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Report on Farmers Participatory Field Trials

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KEYWORDS	Farmer participatory field trials, wheat, potatoes, soybean, buckwheat, organic agriculture
ABSTRACT (FOR DISSEMINATION)	Farmer participatory field trials were started with pre-trials in 2020 and were continued 2021-2023. Many additional trials were carried out. The ECOBREED consortium was able to mobilise 68 farmers in 12 countries. The FPTs gave the base to spread know-how to other farmers and stakeholders, increase awareness on organic breeding and increase use of organic seed, organic varieties and organic heterogenous material.
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Executive summary

Farmer Participatory field trials started with pre-trials. Bulking up of wheat seed for FPT in 2020-21 took place in the 2019-20 season at SMA (UK) and PRO-BIO (CZ). This involved an early maturing sub-set of varieties for FPT (to be used in Austria, Slovenia and Serbia) and a later sub-set for use in the UK. This initial bulking up of material gave us the potential for an initial screening and evaluation of the selected varieties. Other pre-trials took place at IHAR (PL), NATUR (DE), KIS (SI) with potatoes and PRO-BIO (CZ) with buckwheat.

Farmer participatory field trials were planned with farmer groups and stakeholders. The groups also discussed future training and demonstration events. When in-person meetings were not possible because of COVID-19 restrictions, farmers were asked on the phone. Project partners prepared the trials in video conferences held in August 2020 for wheat and January 2021 for the other crops. Lists of core/common varieties were established. Trials from Crete were re-distributed following the withdrawal of GEOKOMI from ECOBREED. The wheat trials were re-allocated to Serbia and Italy, the soybean trials to Slovenia and Austria. There were additional trials on wheat in SI and potatoes in DE.

Farmer participatory field trials were continued in 2021-2022 according to plan. Only in Romania one trial could not be executed and had to repeated in 2023.

List of varieties was discussed in 2021 at field days, meetings and workshops with farmers and stakeholders. The lists of varieties stayed similar for as many varieties as possible for the following years. Although we lost the US farms, we were able to compensate this with new farms in 2022 also there were additional trials on wheat in SI, wheat in CZ and potatoes in DE.

Many additional Farmer Participatory field trials took place in 2023. Therefore, in total 57 Farmer Participatory field trials took place than planned at the beginning of the project. The trials gave the opportunity for assessing more data to improve data quality and additional field days/field visits that enabled intensifying communication between farmers, researchers and other stakeholders. List of assessments for 2023 and data input were finalised. Further trials on microbial inoculants were continued.

The ECOBREED consortium was able to mobilise 68 farmers in 12 countries to carry out farmer participatory trials. The FPTs gave the base to spread know-how to other farmers and stakeholders, increase awareness on organic breeding and increase the use of organic seed, organic varieties and organic heterogeneous material. This was done by field visits, training events, demonstration events, other meetings, publications and presentations. Trials with seed treatments were carried out in several years. Whereas most results in wheat in UK were good and promising there were no significant results

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for wheat in Austria. An Austrian seed inoculation for soybeans did not work at all in Germany.

Introduction

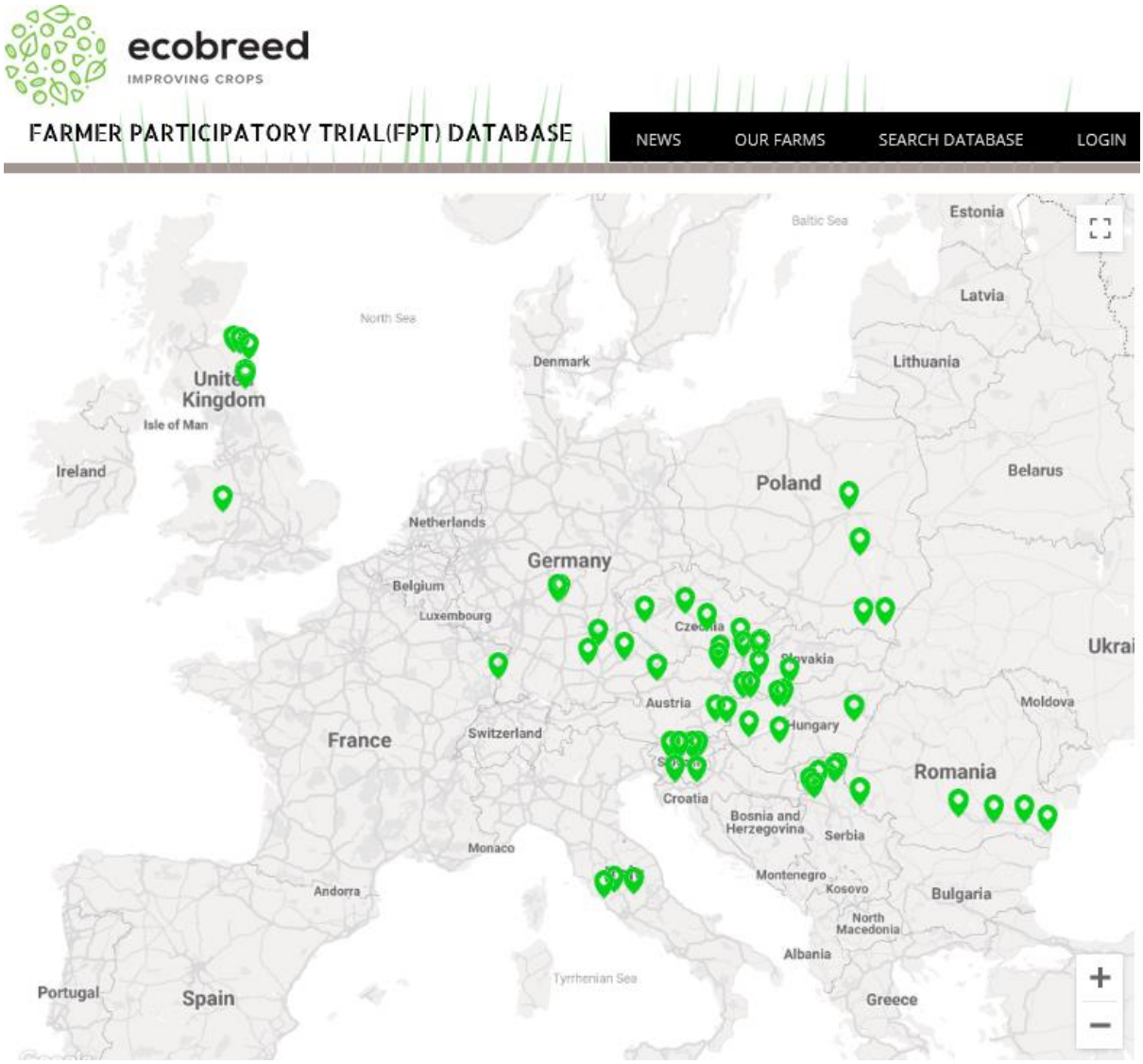

Fig 1 Map of farms used in FPT.

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Pre-trials 2020

Pre-multiplication of wheat seed 2019-2020

Bulking up of wheat seed for FPT in 2020-21 took place in the 2019-20 season at SMA (UK) and PRO-BIO (CZ). This involved an early maturing sub-set of varieties for FPT (to be used in Austria, Slovenia and Serbia) and a later sub-set for use in the UK. This initial bulking up of material gave us the potential for an initial screening and evaluation of the selected varieties. Other pre-trails took place at IHAR (PL), NATUR (DE), KIS (SI) with potatoes and PRO-BIO (CZ) with buckwheat.

ECOBREED farmer participatory field trials 2020–2021

Farmer participatory field trials were planned in 2020 with farmer groups and stakeholders. The groups also discussed future training and demonstration events. When in-person meetings were not possible because of COVID-19 restrictions, farmers were asked on the phone. Project partners prepared the trials in video conferences held in August 2020 for wheat and January 2021 for the other crops. Lists of core/common varieties were established. Trials from Crete were re-distributed i.e, the wheat trials took place in Serbia and Italy, the soybean trials in Slovenia and Austria. Execution of FPTs has been done according to plan. There were additional trials on wheat in SI and potatoes in DE.

Table 1 Total number of farms and genotypes 2021.

FARMS									
	UK		SI	US	RS		IT	AT	
	UNEW	SMA	KIS	WSU	GS	IFVC	UNITUS	BOKU	NATUR
Wheat		4	1		1	2	3	4	
Buckwheat	4		4	3					
Soybean			2		1	4			2
Potato			4						
	4	4	11	3	2	6	3	4	2
FARMS									
	CZ	PL	HU		RO	SK		DE	
	PRO-BIO/CRI	IHAR	UP	MTA	NARDI	BIOMILA	NPPC	NATUR	
Wheat				3		3	1		
Buckwheat	5								
Soybean					4			6	
Potato		4	4					1	
	5	4	4	3	4	3	1	7	
GENOTYPES									
	UK		SI	US	RS		IT	AT	
	UNEW	SMA	KIS	WSU	GS	IFVC	UNITUS	BOKU	NATUR
Wheat		36	22		9	18	27	40	
Buckwheat	28		32	42					
Soybean			16		6	24			23
Potato			52						
	28	36	114	42	15	42	27	40	23

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GENOTYPES								
	CZ	PL	HU		RO	SK		DE
	PRO-BIO/CRI	IHAR	UP	MTA	NARDI	BIOMILA	NPPC	NATUR
Wheat				24		24	8	
Buckwheat	50							
Soybean					35			58
Potato		44	48					10
	50	44	48	18	35	24	8	68

- Total number of farms: 62 (7 farms with 2 crops, one farm with 3 crops)
- Total number of trials: 70
- Total number of genotypes: 689

ECOBREED farmer participatory field trials 2022

Farmer participatory field trials were continued in 2021-2022 according to plan. Only in Romania one trial could not be executed and had to repeated in 2023. List of varieties was discussed at field days in 2021 and meetings and workshops with farmers and stakeholders. The lists of varieties stayed similar enabling two years results for as many varieties as possible. Although we lost the US farms, we were able to compensate this with new farms in 2022. There were additional trials on wheat in SI, wheat in CZ and potatoes in DE.

Table 2 Total number of farms and genotypes.

FARMS								
	UK		SI	RS		IT	AT	
	UNEW	SMA	KIS	GS	IFVC	UNITUS	BOKU	NATUR
Wheat		4	1	1	1	3	4	
Buckwheat	4		4					
Soybean			2	1	3			3
Potato			4					
	4	4	11	2	5	3	4	3
FARMS								
	CZ	PL	HU	RO	SK		DE	
	PRO-BIO/CRI	IHAR	MATE	NARDI	BIOMILA	NPPC	NATUR	
Wheat	1				3	1		
Buckwheat	4							
Soybean				3			6	
Potato		4	4				2	
	5	4	4	3	3	1	8	
GENOTYPES								
	UK		SI	RS	IT		AT	
	UNEW	SMA	KIS	GS	IFVC	UNITUS	BOKU	NATUR
Wheat		40	22		14	30	40	
Buckwheat	28		34					
Soybean			16	10	27			35
Potato			108					
	28	40	180	10	41	30	40	35

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GENOTYPES								
	CZ	PL	HU	RO	SK		DE	
	PRO-BIO/CRI	IHAR	MATE	NARDI	BIOMILA	NPPC	NATUR	
Wheat	15				24	8		
Buckwheat	49							
Soybean				31			66	
Potato		89	60				22	
	64	89	60	31	24	8	88	

- Total number of farms including ATK: 62 (5 farms with 2 crops, one farm with 3 crops)
- Total number of trials: 68
- Total number of genotypes including ATK: 798

ECOBREED farmer participatory field trials 2022–2023

Many additional Farmer Participatory field trials took place in 2023. Therefore, in total 57 more Farmer Participatory field trials took place than planned at the beginning of the project. The trials gave the opportunity for assessing more data to improve data quality and additional field days/field visits that enabled intensifying communication between farmers, researchers and other stakeholders. List of assessments 2023 and data input were finalised. Further trials on microbial inoculants were continued.

Table 3 Total number of farms and genotypes 2023.

FARMS								
	UK		SI	RS		IT	AT	
	UNEW	SMA	KIS	GS	IFVC	UNITUS	BOKU	NATUR
Wheat	1	4	1		1	1	3	
Buckwheat	2		3					
Soybean			2	1	2			1
Potato			4					
	3	4	10	1	3	1	3	1
FARMS								
	CZ	PL	HU		RO	SK		DE
	PRO-BIO/CRI	IHAR	UP	MTA	NARDI	BIOMILA	NPPC	NATUR
Wheat				6		3	2	
Buckwheat	3							
Soybean					3			5
Potato		3	3					
	3	3	6	6	3	3	2	5
GENOTYPES								
	UK		SI	RS		IT	AT	
	UNEW	SMA	KIS	GS	IFVC	UNITUS	BOKU	NATUR
Wheat		65	22		1	10	42	
Buckwheat	12		6					
Soybean			10	4	5			16
Potato			66					
	12	65	104	4	6	10	42	16

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GENOTYPES								
	CZ	PL	HU		RO	SK		DE
	PRO-BIO/CRI	IHAR	UP	MTA	NARDI	BIOMILA	NPPC	NATUR
Wheat				48		24	38	
Buckwheat	10							
Soybean					28			34
Potato		30	18					
	10	30	18	48	28	24	38	34

- Total number of farms: 52 (4 farms with 2 crops, one farm with 3 crops)
- Total number of trials: 57
- Total number of genotypes (including populations) 489

Farmer participatory trials on wheat

Farmer participatory trials in Slovenia

General introduction for all crops

Methods

Construction of the farmer group and knowledge of the farms: Farmer group: central elements of the FTP

The group of farmers was formed through exchanges with agricultural technicians and plant breeding experts on site. The criteria considered were: a farm that has been organic for several years, crops grown on the farm, willingness to experiment, ease of communication, interest in plant breeding and geographical diversity of farms. Six farms were selected to participate in the farmer participatory trials (FPT).

Meetings and questions

In April 2021, a first meeting was organised via Zoom to present the ECOBREED project and the trial conditions, the selection of varieties for each crop and the objectives of the trials. A financial compensation for the trial was distributed according to the type of crop.

In May 2021, we organised a meeting at each farm based on a questionnaire and a visit to the plots where the trials were established or planned. The aim of this meeting was:

- Describe the farms involved in the project in order to complete the common database.
- Identify the technical resources required to carry out the trial (choice of plot, equipment, crop rotation, labour, etc.) as well as the intangible resources available (knowledge of the crop, technical and professional network, time available, etc.).
- Identify appropriate means of communication and the people responsible for the trial.

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- Get to know each other: Understand their motivation for participating in the project. Identify the objectives and working methods of each farm and their commitment to organic farming.

In March and April 2022, we conducted a second round of questionnaires. The aim of this questionnaire was to:

- Feedback on the first year of trials in terms of: (1) OVERALL ASPECT: communication, tools, events and their participation or not, administrative aspects. (2) Trials for each crop: whether it is easy to record and evaluate the characteristics of each one.
- Mutual acquaintance: exchange of good and bad memories.
- Exchange of remarks or needs to develop the protocol or to facilitate future seasons.

Visits to trials

Staff from KIS visited the trials to evaluate certain parameters, photograph the trials and talk to farmers about certain diseases, pests, conditions, etc.

Facilities for co-operation

Supports

Crop monitoring documents have been made available containing a summary of the ECOBREED project, data on WP6, technical information on the crops and varieties tested, photos and tools to assess diseases and pests, and a table to compile the information in order to summarise everything in a single medium.

Various means of communication

During the first meeting, the suggestion to vary the media was confirmed and desired, as the partner farmers were adept with e-mail or written communication. A VIBER group was set up to exchange photos and images.

Discussion

The trials were conducted over 2 seasons for potatoes, soybean and buckwheat with 3 seasons for wheat. The information for the database was successfully collected. Unfortunately, a cyber-attack prevented the information from being made available to a wide audience. The trials were successfully carried out by farmers. The observations and evaluations were carried out with varying degrees of ease in the parties. Questions about technical means and intangible resources were discussed in advance, which facilitated the set-up and follow-up of the trials.

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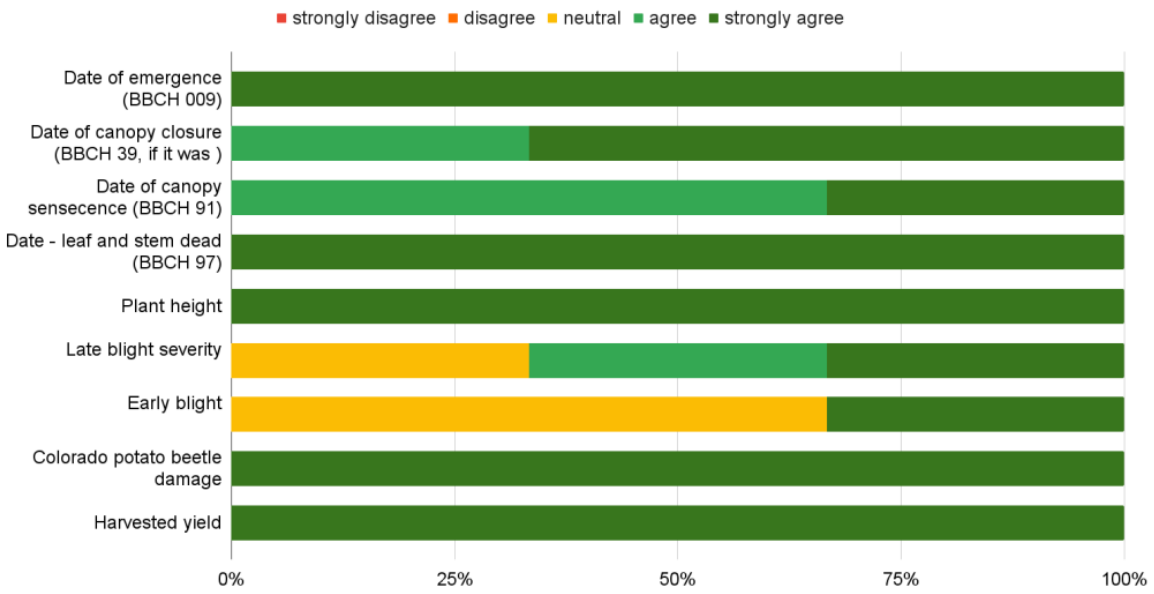

Fig 2 Composition of farmers' response concerning the ease of assessing potato characteristics in FPT 2020/2021 trials.

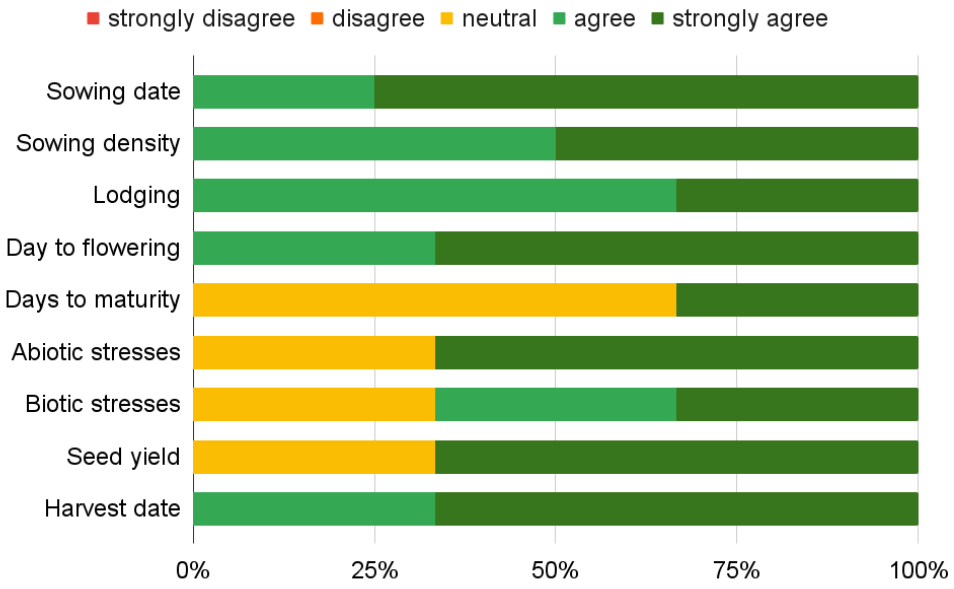

Fig 3 Composition of farmers' response concerning the ease of assessing buckwheat characteristics in FPT 2020/2021 trials.

The means of communication used varied according to the habits and preferences of the farmers: paper documents, email, phone calls, messages or exchanges in a private group via an application. Visits to the farms also enabled an exchange of information on site. More detailed feedback on whether the implementation of certain notations was easy or not made it possible to modify the protocols and accompany the evaluations.

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Trials

During 3 seasons 2020/2021, 2021/2022 and 2022/2023, two trials with winter wheat varieties were conducted in the organic fields of the Agricultural Institute of Slovenia. A total of 22 varieties were included in the trials, namely Ingenio, Savinja, Tata mata, Reska, Primorka, Marinka, Illico, Izalco CS, Gorolka, Vulkan, Nexera 923, Liocharlis, Arnold, Capo, Aurelius, Albertus, IS Laudis, Purino, Viki, Wendelin, Edelmann, and Ehogold. Sowing dates were 28/10/2020, 22/10/2021, 26/10/2022. KIS researchers and technical staff monitored and evaluated plant development throughout the growing season, with the trials ultimately being harvested on July 25th, 2023. Samples were taken for further analyses, including protein content, sedimentation value, starch content, gluten content, TKW, and test weight. The data collected during the growing period and harvest were processed and subsequently incorporated into the shared Excel sheet database.

