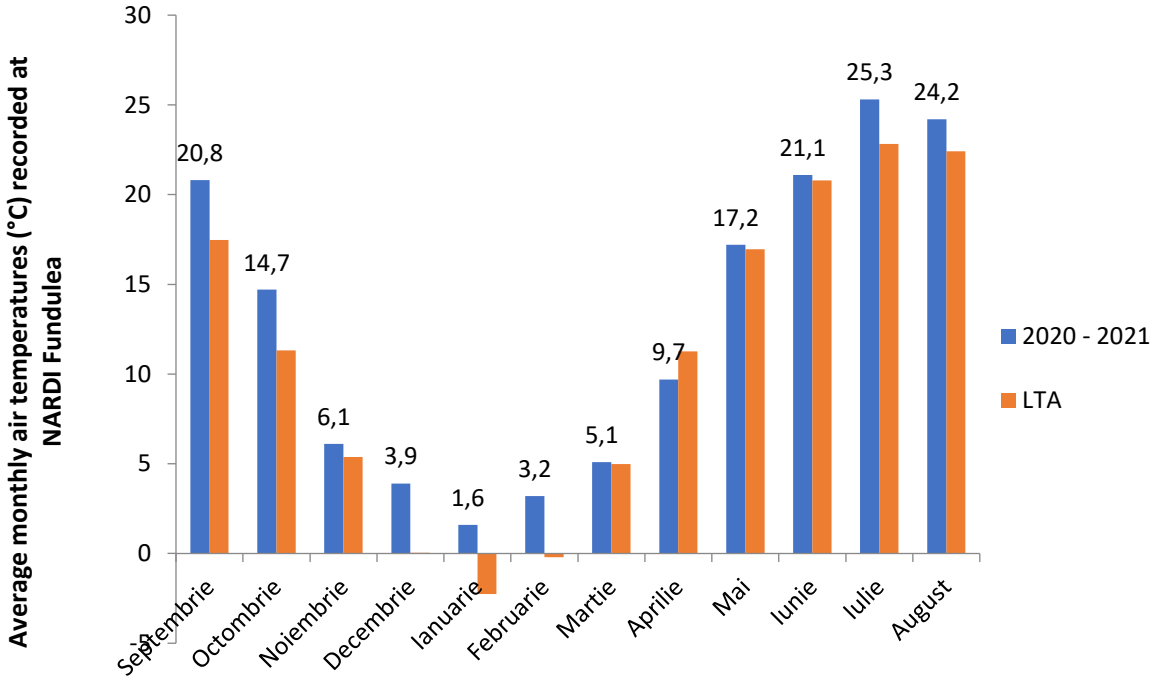

Figure 29. Average monthly air temperatures recorded at NARDI Fundulea, in the period September 2020 – August 2021 compared to Long Term Average (LTA)

Regarding precipitation (Figure 30), in the period considered there were seven months - October and November 2020 and February, April, May, July and August 2021 - in which precipitation was below the multiannual average (LTA). However, the temporal distribution of precipitation was very different from normal with the June exceptionally rainy (135 mm). Because of this, only one mechanical weeding operation was carried out and, indirectly, weeds were favoured. However, the months of July and August were dry, which favoured the drying of the soybean and the harvesting in good conditions of the tested varieties.

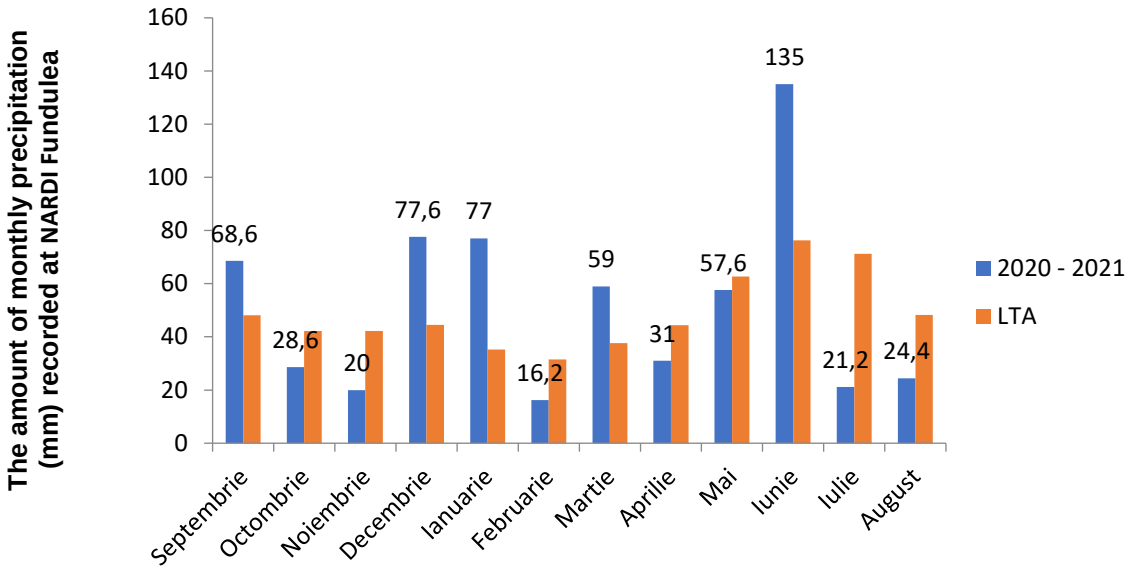

Figure 30. The amount of monthly precipitation from September 2020 – August 2021 and the multi-year monthly averages (LTA) recorded at NARDI Fundulea

3.4.1. Material and methods

In all FPTS, the soybean varieties belong to Austrian (GL Melanie, Obelix, Christine and Lenka), Serbian (NS Apolo, Valjevka, NS Mercury and Rubin) and Romanian (Ovidiu F, Camelia F and Fabiana F) genetics. Due to the very small number of seed received from the Austrian colleagues, only at two FPTs - *NARDI Fundulea and ECO-VIAL Ștefan cele Mare* - the entire set of 10 were cultivated, respectively 11 varieties, and in the other two FPTs - *SCDA Valu lui Traian and Organic Green Cooperativa Agricola Negrași* - only 7 varieties were cultivated (Table 33).

Table 33. Soybean varieties name and GM on 4 FPT Farms (irrigated)*

Variety name	Maturity Group (MG)	Organic field SCDA Valu lui Traian	ECO-VIAL* Ștefan cel Mare	Agroecological Research&Innovation Center NARDI Fundulea	Organic Green Cooperativa Agricola Negrași /Argeș
GL MELANIE	000		x	x	
OBELIX	000		x	x	
CHRISTINE	00		x	-	
LENKA	00		x	x	
OVIDIU F	00	x	x	x	x
CAMELIA F	0	x	x	x	x
VALJEVKA	0	x	x	x	x
FABIANA F	I	x	x	x	x
NS APOLO	I	x	x	x	x
NS MERCURY	I	x	x	x	x
RUBIN	II	x	x	x	x

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Also, soybean varieties were sown on different dates (27.04.21 at ECO-VIAL, 29.04.21 at SCDA Valu lui Traian, 08.05.21 at Organic Cooperativa Agricola Negrași and 19.05.21 at NARDI Fundulea) and placed in strip-plots, 3 rows of each variety, at a distance of 50 cm between rows, along the entire length of the plot and with different types of sowing machines.

Figure 31. Sowing soybean FTP "NARDI Fundulea"/19.05.2021

According to journals of the organic Demo soybean, from September 2020 to October 1, 2021, different types of soil work (disking and ploughing), seedbed preparation, sowing, mechanical weeding at least once and with various equipment *(cultivator, Hatzenbichler harrow, rotary hoe)*, irrigation at ECO-VIAL Stefan cel Mare and harvesting.

Figure 32. Irrigation of soybean FPT "ECO-VIAL Stefan cel Mare"/24.05.2021

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Figure 33. Weeding of soybean FPT "NARDI Fundulea"/07.06.2021

During the soybean growing season, all observations and measurements (25) that are provided in WP 6.2 "Data sheet" were made.

3.4.2. Results

In this part we will present and discuss two of the most important parameters for any plant grown in an organic system: Yield (kg/ha) and Degree of weeding.

Figure 34. Soybean FPT "NARDI Fundulea"/11.06.2021 and 02.08.2021

Grain yields and TGW in 3 soybean FPTs (Table 34) were very variable and depended on sites natural characteristics, soybean varieties traits and soybean DEMO technologies. În this context the highest Yield (1518 kg/ha) and TGW (130 g) recorded at ECO-VIAL Stefan cel Mare, in irrigation conditions and the lowest yield and TGW, at Organic Green

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Cooperativa Negrași - 725 kg/ha, respectively 89 g and at NARDI Fundulea – 541 kg/ha, respectively 117 g.

The Yields and TGW was certainly influenced by the low density of soybean plants due first by the small seeds quantity sowed which increased distance between seeds at >5 cm and, mainly the loss of many plants by mechanical weeding in specially with rotary hoe at ECO-VIAL, strong attack of pigeons at NARDI Fundulea (Figure 35), and sowing soybean two days after preparing the land at SCDA Valu lui Traian and Organic Green Cooperativa Agricola Negrași.

Figure 35. Pigeons in Organic Soybean DEMO and feeds of pigeons in spring

Following all these unfortunate events, the infestation with weeds on the plant rows was high everywere, but mainly at ECO-VIAL Ștefan cel Mare and Organic Green Cooperativa Agricola Negrași where the number of weeds was higher than the number of soybean plants (Table 34).

Table 34. The soybean and weeds plant/m2 in 3 Romanian FPTs

	ECO-VIAL Ștefan cel Mare	**NARDI Fundulea**	**Organic Green Cooperativa Agricola Negrași**
Soybean plants (No/m^2)	18.90	28.40	35.00
Weeds plants (No/m^2)	20.40	11.27	87.43

Also, the spectrum of weeds seems to be specific to each agriculture area (Table 35) as:

- at ECO-VIAL Ștefan cel Mare with dominant weeds: *Sorghum halepense*, *Amaranthus retroflexus*, *Descurainia sophia* and *Datura stramonium*, and rarely *Solanum nigrum* and *Abutilon theophrasti*,

- at NARDI Fundulea, with dominant weeds: *Setaria viridis*, *Echinochloa crus-galli*, *Solanum nigrum* and rarely *Ambrosia* sp., *Chenopodium album* and *Sorghum halepense*,
- at Organic Green Cooperativa Agricola Negrași with dominant weeds *Setaria viridis*, *Echinochloa crus-galli*, *Digitaria sanguinalis* and *Hibiscus trionum*, and rarely *Rumex acetosella*, *Polygonum persicaria* and *Polygonum aviculare*.

Table 35. The spectrum of weeds in 3 Romanian FPTs

ECO-VIAL Ștefan cel Mare		**NARDI Fundulea**		**Organic Green Cooperativa Agricola Negrași**	
Weed name	%	Weed name	%	Weed name	%
Sorghum halepense	66.96	*Setaria viridis*	61.77	*Setaria viridis*	54.74
Amaranthus retroflexus	23.21	*Echinochloa crus-galli*	28.70	*Echinochloa crus-galli*	22.06
Descurainia sophia	5.36	*Solanum nigrum*	5.17	*Digitaria sanguinalis*	16.83
Datura stramonium	1.79	*Ambrosia sp.*	1.52	*Hibiscus trionum*	5.56
Setaria viridis	0.89	*Chenopodium album*	1.49	*Rumex acetosella*	0.33
Solanum nigrum	0.89	*Sorghum halepense*	0.87	*Polygonum persicaria*	0.33
Abutilon theophrasti	0.89	*Xanthium strumarium*	0.50	*Polygonum aviculare*	0.16

As regards the effect of soybean varieties, only the yield depended on variety, in each of DEMO site the soybean varieties with the highest yield were GL MELANIE (2691 kg/ha), FABIANA F (2277 kg/ha) and OBELIX (2221 kg/ha) at Stefan cel Mare, VALJEVKA (1370 kg/ha) at Organic Green Cooperativa Agricola Negrași and NS MERCURRY (1252 kg/ha) at NARDI Fundulea.

*Table 36. Grain yield (t/ha) and TGW (g) from 3 FPT sites presented @11% moisture content (*irrigated)*

Variety name	**Maturity Group (MG)**	**ECO-VIAL* Ștefan cel Mare**		**Agroecological Research & Innovation Center NARDI Fundulea**		**Organic Green Cooperativa Agricola Negrași /Argeș**	
		Yield	TGW	Yield	TGW	Yield	TGW
GL MELANIE	000	2691	126	326	105	-	-
OBELIX	000	2221	119	700	128	-	-
CHRISTINE	00	1688	128	-	-	-	-
LENKA	00	587	119	686	168	-	-
OVIDIU F	00	1401	133	290	110	310	81
CAMELIA F	0	1015	138	271	98	440	96
VALJEVKA	0	1040	138	576	102	1370	94
FABIANA F	I	2277	126	483	124	634	90
NS APOLO	I	1104	118	354	105	843	96
NS MERCURY	I	1117	156	1252	106	710	78
RUBIN	II	1560	131	412	124	769	90
Average		***1518***	***130***	***541***	***117***	***725***	***89***

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The soybean seeds protein and oil content (table 36) negative correlation, in the sense that the big content in protein means less oil content, is quite known and it happened in Romanian FPTs 2021 too. Also, the protein content depends obviously on TGW. In these FPTs, the exception was the highest oil content (24,17 %) in soybean seeds at FPT Organic Green Cooperativa Agricolă Negrași with the smallest TGW (89 g).

