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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 funding 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 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

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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.

Here is the second bulletin on the results of farmer participatory field trials within ECOBREED devoted to trials performed in 2023.

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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 2021 at the same locations as in the previous year. Newlands on 25 September at a seed rate of 230 kg/ha, Nisbet Hill Farm (230 kg/ha) on 7 October 2020, Thornton Farm (230 kg/ha) on 8 October and at Gilchesters on 24 October. At Newlands the field used was the same as in the previous season i.e. a second wheat with the following cultivation system: straw from previous crop baled and removed, ploughed in very dry conditions, two passes with a Horsch Carrier prior to drilling with a Vaderstadt Rapide and finally rolled. A plot of spelt (variety Zollenspeltz) was included in the trial for comparison.

At Newlands there were 10 wheat varieties used with both KWS Extase and Allessio having the DK20 biostimulant seed dressing, which with the additional plot of spelt resulted in 13 plots. At Nisbet Hill nine varieties were grown but the varieties Royal and Alessio also had DK20 seed dressing applied which resulted in 11 plots. At Thornton Farm there were 11 varieties with both KWS Extase and Theodore having the DK20 and Sikulo seed treatments. At Thornton Farm, Nisbet Hill and Gilchesters the foliar biostimulant Fixio (from ITAKA) was also used on part of the trial (at a rate of 1.5 kg/ha) being applied on 15 May at Thornton Farm, 10 May at Nisbet Hill Farm and 12 May at Gilchesters. Fixio was applied rather late (due to late arrival of the product from Italy) and probably one month beyond the optimum timing at GS30 as recommended by the manufacturer ITAKA.

The first disease assessment at Gilchesters Organics was carried out on 17th June for leaf blotch and yellow rust while at the other 3 sites, Nisbet Hill Farm, Thornton Farm and Newlands the first disease assessment was carried out on 20 June 2022. Further disease assessments were then carried out at Nisbet Hill, Thornton Farm and Newlands on 5 and 18 July 2022. Disease data for each site are presented in Tables 5-8. 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).

At both Newlands and Thornton Farm there were clear signs of early senescence recorded on 5 July (Fig. 1and 2). This was likely due to the warm/dry conditions in the UK, but also soil type and the likely impact of the crop being a second wheat at Nisbet Hill with likely effects of Fusarium and Take-all fungal diseases on crop growth. The early senescence meant that at the visit on 18 July there was little green tissue left at both Newlands and Thornton Farm with the exception of the varieties KWS Extase, Theodore and Wendelin

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which maintained green leaf area for longer at both sites. The commercial crops surrounding the FPT trials at Thornton Farm and Newlands were harvested at least 2 weeks earlier than in the previous season (at Thornton Farm it was harvested on 12 August with a grain moisture content of 13.6-13.9%) reflecting the warm and dry conditions during the summer months. FPT trial plots were harvested at a similar time to the previous season due to a machine breakdown and difficulty/delay in getting the parts.

Fig. 1. Wheat FPT at Thornton Farm on 5 July 2022 showing clear signs of crop stress and senescence.

Lodging assessment and plant height were recorded just prior to harvest. All trials were combined with a Deutsch plot combine (Newland - 29 August, Thornton Farm - 30 August, Nisbet Hill - 31 August, Gilchesters - 2 September) and all grain yields (Table 1) are presented @15% moisture content. The FPT trial at Nisbet Hill was combined on Wednesday, 31 August 2022. Fixio had been applied to a 40 m length at the East of the trial and at harvest a combine cut of 25 m was taken. From the control treatment the combine cut varied from 28.3 to 31 m. Grain samples were retained at harvest for moisture content determination (with an average grain moisture content of 17%) and grain quality analyses.

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At Nisbet Hill Fixio had been applied to a 40 m length at the East of the trial and at harvest a combine cut of 25 m was taken. From the control treatment the combine cut varied from 28.3 to 31 m. Grain samples were retained at harvest for moisture content determination (with an average grain moisture content of 17%) and grain quality analyses.

Fig. 2. FPT at Newlands on 5 July 2022 showing clear early senescence.

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Fig. 3. FPT trial at Gilchesters with a high level of docks.

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2.1.1. Grain yield

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

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	5.56	4.44	4.88	3.27
Wendelin	2.96	5.15	5.66	4.53
Alessio (2)	3.16	4.47	4.65	2.34
Roderik	4.22	3.53	5.26	1.09
KWS Extase	5.99	5.70	-	0.95
KWS Extase + Sikulo	6.19	-	-	-
KWs Extase + DK20	6.32	6.22	-	-
Alessio	3.99	5.00	5.63	3.64
Alessio + DK20	-	4.38	5.81	3.90
Wakelyns popl^{n}	5.24	5.58	5.44	4.15
Barranco	4.86	4.81	6.51	2.94
Royal	3.77	4.57	4.76	3.83
Royal + DK20	-	-	6.43	1.78
Theodore	4.34	-	-	-
Theodore + Sikulo	4.05	-	-	-
Theodore + DK20	4.34	-	-	-
Viki	2.59	4.25	6.30	4.55
Laurin	-	-	-	0.21
Black Russian	-	-	-	3.65
Brandex Popl^{n}	-	-	-	2.28
Barber II	-	-	-	5.35

The drilled Liocharls population was the variety Alessio with the mistake in the original seed consignment sent to the UK following multiplication. This mistake was clear as the seed drilled was a 100% homogeneous and fully awned variety whereas Liocharls is a mixture of awned and non-awned with greater heterogeneity than Wakelyn's. Grain yields from Thornton Farm, Newlands and Nisbet Hill were similar but higher than at Gilchesters (Table1). The highest yielding variety at Thornton Farm and Newlands was the conventional (Group 2 variety on UK Recommended List) breadmaking variety KWS Extase. At Nisbet Hill Farm Barranco that was the highest yielding variety with 6.51 t/ha but this variety produced just over 4.8 t/ha at both Thornton Farm and Newlands. The Group 4 hard wheat variety Theodore was only grown at Thornton Farm but showed a very disappointing performance with just over 4 t/ha. There was high variability in the yield data from Gilchesters and this was likely due to the high level of dock weeds present (Fig. 3) having a clear impact on the grain yield of some varieties. Although most of the docks were cut prior to the open day on 25 July the level of infestation was high and as a result likely to have had a clear impact on the grain yields at that site. At Gilchesters Barber

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II was the highest yielding variety (with a very respectable 5.35 t/ha) but Roderik and KWS Extase were both below 1 t/ha. Wakelyn's population showed a good consistent performance across all 4 sites and was the second highest yielding variety at Newlands (5.58 t/ha). Alessio (2) produced an average yield of 4.47 and 4.65 t/ha at Newlands and Nisbet Hill respectively but was much lower at both Thornton Farm and Gilchesters. At Thornton Farm the seed treatment Sikulo from ITAKA increased the grain yield of KWS Extase by 0.2 t/ha but on the variety Theodore grain yield from the Sikulo treatment was 0.29 t/ha lower than the untreated. There was high variability in the performance of DK20 across the 4 sites in 2021-22. The seed treatment DK20 at Thornton Farm resulted in a 0.33 t/ha increase in grain yield on KWS Extase compared to the control but with no effect at all on the variety Theodore. At Newlands DK20 resulted in a 0.52 t/ha grain yield increase in the variety KWS Extase compared with the control but in the variety Alessio the reverse was true with the untreated control having a 0.62 t/ha higher grain yield than the DK20 treatment. The largest effect of DK20 was observed at Nisbet Hill Farm whereby the seed treatment resulted in a 0.18 t/ha higher grain yield on the variety Alessio but a 1.67 t/ha increase in the variety Royal when compared with the control. At Gilchesters DK20 increased the grain yield of Alessio by 0.26 t/ha but in the variety Royal the control treatment had a 2.05 t/ha higher grain yield than DK20.

Table 2. Grain yields (t/ha @15% moisture content) from Thornton Farm in response to Fixio application in the 2021-22 season.*

	Control	Fixio
Theodore + Sikulo	4.05	4.35
Theodore	4.34	5.07
Theodore + DK20	4.34	4.42
KWS Extase + Sikulo	6.19	5.80
KWS Extase	6.88	6.99
KWS Extase + DK20	6.32	5.93
Alessio	3.99	4.84
Roderik	4.22	4.32
Alessio (2)	3.16	3.66
Viki	2.59	3.85
Wakelyns Popl^{n}	5.24	5.18
Royal	3.77	4.98
Wendelin	2.96	3.98
Barranco	4.86	4.57
KWS Extase	4.38	6.82
Purino	5.56	5.18

*Combine yields at Thornton Farm were based on 10 m cut length (21 m^2 area) for the control and 9.2 m cut length (19.32 m^2 area) for the Fixio treatment

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Table 3. Grain yields (t/ha) @15% moisture content from Gilchesters in response to Fixio application in the 2021-22 season.*

	Control	Fixio
Roderik	1.09	2.02
KWS Extase	0.95	3.59
Barranco	2.94	1.01
Viki	4.55	2.25
Alessio (2)	2.34	5.49
Wakelyns Popl^{n}	4.15	2.92
Brandex Popl^{n}	2.28	4.79
Royal	3.83	0.90
Laurin	0.21	0.76
Purino	3.27	1.95
Alessio	3.64	5.33
Barber II	5.35	3.62
Red Russian	3.65	-
Wendelin	4.53	3.07
Royal + DK20	1.78	3.38
Alessio + DK20	3.90	1.77

*Grain yields at Gilchesters were based on 30 m cut length (59 m^2 area) for the control and 30 m cut length (60m^2 area) for the Fixio treatment

Table 4. Grain yields (t/ha) @15% moisture content from Nisbet Hill in response to Fixio application in the 2021-22 season.

	Control	Fixio
Royal + DK20	6.43	5.23
Viki	6.30	5.65
Alessio + DK20	5.81	5.99
Alessio	5.63	5.44
Alessio (2)	4.65	4.98
Purino	4.88	5.54
Wakelyns popl^{n}	5.44	5.16
Wendelin	5.66	5.94
Royal	4.76	6.26
Roderik	5.26	5.84
Barranco	6.51	6.89

*Grain yields at Nisbett Hill were based on 30 m cut length (60 m^2 area) for the control and 25 m cut length (50m^2 area) for the Fixio treatment

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The biostimulant Fixio from ITAKA was again used in the spring at Thornton Farm, Nisbet Hill and Gilchesters. At Thornton Farm (Table 2) when averaged across all varieties Fixio resulted in a 0.41 t/ha yield increased compared with the control treatment. At Gilchesters the Fixio treatment resulted in a 0.17 t/ha yield reduction (Table 3) compared to the untreated control when averaged across all varieties. At Nisbet Hill Farm (Table 4) Fixio resulted in a 0.15 t/ha yield increase when averaged across all varieties compared to the control.

2.1.2. Disease results

Table 5. Septoria leaf blotch and yellow rust disease levels from Nisbet Hill Farm on 20 June, 5 and 18 July in the 2021-22 season.

	20 June (GS62-63)		5 July (70)		18 July (GS75)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust	*S tritici*	Yellow rust
Royal +DK20	0, 0, 10	1.2	4, 24, 66	4.1	-	7.4
Viki	0, 5, 18	1.1	5, 23, 49	1.4	19, 56, 98	4.9
Alessio DK20	0, 9, 38	1	12, 61, 97	3.7	-	8.0
Alessio	2, 11, 44	1	11, 51, 96	2.6	-	8.0
Alessio (2)	1, 15, 53	1	23, 72, 100	1.6	-	8.0
Purino	0, 18, 27	1	4, 43, 83	1	28, 86, 100	4.8
Wakelyns Popl^{n}	0, 4, 38	1	5, 40, 82	1	56, 88, 98	6.0
Wendelin	0, 1, 19	1	1, 25, 79	1	38, 79, 100	6.5
Royal	0, 3, 44	1	10, 34, 77	1.3	-	8.0
Roderik	0, 5, 31	1	12, 30, 70	1.6	-	8.0
Barranco	0, 4, 17	1.2	14, 45, 91	2.0	31, 72, 100	7.9

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

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

On 20 June 2022 at Nisbet Hill Farm yellow rust levels were low with only limited signs of infection in the varieties Royal, Viki and Barranco (Table 5). By 5 July there had been a clear increase with the varieties Viki and Alessio being worst affected but still no disease observed in the varieties KWS Extase, Purino, Wakelyn's population and Wendelin. By the 18th of July all varieties had yellow rust but with the varieties KWS Extase, Viki and Purino showing only moderate infection levels. For *Septoria tritici* the variety KWS Extase showed the lowest disease levels at all timings. Due to the very warm summer, crop development was in advance of the previous season by about 10-14 days and so that by 18 July some varieties were starting to turn which meant that *S. tritici* disease levels were not recorded

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on the more advanced early maturing varieties but at this time KWS Extase still had low levels of disease on leaves 1 and 2.

Table 6. Septoria leaf blotch and yellow rust disease levels from Newlands Farm on 20 June and 5 July in the 2021-22 season.

	20 June (GS62-63)		5 July (70)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust
Alessio	1, 8, 38	1.2	10, 31, 89	3.0
Royal	0, 5, 51	1	9, 26, 89	1
KWS Extase	0, 2, 18	1	2, 22, 79	1
KWS Extase + DK20	0, 1, 14	1	0, 16, 84	1
Purino	3, 14, 29	1	7, 27, 89	1
Alessio (2)	9, 17, 50	1	12, 29, 83	1
Viki	0, 12, 27	1.6	9, 60, 95	1.2
Roderik	0, 11, 32	1.5	10, 24, 62	2.6
Wendelin	0, 2, 9	1	1, 14, 70	1
Barranco	0, 0, 22	1	4, 25, 56	2.6
Wakelyns Popl^{n}	0, 4, 34	1	7, 25, 92	1
Alessio + DK20	4, 12, 33	2.5	7, 25, 70	2.1
Zollernspelt	-	8	-	8

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

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

At Newlands there was yellow rust infection on 20 June in the varieties Alessio, Viki and Roderik with Barranco also showing symptoms on 5 July (Table 6). On 20 June, *S. tritici* levels were low in the varieties KWS Extase and Wendelin. On 5 July KWS Extase and Wendelin again had the lowest *S. tritici* levels but for most other varieties leaf 3 had been almost completely lost to the disease while Viki also had 60% of leaf 2 infected. As at Thornton Farm the warm dry conditions meant that disease assessment was not possible on 18 July due to extensive crop senescence but with some lodging evident at the front end of the variety Royal.

At the disease assessment dates of 20 June and 5 July at Thornton Farm (Table 7) only very low yellow rust disease levels were recorded and on a limited number of varieties with highest recorded levels on Viki, Royal and Barranco. For *Septoria tritici* the conventional UK varieties KWS Extase and Theodore had the lowest levels recorded. Due to the very warm summer, crop development was in advance of the previous season by about 10-14 days and so that by 18 July most varieties were starting to turn as this was clearly noticeable at the Open Day held on Monday 4 July.

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Table 7. Septoria leaf blotch and yellow rust disease levels recorded from Thornton Farm on 20 June and 5 July in the 2021-22 season.

	20 June (GS62-63)		5 July (70)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust
Theodore + Sikulo	0, 0, 1	1	0, 0, 23	1
Theodore	0 ,0, 3	1	0, 0, 19	1
Theodore + DK20	0, 0, 4.5	1	0, 1, 46	1
KWS Extase + Sikulo	0, 0, 1.5	1	0, 7, 28	1
KWS Extase	0 ,0, 0	1	0, 2, 14	1
KWS Extase + DK20	0, 0,1.5	1	0, 5, 34	1
Alessio	0, 6, 38	1	0, 12, 58	1
Roderik	0, 17, 23	1	0, 13, 44	1.1
Alessio (2)	3, 12, 36	1	0, 6, 20	1
Viki	0, 8, 21	1.2	5, 11, 47	1.6
Wakelyns Popl^{n}	0, 4. 14	1.2	2, 7, 57	1.2
Royal	0, 0, 14	1.6	0, 12, 42	1.6
Wendelin	0, 12, 24	1	0, 8, 37	1
Barranco	0, 1, 21	1.1	1, 17, 61	1.5
KWS Extase	0, 0, 3	1	0, 4, 38	1.2
Purino	0, 11, 20	1.2	3, 23, 57	1

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

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

The crop starting to turn very early in the season was likely due to the very warm and dry conditions possibly linked to lighter sandier soil (as evidenced by the patchiness across the field) and was also observed at Newlands Farm both in the FPT trial and the commercial crop surrounding the trial. By the time of the third disease assessment only the varieties, Viki, Wendelin and Theodore had any green canopy and this was rather limited. The commercial crop in this field surrounding the FPT was harvested on Friday 12 August with an average grain yield of 5.5 t/ha and a moisture content of 13.6-13.9%.

At Gilchesters yellow rust levels were much higher (Table 8) than at the other 3 sites for the first two sampling dates, i.e.10 and 27 June, but disease levels had then decreased by the final sampling date on 13 July which was the reverse of the situation at Nisbet Hill Farm (Table 5). Earlier in the season on 10 and 27 June the varieties Wendelin, KWS Extase and Brandex population showed the lowest leaf blotch (*S. tritici*) and this continued through to 13 July with the variety Wendelin showing very low leaf blotch levels on leaves 1 and 2.

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Table 8. Septoria leaf blotch and yellow rust disease levels from Gilchesters on 10 June, 27 June and 13 July in the 2021-22 season.

	10 June (GS51-57)		27 June (GS63-69)		13 July (GS77)	
	*S tritici**	Yellow rust**	*S tritici*	Yellow rust	*S tritici*	Yellow rust
Roderik	0.1, 0.9, 2.5	3	17.5, 17, 46	1.5	17, 55, 100	1.2
KWS Extase	0, 0, 0.1	1.6	3.1, 5.6, 21	2.3	19, 48, 85	1.9
Barranco	0, 0.1, 1.9	4	9.5, 35, 75	1.9	6, 98, 100	1.3
Viki	0, 0, 0.2	4	9.6, 24, 61	1.5	37, 72, 100	1
Alessio (2)	0, 0.2, 1.4	1.7	0.4, 5.0, 19	1	11, 69, 100	1
Wakelyns Popl^{n}	0, 0.7, 1.5	2.8	1.8, 6.6, 32	1.4	6, 17.5, 85	1
Brandex Popln	0, 0.1, 0.1	2	0, 1.1, 9.1	1	17, 25, 100	1
Royal	0, 0.1, 2.5	2.2	4.7, 12.1, 59	2.7	58, 84, 93	2.5
Laurin	0.1, 0.3, 2	3	6.6, 32, 78	4.8	26, 78, 100	1.1
Purino	0, 0.1, 0.7	4.6	7, 11.5, 79	2.6	50, 95, 100	2.8
Alessio	0.1, 0.1, 0.6	1.6	1.2, 6.2, 47	1	19, 59, 100	1
Barber II	0.1, 2.9, 6.1	4.3	6.6, 12, 53	1.8	19, 57, 98	1
Red Russian	0, 1.4, 1.7	1.8	0.1, 3.6, 31	1	2.5, 9.5, 100	1
Wendelin	0, 0, 0.71	1.2	0.6, 1.7, 9.1	1	1, 3, 72	1
Royal + DK20	0, 0.7, 1.3	1.9	4.8, 26, 71	1.9	44, 86, 100	2.3
Alessio + DK20	0, 0.1, 0.9	2.0	1.2, 4.5, 38	1.4	4.5, 50, 100	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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2.1.3. Grain quality

Table 9. Grain protein (%) from the four FPT sites presented @15% moisture content in the 2021-22 season.

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	11.2	10.6	14.2	12.5
Wendelin	11.0	11.7	13.6	13.1
Alessio (2)	11.2	10.6	12.9	12.2
Roderik	11.4	11.6	12.7	13.6
KWS Extase	9.6	9.2	-	13.0
KWS Extase + Sikulo	9.4	-	-	-
KWS Extase + DK20	9.0	9.5	-	-
Alessio	11.0	10.5	13.7	13.1
Alessio + DK20	-	11.4	13.5	14.1
Wakelyns popl^{n}	10.6	10.4	12.4	13.7
Barranco	9.9	10.4	13.0	12.3
Royal	10.8	10.5	12.3	14.7
Royal + DK20	-	-	13.3	14.3
Theodore	9.1	-	-	-
Theodore + Sikulo	9.4	-	-	-
Theodore + DK20	9.0	-	-	-
Viki	11.1	11.0	14.7	15.2
Laurin	-	-	-	15.1
Red Russian	-	-	-	13.9
Brandex popl^{n}	-	-	-	12.1
Barber II	-	-	-	13.6

Grain protein content was much higher at Gilchesters and Nisbet Hill than at the other two sites. At Gilchesters only Barranco and Brandex population had a protein content <13% while at Nisbet Hill it was only the varieties Roderik, Wakelyn's population and Royal. At Thornton Farm and Newlands no variety achieved a protein content of 12% or higher. Where the UK Recommended List Group 2 variety KWS Extase was grown the protein content was lower than 10% at Thornton Farm and Newlands while at Gilchesters it achieved 13%. The high protein contents observed at Gilchesters in 2022 also confirmed the results for that site in 2021. The use of the biostimulant DK20 increased grain protein content of the variety Alessio by 0.9 t/ha at Newlands and 1.0 t/ha at Gilchesters.

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Table 10. Grain Hagberg Falling Number (s) from the four FPT sites in the 2021-22 season.

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	353	343	353	337
Wendelin	310	273	341	344
Alessio (2)	354	345	365	363
Roderik	309	305	347	365
KWS Extase	321	310	-	353
KWS Extase + Sikulo	319	-	-	-
KWS Extase + DK20	327	315	-	-
Alessio	353	312	381	362
Alessio + DK20	-	309	371	367
Wakelyns popl^{n}	239	206	319	276
Barranco	267	272	349	305
Royal	220	253	340	341
Royal + DK20	-		354	369
Theodore	166	-	-	-
Theodore + Sikulo	161	-	-	-
Theodore + DK20	147	-	-	-
Viki	317	349	399	368
Laurin	-	-	-	332
Red Russian	-	-	-	346
Brandex popl^{n}	-	-	-	276
Barber II	-	-	-	285

HFN was high in the 2021-22 season generally due to the warm and dry weather during late grain filling and harvest. The highest levels were at Nisbet Hill Farm where all varieties had a HFN of >300. Wakelyn's population had a particularly low HFN at Thornton Farm (239 s) and Newlands (206 s) but was >250 s at the other two sites. Viki had a consistently HFN which was >300 s at all 4 sites.

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Table 11. Grain specific weight (kg/hl) from the four FPT sites in the 2021-22 season.

	Thornton Farm	Newlands	Nisbet Hill	Gilchesters
Purino	76.7	72.5	77.0	74.3
Wendelin	79.1	78.2	81.0	79.6
Alessio (2)	78.2	75.1	81.4	78.9
Roderik	77.7	76.4	80.4	75.6
KWS Extase	75.3	71.6	-	72.7
KWS Extase + Sikulo	75.0	-	-	-
KWS Extase + DK20	74.7	72.1	-	-
Alessio	78.8	76.4	80.5	78.5
Alessio + DK20	-	77.8	80.6	79.1
Wakelyn's popl^{n}	77.9	76.2	78.9	76.6
Barranco	75.6	75.4	76.6	75.4
Royal	79.7	76.4	81.6	76.7
Royal + DK20	-	-	82.0	77.2
Theodore	72.7	-	-	-
Theodore + Sikulo	72.1	-	-	-
Theodore + DK20	72.5	-	-	-
Viki	75.1	73.2	77.7	75.6
Laurin	-	-	-	75.9
Red Russian	-	-	-	75.3
Brandex Popl^{n}	-	-	-	76.2
Barber II	-	-	-	77.9

Very high grain specific weights were observed at all 4 sites which confirms UK grain quality data (AHDB Cereal Quality Survey 2022. Available at Cereal Quality Survey | AHDB) for that season where with abundant sunshine during the grain filling period being the reason. Very high grain specific weight was observed at Nissbet hill where the lowest variety was Barranco with 76.6 kg/hl.

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2.2. Wheat farmer participatory trials in Austria

In the 2021/2022 season, FPTs were established at four Austrian organic farms located in different agro-ecological zones of Austria. Seeds for the trials were provided by the breeding companies Secobra, Probstdorfer Saatzucht, Saatbau Linz, Saatzucht Edelhof, and Dottenfelder Hof. All trials experienced a low level of winter precipitation and due to the cool weather during thre end of winter and early spring crop development was decelerated. End of March/beginning of April the crop stands were still at BBCH29 (end of tillering). Ground cover was between 25% and 32% as measured by the Canopeo App. In April and May the crop stands have developed fast due to higher than usual temperatures, resulting in heading dates at end of May which is comparable to previous seasons. From heading onwards, precipitation at the single locations was 20-30% less than the 1991-2020 long-term mean and mean temperature was +1.4 °C. Additionally more hot days were recorded.

The first FPT trial was established on 20 October 2021 in the production area “Seewinkel” at the farm of Petra Borchert (Hauptstr. 18, 7151 Wallern im Burgenland; test site: 47.703782, 16.994403; pre-crop: winter wheat). The ECOBREED trial is integrated into the Austrian BioNet trial at that test site and includes the following 15 varieties: Alicantus, Arminius, Arnold, Aurelius, Blickfang, Capo, Christoph, Edelmann, Ehogold, Energo, Izalco CS, Mandarin, Mv Elit CCP, Mv Pantlika, and Tillsano. Crop establishment of Blickfang was significantly lower than for the other varieties. Pre-crop was wheat, sowing was done with a density of 325 seeds per m² and the trial was fertilized with 20 t/ha manure. First harrowing was done on 28 March 2022. Harvest was on 30 June at a grain moisture content of about 12%. Subsequently grain samples were analysed by a Foss InfratecTM. The specific adaptation of Austrian wheat varieties to the growing conditions and quality requirements is demonstrated by the calculated protein yield with Aurelius (800 kg/ha) being top, followed by Christoph (773 kg/ha), Energo (743 kg/ha), Arnold (726 kg/ha), Ehogold (693 kg/ha), and Capo (688 kg/ha). Varieties of foreign origin realised significantly lower protein yields with Izalco CS (533 kg/ha), Blickfang (304 kg/ha), Mv Elit CCP (297 kg/ha), and Mv Pantlika (271 kg/ha) at the end. Considering the Austrian limits for organic quality wheat (*Qualitätsweizen*) for protein content and test weight, i.e. 12% and 80 kg/hL, the following varieties would have been not accepted: Blickfang, Mv Elit CCP and Mv Pantlika with inferior performance in both traits, Edelmann and Izalco CS with inferior test weight but at least reaching the threshold of 78 kg/hL for acceptance with a price reduction. Contrary, many varieties reached the thresholds for organic *Premiumweizen* (13% protein) or even *Ultimateweizen* (14% protein).

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Table 12. Results of the winter wheat trial in Wallern in Burgenland, 2022.

Genotype	Grain yield (dt/ha) at 14% H_2O	Protein content (%)	Wet gluten content (%)	Test weight (kg/hL)		1000 grain weight (n)
Alicantus	40.96	14.8	34.1	80.0		45.7
Arminius	43.62	15.6	35.8	80.4		46.9
Arnold	47.42	15.3	35.3	82.0		41.7
Aurelius	55.17	14.5	32.9	80.2		44.2
Blickfang	26.91	11.3	24.1	77.0		40.9
Capo	47.42	14.5	33.1	80.6		42.4
Christoph	56.39	13.7	30.9	80.1		42.4
Edelmann	46.19	13.5	30.0	79.9		40.5
Ehogold	43.57	15.9	37.2	81.4		43.6
Energo	50.10	14.8	34.1	80.2		44.2
Izalco CS	35.80	14.9	34.1	79.4		40.1
Mandarin	43.47	14.2	32.7	80.1		44.9
Mv Elit CCP	29.44	10.1	20.6	75.4		42.9
Mv Pantlika	29.51	9.2	19.7	74.5		47.8
Tillsano	48.81	14.0	32.2	80.8		41.0

The second trial was sown with a sowing density of 380 seeds per m² on 27 October 2021 in the production area "Hollabrunn-Mistelbacher Gebiet" at the farm of Andreas Patschka (Zeile 85, 2020 Aspersdorf; test site 48.595837, 16.092189; pre-crop: common bean). Plot size was 1000-1400 m². The trials include the following 9 varieties: Aristaro, Arminius, Blickfang, Capo, Edelmann, Liocharls, Mandarin, Wendelin, and Lennox as border plot variety (farmer's choice). By 15 April 2022 the trial was two times harrowed. Wendelin was significantly later in germination and juvenile growth. By 23 May most varieties were already heading (BBCH53-57), except Aristaro (BBCH49) and Wendelin (BBCH47). Mandarin was at that time already flowering (BBCH67). On 21 July a 40 m² core plot was harvested by a Wintersteiger Delta combine at a grain moisture content of about 10%. The highest protein yield was realised by Lennox (637 kg/ha), followed by Capo (614 kg/ha), Blickfang (606 kg/ha) and Mandarin (602 kg/ha). All other varieties realised less than 500 kg/ha protein yield, i.e. Liocharls Population (582 kg/ha), Wendelin (579 kg/ha), Arminius (558 kg/ha), Aristaro (537 kg/ha) and Edelmann (509 kg/ha). Considering the Austrian limits for organic quality wheat for protein content and test weight, all varieties would have been rejected because of protein content <12%. Lennox also missed the threshold for test weight. With respect to protein content, Blickfang, Edelmann and Lennox also missed the lower requirement of 11% for Mahlweizen.

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Table 13. Results of the winter wheat trial in Aspersdorf, 2022.

Genotype	Grain yield (dt/ha) at 14% H_2O	Protein content (%)	Test weight (kg/hL)		1000 grain weight (g)	Spikes/m² (n)
Aristaro	47.56	11.3	82.6		43.6	479
Arminius	48.95	11.4	83.3		49.6	427
Blickfang	58.84	10.3	80.8		43.7	448
Capo	54.30	11.3	84.4		45.1	367
Edelmann	48.91	10.4	83.2		41.2	500
Lennox	60.06	10.6	79.0		43.2	432
Liocharls Pop.	50.18	11.6	81.5		44.9	377
Mandarin	52.84	11.4	82.7		48.6	431
Wendelin	51.67	11.2	82.5		43.6	377

The third trial was sown on 27 October 2021 in the production area "Herzogenburg-, Tulln-, Stockerauer Gebiet" at the farm of Hermann Schwarzl (Dorfstr. 20, 3463 Starnwörth; test site: 48.424772, 16.032189; pre-crop: oilseed pumpkin). The trial included the following 9 varieties: Alessio, Aristaro, Arminius, Blickfang, Capo, Edelmann, Mandarin, Wendelin, and Christoph as border plot (farmer's choice). Second harrowing was carried out on 22 April. On a field day on 7 June 2022, some individual spikes infected with common bunt were observed in individual strip plots despite that certified organic seed was used. Harvest was done on 5 July 2022. Highest protein yields were realised by Wendelin (676 kg/ha), Arminius (635 kg/ha), Aristaro (626 kg/ha) and Capo (601 kg/ha), followed by Blickfang (585 kg/ha), Edelmann (572 kg/ha), Christoph (548 kg/ha), Mandarin (523 kg/ha) and Alessio (467 kg/ha). Summarising the three trials in the eastern part of Austria, only Capo realised protein yields above 600 kg/ha in each trial which demonstrates the broad adaptation of this variety to organic production at each site of the main Austrian wheat production area. Considering the Austrian limits for organic wheat for protein content and test weight, all varieties would have been rejected a premium payment as quality or baking wheat because of protein contents <11%, whereas test weight was significantly above the required limit of 80 kg/hL for the highest quality class.

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Table 14. Results of the winter wheat trial in Starnwörth, 2022.