The results of plant height are presented (Fig 4). Cultivars highlighted in green showed a greater height compared to the average height within their respective trials over 3 years. The average plant height in the initial trial measured 91 cm, while in the second trial, it reached 100 cm. In the first trial, plant height varied from 69 cm (Tata mata, 2022) to 117 cm (Marinka, 2023). In the second trial, plant height ranged from 81 cm (Aurelius, 2022) to 118 cm (Liocharlis, 2023). Notably, the cultivars exhibiting the tallest plants were Liocharls CCP, Capo, Illico, Wendelin, Ehogold in Aurelius.

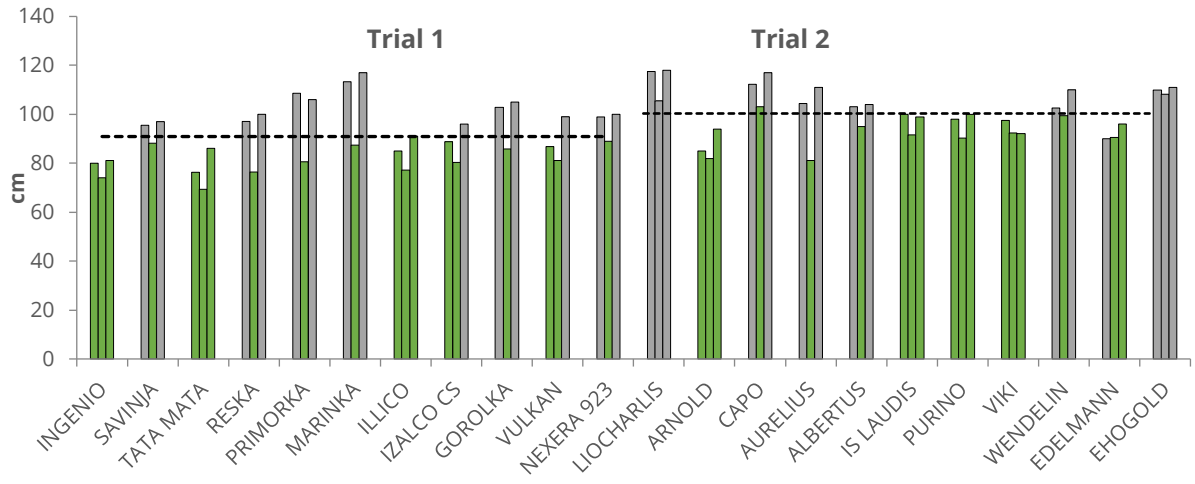

Fig 4 Comparison of winter wheat plant height (cm) during 3 seasons 20/21, 21/22, 22/23.

Grain yields with 14% moisture are shown in the next figure. Cultivars selected within the ECOBREED initiative exhibited higher average yields for 3 years. The average grain yield in Trial 1 amounted 4,985 kg/ha, while in Trial 2 it reached to 5,398 kg/ha. It is noteworthy that in the 2022/2023 season, for the first time in the tests, the Slovenian-selected varieties achieved a better average yield than the varieties selected by ECOBREED, which represents a departure from the trend observed in the two previous seasons. There was smaller variation among the cultivars in Trial 2 compared to cultivars in Trial 1. Comparing

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cultivars in Trial showed average grain yields ranging from 4 033 kg/ha (Tata mata, 2023) to 5,891kg/ha (Illico, 2023), while in Trial 2 average grain yields ranged from 3,942 kg/ha (Arnold, 2023) to 6,898 kg/ha (Edelmann, 2022). The highest yielding cultivars were Edelmann (6,898 kg/ha 2022), Ehogold (6,832 kg/ha 2022), Purino (6,810 kg/ha 2022), Purino (6,670 kg/ha 2021), Purino (5,121 kg/ha). The lowest were Arnold (3,942 kg/ha 2023), Tata mata (4,033 kg/ha 2023), Edelmann (4,138 kg/ha, 2023), Savinja (4,226 kg/ha, 2023).

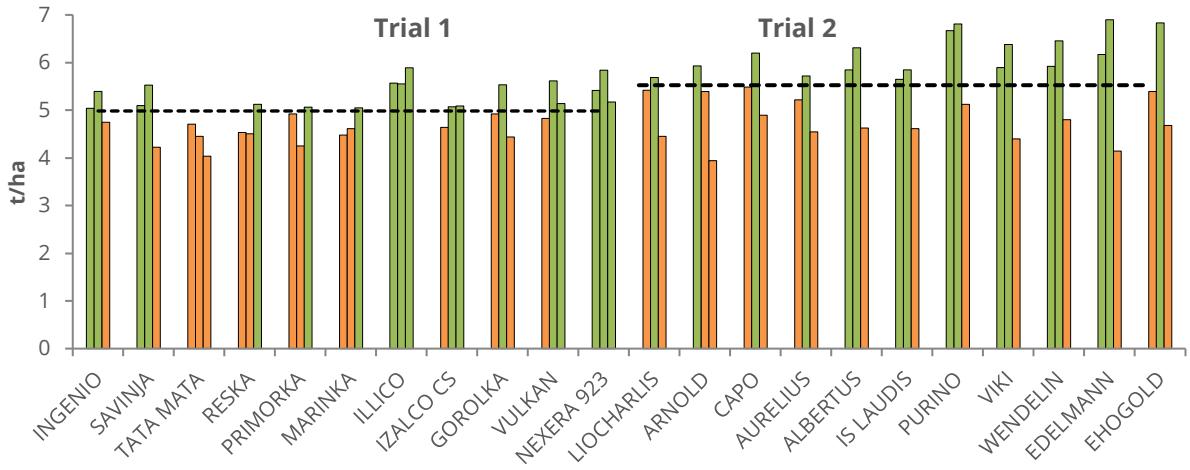

Fig 5 Comparison of winter wheat varieties yield (t/ha) during 3 seasons 20/21, 21/22, 22/23.

During the 3 seasons, *Septoria tritici* was the most prevalent disease observed in the trials (2020/2021: estimates of 6.8 and 6.7 for Trial 1 and Trial 2, respectively; 2021/2022: values of 2.1 and 2.0; 2022/2023: estimates of 4.1 in both trials). Other pest and diseases were noticed and evaluated.

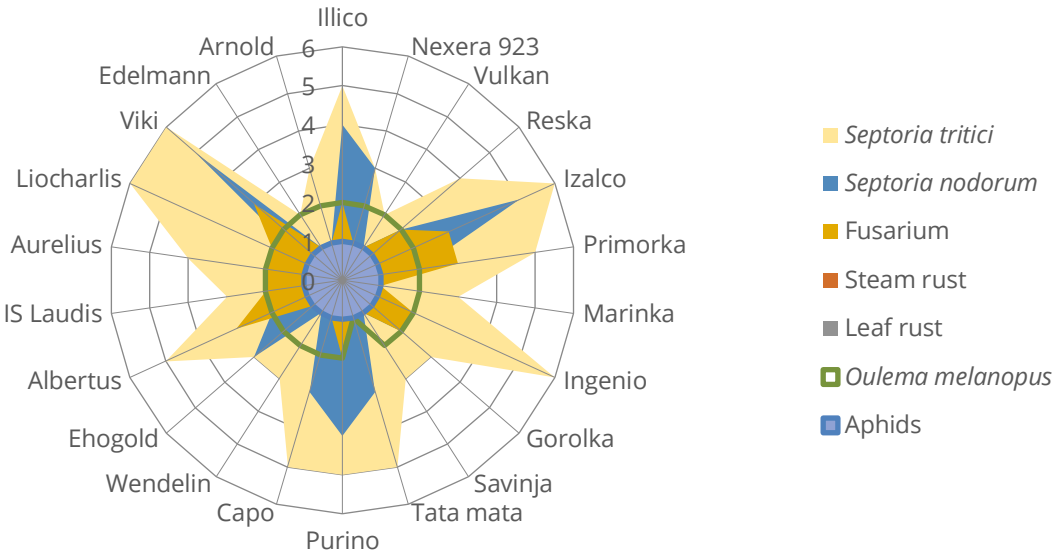

Fig 6 Disease and pest prevalence for selected cultivars in organic trials at Jablje in the growing season 2022/2023.

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Samples were analysed, including protein content, sedimentation value, starch content, gluten content, TKW, and test weight. Results of analysis are shown in the table below.

Table 4 Test weight, content of protein, sedimentation value, percentage of wet gluten and percentage of starch in grains of selected cultivars in organic trials at Jablje in the growing seasons 2020/2021, 2021/2022 and 2022/2023.

	2020/2021					2021/2022					2022/2023				
Cultivar	**kg**	**%, DM**	**ml**	**%**	**%, DM**	**Kg/hl**	**%, DM**	**ml**	**%**	**%, DM**	**kg**	**%, DM**	**ml**	**%**	**%, DM**
Ingenio	70.4	9.8	26	19	70.9	75.5	10.4	28	20.9	69.9	71	11	31	21.9	68.8
Savinja	76	10	29	19	72.2	79.2	10.4	30	20.4	70.7	76	13.2	47	27	68.3
Tata Mata	80.2	10.6	31	22	72.7	82.6	11.8	36	24.9	71	79	12.9	41	26.7	69.7
Reska	76.8	10.5	29	21	72.4	80.7	10.5	28	20.5	70.8	78	11.6	35	23.6	70.9
Primorka	75.5	9.3	26	17	71.9	79.7	10.3	29	19.9	70.7	77	10.8	30	20.9	70.4
Marinka	74.7	9.5	27	18	71.9	78.3	10.5	31	19.6	69.7	76	10.6	31	20.4	70.2
Illico	72.3	8.6	21	16	72.5	78.7	9.8	24	17.6	71.5	76	9.5	26	17.1	71.8
Izalco CS	77.1	11.5	35	24	72.1	81.5	12.3	38	26.4	70.9	82	12	37	24.4	70.6
Gorolka	80.3	10.1	25	20	72.7	84.3	11.6	36	24.2	70.5	79	13.1	43	26.8	70.5
Vulkan	73.9	9.9	27	19	72.3	80	11.2	32	23	71.2	78	11.1	31	21.6	71.3
Nexera 923	76	9.4	26	19	73.5	80.9	11.1	33	22.9	71.4	79	10	29	20.4	72.3
Average	**75.7**	**9.9**	**28**	**19**	**72.3**	**80.1**	**10.9**	**31.4**	**21.8**	**70.8**	**77**	**11.4**	**35**	**22.8**	**70.5**
Liocharlis	72.4	9.4	25	17	72.1	81.3	11.9	38	25.3	69.4	78	11	31	22	71.3
Arnold	73.3	10.2	28	18	70.3	79.1	11.5	34	23.8	67.4	78	11.4	34	22.1	69
Capo	78.1	10.1	27	20	72.8	84.4	12.4	44	27.6	69.3	82	11	33	22.5	72.3
Aurelius	73.9	9.5	27	19	72.5	83.3	11.6	37	24.6	70.5	80	10.5	30	21.6	72.1
Albertus	76.1	10.6	34	20	72.2	83.3	12.4	44	27.5	69.9	81	12.2	42	25.3	70.9
IS Laudis	74.3	10.4	29	20	71.1	81.6	11.5	36	23.9	69.3	79	10.3	28	19.8	71.3
Purino	72.3	8.9	23	16	72.3	79.4	11.7	36	25.2	68.4	75	9.9	26	18.5	71
Viki	70.7	10.4	29	19	69.3	78.7	13.6	48	31.1	65.7	74	10.9	30	20.4	68.8
Wendelin	72.9	9.9	26	17	70.1	82.6	12.8	43	28.1	66.9	80	11.4	32	23	69.8
Edelmann	75.2	10.4	31	20	72.5	82.9	11.7	37	24.5	70.4	80	11.5	34	22.6	71.4
Ehogold	76.1	9.4	23	18	72.9	84.6	12.4	44	27.5	68.9	81	10.2	28	20.7	73.1
Average	**74.1**	**9.9**	**28**	**19**	**71.6**	**81.9**	**12.1**	**40.1**	**26.3**	**68.7**	**79**	**10.9**	**32**	**21.7**	**71**

In Fig. 7 varieties are visible by their yield compared to average yield and their protein content compared to average protein content in 3 seasons. The varieties of Trial 2 selected for ECOBREED project and cultivated in 2022 are well represented in the upper quarter (higher protein content and higher yield compared to average).

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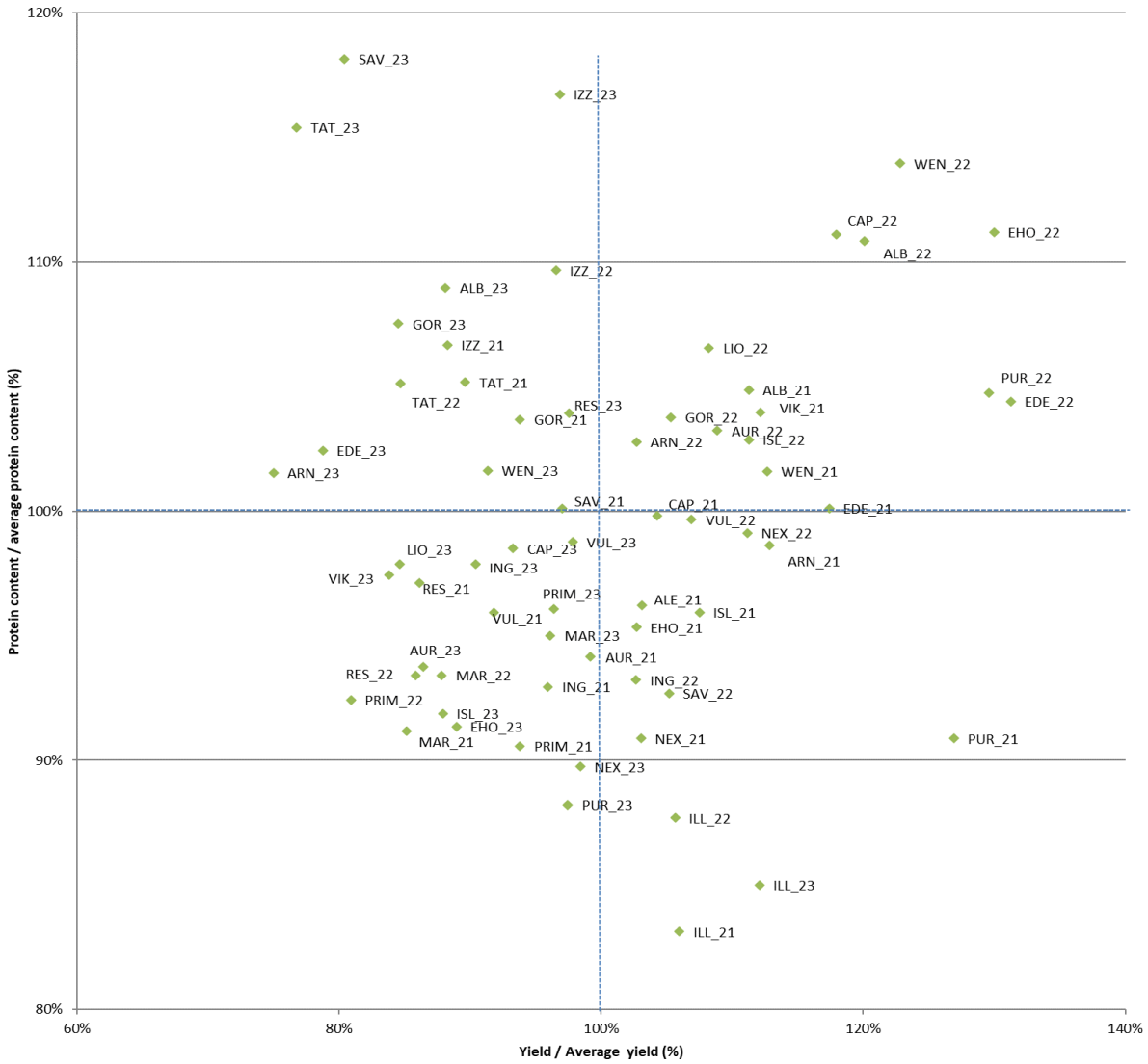

Fig. 7. Varieties by yield compared to average yield and protein content compared to average protein content in seasons 20/21, 21/22 and 22/23.

Farmer participatory trials in Serbia

2021

Winter wheat farmer participatory field trials were performed by the Institute of Field and Vegetable Crops (IFVC) on three organic farms located in the north Serbian province Vojvodina (typical Pannonian plain). The aim of these trials was to support farmers in selection of wheat varieties that are suitable for their agro-climatic region. Furthermore, during the growing season, we trained farmers how to select varieties that are most convenient for their environment. On each farm 9 winter wheat varieties were included, and four of them were varieties from Serbia that are most suitable for organic farming. Plot size was 300 m^2 (3 x 100 m).

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Table 5 List of varieties sown on farms.

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

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

- Čenej-Nada Letić (1 December 2020)
- Čurug-Global Seed (4 December 2020)
- Šuljam-Ignjat Jurišić (2 December 2020)

Sowing rate was 600/m^2 as sowing was outside the optimum date. Harvest of the WP6 varieties from Serbia (9) was performed with the hand harvester. From each farm, samples were collected and post-harvest analyses were performed. For sampling, we built a frame size 1 x 1 m and samples were taken from four spots on each plot.

2022

Winter wheat farmer 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 receiving 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 6 List of varieties on WP6 wheat Farms (2022).

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

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Table 7 Farms, locations, sowing and harvest dates in Serbia.

Farm	Location	Sowing time	Harvest time
Ignjat Jurišić (Zlatno zrno)	Šuljam	15.12.2021.	08.07.2022.
IFVC - experimental field	Rimski šančevi	13.12.2021.	06.07.2022.

Harvest of the WP6 varieties from Serbia was performed by hand using a 1 m^2 harvest area. For each variety, samples were taken from four locations in each plot. Samples from each farm were collected and post-harvest analyses were performed.

Fig 8 Hand harvesting of wheat FPT (Šuljam 8 July 2022).

Average values of the examined traits are shown in Table 26. Grain yield varied between varieties and among locations. The highest average yield (54 dt/ha) was recorded for the variety Capo at the Šuljam location, while the lowest value was recorded for 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 for NS 40S (IFVC). Highest protein (IFVC) and wet gluten content (Šuljam) were recorded for variety Capo, while PS Dobromila (IFVC) had the highest sedimentation value (50.2). The lowest protein, sedimentation and wet gluten content were recorded for NS Mila at the IFVC experimental field. Environmental conditions during anthesis and grain filling period were not suitable for the development of common wheat diseases.

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Table 8 Examined traits of WP6 wheat varieties.

IFVC							
Traits/Variety	Mv	PS Dobromila	Capo	NS 40S	NS Obala	NS Ilina	NS Mila
Harvest yield (dt/ha)	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 40S	NS	NS Ilina	NS Mila	NS
Harvest 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

Farmer participatory trials in Slovak Republic

The FPT trials were established on the following farms:

- SEMA HŠ s.r.o., Nový Dvor, 92521 Sládkovičovo
- Biomila SK, s. r.o., Rudník 428, 906 23
- SHR Vladimír Zeman
- SHR Martin Kolárik

The evaluation followed WP2 Wheat Descriptor for T2.1: the developmental phase of BBCH 25: WINTER RESPONSE/ WINTER HARDINESS, SNOW MOULD, BBCH 31: GROWTH HABIT, GROUND COVER, BBCH 39 FLAG LEAF EMERGENCE, infestation by diseases and pests (damage), BBCH 55 Heading, BBCH 65 Flowering, BBCH 67 Flag leaf length/Flag leaf width, BBCH 67 Flag leaf inclination, AWNEDNESS, Glume colour, BBCH 87 Plant height, BBCH 87 Lodging, BBCH 83 Common bunt, BBCH 83 Loose smut, BBCH 83 Fusarium, Steam solidness, Ear attitude/habit, Ear spike density, 1000 grain weight, Test/hectolitre weight, Grain seed size and shape

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SEMA HŠ s.r.o., Nový Dvor, 92521 Sládkovičovo

A total of eight wheat varieties (both domestic and international) were sown on the 24th of September 2020 in plots with a minimum plot size of 300 m^2. Selected varieties were chosen for their specific traits for organic cultivation and low-input trials. Prior to the seedling, weeds were controlled using the false seedbed method. The sowing density was 450 plants per m^2 at each location.

Cultivars were evaluated during the vegetation period on all farms: reaction to diseases and pests, plant height, lodging, and yield. Ground cover, lodging susceptibility, diseases, and pests were assessed using a 1-9 scale (1 meaning low prevalence). The weather conditions during the vegetation period were generally good for the vegetation and development of wheat. The highest precipitation was recorded during May i.e. 92.7 mm. The summer was too hot with high temperatures, and heavy rainfall during July signed particularly on the quality of post-harvest wheat. The harvest in the year 2021 was characterised as wet and it was delayed by rainfall and high humidity. The harvest was done on 27 July 2021, when wheat reached full maturity and had a moisture level of 14%. A representative grain sample of 1 kg was used to determine the moisture and quality parameters, such as protein, moisture, starch, volume weight, sedimentation index, falling number, dry matter, and nitrogen. The wheat was generally healthy and free of major diseases and pests. The only diseases that were observed in the field trials were *Tilletia caries* and *T. controversa*, which cause bunt or stinking smut in wheat. However, their occurrence was very low and all varieties showed good tolerance to them. The yield report showed a wide range of results, from 6.29 to 7.15 t/ha. The lowest yield was recorded for PS Dobromila, while the highest yield achieved by IS Laudis. The results reveal some interesting differences and similarities among the trials. The protein content was not significantly different between the trials, ranging from 10.64 to 12.07 %. The highest protein content was achieved for Aurelius, while the lowest was for Ehogold. The wet gluten percentage was also similar among the trials, varying from 21.8 to 26.4%, which corresponds to quality class A. The highest wet gluten percentage was reached by Wendelin, and the lowest by Ehogold.