*Table 37. Protein and Oil content (%) from 3 Romanian FPTs/2021 (*irrigated)*

Variety name	Maturity Group (MG)	ECO-VIAL* Ștefan cel Mare		Agroecological Research&Innovation Center NARDI Fundulea		Organic Green Cooperativa Agricola Negrași /Argeș	
		Protein	Oil	Protein	Oil	Protein	Oil
GL MELANIE	000	42.22	20.79	42.86	20.41	-	-
OBELIX	000	43.65	20.49	39.77	22.28	-	-
CHRISTINE	00	42.00	20.58	-	-	-	-
LENKA	00	43.66	19.91	45.09	20.93	-	-
OVIDIU F	00	42.22	20.79	44.22	20.24	31.20	25.11
CAMELIA F	0	44.29	19.00	42.09	21.47	34.23	23.18
VALJEVKA	0	44.78	18.87	41.01	21.63	31.06	24.65
FABIANA F	I	43.16	20.94	43.33	20.75	32.87	24.07
NS APOLO	I	43.09	19.89	40.92	21.91	31.49	25.32
NS MERCURY	I	43.50	19.83	43.46	20.65	36.65	22.86
RUBIN	II	42.17	20.98	44.46	20.02	34.26	23.98
Average		***43.16***	***20.19***	***43.07***	**20.95**	**33.11**	***24.17***

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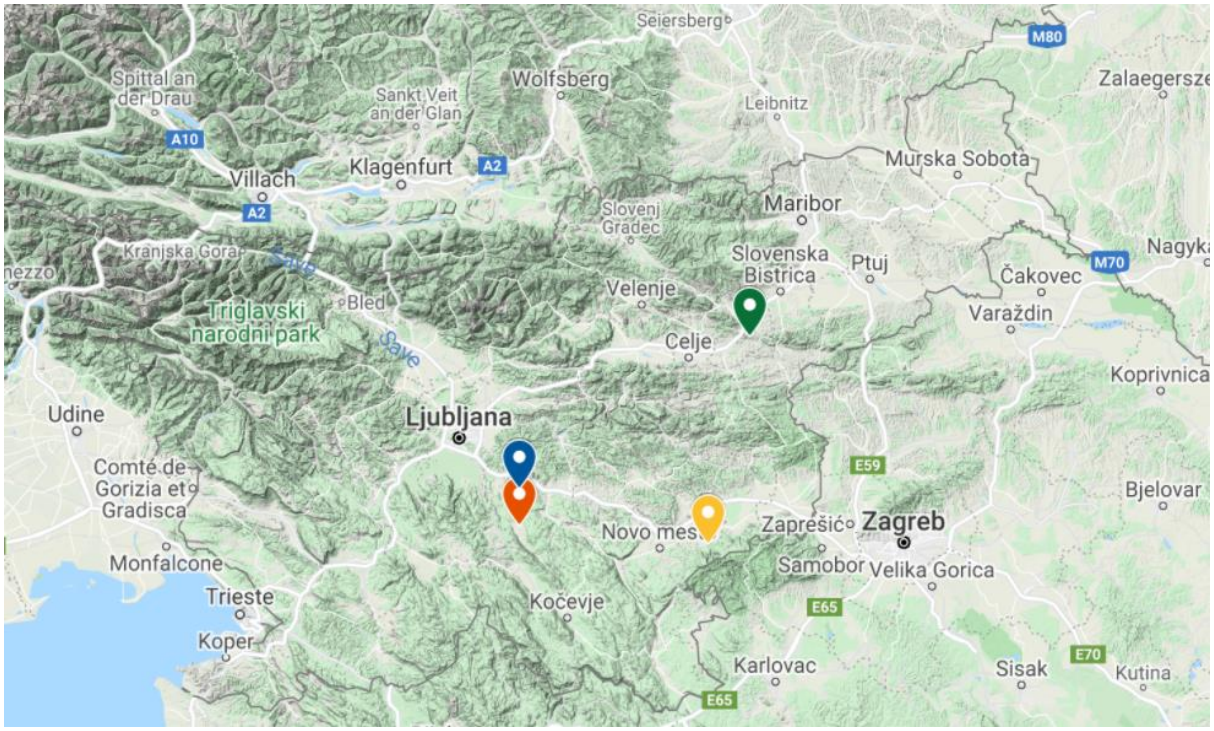
4. Potato

4.1. Potato farmer participatory trials in Slovenia

4.1.1. Methods: Locations and conditions of trials

In 2021 the farmer participatory trials program within the ECOBREED project started on four organic farms located in continental part of Slovenia in two different regions (Štajerska and Dolenjska region). Altitude of these farms (experimental locations) is between 262 m and 520 m (cf. Figure 36).



Name place	Farm Elevation	Type of landscape	Pedo-climatic zones/regions	Farm size (ha)	Farm type	Organic since (years)
Grosuplje	335	Valley	Continental temperate climate	12	Mixed	+20
Šentjernej	262	Plain	Continental temperate climate	5,5	Mixed	+5
Videm Dobrepolje	441	Valley / "plateau"	Continental temperate climate	24	Mixed	+12
Ponikva	520	On the hills	Continental temperate climate	8,3	Mixed	+20

Figure 36. Locations of potato trials and main characteristics

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Conditions of trial: The selection of 13 varieties was done partly by researchers, farmers and consultants. The objective was to obtain a panel of varieties with different properties according to yielding capacity, earliness, resistance to late blight and PVY, utilization, skin and flesh colour and other characteristics (cf. Table 38).

Table 38. Varieties of potatoes and properties

Variety	Earliness	Resistance to late blight
DELILA	late	yes
OTOLIA	intermediate	yes
CAROLUS	intermediate	yes
LEVANTE	intermediate	yes
ALOUETTE	intermediate	yes
KIS KOKRA	intermediate	yes
KELLY	late	yes
MAGNOLIA	early	no
SALOME	early	no
TINCA	intermediate	yes
TWISTER	early	yes
TWINNER	early	yes
BOTOND	early	no

A panel of criteria was established by researcher and farmers/consultants to compare varieties in different locations with different farming management: planting date, planting density, date of emergence (BBCH 009), date of canopy closure (BBCH39), date of senescence (BBCH 91), plant height, late blight and early blight severity of symptoms, severity of black scurf (*Rhisoctonia*) symptoms, colorado potato beetle damage, yield, tuber size, dry matter, cooking type, taste discoloration of flesh after cooking, tuber disorders, regularity of tuber shape, depth of eyes.

Planting density varied between 4.7 and 5.7 plant per m². The planting period was done between the 24 April and 11 May with semi-automatic planter.

The fertilizations, weed management and pest management were made by farmer according to organic farming.

The year 2021 was difficult for potato growers across Slovenia, with shortage of rainfall in June and July compared to an average year and long periods of high temperatures.

4.1.2. Results

Yield and state of crop

If the dry conditions of 2021 were favourable for health status of potato plants, but it had negative affect on yield, tuber size and quality. Crops in all 4 locations were not damaged by foliage diseases or pest. Early blight was observed by one farmer at 8 varieties that were affected between 5 and 50 % of total leaf area at the end of August.

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Colorado beetle was present in all locations, one farm observed 5 % of damage at each variety. Two farms were spraying (1 or 2 times) with organic insecticide LASER PLUS and they managed to hand picking of Colorado potato beetle larvae.

Weed was present but not noticed as a major problem by farmers.

The ranges of plant height according to varieties were not the same between locations. The plant height was between 25 cm and 61 cm. Varieties as CAROLUS and KIS KOKRA were the tallest varieties with average height of about 58 and 52 cm. Twinner had the lowest plant height with an average about 31 cm (cf. Figure 37).

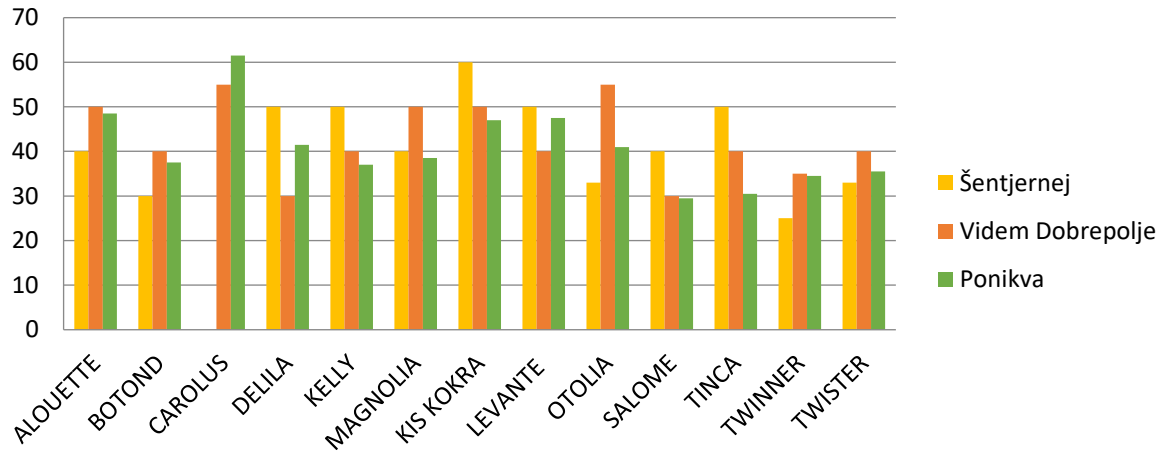

Figure 37. Plant Height (cm) for each potato varieties in 3 locations

In the four locations the range of good yield is different, but we can see that LEVANTE, KIS KOKRA AND MANGNOLIA appeared respectively 4, 2 and 2 times in the top of range yield. Varieties yields are presented in the table for each place. Yields, which were 30 % above average of all varieties per location, were marked in green. Yields, which were 30 % below average, were in red. LEVANTE yield was always above yield average on four locations between (38 and 76 %). KIS KOKRA, MAGNOLIA, CAROLUS and BOTOND had good yield above or near average. Twinner yields were between 30 % and 60 % below the average of all varieties on all four locations (cf. Table 39).

The numbers of tubers per plant in three locations was between 6.9 and 9.3. LEVANTE and KIS KOKRA plants had always more than average number of tubers per plant. SALOME and TWISTER were more contrasted between locations. DELILA had the lowest number of tubers per plant (cf. Figure 38).

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Table 39. Comparison of varieties' yields for each location

Harvested yield (t/ha)	Videm Dobrepolje	Ponikva	Grosuplje	Šentjernej
ALOUETTE	18.1	29.8	20.9	10.2
BOTOND	24.6	29.1	12.4	26.0
CAROLUS	27.1	26.9	17.0	12.0
DELILA	9.6	20.0	16.5	11.8
KELLY	15.1	19.6	20.2	9.0
KIS KOKRA	27.3	30.9	17.5	26.4
LEVANTE	27.7	52.7	27.1	26.0
MAGNOLIA	22.6	46.5	27.3	16,9
OTOLIA	21.6	32.7	17.8	8.4
SALOME	14.3	18.2	10.8	10.9
TINCA	17.7	33.4	15.5	10.1
TWINNER	13.6	14.5	7.3	9.4
TWISTER	20.6	43.2	15.7	14.9
Average	**20.0**	**30.6**	**17.4**	**14.7**

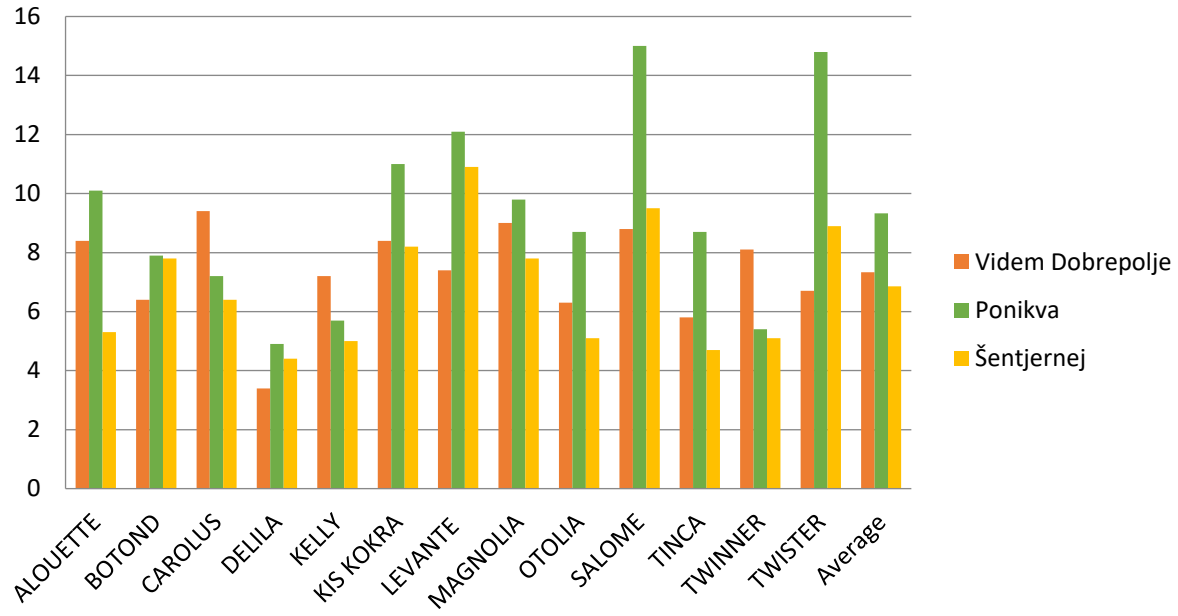

Figure 38. Number of tubers per plant for each variety in 3 locations

The tuber size was determined (weighed and counted) on square mesh of sizes <25mm, 25-45 mm, 45-65 mm, >65 mm. KIS KOKA, DELILA and BOTOND were the 3 varieties with the biggest tubers, on average 87 g, 76 g and 73 g. KIS KROKRA had more tubers in fraction 45-65 mm than other two (cf. Figure 39).