Genotype	Grain yield (dt/ha) at 14% H_2O	Protein content (%)	Test weight (kg/hL)	1000 grain weight (g)	Spikes/m² (n)
Alessio	49.63	9.4	85.2	43.5	390
Aristaro	59.04	10.6	84.9	46.0	414
Arminius	65.48	9.7	82.4	49.8	543
Blickfang	62.28	9.4	83.2	46.1	397
Capo	64.58	9.3	86.2	45.4	559
Christoph	57.03	9.6	82.7	51.3	442
Edelmann	59.56	9.6	84.9	41.7	550
Mandarin	63.76	8.2	82.6	46.6	541
Wendelin	66.29	10.2	85.2	47.6	450

The last trial was sown on 20 October 2021 in the production area "Grieskirchen-Kremsmünster Gebiet" at the farm of Anton Berger (Hinterleiten 1, 4673 Gaspoltshofen; test site: 48.164910, 13.755902; pre-crop: grass-clover ley). The trial included the following 7 varieties: Arminius, Blickfang, Liocharls population, Purino, Rübezahl, Tobias, Wendelin, and Lukullus as farmer's choice. No manure was applied to the FPT plots but only to the rest of the field. Weed infestation was scored during the field day on 17 June 2022 and revealed a heavier infestation with cornflower (*Centaurea cyanus*) and cleavers (*Galium aparine*) in the Secobra varieties Blickfang, Purino, Rübezahl and Wendelin. Harvest was done on 18 July 2022. The highest protein yield on this site was realised by Lukullus (784 kg/ha), followed by Arminius (780 kg/ha), Blickfang (764 kg/ha), Purino (666 kg/ha), Liocharls Population (641 kg/ha), Tobias (615 kg/ha), Wendelin (609 kg/ha) and Rübezahl (565 kg/ha). Considering the Austrian limits for organic wheat for protein content and test weight, the tested varieties would have been classified as follows: Arminius, Tobias and Wendelin as Qualitätsweizen, Blickfang, Liocharls Population and Lukullus as Mahlweizen, whereas Purino missed the limit of 78 kg/hL for test weight, and Rübezahl the limit of 11% for protein content for Mahlweizen and would be, thus, traded only as organic feed wheat.

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Table 15. Results of the winter wheat trial in Gaspoltshofen, 2022.

Genotype	Grain yield (dt/ha) at 14% H_2O	Protein content (%)	Test weight (kg/hL)	1000 grain weight (g)	Spikes/ m^2 (n)
Arminius	64.44	12.1	83.8	45.9	422
Blickfang	66.44	11.5	81.2	41.9	459
Liocharls population	55.70	11.5	80.3	44.2	369
Lukullus	66.99	11.7	81.6	41.7	399
Purino	52.03	12.8	75.9	38.3	418
Rübezahl	57.02	9.9	78.6	45.4	407
Tobias	50.82	12.1	83.2	39.2	442
Wendelin	49.12	12.4	80.4	45.7	385

2.3. Wheat participatory field trials in the Slovak Republic

The participatory field trials were performed on four organic farms located in Slovakia (Table 16 and Fig. 4).

Table 16. 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

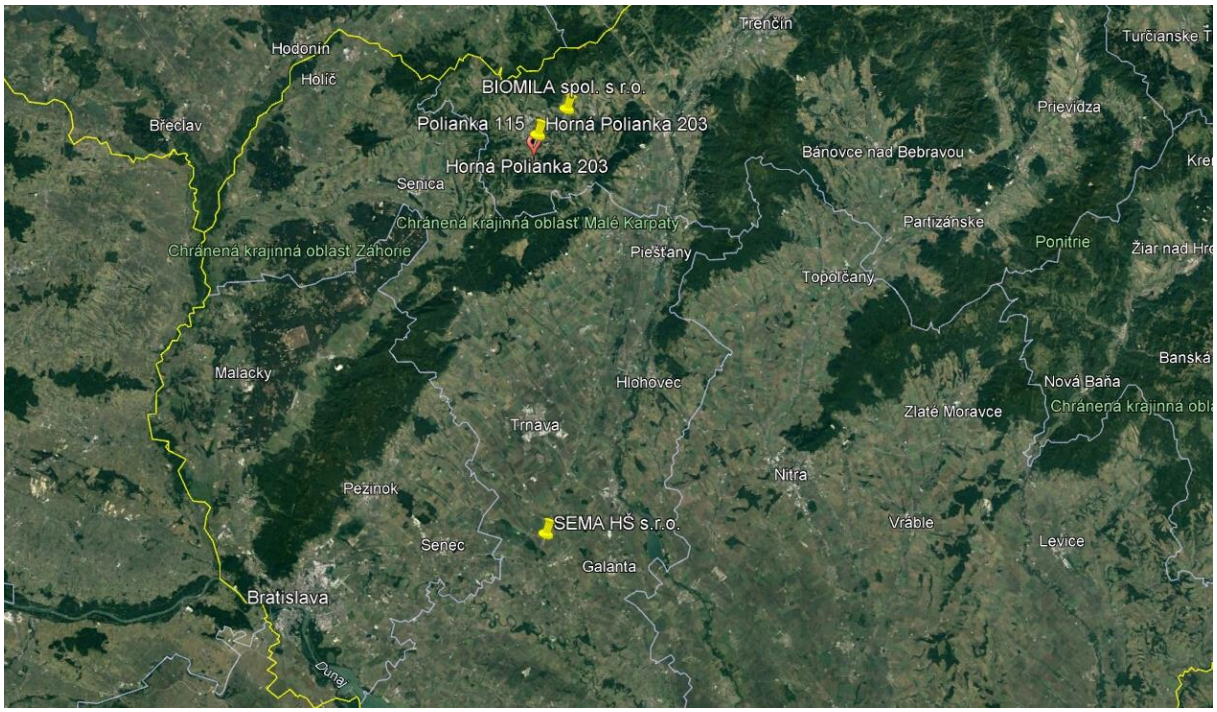

Fig. 4. Location map of the four farms in Slovakia.

A total of eight wheat varieties (both domestic and international) were sown in autumn 2021 in plots with a minimum plot size of 300 m^2 (Table 17). Selected varieties were chosen for their specific traits for organic cultivation and low-input trials. The tillage of the experimental plots was conventional. The sowing dates and conditions were different. Cultivars were seeded on 18 October 2021 in SEMA HŠ s.r.o. Sládkovičovo and 29 October 2021 in Rudník (Biomila spol. s.r.o., SHR Martin Kolárik, SHR Vladimír Zeman). Prior to the seedling, weeds were controlled using the false seedbed method. The sowing density was

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450 plants per m^2 at each location. Inter-row cultivation was performed three times during the growing season and weed infestation was low.

Table 17. The list of varieties with their 1000 grain weight (TGW).

Variety name	TGW (g)	Seeding rate (g/m^2)
Allesio	42.8	22.50
Arnold	38.2	18.00
Aurelius	39.4	18.00
Ehogold	41.4	18.00
Is Laudis	43.8	20.25
Capo	40.3	18.00
Viki	38.3	20.25
PS Dobromila	47.1	20.25

Cultivars were evaluated during the vegetation period on all farms: winter response, growth habit, ground cover, flag leaf emergence, date of heading, number of wheat heads, plant height (cm), canopy, lodging, identification and scoring of diseases, and pests using a 1-9 scale (1 meaning low prevalence), grain yield (kg/ha), test weight (kg/hl).

The weather conditions during the vegetation period on all farms were generally good for the vegetation and development of wheat. The summer was too hot, followed by high temperatures and lack of rain, particularly the quality of wheat harvested.

Participatory field trials were harvested at the end of July 2022 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 (protein, moisture, starch, volume weight, sedimentation index, falling number, dry matter, and nitrogen).

Generally, wheat had no significant issues with diseases and pests. *Tilletia caries*, *T. controversa* and *Septoria tritici* were the most prevalent diseases observed in field trials, but the occurrence was very low (Tables 18 & 19). Varieties appear to have good tolerance to the diseases and pests.

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Table 18. Disease evaluation Tilletia caries, Tilletia controversa, Septoria tritici and agronomic characters varieties of plant height, lodging, and grain yield levels in the 2021-22 season from farm SEMA HŠ s.r.o. in Sládkovičovo.

Variety name	*Tilletia caries*	*Tilletia controversa*	*Septoria tritici*	Plant height (cm)	Lodging	Grain yield (t/ha)
Allesio	1	1	1	103	1	7.00
Arnold	1	1	1	100	1	6.14
Aurelius	1	1	1	114	1	7.04
Ehogold	1	1	1	118	1	7.01
IS Laudis	1	1	1	106	1	7.02
Capo	1	1	1	108	1	7.23
Viki	1	1	1	104	1	7.00
PS Dobromila	1	1	1	106	1	6.80

Table 19. Disease evaluation of Tilletia caries, Tilletia controversa, Septoria tritici and agronomic characters varieties of plant height, lodging, and grain yield levels in the 2021-22 season from farm Biomila, spol. s.r.o.

Variety name	Tilletia caries	Tilletia controversa	Septoria tritici	Plant height (cm)	Lodging	Grain yield (t/ha)
Allesio	**1**	**1**	**3**	**103**	**1**	**1.8**
Arnold	**1**	**1**	**3**	**99**	**1**	**2.40**
Aurelius	**1**	**1**	**3**	**113**	**1**	**1.90**
Ehogold	**1**	**1**	**3**	**115**	**1**	**1.80**
IS Laudis	**1**	**1**	**3**	**106**	**1**	**1.50**
Capo	**1**	**1**	**3**	**108**	**1**	**1.80**
Viki	**1**	**1**	**3**	**102**	**1**	**1.50**
PS Dobromila	**1**	**1**	**3**	**107**	**1**	**2.00**

The mean grain yields calculated to 14% moisture are shown in Table 3 and Fig. 2. They varied between varieties and among locations. The highest yielding cultivar was Capo 7.23 t/ha at the SEMA HŠ s.r.o. location, while the lowest was recorded for IS Laudis at 1.4 t/ha (SHR Vladimír Zeman).

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Table 20. Mean grain yield at four locations in growing season 2021/2022.

Location	Mean grain yield (t/ha)
SEMA HŠ Sládkovičovo	6.94
SHR Martin Kolárik	1.81
Biomila, spol. s.r.o.	1.8
SHR Vladimír Zeman	1.7

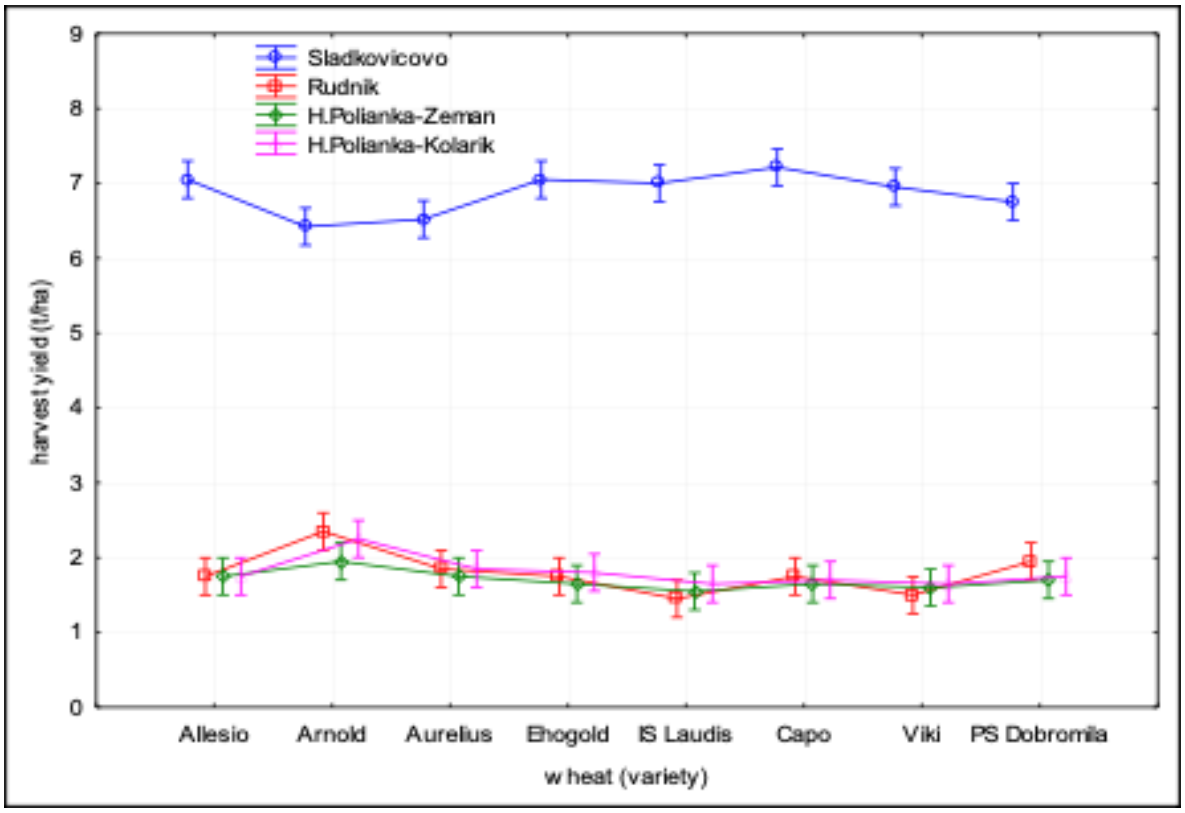

Fig. 5. Mean grain yield at four locations in growing season 2021/2022.

Results of the analysis on starch, wet gluten, sedimentation index, volume weight, and proteins are shown in Tables 21 and 23.

The highest protein content was produced by Viki (12.08%) at SEMA HŠ s.r.o. and the lowest by Aurelius (9.3%) at SHR Martin Kolárik. The mean highest protein content was at SEMA HŠ s.r.o. 11.96 % and the mean lowest at Biomila spol. s.r.o. 10.3% (Tables 21 and 23).

The sedimentation value also showed the differences between the mean values of all trials.

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Values ranged from 50 ml (IS Laudis) at SEMA HŠ s.r.o. to 27 ml (Aurelius) at SHR Martin Kolárik. The highest mean value was 44.13 ml at SEMA HŠ s.r.o. and the lowest at SHR Martin Kolárok 32.88 ml (Table 4. and Table 6.). The percentage of wet gluten was the highest at SEMA HŠ s.r.o. 25.53% and the lowest at SHR Martin Kolárik 18.8% (Table 4. and Table 6.). In the range of varieties, the highest percentage had IS Laudis 27% at SEMA HŠ s.r.o. and the lowest Aurelius 16.7% at SHR Martin Kolárik. The highest starch values were analysed at BIOMILA spol. s.r.o. 62.6% and the lowest at SEMA HŠ s.r.o. 61.49%. Among the varieties, the highest content produced Capo 63.5% at Biomila spol. s.r.o. and the lowest Viki 59.7% at Sema HŠ s.r.o. The variety with the highest test weight produced Ehogold 84.5 kg/hl at Sema HŠ s.r.o. and the lowest Viki 76.3 kg/hl at SHR Martin Kolárik.

Table 21. Test weight, protein content, sedimentation value, percentage of wet gluten, and percentage of starch in grains in organic trials in growing season 2021/2022.

Location	Protein (%DM)	Sedimentation value (ml)	Wet gluten (%DM)	Starch (%DM)	Test weight (kg/hl)
SEMA HŠ s.r.o. Sládkovičovo	11.96	44.13	25.53	61.49	82.54
Biomila, spol. s.r.o.	10.3	33.1	19	62.6	80.1
SHR Vladimír Zeman	11.3	40.1	22.3	61.9	81
SHR Martin Kolárik	10.31	32.88	18.8	62.34	79.63

Table 22. Values of indicators of quality characteristics of selected varieties in organic trials at farm SEMA HŠ s.r.o. Sládkovičovo in growing season 2021/2022.

Variety name	Starch (%)	Wet gluten (%)	Sedimentation index	Volume weight (kg/hl)	Protein (%)
Allesio	61.6	25.5	42	82.1	12.1
Arnold	61.8	23.3	39	80	11.0
Aurelius	62.6	24.8	44	83.4	11.4
Ehogold	62.5	25.1	46	84.5	11.5
IS Laudis	60.9	27	50	83.3	12.6
Capo	61.2	26.2	42	83.8	12.2
Viki	59.7	26.1	45	79.2	12.8
PS Dobromila	61.6	26.2	45	84	12.1
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					

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Table 23. Values of indicators of quality characteristics of selected varieties in organic trials at farm Biomila, spol. s.r.o. SHR Vladimír Zeman and SHR Martin Kolárik in growing season 2021/2022.

BIOMILA, spol.s.r.o.	Allesio	Arnold	Aurelius	Ehogold	IS Laudis	Capo	Viki	PS Dobromila
Protein (%)	11.2	10.4	9.5	10.5	10.4	9.9	10.3	10.5
Sedimentation index	34	35	28	35	35	33	31	34
Wet gluten (%)	20.4	19.6	17.1	19.8	19	18.3	17.7	19.8
Starch (%)	61.8	62.1	63.2	63.1	62.4	63.5	61.5	62.8
Test weight (kg/hl)	77.7	77	81.5	81.5	83.4	81.7	77.4	80.5

SHR Vladimir Zeman	Allesio	Arnold	Aurelius	Ehogold	IS Laudis	Capo	Viki	PS Dobromila
Protein (%)	11.6	10.7	11.5	11.4	10.7	11.7	11.1	11.3
Sedimentation index	41	39	43	40	39	39	41	39
Wet gluten (%)	23	21.1	23	23.5	21.7	21.4	22.5	22
Starch (%)	61.5	62.1	62.2	61.2	62.6	60.8	62.7	61.9
Test weight kg/hl)	82	82.3	82.1	79.2	83.6	76.9	82.2	80

SHR Martin Kolárik	Allesio	Arnold	Aurelius	Ehogold	IS Laudis	Capo	Viki	PS Dobromila
Protein (%)	10.7	10.4	9.3	10.5	10.5	10	10.3	10.8
Sedimentation index	32	35	27	35	36	32	31	35
Wet gluten (%)	19.5	19.5	16.7	19.8	19.1	18.3	17.3	20.2
Starch (%)	61.9	61.9	62.6	62.7	62.5	63.2	61.8	62.1
Test weight kg/hl)	78.9	77.8	81.1	81.9	79.1	81.8	76.3	80.1

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

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Fig. 6. Participatory field trails and Field Day in Slovakia.

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2.4. Wheat farmer participatory trials in Serbia

Winter wheat farmers participatory field trials (season 2021/2022) were performed on two farms located in the north Serbian province Vojvodina (typical Pannonian plain). Due to difficulty of getting seeds from all varieties that we sowed last year, we had only 7 varieties in Task 6.2. On each farm 7 (+1) winter wheat varieties were included, and four of them were varieties from Serbia that are most suitable for organic farming. Variety NS OBI-CCP was included only on Šuljam farm. Plot size was 300 m^2 (3 x 100 m) and seed rate was 600 seeds/m^2 as sowing was outside the optimum date.

Table 24. List of varieties on WP6 wheat Farms (2022).

1	MV CCP
2	PS Dobromila
3	Capo
4	NS 40S
5	NS Obala
6	NS Ilina
7	NS Mila
8	NS OBI CCP-Šuljam only

Table 25. Farms, locations, sowing and harvest dates in Serbia.

Farm	Location	Sowing date	Harvest date
IFVC - experimental field	Rimski šančevi	13. 12. 2021	06. 07. 2022
Ignjat Jurišić (Zlatno zrno)	Šuljam	15. 12. 2021	08. 07. 2022

Harvest of the WP6 varieties from Serbia was performed with the hand-held harvester. We used a frame size 1x1 m for harvest area. From every variety, samples were taken from four (4) locations in each plot. Samples from each farm were collected and post-harvest analyses were performed.

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Fig. 7. Hand harvesting of wheat FPT (Šuljam 08.07.2022).

2.4.1. Results

Average values of the examined traits are shown in Table 26. Grain yield varied between varieties and among locations. The highest average value for harvest yield (54 dt/ha) was recorded for the variety Capo at the Šuljam location, while the lowest value was recorded for the MV Elite (25 dt/ha) at the IFVC experimental field. Moreover, Capo had the highest average test weight of 82.2 kg/hl (Šuljam), while the lowest test weight of 73.2 kg/hl was recorded for NS Mila (IFVC). The highest average TKW (42.6 g) was recorded for the variety PS Dobromila (Šuljam), while lowest average value for TKW (34.4 g) was recorded in the NS 40S (IFVC).

Highest protein (IFVC) and wet gluten content (Šuljam) are recorded for variety Capo, while PS Dobromila (IFVC) had the highest sedimentation value (50.2). The lowest protein, sedimentation and wet gluten content are recorded for NS Mila at the IFVC experimental field. Environmental conditions during the anthesis and grain filling period were not suitable for the development of common wheat diseases.

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Table 26. Examined traits of WP6 wheat varieties.

IFVC							
Traits/Variety	Mv	PS	Capo	NS 40S	NS	NS	NS
Yield (dt/ha) Harvest	25	28	36	32	41	28	35
Protein (%)	11.8	13.1	15.2	11.8	10.9	11.3	10.2
Sedimentation (ml)	33.1	50.2	47.3	33.4	23.4	27.1	22.6
Wet gluten (%)	33.9	34.5	37	22.6	25.7	26.2	16.2
Test weight (kg/hl)	76.5	80.3	79	73.3	77.6	73.3	73.2
TKW (g)	38.5	40.6	39.8	34.4	39.3	40.5	37.7
Septoria tritici (%)	0	0	20	0	0	0	0
Steam rust (1-9)	1	1	1	1	1	1	1
Leaf rust (1-9)	1	1	1	1	1	1	1
Yellow rust (1-9)	1	1	1	2	1	1	1

Šuljam								
Traits/Variety	Mv	PS	Capo	NS	NS	NS	NS	NS
Yield (dt/ha)	29	41	54	36	23	30	31	27
Protein (%)	12.1	12.7	14.6	11.4	11.3	10.7	10.4	12.3
Sedimentation (ml)	30.6	48.3	45.8	31.5	22.7	25.2	23.6	26.4
Wet gluten (%)	31.4	33.2	37.2	23.3	24.6	24.1	18.1	24.8
Test weight (kg/hl)	74.1	79.6	82.2	76.4	74	75.2	75.7	78.3
TKW (g)	39.3	42.6	37.6	36.2	40.5	38.7	35.2	37.2
Septoria tritici (%)	0	0	15	0	0	0	0	20
Steam rust (1-9)	1	1	1	1	1	1	1	1
Leaf rust (1-9)	1	1	1	1	1	1	1	2
Yellow rust (1-9)	1	1	1	2	1	2	1	1

2.4.2. Wheat participatory plant breeding in Serbia

In 2021/2022 we conducted 6.3 wheat trial on one location in Serbia. Golden Grain (Zlatno zrno) farm is certified organic. The trial consisted of 3 plots (plot=2x1 m), 6 rows per plot, hand sowed. NS OBI-CCP is the name of the wheat population.

- Šuljam-Ignjat Jurišić (Zlatno zrno)
- Sowing date: 17.11.2021.
- Harvest date: 08.07.2022.
- GPS: 45.05'33.4'' N, 19.41'04.7'' E

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2.5. Durum wheat trials in Italy

In the frame of the ECOBREED project, for the second year was performed a participatory breeding program in the three farms located in the central area of Italy from inland to the seaside, respectively at Rieti (400 m asl), Viterbo (300 m asl) and Montalto di Castro (68 asl). For each farm plots of 300 m^2 were evaluated with nine genotypes of different origin (from the Mediterranean basin to Central Europe) and one population composed of a mix with 27 different accessions. They have been evaluated for traits such as ground cover (GCover), growth habit (GHabit), phenological stages using the BBCH scale (Lancashire et al. 1991), 1m^2 grain yield, and grain quality with NIR analysis during the 2021-2022 growing season. The weather during the season was characterised by an extended and deep drought event which affected much of the Italian territory from January 2022 onwards. For this reason, and due to the late sowing, the amount of grain from the plots in Viterbo wasn't enough for NIR analysis. Before the harvest two evaluation events were organised where farmers from all over the area were invited to evaluate the trail and give a judgment on the genotypes through a questionnaire. They scored each plot with a mark between 0 and 10 looking at homogeneity, ground cover, the ability to compete with wild grass, tillering, tolerance to biotic and abiotic stress, plant height, number and size of ears (Fig. 1). Unfortunately, it wasn't possible to organise the event at the farm of Rieti.

2.5.1. Results

The genotypes, sown in late January in Viterbo, showed great differences for all traits, due to the long period with lack of water. All the plots registered a low ground cover index and a shorter phenological cycle with less tilling which led to less production (Table 27). However, the genotype with more production was one with the origin in the Mediterranean basin (Azeghar2-1(56)) followed by the CCP population. In the mountain area of Rieti big differences between the genotypes originated in the Mediterranean basin and Central Europe are not reported although the latter have shown a better ground cover and therefore a better competition to wild grass, which is an important factor for organic production (Table 28). At the farm of Montalto di Castro the best genotypes were the ones with origin in the Mediterranean basin plus the population which has shown a good ability of adaptation to the stress conditions (Table 29). Considering the yield, the grain quality, and the ability of ground cover we can report that the best genotypes for Viterbo were Azeghar2-1(56) followed by the CCP population and Mv. Pelsodur. In Montalto di Castro again Azeghar2-1(56) was followed by the population and Vulci; meanwhile, in Rieti the best genotypes were Lunadur, HFN 94n, and Azeghar2-1(56). Although our measurements led to the choice of some genotypes, this disagrees with the

evaluation of the farmers, following the traits previously listed; their attention was on other genotypes (Fig. 8 A and B). In Viterbo, considering the late sowing and the lack of water, they were marked as the best line MVTD15-19 mostly for its higher percentage of ground cover. Meanwhile, in Montalto di Castro, they choose as the best genotype Mv-Pelsodur, followed by Senatore Cappelli which is an ancient Italian variety.

Figure 8. ECOBREED WP6 evaluation event with the farmers at the field trial located in Montalto di Castro.

Table 27. Measurement of the ground cover ability (Gcov), the growth habit (Ghabit), the phenological stage (BBCH) and the grain yield in 1 m^2 in Viterbo.

Genotypes	Gcov24/03	Gcov03/05	Ghab24/03	BBCH24/03	BBCH03/05	1m² yield (g)
Azeghar2-1 (56)	10.5	37.8	3	22	49	118.3
HFN 94n	12.4	29.1	5	22	49	86.1
Lunadur	9.6	34.9	8	21	37	78.5
MVTD15-19	14.2	47.3	7	22	37	50.1
Ousloukos	17.2	38.9	2	22	39	83.4
Mv-Pelsodur	11.9	38.5	7	21	39	97.6
Sebatel2(45)	13.7	44.5	4	21	50	68.8
Sen. Cappelli	18.3	44.3	4	22	45	40.4
Vulci	8.2	35.3	5	21	39	55.5
Population	13.3	44.0	5	22	-	109

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Table 28. Measurement of the ground cover ability (Gcov), the growth habit (Ghabit), the phenological stage (BBCH), the grain yield in 1 m^2, the grain protein content (Prot) and the wet gluten in Rieti.

Genotypes	Gcov23/03	Gcov02/05	Ghab23/03	BBCH02/05	1m² yield	Prot (%)	Wet Gluten (%)
Azeghar2-1(56)	17.33	54.8	5	37	346.5	12.8	25.7
HFN 94n	11.4	70.7	4	37	357	14.7	30
Lunadur	14.07	70.3	4	30	361	11.7	23.3
MVTD 15-19	18.04	75.2	3	37	323	13.7	27.8
Ousloukos	27.51	76.0	6	39	221.7	11.7	23.3
Pelsodur	14.8	53.4	5	37	235	13.6	27.6
Makaroni	17.15	75.7	6	37	232.3	10.1	19.6
Sen. Cappelli	18.86	61.8	7	39	270.5	10	19.2
Vulci	22.69	77.2	8	39	272.7	10.8	21
Population	14.15	76.3	4	40	333	11	21.9

Table 29. Measurement of the ground cover ability (Gcov), the growth habit (Ghabit), the phenological stage (BBCH), the grain yield in 1 m^2, the grain protein content (Prot) and the wet gluten in Montalto di Castro.

Genotypes	Gcov15/03	Ghab15/03	BBCH15/03	BBCH17/05	1m² yield (g)	Prot (%)	Wet Gluten (%)
Azeghar2-1(56)	54.2	2	30	73	358.6	11.4	22.4
HFN 94n	48.4	2	29	71	174.2	15.4	32
Lunadur	40.9	7	23	69	270.8	17	35.5
MVTD15-19	35.2	7	23	69	161.3	13.3	27.3
Ousloukos	30.1	4	27	73	262.1	12	23.8
Mv-Pelsodur	42.7	5	27	69	202	13.5	27.4
Sebatel2(45)	55.0	2	30	75	247	15.8	32.5
Sen. Cappelli	69.4	2	30	69	180.5	13.6	28
Vulci	64.3	7	29	73	306	14.9	30.5
Population	29.3	3	29	73	327.2	13.9	28.1

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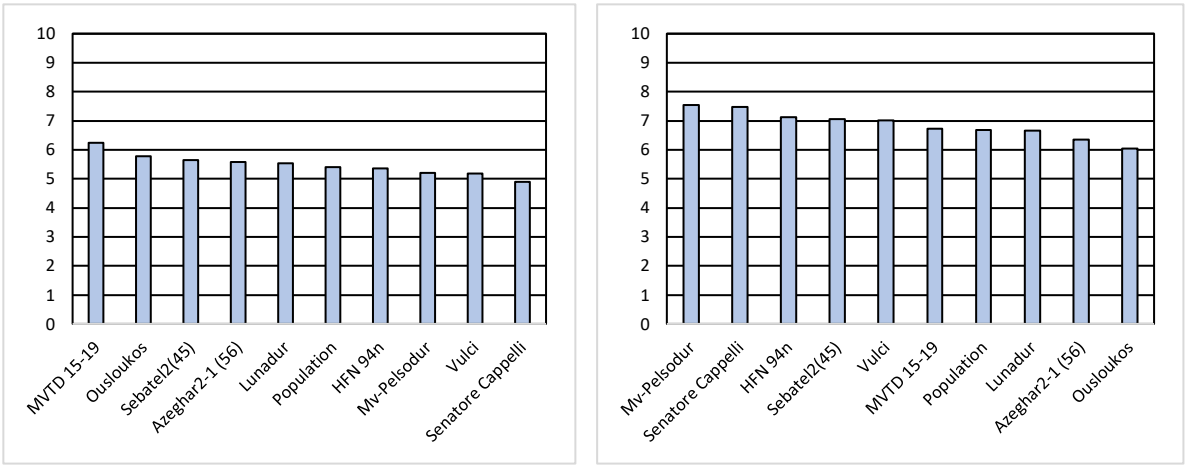

A B

Fig. 9. Mean score from the evaluation of the farmer in Viterbo (A) and Montalto di Castro (B). The score was calculated making the mean of all traits for each variety.

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2.6. Participatory plant breeding in Hungary

The Hungarian on-farm organic wheat trials started in autumn 2020 (see ECOBREED bulletin on participatory trials in 2021). Winter wheat varieties and two populations (Mv Elit CCP, Mv Bio2020 Pop) were sent to organic farmers with the aim to start participatory testing (PVS: participatory variety selection) and breeding (PPB: participatory plant breeding) on their farms. Trials were run on 3 farms in 2021 completed with 2 additional farms from the following year, thus, besides the two Hungarian and one Slovakian locations (Szár, Füzesgyarmat and Zselíz), two other Hungarian farms at Kömlő and Tornyiszentmiklós (Organic Valley) were involved in the experiment (Fig. 10). All farms are part of the on-farm trial network of ÖMKi (Hungarian Research Institute of Organic Agriculture), the research partner of ATK (Centre for Agricultural Research).