The sedimentation index was more variable among the trials, indicating different levels of gluten quality. The highest sedimentation index was obtained by Wendelin and PS Dobromila, which reached the value of at least 40 ml. The lowest sedimentation index was recorded by Ehogold, which had only 34 ml. The volume weight was another parameter that showed some variation among the trials, reflecting the density and quality of grains. The highest volume weight was attained by Hungary population, which had 82.5 kg/hl, while the lowest was by Viki, which had only 75.3 kg/hl. The starch content was inversely related to the protein content, as the trials with higher protein content had lower starch content. The highest starch content was observed in Ehogold, which had

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62.3%, while the lowest was in Viki, which had 58.9%. The falling number was not a problem for any of the trials, as they all had high values, exceeding 200. The falling number measures the alpha-amylase activity in the grains, which affects the bread-making quality. Higher values indicate lower alpha-amylase activity and better bread-making quality.

During the season 2021/2022 a total of eight wheat varieties (both domestic and international) were sown on 18 October 2021. The harvest was on the 11th of July 2022, when wheat reached full maturity and had a moisture level of 14%. A representative grain sample of 1 kg was used to determine the moisture and quality parameters, such as protein, moisture, starch, volume weight, sedimentation index, falling number, dry matter and nitrogen. The wheat was generally healthy and free of major diseases and pests. The only disease that was observed in the field trials was Septoria with highest score of 4 and 3 by all varieties. Best tolerance was IS Laudis and Capo – scoring number 2. The yield report showed a wide range of results, from 6.14 to 7.23 t/ha. The lowest yield was recorded by Arnold, while the highest yield was achieved by Capo. The highest protein content was produced by Viki (12.08 %) and the lowest by Arnold (11.00 %). The mean highest protein content was at SEMA HŠ s.r.o. 11.96 %. The sedimentation value also showed the differences between the mean values of all trials. Values ranged from 39 (Arnold) to 50 ml (IS Laudis). The highest mean value was 44.13 ml. The percentage of wet gluten was the highest 27 % (IS Laudis) and the lowest 23.3 % (Arnold). The highest starch values were analysed by Aurelius (62.5%) and the lowest by Viki (60.2 %).

The trial 2022/2023 in SEMA HŠ s.r.o. was sown on the 8th of October, and all eight varieties (Arnold, Alessio, Aurelius, Ehogold, Viki, Capo, PS Dobromila, IS Laudis) looked healthy and very promising. The level of weed infestation was low.

The trial showed very promising results until harvest, with low weed and disease infestation across all varieties. The most infested varieties were Viki and Arnold, but they still had acceptable levels of damage. The other varieties had very few or no signs of infection. The harvest was done on 10 July 2023, and the yield data was collected and analysed. The best yield was achieved by Capo and Viki, with 6.8 and 6.5 t/ha respectively. The lowest yield was recorded by Arnold and Ehogold, with 4.9 t/ha hectare. The highest protein content was produced by Viki (13.0 %) and the lowest was Aurelius (11.1 %) The mean highest protein content was 12.1 %. The sedimentation value also showed the differences between the mean values of all trials. Values ranged from 45 ml (IS Laudis and Ehogold) to 40 ml (Capo). The highest mean value was 41.75 ml. The percentage of wet gluten was the highest at 26.5 % (PS Dobromila) and the lowest at 22.9 % (Arnold). The highest starch values were 62.1 % (Aurelius) and the lowest 60.7 % (Capo). The variety with the highest test weight was PS Dobromila 83.8 kg/hl and the lowest Viki 78.0 kg/hl.

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BIOMILA SK, s.r.o./ SHR Vladimír Zeman/ SHR Martin Kolárik

The season of 2020/2021 was a tough one for the trial in Polianka and Rudník, which included eight varieties: Aurelius, Hungary CCP, Ehogold, Viki, IS Laudis, PS Dobromila, Wendelin, and Arnold. The trial faced many difficulties, such as late sowing dates due to bad weather and a lack of agricultural machinery. The trial also suffered from the attacks of wild animals, such as wild boar, fallow deer and red deer, which destroyed the crops and made the harvest impossible.

During the season 2021/2022 a total of eight wheat varieties (both domestic and international) were sown on 29 October 2021. Participatory field trials were harvested at the end of July 2022 according to the full maturity stage with moisture at 14 %. Approximately 1kg of representative grain sample was used for moisture determination and quality analyses (proteins, moisture, starch, volume weight, sedimentation index, falling number, dry matter, and nitrogen). The wheat was generally healthy and free of major diseases and pests. The lowest grain yields were recorded for IS Laudis at 1.4 t/ha (SHR Vladimír Zeman) and the highest Arnold 2.40 t/ha (BIOMILA SK, s.r.o.). The mean grain yield in Biomila SK, s. r. o., SHR Martin Kolárik, and SHR Vladimír Zeman was much lower than in the southern part of Slovakia in SEMA HŠ s.r.o. Sládkovičovo largely due to the fact that it had been sown under different conditions. Also, the northern location of trials, soil quality, and high population of wild animals played a significant role in grain yield. The highest protein content at 11.7% Capo (SHR Vladimír Zeman) and the lowest by Aurelius at 9.3% (SHR Martin Kolárik). The sedimentation value also showed the differences between the mean values of all trials. Values ranged from 43 ml (Aurelius) at SHR Zeman to 27 ml (Aurelius) at SHR Kolárik. The percentage of wet gluten was the highest at SHR Zeman 23.50 % (Ehogold) and the lowest at SHR Martin Kolárik 16.7 % (Aurelius). The highest starch values were analysed at BIOMILA SK, s. r. o. 63.5% (Capo) and the lowest 61.20 % SHR Zeman (Ehogold). The variety with the highest test weight produced IS Laudis 83.4 kg/hl at SHR Zeman and the lowest Viki 76.3 kg/hl at SHR Martin Kolárik.

Field trials in Biomila SK, s. r. o., SHR Martin Kolárik, and SHR Vladimír Zeman during the season 2022/2023 were in poorer conditions, damaged by wild animals (wild boar and deer). The level of weed (*Tripleurospermum inodorum, Cirsium vulgare, Galium aparine, Equisetum arvense, Lamium purpureum*) infestation was up to 50% during March. The sowing was delayed to 04/11/2022 because of the intense rain period that affected the area. During May and June, the weed infestation (*Tripleurospermum inodorum, Cirsium vulgare, Galium aparine, Equisetum arvense, Lamium purpureum*) reached up to 100% in some plots, and completely overtook the plants. Growth and development were severely hampered by the weed competition for light, water and nutrients and plants were stunted, thin and pale and had very low or no grain production. Due to this situation, it

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was impossible to conduct any evaluations of the trial's performance during July - September 2023. The weed biomass was too high to allow any measurements or observations. After discussing with the farmers, we agreed that the trials were impossible to harvest. The yield data would be unreliable and meaningless, as the plants were almost non-existent. The weed infestation also posed a risk of contamination and damage to the harvester.

Fig. 9. Farmer Participatory Trial in SEMA HŠ s.r.o., Nový Dvor, 92521 Sládkovičovo/ Season 2020/2021.

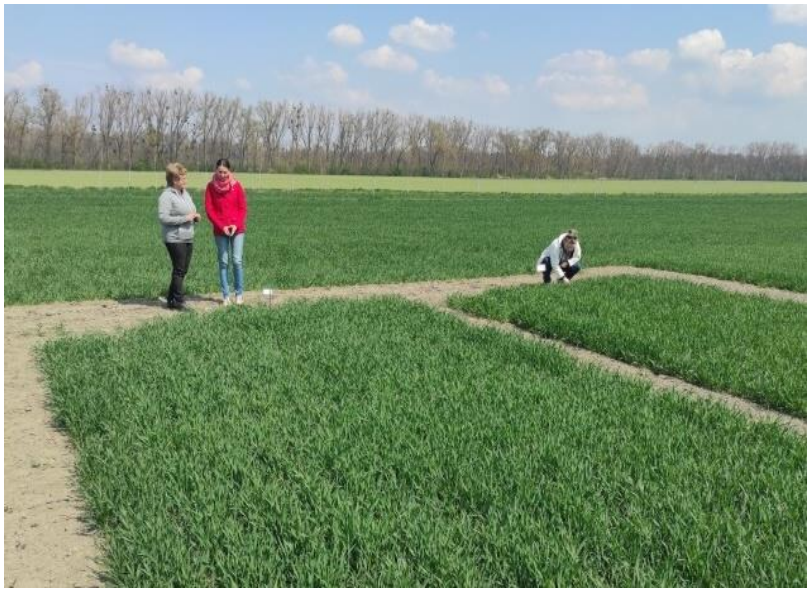

Fig. 10. Farmer Participatory Trial in SEMA HŠ s.r.o., Nový Dvor, 92521 Sládkovičovo/ Season 2021/2022.

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Fig. 11. Farmer Participatory Trial in SEMA HŠ s.r.o., Nový Dvor, 92521 Sládkovičovo/ Season 2022/2023.

Farmer participatory trials in Czech Repbulic

2020

PROBIO multiplied 14 varieties of winter wheat for partners in Austria, UK, Slovakia, Slovenia and Serbia. The list of varieties: Alessio (Probstdorfer Saatzucht); Arnold (Probstdorfer Saatzucht); Capo (Probstdorfer Saatzucht); Aurelius (Saatbau Linz); Albertus (Saatbau Linz); Wendelin (Secobra Saatzucht GmbH); Purino (Secobra Saatzucht GmbH); Viki (Selgen); IS Laudis (Istropol Solary); PS Dobromila (NPPC Viglas-Pstrusa); Edelmann (Edelhof); Ehogold (Edelhof); Hungarian population; Liocharls population.

PROBIO laboratory did qualitative assays of the winter wheat varieties. The highest protein content was found for MV – ELIT – CCP at 16 %, IS Laudis at 15.9 % and Edelmann at 15.6 %. The highest yield was recorded for variety Albertus at 4.56 t/ha, Aurelius at 4.35 t/ha and Aleessio and Arnold at 4.26 t/ha.

On 12 October 2021 an additional winter wheat trial was established at EKOFARMA PROBIO s.r.o. Seed rate was 230 kg/ha. The list of varieties: Scaro (Getreidezüchtung Peter Kunz); Penelope (Selgen, a.s.); LG Orlice (Limagrain Europe); Lorien (Selgen, a.s.); Poesie (Getreidezüchtung Peter Kunz); Butterfly (Selgen, a.s.); Prim (Getreidezüchtung Peter Kunz); Wiwa (Getreidezüchtung Peter Kunz); Tengri (Getreidezüchtung Peter Kunz); Royal (Getreidezüchtung Peter Kunz); Centurion (ASUR PLANT BREEDING S.A.S.); LIOCHARLS-POPULATION (OHM) (LWG Dottenfelderhof KG); MV – ELIT – CCP (OHM) (ATK MGI); Wendelin (Secobra Saatzucht GmbH); Alessio (Probstdorfer Saatzucht GesmbH & Co KG).

PROBIO did qualitative assays of winter wheat varieties and separate harvest for yield estimation. Varieties with the highest yield of 3.3 t/ha were Alessio, Centurien and Lorien.

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Varieties with the highest protein content was Prim with 16.9 %, Wiwa 16.5 % and Tengri with 16 %. The lowest yield of 2.6 t/ha was recorded for varieties Scaro, Penelope, Prim, Wiwa, Tengri and Wendelin. Variety with the lowest protein content was Centurien with 13.2 %. Two populations – Liocharls and MV – ELIT were at about 3 t/ha with a protein content of 15.3 % for both of them.

Farmer participatory trials in Italy

First year 2020/2021

Agreements were stipulated in autumn 2020 with three organic farmers to have participatory field trials in durum wheat in central Italy.

The three farmers were select in order to have a transect going from seaside to inland in central Italy. These were:

- Armando Aquilani from Montalto di Castro 68 m asl;
- Caludio Pagnliaccia from Viterbo 311 m asl
- Maurita from Rieti 375 m asl, and just under the Terminillo Mountain.

Since there were not sufficient seeds to put the same accessions in all three locations the 9 selected accessions were sown in each farmers' field:

- For Montalto di Castro sowing was on 27/11/2020: Lunadur, HFN94, Vulci, Sebatel2(45), Mv-Pelsodur, MVTD15-19, Azeghar2-1(56), Fuego, and a varietal mixture containing several of the selected accessions.
- For Viterbo sowing was on 25/11/2020: Senatore Cappelli, MVTD15-19, Vulci, Gibaltar, Ouskoulos, Mv-Makaroni, Azeghar2-1(56), Fuego, and Mv-Pelsodur
- For Rieti sowing was on 30/11/2020: Makaroni, Ouskoulos, Gibaltar, HFN94, Fuego, Vulci, Lunadur, Sebatel2(45), and a varietal mixture containing several of the selected accessions.
- For each accession were sown 3.5 kg of seeds on plots of 3x10m.

During the growing seasons the farmers were visited by UNITUS staff and, together with the farmer, several morphological characteristics such as percentage of ground cover, growth habit, tillering and growth stage, disease and Plant height were recorded.

Farmers were visited at their farmers' fields on several dates. Montalto was visited on 6/5/21, 25/5/21, 1/6/21, 30/6/21. Viterbo was visited on 6/5/21, 7/6/21, 30/6/21. While Rieti was visited on 9/5/21, 31/5/21.

The Plants in Rieti were affected by high rainfall during winter that reduced the germination since the field was under water. In Viterbo the -7°C reached in February killed some plants and several spikelet's. Likely in Montalto the wheat ear was much better, and

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the plants did not suffer as the other farmers' fields. But to the COVID restriction and the plots affected by unusual weather was not run the field days extended to other farmers.

Fig. 12. Montalto landscape in 2021.

Fig.13. Plots in Viterbo Farmer field. Plant height was very low due to severe frost.

The pre-harvest was performed collecting plants from a 1 m^2 in each Plot. This was done in Viterbo and Montalto on 30/6/21. Harvest by combine of all plots were carried out in the Montalto and Viterbo Farmer fields. Farmer measured the yield and kept the seeds of all the lines except for the populations in Montalto where the harvested seeds were returned to be used in future years.

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Second year 2021/2022

The farmers from Montalto di Castro (Armando Aquilani), Viterbo (Claudio Pagliaccia), and Rieti (Maurita) have been contacted and requested to participate in the trails also this season. All of them agreed. Seeds were brought to the farmers. For each variety listed in Table 6 were sown 3.5 kg of seeds. The size of the plots is according to the width of the sowing machine and the metres necessary to empty the seed tank in relation to the sowing density used by each farmer in their relative farm in order to respect their agricultural methodology on our durum wheat accessions.

Table 9 Durum wheat accessions sown in Montalto di Castro, Viterbo, and Rieti.

	Montalto di Castro and Viterbo		**Rieti**
N°	GEN	N°	GEN
1	Azeghar	1	Azeghar
2	HFN	2	HFN
3	Lunadur	3	Lunadur
4	MVTD 15-19	4	MVTD 15-19
5	Ousloukos	5	Ousloukos
6	Pelsodur	6	Pelsodur
7	Sebatel	7	Makaroni
8	Senatore Cappelli	8	Senatore Cappelli
9	Vulci	9	Vulci
10	Mix	10	Mix

Fig. 14. Sowing at Caludio Pagnliaccia from Viterbo 311 m asl.

At Montalto di Castro the sowing was performed in December 2021 while in Rieti and Viterbo the sowing was delayed to 15 January 2022 and 19 January 2022, respectively, because of the intense rain period that affected Italy at the end of December 2021 and the beginning of January 2022. At Montalto di Castro (Aquilani), Rieti (Maurita), and Viterbo (Pagliaccia) measurements of the percentage of field coverage (%), growth habit, and phenological stage (BBCH scale) were taken respectively on 15 March, 23 March and 24 March.

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The field located at Montalto di Castro, with the sowing performed in December 2021, and the field located at Rieti, with the sowing performed on 15 January 2021, looked much better than the field in Viterbo with the sowing performed on 19 January 2022. The ferment in Montalto di Castro escaped the drought with an early sowing strategy, while the farmer in Rieti could count on the mountain environment with higher water content for a longer period than for hills or valleys. The field and the plants in Viterbo were affected by drought The genotypes sown in the three farms partners of the programme were analysed with the farmers. During the period from April to June, each plot was evaluated for traits such as growth-stage, plant height, lodging, disease, pathogen-resistance, spike length etc.

Meanwhile in Montalto di Castro and Viterbo were organised ECOBREED Task 7.3 demonstration and evaluation events where farmers from all around the towns were invited. Each farmer had a questionnaire to fill with some preliminary questions about their opinion on the most important traits for organic farming and some more specific questions related to the genotypes cultivated in the respective farms.

Fig. 15. UNITUS evaluation and demonstration event at Montalto di Castro.

The harvest of the ten genotypes was performed in Montalto di Castro, Viterbo and Rieti respectively on 15 July 2022, 7 July 2022 and 20 July 2022. As for the other season, before the harvest 1m^2 of each plot was removed and seeds were analysed for yield, protein content, wet gluten content and humidity. Unfortunately, the square meter production for some genotypes grown in Viterbo and Rieti, wasn't enough for NIR analysis. All collected data are under statistical analysis.

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Table 10 Post-harvest data of genotypes tested in Viterbo and Montalto di Castro.

Genotypes	Montalto di Castro				Viterbo
	1 m^2 yield (g)	Humidity (%)	Protein content (%)	Wet gluten (%)	1 m^2 yield (g)
Azeghar2-1 (56)	358.6	11.7	11.4	22.4	118.3
HFN 94n	174.2	12.4	15.4	32	86.1
Lunadur	270.8	14.3	17	35.5	78.5
MVTD15-19	161.3	14.9	13.3	27.3	50.1
Osloukos	262.1	11.5	12	23.8	83.4
Mv-Pelsodur	202	12.6	13.5	27.4	97.6
Sebatel2(45)	247	11.4	15.8	32.5	68.8
Sen. Cappelli	180.5	14.6	13.6	28	40.4
Vulci	306	11.5	14.9	30.5	55.5
MIX Population	327.2	11.6	13.9	28.1	109

Table 11 Post-harvest data of genotypes tested in Rieti.

Genotypoes	1 m^2 yield (g)	Humidity (%)	Protein content (%)	Wet gluten (%)
Azeghar2-1 (56)	346.5	11.6	12.8	25.7
HFN 94n	357	11.5	14.7	30
Lunadur	361	12.5	11.7	23.3
MVTD15-19	323	11.6	13.7	27.8
Osloukos	221.7			
Mv-Pelsodur	235	12.4	13.6	27.6
Mv-Makaroni	232.3	11.4	10.1	19.6
Sen. Cappelli	270.5	11.6	10	19.2
Vulci	272.7	11.4	10.8	21
Population	333	11.4	11	21.9

Third year 2022/2023

Table 12 Evaluation of 10 selected genotypes.

ID	Genotype	stage	longing	pathogens
1	Sebatel	55	No	No
2	Pelsodur	51	No	No
3	IcaJin	58	No	No
4	HFN94n	57	No	No
5	S.Capelli	37	No	No
6	Azeghar	59	No	No
7	Vulci	36	No	No
8	Lunadur	35	No	No
9	MVTD15-19	35	No	No
10	mix pop	51	No	No

Seeds of ten accessions were distributed to the Aquilani farmer in Montalto di Castro, and to Pagliaccia in Montefiascone. The accessions are: Sebatel, Pelsodur, IcaJin, HFN94n, S.Capelli, Azeghar, Vulci, Lunadur, MVTD15-19, mix pop.

Farmer Pagliaccia in Montefiascone got some personal problems associated with climatic conditions so he was not able to sow the seeds until the end of March, the seeds given to him was recollected since such a late sowing would not give any useful results.

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In the field located at Montalto di Castro 10 selected genotypes were sown at the end of December 2022. 3.5 kg of seeds for each variety were sown in strip plots using the seed density used normally by each farmer. During the period from April to June, each plot was evaluated for traits such as growth-stage, lodging and disease levels.

Farmer participatory trials in the United Kingdom

Wheat FPT varieties evaluated included organic varieties from across Europe identified by the ECOBREED project as having greatest potential for organic production in comparison to farmer grown varieties initially Revelation in the first years (2020 and 2021) but then progressing to KWS Extase, Theodore, KWS Dawsum etc in later years. The farmer grown own varieties were popular conventional varieties from the UK Recommended List. In terms of yield it was the UK conventional varieties that out-performed the European Organic varieties (either bred or selected under organic management) in generally all trials. However, the organic variety Wendelin that is very popular in southern Germany always showed high resistance to foliar disease in the field but this was not reflected in it's grain yield, but had a high grain quality. The organic varieties from Europe particularly Roderik, Barranco, Purino and Alessio were very susceptible to yellow rust which was at high levels particularly in the 2020 and 2021 seasons.

The CCP Wakelyn's YQ population was grown in all years and produced an average yield across the varieties/treatments except for 2023 where severe lodging at Thornton Farm, Nafferton, Nesbit Hill and Gilchester's resulted in a very low grain yield for this tall CCP. Only having the Wakelyn's YQ CCP in the UK limited the potential for comparison of the performance of CCPs against pure line varieties.