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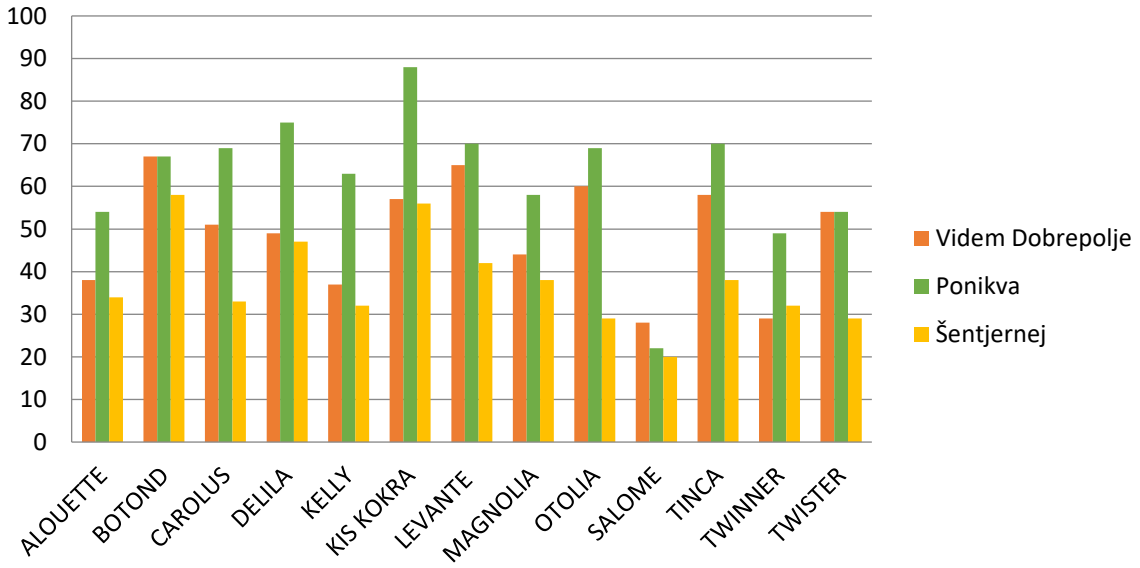

Figure 39. Average tuber size (mm) for each variety in 3 locations in mm

About visual, organoleptic and chemical aspects of harvest:

The dry matter determines the quality of potato and values over 19 - 20 % gives the potato its distinct taste and aroma. It depends on genotype, growing conditions, agritechnics and length of growing season. In general, dry matter content of all varieties at all four organic locations was higher than long term values for conventional farming. Varieties OTOLIA and MAGNOLIA had the highest percentage of dry matter (on average for four locations 26 and 25 % respectively), which is way above optimal dry matter for canning (around 20 %). Despite that Twister had the lowest percentage of dry matter (the average for four locations was 19 %), it still reached optimal values (cf. Figure 40).

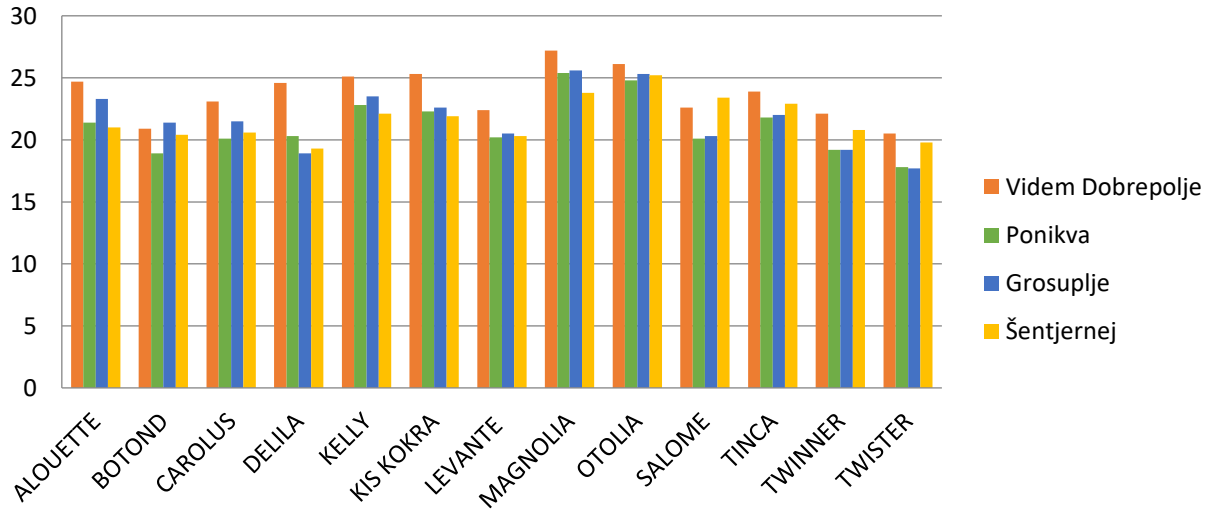

Figure 40. Dry matter (%) for each variety in 4 locations

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The visual traits and sensorial analysis were done at the Agricultural Institute of Slovenia. There was practically no discoloration of flesh 20 minutes after cooking, except of minor discoloration of KIS Kokra and Botond in Grosuplje. Only at some varieties disintegration was noticed with the highest values in Videm Dobrepolje.

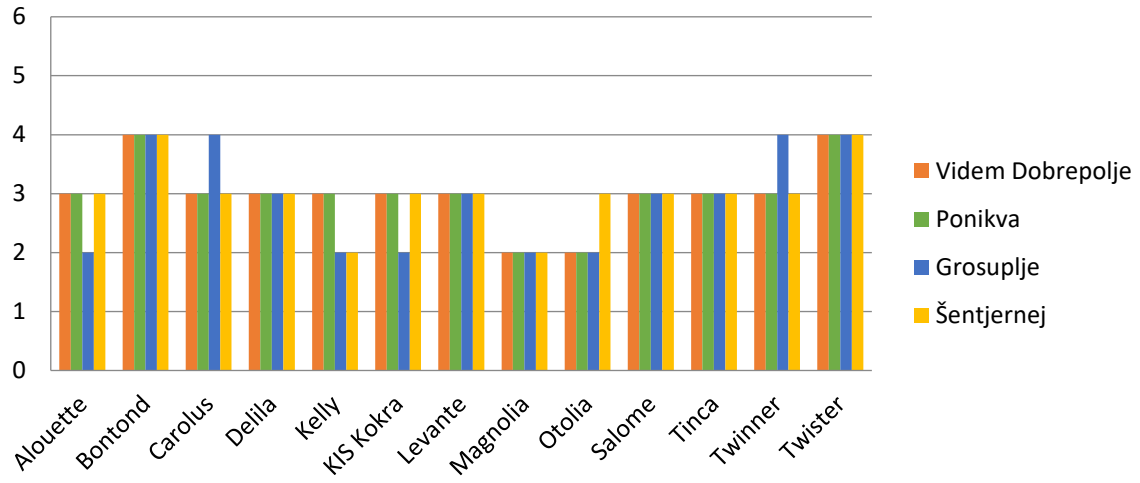

Figure 41. Taste (aroma) *of tuber for each variety in 4 locations (1 excellent, 2 very good, 3 good, 4 acceptable, 5 worse, 6 unsuitable)*

Most of the varieties in all 4 locations had at least good taste, which is very good result in such weather conditions (cf. Figure 41). Botond and Twister had only acceptable taste. There was also very little other taste, one very strong was in Ponikva at Delila variety. The general impression was noticed on 10 points scales from 1 - excellent, 2 - very good, 3 -good, 4 - acceptable, 5 - worse, 6 to 10 - unsuitable. Most of the varieties had the score "3" for the four locations. KELLY and MAGNOLIA obtained the score of 2 at least for one location. Worse general impression had BOTOND with an average of score 4.8 and then Twister obtained 4 (cf. Figure 42).

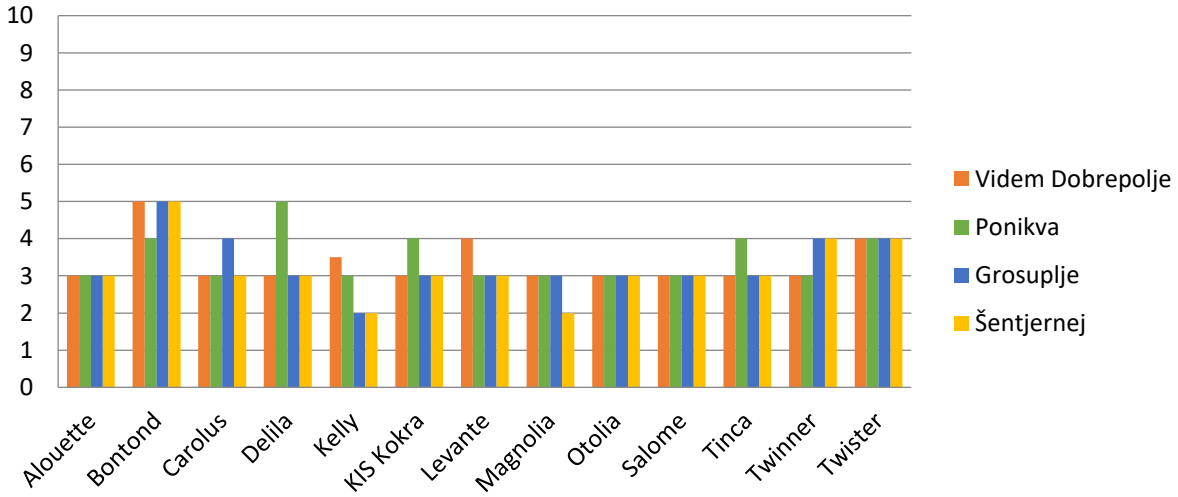

Figure 42. General impression for each variety in 4 locations (1 excellent, 10 unsuitable)

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The cooking types were also evaluated using four grade scale (A firm flesh - salads, B multipurpose uses, C mealy, D floury) (cf. Table 40). They can be also intermediate types of AB, BC etc. Among consumers salad type A is preferable since potato does not disintegrate. Type B is the most usable multipurpose, while BC is more mealy, more suitable for baking and frying. C is very mealy, and suitable for bread etc. Cooking types of BC and C or D correlates with higher dry matter content. Variety Magnolia had A type on 3 locations. Some varieties were very stable regarding cooking type Twinner, Twister, while some other varieties ranged from A to BC, depending on growing conditions.

Table 40. Cooking type for each variety samples in 4 locations

Cooking type	Videm Dobrepolje	Ponikva	Grosuplje	Šentjernej
Alouette	BC	BC	B	BC
Botond	BC	B	B	B
Carolus	B	B	B	BC
Delila	BC	BC	AB	B
Kelly	BC	BC	AB	AB
KIS Kokra	BC	BC	B	BC
Levante	BC	B	B	B
Magnolia	AB	BC	AB	AB
Otolia	AB	BC	AB	B
Salome	AB	B	B	B
Tinca	B	AB	B	B
Twinner	B	B	B	B
Twister	B	B	B	B

4.2. Potato farmer participatory trials and breeding in Poland

Since potato cultivars suitable for organic farming should have a slightly different set of 'mandatory characteristics' than conventional ones, breeding of such cultivars differ from conventional breeding. It is believed that selection of cultivars destined to organic farming could be strongly improved by active participation of farmers (Participatory Breeding). Vision on organic plant breeding is based on the cyclic interaction between plant and environment, and between farmer (and the rest of the production chain) and breeder. Cultivars will be optimally adapted to organic growing conditions when they have been selected, maintained and multiplicated in these conditions. Therefore, in the ECOBREED project conduction of a series of field trials in contrasting soil and climate zones were planned. In the frame of this network of field trials local organic farmers will be involved into breeding process and their activities will includes among others evaluation of cultivars and selection of breeding materials that are particularly suited to their requirements and preferences (Farmer Participatory Trials). In the case of potatoes, each participant committed to cooperate with at least four farmers who run their farms under the organic system. IHAR-PIB started cooperation with four such

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farms. Two of them are located in Podkarpackie voivodeship (Połomia and Tuligłowy) and are located in the Mazowieckie voivodeship (Jadwisin and Grabów).

4.2.1. Potato cultivars assessment

The first part of this experiments was conducted on a group of cultivars selected from the Ecobreed potato work collection. Thanks to this, farmers can actively engage in the breeding process, having the opportunity to choose cultivars adapted to their specific environment and growing conditions. In 2021 in Poland 10 selected potato cultivars from work collection (Alouette, Carolus, Otolia, Twister, Twinner, Levante, Kokra, Sarpo Mira, Bzura, Gardena) were planted in 4 organic (three organic and one low input) locations. From each cultivar were planted 100 tubers. During the vegetation period cultivars were systematically evaluated for a set of phenotypic traits (Figs. 43-44). During the growing season, farmers assessed the date of planting, harvested, emergence, plant height, damage caused by pathogens and pests. These observations are presented in tables 32-35

The biggest problem for some farmers in season 2021 was the Colorado potato beetle. The percentage of damage caused by this pest depended on the cultivar and locations. Level of damage ranged from 10 to 90 % (tables 41-44). Only in Jadwisin damage caused by the Colorado potato beetle were not observed. The applied insecticide SpinTor 240SC based on spinosad was high toxicity for the Colorado potato beetle.

Table 41. Field observation - experiment in Grabów (PL2021)

Cultivar	Planting date	Harvested date	Date of emergence	Mean plant height in cm	Colorado potato beetle damage (%)
Alouette	06.05	02.09	27.05	24	5
Carolus	06.05	02.09	25.05	34	30
Levante	06.05	02.09	25.05	25	10
Twinner	06.05	02.09	25.05	27	90
Twister	06.05	02.09	27.05	26	10
Otolia	06.05	02.09	25.05	36	5
Kokra	06.05	02.09	25.05	25	5
Bzura	06.05	02.09	27.05	21	10
Gardena	06.05	02.09	25.05	17	20
Sarpo Mira	06.05	02.09	25.05	15	2

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Table 42. Field observation - experiment in Jadwisin (PL2021)

Cultivar	Planting date	Harvested date	Date of emergence	Mean plant height in cm	Colorado potato beetle damage (%)
Alouette	26.04	07.09	18.05	31	0
Carolus	26.04	07.09	24.05	34	0
Levante	26.04	07.09	24.05	20	0
Twinner	26.04	07.09	18.05	28	0
Twister	26.04	07.09	21.05	24	0
Otolia	26.04	07.09	18.05	31	0
Kokra	26.04	07.09	21.05	28	0
Bzura	26.04	07.09	18.05	28	0
Gardena	26.04	07.09	20.05	23	0
Sarpo Mira	26.04	07.09	18.05	27	0

Table 43. Field observation - experiment in Tuligłowy (PL2021)

Cultivar	Planting date	Harvested date	Date of emergence	Mean plant height in cm	Colorado potato beetle damage (%)
Alouette	04.05	14.09	05.06	50	10
Carolus	04.05	14.09	05.06	40	20
Levante	04.05	14.09	05.06	40	20
Twinner	04.05	14.09	03.06	30	50
Twister	04.05	14.09	03.06	35	20
Otolia	04.05	14.09	01.06	35	20
Kokra	04.05	14.09	05.06	40	20
Bzura	04.05	14.09	03.06	50	10
Gardena	04.05	14.09	01.06	40	20
Sarpo Mira	04.05	14.09	01.06	50	10

Table 44. Field observation - experiment in Połomia (PL2021)

Cultivar	Planting date	Harvested date	Date of emergence	Mean plant height in cm	Colorado potato beetle damage (%)
Alouette	28.04	10.09	02.06	35	85
Carolus	28.04	10.09	02.06	36	90
Levante	28.04	10.09	07.06	28	100
Twinner	28.04	10.09	30.05	28	100
Twister	28.04	10.09	02.06	28	95
Otolia	28.04	10.09	02.06	34	80
Kokra	28.04	10.09	01.06	31	90
Bzura	28.04	10.09	31.05	33	80
Gardena	28.04	10.09	30.05	27	95
Sarpo Mira	28.04	10.09	30.05	31	80

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Figure 43. Experimental field in Grabów (PL2021). Plant height measurement (photos by Beata Tatarowska)

After harvest for each cultivar the following traits were assessed: total yield (kg/bush), tuber shape, depth of eyes, regularity of tuber shape, starch (%), tubers defects, taste and darkening raw and cooking of tubers (photos 3-4). On figure 1 is presented mean total yield (kg/bush) obtained from each cultivar in four localities. The highest average yield per bush was recorded in Tuligłowy (1,00 kg/bush). The lowest was recorded in Połomia (0,25 kg/bush). The best-yielding was cultivar Twister (1,06 kg/bush), whereas the lowest cultivar Twinner (0,42 kg/bush). The low tuber yield in Połomia was caused by a strong attack of the Colorado potato beetle. The bushes in Połomia were damaged by Colorado potato beetle almost in 100% (table 45).