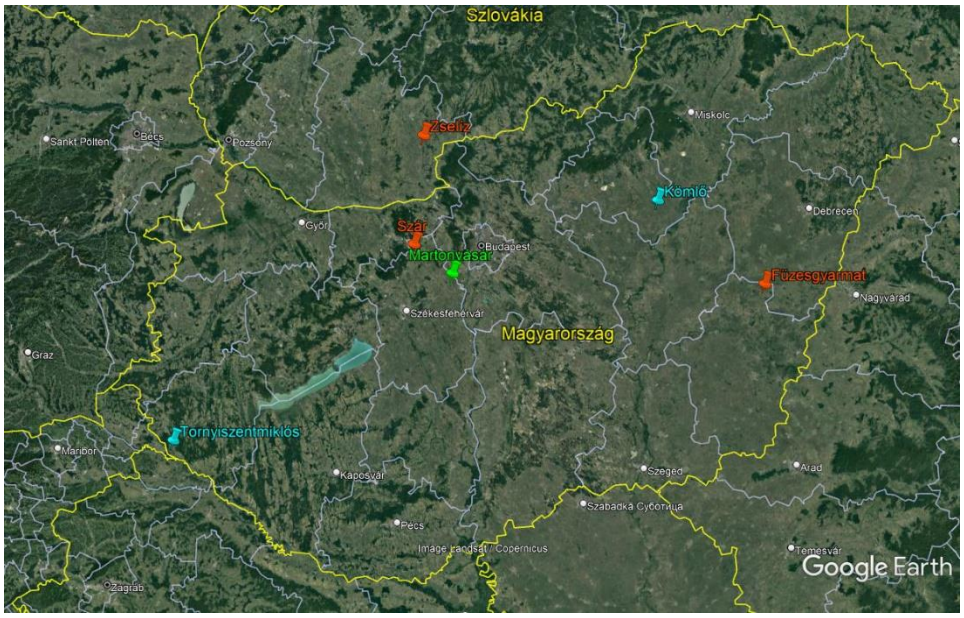

Fig. 10. Locations of participatory plant breeding trials organized by ATK. Participating organic farms are in red (2021, 2022) and blue (2022), breeding station (ATK) in green.

Like the previous year, cultivars were evaluated by farmers during the vegetation period in 2022. After farmers variety selection carried out in 2021, 3 more cultivars were examined at Szár, and two cultivars less at the other farms in 2022. Breeders of ATK visited the farms and they discussed the steps of observation, selection and harvest of trials with the farmers. The year 2022 was extremely dry, thus no lodging or pathogen symptoms could be detected on the cultivars. Only cereal leaf beetle (*Oulema melanopus*) damage was observed in Szár and Martonvásár (ATK). All trials were harvested in time and near infrared (NIR) rapid quality measurement was performed on the harvested seed samples. Yield was determined from 5 random samples collected manually from 1 m^2 areas of each

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medium sized plots on the farms. The trial on the farm near Szár was operating with smaller plots, thus they were harvested the full plot using a small plot combine harvester. Yield and quality data for the 2022 on-farm trials are shown in Table 30 (medium sized plots) and Table 31/Fig. 11 (small plots). Yield results of participatory trials are hard to 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.

Based on the results of the on-farm trials, Mv Elit CCP showed mostly the highest protein and gluten contents and best Zeleny sedimentation value, while the Mv varieties were superior at Zselíz (by Biocentrum). Most of the Mv cultivars had a few percent weaker quality than the trial average at all farms, except in Zselíz. There were more varieties under examination as the part of ÖMKi's on-farm trial network, but the Mv cultivars could perform near or above the trial average of the given farm in 2022. Only in Tornyiszentmiklós (Organic Valley) very low yield from Mv Elit CCP could be seen, while grain yield of all the other Mv cultivars were above the trial average, except for 2 varieties in Kömlő (Table 30).

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Table 30. Agronomic results of Mv cultivars tested in 4 farms using medium sized plots (Hungary, 2022).

Site	Cultivar	Grain yield		Grain protein content		Gluten content		Test weight		Zeleny sedimentation	
		t/ha	% of trial avg.	%	% of trial avg.	%	% of trial avg.	kg/100L	% of trial avg.	mL	% of trial avg.
Füzes-gyarmat	Mv Bio2020 Pop	3.08	122%	12.9	95%	26.3	93%	79	100%	42	90%
	Mv Elit CCP	3.04	120%	13.5	100%	27.7	98%	79	100%	46	99%
	Mv Pántlika	3.12	123%	13.4	99%	27.8	99%	78	99%	46	99%
	Mv Tarsoly	3.19	126%	12.9	95%	26.7	95%	77	98%	43	92%
	Mv Uncia	2.85	112%	12.7	94%	26.4	94%	79	100%	40	86%
Biocentrum	Mv Elit CCP	4.90	100%	15.7	99%	33.3	97%	79	100%	58	99%
	Mv Pántlika	5.25	107%	16.2	102%	35.3	103%	81	102%	62	105%
	Mv Tarsoly	5.25	107%	16.1	102%	34.8	102%	79	100%	61	104%
	Mv Uncia	5.25	107%	16.5	104%	35.7	104%	78	99%	62	105%
Kömlő Farm	Mv Elit CCP	2.21	105%	14.2	114%	30.3	119%	-	-	51	124%
	Mv Kikelet	1.89	90%	12.1	97%	24.3	95%	-	-	39	95%
	Mv Pántlika	1.47	70%	12.3	99%	24.8	97%	-	-	38	93%
	Mv Tarsoly	2.20	105%	10.6	86%	19.6	77%	-	-	29	71%
	Mv Uncia	2.69	128%	11.5	93%	22.8	90%	-	-	31	76%
Organic Valley	Mv Elit CCP	1.90	53%	10.7	93%	18.0	85%	-	-	23	77%

The small-plot PVS trial was harvested in Szár, and after the measurement of the harvested grains from the three replications, one-way ANOVA was carried out. Significant difference was detected only between some of the best and the worst yielding cultivars, however grain yields of the two Mv populations were below the trial average, 7.58 t/ha (Fig. 11).

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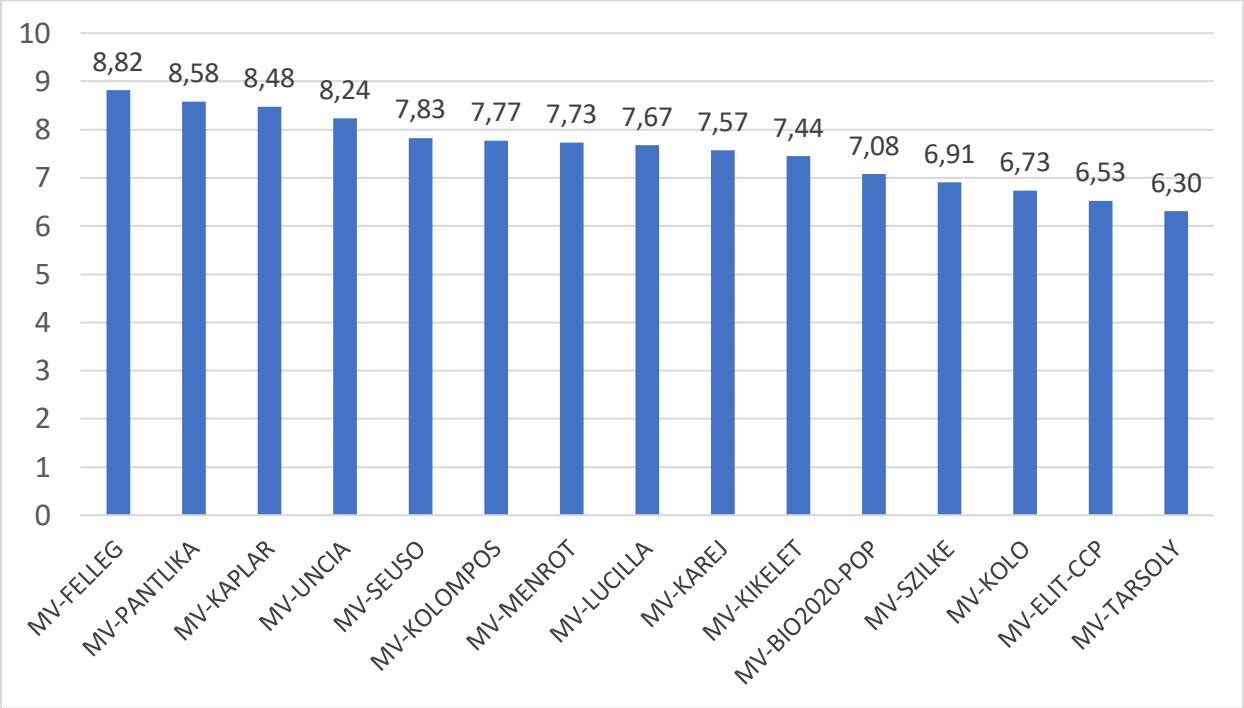

Fig. 11. Grain yield (t/ha) of 15 Mv cultivars grown on organic replicated small plots (Szár, 2022).

Quality of cultivars tested at Szár was measured with a rapid (NIR) grain quality analyser. The variety, Mv Szilke had the highest protein and gluten contents, so as Zeleny sedimentation volume, followed by the two populations, except for the gluten content of Mv Bio2020 Pop, which was beaten also by 2 other varieties, Mv Tarsoly and Mv Felleg. At the same time, unlike the other population, test weight and thousand grain weight of Mv Elit CCP were found to be above the trial average in Szár, while the best quality variety, Mv Szilke had the lowest values regarding these traits (Table 31).

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Table 31. Rapid (NIR) grain quality measurement data of winter wheat cultivars tested on replicated small plots at the organic field near Szár (Hungary, 2022).

Cultivar	Grain protein content (%)	Gluten content (%)	Zeleny sedimentation (mL)	Test weight (kg/100L)	Thousand grain weight (g)
MV-SZILKE	14.3	34.1	58.3	76.5	33.3
MV-ELIT-CCP	14.1	33.5	53.7	81.7	42.0
MV-BIO2020-POP	13.6	31.7	48.5	81.3	40.4
MV-TARSOLY	13.4	32.4	43.4	78.4	37.8
MV-SEUSO	13.2	29.5	39.5	81.1	41.0
MV-FELLEG	13.1	32.1	45.6	81.3	43.1
MV-LUCILLA	13.0	31.3	43.3	83.8	38.1
MV-KIKELET	12.9	29.7	38.4	84.8	49.9
MV-PANTLIKA	12.8	28.2	35.6	81.4	46.1
MV-KAREJ	12.7	29.5	40.7	84.6	44.8
MV-UNCIA	12.6	27.6	36.3	84.3	41.7
MV-KAPLAR	12.2	27.1	33.0	80.2	37.3
MV-KOLO	11.7	28.7	32.1	82.2	40.8
MV-MENROT	11.4	26.2	29.5	82.1	46.1
MV-KOLOMPOS	11.0	24.4	23.2	78.8	53.0
Trial mean	**12.8**	**29.7**	**40.1**	**81.5**	**42.4**

Our participatory plant breeding (PPB) program was started based on the two populations (Mv Elit CCP and Mv Bio2020 Pop) sown by farmers. Positive selection of spikes was performed on both populations by 3 farmers in 2021 (Fig. 12). Selected spikes were sent to ATK and threshed into 6 bulks resulting in 6 new subpopulations (based on the population and farm of origin).

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Fig. 12. Farmer with his own selected spikes as a step for participatory plant breeding (Szár, 2021).

The new sub-populations and the unselected ("original") populations were sown at two locations in October 2021 (on-station (Martonvásár, ATK) and on-farm (Szár, farmer)) in non-replicated, small-plot trials for multiplication and testing. Sowing of the plots at the on-farm location occurred later, therefore the early soil coverage was weaker than at Martonvásár. In average at the two sites, soil coverage of the selected sub-populations (in comparison to the original populations) was higher in the case of Mv Elit CCP: sub-population Mv Elit CCP FGY had higher value. In the case of the other population, the original plots covered 2-3% more from the soil than its sub-populations at the beginning of tillering. Average heading of the sub-populations occurred later or on the same day as that of their original populations, except for the sub-population of Mv Bio2020 Pop selected at Zselíz, which showed improvement in earliness. At the same time, this sub-population was the tallest, either, followed by the other sub-population selected at the same farm (Zselíz). Based on these mean plant height data, the farmer preferences can be revealed, namely, the farmer in Zselíz had selected taller plants, while the farmer in Szár had selected shorter plants from the population resulted in taller and shorter sub-populations, respectively (Table 32).

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Table 32. Assessment data and grain yield of PPB sub-populations developed by the participating farmers and grown in organic fields of ATK (on-station) and Szár (on-farm) (Hungary, 2022).

Subpopulation	Farm of origin	Early soil coverage (%)			Heading date (1=1st May)			Plant height (cm)			Grain yield (kg/6m²)		Grain yield (t/ha)	
		on-station	on-farm	avg.	on-station	on-farm	avg.	on-station	on-farm	avg.	on-station	on-farm	avg.	Rank
MV-ELIT-CCP-SZR	Szár	61	24	43	16	19	18	85	86	86	4.64	4.98	8.01	1
MV-BIO2020-POP	ATK	58	24	41	13	16	15	82	83	83	4.72	4.84	7.96	2
MV-BIO2020-POP-SZR	Szár	56	20	38	14	16	15	76	81	79	3.85	5.25	7.58	3
MV-ELIT-CCP	ATK	71	26	49	14	16	15	86	88	87	3.59	5,18	7.30	4
MV-BIO2020-POP-ZS	Zselíz	57	21	39	13	15	14	96	91	94	4.41	4,32	7.28	5
MV-ELIT-CCP-ZS	Zselíz	68	24	46	14	16	15	90	89	90	4.48	3,83	6.93	6
MV-BIO2020-POP-FGY	Füzesgyarmat	57	20	39	14	16	15	86	88	87	4.00	4.26	6.88	7
MV-ELIT-CCP-FGY	Füzesgyarmat	71	27	49	14	17	16	84	89	87	3.58	3.87	6.20	8

Grain yield of the non-replicated plots were measured after harvesting the small plots. Based on the average of the 2 sites, only the sub-population of Mv Elit CCP selected in Szár yielded more than the original population. At the same time, the yield of Mv Bio2020 Pop was improved in Szár by 8.6% due to the participatory selection. It must be also noted, that Mv Bio2020 Pop and its sub-population selected in Zselíz showed the highest yield stability across the 2 sites with a coefficient of variation around 1% (Table 32).

Rapid quality test (using NIR technology) of the cultivars were carried out for main quality traits (Table 33). Based on the results, the positive effect of the selection site can be seen, because the sub-populations selected in Szár and tested in Szár showed better performance than the respective original populations regarding each quality trait. Moreover, only the sub-population of Mv Elit CCP selected in Szár had higher mean protein and gluten contents than the two original populations followed by the other sub-population of Szár on the fourth place. The other 4 sub-populations originating from the other 2 farms had lower mean protein and gluten contents, among which Mv Elit CCP and the selection site Zselíz were the better performing. In the case of Zeleny sedimentation, the Mv Bio2020 Pop-SZR sub-population also outperformed its original population, while all the sub-populations had higher average test weight than the respective original populations. Regarding the average thousand grain weight, only the Mv Elit CCP FGY sub-population had smaller grains than its original population, while – like test weight – positive farmer selection effect was found regarding the other sub-populations.

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Table 33. Rapid (NIR) grain quality measurement data of PPB sub-populations developed by organic farmers and examined on-station (Martonvásár, ATK) and on-farm (Szár, farmer) using small (6 m^2) non-replicated plots in organic fields (Hungary, 2022).

Cultivar	Grain protein content (%)			Gluten content (%)			Test weight (kg/100L)			Zeleny sedimentation (mL)			Thousand grain weight (g)		
	Szár	ATK	Avg.	Szár	ATK	Avg.	Szár	ATK	Avg.	Szár	ATK	Avg.	Szár	ATK	Avg.
MV-ELIT-CCP-SZR	15.7	10.1	12.9	36.1	22.7	29.4	81.6	82.4	82.0	65.1	19.1	42.1	44.1	44.9	44,5
MV-ELIT-CCP	14.3	9.0	11.7	33.6	19.7	26.7	81.4	81.8	81.6	54.9	17.0	36.0	43.5	44.2	43,9
MV-BIO2020-POP	13.2	9.7	11.5	30.5	19.8	25.2	81.5	80.1	80.8	42.2	15.1	28.7	43.0	43.5	43,3
MV-BIO2020-POP-SZR	13.8	9.0	11.4	31.5	18.3	24.9	82.2	80.1	81.2	48.7	12.1	30.4	44.6	46.5	45,5
MV-ELIT-CCP-ZS	10.9	11.3	11.1	24.3	25.4	24.9	81.2	82.2	81.7	27.5	27.2	27.4	44.2	48.1	46,2
MV-ELIT-CCP-FGY	12.3	9.3	10.8	28.1	20.4	24.3	80.9	82.5	81.7	30.2	17.3	23.8	40.0	44.6	42,3
MV-BIO2020-POP-ZS	10.8	9.8	10.3	24.0	20.0	22.0	81.5	81.4	81.5	22.0	16.9	19.5	43.8	45.6	44,7
MV-BIO2020-POP-FGY	11.2	9.1	10.2	24.4	17.9	21.2	81.4	80.3	80.9	25.0	14.7	19.9	43.8	45.9	44,8

The effectiveness of the selection on other sites could be examined a couple of years later, when the multiplied seeds will be enough to return to those farms. In the next season (2023), small plot-trials will be continued at the same two locations (Martonvásár, Szár) using three randomised replications of the populations and sub-populations with different selection origin.

Similar to the previous year, our participatory trials, their preliminary results and ECOBREED project were presented at the Hungarian Organic Field Day in June 2022 at Szár (Fig. 4). The demonstration event was organized by ÖMKi.

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Fig. 13. Organic Field Day at Szár, 21 June 2022.

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2.7. Wheat farmers participatory field trials in Slovenia

2.7.1. Methods

The winter wheat farmer participatory trial in Slovenia was conducted at the Agricultural Institute of Slovenia's testing station in Jablje, which has an organic field and is located at 46°08'37.3" N, 14°34'39.2" E; 320 m a.s.l., with a sub-alpine climate. The soil type at the trial was Umbrian planosol with a silt loam texture.

The trial utilised 22 cultivars (both domestic and international) chosen based on specific traits for organic cultivation and performance in organic and low-input trials. The Slovenian experts chose Ingenio, Savinja, Tata mata, Reska, Primorka, Marinka, Illico, Izalco CS, Gorolka, Vulkan, and Nexera (i.e. Trial 1), while the ECOBREED project selected Liocharls, Arnold, Capo, Aurelious, Albertus, IS Laudis, Purino, Viki, Wendelin, Edelman, and Ehogold (i.e. Trial 2). The experimental plots were tilled conventionally using a 25 cm deep plough for seed-bed preparation with cultivation. A three-year crop rotation of maize, winter wheat or winter spelt, and spring peas was practiced. Weeds were controlled using the false seedbed method before seeding. The cultivars were seeded at a density of 400 viable seeds/m^2 using the Wintersteiger experimental plot seeder on 28 October 2020. The design was a randomised block with four replications, and the plot size was 15 m^2 (6 × 2.5 m). During vegetation, 63 kg N/ha was added using Azocor 10.5% at the tillering and stem elongation phases. No mechanical weed control, fungicides, or insecticides were applied. Traits evaluated included date of heading, number of wheat heads, plant height (cm), canopy, lodging susceptibility, 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, lodging susceptibility, diseases and pests were assessed using a 1–9 scale.

At the full maturity stage, the trials were harvested using a Wintersteiger Nursery Master plot harvester. Moisture determination and quality analyses were performed on approximately 1 kg of representative grain samples. The contents of moisture, protein, starch, and wet gluten were analysed using the Infratec Nova NIR analyser. Additionally, sedimentation values were analysed using the Zeleny sedimentation test.

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2.7.2. Results

Winter wheat experienced generally favourable weather conditions during its vegetation period, promoting its growth and development. In comparison to the previous season, this season experienced a similar level of warmth (+0.1 °C), but with significantly less precipitation (-462 mm) during the same period.

Table 34. Mean daily air temperature and cumulative monthly precipitation during the 2021/2022 growing season at Jablje, from sowing to harvest.

Year	**2021/2022**	
	Temperature (°C)	Precipitation (mm)
October	8.1	47.4
November	4.2	172.9
December	-0.9	95.0
January	-1.4	24.6
February	2.7	41.2
March	3.6	7.3
April	8.4	85.9
May	16.0	52.9
June	21.2	75.2
July	21.4	24.2
Mean/sum	**8.3**	**626.6**

Fig. 14 displays the results of the plant height analysis. The mean plant height in the second trial was greater than that of the first trial (94.4 cm and 80.5 cm, respectively). In Trial 1, the plant height ranged from 69.3 cm (Tata mata) to 87.3 cm (Marinka), while in Trial 2, the range was from 81.1 cm (Aurelius) to 108.2 cm (Ehogold). The cultivars with the tallest plants were Liocharls, Ehogold, and Capo. In general, the plant heights were smaller compared to the previous growing season.

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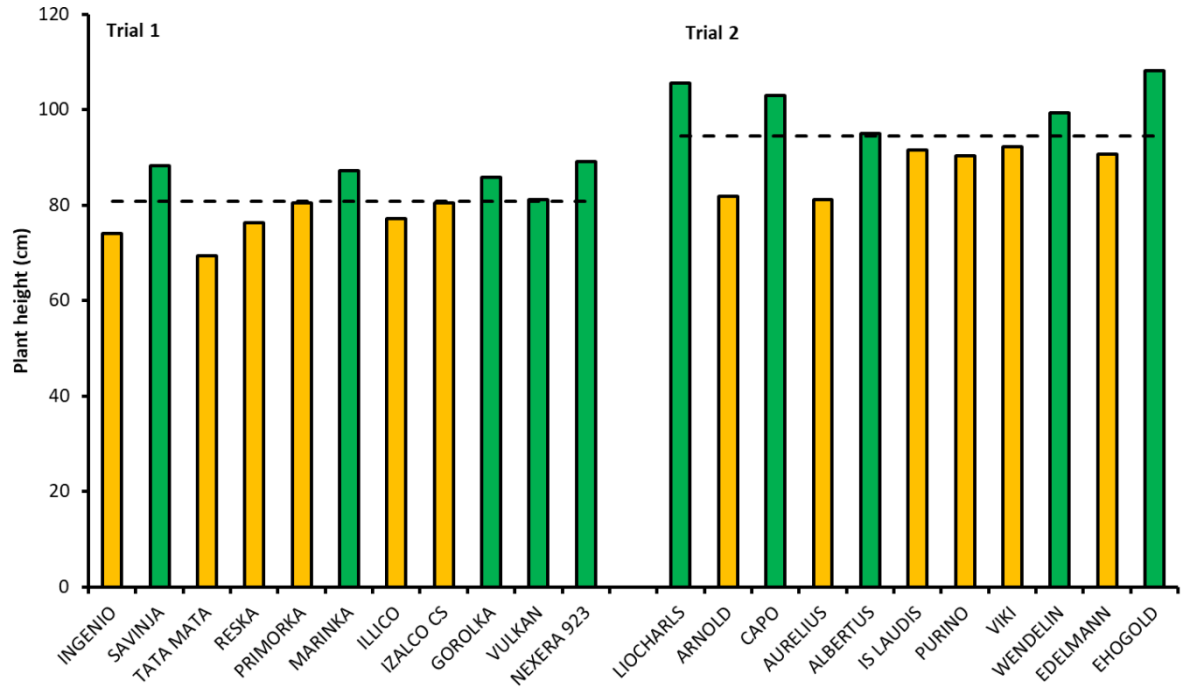

Fig. 14. Plant height of the individual cultivars (columns) and trial mean (dotted line) in organic trials at Jablje in growing season 2021/2022. Green-shaded cultivars exceed the mean height of their respective trials.

Table 35. Estimates of ground cover and lodging tolerance for selected cultivars in organic trials at Jablje during the 2021/2022 growing season, using a 1-9 scale.

Cultivar	Ground cover	Lodging	Cultivar	Ground cover	Lodging
Ingenio	6	1	Liocharls	8	1
Savinja	7	1	Arnold	7	1
Tata mata	6	1	Capo	7	1
Reska	8	1	Aurelious	8	1
Primorka	8	1	Albertus	8	1
Marinka	8	1	IS Laudis	7	1
Illico	8	1	Purino	8	1
Izalco CS	8	1	Viki	8	1
Gorolka	7	1	Wendelin	8	1
Vulkan	8	1	Edelmann	8	1
Nexera 923	7	1	Ehogold	8	1
Mean	**7.4**	**1**	**Mean**	**7,7**	**1**

Table 35 shows that while no differences in lodging tolerance were observed among cultivars, minor differences in ground cover were noted. Ground cover estimates, scored on a 1-9 scale (with 9 indicating the highest ground cover), were smaller for cultivars in Trial 1 (mean estimate 6.2) compared to Trial 2 (mean estimate 7.0). The ground cover of cultivars ranged from 6 to 8 in Trial 1 and from 7 to 8 in Trial 2. However, the observed

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differences in ground cover between cultivars were not reflected in differences in weed presence during the 2020/2021 growing season.

The prevalence of diseases was significantly lower in the 2021/2022 season compared to the previous season, which may be attributed to the higher amount of precipitation received during that season. *Septoria tritici* was the most prevalent disease observed in the field trials, with no difference in its prevalence between the trials (values of 2.1 and 2.0 for Trial 1 and Trial 2, respectively). However, individual cultivars showed some differences in tolerance. In Trial 1, *Septoria* values ranged from 1.0 (Tata Mata, Reska, Primorka, Marinka) to 5.0 (Vulkan), while in Trial 2, values ranged from 1.0 (Albertus, Purino, Viki, Wendelin) to 4.0 (Aurelius). Leaf rust was also observed in the trials. In Trial 1, a value of 3 (the highest) was recorded for Primorka while in Trial 2, a value of 3 (the highest) was recorded for Viki. The cereal leaf beetle (*Oulema melanopus*) was the most prevalent pest found in the trials. Mean estimates of trials showed that ECOBREED-selected cultivars exhibited higher damage from the beetle also in this season (mean values of 1.9 and 3.0 for Trial 1 and Trial 2, respectively). In Trial 1, the highest value of 2 was found for most cultivars, while in Trial 2, the highest level of 5 was found for cultivar IS Laudis. Aphids were generally present on all cultivars, with only minor variation among them.

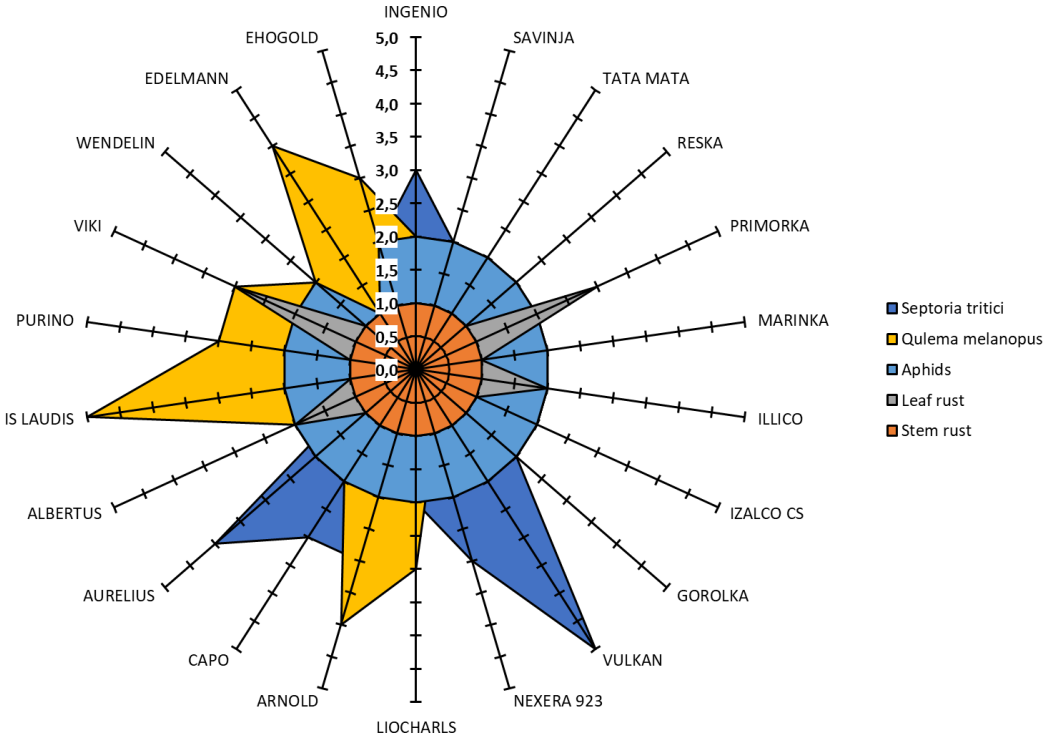

Fig. 15. Scoring of disease and pest prevalence for selected cultivars in organic trials at Jablje in growing season 2021/2022.

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Fig. 16 illustrates the grain yields calculated at 14% moisture. ECOBREED-selected cultivars exhibited higher mean grain yields in organic production. Mean grain yield in Trial 1 was 5124 kg/ha, while in Trial 2 it was 6231 kg/ha. Additionally, there was less variation among cultivars in Trial 2 than in Trial 1. The mean grain yields of cultivars in Trial 1 ranged from 4252 kg/ha (Primorka) to 5841 kg/ha (Nexera), whereas in Trial 2, the mean grain yields ranged from 5398 kg/ha (Arnold) to 6898 kg/ha (Edelmann). Edelman, Ehogold, and Purino were the highest-yielding cultivars (ca. 6800 kg/ha). It is worth noting that higher grain moistures at harvest were again observed for cultivars in Trial 2, but none exceeded 14%.

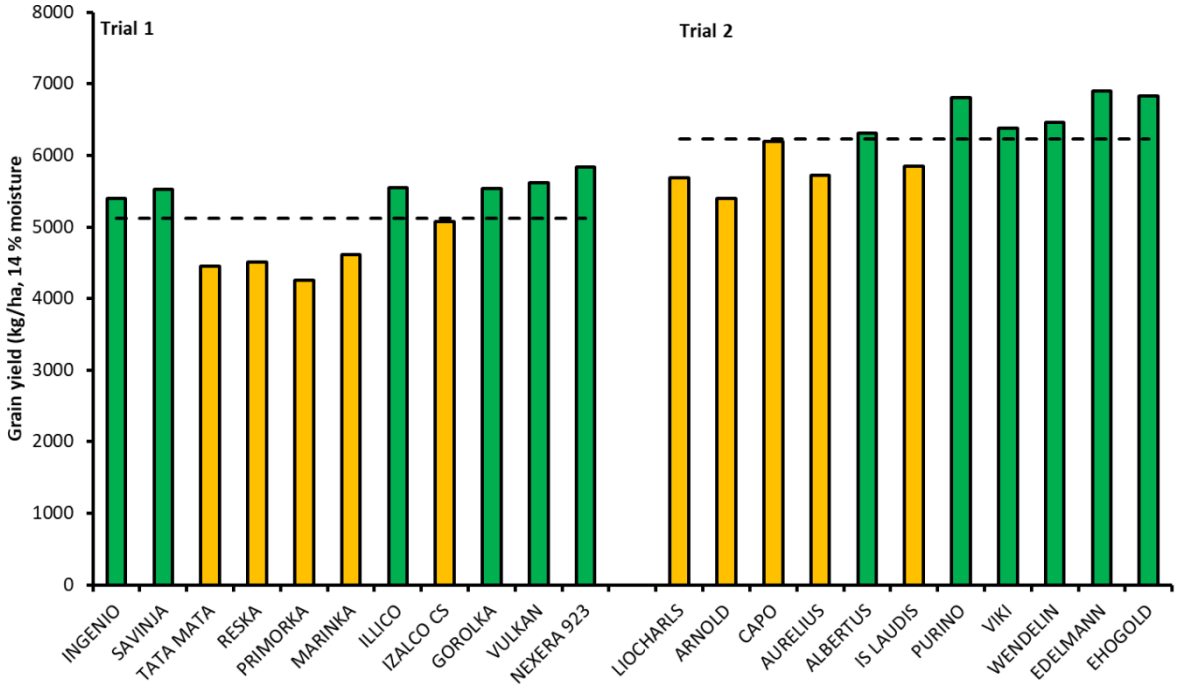

Fig. 16. Grain yields of individual cultivars (shown in columns) and the trial mean (dotted line) in organic trials conducted at Jablje during the 2020/2021 growing season. Cultivars that yielded higher than the mean of their respective trial are highlighted in green.