A number of seed dressings (i.e. Tiros, Sikulo, DK-20, AminoA Staart and Newton) were evaluated across the trials together with the foliar applied biostimulant Fixio. The seed dressings used had no effect on grain yield and/or grain quality. However, the biostimulant Fixio had a clear effect on grain yield with an increase of 1.04 t/ha at Thornton Farm in 2021, 0.45 t/ha at Thornton Farm in 2022, 2.73 t/ha at Thornton Farm in 2023 and 1.47 t/ha at Nesbit Hill in 2023 when averaged across all varieties/treatments. There was no clear effect of Fixio on grain yield at Gilchester's (2021, 2022 and 2023) and Nesbit Hill (2022).

A number of varietal mixtures were evaluated in 2023 (generally a 3-way blend but also a 10-variety blend) but with no clear benefit to grain yield, foliar disease or grain quality when compared with the pure line varieties.

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2020

The seed for multiplication grew well. During the growing season, the trial received elemental sulphur and manganese for deficiencies. Half of the trial received poultry manure and the trials were hand rogued for *Avena Fatua* (Wild oat). During the growing season, the trials were monitored for morphological, phenological and agronomic traits.

Fig. 16. FTP at Thornton Farm in 2020.

In May 2020, SMA assisted Newcastle University in trialling the FPT Database, for further roll out to the Participatory Farms.

Due to Covid-19, it was not possible to hold an on-farm Open Day in July 2020. Instead, SMA made a 13-minute film about the ECOBREED project, the farm and the trials. This has been viewed 87 times, therefore likely reaching a wider audience than a trials day itself. A trials Open Day was organised in July 2021. 1,700kg of multiplied seed was harvested on 2 September 2020. Of the selected seeds, the ORC Wakelyn's Population and Wendelin performed well, their yields only exceeded by KWS Zyatt & KWS Extase, which were farmer selected. The seed was then bagged, weighed, cleaned and re-bagged into smaller bags for distribution to farmer participatory trial sites.

Three further organic farms agreed to become grow Farmer Participatory Trials. These are spread across southern Scotland and Northern England, with approximately 110 km between the farthest ones. These were provided with eight wheat varieties and one biostimulant treated sample to grow.

2021

From the seed grown in 2019/20, three new varieties were added, Roderick, Liocharls CCP and Viki. One poor performing variety was excluded from the second year i.e. Wiwa. Here at Thornton Farm, 15 different plots were sown on 11th October 2020. These included two trials of seed treated with Itaka's Sikulo biostimulant product. Itaka is a

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partner in our sister project, BRESOV. We also included seed treated with another Biostimulant, Unium Biscience's Tiros.

Fig 17 FTP in 2021.

Plant populations/germination counts were performed and the field was grazed with sheep to encourage tillering prior to spraying with elemental sulphur and manganese. 24m of the trial received a foliar spray of Itaka's Fixio product and the other end of the trial received a top dressing of poultry manure.

We held an Open Day at LC Smales & Son Ltd on 6 July 2021. It was attended by 23 people. A good, informative day, although a little wet. The trials at 3 of the farmer sites were combined on 23-25th August by Newcastle University plot combine. The highest yielders were KWS Extase, Revelation and Wendelin, with a top of 12.8 t/ha! We saw a great response from Itaka's Fixio product, adding on average 1 t/ha across all varieties.

2022

The 2021/22 wheat trials at LC Smales & Son Ltd and three other farmer sites across Southern Scotland and Northern England were drilled in late September/early October. In addition, evaluation of Agrimax's DK-20 and Itaka's Sikulo biostimulant seed dressings were included.

The wheat trials were grazed with sheep for 5 days from 27th January to reduce disease and encourage tillering. In addition, the results from fungi testing earlier in the winter were received. This showed that the only wheat pathogen present was *Pythium sylvaticum*. Beneficial fungi noted included *Linnemannia hyaline* and *Candida sake*.

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Fig. 18. Sheep grazing the trials on 27th January 2022.

Fig. 19. Wheat trials on 12th April 2022.

Itaka's Fixio Biostimulant was applied to a third of the trial at 3 farmer sites in early May. The wheat trials were harvested 29/30 August, with yields varying from 2.59 – 6.88 t/ha. The Fixio trials saw on average of 0.44 t/ha uplift.

2023

On 10 October, 21 x 4m wide trial strips were drilled at Thornton Farm. These included 11 pure wheat varieties, 1 composite population, 3 NABIM group wheat mixes, 1 mixture of all the prior year's trial varieties, two seed dressing/biostimulants on two varieties, a wheat/bean mix and a pure winter bean. The pure wheat varieties were made up of

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Wendelin and the most organically suited conventional UK available wheat varieties. The trials also included seed dressings of AminoA Staart and Interagro's Newton.

On 25th October, a further 3 trial strips were drilled of pure beans and two different mix ratios of wheat/beans. The trials got a good start in a warm Autumn.

Fig. 20. FPT at Thornton Farm on 25th October 2022.

In addition, farmer participatory trials were drilled at four sites in North Northumberland/ Southern Scotland.

The farmer participatory wheat trials grew well over the winter. Population counts were carried out on two farms. Planning was put in place to apply a biostimulant (Fixio) to a section of the wheat trials on four farms in April.

The Wheat Trials at 5 farmer sites in the UK grew well despite limited rain. At four sites, the trials were partially treated with Itaka's biostimulant 'Fixio' at GS30 in April. One side of the trials was treated so that a comparison to untreated can be made.

SMA held an open day on 11 July 2023. It was well attended by 23 farmers, agronomists and organic specialists. We looked at the ECOBREED wheat and buckwheat trials, as well as Liveseeding oat and bean trials.

The wheat trials at the farmer participatory trial sites were harvested between from 25th to 30th August with Newcastle University's plot combine. The trials showed a fair variation, with an average yield of Fixio treated plots of 8.49 t/ha against 5.65t/ha untreated, at Thornton Farm. The Wakelyn's Population has severely lodged, due to its tall height, in high winds.

Farmer participatory trials in Austria

Farmer participatory trials (FPT) with winter wheat (*Triticum aestivum* L.) in Austria were carried out from 2021 to 2023 on organic farms in different agro-ecological zones of Austria, i.e. the production areas (i) "Seewinkel" (47.7284, 16.9370), (ii) "Hollabrunn-Mistelbacher Gebiet" (48.5667, 16.0833), (iii) "Herzogenburg-, Tulln-, Stockerauer Gebiet" (48.4303, 16.0306), (iv) "Grieskirchen-Kremsmünster Gebiet" (48.1495, 13.7254), and (v) "Marchfeld" (48.2466, 16.5653). With exception of (iv) all other production areas were

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located in the north-eastern hills and lowlands which is a traditional production area of high protein quality wheat. In total, trials were carried out in 13 environments (location by year) with 40 genotypes (i.e. 31 cultivars and 9 populations). Eight cultivars (i.e. 'Alessio', 'Aristaro', 'Arminius', 'Arnold', 'Aurelius', 'Capo', 'Edelmann', 'Wendelin') and two populations (i.e. 'Liocharls Population', 'Mv Elit CCP') were tested in 6 to 11 environments. Due to the diverse origin of the germplasm a great variability in grain yield was observed ranging from 2526 to 10061 kg/ha. Generally, the lowest grain yields were recorded in the Seewinkel region with an average yield of 4108 kg/ha, whereas the highest yields were recorded for the Tulln (6720 kg/ha) and Hollabrunn (6396 kg/ha) area. Results for the reduced number of 10 genotypes which were grown in the majority of environments are shown in Table 10. It is obvious that differences between locations were more important than differences between years. Considering genotypes, only 'Arnold' fulfilled in all environments the Austrian market limits for organic baking wheat, i.e. 78 kg/hl test weight and 11 % grain protein content (GPC). Fails in market criteria were mainly caused by too low GPC values. The two populations 'Liocharls Population' and 'Mv Elit CCP' were not competitive in grain yield with the most popular cultivars 'Capo' and 'Aurelius', with respect to market criteria 'Liocharls Population' performed well, whereas 'Mv Elit CCP' missed the criteria in each of the four environments.

Table 13 Mean values of grain yield, test weight and protein content for genotypes, locations and years. Values for genotypes are best linear unbiased estimators (BLUEs), values for locations and years are best linear unbiased predictors (BLUPs).

Genotype	Grain yield (kg/ha)	Test weight (kg/ hl)	Protein content (%)	Market criteria fails (%)
Alessio	5154	83.3	12.2	14.3
Aristaro	5102	81.7	12.7	16.7
Arminius	5500	82.9	12.1	7.1
Arnold	5575	83.3	12.8	0.0
Aurelius	5885	82.5	12.0	16.7
Capo	5472	83.5	11.7	18.2
Edelmann	5506	82.5	11.3	22.2
Liocharls Population	4938	81.4	11.6	11.1
Mv Elit CCP	5346	81.6	10.6	25.0
Wendelin	5339	81.6	12.7	16.7
Year				
2021	5516	81.3	12.6	
2022	5305	82.1	12.2	
2023	5324	83.9	11.1	
Location				
Aspersdorf (ii)	5855	84.0	12.2	
Gaspoltshofen (iv)	5540	81.9	11.4	
Raasdorf (v)	4891	80.4	13.2	
Starnwörth (iii)	6361	85.0	11.5	
Wallern (i)	4261	80.8	11.5	

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Besides the FPTs a field experiment with two different seed treatments with biostimulants was carried out in 2022 and 2023 at the test site in the Marchfeld production area. Seeds of cultivars 'Capo' and 'Aristaro' were treated with RhizoVital® 42 F (*Bacillus velezensis* FZB42) or T-Gro Easy-Flow® (*Trichoderma asperellum*) immediately before sowing. Statistical analysis across the two years revealed no significant effect on grain yield, grain weight, test weight or protein content (Table 11).

Table 14 Mean values of grain yield, grain weight, test weight and protein content for genotypes and biostimulant treatments. Mean values are best linear unbiased estimators (BLUEs) and based on a two year's (2022 & 2023) trial in Raasdorf, Austria.

Genotype	Grain yield (kg/ha^{-1})	1000 grain weight (g)	Test weight (kg hL^{-1})	Protein content (%)
Aristaro	6970	44.1	81.3	12.4
Capo	6648	42.0	83.1	11.5
Treatment				
Control	6785	43.0	82.1	11.9
RhizoVital®	6805	43.0	82.2	11.9
T-Gro Easy-Flow®	6837	43.1	82.2	12.0

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Farmer participatory trials on potatoes

Farmer participatory trials in Slovenia

During the two seasons 2021 and 2022, 13 potato varieties were grown in FPT on four organic farms in Slovenia from 24 April to 11 May 2021 and from 24 March to 18 April. All collected data was compiled in a common Excel database. Based on this data, a bulletin was created for the farmers containing information on the performance of the different potato varieties and clones during the season.

Pest & diseases: In 2021, the harvests at all 4 locations were not damaged by leaf diseases or pests. Late blight was observed by one farmer on 8 varieties with between 5 and 50 % of the total leaf area infested at the end of August. The Colorado potato beetle was present at all locations, with one farm observing 5 % damage on each variety. Two farms sprayed (1 or 2 times) with the organic insecticide LASER PLUS and succeeded in hand-picking the Colorado potato beetle larvae. Although weeds were present, they were not perceived as a major problem by the farmers.

Table 15 Rhizoctonia on tuber, silver scurf and common scab of 13 potatoes varieties at 4 locations in 2022 (SLO).

	Rhisoctonia on tubers (1-6)		Silver scurf (1-6)		Common scab (1-6)	
	Average	Data range	Average	Data range	Average	Data range
ALOUETTE	1.0	1;1	3.3	2;5	1.0	1;1
BOTOND	1.3	1;2	1.8	1;3	1.3	1;2
CAROLUS	1.5	1;2	1.3	1;2	2.3	1;4
DELILA	1.0	1;1	5.3	4;6	1.3	1;2
KELLY	1.8	1;3	1.5	1;3	4.0	1;6
KIS KOKRA	1.3	1;2	1.8	1;3	1.0	1;1
LEVANTE	1.0	1;1	1.3	1;2	3.5	2;5
MAGNOLIA	1.3	1;2	1.0	1;1	2.0	1;3
OTOLIA	1.5	1;2	1.5	1;3	1.5	1;2
SALOME	1.0	1;1	1.5	1;3	1.3	1;2
TINCA	1.5	1;2	2.8	1;4	1.8	1;3
TWINNER	1.3	1;2	1.8	1;3	1.5	1;2
TWISTER	1.8	1;3	1.8	1;3	2.0	1;3
Average	1.3		2.0		1.9	

The conditions in 2022 were favourable for the health of potato plants and the yield. No late blight was detected at all 4 locations. The plots were also not damaged by pests. Late blight was observed on the variety Otolia on 4 farms, on Levante at 2 farms and on Twinner at one farm.

Overall, the trials were less affected by Rhizoctonia, silver scurf and common scab. Rhizoctonia is represented with an average score of 1.3. The most severely affected varieties were Kelly (1.8) and Twister (1.8). Silver scurf is present with an average score of 2.0. The most affected varieties were Delila (5.3) and Tinca (2.8). The most spared varieties

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are Magnolia (1), Levante (1.3) and Catrolus (1.3). Common scab affects the varieties only slightly overall, with an average score of 1.9. The most affected varieties are Kelly (4.0) and Levante (3.5). The varieties most spared are Alouette (1) and KIS Kokra (1).

Number of tubers per plant: The number of tubers per variety was slightly lower in 2021 than in 2022 (6.8 and 7.2 respectively). The order of results was similar. The lowest number of tubers was recorded for Delila (4 in 2021; 4.6 in 2022), Twinner (5.1; 6.2), Kelly (5.6; 6.2). With the highest results for Levante (9; 10.1), Salome (9.2; 8.7) and Twister (8.4; 7.6).

Table 16 Average number of tubers per plant for 13 varieties in 2021 and 2022.

	Average 2021	Min 2021	Max 2022	Range 2021	Average 2022	Min 2022	Max 2022	Range 2022	Average 21-22
ALOUETTE	7.1	4.5	10.1	4.5;10.1	7.9	4.5	8.4	4.5;8.4	7.5
BOTOND	6.0	2	7.9	2;7.9	6.5	2	10.1	2;10.1	6.2
CAROLUS	6.7	3.7	9.4	3.7;9.4	6.3	3.7	9.4	3.7;9.4	6.5
DELILA	4.0	3.3	4.9	3.3;4.9	4.6	3.3	7.2	3.3;7.2	4.3
KELLY	5.6	4.5	7.2	4.5;7.2	6.2	4.5	7.2	4.5;7.2	5.9
KIS KOKRA	7.9	3.9	11	3.9;11	7.0	3.9	8.4	3.9;8.4	7.5
LEVANTE	9.0	5.6	12.1	5.6;12.1	10.1	5.6	11	5.6;11	9.5
MAGNOLIA	7.5	3.2	9.8	3.2;9.8	8.4	3.2	12.1	3.2;12.1	7.9
OTOLIA	5.9	3.6	8.7	3.6;8.7	7.3	3.6	9.8	3.6;9.8	6.6
SALOME	9.2	3.4	15	3.4;15	8.7	3.4	9.5	3.4;9.5	8.9
TINCA	5.5	2.8	8.7	2.8;8.7	7.4	2.8	15	2.8;15	6.4
TWINNER	5.2	2	8.1	2;8.1	6.2	2	8.7	2;8.7	5.7
TWISTER	8.5	3.5	14.8	3.5;14.8	7.6	3.5	8.9	3.5;8.9	8.0
Average	6.8				7.2				7.0

Yield: Fig. 21 shows the distribution of yield for 13 varieties at 4 locations in 2 seasons. KIS Kokra and Levante had the highest medians (31.9 and 30.6 t/ha, respectively), they also reached the highest maximum yields (52.7 and 46.8 t/ha, respectively) and the highest minimum values (26.4 and 26.1 t/ha, respectively). As "all-terrain" varieties, these 2 varieties appeared to be very high-yielding regardless of weather and growing location. Twinner and Delila had the most uniform yields (14.1 and 14.2 t/ha respectively). They achieved the lowest yield under all conditions in these 2 seasons and 4 locations. Carolus and Botond were the 2 varieties with the lowest interquartile range of yield (7.0 and 7.2 t/ha, respectively). These 2 varieties were more stable regardless of location and weather conditions. Twister had the largest interquartile range in yield (23.6 t/ha) and appeared to behave very differently between production sites and/or seasons.

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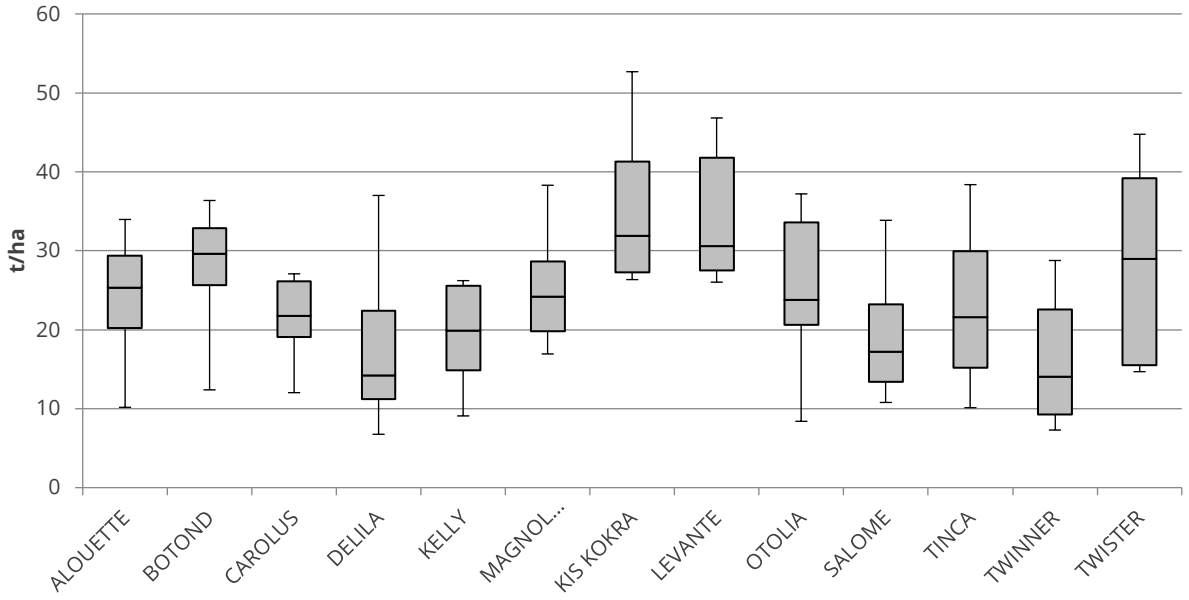

Fig. 21. Potato yield for 13 varieties at 4 locations in 2 seasons FPT 2020/2021 trials and 2021/2022 (SLO).

Tuber size and yield: Tuber size per variety was lower in 2021 than in 2022 (63.2 and 78.3 g respectively). The order of results was similar. The lowest tuber weights were Salome (34.5 g in 2021; 58.5 g in 2022), Twinner (47 g; 66 g), Alouette (55.8 g; 69.5 g). KIS Kokra (87.3 g; 92.8 g) and Botond (81.3 g; 101.8 g) had the highest results (Table 14) .

Table 1517Average tuber weight (g) for 13 varieties in 2021 and 2022.

	Average 2021	Min 2021	Max 2021	Range 2021	Average 2022	Min 2022	Max 2022	Range 2022	Average 21-22
ALOUETTE	55.75	34	97	34;97	69.5	34	97	34;97	62.625
BOTOND	81.25	58	133	58;133	101.75	54	133	54;133	91.5
CAROLUS	62.5	33	97	33;97	68.5	33	97	33;97	65.5
DELILA	69	47	105	47;105	85.75	47	105	47;105	77.375
KELLY	56.5	32	94	32;94	73.25	32	94	32;94	64.875
KIS KOKRA	87.25	56	148	56;148	92.75	56	148	56;148	90
LEVANTE	70	42	103	42;103	71.5	42	103	42;103	70.75
MAGNOLIA	63.25	38	113	38;113	79.75	38	113	38;113	71.5
OTOLIA	65.75	29	105	29;105	83	29	105	29;105	74.375
SALOME	34.5	20	68	20;68	58.5	20	69	20;69	46.5
TINCA	71	38	118	38;118	71.75	22	118	22;118	71.375
TWINNER	47	29	78	29;78	66	29	78	29;78	56.5
TWISTER	58	29	95	29;95	95.25	29	95	29;95	76.625
Average	63.2				78.3				70.7

In Fig. 22 we see the distribution of the varieties when yield is compared to the average yield of the varieties over these 2 seasons (in %) (X-axis) and the percentage of tubers over 45 mm compared to the average of this value for all varieties over the 2 seasons (in %) (Y-axis). Each point represents a result for a variety tested on a farm for one year. 28 points are in the lower left quarter (below average yield and proportion of tubers >45 mm below average). Otolia and Salome were the 2 most represented varieties in this group.

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37 points are in the upper left quarter (above-average yield and above-average proportion of tubers >45 mm). Botond and KIS Kokra were the 2 most represented varieties in this group.