In 2021, the highest starch content was recorded for cv. Bzura (16,6 %), while the lowest for cv. Levante (9,9 %). In 2021 in all locations and for all cultivars were noted high values for taste. The values ranged from 5,8 for cv. Gardena in Grabów to 8,0 for cvs. Levante, Otolia, Twister in Jadwisin. On Figure 48 were presented results from darkening tubers of raw and cooked potato flesh. Both cooked and raw potatoes darkened the weakly in all locations. Mean value for darkening of cooked tubers after 10 minutes and 24 h ranged from 6,4 for cv. Kokra to 8,4 for cv. Otolia. While darkening of raw potato flesh range from 6,9 for cv. Sarpo Mira to 8.1 for cv. Alouette (Figure 48). Tuber morphology in all locality was correct. Mean values for depth of eyes range from 6,8 in Grabów to 7,5 in Połomia. For regularity of tuber shape values range from 6,6 in Tuligłowy to 7,1 in Jadwisin (Figure 49).

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Figure 44. Experimental field in Połomia (PL2021). Damage caused by Colorado potato beetle (photos by Michał Noworól)

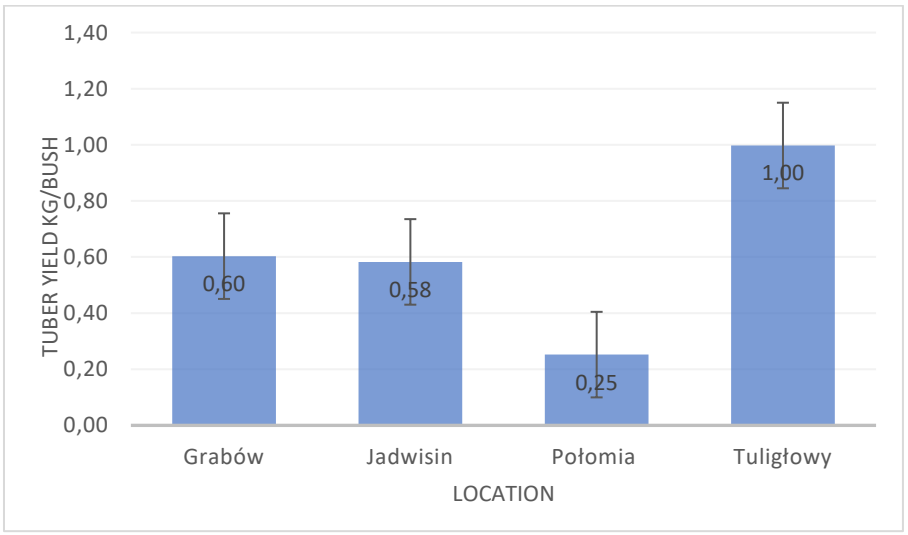

Figure 45. Mean values for total yield in kg/bush in four localities (PL2021)

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Table 45. Total yield (kg/bush) for 10 cultivars in four localities (PL2021)

Cultivar	Mean total yield (kg/bush)				
	Grabów	Jadwisin	Połomia	Tuligłowy	Mean value
Alouette	0,83	0,81	0,18	1,02	0,81
Bzura	0,73	0,83	0,25	0,80	0,70
Carolus	0,34	0,38	0,17	0,78	0,54
Gardena	0,50	0,69	0,31	1,14	0,82
Kokra	0,71	0,63	0,30	1,01	0,78
Levante	0,89	0,33	0,07	0,63	0,53
Otolia	0,75	0,64	0,29	1,21	0,88
Sarpo Mira	0,71	0,49	0,32	1,25	0,88
Twinner	0,25	0,36	0,22	0,57	0,42
Twister	0,55	0,67	0,41	1,57	1,06

Table 46. Taste for 10 cultivars in four localities (PL2021)

Cultivar	Taste (in scale 1-9; where 9 means very tasty)				
	Grabów	Jadwisin	Połomia	Tuligłowy	Mean value
Alouette	7,4	7,4	7,6	7,8	7,6
Bzura	7,0	7,6	7,0	7,2	7,2
Carolus	7,4	7,6	7,6	7,4	7,5
Gardena	5,8	7,4	7,4	7,6	7,1
Kokra	6,8	6,8	6,6	6,4	6,7
Levante	7,2	8,0	7,2	7,4	7,5
Otolia	7,8	8,0	7,8	8,2	8,0
Sarpo Mira	7,5	7,0	7,4	6,4	7,1
Twinner	7,4	7,6	7,4	7,4	7,5
Twister	7,4	8,0	7,4	7,4	7,6

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Figure 46. Description of organic experiments in Połomia (PL2021) (photos Beata Tatarowska)

Figure 47. Description of organic experiments in Tuligłowy (PL2021) (photos Beata Tatarowska)

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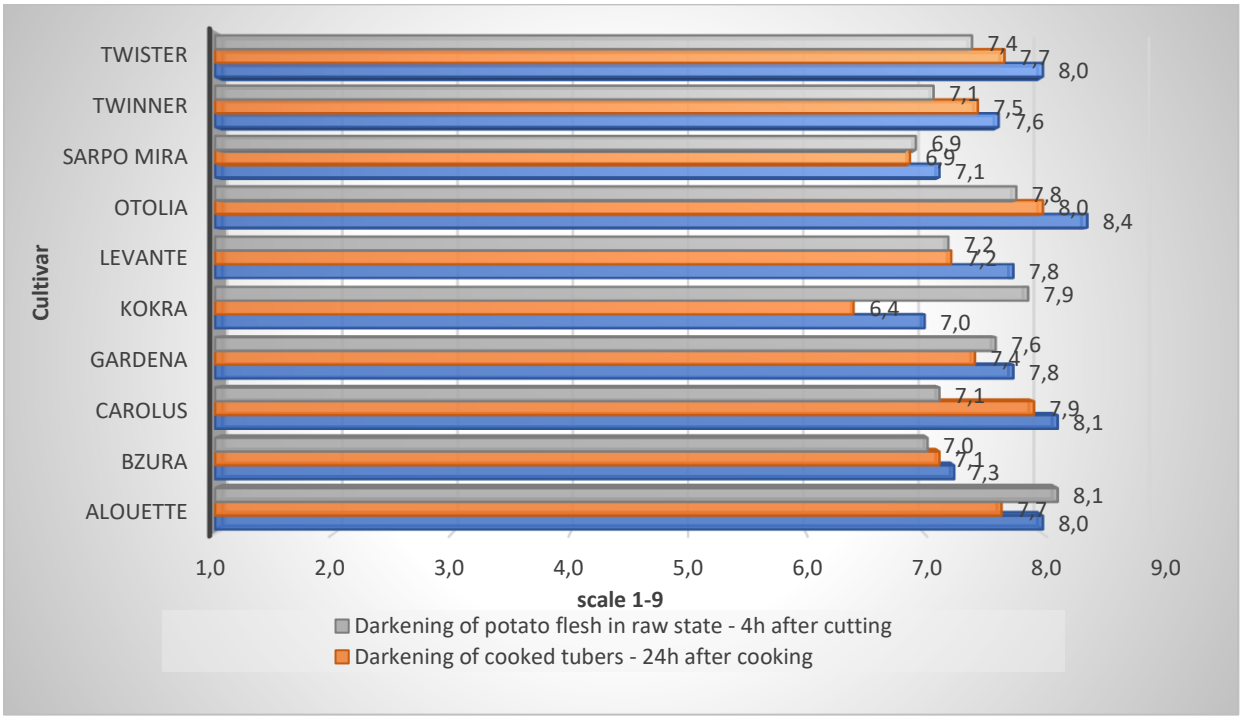

Figure 48. Mean values for darkening of tubers: cooked and raw (PL2021)

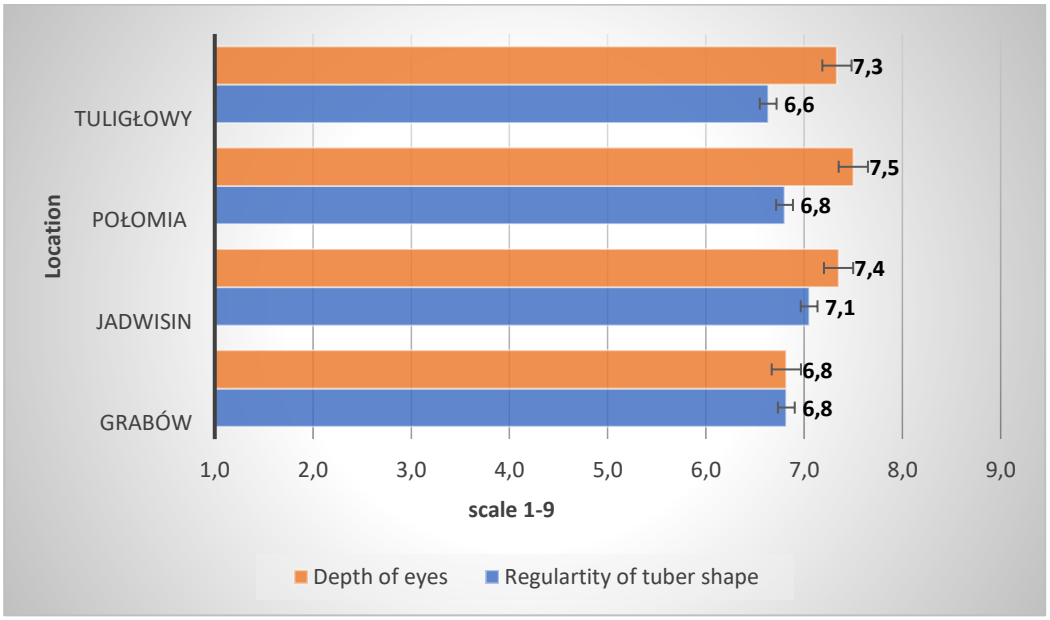

Figure 49. Mean values for depth of eyes and regularity of tuber shape (PL2021)

4.2.2. *Selection of potato breeding material*

The second part of these experiments were conducted on potato breeding material in 2021, 15 selected potato breeding lines were planted in two locations (Tuligłowy and Połomia). In each location breeding lines were planted in three replications. During the

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growing season, farmers assessed the date of planting, harvested, emergence, plant height, damage caused by pathogens and pests. These observations are presented in Tables 38 and 39. In Połomia was recorded a high level of damage caused by the Colorado potato beetle (Table 47, Figure 50). Breeding lines were damaged from 75 % to 100 %. The damage influenced on the low total yield of tubers obtained for the breeding lines in this locality (mean 0,2 kg/bush) (figure 51).

Table 47. Field observation – experiment in Tuligłowy (PL2021)

Breeding lines	Planting date	Harvested date	Date of emergence	Mean plant height in cm	Colorado potato beetle damage (%)
EB-21-4	04.05	14.09	03.06	35	20
EB-21-20	04.05	14.09	01.06	40	20
EB-21-25	04.05	14.09	03.06	35	20
EB-21-31	04.05	14.09	01.06	45	20
EB-21-38	04.05	14.09	01.06	40	20
EB-21-71	04.05	14.09	05.06	40	20
EB-21-72	04.05	14.09	05.06	40	20
EB-21-91	04.05	14.09	01.06	35	20
EB-21-97	04.05	14.09	03.06	45	20
EB-21-107	04.05	14.09	03.06	40	20
EB-21-108	04.05	14.09	03.06	40	20
EB-21-112	04.05	14.09	01.06	40	20
EB-21-115	04.05	14.09	05.06	40	20
EB-21-126	04.05	14.09	03.06	35	20
EB-21-151	04.05	14.09	05.06	45	20

Table 48. Field observation - experiment in Połomia (PL2021)

Breeding lines	Planting date	Harvested date	Date of emergence	Mean plant height in cm	Colorado potato beetle damage (%)
EB-21-4	28.04	10.09	29.05	30	95
EB-21-20	28.04	10.09	30.05	24	70
EB-21-25	28.04	10.09	29.05	20	100
EB-21-31	28.04	10.09	31.05	22	100
EB-21-38	28.04	10.09	01.06	30	100
EB-21-71	28.04	10.09	28.05	34	75
EB-21-72	28.04	10.09	28.05	36	100
EB-21-91	28.04	10.09	31.05	30	100
EB-21-97	28.04	10.09	02.06	30	100
EB-21-107	28.04	10.09	30.05	31	80
EB-21-108	28.04	10.09	29.05	25	95
EB-21-112	28.04	10.09	01.06	35	100
EB-21-115	28.04	10.09	01.06	36	100
EB-21-126	28.04	10.09	02.06	28	95
EB-21-151	28.04	10.09	29.05	28	100

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Figure 50. Mean values for total yield in kg/bush in Połomia and Tuligłowy (PL2021)