Table 36 presents the results of an analysis of several quality traits in wheat cultivars across the two trials. The mean test weight was higher in Trial 2, ranging from 75.5 kg/hl to 84.6 kg/hl, with the cultivars Gorolka, Ehogold and Capo having the highest test weight. The protein content showed no significant differences between the trials, ranging from 9.8% to 12.3% in Trial 1 and 11.5% to 13.6% in Trial 2. Cultivars Viki, Izalco CS, Capo, Albertus and Wendelin had the highest protein content (>12 %). The highest yielding cultivars showed lower protein content, indicating a likely dilution effect. The sedimentation values also showed no significant difference between the mean values of both trials, ranging from 24 ml (Illico) to 38 ml (Izalco) in Trial 1 and 34 ml (Arnold) to 48 ml (Viki) in Trial 2. Izalco CS, Albertus, Capo, Viki, Ehologold and Edelman had the highest

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sedimentation values (> 38 ml), while cultivars with higher grain yield generally showed smaller sedimentation values. The percentage of wet gluten ranged from 17.6% (Illico) to 26.4% (Izalco) in Trial 1 and 23.8% (Arnold) to 31.1% (Viki) in Trial 2. The percentage of starch generally had smaller variation than other quality traits, ranging from 69.7% to 71.5% in Trial 1 and 65.7% to 70.5% in Trial 2.

Table 36. Data on selected quality traits of wheat cultivars grown organically at Jablje during the 2021/2022 growing season. The traits analysed include test weight, protein content, sedimentation value, percentage of wet gluten, and percentage of starch.

Cultivar	Test weight Kg/hl	Protein content %, DM	Sedimentation value ml	Wet gluten %	Starch %, DM
Ingenio	75.5	10.4	28.0	20.9	69.9
Savinja	79.2	10.4	30.0	20.4	70.7
Tata Mata	82.6	11.8	36.0	24.9	71.0
Reska	80.7	10.5	28.0	20.5	70.8
Primorka	79.7	10.3	29.0	19.9	70.7
Marinka	78.3	10.5	31.0	19.6	69.7
Illico	78.7	9.8	24.0	17.6	71.5
Izalco CS	81.5	12.3	38.0	26.4	70.9
Gorolka	84.3	11.6	36.0	24.2	70.5
Vulkan	80.0	11.2	32.0	23.0	71.2
Nexera 923	80.9	11.1	33.0	22.9	71.4
Mean	80.1	10.9	31.4	21.8	70.8
Liocharls	81.3	11.9	38.0	25.3	69.4
Arnold	79.1	11.5	34.0	23.8	67.4
Capo	84.4	12.4	44.0	27.6	69.3
Aurelious	83.3	11.6	37.0	24.6	70.5
Albertus	83.3	12.4	44.0	27.5	69.9
IS Laudis	81.6	11.5	36.0	23.9	69.3
Purino	79.4	11.7	36.0	25.2	68.4
Viki	78.7	13.6	48.0	31.1	65.7
Wendelin	82.6	12.8	43.0	28.1	66.9
Edelmann	82.9	11.7	37.0	24.5	70.4
Ehogold	84.6	12.4	44.0	27.5	68.9
Mean	81.9	12.1	40.1	26.3	68.7

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3. Soybean

3.1. Soybean participatory trials in Serbia

As part of the ECOBREED project, farmer participatory trials for organic soybean were set up in Serbia. By setting up trials direct with organic producers, it was possible for them to assess the adaptability of the soybean varieties for organic production in specific agro-ecological conditions. This is one way for organic producers to contribute and to be involved in the process of creating new varieties, especially in CCP population observations.

During the 2022. organic farmers actively participated in the trial observations and received training on various occasions (location of trainings and demonstration events: Rimski šančevi and Šuljam) on how to select soybean variety that is better suited to their region and growth conditions.

Fig. 17. Šuljam trial and demonstration event.

The soybean trials were set up in 2022 at four locations (Rimski šančevi, Šuljam, Bela Crkva, Čurug).

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Fig. 18. Trial locations in Serbia in 2022.

Up to nine (9) soybean varieties (000, 00, 0, I, II maturity groups) were evaluated in a network of large-plot trials in Serbia (Tab. 1.).

Table 37. Tested soybean varieties in 2022.

000	00	0	I	II
Favorit	NS Mercury Taifun *Xonia	Galina Zora NS Altis	NS Apolo	Rubin

Varieties from two breeding companies were tested (*Xonia, Saatgut Gleisdorf, Austria; Favorit, Taifun, NS Mercury, NS Altis, Galina, Zora, NS Apolo, and Rubin, Institute of Field and Vegetable Crops, Novi Sad, Serbia). Crops were sown during April and at the beginning of May and harvested in September/October. 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/June), manual weed control, and harvest in September/October, according to maturity group. On all farms, field emergence, sowing density, growth development, ground cover, height and lodging were evaluated as well as occurrence of diseases and pests. Soybean varieties (00-II maturity groups) showed different adaptability to specific farm site conditions.

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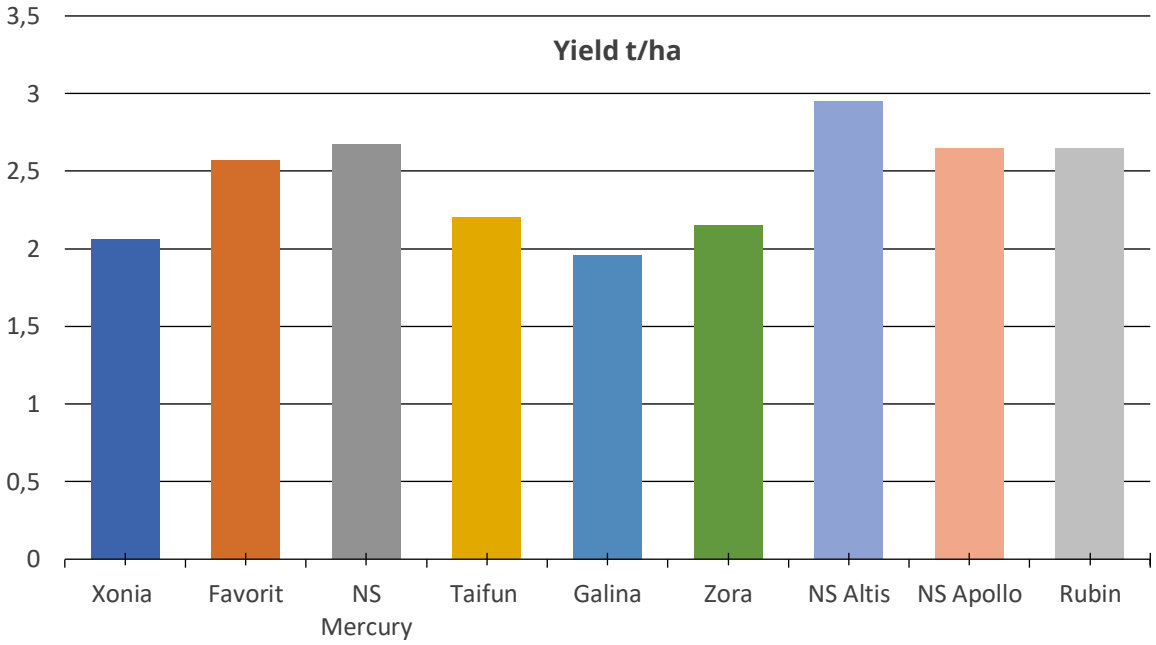

Fig. 19. Average yield for all locations in Serbia.

Agro-climatic factors had a significant impact on soybean yields in 2022 (Table 2.), especially because of unusually hot summer temperatures, a lack of precipitation during the crucial periods of soybean development, and precipitation during the harvest of soybeans in September and October. The average yield in all locations was in the range of 1.8 to 3.2 t/ha, which is significantly above the average for this year given the uniqueness of the year and unfavourable weather circumstances for soybean production. The variety NS Altis (0) had the highest yield at the Rimski šančevi location with a yield of 3.2 t/ha. The variety Merkur (00), with a yield of 3.3 t/ha, was chosen for the Šuljam location. After first year of CCP observation, average yield was 1.9 t/ha, and material showed variation regarding maturity groups, and different morphological traits. After two years of setting up participatory trials for organic production the farmers got a solid foundation and a direction for selecting a soybean variety for specific agro-ecological conditions that is in line with the farmers' requirements and the established production goal. Farmer participatory trials are a crucial milestone to define local criteria for variety selection and CCPs observations and for increased adoption of new and improved soybean varieties into low-input and organic production.

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3.2. Soybean trials in Germany and Austria

The 2022 soybean trials were sown on six organic farms in Germany and three organic farms in Austria. At the new farm in Austria the focus was on testing populations from IFVC Serbia and Saatzucht Gleisdorf with no assessment of yield data. Five of the six German farms were 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 again different with Jobst Farm starting on 16 April and ending at Schalk Farm on 20 May. The subsequent weather was dry or very dry on most locations causing harvest starting at end of August with partially very low yields.

The varieties selected partly by researchers from the project and partly by the farmers/consultants were almost the same as in 2021. The Serbian variety NS Mercury was only sown at four locations because of late maturity but the variety Favorit from Serbia was sown for the first time at four locations. 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. GL Melanie was grown at all 8 farms with yield data and Obelix was grown at the same 7 farms as in 2021. On most farms, field emergence, juvenile development, ground cover, growth height, lodging and maturity were evaluated. Diseases and pests did not occur. On one location in the varieties Obelix and Favorit pods burst due to hot weather conditions before harvest.

Varieties from the breeding partners:

- NS Mercury showed better results than in 2021. Protein content was above average.
- The Serbian varieties Favorit (maturity 000) and Galina (maturity 0) were grown for the first time, Favorit at four farms and Galina at two farms in Austria. Yield of both varieties was average or below average, protein was above average.
- The Serbian population NS CCP did not mature in two of the three locations in Germany while at the other location yield was low. At Jugovits Farm in Austria the focus was on selection together with some Saatzucht Gleisdorf populations, so yield was not evaluated.
- The 00 variety Lenka, which is important for growing edibles, was grown on four farms in Germany and one farm in Austria again. It showed average to good yields and a high protein content as expected.
- 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 lower yields.

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In our trials, the variety did not disappoint again. Yield and protein content were close to average.

- The 000 variety GL Melanie was grown at all locations and did not repeat the very good results of 2021.
- The 000 variety Obelix had mixed results in yield again and protein below average.

Farmers'/advisers' choice:

- In Germany the popular variety ES Comandor showed unstable or weak yields again. ES Compositor showed better results. Abaca showed average to good yield, but protein was low. Achillea was grown for the first time on five farms and showed good results at all locations. In Austria, ES Director and Altona did not repeat the very good results of 2022. RGT Satelia, ES Collector, Altona and Svelte showed good yield but were grown only at one or two farms. Tofina and ES Mentor showed good protein content as expected.
- Differences in protein from farm to farm was much higher in 2022 than in 2021.
- The trial with the Austrian seed treatment at Neder Farm failed. Plant were yellow without nodules and protein content of the seeds was much lower.

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Table 38. Yield in dt/ha for 2023. The two varieties with highest yields are marked in green, and the two with lowest in red.

Variety/Farmer	Sölch	Endres	Hopf	Binder	Jobst	Neder	Güssing	Schalk
NS Mercury				16	39		23.9	35.5
Lenka		28.3	49	30	27			37.5
Xonia					31		25.6	35.5
Obelix	19.9	22.8	43.6	31	54	13.1		35
GL Melanie	17.9	28.1	42.3	27	39	6.5	34.2	35.5
Favorit	15.7			31	31	4.8		
Galina							24.2	34
NS CCP				22				
ES Comandor	21.8	22.3	39.7		27	13.3	16.9	
Adelfia	16.6	27	42.6	34				40
Tofina	18.9	23.9	34.2	31	41			
ES Compositor	21.9	31	45.4					
Achillea	20.1		50.1	31			22.6	35.5
Abaca	21.4		41.8	31		10.9		
Alicia	18.4	25.1	44.7					
ES Mentor				31				
RGT Sphinxa			45.3					
RGT Satelia			50.5		37			
SY Livius			44.1					
ES Collector			51.2					
Xena						3.2		
22517						1.4		
ES Director							22.1	40.5
Alvesta							21.9	39
GL Leonie (08)							17.9	
GL Judith (20)							21.6	
Altona							25.7	43
Svelte							27.9	
Atacama							20.8	
Average	***19.3***	***25.7***	***44.6***	***28.6***	***36.3***	***7.8***	***23.5***	***37.2***

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Table 39. Protein % - 2023. The two varieties with highest yields are marked in green, and the two with lowest in red.

Variety/Farmer	Sölch	Endres	Hopf	Binder	Jobst	Neder	Güssing	Schalk
NS Mercury				41.9	47.6		41.8	44.5
Lenka		43.9	43.5	44	46.1			47.9
Xonia					45.3		42.4	42
Obelix	40.2	40.2	38.7	44.9	46	40		40.8
GL Melanie	43.5	42.6	39.9	44.1	47.5	40.6	41.7	43.1
Favorit	41.7			45.7	46.5	41.8		
Galina							44.6	42.4
NS CCP				43.3				
ES Comandor	43.2	42.1	41.1		46.9	40.7	43.6	
Adelfia	44.5	42.5	40.6	43.8				43.5
Tofina	45.5	42.6	43.3	44.2	43.5			
ES Compositor	43.2	41.9	40.9					42.6
Achillea	44.2		41.6	45.2			44.5	43.7
Abaca	41.8		39.3	41.8		36		
Alicia	43	40.4	39.7					
ES Mentor				45	45.4			
RGt Sphinxa			41.3					
RGT Satelia			41.3		46.8			
SY Livius			42					
ES Collector			40.3					
Xena						41.2		
22517						46.1		
ES Director							42.9	43.9
Alvesta							43.4	44.1
GL Leoni (08)							43.5	
GL Judith (20)							41.2	
Altona							42.8	43.7
Svelte							42.4	
Atacama							43.5	
Average	***43.1***	***42.0***	***40.9***	***44.0***	***46.2***	***41.4***	***42.4***	***43.5***

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Table 40. Yield in dt/ha - 2022. The two varieties with highest yields are marked in green, and the two with lowest 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	
Xonia				49.1	30		28	34.4
Obelix	33.6	43.2	42.2	37.5	17	17.2	23	
GL Melanie	47.6	46.2	36.3	31.4	21.4	15.7	48	36.7
ES Comandor	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				
ES Compositor	42.3	59		20.8		12	32	42.1
Aurelina	40.2	53.2						
Arcardia	44.4		38		18.2			
ES Mentor	40.3			26.2	22.4		35	38.8
Alicia	47							
Yakari		59.3						
Achillea			42.6					39.8
SY Livius			41.2					
Primus				29				
Xena						27.4		
22517						23.6		
EGZ19111						19.8		
ES Director							36	44.1
Alvesta							27	42.6
GL 08							26	
GL 20							27	
Altona							37	43.3
Average	***39.3***	***48.0***	***38.5***	***30.7***	***21.3***	***18.3***	***31.4***	***39.6***

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Table 41. Protein % - 2023. The two varieties with highest yields are marked in green, and the two with lowest in red.

Variety/farmer	Sölch	Endres	Hopf	Binder	Jobst	Neder	Güssing	Schalk
NS Mercury		41.2			42.6			42.5
Lenka		45.8	46.4	42.2	46.0		42.5	
Xonia				40.1	40.7		40.3	41.2
Obelix	42.2	40.0	41.0	40.8	40.1	45.2	39.0	
GL Melanie	41.4	41.3	40.7	40.1	42.4	41.4	42.2	42.4
ES Comandor	41.9	40.9	41.6		41.1	41.2		
Adelfia	42.2							
Aurelia				44.3	42.3			
Tofina	44.5	43.2	43.8	43.8	43.6			
RGT Sphinxa			42.9	43.5				
ES Compositor	42.5	41.5		40.7		41.9	41.7	43.5
Aurelina	44.5	44.1						
Arcardia	42.0		39.6		39.6			
ES Mentor	42.2			42.7	42.7		40.0	43.4
Alicia	41.2							
Yakari		42.9						
Achillea			40.9				42.3	44.1
SY Livius			43.0					
Primus								
Xena								
22517						43.3		
EGZ19111						44.1		
ES Director							41.6	42.3
Alvesta								44.2
GL 08							44.4	
GL 20							39.7	
Altona							40.7	42.4
Average	***42.5***	***42.3***	***42.3***	***42.0***	***42.1***	***42.8***	***41.3***	***42.9***

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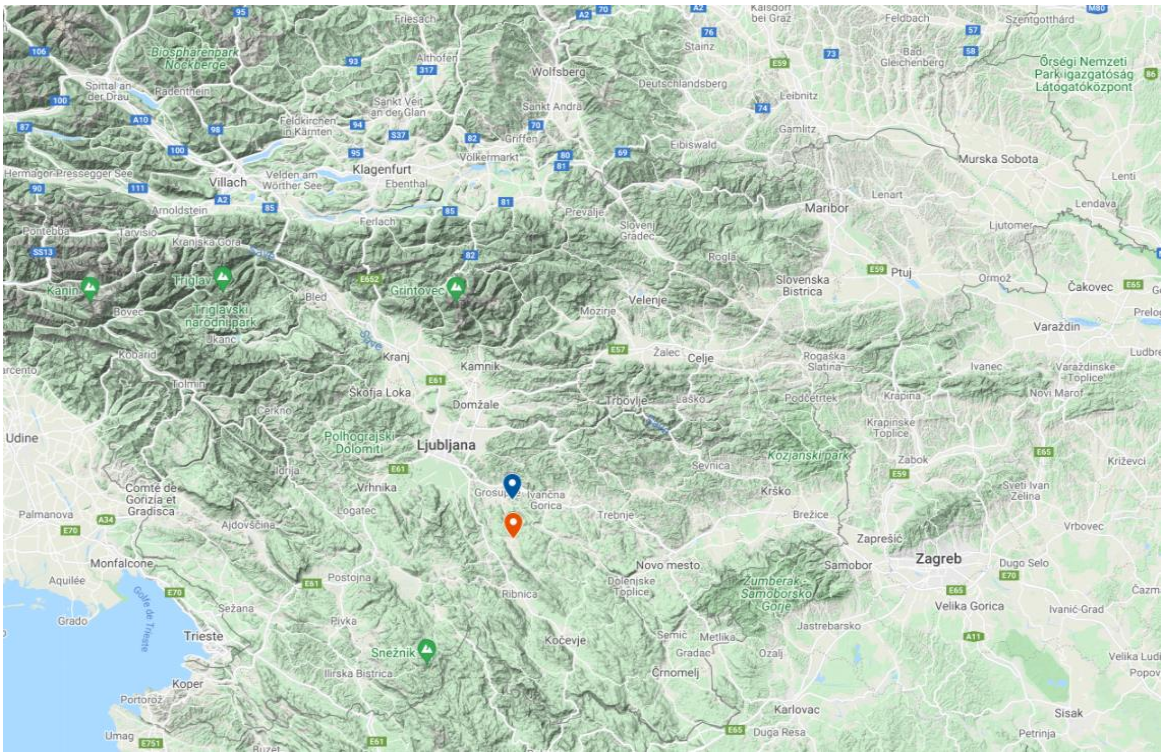
3.3. Soybean farmers participatory field trials in Slovenia

3.3.1. Methods

As part of the ECOBREED project, participatory trials for soybean farming were established in 2022 on two organic farms in the Dolenjska region of Slovenia (refer to Table 42). The trial plots were in Grosuplje, where the soil texture was silt, and in Videm Dobrepolje, where the soil texture was clay silt. Both locations experience a continental climate.

Table 42. Locations of soybean trials and main characteristics of the organic farms.

Name place	Location of the trial	Farm Elevation	Type of landscape	Pedo-climatic zones/regions	Farm size	Farm type	Organic since (years)
Grosuplje	45°56'26.0"N 14°41'31.0"E	335	Valley	Continental temperate climate	12	Mixed	**+20**
Videm Dobrepolje	45°51'30.5"N 14°42'41.2"E	441	Valley / "plateau"	Continental temperate climate	24	Mixed	**+12**



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Researchers and variety experts selected a total of eight soybean cultivars (GL MELANIE, EZRA, OBELIX, XONIA LENKA, NS MERCURY, NS ATLAS, and GALINA) for testing. These cultivars were chosen based on differences in their maturity rating, growth type (determinant and semi-determinant), as well as various other morphological and quality traits (Table 43).

Table 43. List of soybean varieties and their maturing ratings selected for farmer 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	Mid Early

Minimal tillage without ploughing was used for the trials at the Grosuplje location, while intensive conventional tillage involving a 25 cm deep plough followed by seedbed preparation with cultivation was used at the Videm Dobrepolje location. Soybean was first included in the farms' crop rotation in the ECOBREED trials in 2021. The trials in 2022 were established on 30th April, and 20th May using farm-available seeders, with a density of 57 and 48 seeds/m^2, respectively, and a row spacing of 70 cm at both locations. The seeds were not inoculated.

To assess the development and agronomic performance of the cultivars, several traits were evaluated, including 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 grain moisture at harvest (%). Yield was estimated by manual sampling of 0.7 m^2 with four repetitions for each variety, and grain samples were collected for protein content analysis. At both locations, buckwheat was the previous crop in the rotation before soybean was planted.

3.3.2. Results

Table 44 presents the basic weather conditions during the vegetation period, which were variable. A cold and wet May delayed emergence and early development, while hot and dry conditions in August and September accelerated the maturation of the cultivars. In comparison to the previous season, 2022 was warmer (+1.4°C) and had higher precipitation (+124 mm), although the months of July and August were very dry.

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Table 44. Mean daily air temperature and cumulative monthly precipitation from sowing to harvest of soybeans during the 2022 growing season, recorded at the Novo Mesto weather station.

Year	**2021**	
	Temperature (°C)	Precipitation (mm)
April	10.0	95.8
May	17.5	129.2
June	22.1	141.0
July	23.0	65.0
August	21.7	54.3
September	15.4	262.4
October	13.8	32.6
Mean/sum	**17.6**	**780.3**

In Grosuplje, soybean plants emerged 13 days after sowing, and their subsequent development was normal. In Videm Dobrepolje, plants emerged 7 days after sowing, followed by normal development. Farmers reported no damage from pests or diseases.

In general, the plants were taller at the Videm Dobrepolje location (+11 cm, Fig. 20). The variety NS Mercury reached the greatest height at Grosuplje (90 cm), while EZRA was the smallest (54 cm). At Videm Dobrepolje, NS Atlas was the tallest (95 cm), while Xonia and Galina were the smallest (78 cm). Although the heights of the first pods were not recorded by the farmers this season, they estimated them to be between 14-20 cm.

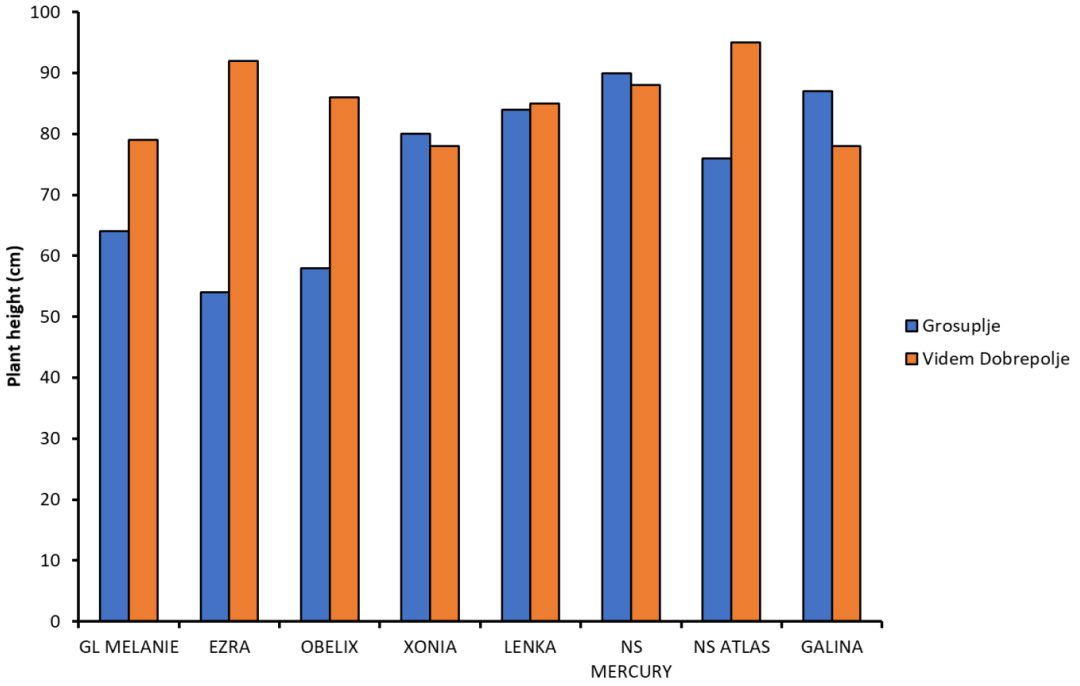

Fig. 20. Mean heights of soybean plants for each variety recorded at both trial locations.

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The differences between maturity groups were noticeable at both locations, affecting the timing of harvest and related grain losses. At Grosuplje, the earlier maturing varieties were harvested first, followed by the later maturing varieties, which were harvested 10 days later. At Videm Dobrepolje, all varieties were harvested at the same time, and some grain losses were observed with the earliest varieties, which were overripe. However, no losses were observed for the later maturing groups. In general, yields were similar at both locations, with a mean difference of 700 kg/ha (Table 45). At Grosuplje, yields ranged from 20.5 t/ha (Ezra, maturity group 0) to 34.6 t/ha (Lenka, maturity group 00). At Videm Dobrepolje, grain yield ranged from 18.1 t/ha (Lenka) to 39.6 t/ha (Obelix, maturity group 000). Variety OBELIX produced the highest yield in both locations, with 34.6 t/ha in Grosuplje and 39.2 t/ha in Videm Dobrepolje. Varieties LENKA and GALINA also showed relatively high yields in both locations, while varieties EZRA and XONIA performed better in Videm Dobrepolje. Varieties GL MELANIE and NS ATLAS produced better yields in Grosuplje, while NS MERCURY performed better in Videm Dobrepolje. The overall average yield for all varieties was 26.9 t/ha in Grosuplje and 27.6 t/ha in Videm Dobrepolje.

Table 45. Grain yields of the soybean cultivars at the locations Grosuplje and Videm Dobrepolje.

Yield (t/ha)	Grosuplje	Videm Dobrepolje
GL MELANIE	28.8	25.4
EZRA	20.5	26.6
OBELIX	34.6	39.2
XONIA	23.1	36.9
LENKA	34.0	18.1
NS MERCURY	19.4	27.2
NS ATLAS	26.4	22.3
GALINA	28.2	25.3
Average	**26.9**	**27.6**

Table 5 provides information about the protein and oil content of different varieties of soybean at the locations - Grosuplje and Videm Dobrepolje. There is significant variation in the protein and oil content of the different varieties, with protein content ranging from 314 g/kg to 382 g/kg, and oil content ranging from 220 g/kg to 254 g/kg. The average protein content across all varieties is 352 g/kg at Grosuplje and 360 g/kg at Videm Dobrepolje. The average oil content across all varieties is 237 g/kg at Grosuplje and 226 g/kg at Videm Dobrepolje. The data also shows that there are some differences in protein and oil content between the two locations. For example, the average protein content is slightly higher at Videm Dobrepolje than at Grosuplje, while the average oil content is slightly higher at Grosuplje than at Videm Dobrepolje. It is not clear why these differences

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exist, but it could be due to differences in soil type, climate, or other environmental or management factors.

Table 46. Content of protein and oil in the seed of soybean cultivars at the locations Grosuplje and Videm Dobrepolje.

	Grosuplje		Videm Dobrepolje	
Variety / content (g/kg):	**Protein**	**Oil**	**Protein**	**Oil**
GL MELANIE	378	230	357	228
EZRA	317	245	362	222
OBELIX	363	228	343	235
XONIA	366	237	373	224
LENKA	382	231	359	231
NS MERCURY	344	241	370	220
NS ATLAS	314	254	361	223
GALINA	353	233	357	224
Average	**352**	**237**	**360**	**226**

The data presented in Table 46 provides useful insights for organic farmers and researchers interested in selecting soybean varieties with high protein or oil content. By comparing the values for different varieties at different locations, it is possible to identify which varieties perform best under specific conditions. Moreover, the yields obtained at both locations suggest that organic soybean cultivation is feasible in this region, with potential for further optimisation through appropriate management practices and variety selection. This could lead to increased profitability for farmers while promoting sustainable agricultural practices. Therefore, the data can serve as a valuable resource for decision-making and crop planning in the organic farming sector.

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3.4. Soybean farmer participatory trials in Romania

Farmer participatory trials of soybean were established at four Romanian organic farms: Agroecologic Research & Innovation Center of NARDI Fundulea in county Călărași, ECOFRUCT and ECOVIAL Ștefan cel Mare in county Călărași and AGROTERRA Agigea in county Constanța. The Romanian organic soybean DEMO farms are located in Development regions South-Muntenia (3) and South – East (1), at diferrent altitudes and geographical coordinates and are place on cernozemic soils (Fig. 21, Table 47).

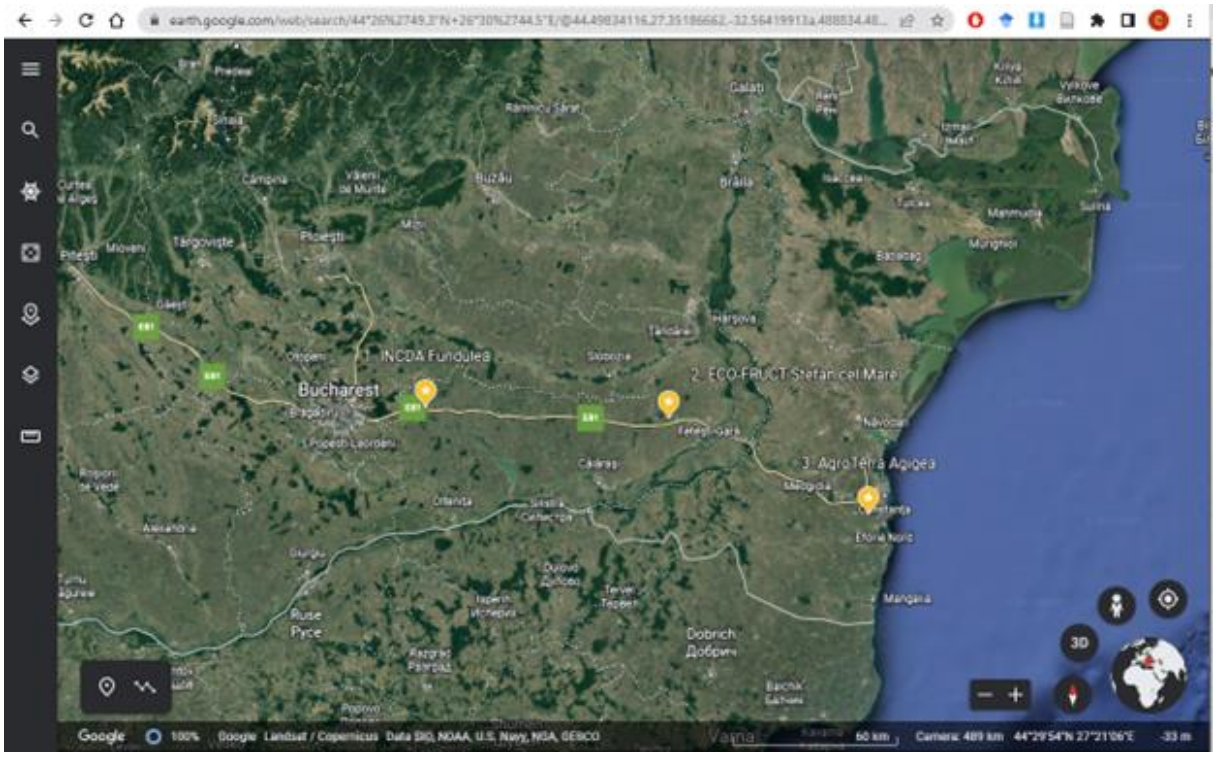

Fig. 21. Map of Romanian ECOBREEED Soybean Demo Farms.