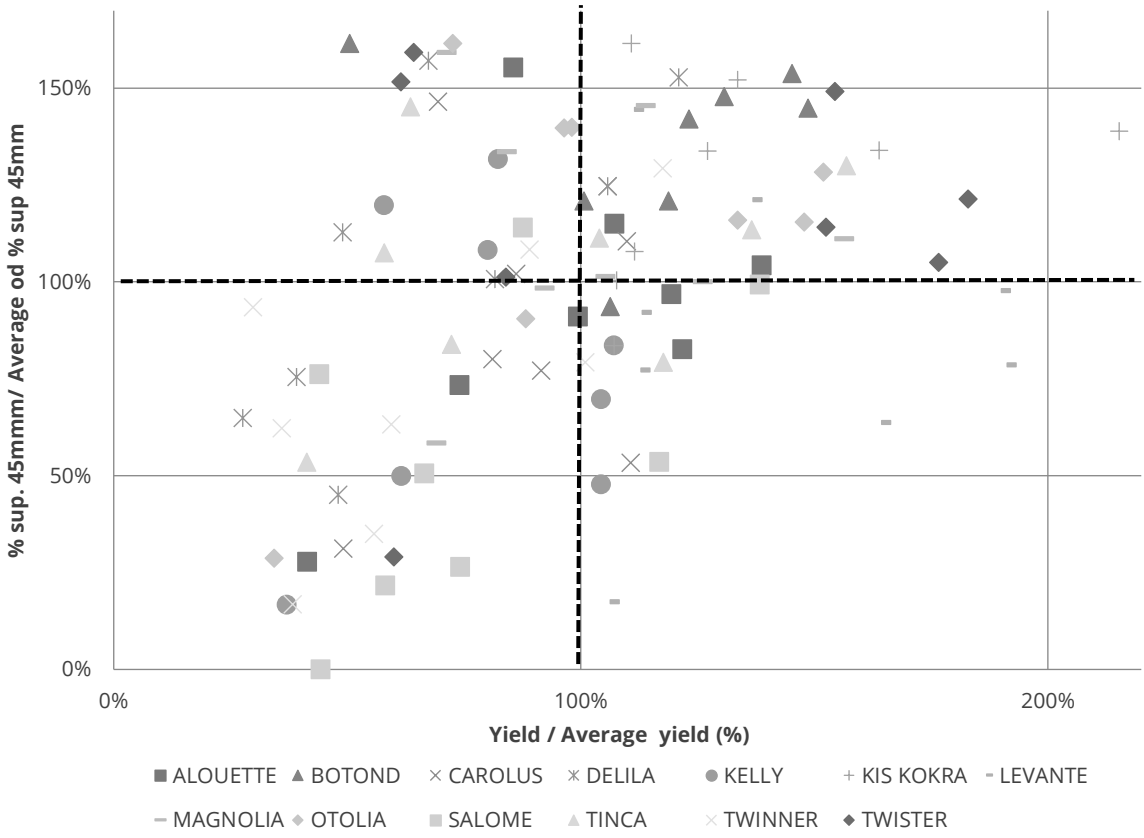

Fig. 22. Comparison of potato varieties by yield and % of tubers >45mm in 2021 and 2022 at 4 locations.

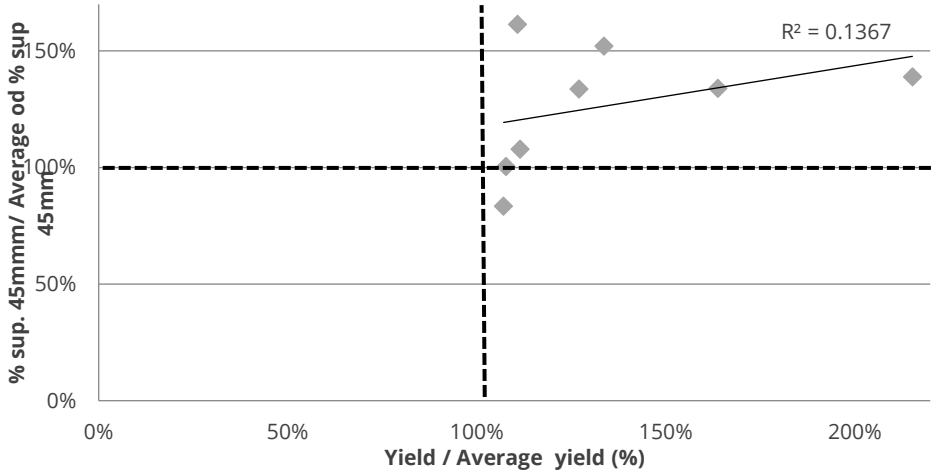

Fig 23 KIS Kokra; Yield and fraction >45mm compared to average of all varieties in 2021 and 2022 at 4 locations.

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Visual, organoleptic and chemical properties: Dry matter was almost as high in 2021 as in 2022 (22.1 and 22.2% respectively). The order of the results was similar. Magnolia (25.5; 25.9), Otolia (25.4; 25.5) and KIS Kokra had the higher dry matter content. Twinner (20.3; 18.8) and Twister (19.0; 20.2) had the higher dry matter content.

Table 16 Average dry matter for 13 varieties in 2021 and 2022.

	Average 2021	Min 2021	Max 2021	Range 2021	Average 2022	Min 2022	Max 2022	Range 2022	Average 21-22
ALOUETTE	22.6	21.0	24.7	21;24.7	22.2	19.5	23.8	19.5;23.8	22.4
BOTOND	19.8	18.9	20.9	18.9;20.9	20.7	18.7	22.5	18.7;22.5	20.2
CAROLUS	21.3	20.1	23.1	20.1;23.1	22.1	19.9	23.3	19.9;23.3	21.7
DELILA	21.4	19.3	24.6	19.3;24.6	20.3	19.2	22.0	19.2;22	20.8
KELLY	23.4	22.1	25.1	22.1;25.1	22.1	20.4	25.1	20.4;25.1	22.7
KIS KOKRA	23.0	21.9	25.3	21.9;25.3	24.4	21.2	26.8	21.2;26.8	23.7
LEVANTE	20.9	20.2	22.4	20.2;22.4	22.1	20.8	23.9	20.8;23.9	21.5
MAGNOLIA	25.5	23.8	27.2	23.8;27.2	25.9	23.7	28.8	23.7;28.8	25.7
OTOLIA	25.4	24.8	26.1	24.8;26.1	25.5	23.8	27.2	23.8;27.2	25.4
SALOME	21.6	20.1	23.4	20.1;23.4	22.3	20.4	25.2	20.4;25.2	22.0
TINCA	22.7	21.8	23.9	21.8;23.9	22.1	18.4	25.0	18.4;25	22.4
TWINNER	20.3	19.2	22.1	19.2;22.1	18.8	18.3	19.8	18.3;19.8	19.6
TWISTER	19.0	17.7	20.5	17.7;20.5	20.2	17.4	23.1	17.4;23.1	19.6
Average	22.1				22.2				22.1

All varieties had an average flavour between 2.3 and 4.8. The average values were 3.3 in 2021 and 2.9 in 2022. The best taste was achieved by Kelly, KIS Kokra and Otolioa, all 3 of which were rated 2.3 on a 2-year average. Twister (3.8), Twinner (3.8) and Botond (3.5) achieved the highest scores for the 2-season average.

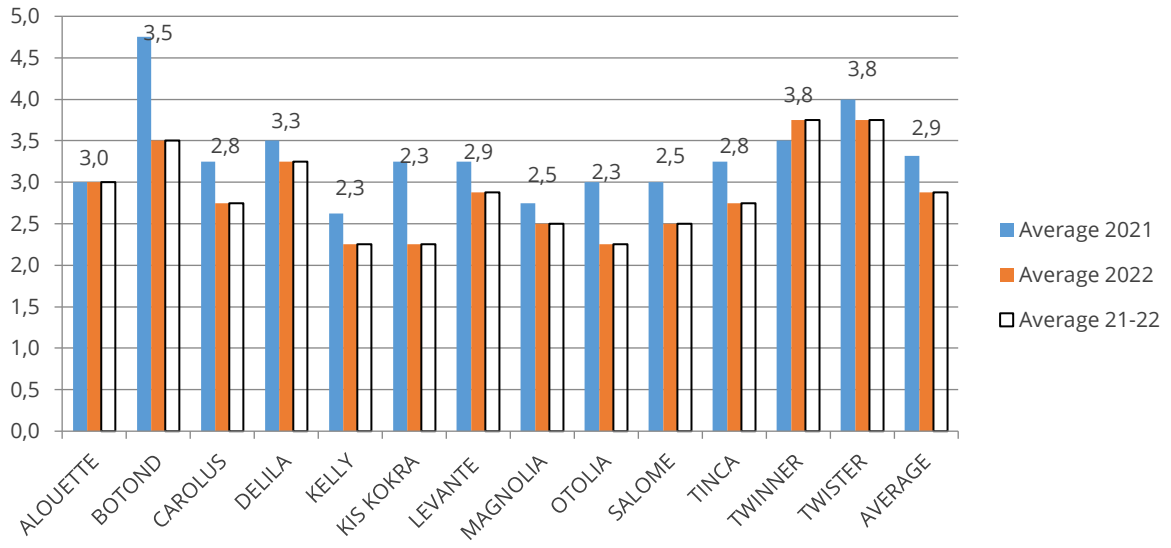

Fig. 24. Comparison of average taste for 13 varieties at 4 locations in 2021, 2022 and average of 2 seasons.

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Farmer participatory trials in Poland

In years 2020 - 2022 we had trials in 4 organic (three organic and one low input) locations with 10 potato cultivars (Alouette, Carolus, Otolia, Twister, Twinner, Levante, KIS Kokra, Tinca, Bzura, Gardena). In 2022 one additional cv (Sarpo mira) was also planted. In each location cultivars were planted with three replications. Two of these locations were on fields belonging to individual farmers from Podkarpackie voivodeship: Połomia and Tuligłowy. Another two were in the Mazowieckie voivodeship: Jadwisin and Grabów (Fig. 1). During the vegetation period cultivars were systematically evaluated for a set of phenotypic traits. In September the materials from each location were harvested. Nine cultivars were subjected to statistical analyses.

Statistical analyses were performed using AMMI model. G x E interaction analysis was performed for 9 cultivars evaluated in 12 environments. In the research we treated each location in each year as individual environment. The statistical results (Table 16) indicate significant differentiation of tuber yield among genotype in individual environments. It was found that environment (E, where E = L × Y), genotype (G) and interaction (G x E) were main effects, which significantly affected tuber yield. The contribution of factor genotype (G) to explaining the observed variability was 14.3 %, environment (E) 52.3% and interaction G x E 23.6%. It follows that, the highest influence on determining the variability of tuber yields was environment, smaller interactions G x E, while the least effect was from genotype. In AMMI analysis, the sum of squares deviations for interactions G x E has been divided on the sum of squares deviations for interaction principal components (IPC). The first five IPC were statistically significant. IPC1 was responsible for 46.1% and IPC2 for 22.6% sum of squares for interaction G x E. IPC1 and IPC2 was used for further statistical analyses.

Table 17 AMMI analysis of variance of tuber yield of potato evaluated in 12 environments (PL 2020 -2022).

Source of variation	DF	Sum of Square	Mean Square	Variability %	G x E explained %	F Statistic
Total	251	39.1594	0.1560	100.0		
Environment* (L x Y = E)	11	20.4790	1.8617	52.3		45.987**
Replication (R)	16	0.6477	0.0405	1.7		1.634
Genotype (G)	8	5.6138	0.7017	14.3		28.325**
Genotype x Environment (G x E)	88	9.2477	0.1051	23.6		4.242**
IPC 1	18	4.2657	0.2370	10.9	46.1	4.242**
IPC 2	16	2.0936	0.1309	5.3	22.6	2.873**
IPC 3	14	0.9752	0.0697	2.5	10.5	2.159**
IPC 4	12	0.8059	0.0672	2.1	8.7	1.931**
IPC 5	10	0.4604	0.0460	1.2	5.0	1.596**
IPC 6	8	0.3663	0.0458	0.9	4.0	1.451
IPC 7	6	0.2016	0.0336	0.5	2.2	1.133
IPC 8	4	0.0790	0.0197	0.2	0.9	0.797
Error	128	3.1711	0.0248	8.1		

**P<0.01; DF = Degrees of freedom; *Environment = Location x Year; IPC = interaction principal component

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In the next step cultivars with broad adaptation to differ were environmentally distinguished. In Table 17, these statistics are presented: mean values for tuber yield (kg/bush), standard deviation (SD), index for ranks for mean, measure of yield advantage of the i-th cultivar (Ri) and measure Kang (YSi). The highest tuber yield was noted for cvs. Twister (1.19), Alouette (0.96) and Otolia (0.95). The analysis of cultivars in terms of measures of broad adaptation showed that cvs. Twister, Alouette, KIS Kokra, Otolia and Bzura have a higher degree of adaptation in a broad sense, while cvs. Twinner, Carolus, Gardena and Levante have a lower degree of adaptation in a broad sense. Cultivars with Ri closer to 1 always yielding above environmental means. Measure Kang (YSi) showed that cultivars Twister, Alouette, KIS Kokra, Levante and Gardena characterised by a relatively higher (compared to other cultivars) degree of wide adaptation.

Cultivars Twister, Alouette, KIS Kokra, Levante and Gardena can be recommended for the ecological cultivation across all environments in Poland. A different response of potato cultivars to environmental factors suggests that there is a need to select potato cultivars in various locations and years.

Table 20 Measures of wide adaptation for 9 potato cultivars for tuber yield (PL 2020 -2022).

Cultivar	Mean	SD	Rank	Measure of yield of advantage of the *i-th* cultivar (R_i)	Measure Kang (YS_i)
Alouette	0.92	0.36	3	0.75 (2)	8 (2)
Bzura	0.85	0.24	6	0.58 (5)	0 (7)
Carolus	0.71	0.28	8	0.08 (8)	0 (7)
Gardena	0.78	0.26	7	0.33 (7)	2 (5)
Kokra	0.89	0.41	4	0.75 (2)	7 (3)
Levante	0.86	0.39	5	0.50 (6)	3 (4)
Otolia	0.95	0.54	2	0.67 (4)	1 (6)
Twinner	0.63	0.29	9	0.08 (8)	-1 (9)
Twister	1.19	0.45	1	0.92 (1)	12 (1)

The GGE biplots analysis based on AMMI model for performance of 9 potato cultivars were constructed based on the values of the first two interactions principal component scores (IPC1 and IPC2) which explained 68.7 % of the potato yield variation due to genotype and G x E interaction. Fig 25 shows the association or relationship between the different environments and cultivars. Environments which are located at larger distances from the centre of biplot contributed the most to G × E interaction. Environments with small vector angles tend to have closer similarity and those with wide vector angles show minimum association. The greatest contribution in this interaction was observed for environments: Grabów 2021, Tuligłowy 2020 and 2021, while the smallest one for: Jadwisin 2021 and 2022, Grabów 2022, Połomia 2020 and 2021. Cultivars and environments on the right side of the figure have higher tuber yields than average. While cultivars and environments on the left side have tuber yield below average. Cultivars yielding better than environmental average was cvs.: Twister, Otolia, Alouette, KIS Kokra

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and Levante, while weaker than environmental average cvs.: Bzura, Twinner, Carolus and Gardena.

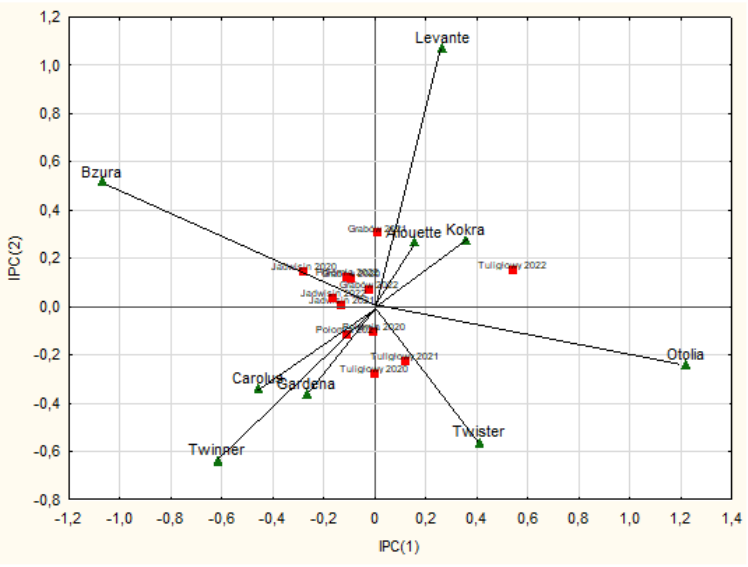

Fig. 25. Biplot analysis of GEI for first two IPC scores (IPC1 vs IPC2) for tuber yield (PL 2020 – 2022).

On Fig. 26 are presented cultivars and environments relative to first IPC1. Cultivars and environments which are located near axis IPC1 (with small effects of IPC) characterised by small participation in interactive variability. These cultivars and environments can be classified as stable. The GGE biplot analysis shown that Twister, Alouette, KIS Kokra and Levante was the most stable cultivars in tuber yield in all 12 environments and can be considered as adaptable to all environments.

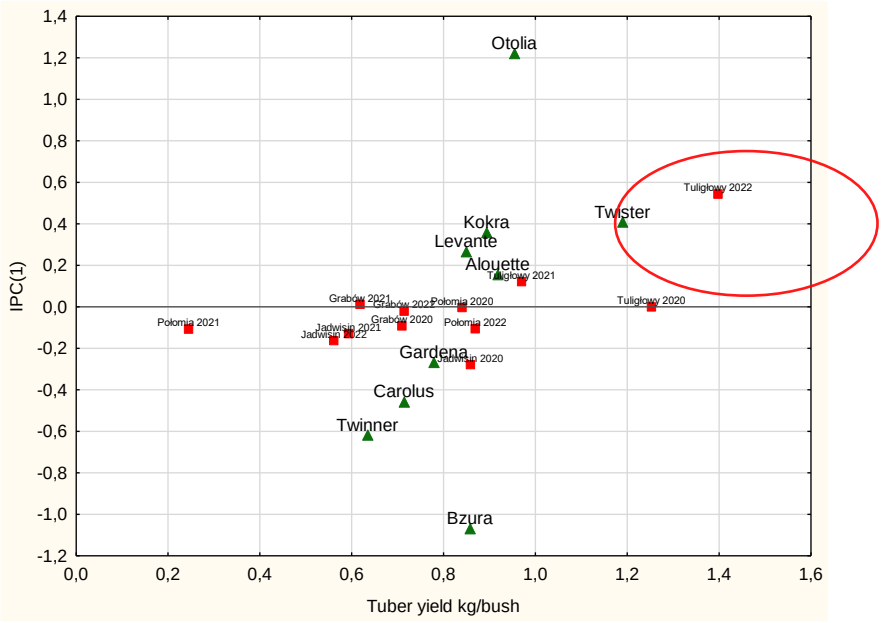

Fig. 26. Biplot analysis of GEI for the IPC1 scores and tuber yield of 9 potato cultivars across 12 environments (PL 2020 – 2022).

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Morphological traits of potato tubers (PL 2019 – 2021)

After harvesting morphological traits of potato tubers were assessed. In each year yield was evaluated in terms of regularity of tuber shape and depth of eyes. These characters of tubers were assessed on a 1-9 scale where 9=the best.

Potato tubers from three years of experiments had good regularity of tuber shape and shallow depth of eyes. The following data are presented in Table 18: mean values for regularity of tuber shape and depth of eyes, standard deviation (SD) and rank for mean values. Analysis of variance for regularity of tuber shape and depth of eyes are also presented. It was found that genotype (G), localisation (L), year (Y) and all interactions (double and triple) were significantly affected regularity of tuber shape. Analysis of variance for depth of eyes showed statistically highly significant differences for genotype (G) and interactions (G × L), (G x Y) and (G x L x Y).

Table 18 Mean values and standard deviations for depth of eyes and regularity of tuber shape in individual years (PL 2020 – 2022).

Year	Depth of eyes (scale 1-9)		Regularity of tuber shape (scale 1-9)	
	Mean	SD	Mean	SD
2020	7.4	±0.06	7.0	±0.08
2021	7.3	±0.11	6.8	±0.13
2022	7.3	±0.08	7.0	±0.09

Table 19 Result for mean values, standar deviation, index for ranks for mean values for depth of eyes and regularity of tuber shape (PL 2020 – 2022).

Cultivar	Depth of eyes (scale 1-9)			Regularity of tuber shape (scale 1-9)		
	Mean	SD	Rank	Mean	SD	Rank
Alouette	7.8	±0.34	1	7.6	±0.49	1
Bzura	6.1	±0.61	7	5.8	±0.94	8
Carolus	7.6	±0.46	3	7.4	±0.54	2
Gardena	7.3	±0.44	5	6.6	±0.66	6
KIS Kokra	6.6	±0.46	6	6.5	±0.49	7
Levante	7.8	±0.39	1	7.1	±0.74	5
Otolia	7.4	±0.57	4	7.1	±0.69	5
Twinner	7.6	±0.52	2	7.3	±0.57	3

Table 20 ANOVA results for morphological traits (PL 2020 – 2022).