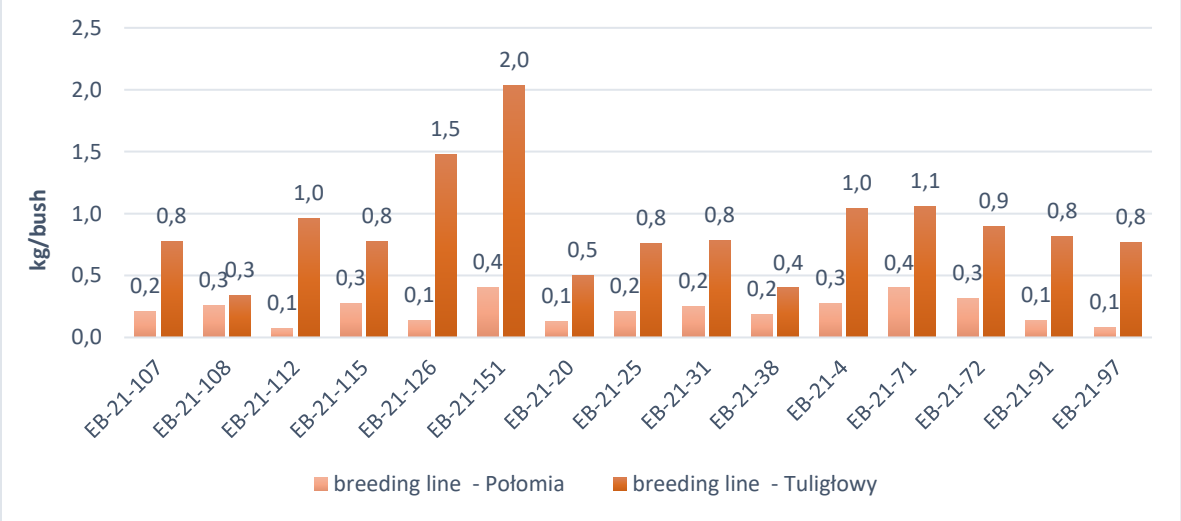

Figure 51. Mean values for total yield in kg/bush for 15 breeding lines evaluated in Połomia and Tuligłowy (PL2021)

On Figure 51 is presented the mean total yield (kg/bush) obtained from each breeding line in Połomia and Tuligłowy. The best-yielding in Tuligłowy was breeding line EB-21-151 (2,0 kg/bush), whereas the lowest line EB-21-108 (0,3 kg/bush). In Połomia breeding lines they yielded much weaker than in Tuligłowy. Total yield in kg/bush in Połomia range from 0,1 kg/bush to 0,4 kg/bush (Figure 38). Tuber morphology for 15 breeding lines is presented in Table 49.

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Table 49. Mean values for depth of eyes and regularity of tuber shape for 15 breeding lines evaluated in Połomia and Tuligłowy (PL2021)

Breednin line	Depth of eyes (in scale 1-9)		Regularity of tuber shape (in scale 1-9)	
	Połomia	Tuligłowy	Połomia	Tuligłowy
EB-21-107	7,0	8,0	7,0	6,0
EB-21-108	7,0	7,0	7,0	5,0
EB-21-112	8,0	8,0	8,0	8,0
EB-21-115	8,0	8,0	8,0	8,0
EB-21-126	7,0	8,0	7,0	8,0
EB-21-151	7,0	8,0	7,0	7,0
EB-21-20	7,0	8,0	7,0	8,0
EB-21-25	7,0	7,0	6,0	6,0
EB-21-31	7,0	7,0	6,0	7,0
EB-21-38	8,0	7,0	7,0	7,0
EB-21-4	7,0	8,0	6,0	8,0
EB-21-71	7,0	7,0	7,0	8,0
EB-21-72	8,0	6,0	7,0	6,0
EB-21-91	7,0	8,0	7,0	7,0
EB-21-97	8,0	7,0	7,0	6,0
Mean value	**7,3**	**7,5**	**6,9**	**7,0**

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4.3. Potato farmer participatory trials in Germany

The 2021 potato trial took place at the Pfülb farm in Lower Franconia. The focus was on varieties with resistance to late blight. This was an important trait in the rainy summer of 2021. This could be clearly seen during the trial visit in early August because the farm does not use copper. While the standard varieties had no foliage at all, the resistant varieties still had green leaves. The resistant and tolerant varieties grown were Sevilla, Tentation, Twister, Levante, Otolia and Allians, with Seville coming out ahead in the scoring. Taste of these varieties was good. Fortunately, late blight resistant varieties are increasingly finding their way into the seed supply and the official variety recommendations. In Bavaria, these include Sevilla, Tentation, Twinner and Twister.

Table 50. Diseases and pests: 1 low, 9 high; Cooking type: 1 mealy, 9 firm; Geschmack: 1 good, 9 bad

Variety	Agria	Twister	Tentation	Sevilla	Otolia	Levante	Allians	Marquise	Laura	Linda
Late blight	9	6	6	3	4	5	5	9	9	9
Early blight	X									
Col. Beetle	6	5	6	5	3	6	6	6	6	7
Yield t/ha	80	106	57	94	118	70	37	100	100	120
Size 65+	10	37	6	11	3	3	4	9	16	3
45-65 mm	51	51	45	56	34	53	39	53	36	13
Size 45-	39	12	49	33	63	44	57	38	48	74
Cooking type	3	2	6	6	6	6	2	4		2
Taste	2	1	4	2	2	3	2	2		2

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4.4. Potato farmer participatory trials in Hungary

4.4.1. Methods: Locations and conditions of trials

In 2022 the farmer participatory trials program within the ECOBREED project was conducted on four organic farms (at Szár, Rábcakapi, Szakály and Zalavár) located in different parts of Hungary having different ecological conditions in four different regions: Fejér, Győr-Moson-Sopron, Tolna and Zala county (Figure 52).

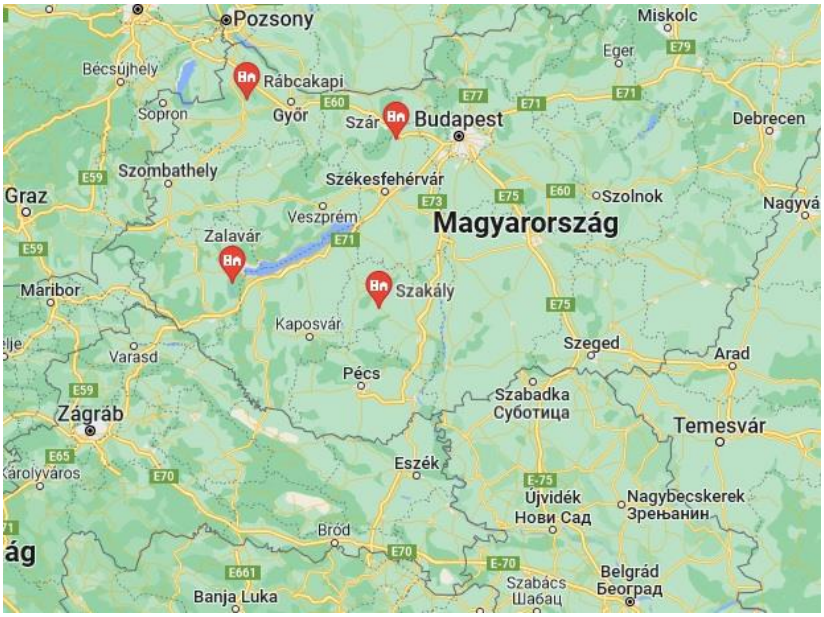

Figure 52. Locations of potato trials in Hungary

Conditions of trials: The selection of 12 varieties was done partly by researchers, farmers and consultants. One hundred tubers were planted from each variety at all locations in a non-replicated trial. The planting was done between 12 - 28 April. Each partner used its own regular farming methodology (nutrition, weed and pest management).

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Table 51. List of tested varieties in Hungary

Variety	Maturity	Resistance to late blight	Resistance to PVY
OTOLIA	intermediate	yes	no
LEVANTE	intermediate	yes	no
ALOUETTE	intermediate	yes	no
KIS KOKRA	intermediate	yes	yes
MAGNOLIA	early	no	yes
TINCA	intermediate	yes	moderate
TWISTER	early	yes	moderate
TWINNER	early	yes	moderate
BASA	intermediate	moderate	yes
BALATONI RÓZSA	early	no	yes
BALATONI SÁRGA	intermediate	no	yes
BOTOND	early	moderate	yes

The goal of the experiment was to compare the varieties at different locations with different farming management to test their adaptation to different local conditions. Data on planting date, date of emergence, date of canopy closure, date of senescence, plant height, severity of symptoms of PVY, late blight early blight, black scurf symptoms, Colorado potato beetle damage, yield, tuber size, dry matter, cooking type, after cooking discoloration, tuber disorders, regularity of tuber shape, depth of eyes were recorded.

The year 2021 was difficult for potato growers all across Hungary, with shortage of rainfall in June and July compared to an average year and long periods of high temperatures.

4.4.2. Results

Yield and state of crop

Climatic conditions of 2021 were favourable for health status of potato plants regarding fungal pathogens, but it had negative affect on yield, tuber size and quality. Colorado potato beetle was present at all locations. Growers sprayed (1 or 2 times) with organic insecticide LASER PLUS to prevent severe damage. Weed was present but not noticed as a major problem by farmers. PVY infection was observed on all plants of susceptible varieties. Different levels of late blight infections were observed on all 12 genotypes. The symptoms of early blight were severe only in 1-2 cases.

The plant height of varieties was different between locations, varying between 40 - 66,5 cm. Varieties as Basa and Balatoni sárga were the tallest varieties with average height of about 85 and 80 cm at Szakály. Balatoni rózsa had the lowest plant height with an

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average about 40,75 cm. KIS Kokra, Otolia and Twinner had almost equal height at all farms (Figure 53).

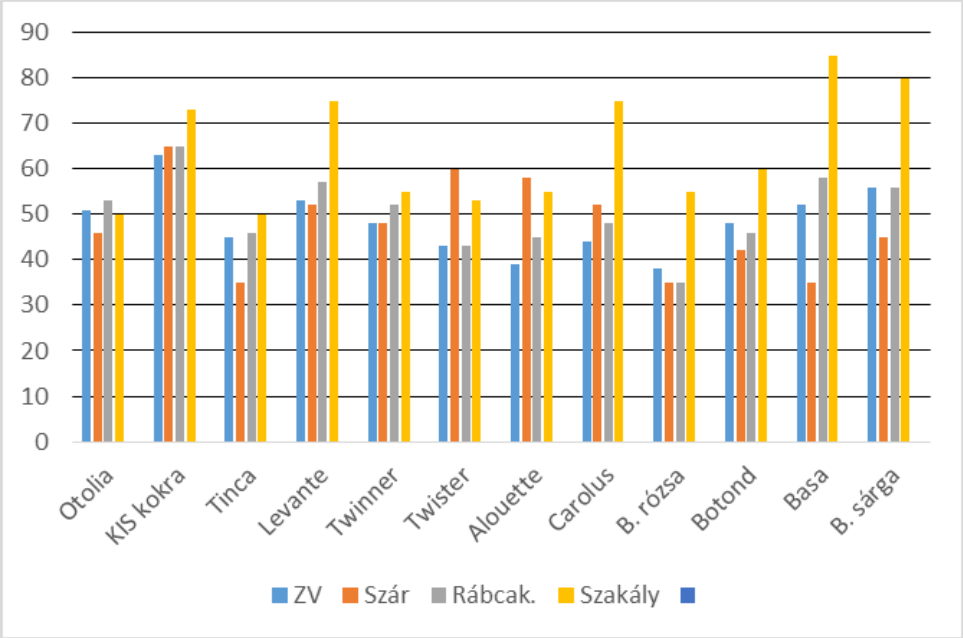

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Figure 53. Plant Height (cm) for each potato varieties in 3 locations

Regarding yield big differences were found between varieties and locations (Table 52). Highest average yield was detected at farm Szakály, while the lowest at Szár. BALATONI RÓZSA, BALATONI SÁRGA, KIS KOKRA, and BOTOND showed the highest yield potential. Yields, highest in each location are marked in green. Yields, lowest, are marked in red. Yield of ALOUETTE were below the average of all varieties at all locations.

Table 52. Average yield of tested varieties (t/ha)

VARIETIES	ZALAVÁR	SZÁR	RÁBCAKAPI	SZAKÁLY	AVERAGE YIELD
OTOLIA	10.79	2.06	3.41	5.61	5.47
KIS KOKRA	11.70	4.45	12.38	8.54	**9.27**
TINCA	6.73	1.67	4.71	8.42	5.38
LEVANTE	7.81	1.07	7.29	11.27	6.86
TWINNER	5.13	1.86	8.25	9.02	6.07
TWISTER	4.27	0.75	8.37	6.88	5.07
ALOUETTE	3.70	0.73	2.01	1.73	2.04
CAROLUS	5.87	2.92	5.28	5.41	4.87
BALATONI RÓZSA	9.14	2.95	9.04	20.12	**10.31**
BOTOND	7.67	2.61	12.19	13.22	**8.92**
BASA	8.53	1.22	8.54	9.47	6.94
BALATONI SÁRGA	13.7	0.35	11.77	11.29	**9.28**
Average	**7.92**	**1.88**	**7.77**	**9.25**	**6.71**

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The tuber size distribution of total yield was determined for each location (% of total yield, <45mm, 45-65mm, >65 mm (Figs. 54-56).