Table 47. Geographical settlement and soil types of the soybean FPTs in 2022.

Nr.	Farm Demo (FPTs) Name	Altitude	Position	Development regions	Soil types
1	Agroecological Research&Innovation Center/NARDI Fundulea	63	44°26'821"N 26°30'742"E	South - Muntenia	Chernozem
2	ECO-VIAL Ștefan cel Mare	33	44°25'14.2"N 27°38'27.6"E	South - Muntenia	Chernozem
3	ECO-FRUCT Ștefan cel Mare	30	44°24'762"N 27°38'397"E	South - Muntenia	Chernozem
4	AGROTERRA Agigea	63	44°05'370"N 28°33'646"E	South – East	Chernozem

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Climatic data recorded for the period September 2021 – August 2022 at NARDI Fundulea shows that the monthly air temperature (Figure 22) was highest than the multiannual average values (LTA), excepting in September and October 2021 when the air temperature was similar to LTA and the agriculture year 2021 - 2022 was the second warmest year of the last 60 years.

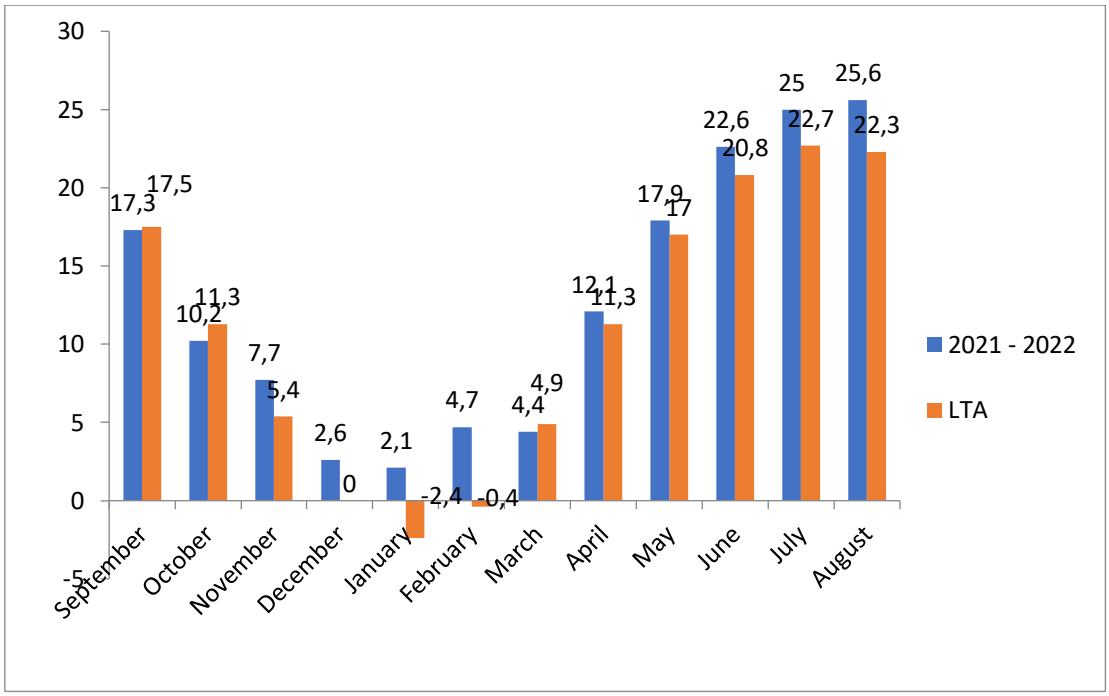

Fig. 22. Average monthly air temperatures recorded at NARDI Fundulea, in the period September 2021 – August 2022 compared to Long Term Average (LTA).

Regarding precipitation (Fig. 23), in the period considered, only in one month - October 2021, the precipitations were higher than LTA. In the rest of months, the sum of precipitations in the agriculture year 2021 - 2022 were below the long-term average (LTA), the monthly precipitation deficit varying between 2.5–44.5 mm, the year precipitation deficit - 249.1 mm being the biggest in the last 60 years.

Also, the Fundulea climatic scenario 2021 – 2022 was similar for all DEMO centres, but ECOFRUCT and ECOVIAL Ștefan cel Mare and AGROTERRA Agigea solved these climate problems by irrigation.

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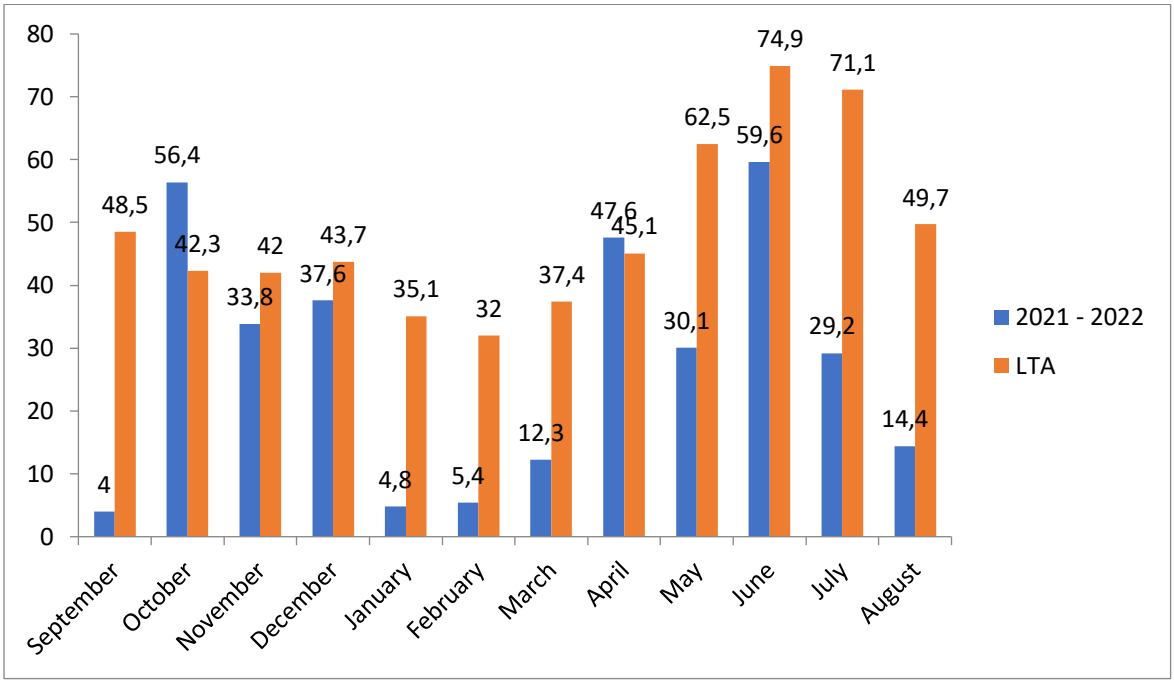

Fig. 23. The amount of monthly precipitation from September 2021 – August 2022 and the multi-year.

3.4.1. Material and methods

Romanian (Ovidiu F and Fabiana F) and USD (STK 01, STK 02 and STK 03). Also, in all Soybean DEMOs we tested and 3 soybean varieties mixtures: NS Mercury + Fabiana F, Favorit + Ovidiu F and STK 01 + Ovidiu F (Table 48).

Table 48. The name and MG of soybean varieties cultivated in 4 Romanian FPTs.

Variety name	Maturity Group (MG)	NARDI Fundulea	ECOFRUCT* Stefan cel Mare	ECOVIAL* Ștefan cel Mare	AGROTERRA* Agigea
NS Mercury	I	x	x	-	x
Fabiana F	I	x	x	x	x
NS Mercury + Fabiana F	?	x	x	x	x
Favorit	00	x	x	-	x
Ovidiu F	0	x	x	x	x
Favorit + Ovidiu F	?	x	x	x	x
STK 02	I.1	x	x	x	x
STK 01 + Ovidiu F	?	x	x	x	x
STK 03	I.3	x	x	-	x
STK 01	0.6	x	x	-	x

*irrigated

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The soybean varieties were sown on different dates: 27 April 2022 at NARDI Fundulea, 6 May 2022 at AGROTERRA Agigea, 9 May 2022 at ECOFRUCT and 19 July 2022 at ECOVIAL Ștefan cel Mare. Also, each variety were placed in 3 rows strips at the distance between rows of about 50 cm at NARDI Fundulea and ECOFRUCT and ECOVIAL Ștefan cel Mare and at 70 cm at AGROTERRA and sowed along the entire length of the plot and with different types of seed drills: HEGE for experimental plots at NARDI Fundulea, MATERMACC at ECOFRUCT and ECOVIAL Ștefan cel Mare and SFOGGIA at AGROTERRA Agigea.

Fig. 24. Sowing soybean at FTPs "NARDI Fundulea" and "ECOFRUCT Ştefan cel Mare.

According to organic journals 2021 - 2022, each soybean Demo have specific agricultural technology:

- NARDI Fundulea DEMO technology consisted of: chopping crop residue after previous crop (maize), especially weeds; land scarification with Knocke; fertilising with BIO-FER NATURE (375 kg/ha); discing 2 times and ploughing in autumn 2021 and seed-bed preparing by working of the land with Angeloni POKER 300 complex combination cultivator and other combination (2 times); inoculastion of seeds with POLIRIZ S - a mixture of 6 Bradirhizobium strains; sown on 27 April 2022; weeding - mechanically (1 time) and by hand (2 times) and harvesting mechanically in September 2022;
- ECOFRUCT technology consisted of: soil till with Tiger equipment; fertilisation with fermentated chicken manure (12 t/ha); seed-bed preparing with combination cultivator and sown with canola in autum 2021 but because rape establishment was compromised, soybean seedbed prepariion took place with a combination cultivator; inoculation of soybeen seeds with POLIRIZ S, a mixture of 6 Bradirhizobium strains and sowing on 9 May 2022; manually weeding (1 time); irrigation (4 times x 30 l/m^2), as well as mechanically harvesting in September 2022;

- ECOVIAL technology was specific of the second crop: seedbed preparing with the combination cultivator and sowing on 19 July 2022;
- AGROTERRA Agigea technology was specific for the organic soybean with conventional land cultivated previously with convențional maize full infested with *Xanthium strumarium*: seed-bed preparation with a combination cultivator; inoculation of soybean seeds with POLIRIZ S, a mixture of 6 Bradirhizobium strains and sowing on 5 May 2022; hand weeded (1 time), irrigation (3 times x 40 l/m^2), as well as harvesting mechanically in September 2022.

Fig. 25. Mechanical weeding of soybean at FPT "NARDI Fundulea"/26 May 2022.

During soybean seedling and growing seasons, all observations and measurements were made that are provided in FPT assessments 2022 of WP 6.2: monitoring Agriotes sp. with pheromone traps (Figure 25), estimation of the degree of weed infestation (%) and Pigeon attack at NARDI Fundulea, as well as Number of nodes sites per plant, Number of plants/m^2, Yield (dt/ha) and TGW (g) at harvest for all FPTs.

Fig. 26. Pheromone traps for Agrotes sp. at soybean FPT "NARDI Fundulea 2022.

3.4.2. Results

In this part it is presented and discussed the most important parameters for soybean growing in organic system in 2022, chronologically:

Dynamics of the infestation of *Agriotes* sp. in soybean at NARDI Fundulea 2022: This information is from ECOBREED soybean T4.1 and T4.2 which are in the same land with FPT Fundulea, but separated by a windbreak, and it is presented in bulletin because we observed many dry plants early for each variety because of the Agriotes sp. In this study *Agriotes obscurus* and *Agriotes ustulatus* monitoring started when we got traps on 20 June 2022 which was at least one, maybe two months late of when flying *Agriotes* sp. started and it stopped at the beginning of August. In ECOBREED Fundulea the *Agriotes obscurus* seems to be dominant and more abundant than *Agriotes ustulatus*, mainly in the first period of monitoring.

Table 49. Monitoring of Agriotes sp. at NARDI Fundulea FPT 2022.

Date	*Agriotes obscurus*	*Agriotes ustulatus*	Date	*Agriotes obscurus*	*Agriotes ustulatus*
20.06.2022	381	99	15.07.2022	4	19
24.06.2022	609	72	19.07.2022	12	45
27.06.2022	526	97	22.07.2022	31	23
30.06.2022	79	67	26.07.2022	4	17
04.07.2022	112	198	29.07.2022	12	12
07.07.2022	52	8	03.08.2022	1	7
12.07.2022	18	36			

Weed infestation in Romanian soybean FPTs in 2022: The crops infestation with weeds is another specific and serious problem in organic farming, weeds being the main competitor for soil water and nutrients, especially for soybean. In our FPTs, the weeds infestation of soybean in 2022 was specific for each FPT: at NARDI Fundulea with *Echinochloa cruss–galli* (ECHCG), *Setaria viridis* (SETVI) and *Ambrosia* sp. (AMBEL), at ECOFRUCT Ștefan cel Mare with *Chenopodium album* (CHEAL), *Amaranthus retroflexus* (AMRE) and *Datura stramonium* (DATST) and at ECOVIAL Ștefan cel Mare with *Raphanus raphanistrum* (RAPRA), *Amaranthus retroflexus* (AMARE) and *Chenopodium album* (CHEAL), and at AGROTERRA Agigea with *Sorghum halepense* (SORHA), *Setaria viridis* (SETVI) and *Xanthium strumarium* (XANTST). In these FPTs, we studied only the weeds within the soybean rows because these cannot be controlled by mechanical weeding (Fig. 27), with the STK 02 soybean variety at FPT Fundulea infested with weeds on row because of lowest density of seeds at sowing.

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Table 50. The spectrum of weeds on the row in 4 soy Romanian FPTs in 2022.

NARDI Fundulea (STK 02)		**ECOFRUCT Ștefan cel Mare**		**ECOVIAL Ștefan cel Mare**		**AGROTERRA Agigea**	
Weeds	%	Weeds	%	Weed	%	Weed	%
Echinochloa crus-galli	73,00	Chenopodium album	48,00	Raphanus raphanistrum	35,00	Sorghum halepense	60,00
Setaria viridis	23,00	Amaranthus retroflexus	47,00	Amaranthus retroflexus	33,00	Setaria viridis	38,00
Ambrosia sp.	4,00	Datura stramonium	5,00	Chenopodium album	32,00	Xanthium strumarium	2,00

Fig. 27. Soybean at FPT "NARDI Fundulea" – STK 02/ 4 July 2022.

Harvested soybean plant number in Romanian FPTs: The harvested soybean plant number in all Romanian FPTs in 2022 was less than the number of seeds sown i.e. 38.7 % at NARDI Fundulea, 44.2 % at ECOFRUCT Ștefan cel Mare and 40.9 % at AGROTERRA Agigea mostly due to a series of negative factors observed - e.g. attacks of wild pigeons at Fundulea, domestic pigeons at ECOFRUCT Ștefan cel Mare and of European hares at Agroterra Agigea.

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Table 51. Number of sobeany seeds sown and of harvested plants in Romanian FPTs.

Soybean variety	Agroecological Reseach, Innovation and Technical Assistance Center of NARDI Fundulea		ECOFRUCT* Ștefan cel Mare		AGROTERRA* Agigea	
	Sown seeds (m^2)	Harvested plants (m^2)	Sown seeds (m^2)	Harvested plants (m^2)	Sown seeds (m^2)	Harvested plants (m^2)
Mercury	56	28	56	31	41	28
Fabiana F	60	37	60	33	44	38
Mercury + Fabiana F	59	40	59	32	43	34
Favorit	45	28	45	25	33	20
Ovidiu F	54	28	54	20	39	18
Favorit + Ovidiu F	51	31	51	28	37	14
STK 02	41	32	41	26	30	8
STK 01 + Ovidiu F	44	22	44	27	32	12
STK 03	31	27	31	21	23	14
STK 01	27	14	27	18	20	16
Average	*47*	*27*	*47*	*26*	*34*	*20*

Effect of soybean inoculation in Romanian FPTs: According to Table 52, except for ECOFRUCT Ștefan cel Mare where the effect of inoculation was zero, in others FPTs, the inoculation was more (e.g. Fundulea FPT) or less (e.g. AGROTERRA Agigea) efficient, and the causes of these negative phenomena must searched in fertilisation system in the case of ECOFRUCT and in previous conventional technologies at AGROTERRA. Also, the number of node sites per plant seems to be specific for each variety.

Table 52: Number of node sites per plant at harvesting for soybean varieties in 3 Romanian FPTs.

Soybean variety	NARDI Fundulea	ECOFRUCT* Ștefan cel Mare	AGROTERRA* Agigea
Mercury	67	0	18
Fabiana F	73	0	17
Mercury + Fabiana F	68	0	27
Favorit	112	0	26
Ovidiu F	70	0	14
Favorit + Ovidiu F	78	0	15
STK 02	64	0	17
STK 01 + Ovidiu F	52	0	12
STK 03	40	0	11
STK 01	26	0	16
Average	**65**	**0**	**17**

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Soybean grain yield and TGW in 4 Romanian FPTs: In 2022, the soybean grain yield and thousand grain weight (TGW) are according to natural characteristics of DEMO sites, soybean varieties traits and DEMO technologies. So, the highest yields (2118 - 3654 kg/ha) and TGW (142.5 – 180.7 g) was recorded at ECOFRUCT Stefan cel Mare, under irrigation conditions and long standing organic farming practices, and the lowest yield and TGW, at NARDI Fundulea 455-792 kg/ha, and 71.6 – 105.5 g respectively at NARDI Fundulea, under non-irrigation conditions. Also, the yields and TGW at AGROTERRA Agigea would have been like ECOFRUCT, for the variety Mercury, if the soybean vegetation would not have been affected by conventional technology, except irrigation, and from an incredible attack of European hares.

These parameters were certainly influenced by the low sowing density of soybean plants, due, firstly to due to the small seeds quantity which increased distance between seeds at >5 cm and, mainly from the loss of many plants by mechanical weeding especially with rotary hoe at ECOFRUCT, the strong attack of pigeons during the germination phase at NARDI Fundulea, and of soybean sowing on conventional land at AGROTERRA Agigea, as well as the ECOVIAL decision to abolish soybeans second crop area (23 ha) because of weak and uneven emergence of soybeans plants and of the infestation with a large number of broadleaf weeds (AMARE, CHEAL, RAPRA).

Table 53. Grain yield (t/ha) and TGW (g) from 4 FPT sites presented at 11% moisture content.

Soybean variety	Maturity Group (MG)	Agroecological Reseach, Innovation and Technical Assistance Center Fundulea		ECOFRUCT* Ștefan cel Mare		AGROTERRA* Agigea		ECOVIAL* Ștefan cel Mare	
		Yield *(dt/ha)*	TGW *(g)*	Yield *(dt/ha)*	TGW *(g)*	Yield *(dt/ha)*	TGW *(g)*	Yield *(dt/ha)*	TGW *(g)*
Mercury	I	7.52	105.5	32.48	168.6	23.61	150.7	-	
Fabiana F	I	4.85	90.8	30.66	144.5	1.07^{xxx}	136.2	0.00^{xx}	0.00
Mercury + Fabiana F	?	4.55	91.4	28.63	144.8	0.00^{xxx}		0.00^{xx}	0.00
Favorit	00	7.92	98.7	21.18	145.8	0.00^{xxx}		-	-
Ovidiu F	0	6.97	97.0	33.67	170.6	1.48^{xxx}	169.0	0.00^{xx}	0.00
Favorit + Ovidiu F	?	6.55	96.8	28.57	142.5	0.00^{xxx}		0.00^{xx}	0.00
STK 02	I.1	0	71.6	34.9	143.1	0.00^{xxx}		0.00^{xx}	0.00
STK 01 + Ovidiu F	?	5.98	95.3	36.54	147.2	0.00^{xxx}		0.00^{xx}	0.00
STK 03	I.3	6.23	93.1	30.45	180.7	0.00^{xxx}			
STK 01	0.6	7.07	96.4	31.8	179.1	0.00^{xxx}			
Average		*5.76*							

x - irrigated; xx – infestation with AMRE, CHEAL and RAPRA; xxx - European hare attack

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3.4.3. Conclusions

1. Agriculture year 2021 – 2022 was the second warmest and alone the driest of the last 60 years for Romania.
2. The agriculture technologies, except for soybean varieties, are specific for each FPT, depending on equipment available, soil characteristics and experience in organic farming.
3. The soybean tested varieties belong to three genetic groups - Serbian (Favorit and NS Mercury), Romanian (Ovidiu F and Fabiana F) and USD (STK 01, STK 02 and STK 03). Also, in all FPT the effect of 3 soybean variety mixtures: Mercury + Fabiana F; Favorit + Ovidiu F and STK 01 + Ovidiu F was studied.
4. Soybean inoculation with mixture of *Bradyrhizobium strains* is very efficient, but high levels of mineral or organic fertilisation reduced this efficiency.
5. The sowing density must be about 40 % higher than in conventional agriculture for avoiding infestation with weeds within the rows and to cover plant losses during and after emergence.
6. The weeds are the main competitor of soybean for water.
7. The dominant weeds in Romanian FPTswere: ECHCG, SETVI and AMBEL at NARDI Fundulea, CHEAL, AMARE and DATST at ECOFRUCT and RAPRA, AMARE and CHEAL in soy as second crop at ECOVIAL Ștefan cel Mare, as well as SORHA, SETVI and XANTST at AGROTERRA Agigea.
8. In Romanian FPTs, soybean has many other enemies from sowing to harvesting – wild and domestic pigeons, European hare, *Agriotes* sp., *Tetranychus urticae*, *Etiella zinckenella, Septoria glycinea* etc.
9. The soybean yield and TGw was related to the genetic potential of the variety and soil water supply during vegetation period.
10. The mixture of soybean varieties seems to be efficient only for mixtures with good affinity between varieties (e.g. STK 01 + Ovidiu F).

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4. Potato

4.1. Potato farmer participatory trials in Slovenia

4.1.1. Methods: Locations and conditions of trials

In 2022 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). Altitude of these farms (experimental locations) is between 262 m and 520 m (cf. Fig. 28).

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

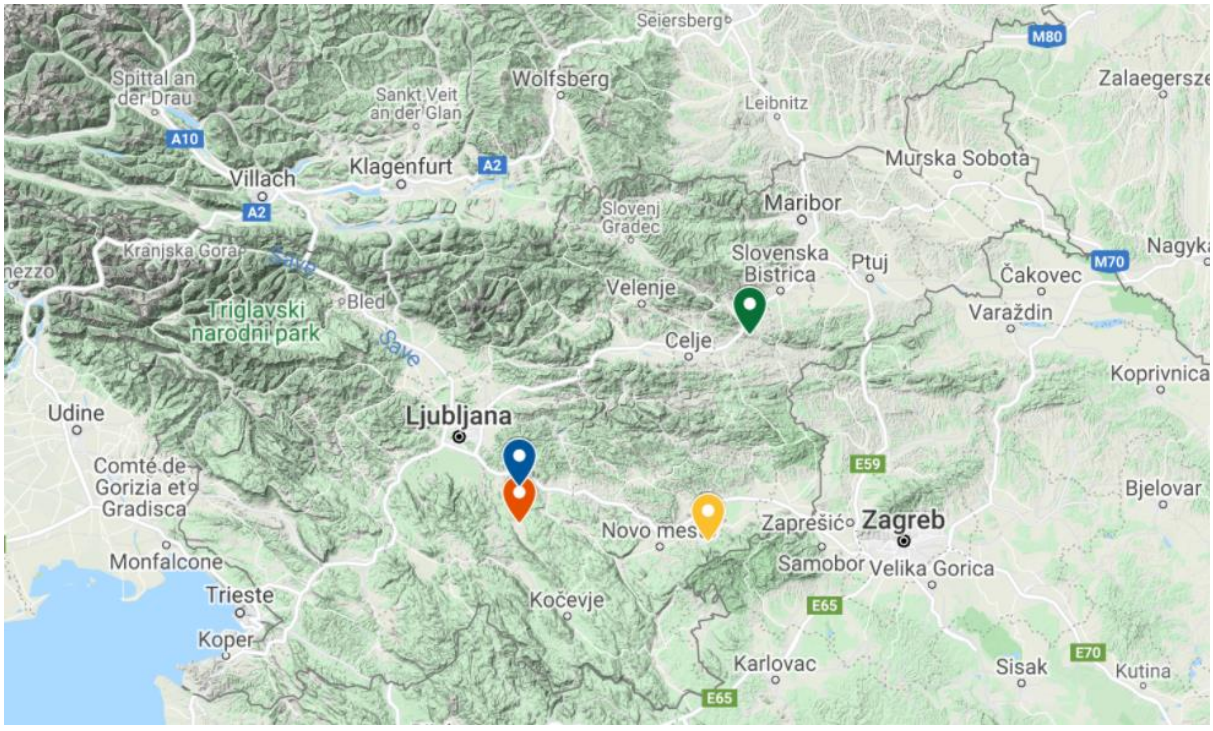

Fig. 28: Locations of potato trials and main characteristics.

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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, market utilisation, skin and flesh colour and other characteristics (cf. Table 54).

Table 54: Varieties of potatoes and properties.

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

A panel of criteria was established by researcher and farmers/consultants to compare varieties in different locations with different farm 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 etc.

Planting density varied between 4.7 and 5.7 plant per m^2. The planting period was done between 24 March and 18 April with a semi-automatic planter.

The fertilisation, weed management and pest management were made by farmer according to organic farming standards/practices.

The year 2022 was very difficult for potato growers across Slovenia. It was very dry in the central and northern part, but in Dolenjska and Štajerska region fields got some more rain with dry periods between. At Šentjernej and Videm Dobrepolje there were also one event with hail.

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4.1.2. Results

Yield and state of crop

The conditions of 2022 were favourable for health status of potato plants and yield. There was no late blight infection noticed in all 4 locations. Plots were also not damaged by pests. Early blight was observed at 4 farms on the variety OTOLIA, 2 on LEVANTE and one on the variety TWINNER.

Colorado beetle was present in all locations, but only in Ponikva caused some damage. The farms were spraying (1 or 2 times) with organic insecticide LASER PLUS and they managed to hand pick/remove 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 30 cm and 80 cm. Variety LEVANTE in Ponikva was by far the tallest. It was one time taller than in Videm Dobrepolje. DELILA and TWINNER had the lowest plant height on average across three locations (cf. Fig. 29).

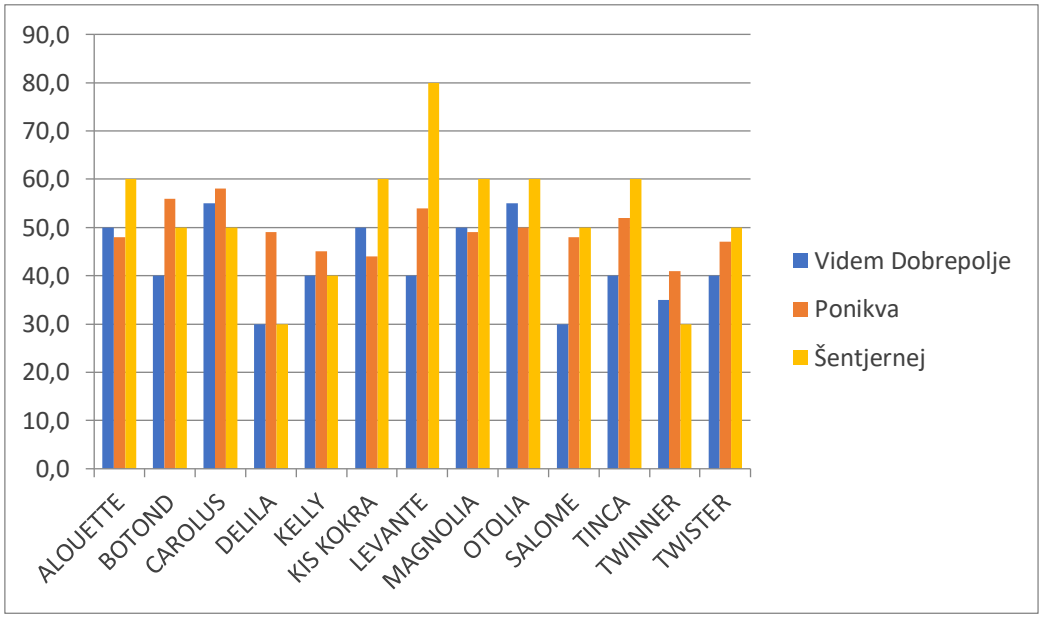

Fig. 29: Plant Height (cm) for potato varieties at 3 locations in Slovenia.

The biggest average yield was achieved in Videm Dobrepolje, followed by Šentjernej, Grosuplje and Ponikva. 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 marked in red. LEVANTE yield was always above yield on 4 locations between (38 and 76 %). KIS KOKRA, MAGNOLIA, LEVANTE and TWISTER

had yield above 40 t/ha. DELILA yields were by far the lowest in Ponikva nd Šentjernej (cf. Table 55).

Table 55: Comparison of variety yields (t/ha) for each location.

Harvested yield (t/ha)	Videm Dobrepolje	Ponikva	Grosuplje	Šentjernej
ALOUETTE	26.3	19.9	29.2	34.0
BOTOND	35.5	26.7	30.1	36.4
CAROLUS	25.9	17.2	19.8	22.4
DELILA	37.0	9.8	29.6	6.8
KELLY	26.2	11.6	25.5	25.5
KIS KOKRA	27.9	26.7	31.1	40.1
LEVANTE	44.8	22.5	33.5	40.2
MAGNOLIA	46.8	21.1	20.6	38.3
OTOLIA	37.2	19.3	24.0	36.2
SALOME	33.9	17.5	16.3	28.6
TINCA	38.4	20.8	14.2	28.8
TWINNER	28.7	17.8	8.8	24.7
TWISTER	37.3	30.9	15.0	44.8
Average	**34.3**	**20.1**	**22.9**	**31.3**

The numbers of tubers per plant in 4 locations was between 2.5 and 12. Some varieties had the highest number of tubers in Videm Dobrepolje and Šentjernej, while the others in Grosuplje. Varieties with the highest tuber numbers were LEVANTE, SALOME and TWISTER. DELILA had the lowest number of tubers per plant in Ponikva and Šentjernej (cf. Fig. 30).