Sources of variation	ANOVA (two – way)				
	Sum of Squares	Degrees of freedom	Mean Square	F Statistic	
	ANOVA results for regularity of tuber shape				
Genotype (G)	60.91	8	7.61	65.13***	
Localisation (L)	3.97	3	1.32	11.32***	
Year (Y)	1.36	2	0.68	5.82**	
(G)x(L)	10.78	24	0.45	3.84***	
(G) x (Y)	8.25	16	0.52	4.41***	

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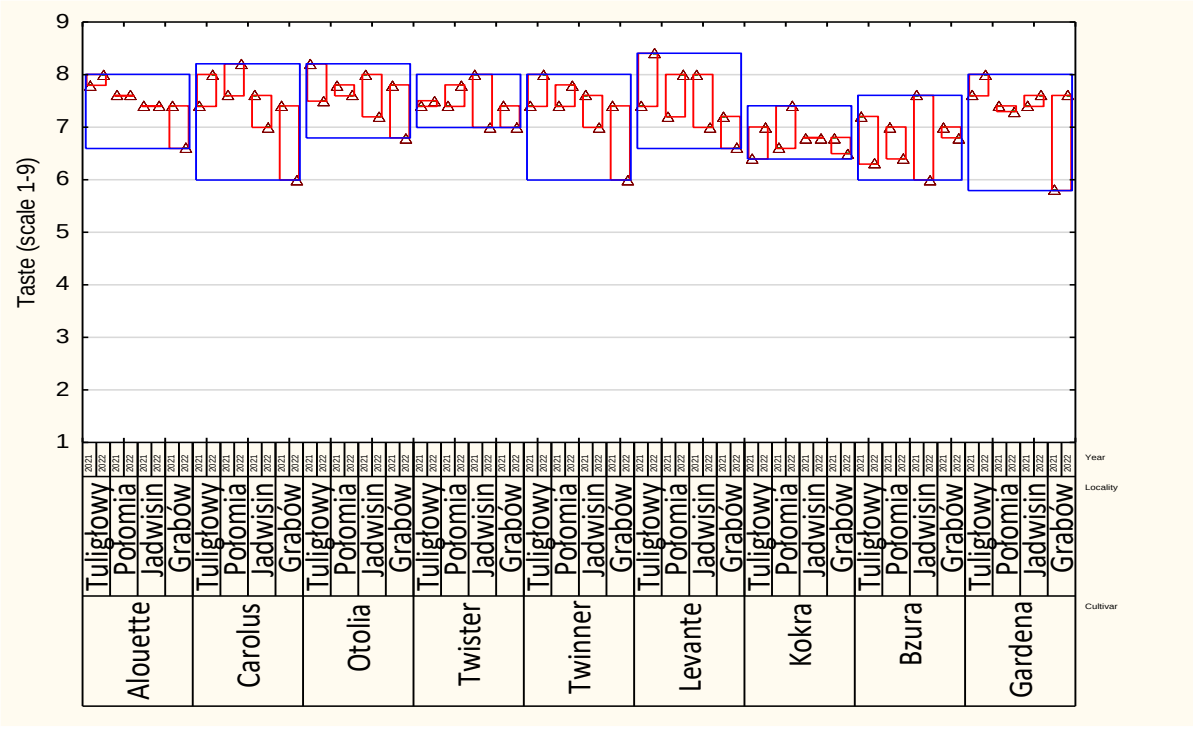
(L) x (Y)	2.45	6	0.41	3.49**	
(G) x (L) x (Y)	10.90	48	0.23	1.94***	
Error	16.83	144	0.12		
	ANOVA results for depth of eyes				
Genotype (G)	61.225	8	7.653	33.91***	
Localisation (L)	1.471	3	0.490	2.17	
Year (Y)	1.280	2	0.640	2.84	
(G)x(L)	23.721	24	0.988	4.38***	
(G) x (Y)	14.728	16	0.920	4.08***	
(L) x (Y)	2.590	6	0.432	1.91	
(G) x (L) x (Y)	21.424	48	0.446	1.98***	
Error	32.500	144	0.226		

*** significant at p < 0.001; ** significant at p < 0.01

Assessment of culinary traits (PL 2020-2021)

By two years of experiments cooking quality (taste, texture and discoloration of tuber flesh) were assessed. All tested cultivars were characterised in individual year and localisation by good taste and non-darkening of flesh tubers both raw and cooked. Mean values for taste and non-darkening of flesh are presented in Fig 27. Statistical analysis showed that genotype (G) and localisation (L) were main effects, which significantly affected values obtained for taste of potato tubers and on non-darkening of flesh tubers both raw and cooked.



*significant at P < 0.05

Fig. 27. Taste of potato cultivars (PL 2020 – 2021).

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Table 21 ANOVA results for darkening and taste of potato tubers (PL 2020 – 2021).

Sources of variation	ANOVA (Main Effects)			
	Sum of Squares	DS	Mean Square	F Statistic
ANOVA results for darkening of potato tubers 10 minutes after cooking				
Genotype (G)	12.069	8	1.509	8.53***
Year (Y)	0.500	1	0.500	2.83
Localisation (L)	3.819	3	1.273	7.20***
ANOVA results for darkening of potato tubers 24h after cooking				
Genotype (G)	13.780	8	1.723	7.54***
Year (Y)	0.073	1	0.073	0.32
Localisation (L)	7.856	3	2.619	11.46***
ANOVA results for darkening of potato flesh 4h after cutting raw state				
Genotype (G)	5.537	8	0.692	2.26*
Year (Y)	0.002	1	0.002	0.01
Localisation (L)	13.121	3	4.374	14.30***
ANOVA results for taste				
Genotype (G)	5.718	8	0.715	3.32*
Year (Y)	0.451	1	0.451	2.09
Localisation (L)	4.296	3	1.432	6.64***

ns=not significant; *significant at P < 0.05; *** significant at P < 0.001

Potato tubers from four ecological localisations were characterised by two years experiments in terms of cooking quality. In Table 22 are presented values for cooking quality types for 10 cultivars. Variability of cooking type was observed depending on year and place of cultivation.

Table 22 Cooking type (PL 2021 – 2022).

	Year 2021				Year 2022			
Cultivar	Tuligłowy	Połomia	Grabów	Jadwisin	Tuligłowy	Połomia	Grabów	Jadwisin
Alouette	BC	BC	BC	BC	B	A	BC	C
Carolus	B	BC	AB	AB	B	A	A	AB
Levante	BC	BC	BC	AB	B	AB	B	BC
Twinner	BC	AB	B	AB/C	AB	AB	BC	AB
Twister	BC	BC	C	B	BC	AB	AB	AB
Otolia	BC	BC	BC	AB	AB	AB	BC	B
KIS Kokra	BC	BC	BC	BC	BC	B	C	BC
Bzura	CD	CD	BC	CD	C	AB	CD	C
Gardena	BC	BC	BC	BC	BC	BC	BC	BC
Sarpo Mira	BC	BC	BC	BC	C	B	BC	BC

Type A – salad, tubers remain whole after boiling, firm, easy to cut out with fine structure, suitable for salad.
Type B – multi – purpose for salad, mashing, french fries, flesh slightly mealy, slightly moist with fairy fine structure.
Type C – mealy for mashing and baking.
Type D – very mealy, it has limited consumption use, for dry and coarse purée and for baking.

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Content of total (TC) and individual carotenoids (IC) (PL 2020)

Total Carotenoid Content (TC) was estimated for tubers obtained from field experiments. For each potato cultivar and each repetition, three tubers were collected, cut into small cubes, frozen in liquid nitrogen, freeze-dried and milled. All analyses were performed using three technical repetitions.

In Fig 28 the mean values of total carotenoid content (TC) in four locations are presented. Mean TC content of tubers ranged from 279.0 µg/100g DM (in Jadwisin) to 332.2 µg/100g DM (in Grabów). Mean lutein content in potato tubers ranged from 51.8 µg/100g DM (in Tuligłowy) to 83.3 µg/100g DM (in Jadwisin). Content of zeaxanthin in all locations were very low and ranged from 1.2 µg/100g DM (in Tuligłowy) to 4.7 µg/100g DM (in Jadwisin).

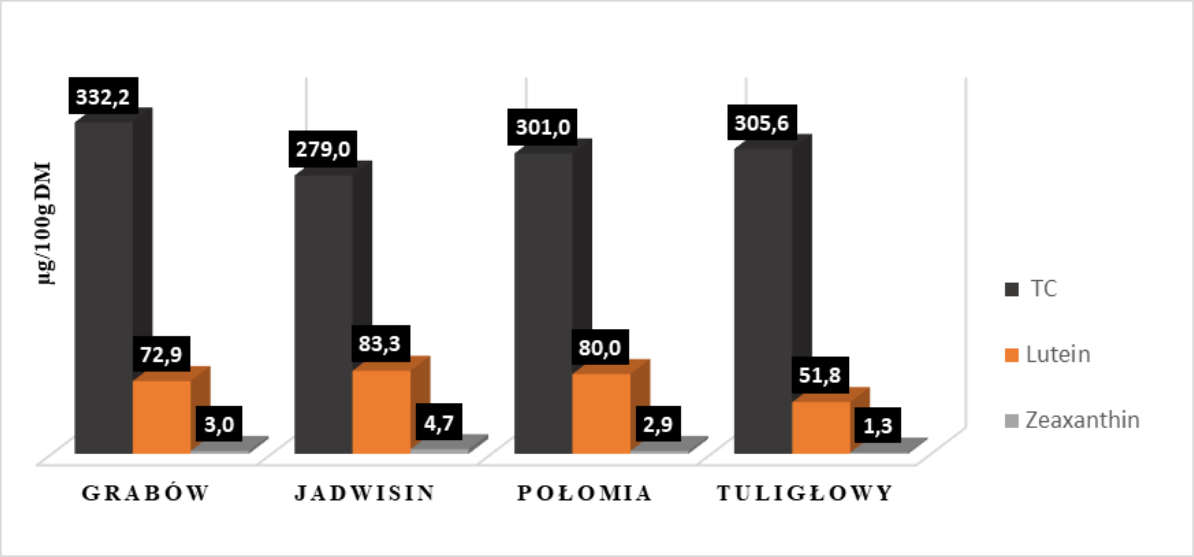

Fig. 28. Content carotenoids (TC and IC) in potato tubers harvested in four localisations (PL 2020).

The values of total carotenoid content (TC) in four ecological localisations for each cultivar are presented in Fig 29. In the group of cvs. from Grabów with the highest level of TC were Gardena, Levante, Otolia, and Twister. Mean values for these cultivars ranged from 468.5 µg/100g DM to 410.3 µg/100g DM. Cultivars from Grabów with the lowest TC are Tinca, Twinner, Bzura and Carolus. Mean values for these cultivars ranged from 151.6 µg/100g DM to 297.1 µg/100g DM. In Jadwisin cvs. with highest TC were KIS Kokra, Twister, Gardena and Otolia. TC for this cvs. ranged from 302.0 µg/100g DM to 373.1 µg/100g DM. The lowest TC in Jadwisin were noted for cvs. Twinner (151.6 µg/100g DM) and Tinca (156.5 µg/100g DM). In Połomia the highest content of TC in potato tubers were noted for two cvs. Twister (429.9 µg/100g DM) and Otolia (408.7µg/100g DM). The least TC were noted for cvs. Twinner (153.2 µg/100g DM) and Tinca (169.4 µg/100g DM). In Tuligłowy the highest TC were produced by cv Otolia (450.7 µg/100g DM) and the lowest by cv Twinner (132.2 µg/100g DM).

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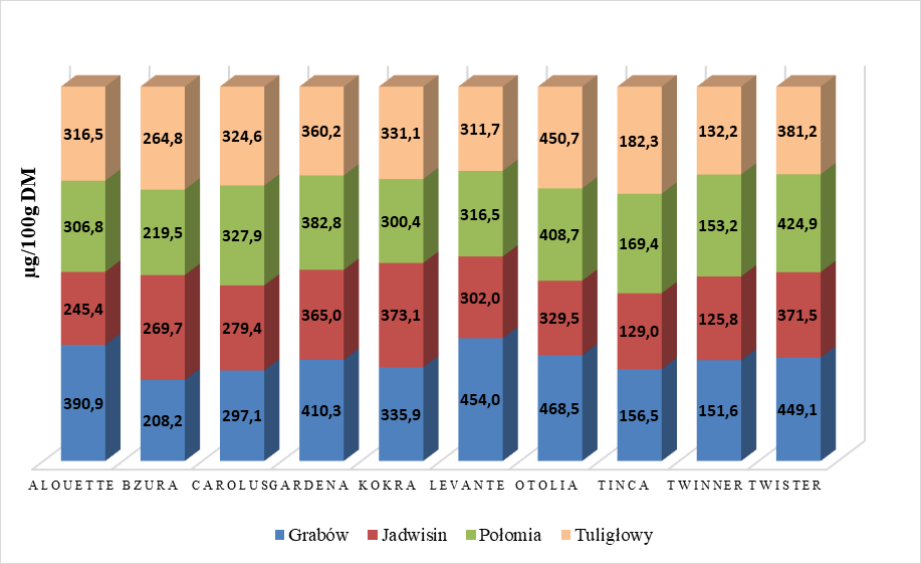

Fig 29 Content of total carotenoids in ten potato tubers harvested in four locations (PL 2020).

Fig 30 presents content of lutein for 10 cultivars evaluated in four ecological locations. The highest variability in the content of lutein depending on the place of cultivation was observed for cv Gardena (range from 12.0 µg/100g DM in Grabów to 102.0 µg/100g DM in Jadwisin). Potato cultivars showed great variability in terms of total and individual carotenoid accumulation in tubers. The concentration of carotenoids in potato tubers were affected both by genotypes and location.

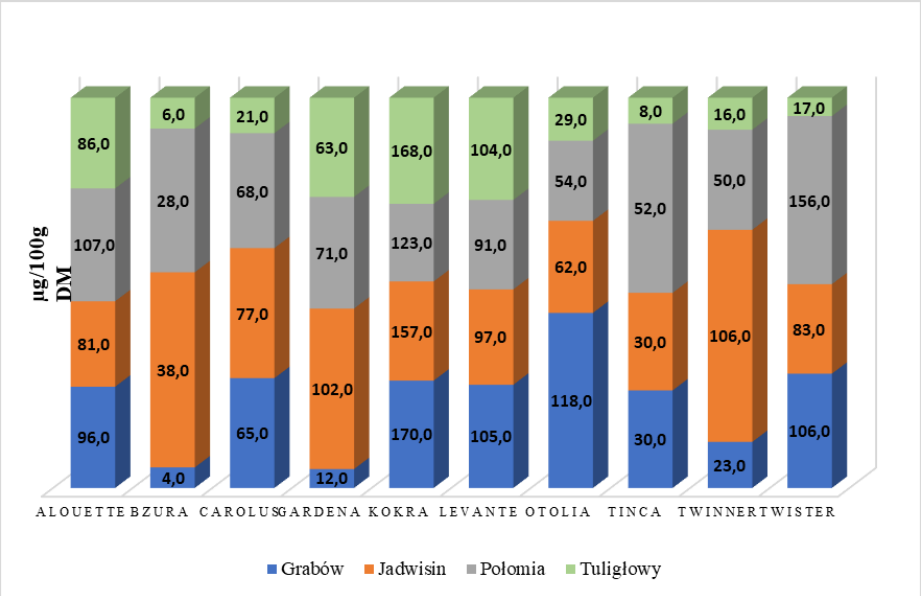

Fig 30 Content of lutein in potato tubers harvested in four locations (PL 2020).

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Farmer participatory trials in Hungary

Goals

To educate organic potato growers how to test and evaluate potato varieties under organic conditions by evaluating a commonly selected list of varieties advised for organic growing with the co-operation of growers and professional potato researchers/breeders. The additional goal was to compare different varieties at different locations under different farming management and ecological conditions to test their adaptation to local circumstances.

Methods

Farmers participatory trials were set up in 2020-2023 in Hungary. During the first two years at four organic farms, at three farms in 2022 and at one in 2023.

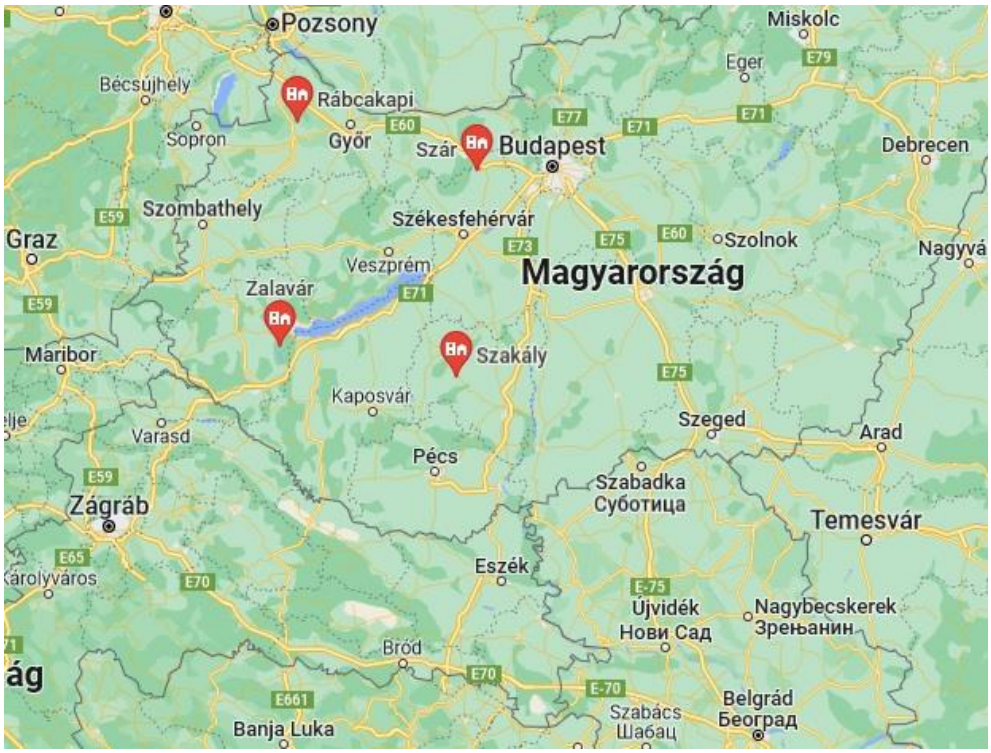

Fig. 31. Location of organic farms involved into the trials in Hungary.

The list of tested varieties is in Table 23. One hundred tubers were planted from each variety at all locations in a non-replicated trial. The plantings were done in April. Each partner used its own regular farming methodology to manage the trials (nutrition, weed and pest management). Measured parameters were recorded partially by the farmers e.g. canopy closure, flowering and ripening time, late blight and early blight infection, total yield, while the tuber characteristics and quality measures (tuber size, dry matter, cooking type, after cooking discoloration, tuber disorders, regularity of tuber shape, depth of eyes) were done by the Potato Research Station of MATE.

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Table 23 List of tested varieties.

2020-2022	2023	Maturity	Resistance to late blight	Resistance to PVY
OTOLIA		intermediate	yes	no
LEVANTE		intermediate	yes	no
ALOUETTE	ALOUETTE	intermediate	yes	no
KIS KOKRA	KIS KOKRA	intermediate	yes	yes
MAGNOLIA		early	no	yes
TINCA		intermediate	yes	moderate
TWISTER		early	yes	moderate
TWINNER		early	yes	moderate
BASA	BASA	intermediate	moderate	yes
BALATONI RÓZSA	BALATONI RÓZSA	early	no	yes
BALATONI SÁRGA	BALATONI SÁRGA	intermediate	no	yes
BOTOND	BOTOND	early	moderate	yes

General circumstances of trials: Farms of Zalavár and Szakály work under non-irrigated conditions on middle heavy soils, while the farm at Szakály and Rábcakapi could work on lighter soils and under irrigated conditions. Weather conditions of all the four seasons could be characterised by less precipitation and higher summer temperatures than the long-term average. From the beginning of the summer, a high degree of drought was characteristic, which reached its peak in general second half of July and early August. Several times, highest daily temperatures reached 35 °C or above. Especially the year of 2022 was dramatic from this point of view when the drought period lasted for almost three months and the highest temperatures could reach the 40 °C.

Damage by Colorado potato beetle was present in each year but could be effectively managed by farmers with 1-2 times spraying with organic insecticide LASER PLUS. Weeds were present on the field especially during the third decade of vegetation period but not noticed as a significant problem by the farmer. They applied mechanical weed control techniques.

Weather conditions in general did not favour development of fungal diseases like early and late blight but was very much favourable for the spreading and epidemy of aphid transmitted viruses (especially PVY). Most of the PVY susceptible varieties become 100 % infected by the virus during the first years of the experiment.

Results

Yield: The plant height of varieties was different between locations and seasons. Average plant height data are presented in Fig 32. Longest shoots were developed by variety Botond, while the shortest by Balatoni rózsa (both are early type of potatoes). Longer shoots were recorded under irrigated conditions in comparison to non-irrigated ones.

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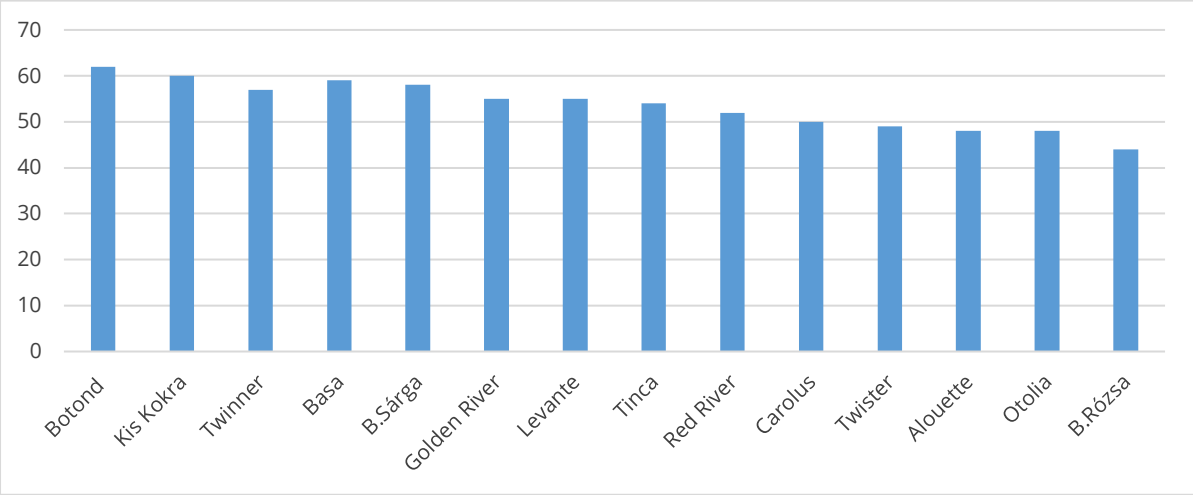

Fig 32 Summarised average plant height (cm)of tested varieties.