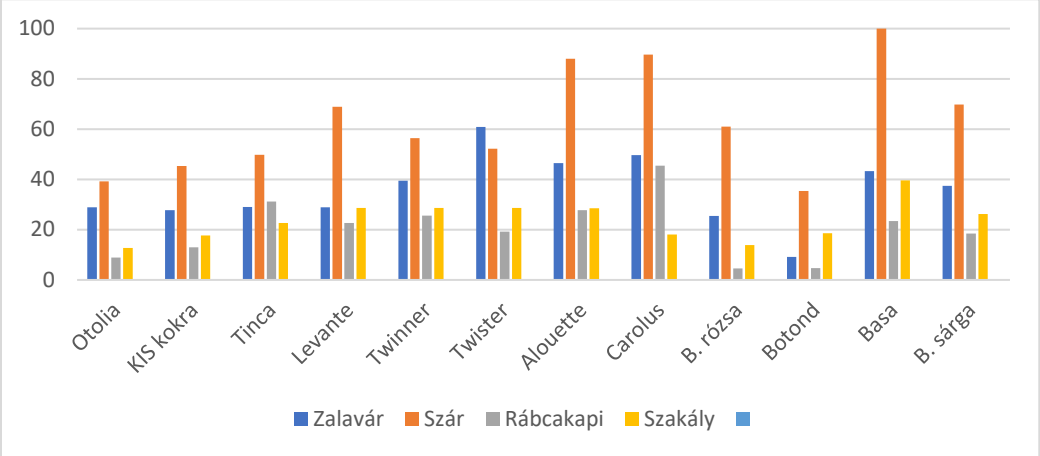

Figure 54. Percentage of tubers below 45mm in diameter

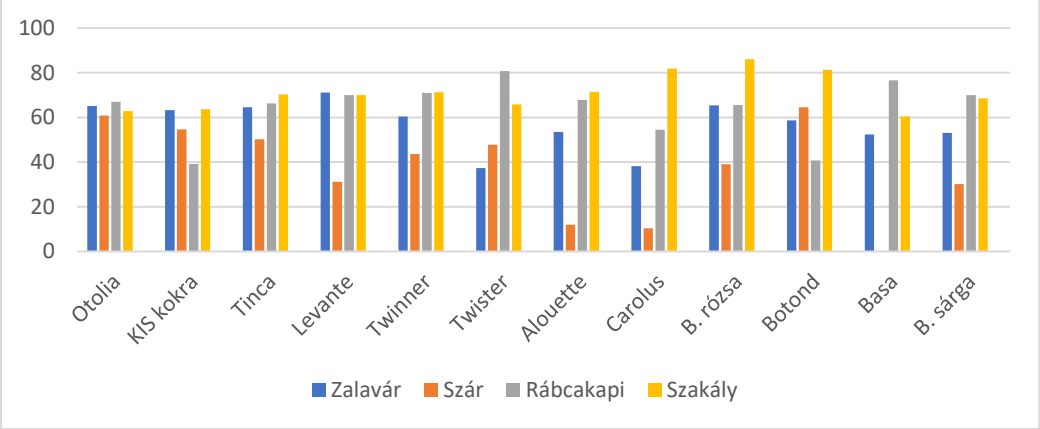

Figure 55. Percentage of tubers between 45-65 mm in diameter

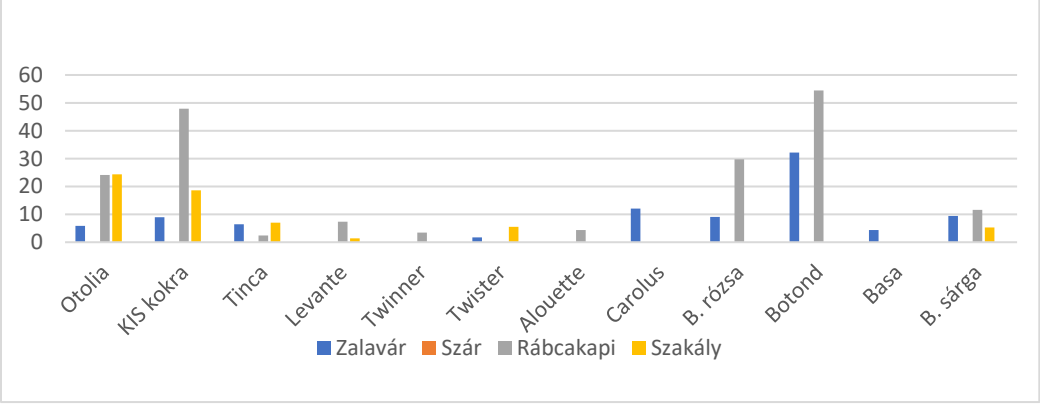

Figure 56. Percentage of tubers above 65 mm in diameter

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From the data it is visible that in case of Szár location the lowest yields are originating from extremely small size of tubers. In general variety Twister and Carolus had the highest rate of small size tubers, while Botond Balatoni rózsa, Kis Kokra and Otolia produced the highest rate of big size tubers.

Dry matter content and cooking type

In general varieties produced moderately high dry matter, above 15 % except Levante, Otolia and Alouette at Zalavár and Twister at Szár. The highest dry matter was produced by variety Twinner and Balatoni sárga at location Szakály (Figure 57).

The cooking types were also evaluated using four grade scale: A firm flesh -salads, B multipurpose uses, C mealy, D floury, while intermediate types are also existing, AB, BC (Table 3). Among consumers salad type A is preferable since tubers does not disintegrate during boiling. Type B is the most used multipurpose, while C is more mealy, more suitable for baking and frying. Cooking types in general correlates with dry matter content.

Growing conditions like weather, soil type and nutrition influences the dry matter content and cooking type. In stressful years with water shortage and high temperatures susceptible varieties can produce lower dry matter only. Based on data this extreme season equalled the results between varieties and locations. Data don't contain extreme values.

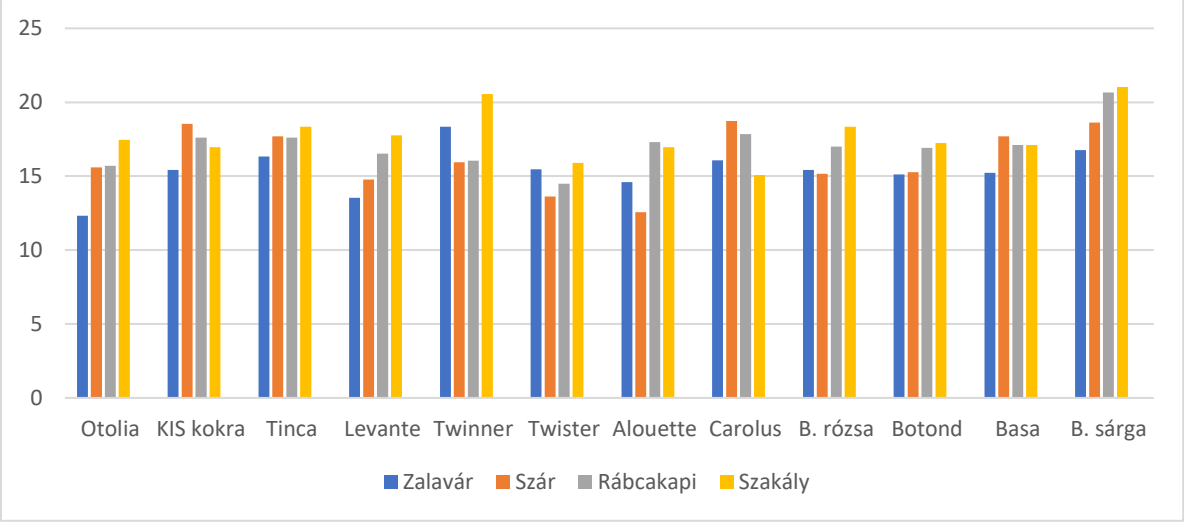

Figure 57. Dry matter content of varieties (%)

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Table 53. Cooking type of tested varieties

Cooking type	ZALAVÁR	SZÁR	RÁBCAKAPI	SZAKÁLY
OTOLIA	AB	AB	B	B
KIS KOKRA	B	BC	B	B
TINCA	B	B	B	B
LEVANTE	B	BC	B	B
TWINNER	B	B	B	B
TWISTER	B	B	B	B
ALOUETTE	BC	BC	B	B
CAROLUS	B	B	B	B
BALATONI RÓZSA	B	B	B	B
BOTOND	B	B	B	B
BASA	A	A	A	A
BALATONI SÁRGA	B	B	B	B

Tuber symptoms affecting marketability

We monitored tubers symptoms and diseases at all locations (common scab, rhisoctonia, silver scurf and fusarium). Highest infection was detected by silver scurf and fusarium. Silver scurf attacked tubers of Alouette at all locations. High infection was detected for Twinner at Szár, for Twister and Carolus at Zalavár. Varieties bred by our Potato Research Station, Keszthely showed the lowest values (Figure 58).

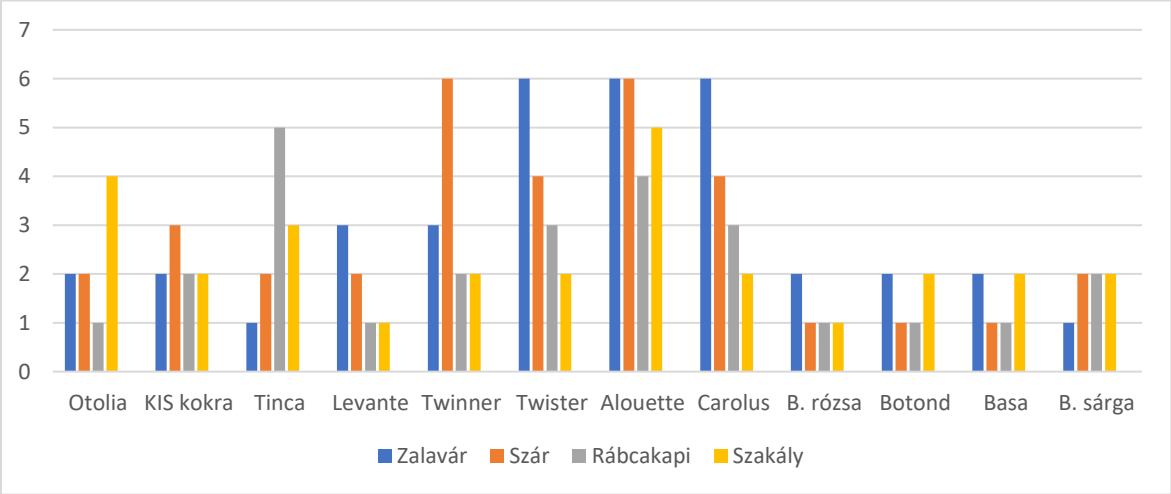

Figure 58. Silver scurf infection of tubers (%)

Fusarium, dry rot of tubers was detected at relatively high rates for all locations (1-9 % of tubers). It can be the consequences of crop rotation applied by growers, the dry season and organic growing conditions. We found significant values especially for location Zalavár and Szár. Varietes Twister, Alouette, Balatoni rózsa and Botond had the highest number of infected tubers (Figure 59).

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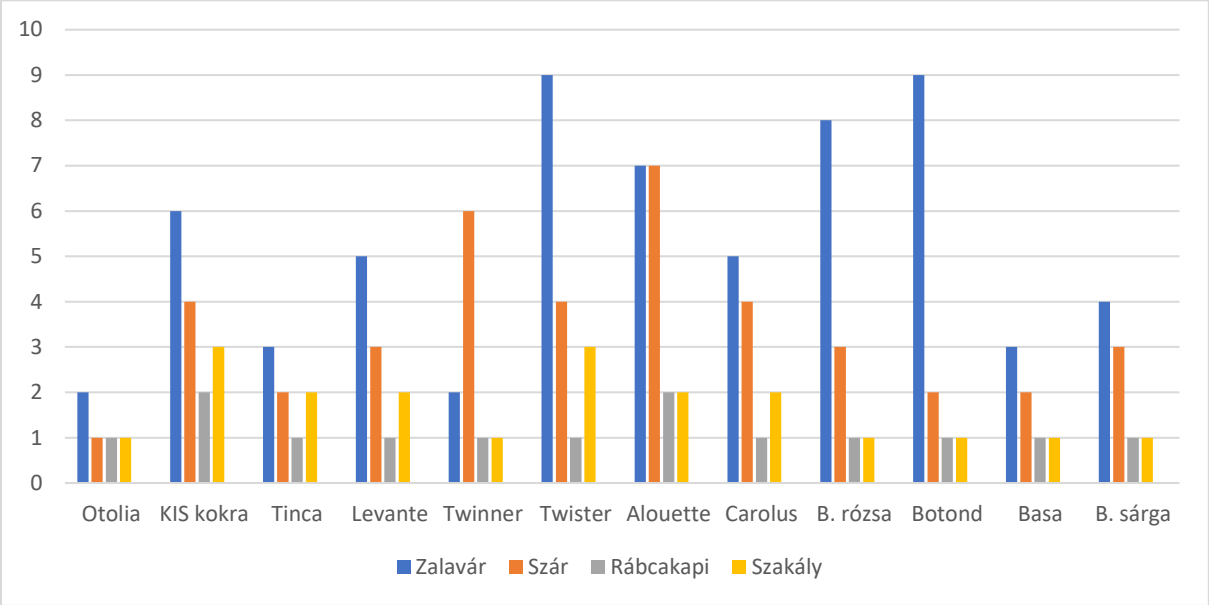

Figure 59. Fusarium infected tubers (%)

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5. Buckwheat

5.1. Buckwheat farmer participatory trials in the UK

All four buckwheat FPT trials were drilled in the spring of 2021 at Gilchesters, Spindlestone, Nafferton Farm and Braodward Hall.

All four buckwheat FPT were established in the UK with trials at Nafferton Farm, Gilchesters and Spindlestone being sown on 14 May 2021 which was about 2 weeks later than planned but due to the late arrival of seed. The trial at Broadward Hall in Hereford was drilled later on 2 June as the seed had to be delivered to Hereford and then heavy rain prevented drilling. All trials were drilled with the same 7 varieties i.e. Cebelica, Le Harpe, Panda, Zoe, Zita, Kora and Billy (we tried to get hold of Bambi seed but the supplier would not send to the UK due to increased paperwork etc. due to BREXIT) at a rate of 75 kg/ha which equates to a target seed rate of 300 seeds/m^2. Three of the four crops established very well at Nafferton Farm, Gilchesters and Broadward Hall (Fig. 60), the exception being at Spindlestone where the weed Charlock (*Sinapis alba*) was a major issue/threat (Fig. 61). At Gilchesters Organics the buckwheat was drilled after a grass/clover ley resulting in low weed pressure but at Spindlestone it was drilled at the end of an arable rotation (hence the high weed pressure) before going into a grass/clover ley in the autumn of 2021.