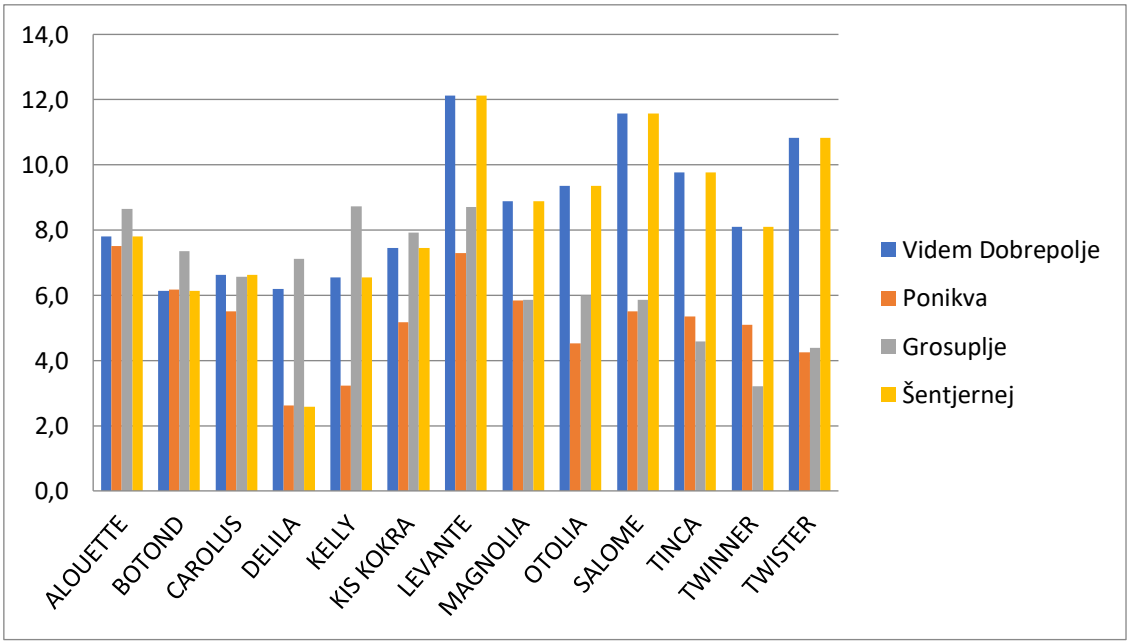

Fig. 30: Number of tubers per plant for each variety in 4 locations.

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The tuber size was determined (weighed and counted) on square mesh of sizes <25 mm, 25-45 mm, 45-65 mm, >65 mm. It ranged from nearly 40 grams to over 160 grams, depending on variety and location. TWISTER had the biggest tubers followed by KIS KOKRA in Ponikva. BOTOND, DELILA and MAGNOLIA were the 3 varieties with the biggest tubers in Videm Dobrepolje (cf. Fig. 31).

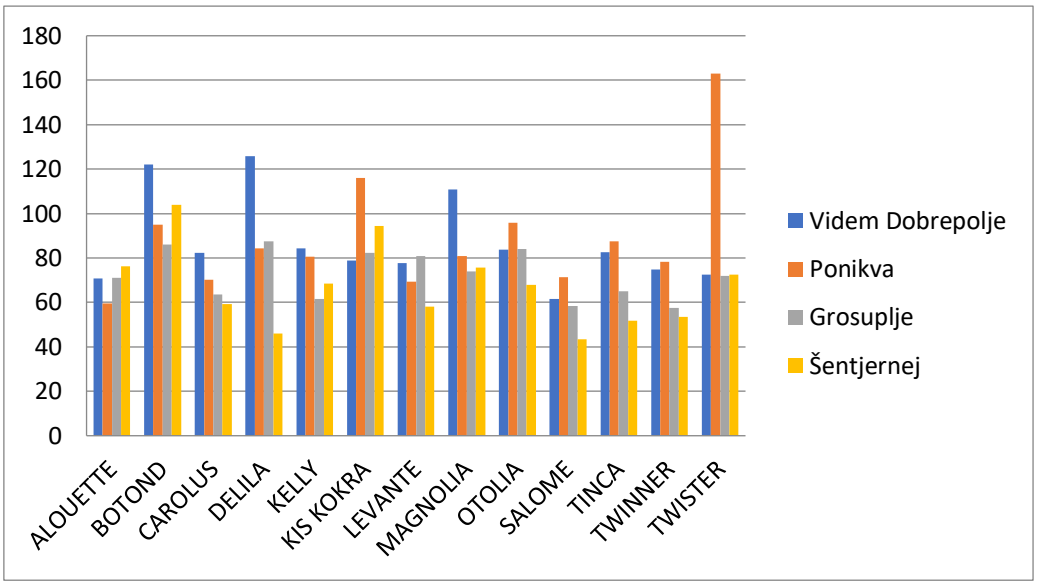

Fig. 31: Average tuber size (g) for each variety in 4 locations.

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 4 locations 26 and 25% respectively), which is way above optimal dry matter for canning (around 20 %). Despite Twister having the lowest percentage of dry matter (the average for 4 locations was 19%), it still reached optimal values (Fig. 32).

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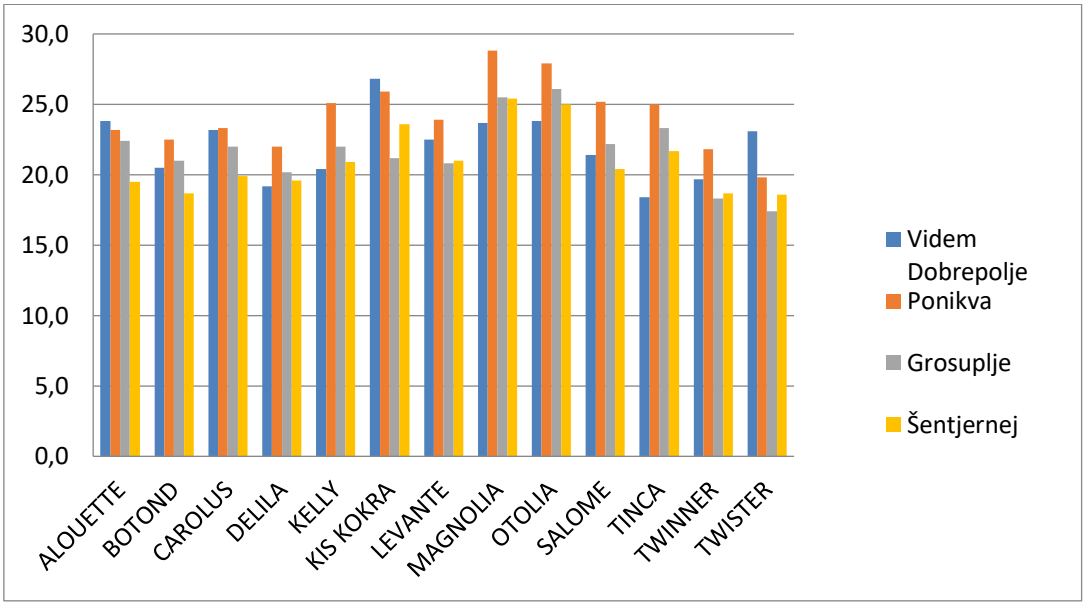

Fig. 32: Dry matter (%) for each variety in 4 locations.

Visual, organoleptic and chemical properties

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 for minor discoloration of KIS Kokra and Botond in Grosuplje. Only for some varieties was disintegration noticed with the highest values in Videm Dobrepolje.

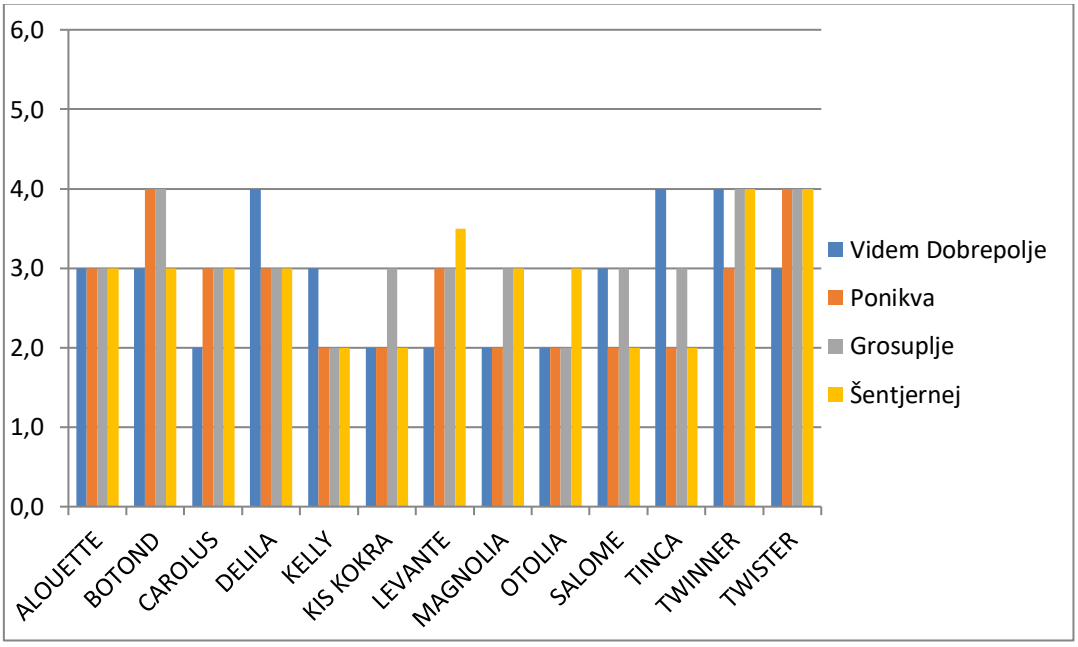

Fig. 33: Tuber taste for each variety in 4 locations (1 excellent, 2 very good, 3 good, 4 acceptable, 5 worse, 6 unsuitable).

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Most of the varieties in all 4 locations had at least good taste, which is very good result in such weather conditions (Fig. 33). BOTOND, TWINNER and TWISTER had only acceptable taste in more than one location. There were also very little other tastes, one very strong was in Ponikva for 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 4 locations. KELLY obtained the score of ˝2˝ at 2 locations. The worst general impression (5) had DELILA in Videm Dobrepolje. BOTOND, TWINNER and TWISTER scored 4 on 3 locations (cf. Fig. 34).

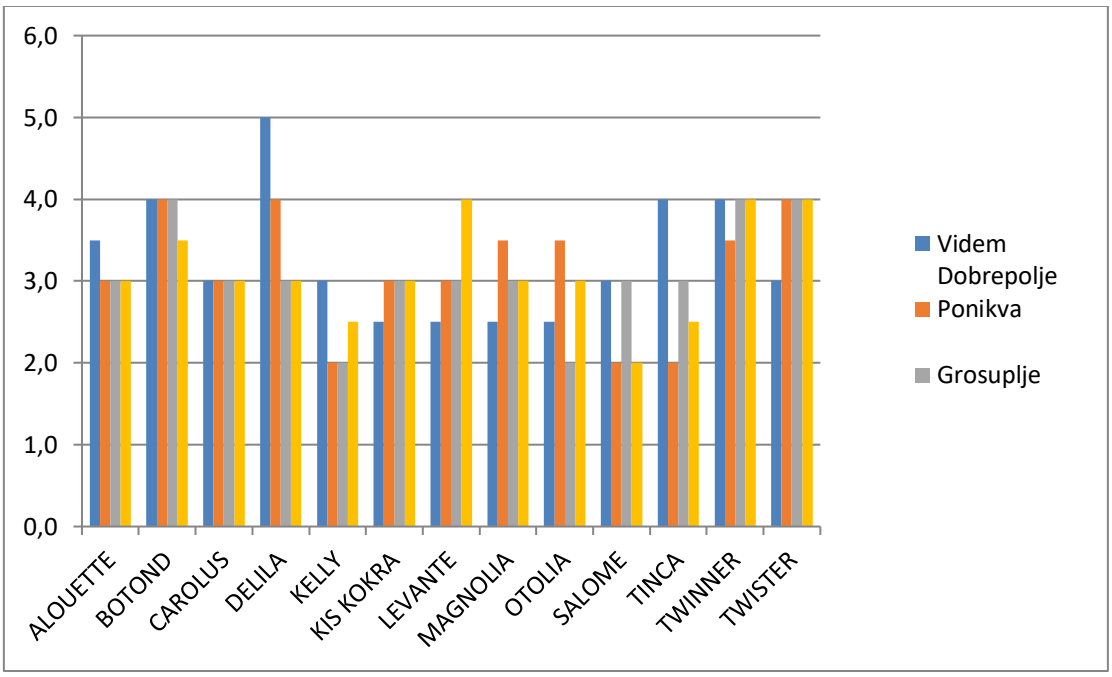

Fig. 34: General impression for each variety in 4 locations (1 excellent, 10 unsuitable).

The cooking types were also evaluated using four grade scale (A firm flesh - salads, B multi-purpose uses, C mealy, D floury) (Table 56). They can be also intermediate types of AB, BC etc. Among consumers salad type A is preferable since potato doesn't disintegrate. Type B is the most usable multi-purpose, 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 correlate with higher dry matter content. Due to rather high dry matter, only MAGNOLIA scored A in Videm Dobrepolje. Some varieties were very stable regarding cooking type B (BOTOND, CAROLUS, DELILA, TWISTER and TWINNER), while some other varieties ranged from A to BC (MAGNOLIA), depending on location and growing conditions.

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Table 56: Cooking type for each variety samples at 4 locations.

Cooking type	Videm Dobrepolje	Ponikva	Grosuplje	Šentjernej
ALOUETTE	BC	B	AB	B
BOTOND	B	B	B	B
CAROLUS	B	B	B	B
DELILA	B	B	B	B
KELLY	B	B	AB	B
KIS KOKRA	BC	B	B	BC
LEVANTE	B	B	B	BC
MAGNOLIA	A	BC	B	BC
OTOLIA	BC	BC	AB	BC
SALOME	B	AB	B	B
TINCA	B	AB	B	AB
TWINNER	B	B	B	B
TWISTER	B	B	B	B

4.2. Potato farmer participatory trials and breeding in Poland

In 2022 eleven cultivars (Alouette, Carolus, Otolia, Twister, Twinner, Levante, Kokra, Tinca, Bzura, Gardena, Sarpo Mira) were planted in the field trial located in Central (Jadwisin and Grabów) and Southeastern part of Poland (Tuligłowy and Połomia) (Figure 35). Each cultivar was planted in 10 hill plots and with 3 replicates.

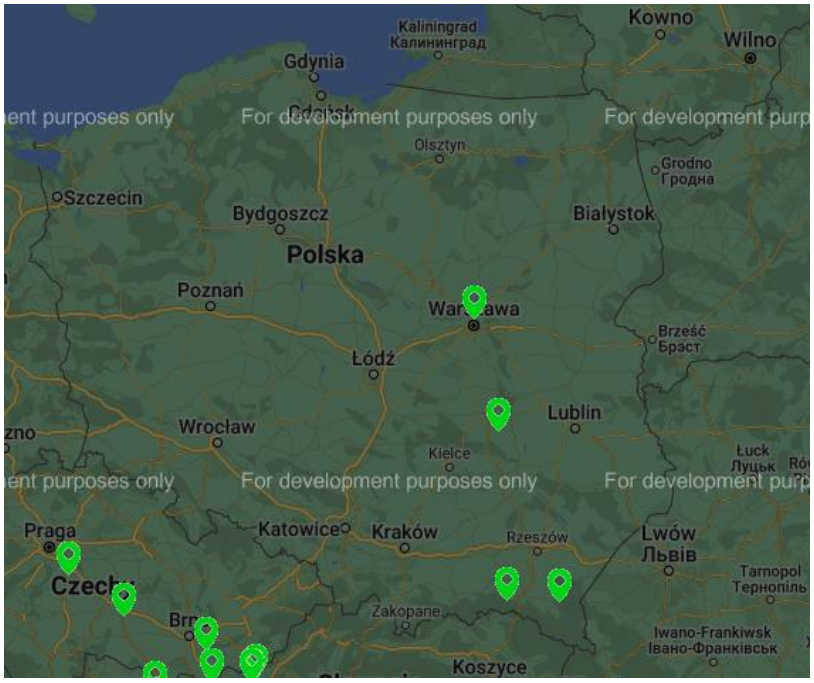

Figure 35: Location map of the four farms in Poland.

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Fig 36: Experimental field in Grabów (PL 2022).

Fig. 37: Harvested in Grabów (PL 2002).

Fig. 38: Experimental field in Jadwisin (PL 2022).

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4.2.1. Results

Systematically potato cultivars are evaluated for a set of phenotypic traits during the growing season and after harvest. After harvest the following traits were evaluated: total yield (kg/bush), tuber shape, depth of eyes, regularity of tuber shape, tuber size, % starch, discoloration of cooked tubers 10 min and 24h after cooking, discoloration of potato flesh in raw state after4 h after cutting and utilisation types. In Fig. 39 is presented total yield (kg/bush) obtained from each cultivar in four localisations. Mean value ranges from 0.5 kg/bush for cvs Twinner and Tinca to 0.9 kg/bush for cvs Alouette, Levante, Otolia, and Sarpo Mira. Out of 11 cultivars evaluated in 2022 eight obtained the highest yield in Tuligłowy (Fig. 39). Looking at farm average the highest yield per bush in 2022 was recorded in Tuligłowy (1.1 kg/bush). The lowest was recorded in Jadwisin (0.6 kg/bush) (Fig. 40).

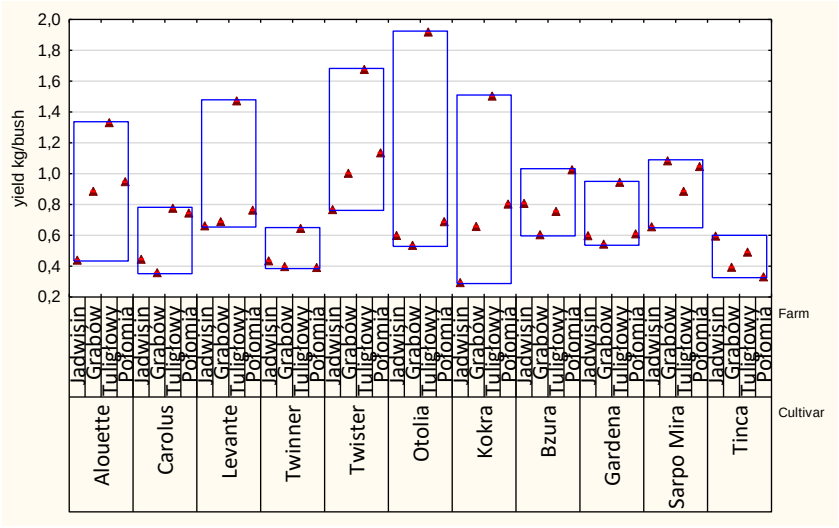

Fig. 39: Total yield (kg/bush) for 11 cultivars in four farms (PL 2022).

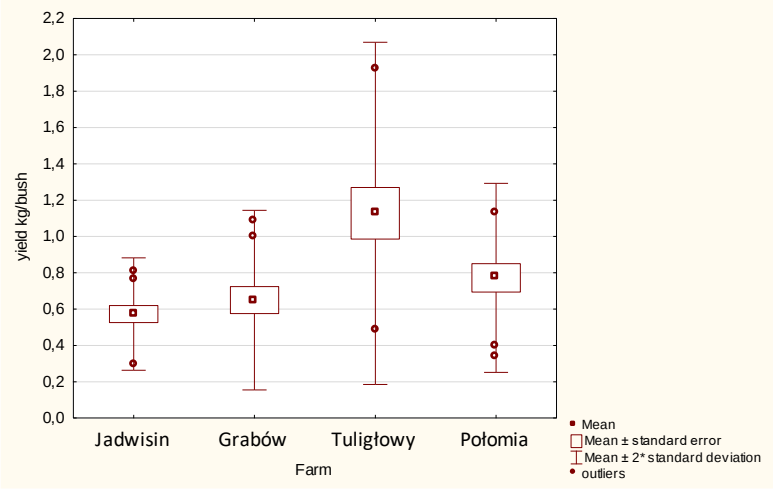

Fig. 40: Mean values for total yield (kg/bush) in four farms (PL 2022).

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Fig. 41: Description of organic experiment in Połomia (PL 2022).

Fig. 42: Description of organic experiment in Tuligłowy (PL 2022).

All potatoes cultivars were placed in store, weighed and graded into 3 categories: >65 mm, 65-45 mm, and <45 mm. In Fig. 40 are shown medians and ranges (min-max) for total tuber yield (kg/bush) in individual 3 categories. For all cultivars in all farms was observed the highest percentage of big size tubers (> 65 mm) (Fig. 43).

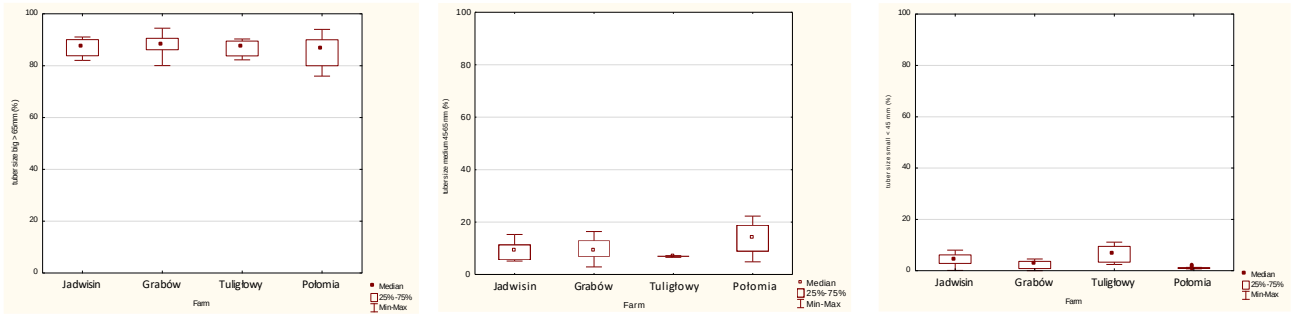

Fig. 43: Tuber size in three categories for 11 cultivars harvested in four farms (PL 2022).

In Fig. 44 are presented morphological traits of potato tubers (eyes and regularity of tuber shape) for 11 cultivars evaluated in 4 experiments. Values for eyes and regularity for tuber shape ranged from 4.0 to 8.0. The greatest variability was observed for Bzura and Sarpo Mira (Fig. 44).

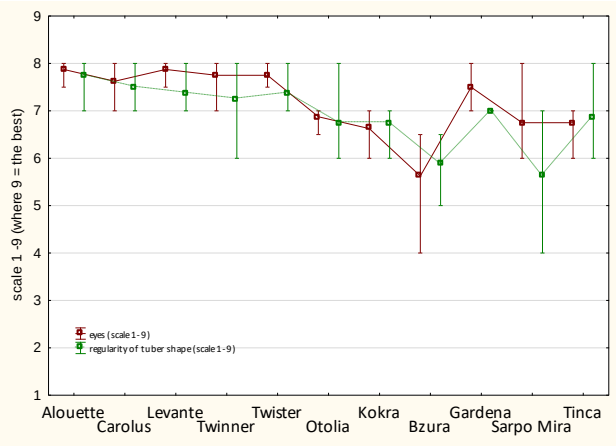

Fig. 44. Eyes and regularity of tuber shape for 11 cultivars in four farms (PL 2022). On the figure is present mean values for each cultivar from four farms and values of minimum and maximum.

In 2022 cooking quality (discoloration of tuber flesh, taste and cooking types) for 11 cultivars were assessed. Mean values for cooking quality for all cultivars in four experiments are presented in Tables 57-59. In Figs. 45 and 48 some examples of texture and darkening of raw tubers are presented. All tested cultivars were characterised by good taste and non-darkening of flesh tubers, regardless of the farm. You can see that tuber cultivars from Połomia darkened less then tubers from other farms (Table 57). This was observed on raw and cooked tubers (Table 57 and 58).

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Table 57: Discoloration of cooked tubers 10 min and 24h after cooking for 11 cultivars in four farms (PL 2022).

Cultivar	Discoloration of cooked tubers 10 min. and 24 h after cooking (scale 1-9)							
	Połomia		Grabów		Jadwisin		Tuligłowy	
	10 min.	24h	10 min.	24h	10 min.	24h	10 min.	24h
Alouette	9.0	8.5	8.0	7.5	8.0	7.8	8.5	7.7
Carolus	8.5	8.2	7.5	7.0	8.0	8.0	8.0	7.7
Levante	9.0	8.7	8.0	7.5	8.5	8.2	9.0	8.5
Twinner	8.5	8.2	7.5	7.5	8.0	8.0	8.0	7.4
Twister	8.0	7.5	7.0	5.9	8.5	8.2	8.0	8.0
Otolia	9.0	8.2	7.5	6.7	8.5	7.9	8.0	7.4
Kokra	7.0	6.7	7.0	6.3	7.0	6.7	7.0	6.0
Bzura	7.5	7.4	7.0	6.1	7.5	7.5	7.5	6.6
Gardena	8.0	7.6	8.0	7.4	8.0	8.0	7.5	7.3
Sarpo Mira	7.5	7.5	7.0	5.5	6.5	6.3	7.0	6.0
Tinca	8.0	7.9	7.5	7.8	8.0	7.5	8.2	7.1

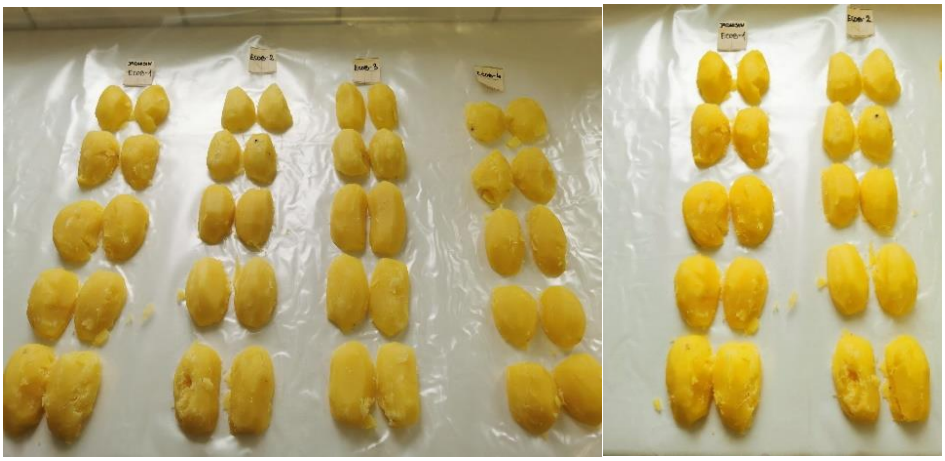

Fig. 45: Discoloration of cooked tubers 10 minutes (left) and 24 hours (right) after cooking (PL 2022).

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Table 58: Discoloration of potato flesh in raw state 4h after cutting for 11 cultivars in four farms (PL 2022).

Cultivar	Discoloration of potato flesh in raw state 4 h after cutting (scale 1-9)				
	Połomia	Grabów	Jadwisin	Tuligłowy	Mean
Alouette	9.0	7.0	7.0	9.0	8.0
Carolus	9.0	6.6	7.6	8.4	7.9
Levante	8.0	6.5	7.0	8.0	7.4
Twinner	8.5	6.5	7.2	7.7	7.5
Twister	8.0	6.5	7.4	7.5	7.4
Otolia	7.8	6.0	7.6	7.6	7.3
Kokra	8.0	6.5	6.4	7.5	7.1
Bzura	7.6	7.0	6.6	6.9	7.0
Gardena	8.5	7.6	7.4	7.8	7.8
Sarpo Mira	7.5	7.0	6.0	7.3	7.0
Tinca	7.4	6.5	7.0	7.4	7.1
Mean	***8.1***	***6.7***	***7.0***	***7.7***	***7.4***

Some cultivars were very stable regarding cooking type (BC) Alouette, Kokra, Gardena and Sarpo Mira while some other cultivars ranged from B, C, BC and CD depending on the growing farms (Table 59).

Table 59: Cooking types for 11 cultivars in four farms (PL 2022).

Cultivar	Cooking types			
	Połomia	Grabów	Jadwisin	Tuligłowy
Alouette	BC	BC	BC	BC
Carolus	BC	AB	AB	B
Levante	BC	BC	AB	BC
Twinner	AB	B	AB/C	BC
Twister	BC	C	B	BC
Otolia	BC	BC	AB	BC
Kokra	BC	BC	BC	BC
Bzura	CD	BC	CD	CD
Gardena	BC	BC	BC	BC
Sarpo Mira	BC	BC	BC	BC
Tinca	BC	B	B	BC

In Fig. 46 are presented taste for 11 cultivars cultivated in 4 localisations. The taste was dependent on the place of cultivation. The best taste was from cultivars cultivated in Tuligłowy and Połomia (Fig. 47). In all locations the tastiest cultivar was Gardena and Tinca. For these cultivars in all locations taste was very similar. The environment did not modify their taste.

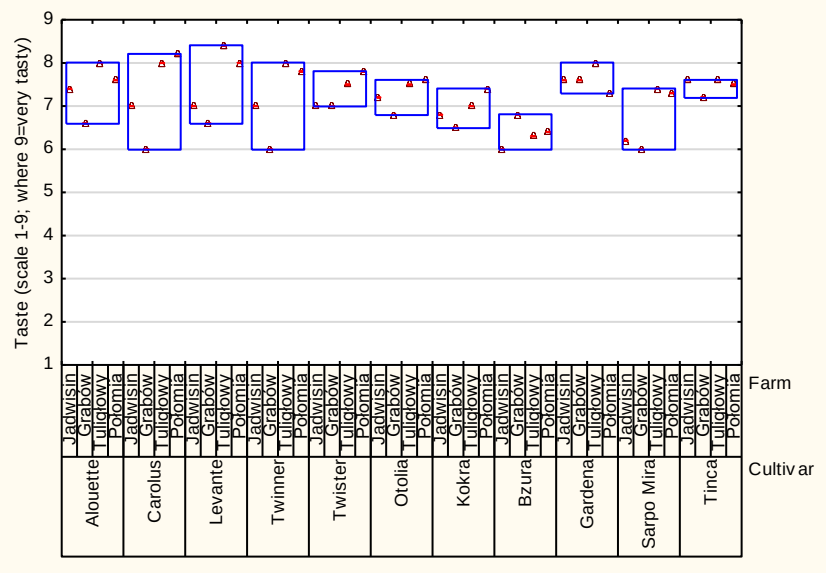

Fig. 46: Taste for 11 cultivars in four farms (PL 2022).

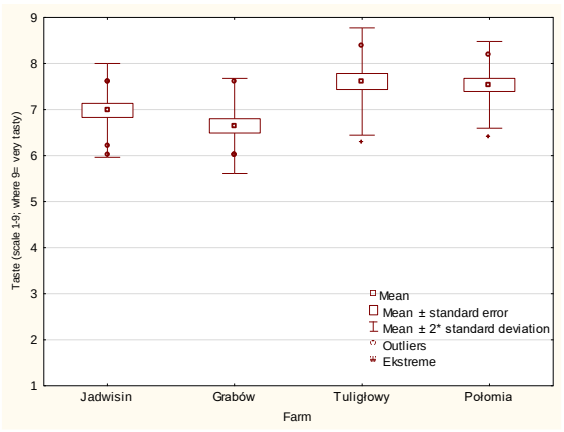

Fig. 47: Taste for 11 cultivars in 4 farms (PL 2022).

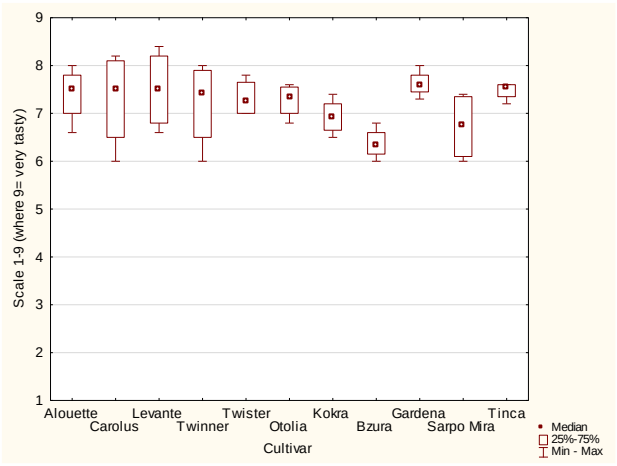

Fig. 48: Discoloration of potato flesh in raw state after 4 h after cutting in Połomia and Tuligłowy (PL 2022).

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In Fig. 49 are shown starch content (%) for 11 cultivars cultivated in 4 farms. The highest content of starch was noted for cvs. Bzura (21.5%) and Sarpo Mira (16.9%). The starch content was dependent on the place of cultivation. This can be seen in Fig. 50.