In terms of total yield there was dramatic differences between seasons and at bit lower extent between locations. Year 2022 had the smallest yield at all the locations with as small as 7.03 t/ha average total yield of varieties. The bests season for potato production was 2020 where the average total yield reached 23.66 t/ha, if we do not count year 2023 (32 t/ha) when new varieties have been involved into the trials (Red river, 38.6 and Golden river 32.6 t/ha). The lowest yield has been reached at the two non-irrigated locations in 2022 (7.92 t/ha at Zalavár, and 1.88 t/ha at Szár). The highest yield was reached by variety Botond at Rábcakapi, in 2023 (38.8 t/ha).

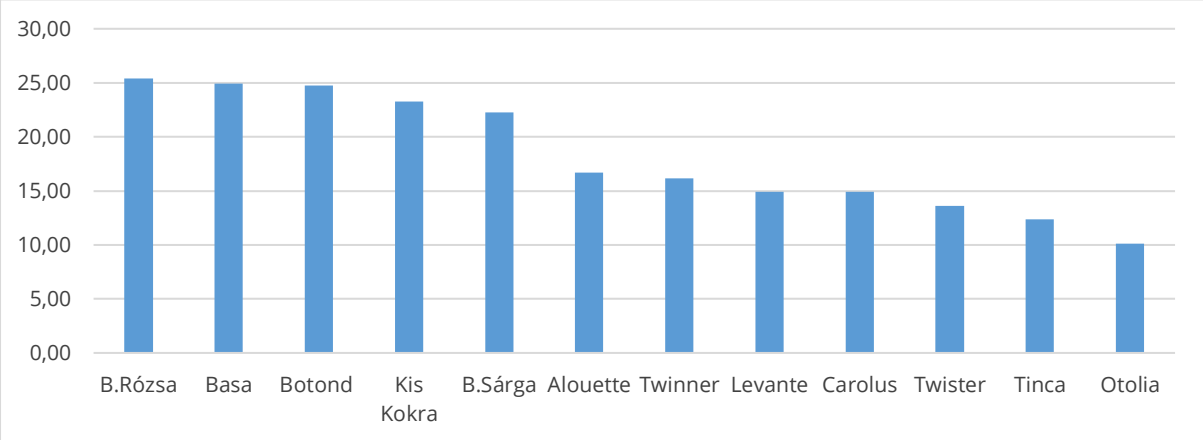

Fig 33 Summarised average total yield of tested varieties (t/ha).

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The relatively low yield of Wester-European varieties is necessarily connected to their PVY susceptibility that caused virological degeneration and yield loss. Due to this reason we decided to involve new resistant varieties into the trial in 2023. Fig 34 shows the tuber size distribution of the varieties as the average of trial years.

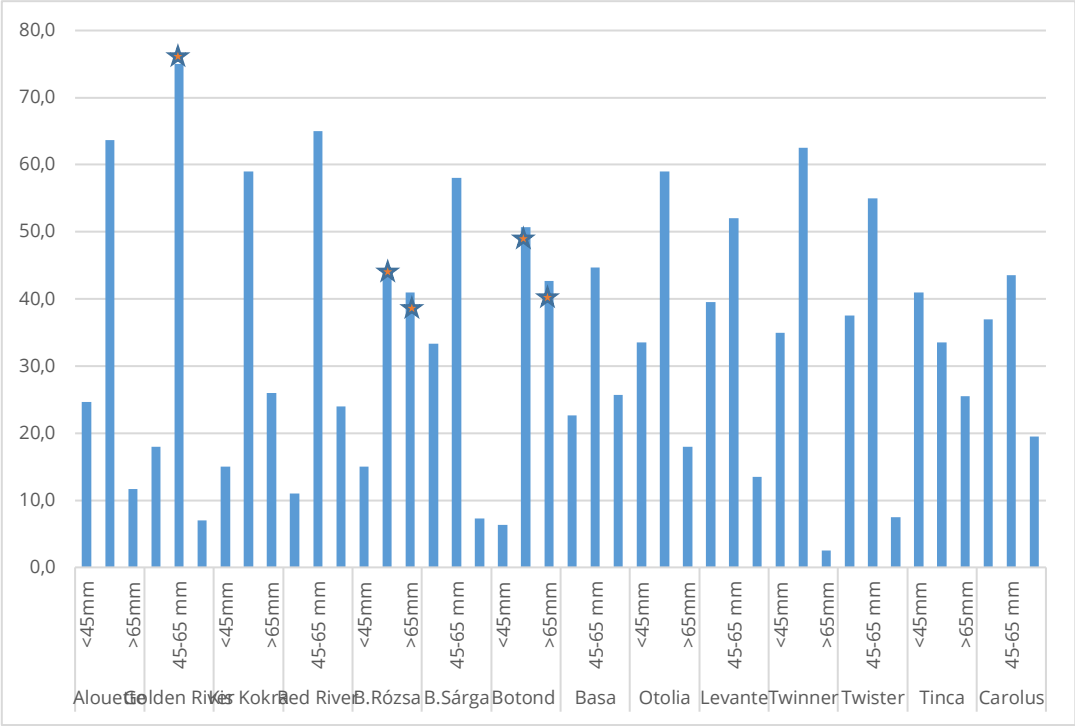

Fig 34 Summarised average of tuber size distribution.

The highest ratio of middle and large sized tubers was produced by the two early varieties, Balatoni rózsa and Botond, while the highest ratio of medium sized tubers was produced by variety Golden river (marked with stars, one year result for Golden river only). Highest ratio of the smallest tubers was produced by the virus susceptible varieties especially under non- irrigated conditions at locations Szár and Zalavár.

Tuber quality parameters

Starch content and cooking type: Dry matter and starch content of potato tubers is in strong correlation to classification into different cooking quality classes. Varieties with lower starch content in general belong to cooking type A or AB (salad varieties). High starch content varieties belong to class C, regularly recommended for frying. General purpose varieties belong to classes B or BC, however other traits e.g. size of starch granules, strength of cell walls etc. has an effect on cooking type too.

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In our trials, in general, starch content and cooking type of the varieties was found to be a stable character and not much different due to season or location/production technology.

Table 24 Cooking type of tested varieties determined at each test location.

Varieties	Cooking type			
	Zalavár	Szár	Rábcakapi	Szakály
Otolia	AB	AB	B	B
KIS Kokra	B	BC	B	B
Tinca	B	B	B	B
Levante	B	BC	B	B
Twinner	B	B	B	B
Twister	B	B	B	B
Alouette	BC	BC	B	B
Carolus	B	B	B	B
Balatoni rózsa	B	B	B	B
Botond	B	B	B	B
Basa	A	A	A	A
Balatoni sárga	B	B	B	B
Golden river			BC	
Red river			BC	

The highest starch content was produced by the varieties Golden river, Red river and Alouette, while the lowest was Botond.

Tube quality traits

Tuber quality traits were determined by testing samples collected from the experimental sites. Tests were done at the Potato Research Station of MATE based on scoring for raw discoloration and after cooking discoloration of tubers as well as scoring for cooked taste.

Table 25 Summarised tuber quality traits of tested varieties.

Varieties	Row discoloration	Cooked discoloration	Taste
Alouette	3	3	4
Golden River	1	1	1
KIS Kokra	2	3	2
Red River	2	2	2
Balatoni Rózsa	2	1	2
Balatoni Sárga	1	1	1
Botond	2	2	2
Basa	1	1	1
Otolia	3	2	2
Levante	3	2	3
Tinca	3	2	3
Twinner	3	2	3
Twister	1	2	2
Carolus	3	1	3

In general, we could state that quality traits of all the varieties reached the limit of GOOD on 1 to 9 scale, where 1 means the best quality. The examined traits were found to be stable and no big differences were found between seasons and trial sites.

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Plant pathology survey of varieties

During the 4 years of the trials plant pathological evaluations of the varieties was done by the participating farmers. Estimation of resistance was based on the affected leaf or tuber surface area (%) and on a 1-9 scale, where 9 nine means the highest resistance or less infection detected.

Incidence of leaf diseases (late blight and early blight) was influenced by the season and the cultural practice (irrigated or non-irrigated conditions). All the seasons in general were dry and hot which was not favourable for late blight disease due to high temperatures and low air humidity, even on irrigated fields. Partially this could be the reason why the varieties have got a relatively high resistance score for late blight. For the development of early blight in general the environmental factors during the second half of the vegetation period were more advantageous. Especially early varieties showed a higher susceptibility to this pathogen closer to their senescence and this is the reason why they have got somewhat lower resistance scores for early blight disease.

In case of tuber diseases, season and location (infection of the soil by the certain pathogen) may highly influence the incidence of tuber diseases. In general, there was only a limited, negligible infection by these pathogens during the tests, so the varieties could get high resistance scores. Only in the case of fusarium disease, in 2022 season at the non-irrigated site Zalavár we detected a high infection (8-9 %), especially for the varieties Twister, Balatoni rózsa and Botond.

Table 29 Pathological survey summary of tested varieties.

Varieties	PVY	Late blight	Early blight	Tuber resistance (Rhizoctonia/Silver scarf/Common scab)
Alouette	6	7,5	6	7
Golden River	9	7	6,5	8
KIS Kokra	8	7	4	7
Red River	9	6	6,5	7
Balatoni Rózsa	9	6,5	7	7
Balatoni Sárga	9	6,5	6,5	7
Botond	9	7	5	7
Basa	9	7	6	8
Otolia	2	7,5	5	6
Levante	5	7,5	5	7
Tinca	3	7,5	7,5	7
Twinner	2	7,5	4,5	7
Twister	3	8	6	7
Carolus	3	7,5	4,5	6

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Summary

Summarising the results of the four experimental years, we can conclude that during this time both the growers and researchers have gained a lot of valuable experience. The growers were able to familiarise themselves with the varieties and new variety candidates most recommended by the breeders for organic cultivation. They gained experience on what kind of traits and how to take them into account when choosing the varieties to grow. For example, it has been proven that resistance to viruses (especially PVY resistance) plays a huge role under Hungarian ecological conditions. Without PVY resistance, susceptible varieties lose their productivity in just 1-2 years, and because of this, they need constant seed potato renewal, which greatly impairs the economics of production. Hungary can be considered a uniform area in terms of the climatic conditions for organic potato cultivation. Despite the different soil type, cultivation method of the individual experimental sites and resistance to fungal diseases, it was not these factors, but the virus resistance and maturity type (earliness) of the varieties that most determined the yield quantity and size distribution of tubers. During the study years, the growers were able to successfully control the damage caused by the potato beetle and phytophthora infection. The only thing that caused a problem in the foliage protection of varieties was Alternaria infection that appeared mostly towards the end of the growing season. In terms of quality characters, all tested varieties passed the exam excellently. Despite belonging to different cooking types, none of the varieties had to be downgraded due to either their raw or after cooking darkening or an unpleasant taste.

Farmer participatory trials in Germany

In Germany, four additional farmer participatory trials with potatoes were conducted in 2020-2022. The reason for these trials was that there is relatively little knowledge about late blight resistant/tolerant varieties in Germany compared to other countries such as France or the Netherlands. We rarely find resistant/tolerant varieties on the official lists of recommended varieties. But this would be crucial for the copper fungicide reduction strategy. In Germany, too, there were prejudices against late blight resistant/tolerant varieties: There are no varieties that taste good and there are no varieties with firm cooking texture. We were able to refute this with our trials.

2020

In Germany 14 varieties (100 tubers each) were planted at Greve farm in Schleswig-Holstein. The score of late blight on 11 August showed good differences between 2.5 (Sevilla) and 9 (Julinka, KIS Slavnik). The yield in dt/ha was between 477 (KIS Slavnik) and 692 (Sevilla, Allians). The taste was scored by two expert test panels as a public test was not possible because of covid-19 restrictions.

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Table 26 FPT at Greve Farm in Germany in 2020.

Variety	Maturity	Late blight 11.8. (1 low -9 high)	Yield dt/ha	Floury (1-7)	Colour (1-5)	Defects in taste (1-9)	Other criteria
Julinka	Early	9,0	674	low (3)	Yellow (4)	Low (2,8)	
Vitabella	Early	Mature	480	Low-medium (4)	Light yellow (3)	Low-medium (4,2)	Iron stains
Allians	Medium-early	8,5	692	low (3)	Yellow (3,8)	Low (2,7)	Wire worms, scab, damage
Simonetta	Medium-early	8,0	632	low (3)	Yellow (4,2)	Very low-low (2)	Virus
Otolia	Medium-early	7,0	573	Low-medium (4)	Light yellow (3)	Low (2,5)	Early blight
KIS Slavnik	Early	9,0	477	Low-medium (4)	Light yellow (2,7)	Low (2,5)	
Tinca	Medium-early	6,0	625	Low-medium (4)	Yellow (3)	Low-medium (4,1)	
Sarpo mira	Medium-late	3,7	612	Low-medium (4)	Light yellow (2)	Low-medium (3,7)	
Carolus	Medium-late	7,0	528	low (3)	Light yellow (3)	Low-medium (3,7)	Black spots
Levante	Medium-late	6,5	754	Low-medium (4)	Yellow (3,8)	Very low-low (2)	Scab
Cammeo	Medium-late	6,5	668	low (3)	Light yellow (2,5)	Medium (4,8)	
Tentation	Medium-late	7,0	520	Low-medium (4)	Light yellow (3)	Low (3)	
Sevilla	Medium-late	2,5	692	Low-medium (4)	Yellow (3,8)	Low (3)	
BIM 13-678-1	Medium-late	7,2	580	Low-medium (4)	Yellow (3,3)	Low (3,2)	Draught tolerant

2021

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

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Table 27 Results of potato FPT in Germany 2021.

Variety	Agria	Twister	Tenta-tion	Sevilla	Otol-ia	Levan-te	Allians	Mar-quise	Lau-ra	Lin-da
Late blight	9	6	6	3	4	5	5	9	9	9
Early blight	X									
Col. Beetle	6	5	6	5	3	6	6	6	6	7
yield t/ha	80	106	57	94	118	70	37	100	100	120
size >65mm	10	37	6	11	3	3	4	9	16	3
45-65 mm	51	51	45	56	34	53	39	53	36	13
size <45mm	39	12	49	33	63	44	57	38	48	74
Cooking type	3	2	6	6	6	6	2	4		2
Taste	2	1	4	2	2	3	2	2		2

Diseases and pests: 1 low, 9 high; Cooking type: 1 mealy, 9 firm; Taste: 1 good, 9 bad

2022

In 2022 two additional trials at Jobst farm and Hörl farm were planted and harvested. At Jobst farm 9 varieties were planted: Polly, Beyonce, Herbstgold, Tentation, Emanuelle, Simonetta, Twinner, Sevilla and Linda. At Hörl Farm 13 varieties were planted: Polly, Beyonce, Herbstgold, Tentation, Emanuelle, Simonetta, Twinner, Sevilla, Levante, Lea, Otolia, Karelia and Laura. Because of bad weather and hail the trials could not be harvested. Tentation and Sevilla showed a higher damage of Colorado beetle at both trials. The farmers organised field visits for the regional farmers groups.

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Farmer participatory trials on soybean

Farmer participatory trials in Serbia

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

2021

Trials in Serbia were established at 5 locations (Global Seed, Ecoagri Serbia, Radomir Maljković, Ignjat Jurišić, Rimski Šančevi). In total 6 varieties were sown at the end of April and beginning of May. First observations related to sowing date, emergence, pest and disease occurrence were collected.

Fig. 35. Šuljam, producer Ignjat Jurišič (RS).

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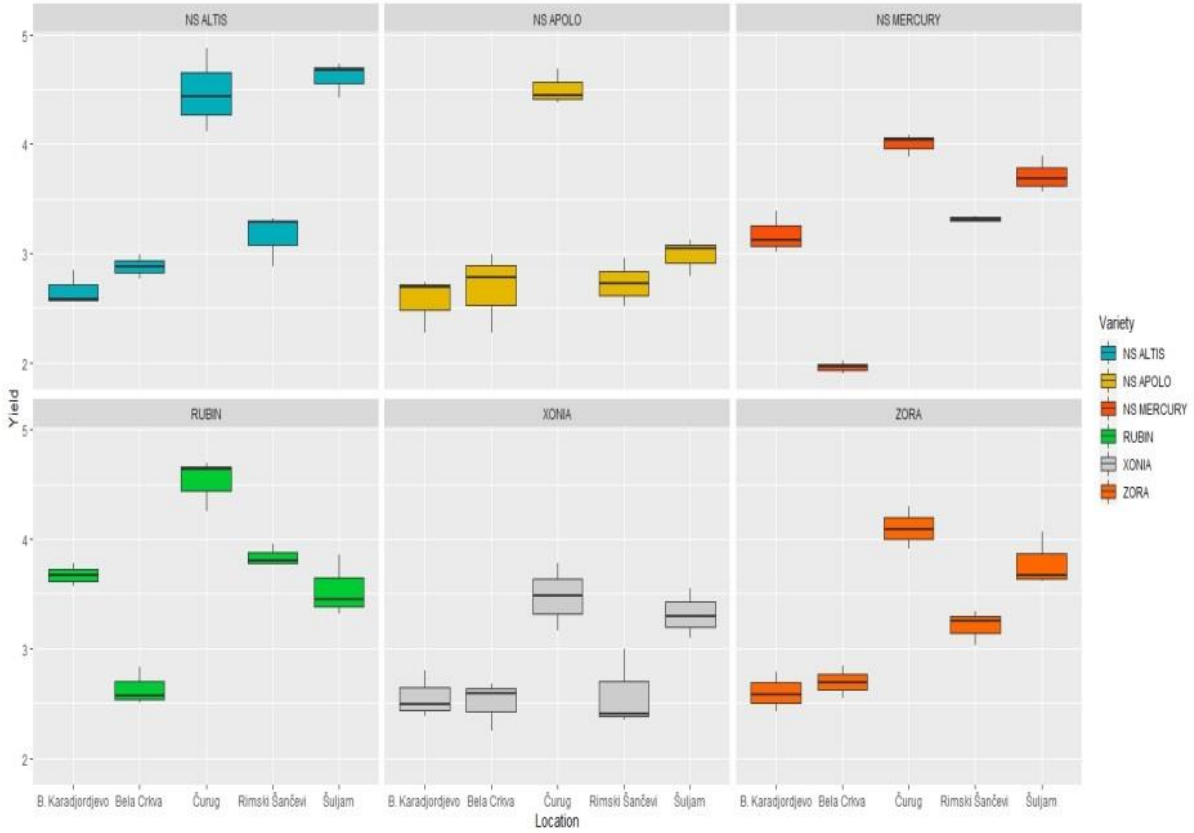
The trials were set up in 2021 at five locations (RimskiŠančevi, Šuljam, BelaCrkva, Čurug, Banatsko Karđorđevo). Six soybean varieties (00, 0, I, II maturity groups) were evaluated in a network of large-plot trials. Varieties from two breeding companies were tested (Xonia, SaatgutGleisdorf, Austria; NS Mercury, NS Altis, Zora, NS Apolo, and Rubin, Institute of Field and Vegetable Crops, Novi Sad, Serbia). Crops were sown in early April and harvested in September. The experiment was set up in the form of strips on an area of 300 m^2 per variety. During vegetation inter-row cultivation was performed twice during the growing season (May), manual weed control, and harvest in September, according to the maturity group. On all farms, field emergence, sowing density, growth development, ground cover, height and lodging was evaluated as well as occurrence of diseases and pests. Soybean varieties (00-II maturity groups) showed different adaptability to specific farm site conditions.



Data for yield are presented as median of 6 varieties per location in 2021, boxes represent the interquartile range.

Fig. 36. Soybean yield (t/ha) in Serbia.