Figure 60. The buckwheat FPT at Gilchesters (left) and Broadward Hall (right) with photographs taken in early July 2021

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Figure 61. Buckwheat FPT at Spindlestone (taken 12 July 2021) showing that the buckwheat (white flowers) is present but being heavily outnumbered by Charlock (Sinapis alba) despite an attempt to mow the top off the Charlock plants

With the buckwheat struggling to get a hold at Spindlestone a mower was put through bot the commercial crop and FPT to try and top the Charlock to give the buckwheat a fighting chance. However, with little effect of the mowing evident the trial was abandoned in early July. Gilchesters Organics the buckwheat was drilled after a grass/clover ley resulting in low weed pressure but at Spindlestone it was drilled at the end of an arable rotation (hence the high weed pressure) before going into a grass/clover ley in the autumn of 2021. The buckwheat FPT's at Gilchesters and Nafferton Farm were sampled on 21 September ($2m^2$ for yield and quality assessment) with crop height and lodging % being recorded prior to swathing. The FPT at Leominster was sampled on 27 September (again $2m^2$ area per plot) with crop height and % lodging also recorded. At Nafferton Farm and Gilchesters plot combine grain yields were also taken and were based on an area of 50 m x 3m i.e. $150m^2$. Combine yields were not taken at Broadward Hall as it was too far away to transport the plot combine. Cebelica was the highest yielding variety at Nafferton Farm (1.07 t/ha) while at Gilchesters Le Harpe, Zita and Panda had similar yields, but Cebelica had the second lowest yield (Table 54). There was more consistency between sites in terms of TGW where both Le Harpe and Cebelica had the lowest values at both sites.

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Table 54. Combine grain yield and moisture content of Buckwheat Farmer Participatory Trial at Nafferton Farm in 2021

	Weight (kg)	MC (%)	Yield @0%MC	Yield @15% MC	TGW (g)
Billy	5.0	26.4	0.25	0.28	21.3
Kora	12.8	23.9	0.65	0.75	21.0
Le Harpe	14.7	25.1	0.73	0.84	16.5
Zita	14.7	25.1	0.73	0.84	22.6
Cebelica	18.7	25.1	0.93	1.07	19.3
Zoe	13.3	24.7	0.67	0.77	20.4
Panda	12.3	24.4	0.62	0.71	20.6

Table 55. Combine grain yield and moisture content of Buckwheat Farmer Participatory Trial at Gilchesters in 2021

	Weight (kg)	MC (%)	Yield @0%MC	Yield @15% MC	TGW (g)
Billy	22	35.8	0.94	1.08	22.1
Kora	*	30.7			21.8
Le Harpe	24	30.7	1.11	1.28	19.9
Zita	24	29.1	1.13	1.30	20.1
Cebelica	18	32.1	0.81	0.93	17.4
Zoe	18	29.1	0.85	0.98	23.3
Panda	24	30.9	1.11	1.27	20.7

* No weight was recorded for Kora as it caused a blockage in the combine

At all sites, biomass samples were taken just prior to harvest on 21 September at Nafferton Farm and Gilchesters and on 27 September at Broadward Hall, Hereford. The degree of lodging and plant height were recorded in the field. At all sites two 1m^2 sampling areas were cut at ground level and returned to the laboratory where seed weight, total biomass, plant number, number of flower clusters per cyme and TGW were recorded.

Table 56. Grain yield and yield components (data presented per m2) of Buckwheat FPT at Nafferton Farm in 2021

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging*	Plant height	Flower clusters /cyme	TGW (g)
Billy	26.4	72.1	98.5	0.27	7	126.7	7	8.28
Kora	171.0	475.4	646.4	0.26	3	111.7	7.2	18.02
Le Harpe	164.0	530.4	694.4	0.24	7	109.1	8.8	12.92
Zita	158.7	500.5	659.2	0.24	7	117.6	7.5	19.46
Cebelica	183.6	734.8	918.4	0.20	7	128.1	7.5	15.34
Zoe	136.4	465.8	602.2	0.23	5	114.9	8.0	17.91
Panda	207.4	698.6	906.0	0.23	3	108.1	7.7	15.76

* Lodging based on a 1-9 scale where 1 = no lodging

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Table 57. Grain yield and yield components (data presented per m2) of Buckwheat FPT at Gilchesters in 2021

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging	Plant height	Flower clusters /cyme	TGW (g)
Billy	127.6	960.7	1088.3	0.12	3	137.4	9.0	18.9
Kora	184.5	344.1	528.6	0.35	3	114.2	6.8	15.6
Le Harpe	125.0	444.1	569.1	0.22	7	139.7	9.3	14.6
Zita	135.2	560.9	696.1	0.19	5	145.8	8.8	18.0
Cebelica	98.4	367.7	466.1	0.21	9	137.7	8.5	15.4
Zoe	172.2	172.2	477.9	0.26	3	134.6	8.7	19.9
Panda	197.7	522.3	522.3	0.27	3	130.9	8.3	19.3

* Lodging based on a 1-9 scale where 1 = no lodging

Table 58. Grain yield and yield components (data presented per m2) of Buckwheat FPT at Broadward Hall in 2021

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging	Plant height	Flower clusters /cyme	TGW (g)
Billy	123.0	368.1	491.1	0.25	3	135.2	7.0	20.4
Kora	171.6	305.2	476.8	0.36	7	119.5	6.8	17.9
Le Harpe	210.3	322.2	532.5	0.39	5	131.9	8.8	13.1
Zita	137.1	304.4	441.5	0.31	7	146.5	8.2	19.7
Cebelica	182.2	349.1	531.3	0.34	7	140.7	7.7	16.9
Zoe	161.1	356.3	517.4	0.31	7	134.5	7.8	19.8
Panda	200.6	342.3	542.9	0.37	7	120.1	5.5	19.1

* Lodging based on a 1-9 scale where 1 = no lodging

Panda recorded the highest biomass grain weight at both Nafferton Farm (Table 56) and Gilchesters (Table 57) but at Broadward Hall it was lower than Le Harpe (Table 58). Cebelica produced the highest total crop biomass at Nafferton farm but had the lowest total biomass at Gilchesters with Billy the highest while at Broadward Hall Panda had the highest total biomass but with relatively little difference between all 7 varieties evident. Kora had the highest HI at Gilchesters and Le Harpe at Broadward Hall. There was little consistency in plant height between sites in that Cebelica was the tallest at Nafferton Farm (128.1 cm), while Zita was the tallest at Gilchesters and Broadward Hall (145.8 and 146.5 cm respectively). The shortest variety was Panda at Nafferton Farm (108.1 cm), while Kora was the shortest at Gilchesters and Broadward Hall (114.2 and 119.5 cm respectively). The low TGW of Le Harpe from the combine (Tables 54-55) was also supported by the biomass sampling data (Tables 56-58). The variety Billy showed slow development and was particularly susceptible to competition from weeds at Nafferton Farm resulting in very low biomass production (Table 54) and grain yield (Table 56). The poor performance of Billy at Nafferton Farm was reflected in the very low plant

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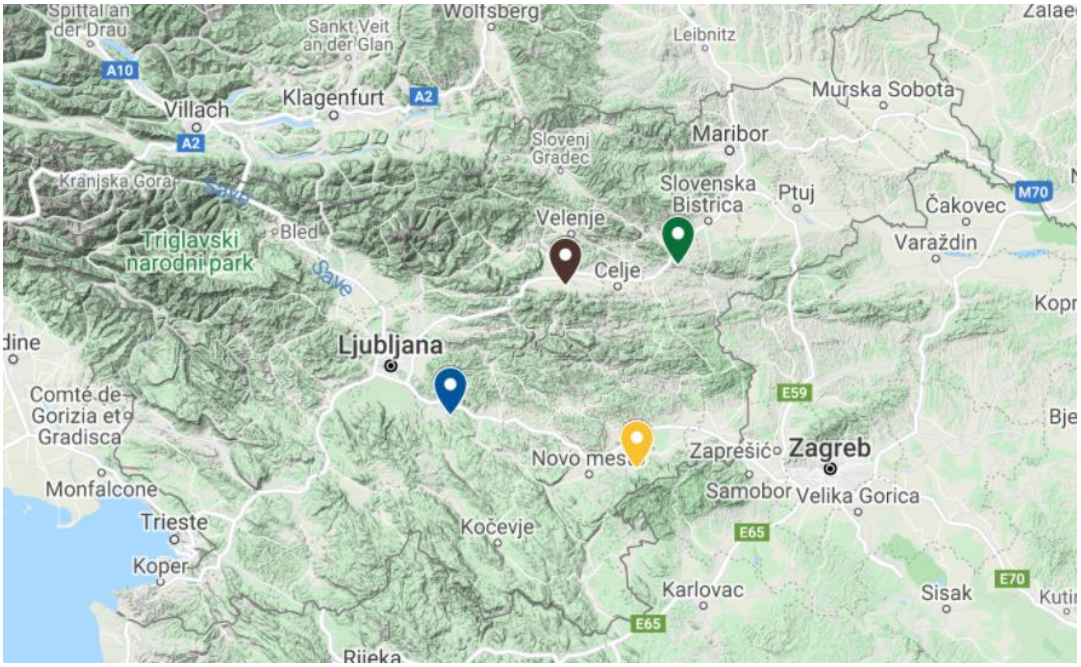
population at harvest (22 plants/m2) which was much lower than all other varieties (63-121 plants/m2) whereas the plant establishment % had only been slightly lower (plant population and establishment data not presented).

5.2. Buckwheat farmers participatory field trials in Slovenia

5.2.1. Methods

The buckwheat participatory field trials within the ECOBREED project were established on four organic farms located in central and southern area of Slovenia (Figure 62).



Name place	Farm Elevation	Type of landscape	Pedo-climatic zones/regions	Farm size	Farm type	Organic since (years)
Grosuplje	335	Valley	Continental temperate climate	12	Mixed	+20
Šentjernej	262	Plain	Continental temperate climate	5,5	Mixed	+5
Prebold	273	Plain	Continental temperate climate	11	Mixed	+10
Ponikva	520	On the hills	Continental temperate climate	8.3	Mixed	+20

Figure 62. Locations of buckwheat trials and main characteristics of the locations

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A total of eight buckwheat varieties (Kora, Panda, Zita, Zoe, Čebelica, Billy, Bamby, La Harpe) were selected for testing by researchers and variety experts. The varieties were chosen based on competitiveness with weeds, duration of growth, seed weight, flower colors, and other characteristics. The previous crops before buckwheat trial were different in each farm (Table 59). Buckwheat was already included in crop rotation of 3 farms and the technology of buckwheat was known to the farmers. Date of sowing was between 15 and 28 July, at the rate of 80 kg/ha and 110 kg/ha. Trials were harvested between the 20 and 29 October, and all varieties at the location were harvested the same day.

Table 59. Crop rotation before buckwheat trial at 4 locations ("1st crop /2nd crop": 1st crop following by a 2nd crop in a same year)

	2018	2019	2020	2021
Grosuplje	wheat / buckwheat	spelt / buckwheat	grass-clover mixture	grass-clover mixture / buckwheat trial
Šentjernej	alfalfa	alfalfa	alfalfa	barley / buckwheat trial
Prebold	maize	barley	phacelia	peas + phacelia / buckwheat trial
Ponikva	potato	maize	pumpkin	early potato / buckwheat trial

The following traits were evaluated to assess the development and agronomic performance of varieties: plant height, crop height, lodging, number of days from seeding to flowering and maturity, number of seed per cyme, 1000-seed weight, chemicals analysis (moisture content, crude protein content, rutin content), abiotic stresses, biotic stresses, seed yield, shattering. In Slovenia, additional traits such as growth and branch shoot habit, plant branching, leaf number, leaf blade length, leaf blade width, compactness of inflorescence, and number of clusters per cyme were also evaluated. Farmers managed the crop cultivation and harvesting and were responsible for the scoring of dates of flowering and full maturity, lodging, abiotic stress and biotic stress and grain yield. Yields are shown in kg/ha at 13 % humidity, except in Ponikva, where moisture at harvest was not measured.

The weather conditions during the growing period were hot and dry. A hailstorm occurred locally 19 days after sowing and damaged the trial at Prebold. After weed outcompeted damaged buckwheat plants trial was abandoned. At Ponikva trial, various damage by deer was observed. Most affected were Panda, Zita and Zoe. Further, a windstorm in September resulted in heavy lodging of buckwheat.

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5.2.2. Results

Farmers noticed a flowering stage between 28 to 35 days after sowing and the full maturity stage between 70-80 days for varieties Kora, Panda, Zita and Zoe, and 80-90 days for varieties Bamby, Billy, Čebelica and La Harpe. Kora and Panda were the earliest varieties, while La Harpe was the latest maturing variety.

Plant height, crop height and the comparison for trials in Ponikva where lodging was strongest are shown in figures 63-65. Panda shows the smallest difference between both heights, indicating a stronger lodging tolerance compared to other varieties. Contrary, Zoe was shown to be the most susceptible to lodging.