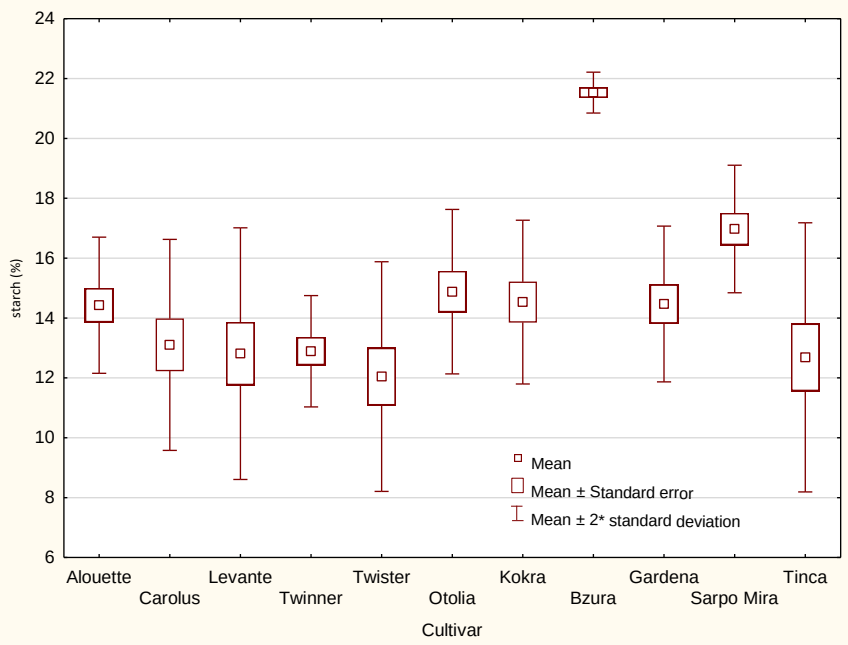

Fig. 49: Starch content (%) for 11 cultivars (PL 2022).

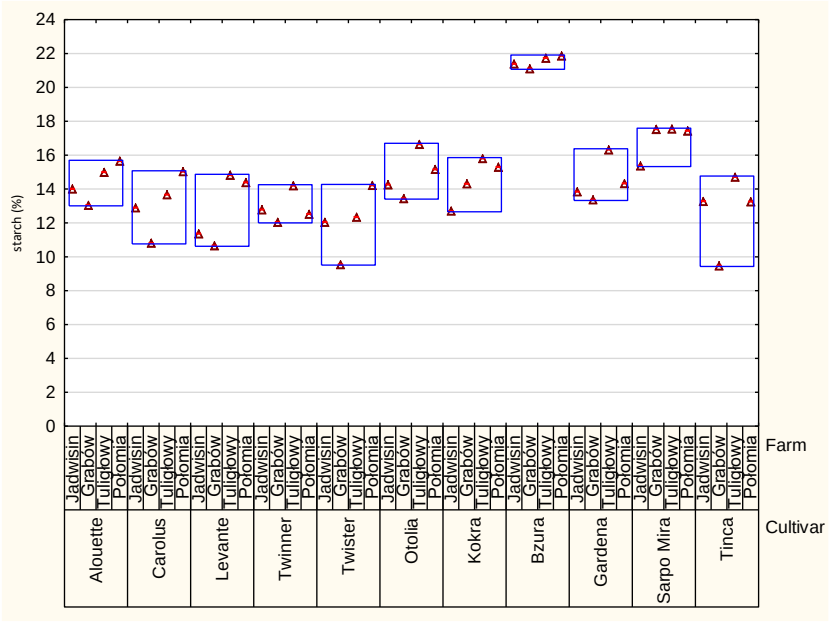

Fig. 50: Starch content (%) for 11 cultivars evaluated in 4 farms (PL 2022).

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4.2.2. TASK 6.3 Participatory Plant Breeding in 2022

In 2022, 15 breeding lines resistant to *P. infestans* were planted in 3 locations (Tuligłowy, Połomia and Jadwisin). During the vegetation period breeding lines were systematically evaluated for a set of phenotypic traits, which were specified in the report. In September the materials were harvested. After harvesting breeding lines were described according to the traits: total yield (kg/bush), tuber shape, depth of eyes, regularity of tuber shape and % starch. In Table 60 is presented total yield (kg/bush) obtained from each breeding line in Tuligłowy, Połomia and Jadwisin (PL 2022). In 2022 the highest mean tuber yield (kg/bush) for breeding lines was noted in Tuligłowy (0.9 kg/bush). In 2022 11 breeding lines were tested for the late blight resistance in laboratory test (detached leaflets test). Six leaflets (three in two replications) were collected from each cultivar grown in the field trial and were inoculated with a 30 ml droplet of sporangia/zoospore suspension (50 sporangia/µl). The infection was scored after 6 days of incubation, using 1 – 9 scale, where 9 means the highest resistance. For this breeding lines the level of resistance ranges from 6.4 (21-IX-5) to 8.8 (21-IX-17) (Table 60).

Table 60: Total yield (kg/bush) for 15 breeding lines at three farms (Poland 2022).

Breeding line	*P. infestans* (leaves)	Total yield (kg/bush)		
		Tuligłowy	Połomia	Jadwisin
21-IX-2	7.7	0.9	1.3	0.7
21-IX-3	8.0	1.1	1.0	0.7
21-IX-4	7.2	0.9	0.7	0.6
21-IX-5	6.4	1.1	0.5	0.5
21-IX-6	8.2	1.1	1.0	0.9
21-IX-8	7.8	1.0	1.2	0.7
21-IX-9	8.0	0.7	0.6	0.7
21-IX-10	8.5	0.4	0.2	0.3
21-IX-11	8.7	0.6	0.3	0.3
21-IX-12	8.0	1.1	1.1	0.7
21-IX-13	7.1	1.1	1.0	0,7
21-IX-14	7.6	0.6	0.3	0,2
21-IX-15	8.1	0.8	0.8	0,6
21-IX-17	8.8	0.9	0.6	0,7
21-IX-18	7.7	0.7	0.7	0,5
Mean	**7.9**	**0.9**	**0.8**	**0.6**

All potato breeding lines were placed in store, weighed and graded into 3 categories: >65 mm, 65-45 mm, and <45 mm. In Fig. 51 are shown the medians and ranges (min-max) for total tuber yield (kg/bush) in individual 3 categories. For all breeding lines in all farms the highest percentage of big size tubers (> 65 mm) was observed (Fig. 51).

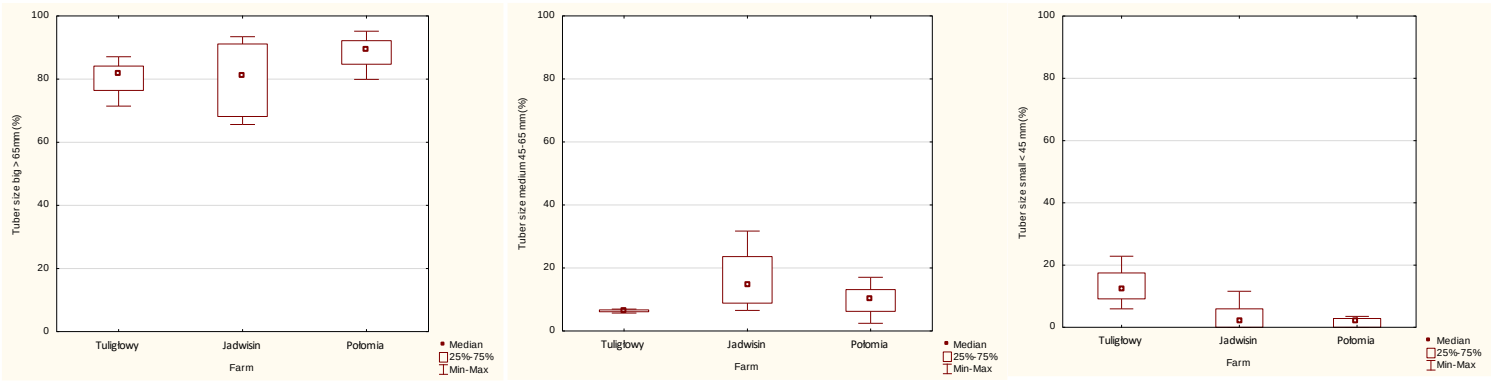

Fig. 51: Tuber size in three categories for 15 breeding lines harvested in three farms (PL 2022).

4.3. Potato farmer participatory trials in Hungary

4.3.1. Methods: Locations and conditions of trials

In 2022 the farmer participatory trials program within the ECOBREED project was conducted on three organic farms (Rábcakapi, Zalavár, Szakály) which are located in 3 different counties (Vas county, Zala county, Győr-Moson-Sopron county). The altitude of these farms (experimental locations) is between 115 m and 200 m (Fig. 52).

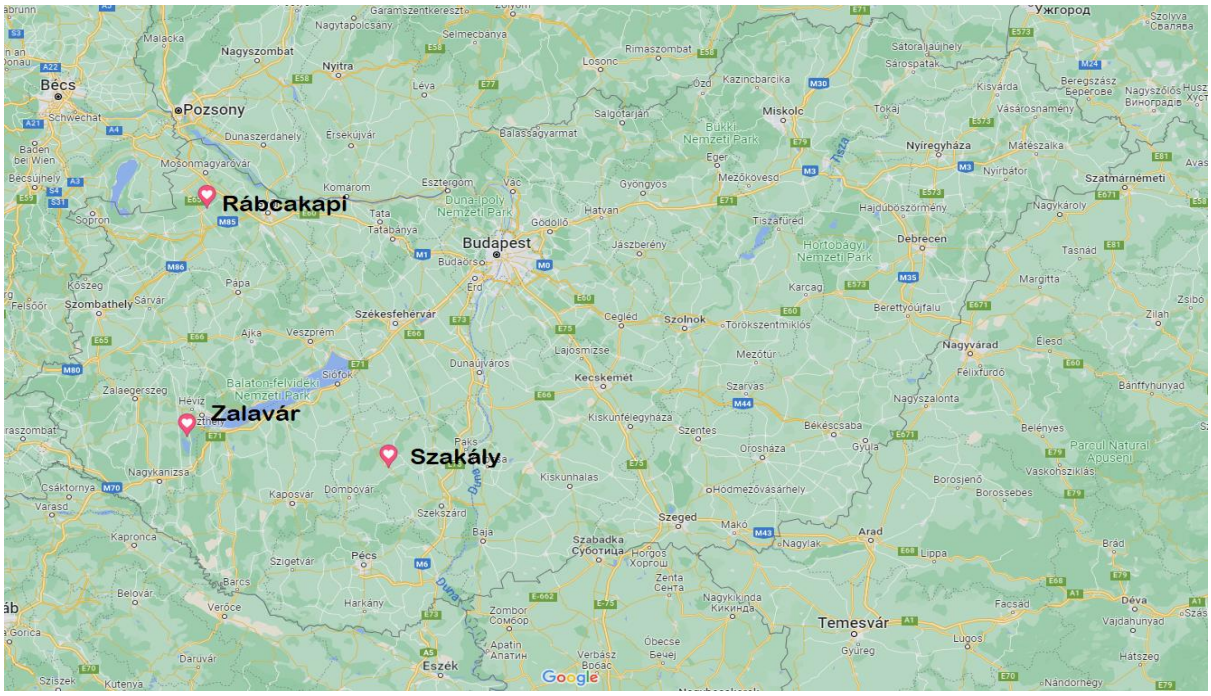

Fig. 52: Locations of potato trials.

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Conditions of the trial: The selection of 12 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, utilisation, skin and flesh colour and other characteristics (Table 61).

Table 61: List of varieties.

Variety	Maturity	Resistance to late blight
Alouette	intermediate	yes
Carolus	intermediate	yes
Kis Kokra	intermediate	yes
Levante	intermediate	yes
Otolia	intermediate	yes
Tinca	intermediate	yes
Twinner	early	yes
Twister	early	yes
Balatoni Rózsa	early	no
Balatoni Sárga	intermediate	no
Botond	early	no
Basa	intermediate	no

A panel of criteria was established by researcher and farmers/consultants to compare varieties at 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, Silver scurf and Fusarium symptoms, Colorado potato beetle damage, yield, tuber size, dry matter, starch content, cooking type, taste discoloration of flesh after cooking, tuber disorders, regularity of tuber shape, depth of eyes.

The planting period was done between the 13-18th of April and by hand.

The fertilization, weed management and pest management were made by farmer according to their organic farming standards/protocol.

In Hungary in 2020 and 2021, there was less precipitation than the long-term average. In 2022 this tendency continued with around 45% less precipitation than the long-term average. From the beginning of the summer, a high degree of drought was characteristic, which reached its peak in mid-August. Several times, temperatures above 35 degrees Celsius were also measured.

The arable lands of Zalavár have unfavourable water management, which is a disadvantage from the point of view of agricultural use. The farmer could not solve the problem by watering. Szakály's arable land is predominantly of good quality, the farmer

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had the opportunity to make up for the lack of rainfall with irrigation. Rábcakapi is a zone of arable land with good local conditions. The area is better due to air humidity and always abundant groundwater reserves, it never suffers from such an intensive drought damage, like Zalavár.

4.3.2. Results

Yield and state of crop

The dry conditions of 2022 were unfavourable for yield, tuber size and quality too. Colorado potato beetle was present at all locations. It was managed by 1-2 times spraying with organic insecticide LASER PLUS. Weed was present especially during the third decade of vegetation but not noticed as a significant 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.

In the 3 locations the range of yield was different, but we can see that KIS KOKRA appeared 2 times in the top of yield. Yields of varieties are presented in Table 62 for each location. Yields, which were 30 % above average of all varieties per location, are marked in green. Yields, which were 30 % below average, are in brown. ALOUETTE, KIS KOKRA, LEVANTE, BALATONI RÓZSA, BALATONI SÁRGA, BOTOND, BASA had good yield above or near average in all places. Twinner yields were below the average of all varieties on all 3 locations (able 62).

Table 62: Comparison of yields for each location (t/ha).

Variety	Zalavár	Szakály	Rábcakapi	Average
Alouette	11.47	14.21	38.54	**21.41**
Carolus	13.82	9.59	19.80	**14.40**
Kis Kokra	37.15	36.90	17.05	**30.37**
Levante	19.52	11.01	18.51	**16.35**
Otolia	14.85	22.60	13.32	**16.92**
Tinca	10.48	12.34	17.00	**13.27**
Twinner	11.40	18.65	20.07	**16.71**
Twister	7.57	9.06	13.14	**9.92**
B.Rózsa	13.00	33.74	30.59	**25.78**
B.Sárga	16.89	21.81	48.26	**28.99**
Botond	9.09	22.07	32.28	**21.15**
Basa	6.59	13.50	40.23	**20.11**
Average	**14.32**	**18.79**	**25.73**	**19.61**

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The ranges of plant height according to varieties were not the same between locations. The plant height was between 40 cm and 70 cm. Varieties CAROLUS, OTOLIA, and TWINNER were the tallest varieties with average height of about 70 and 65 cm. Tinca had the lowest plant height with an average of about 43 cm (Fig. 53).

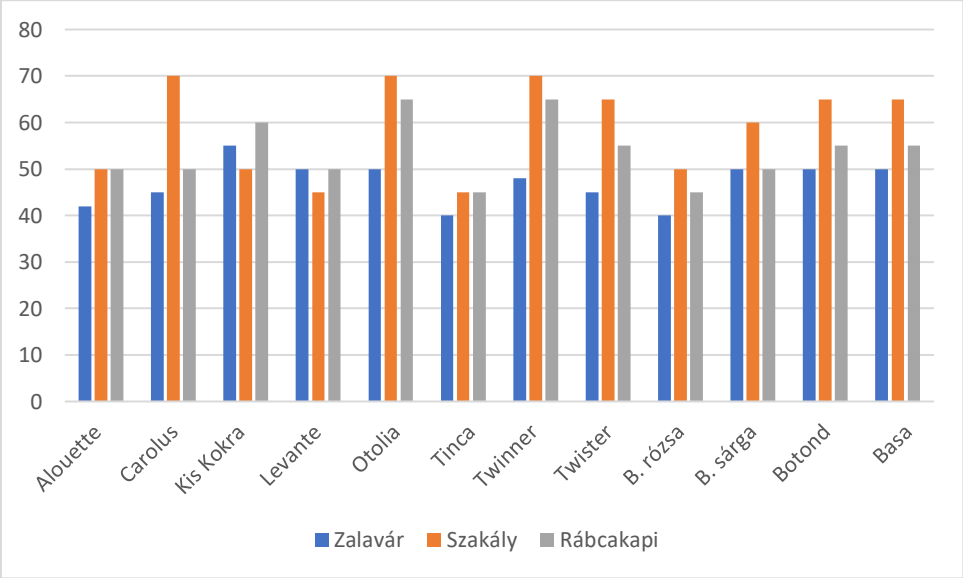

Fig. 53: Plant Height (cm) for each potato varieties at 3 locations.

Fusarium rot occurs after warm or hot summers. A pathological test was carried out on each potato variety at 3 locations. Tubers were graded on a scale of 1-9 (1-low 9- high). We found that Fusarium infection was the highest in the case of LEVANTE, TINCA and TWISTER. The varieties BALATONI RÓZSA, BALATONI SÁRGA, BOTOND, BASA had low infestation at all 3 locations. In Rábcakapi, where the most favorable conditions were (top-soil quality, uniform water supply), low tuber infestation was observed for all varieties (Fig. 54).

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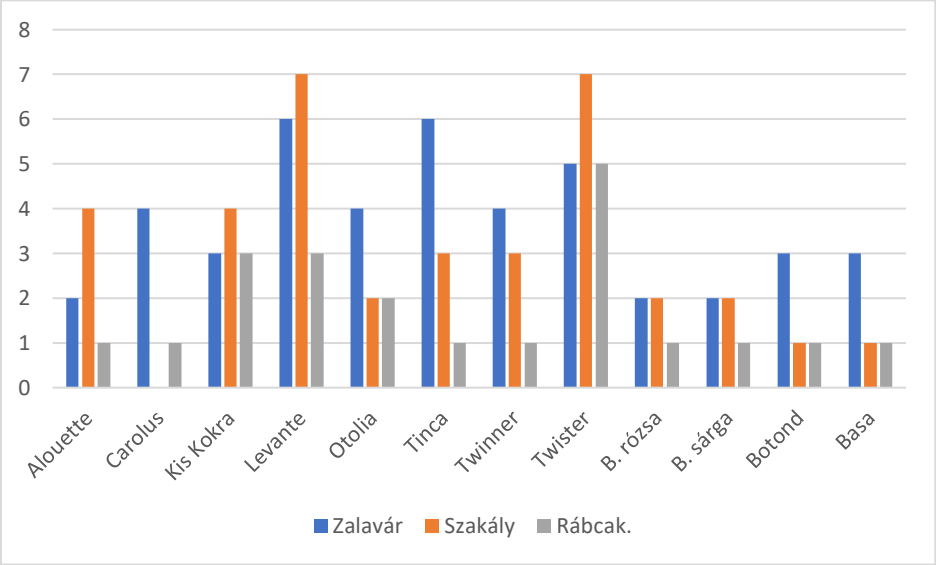

Fig. 54: Fusarium dry rot for potato varieties at 3 locations.

Visual, organoleptic and chemicalproperties

The dry matter affects the quality and cooking type of potato. Its value depends on genotype, growing conditions, agritechnics and length of growing season. Values around 19 - 20% are optimal for general use of potatoes. The variety BALATONI SÁRGA had the highest quantity of dry matter (24% at Rábcakapi) meaning cooking type "C". BALATONI RÓZSA showed the most stabile dry matter content with very low alteration between locations, cooking type "B" (Fig. 55).

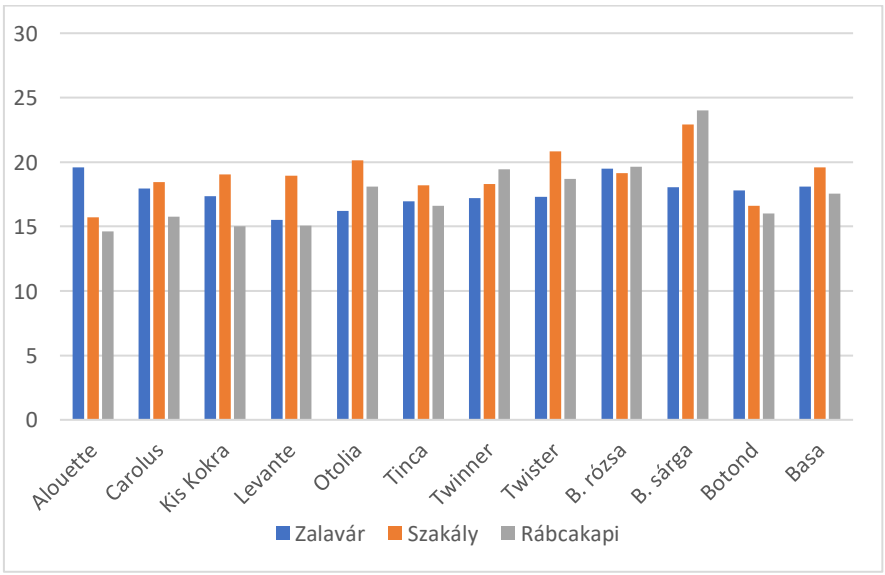

Fig. 55: Dry matter content of varieties at 3 locations.

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The visual traits and sensorial analysis were done at the Research Institute of Keszthely. Discoloration of potato flesh in raw state 4h after cutting was observed. For BALATONI RÓZSAT, BALATONI SÁRGA, BOTOND, BASA varieties there was practically no flesh discoloration 4h after cutting. At ALOUETTE, CAROLUS, OTOLIA, TWINNER, TWISTER varieties the highest values of disintegration were noticed (Fig. 56).

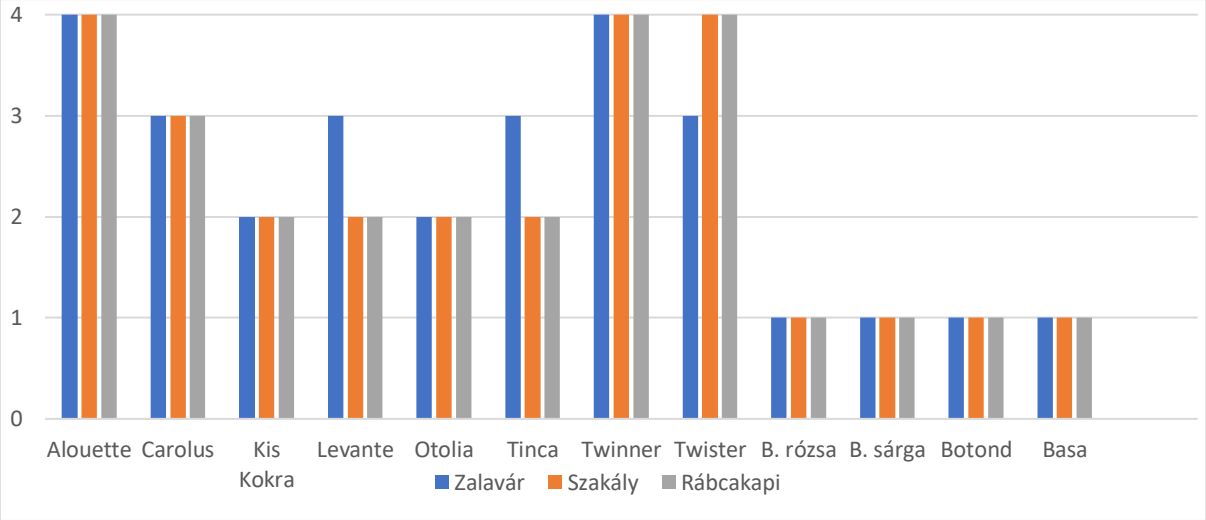

Fig. 56: Fresh discoloration of tuber flesh at 4h after cutting.

Most of the varieties in all 3 locations had very good taste, which is very good result in such weather conditions. LEVANTE and OTOLIA had only acceptable taste in Zalavár. TINCA and TWISTER obtained a score of 2 at least for 1 location. There was no very strong taste in either variety (Fig. 57).

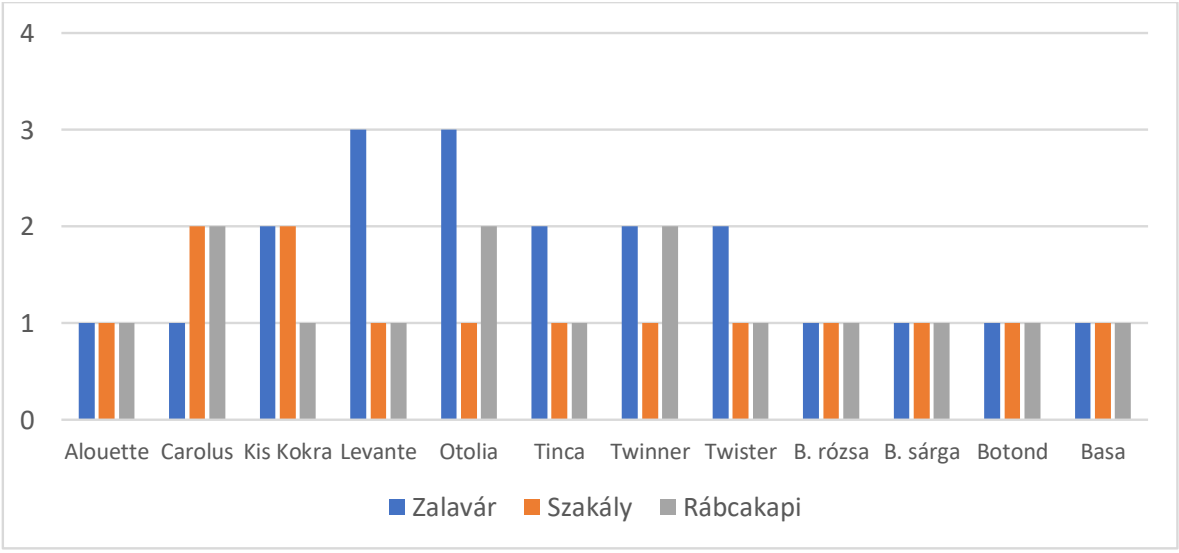

Fig. 57: Taste of cooked tubers at 3 locations (1 very good, 2 good, 3 acceptable, 4 worse).

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The tuber size distribution of total yield was determined for each location (% of total yield, <45mm, 45-65mm, >65 mm. Summarising these results we can state that varieties showing higher resistance to virus infection are being more tolerant to severe drought stress of typical for all location and produced larger and medium sized tubers compared to susceptible ones (Fig. 55-57).

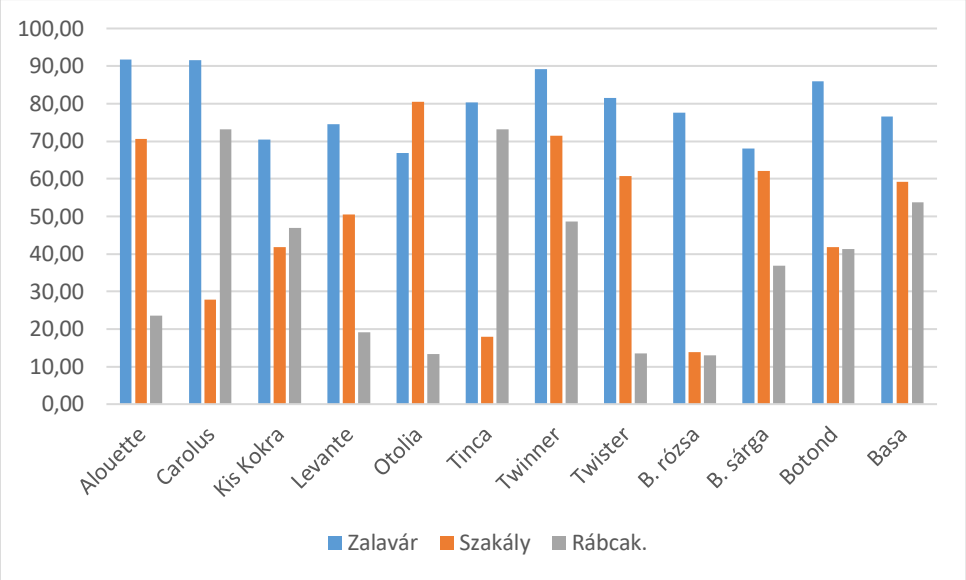

Fig. 58: Percentage of tubers below 45mm in diameter.

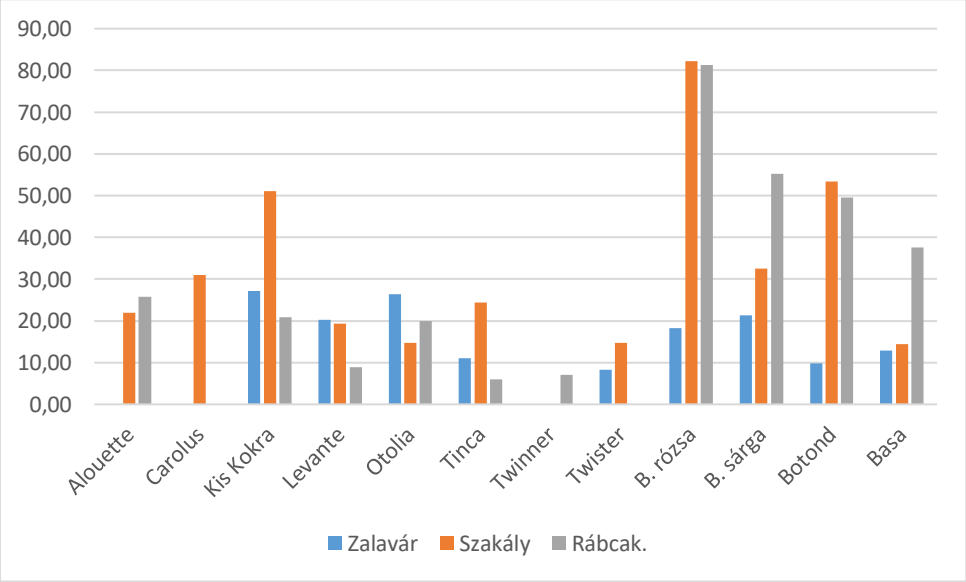

Fig. 59: Percentage of tubers between 45-65 mm in diameter.

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Similar to previous results cooking type of the varieties was not affected by the location (Fig. 60)

Table 63: Cooking type of tested varieties at each location.

Cooking type	Zalavár	Szakály	Rábcakapi
Alouette	AB	AB	AB
Carolus	AB	AB	AB
Kis Kokra	B	B	B
Levante	C	C	C
Otolia	C	C	C
Tinca	B	B	B
Twinner	B	B	B
Twister	B	B	B
B. rózsa	B	B	B
B. sárga	B	B	B
Botond	B	B	B
Basa	A	A	A

From the scoring of harvested tubers for the incidence of silver scurf infection it was obvious the where the most severe drought was recorded, at Zalavar location that tubers had the highest level but still not too high infection from this pathogen.

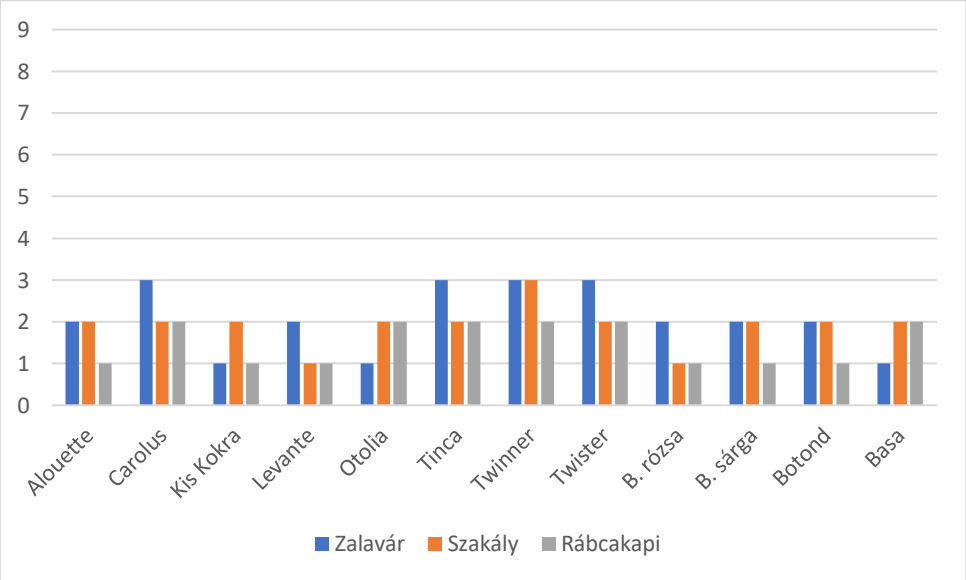

Fig. 60: Silver scurf infection of tubers (1-low, 9-high).