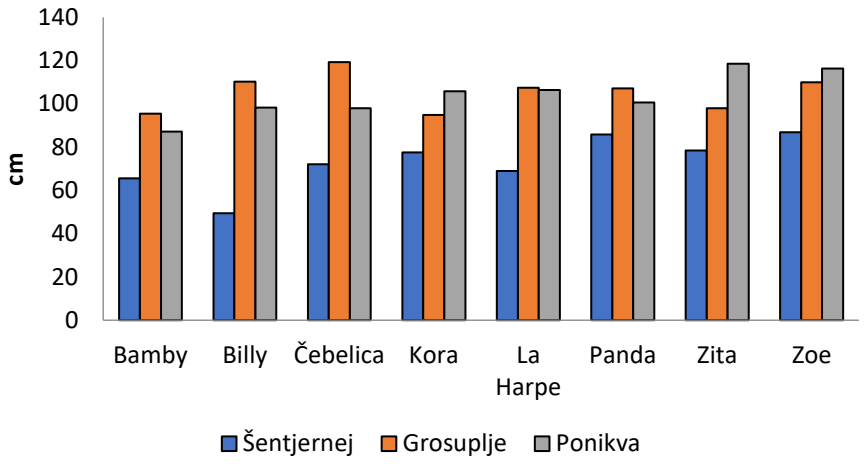

Figure 63. Plant height of buckwheat varieties grown at 3 locations

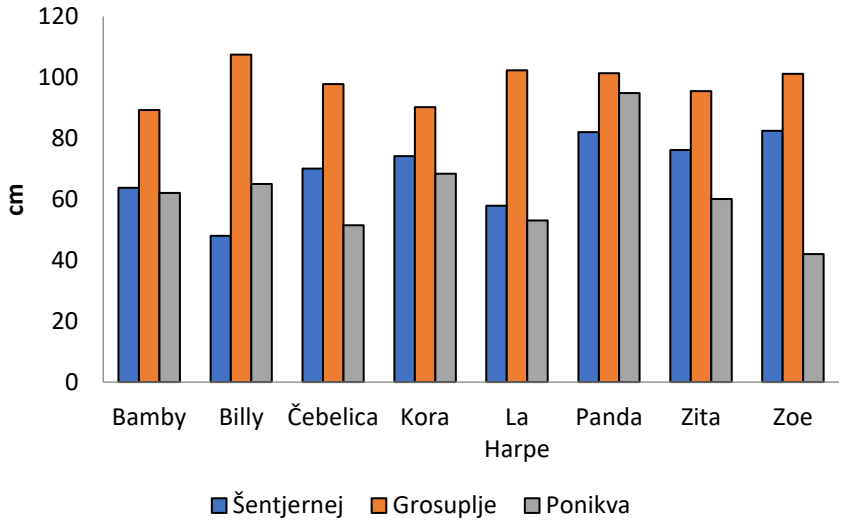

Figure 64. Plant height of buckwheat varieties grown at 3 locations

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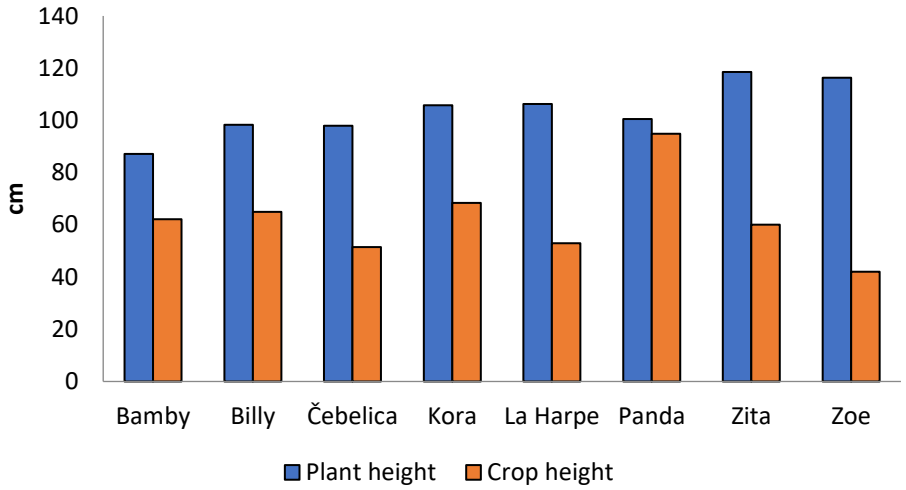

Figure 65. Comparison of plant and crop height of buckwheat varieties at Ponikva

Grain yields are shown in Table 60. Yields that are 15 % above average are marked in green, and yields that are 15 % below average are marked in red. At Grosuplje and Šentjernej varieties Zita and Panda showed highest yields. On the contrary, La Harpe showed the lowest yields at both locations. Variety Billy was appreciated visually for large leaf blade length and width and good ground cover and good weed competitiveness. The yields in Ponikva were obtained by hand harvesting of 4 m^2 and should be interpreted carefully. Variety Billy was the highest yielding and Panda was the lowest yielding variety here. The chemical analysis is in progress.

Table 60. Grain yields of the buckwheat varieties at the locations Grosuplje, Šentjernej and Ponikva

Yield kg/ha	Grosuplje	Šentjernej	Ponikva
Bamby	1529	499	1053
Billy	1708	695	1083
Čebelica	1261	677	1360
Kora	1589	870	1167
La Harpe	852	502	880
Panda	2000	995	699
Zita	2063	959	910
Zoe	1659	586	1057
Average	**1583**	**723**	**1026**

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5.3. Buckwheat field trials in the Czech Republic

Five organic farms have participated in farm trials. 10 to 11 different buckwheat varieties were sown in plots with minimum plot size of 300 m^2. The sowing density was 200 plants per m^2 at each location. The list of varieties, their origin and TGW:

1. Devyatka (Russian federation) – 32.24 g
2. Drushina (Russian federation) – 33.00 g
3. Čebelica (Slovenia) – 22.90 g
4. Le Harpe (France) – 23.58 g
5. Panda (Poland) – 26.38 g
6. Zoe (Czech Republic) – 28.10 g
7. Zita (Czech Republic) – 30.20 g
8. Zamira (Czech Republic) – 27.44 g
9. Kora (Poland) – 27.30 g
10. Billy (Austria) – 27.72 g
11. Bamby (Austria) – 21.58 g

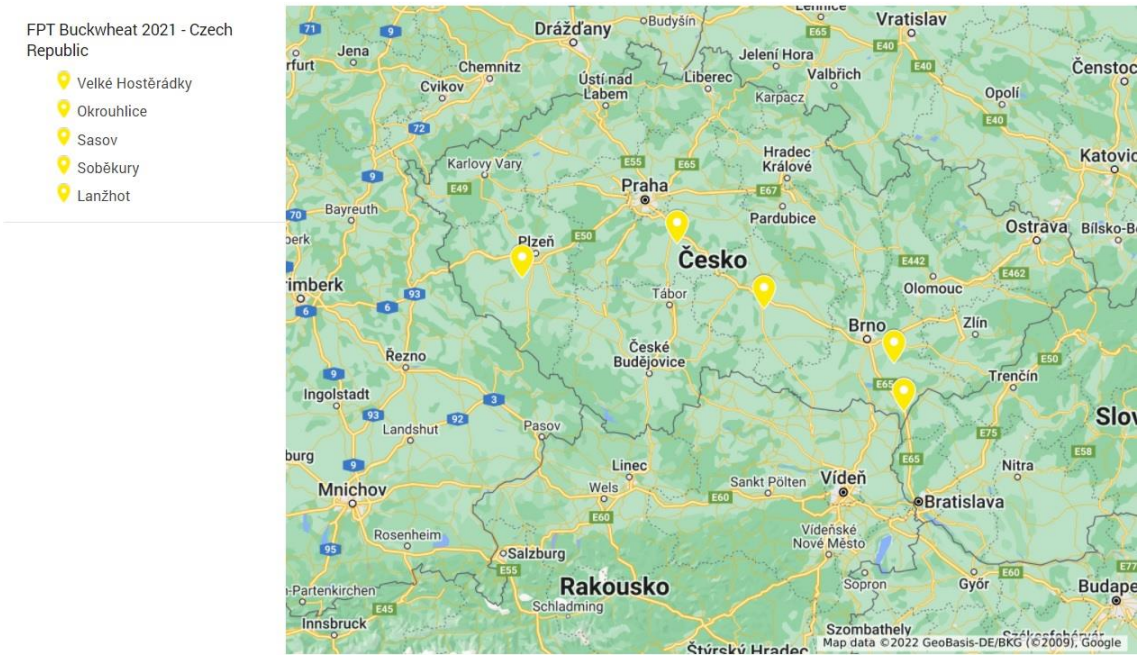

Figure 66. Farm locations within Czech Republic

The key factor of these trials was a communication and discussion about the growth progress and data recorded of different buckwheat varieties along with the farmers.

At the sites Velké Hostěrádky and Lanžhot, the buckwheat trials had to be terminated before reaching full maturity due to high weed infestation. Despite this fact, interesting practical guides can be outlined. All the farms established the trials at the end of May or very beginning of June, due to weather conditions the trials was established 10.6.2021.

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Generally, buckwheat is a very versatile crop, that can be grown for grain production or as a green manure in Czech conditions. It produces large amounts of biomass. This helps to outcompete the weeds. At all plots, the variety Billy had outcompeted weeds very effectively.

Figure 67. Billy variety suppressing weeds very effectively in Lanžhot. All the other varieties were fully infested with weeds. This phenomenon could be seen at different locations as well. Photo: (Adam Brezáni)

Figure 68. Billy variety suppressing dock weed in Sasov. The neighboring varieties are infested by dock weed heavily. Photo: (Adam Brezáni)

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5.3.1. Grain production

Buckwheat can be sown as a main crop for grain production. However, due to its short vegetation period (variety dependent) it is an excellent alternative for a second crop in a production year or as a substitution crop, if the main crop fails for some reason. It is undemanding and heat tolerant crop, which is sown in middle/end of May the earliest. In some regions, later sown – end of June/beginning of July can still reach full maturity. A practical tip for farmers is to include buckwheat after legumes such peas, field peas or crimson clover. Buckwheat can be grown also after winter barley, which is usually harvested earlier than the rest of cereals.

Table 61. Days to maturity of different buckwheat varieties at different localities

Varieties	Locations				
	Velké Hostěrádky	Sasov	Lanžhot	Soběkury	Okrouhlice
Bamby	n/a	120+	n/a	115	120
Billy	n/a	120+	n/a	115	110
Čebelica	n/a	120	n/a	115	120+
~~**Zamira**~~	~~n/a~~	~~n/a~~	~~n/a~~	~~n/a~~	~~n/a~~
Devyatka	n/a	95	n/a	95	100
Drushina	n/a	95	n/a	95	100
Kora	n/a	105	n/a	100	100
Le Harpe	n/a	120	n/a	105	120
Panda	n/a	115	n/a	120	100
Zita	n/a	120+	n/a	120	120
Zoe	n/a	120+	n/a	120	120

According to Table 61 – varieties can be divided into two groups:

- Suitable as a main crop - Blue
- Suitable as a second crop or substation crop – Yellow

Surely, varieties Devyatka, Drushina and Kora can be grown as a main crop as well, but economically it is more suitable to grow buckwheat as a second crop, if the conditions allow – due to its lower yields and undemanding properties. If the farm is located in higher elevation or colder climate, it is better to grow buckwheat as a main crop. Besides short vegetation period, Devyatka and Drushina are low branching and simultaneous maturity determinant varieties. Therefore, it is easier to harvest them. Other buckwheat varieties tend to mature unevenly, which leaves a lot of green residues in harvested mass, which has to be dried and stored properly – adding costs.

Summer of 2021 was humid with 123 % precipitation above 1980-2010 average. Some buckwheat varieties had a higher tendency to branch and produce biomass than others. The longest recorded buckwheat plant had 204 cm! This had an effect on lodging but was dependent upon locality. At some localities all the buckwheat varieties lodged, at some the situation was better. Generally speaking – Drushina and Devyatka were the

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shortest varieties with lower biomass production– meaning that they are easier harvest. However, we need to note, that Drushina had a tendency to lodge, which decreased the yield significantly, even though the number of seeds per cyme was higher in those two varieties than others. The cyme formation of those two varieties is loose compared to the other ones, which are usually semi-compact or compact. The height of other varieties varied between 120 and 180 cm. Medium growth varieties (up to 150 cm) are Kora, Zita, Zoe, Zamira, Panda, Bamby, Čebelice. Billy and Le Harpe are more robust and taller.

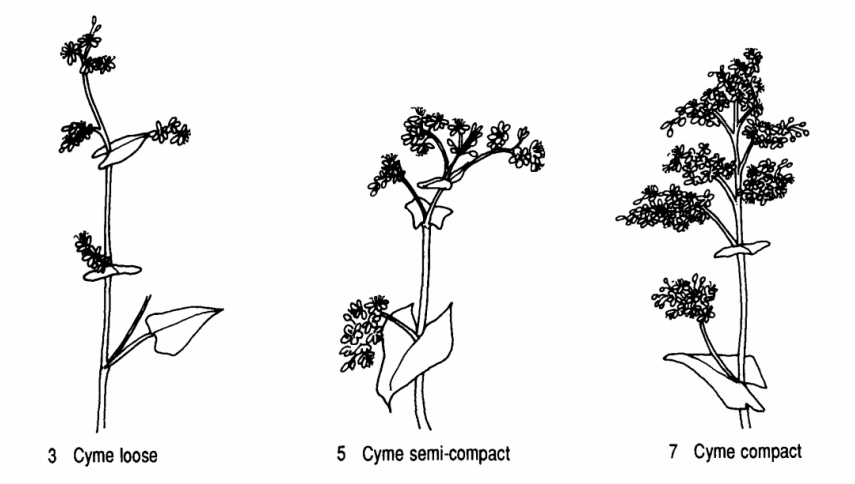

Figure 69. The cyme formation types

Figure 70. Le Harpe variety at Sasov (Photo: Adam Brezáni)

In the region of Czech Republic, buckwheat is processed as groat and then as all-purpose flour. It is not typical to mill the flower as a wholegrain. Therefore, the varieties with higher thousand grain weight (TGW) such as Devyatka, Drushina, Kora, Panda, Zoe, Zita or Zamira will be more demanded for grain production. Varieties as Le Harpe or

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Čebelica are a great option as cover crops. Billy has a higher TGW, but the yield is low and maturity period long, so it is not very suitable for grain production.

Table 62 shows a yield estimation from combine. It is important to note, that the total yield might change depending on the humidity.

Table 62. Off combine yield in dt/ha. Please note, this is the yield directly from combine, at different humidity and maturity levels

Variety	Location	
	Soběkury	Okrouhlice
Bamby	12.83	10.96
Billy	15.42	8.34
Čebelice	21.13	14.90
Devyatka	27.87	19.52
Drushina	19.03	15.86
Kora	22.97	13.24
Le Harpe	18.64	17.72
Panda	17.26	14.76
Zita	24.87	13.31
Zoe	17.01	11.55

Generally, buckwheat has no significant issues with pests or diseases. The limiting factor can be frost, so it is important to establish the crop after the frosts. Attractivity for pollinators can increase the yield up to 25-30 %. The worst variety as a pollinator attractor was Bamby in our trials.

Table 63. TGW in g and netto groat yield in %

Variety	TGW	Location	
		Soběkury – netto groat yield %	Okrouhlice – netto groat yield %
Bamby	21.58	49.42	65.90
Billy	27.58	55.30	54.25
Čebelice	22.90	57.05	66.20
Devyatka	32.24	52.80	63.35
Drushina	33.00	62.75	56.90
Kora	27.30	65.15	65.75
Le Harpe	23.58	51.94	56.80
Panda	26.38	56.98	58.70
Zita	30.20	56.40	61.70
Zoe	28.10	55.37	55.60

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