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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 2022 at Gilchesters, Thornton Farm, Nafferton Farm and Broadward Hall using the same varieties as in 2021. Three of the farms used were the same as in 2021 but with Thornton Farm near Berwick replacing Spindlestone. The trials were drilled earlier than in 2021 when drilling had been delayed due to the late arrival of seed. The trials at Nafferton Farm, Gilchesters and Broadward Hall were all drilled on Thursday, 28 April while the trial at Thornton Farm was drilled on Friday, 29 April. Plant counts were recorded (0.5m^2 quadrat with three replicate counts) at both Nafferton Farm and Gilchesters on 30 May.

All trials were drilled with the same 7 varieties i.e. Cebelica, La Harpe, Panda, Zoe, Zita, Kora and Billy at a rate of 75 kg/ha which equates to a target seed rate of 300 seeds/m^2. At Thornton Farm a mixture of Kora and Zoe was also drilled. All crops had established well but later in the season high weed levels were evident at both Thornton Farm and Nafferton Farm. At Gilchesters and Nafferton the buckwheat trials were drilled after a grass/clover ley while at Thornton Farm it was after winter wheat in the same field that had housed the FPT harvested in 2021.

The Gilchesters site was harvested with a plot combine on 15 September, while the other 3 sites were hand harvested i.e. 1 m^2 quadrats on 27 September at Nafferton Farm, 29 September at Thornton Farm and the 12 October at Broadward Hall. Yield component analysis (quadrat based) at Gilchesters was also taken on 21 September prior to combining.

The FPT trial at Gilchesters looked very good from start to finish (Fig. 61) whereas at Nafferton Farm although the trial established very well (Fig. 62) competition from weeds became an issue later in the growing season especially for the later maturing variety Billy with its poor early vigour such that collecting a seed sample at harvest was not possible. Similarly at Thornton Farm following a very good and even crop establishment and early vegetative growth (Fig. 63) weed competition later in the season became an issue such that at harvest it was not possible to collect seed from the varieties Billy, Panda and Zoe.

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Fig. 61: Buckwheat FPT at Gilchesters on 29 June 2022.

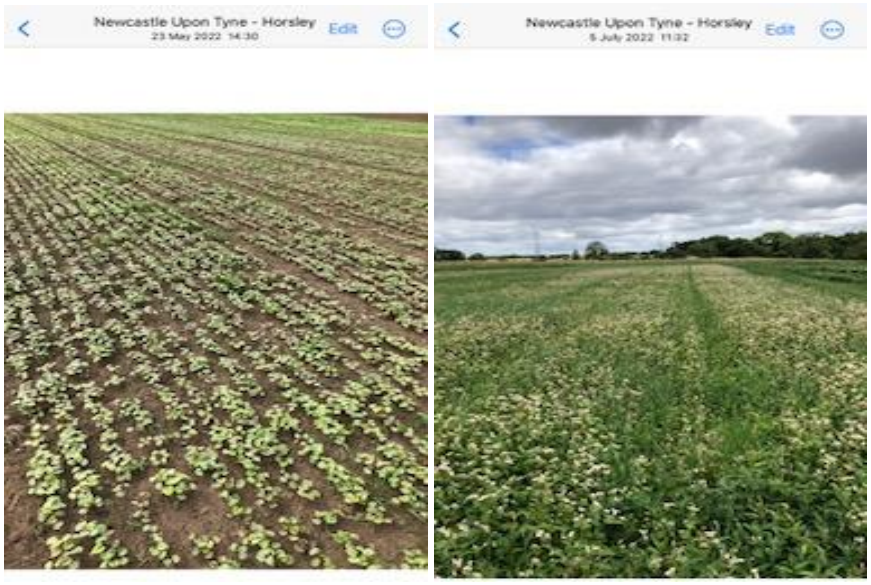

Fig. 62: Buckwheat FPT at Nafferton Farm on 23 May (left) and 9 July (right) 2022.

At Gilchesters the grain yield was high with the highest yielding variety being Kora (2.92 t/ha) closely followed by La Harpe (2.86 t/ha) and Zoe 2.78 t/ha (Table 64). Billy had the lowest grain yield at 0.72 t/ha and this variety with reduced vegetative growth in its early stages makes it far more susceptible to weed competition. This lateness of the variety Billy meant that it was harvested at 47% moisture content compared with the other varieties at c. 30%.

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Fig. 63: Buckwheat FPT at Thornton Farm on 13 May (left) and 4 July (right) 2022.

Table 64: Combine grain yield and moisture content of Buckwheat FPT at Gilchesters Farm in 2022.

	Weight (kg)	MC (%)	Yield @ 0%MC	Yield @15% MC	TGW (g)
Billy	13.6	47	0.63	0.72	25.8
Kora	41.3	30	2.54	2.92	24.7
Le Harpe	40.4	30	2.49	2.86	23.9
Zita	30.7	31	1.82	2.09	26.1
Cebelica	33.7	32	2.02	2.32	24.7
Zoe	35.9	29	2.42	2.78	28.3
Panda	33.3	30	2.06	2.37	25.7

Table 65: Yield components (m^2) of Buckwheat FPT at Gilchesters in 2022.

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging	Plant height (cm)	Flower clusters /cyme	TGW (g)
Billy	102.3	180.8	283.1	0.36	1	73.0	7.7	24.5
Kora	201.0	149.3	350.3	0.57	1	77.6	6.3	23.6
La Harpe	249.6	253.7	503.3	0.50	1	100.0	7.0	20.9
Zita	154.4	120.4	274.8	0.56	1	100.2	6.7	25.0
Cebelica	230.7	226.1	456.8	0.51	1	110.2	6.7	22.3
Zoe	175.2	163.8	339.0	0.52	1	88.6	6.3	24.7
Panda	183.5	158.8	342.3	0.54	1	88.6	6.0	25.2

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

The highest grain yield from quadrat sampling (Table 65) was for La Harpe (249.6 g/m^2) followed by Cebelica (230.7 g/m^2) with the lowest grain weight in the variety Billy (102.3 g/m^2). La Harpe also had the highest total biomass production at harvest (503.3 g/m^2) and Zita the lowest (274.8 g/m^2). Although Billy had the lowest grain weight it had a relatively high straw weight which resulted in the lowest Harvest Index of 0.36. Although La Harpe had the highest total grain weight (Table 65) it was Kora that had the highest HI. Although the late maturing Billy had the lowest grain weight and HI it had the highest flower cluster

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per cyme at 7.7. La Harpe had the lowest TGW (20.9 g) while Panda had the highest (25.2g).

Grain weights at the other sites were much lower than at Gilchesters. The highest grain weight at Nafferton Farm (Table 3) was also from the variety La Harpe (61.8 g/m^2) while Panda had the lowest grain weight (4.9 g/m^2). Le Harpe had the highest number of flower clusters per cyme (7.0) but had the smallest seeds with a TGW of 11.5 compared with Kora and Zoe at 23.7 and 23.1 g respectively. At Nafferton Farm there was a large difference in height between the varieties at maturity with Zita the tallest (91.2 cm) and Panda the shortest (54.6 cm) and no lodging evident.

Table 66: Grain yield and yield components (m^2) of Buckwheat FPT at Nafferton Farm in 2022.

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging*	Plant height (cm)	Flower clusters /cyme	TGW (g)
Billy	-	-	-	-	1	48.2	-	-
Kora	16.8	54.1	70.9	0.24	1	61.0	4.7	23.7
La Harpe	61.8	211.8	273.6	0.23	1	80.6	7.0	11.5
Zita	35.9	102.1	138.1	0.26	1	91.2	6.3	22.0
Cebelica	34.8	131.8	166.6	0.21	1	82.6	5.3	18.3
Zoe	30.6	126.4	157.0	0.19	1	70.0	6.3	23.1
Panda	4.9	25.6	30.5	0.16	1	54.6	5.7	16.0

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

At Thornton Farm La Harpe again had the highest grain weight (135.9 g), total biomass (274.0 g) and flower clusters per cyme (7.7) but with the smallest seed i.e. lowest TGW (20.5 g Table 67). Harvest indices were similar to Gilchesters with Kora having the highest HI at 0.60 and Zita the lowest at 0.40. Similar to Nafferton Farm, Zita was the tallest variety (103.0 cm) followed by Cebelica (89.8 cm).

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Table 67: Grain yield and yield components (data presented per m^2) of Buckwheat FPT at Thornton Farm in 2022.

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging	Plant height (cm)	Flower clusters /cyme	TGW (g)
Billy	-	-	-	-	-	-	-	-
Kora	107.3	72.9	180.2	0.60	1	69.8	6.3	22.4
La Harpe	135.9	138.1	274.0	0.50	1	86.6	7.7	20.5
Zita	67.5	102.1	169.6	0.40	1	103.0	6.3	23.7
Cebelica	46.8	47.6	94.4	0.50	1	89.8	7.0	21.5
Zoe	-	-	-	-	-	-	-	-
Panda	-	-	-	-	-	-	-	-
Kora + Zoe	46.1	40.6	86.7	0.47	1	73.4	6.7	21.7

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

Table 68: Grain yield and yield components (data presented per m^2) of Buckwheat FPT at Broadward Hall in 2022.

	Grain weight (g)	Straw weight (g)	Total biomass (g)	HI	Lodging	Plant height (cm)	Flower clusters /cyme	TGW (g)
Billy	-	-	-	-	-	-	-	-
Kora	-	-	-	-	-	-	-	-
La Harpe	103.1	118.0	221.1	0.47	3	92.0	5.3	19.0
Zita	-	-	-	-	-	-	-	-
Cebelica	157.9	141.9	299.8	0.53	1	99.4	6.7	17.6
Zoe	111.6	127.8	239.4	0.47	7	58.4	5.3	19.6
Panda	117.9	106.1	224.0	0.53	1	94.6	6.3	15.7

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

5.1.1. Conclusions

A very high buckwheat grain yield was recorded at Gilchesters in 2022 which is is much higher than the average buckwheat yield in Europe (1.01 t/ha) (FAOSTAT 2019). The Gilchester yield is also much higher than that obtained from previous studies in central Europe which reported yields ranging between 0.78 – 2.2 t/ha (Kalinova and Vrchotova, 2011; Early et al., 2005). A study by Domingos and Bilsborrow (2021) examined the effect of sowing date (mid vs end of April) on the growth, development, yield and nutritional quality of the buckwheat varieties Bamby and Čebelica over 3 growing seasons (2016-18) in north-east England. In this study the grain yield was 0.77 t/ha (average across varieties, sowing date and season) with the highest grain yield recorded was 1.42 t/ha from the variety Bamby in 2017.

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The trial at Nafferton Farm had a very low HI (range of 0.16-0.26 for the six varieties) which was much lower than the HI recorded at Gilchesters, Thornton Farm and Broadward Hall (mostly around 0.5).

There was consistency in the poor performance of the late maturing variety Billy at all sites in 2022 which confirmed data from the previous season.

Ability to compete with weeds is a key focus of the success of buckwheat in the FPT in the UK over the last two seasons in that after a grass-ley in both seasons at Gilchesters. Greatest problems arising from competition with weeds occurs when buckwheat follows an arable crop in the rotation i.e. Spindlestone in 2021 and Thornton Farm in 2022.

5.1.2. References

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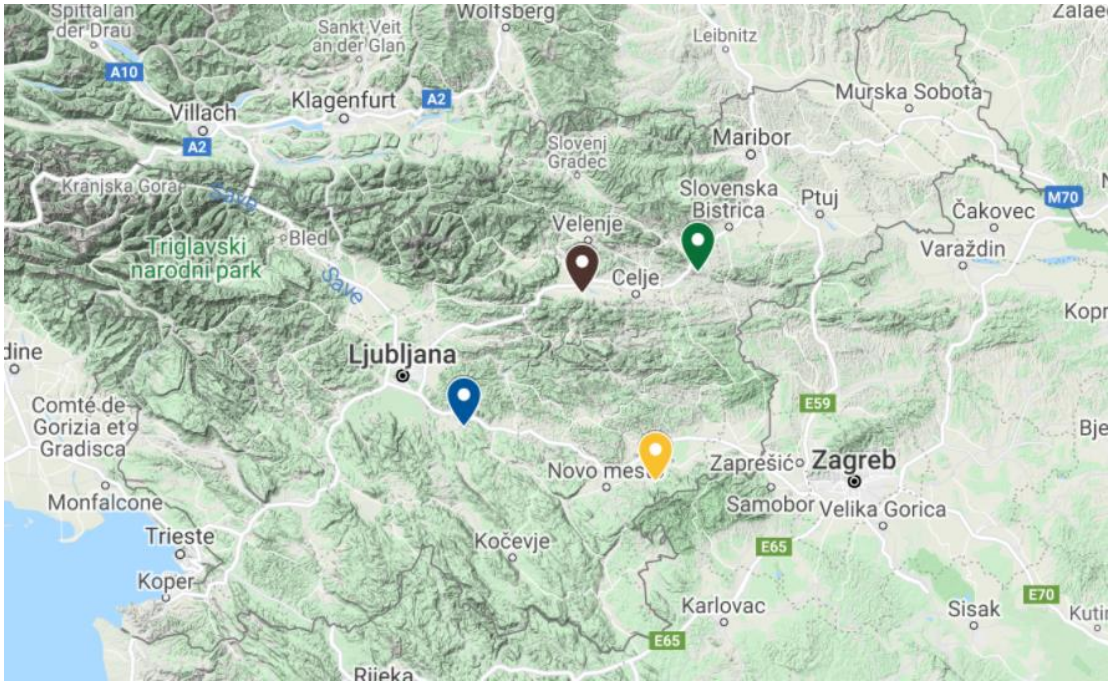
5.2. Buckwheat farmers participatory field trials in Slovenia

5.2.1. Methods

The buckwheat participatory field trials were conducted as part of the ECOBREED project and were established on four organic farms located in the central and southern areas of Slovenia (Fig. 64). The aim of the trials was to evaluate the performance of different buckwheat varieties under organic farming conditions, and to identify varieties that are well-suited for cultivation in this region. The trials involved active participation from farmers, who provided feedback on the performance of the different varieties and shared their experiences and insights.



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

Fig. 64: Locations of buckwheat trials and main characteristics of the locations.

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The buckwheat participatory field trials were conducted under variable weather conditions, including a period of drought that affected the region during the trial period. Despite this challenge, the trials were successful in evaluating the performance of eight buckwheat varieties (Kora, Panda, Zita, Zoe, Čebelica, Billy, Bamby, La Harpe) under organic farming conditions in four different farms located in central and southern Slovenia.

The selection of varieties was based on various criteria, including competitiveness with weeds, duration of growth, seed weight, flower colour, and other characteristics. The farmers had previous experience with buckwheat cultivation, and it was already included in the crop rotation of three of the farms. The trials were sown between 15 and 28 July, using a seed rate of 80 kg/ha and 100 kg/ha. The trials were harvested on 19th September (Ponikva) and 14 October (Grosuplje and Šentjernej), with all varieties at each location being harvested on the same day. The results of the trials provide valuable insights into the performance of different buckwheat varieties under organic farming conditions, including their ability to cope with challenging weather conditions such as drought.

To evaluate the development and agronomic performance of buckwheat varieties, several traits were assessed, including plant height, crop height, lodging, number of days from seeding to flowering and maturity, number of seeds per cyme, 1000-seed weight, chemical analysis (moisture content, crude protein content, rutin content), abiotic stresses, biotic stresses, seed yield, and 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 were responsible for managing the crop cultivation and harvesting, as well as scoring the dates of flowering and full maturity, lodging, abiotic stress, biotic stress, and grain yield. The yields were reported in kg/ha at 13% humidity.

The growing period was characterised by hot and dry weather conditions. The trial at Prebold was not harvested as being too damaged by the combination of weather conditions and damage by animals and weeds. The trial at Šentjernej was damaged by drought affecting the flowering and seed formation.

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5.2.2. Results

Farmers observed that the flowering stage occurred within 26 to 49 days after sowing, while the full maturity stage occurred between 89 to 116 days. However, the strong drought conditions resulted in negligible differences in the date of maturity among the different varieties in all locations.

Plant length and crop height are shown on Figs. 65 and 66, respectively. Looking at the average plant length and height across all locations, we can see that La Harpe was the tallest variety with an average plant height of 73.5 cm and an average plant length of 88.2 cm. The shortest variety was Zita, with an average plant height of 47.3 cm and an average plant length of 52.8 cm. When comparing the plant length and height across the three locations, Ponikva had the tallest plants with an average plant height of 88.2 cm and an average plant length of 73.5 cm, followed by Grosuplje with an average plant height of 66.6 cm and an average plant length of 50.0 cm. Šentjernej had the shortest plants with an average plant height of 45.2 cm and an average plant length of 50.0 cm.

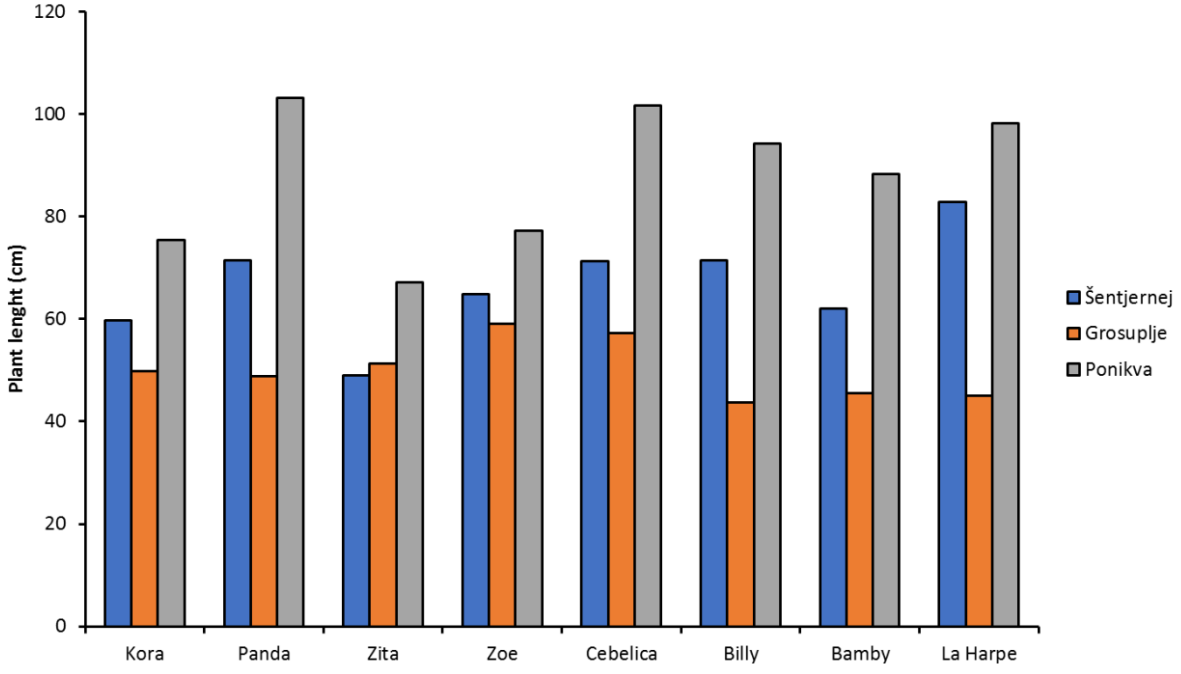

Fig. 65: Plant length of buckwheat varieties grown at 3 locations.

Looking at the plant length and height of each variety within each location, we can see that there are some variations. For example, in Grosuplje, La Harpe had the tallest plants with a plant height of 65.5 cm and a plant length of 82.8 cm, while Zita had the shortest plants with a plant height of 49.1 cm and a plant length of 52.8 cm. In Šentjernej, Panda had the tallest plants with a plant height of 46.3 cm and a plant length of 48.8 cm, while

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Billy had the shortest plants with a plant height of 41.8 cm and a plant length of 43.8 cm. In Ponikva, Panda had the tallest plants with a plant height of 84.3 cm and a plant length of 103.3 cm, while Zita had the shortest plants with a plant height of 55.3 cm and a plant length of 67.3 cm. Overall, lodging was insignificant for all varieties.

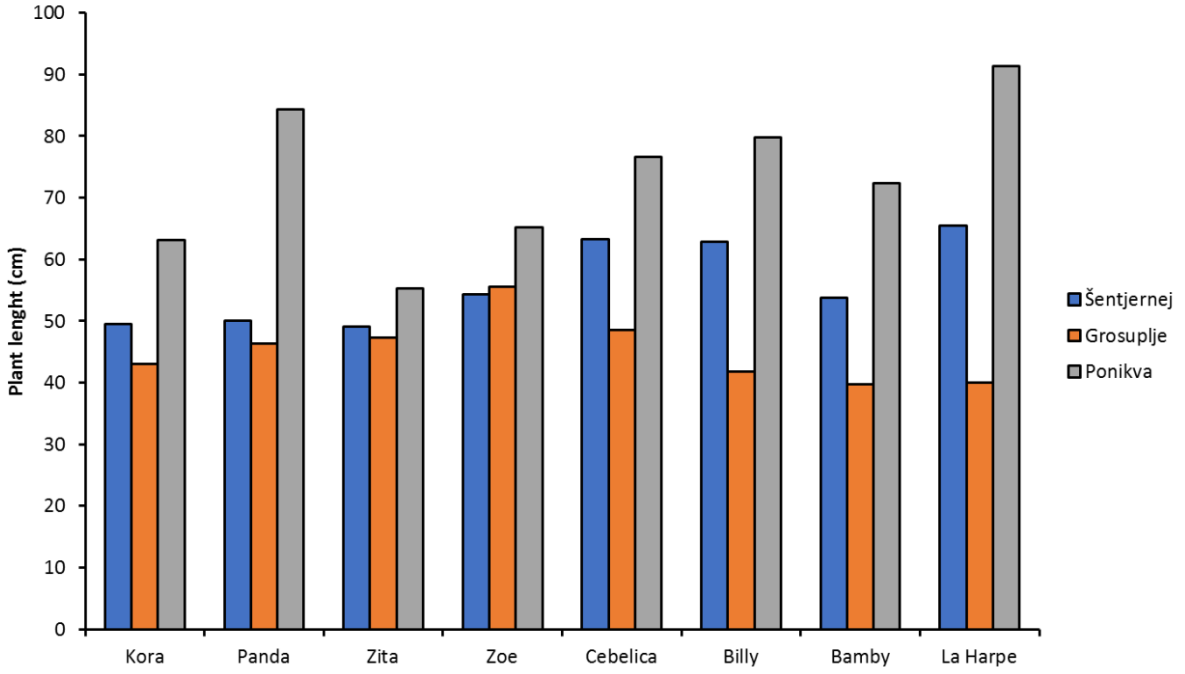

Fig. 66: Plant height of buckwheat varieties grown at 3 locations.

Table 69 shows the yield of eight different varieties of buckwheat grown in three different locations in Slovenia: Grosuplje, Šentjernej, and Ponikva. The yields are reported in kilograms per hectare (kg/ha). Looking at the average yield across all locations, the highest yielding variety was Bamby with an average yield of 939.625 kg/ha. The second highest was La Harpe with an average yield of 980 kg/ha. The lowest yielding variety was Kora with an average yield of 629.333 kg/ha.

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Table 69: Grain yields of the buckwheat varieties at the locations Grosuplje, Šentjernej and Ponikva.

Yield (kg/ha)	Grosuplje	Šentjernej	Ponikva
Bamby	432	65	680
Billy	1251	269	1166
Čebelica	918	164	1140
Kora	952	173	463
La Harpe	980	157	1387
Panda	822	269	441
Zita	1196	213	620
Zoe	966	257	441

When comparing the yields across the three locations, Ponikva had the highest average yield of 792.3 kg/ha, followed by Grosuplje with an average yield of 939.6 kg/ha, and finally Šentjernej with the lowest average yield of 195.8 kg/ha. Looking at the yields of each variety within each location, we can see that there are some variations. For example, in Grosuplje, Billy had the highest yield with 1251 kg/ha, while Bamby had the lowest yield with 432 kg/ha. In Šentjernej, Billy was again the highest yielding variety with 269 kg/ha, while Bamby had the lowest yield with 65 kg/ha. In Ponikva, La Harpe had the highest yield with 1387 kg/ha, while Panda and Zoe had the lowest yield, both with 441 kg/ha.

Overall, the data provides useful information on the yield performance of different buckwheat varieties across multiple locations in Slovenia, which can help farmers and researchers to make informed decisions on variety selection for their specific needs and growing conditions.

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5.3. Buckwheat field trials in the Czech Republic

Four organic farms have participated in farm trials. 12 to 13 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.

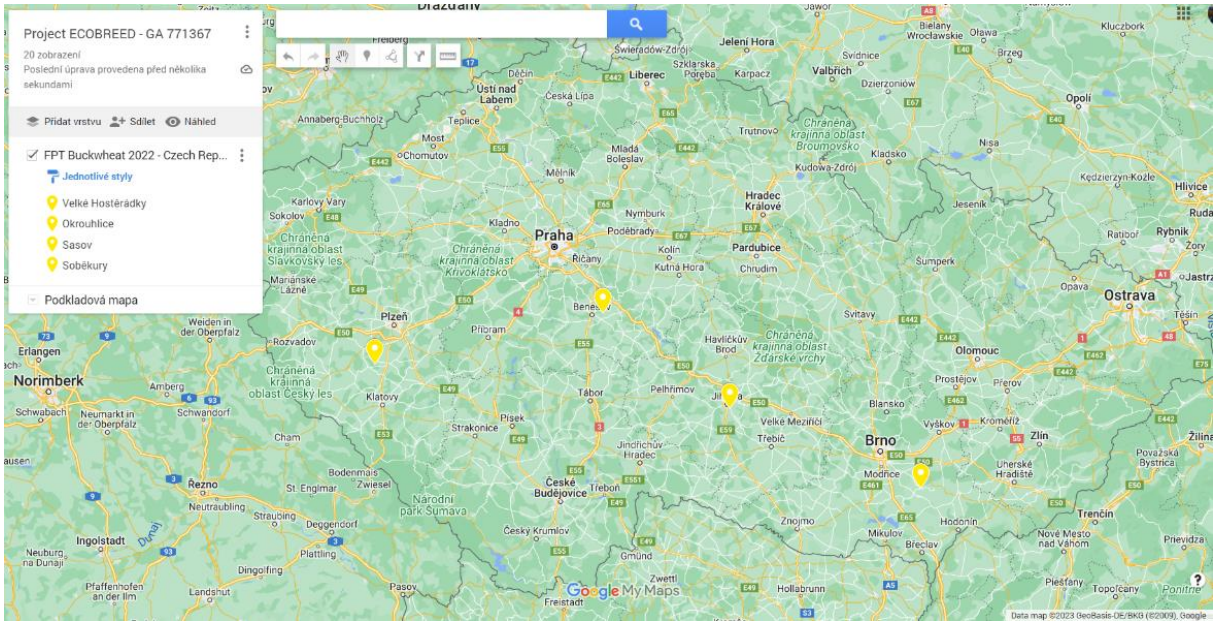

Fig. 67: Farm locations within Czech Republic in 2022.

The list of varieties and their origin.

1. Darja (Slovenia/Denmark)
2. Devyatka (Russian federation)
3. Drushina (Russian federation)
4. Eskalar (Germany)
5. Hajnalka (Hungary)
6. Kora (Poland)
7. Lifago (Germany)
8. Lileja (Slovenia)
9. MHR Korona (Poland)
10. MHR Smuga (Poland)
11. Oberon (Hungary)
12. VB Nojai (Latvia)
13. Zita (Czech Republic)

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The year 2022 was a challenging year for buckwheat growing. Trial in Velké Hostěrádky had to be prematurely terminated just 60 days after sowing due to extreme drought. Trial in Sasov was harvested, but achenes were mostly empty, indicating that all varieties were not pollinated properly. Trial in Okrouhlice was sown into 33 cm wide strips, which allowed inter-row cultivation. Trial was cultivated by a weed harrow in early June and then was inter-row cultivated in late June. Due to intensive precipitation in July the trial could not be cultivated again. Missing of second inter-row cultivation triggered weed growth, especially *Chenopodium albumen* (fat hen). Due to intensive rain and lack of time, the trial was harvested without yield evaluation. Trial in Soběkury was the only trial harvested that year. This can indicate that incorporation of buckwheat into the crop rotation needs to be done with caution.

The goal for 2022 trials was to determine varieties with shorter vegetation period and suitable for grain production, (Table 70). Shorter the vegetation period, the more suitable the variety as a second crop or substitute crop. Longer vegetation period varieties are suitable as a main crop or cover crop.

According to Table 70, varieties can be divided into two groups:

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

Table 70: Days to maturity/vegetation period of different buckwheat varieties at different localities in CZ.

Varieties	Locations			
	Velké Hostěrádky	Sasov	Soběkury	Okrouhlice
Darja	n/a	Permanent flowering, never reached 75% maturity	Permanent flowering, never reached 75% maturity	Permanent flowering, never reached 75% maturity
Devyatka	n/a	95	95	95
Drushina	n/a	95	95	95
Eskalar	n/a	110	105	110
Hajnalka	n/a	115	110	110
Kora	n/a	100	100	105
Lifago	n/a	n/a	Hard to detect	Hard to detect
Lileja	n/a	80	80	85
MHR Korona	n/a	100	95	95
MHR Smuga	n/a	100	95	95
Oberon	n/a	120+	120+	120+
VB Nojai*	n/a	n/a	n/a	n/a
Zita	n/a	120	120	120

* Vegetation period according to breeder is around 100-110 days.

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Fig. 68: Significant lodging of variety Darja. (Photo: Petra Hlásná Čepková).

The precipitation distribution was different in 2022 compared to 2021. All sites had significant drought with very heavy precipitation in a short period of time. Therefore, buckwheat plants were much lower compared to last year. Varieties Devyatka, Drushina, MHR Korona, Lileja and Lifago were lower, reaching a plant length of around 92-102 cm. Kora and Eskalar were medium growth reaching 102 – 110 cm in plant length. Zita, Oberon, Hajnalka, Darja were over 110 cm. Darja was the longest variety with 163,6 cm, but it was a variety prone to significant lodging and uneven ripening (Fig 68). Lodging has not occurred in such scale as last year, but this is interconnected with overall weather and generally lower plants.

*Table 71: Off combine yield in dt/ha. Please note, this is the yield directly from combine harvester, at different humidity and maturity levels. Varieties with * were not combined, but TGW was evaluated from the cyme. ** TGW of Nojai seed was 27.4 g.*

Variety	Soběkury		
	Off combine yield dt/ha	TGW	Soběkury – netto groat yield in %
Darja	7.18	17.32	48.5
Devyatka	6.54	26.07	75.8
Drushina	8.29	27.84	74.4
Eskalar	7.96	22.21	69.8
Hajnalka	8.46	22.72	72.1
Kora	7.29	22.81	65.2
Lifago	n/a	7.96*	n/a
Lileja	n/a	21.02*	n/a
MHR Korona	6.33	25.12	75.3
MHR Smuga	9.76	25.45	68.2
Oberon	8.78	28.65	53.6
VB Nojai**	n/a	n/a	n/a
Zita	8.41	23.58	66.3

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