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

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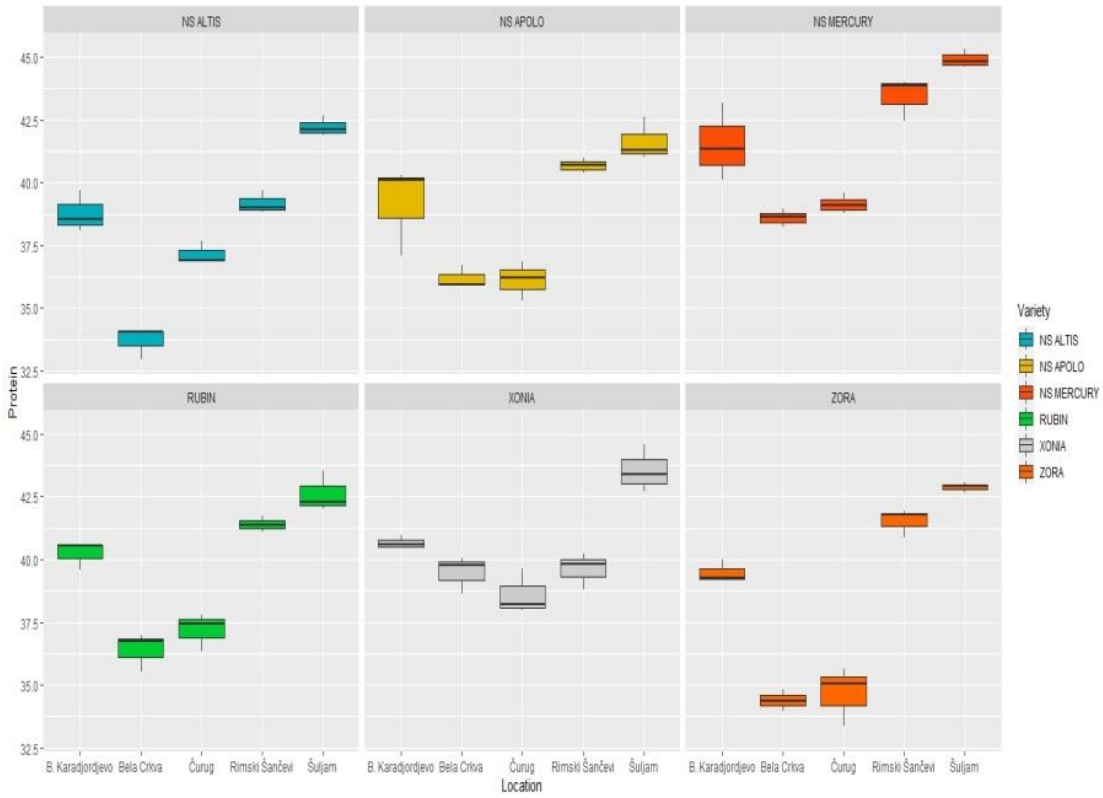

Data for protein content are presented as median of 6 varieties per location in 2021, boxes represent the interquartile range.

Fig. 37. Soybean protein content in Serbia.

2022

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 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 CCP population observations. During the 2022. organic farmers actively participated in the trial observations and received training on various occasions (location of training and demonstration events: Rimski šančevi and Šuljam) on how to select a soybean variety that is better suited to their region and growth conditions. Up to nine (9) soybean varieties (000, 00, 0, I, II maturity groups) were evaluated in a network of large-plot trials in Serbia.

Table 28 Tested soybean varieties in 2022.

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

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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.

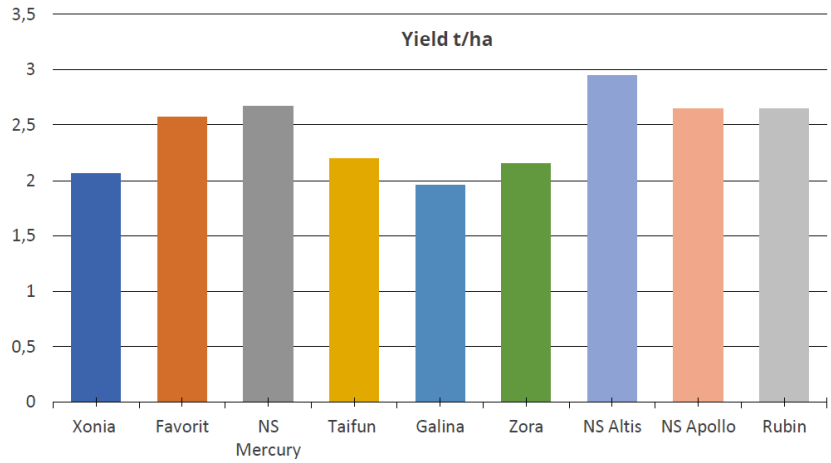

Fig. 38.Average yield for all locations in Serbia.

Fig. 39. Trials at Rimski šančevi in Serbia.

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Agro-climatic factors had a significant impact on soybean yield in 2022, 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 conditions 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.

2023

Farmer Participatory Trials for soybean were finalised (4 locations, 8-9 soybean varieties) during 2022. At two locations the best performing varieties were tested again during 2023. Analysis of protein and oil content were conducted during December.

Table 29 Locations, varieties and CCPs in FTP in 2023.

Locations	Varieties	CCPs
Čurug (24.04.2023)	NS Mercury (00 MG) NS Altis(0 MG) NS Kolos(II MG)	NS CCP
Šuljam (3.05.2023)	NS Mercury (00 MG) NS Altis(0 MG)	NS CCP
Rimski šančevi (5.5.2023)	-	NS CCP

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Farmer participatory trials in Germany and Austria

The 2021 and 2022 farmers participatory trials were sown on six organic farms in Germany and two organic farms (plus one more for PPB in 2022) in Austria. The farms in Austria were part of the substitution of the trials in Crete. In Austria SZG supported NATUR in conducting the trials. The climatic conditions on the farms varied. While some farms can grow varieties with maturity group 00 without problems (especially Austria), other farms are limited to varieties of the earlier maturity group 000. Therefore, the range of varieties on the farms was not the same at all farms.

The varieties were selected partly by researchers from the project and partly by farmers and their advisers. In Germany there was a co-operation with regional farmers organisations Bioland Erzeugerring e.V. and Erzeugerring für naturgemäßen Landbau e.V. The cultivars Lenka, Xonia, Obelix, GL Melanie, GL Judith (only Austria) and GL Leonie (only Austria) originated from Saatzucht Gleisdorf and the cultivars NS Mercury, Favorit, Galina and NS CCP (see report participatory plant breeding) originated from Institute of Field and Vegetable Crops. Because of early maturity GL Melanie could be grown at all farms and Obelix was grown at 7 of the 8 farms. GL Melanie could not repeat very good yield results of 2021 in 2022. Protein content was below average. Although GL Melanie was already on the market at the beginning of the project GL Melanie became a more and more important variety in German organic production during the project. Obelix showed mixed results. Lenka is one of the most import 00 varieties for human consumption. The high amount of protein was confirmed in these trials. Xonia is the first 00 variety with lower content of trypsin inhibitors. Older varieties with those criteria in later maturity groups showed lower yields. Xonia was much better than expected with average results both in yield and protein. The Serbian variety NS Mercury had bad results at the German farms in 2021 so it was replaced by the variety Favorit in 2022. Also, Favorit did not show expected results in the dry summer of 2022. Galina was only grown in Austria and showed results close to average both in yield and protein.

The varieties chosen by the farmers did not show the expected results. Although the varieties ES Comandor, ES Compositor or Abaca are grown at many farms the result was average or unstable. The “tofu” varieties Tofina and ES Mentor showed the expected high protein contents. Production for human consumption has an amount of more than 50% in German organic production. Therefore, the criteria “protein content” and other processing characteristics are most relevant. Some newer SZG varieties have higher protein content. For feed production new varieties could find a market soon. One trial with an Austrian seed treatment at one farm in Germany failed in 2022 although good results from Austria were available. The plants were yellow without nodules and protein content of the seeds was much lower.

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The 2023 soybean trials took place at five farms in Germany and one in Austria. In Germany the farmer participatory trials and participatory plant breeding trials had to be separated. The reason was the late maturity of the Serbian population NS CCP that could not be harvested on two of the three farms in 2022. Therefore, the three trials with NS CCP took place in the warm Rhine valley between Basel and Karlsruhe. In Austria both trials took place at the same farm LFS Güssing. The farmers in Germany like the soybean farmers participatory trials so much they wanted to continue the trials. Therefore, we decided to continue on two farms. The focus in the 2023 trials was on testing new varieties. Only GL Melanie was continued on both farms and was grown at all farms from 2021 – 2023. Both farms only grow varieties with 000-maturity.

Farmer participatory trials in Slovenia

During the two seasons 2021 and 2022, 8 soybean varieties were grown in FPT on two organic farms in Slovenia in Grosuplje on the Pucihar farm and in Videm Dobrepolje on the Farm Marolt farm. Sowing density was 57 and 48 seeds/m^2, respectively. Row spacing was 70 cm at both locations. Seeds were not inoculated. Trials were sown 11 and 21 May 2021 and 30 April and 20 May 2022. Soybean was not present in farms crop rotation before these trials. The following traits were evaluated to assess the development and agronomic performance of cultivars: date of emergence, plant height (cm), height of the lowest pods, canopy, lodging susceptibility, identification and scoring of diseases and pests, grain yield (kg/ha), protein content, oil content and grain moisture (%). The yields were estimated by manual sampling of 0.7 m^2 with four repetitions for each variety on 10 October (130 and 140 days after sowing). Samples of collected grains were taken for the analysis of protein and oil content. All the collected data was compiled in a common Excel database. Based on these data, bulletins were prepared for farmers that contained information on the performance of the various soybean varieties during the 2 seasons.

In 2021 conditions were variable, with cold and wet May delaying the emergence and early development, followed by hot and dry conditions in August and September accelerating maturity of cultivars. The year 2022 was warmer (+1.4°C) and had higher precipitation (+124 mm), although the months of July and August were very dry. At the time of harvest, highest grain losses due to splitting of pods were observed with the earliest varieties, which were over-ripe Grosuplje, the earlier maturing varieties were harvested first, followed by the later maturing varieties, which were harvested 10 days later.

The repartition of seed yield for 8 varieties in 2 locations in 2 seasons is presented (Fig 40). Medians were between 22.1 dt/ha (NS Mercury) and 30.6 dt/ha (Obelix). Obelix and Xonia had the highest medians (respectively 30.6 dt/ha and 27.9 dt/ha). The highest maximum values of seed yield were reached by Ezra, Valjevka/Galina, Obelix and Xonia

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(respectively 41.1, 39.2, 37.7 and 36.9 dt/ha) and the highest minimum values were reached by Obelix and Lenka (respectively 7.9 and 6.2 dt/ha). Ezra, Valjevka/Galina, Obelix and Xonia had the largest gap between minimum and maximum values. Lenka and Xonia had the largest interquartile range of seed yield. NS Mercury and Lenka had the smallest gap between their minimum and maximum values. GL Melanie and NS Atlas had the lower interquartile range of seed yield in the figure. NS Mercury, and NS Atlas had the narrowest medians (respectively 22.1, 23.6 and 24.4 dt/ha).

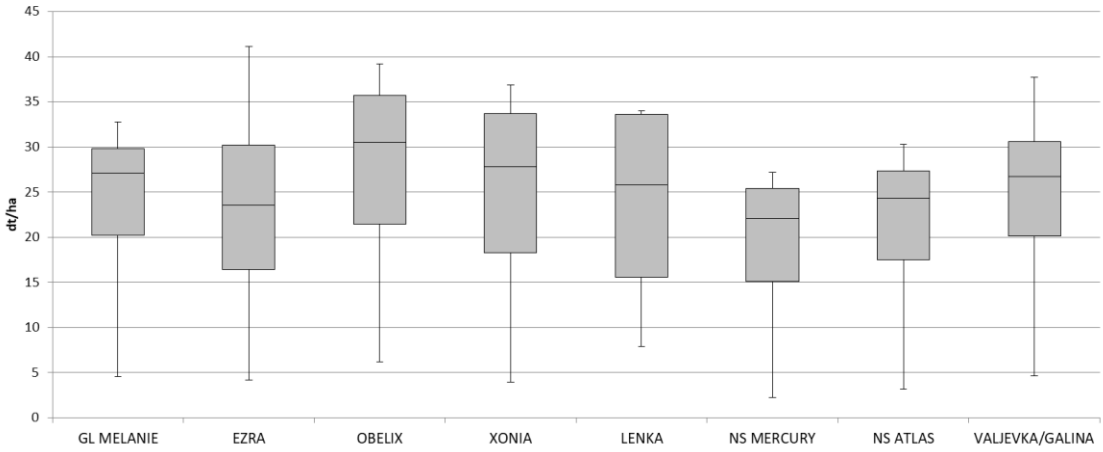

Fig 40 Soybean yield for 8 varieties at 2 locations in 2 seasons FPT 2020/2021 trials and 2021/2022 (SLO).

Protein and oil content were analysed (Fig 41). Protein content ranged from 29.01% (NS Atlas, at Grosuplje in 2021) to 39.85% (Lenka at Grosuplje in 2021). Oil content ranged from 21.45% (Lenka, at Videm Dobrepolje in 2021) to 25.4% (NS Atlas at Grosuplje in 2021). NS Atlas, Ezra and Obelix are cultivars with the lower protein content and the higher oil content. Lenka, GL Melanie and Xonia reached the highest protein content and the lowest oil content.

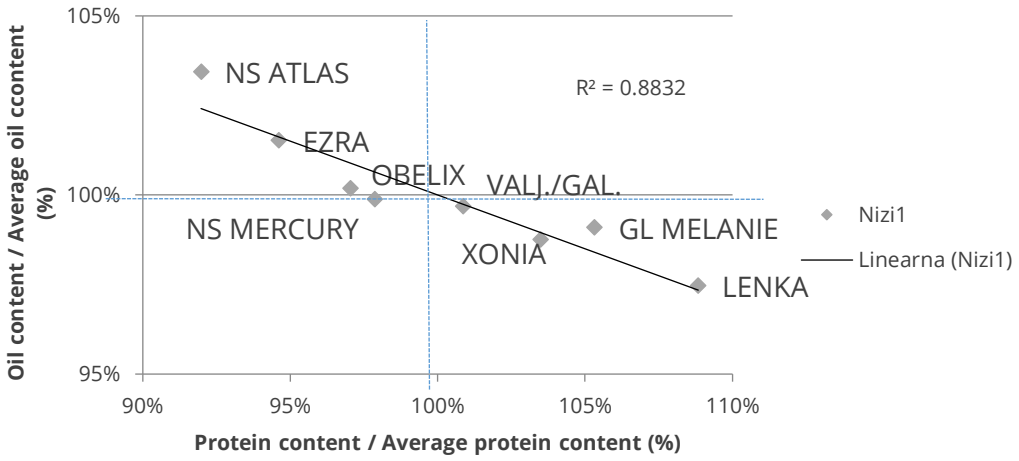

Fig 41 Comparison of varieties according to protein and oil content for 2 seasons FPT 2020/2021 trials and 2021/2022 (SLO).

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Farmer participatory trials in Romania

NARDI Fundulea participated in this task since month 25 of the project by establishment of on-farm soybean variety evaluation trials on 3 – 4 organic farms located in favourable areas for soybean cultivation and in non-irrigated and irrigated fields by established a non-replicated trial to compare the performance of 8 -12 genotypes. For each farm/field detailed soil, agronomic and climatic background data were collected, recorded and published in 3 Bulletins i.e. 2021, 2022 and 2023.

Farmer participatory trials on buckwheat

Farmer participatory trials in Slovenia

During 2 seasons 2021 and 2022, 8 buckwheat varieties were sown in FPT on four organic farms across Slovenia in the second half of July. The harvest dates were between 16 October 2021 and 21 September and 14 October 2022. Unfortunately, violent storms destroyed the buckwheat trials in 2 consecutive years at Prebold on Škorjanc's Farm.

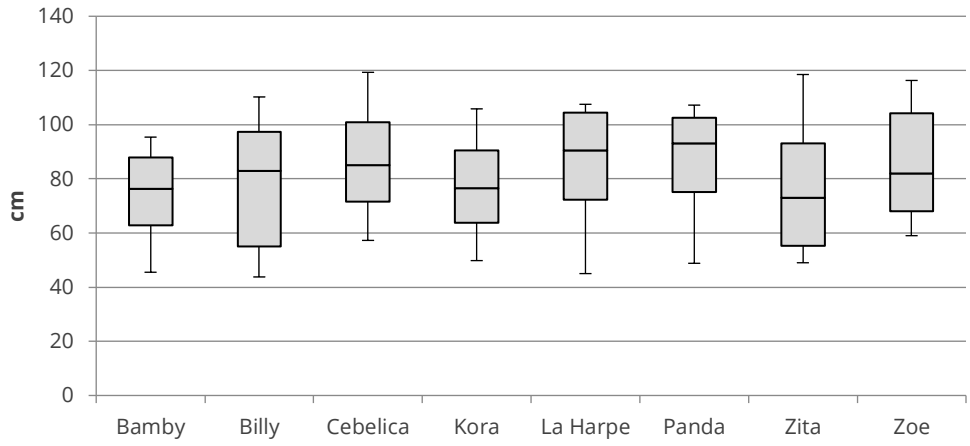

Fig 42 Plant length for 13 buckwheat varieties at 3 locations in 2021 and 2022.

Plant length (Fig 42) averages were for the 2 years in 3 locations between 74.0cm (Bamby) to 58.6cm (Čebelica). The plant length medians had different values and were between 72.9cm (Zita) and (93.2cm (Panda). The distribution of plant length for 13 varieties at 3 locations in 2 seasons is presented. Panda and La Harpe had the highest medians (93.2 and 90.5cm, respectively). Čebelica and Zoe reached the highest maximum values of plant length (respectively 119.3 and 118.5cm). Čebelica and Zoe reached the highest minimum values (57.3 and 59cm). Billy and Zita had the largest gap between minimum and maximum values and the largest interquartile range of plant length. The varieties Bamby, Kora and Panda are in the opposite situation, with the smallest gap between their minimum and maximum values and with the smallest interquartile range of plant length. Zita, Bamby and Billy had the narrowest medians (72.9, 76.4 and 76.5, respectively).

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Crop length averages were for the 2 years at 3 locations between 63.5cm (Bamby) to 74.5cm (Panda). The crop length medians had different values and were between 57.7cm (Zita) and 83.2cm (Panda). The repartition crop length for 13 varieties at 3 locations in 2 seasons is presented in this Fig 43. Panda and Čebelica had the highest medians (respectively 83.2 and 66.7cm). Billy and La Harpe reached the highest maximum values of crop length (respectively 107.5 and 102.3cm). Čebelica and Zita reached the highest minimum values (48.5 and 47.3cm). Billy and La Harpe had the largest gap between minimum and maximum values. Panda and La Harpe had the largest interquartile range of crop length. The varieties Bamby, Čebelica, Zita and Kora are in the opposite situation, with the smallest gap between their minimum and maximum values and with the lower interquartile range of crop lengths. Zita, Zoe and Bamby had the narrowest medians (respectively 57.7, 60.4 and 63.0).

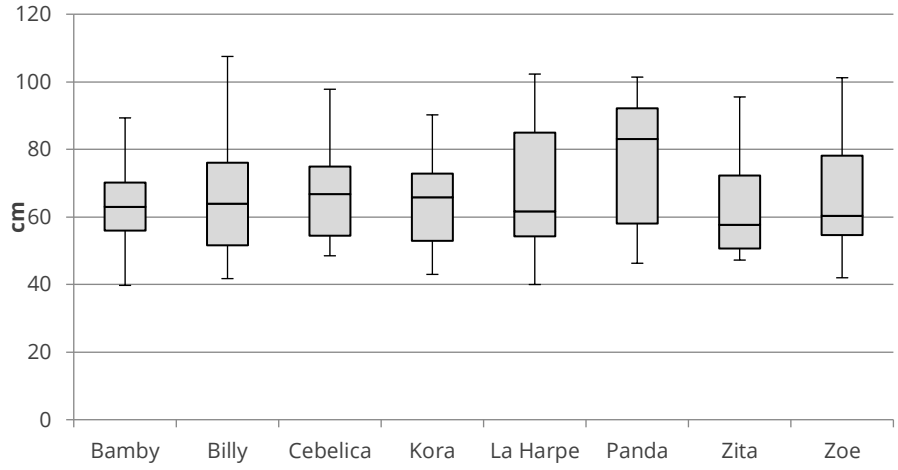

Fig. 43. Crop length for 13 buckwheat varieties at 3 locations in 2021 and 2022.

Lodging: Lodging was higher at Ponikva in 2021. The varieties with the higher score 2.7 were Zita, Zoe and Čebelica. The lower score was 1.8 reached by Bamby and Panda.

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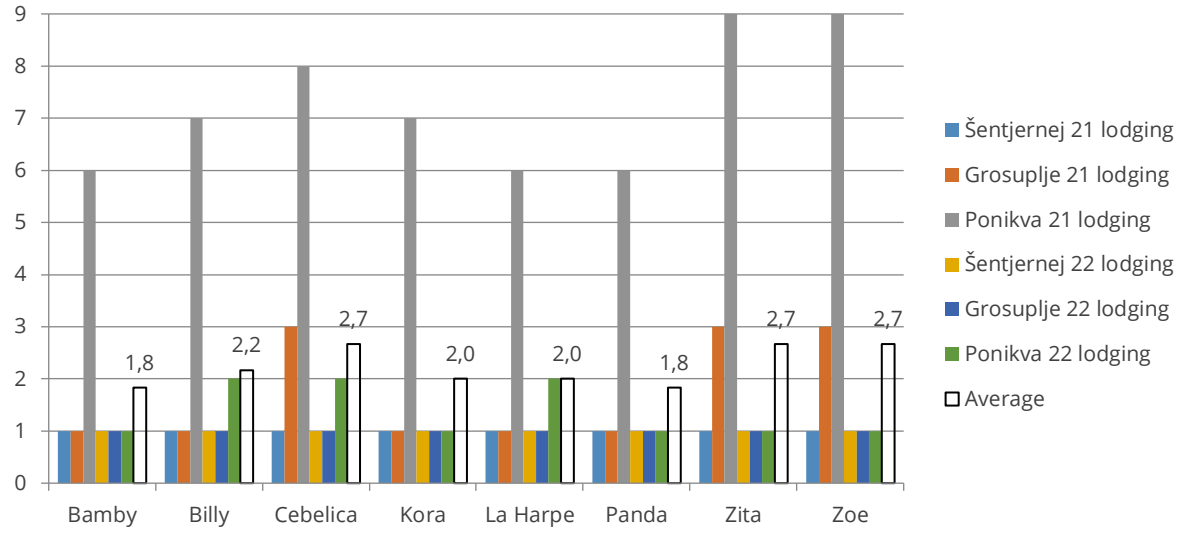

Fig. 44. Lodging of buckwheat varieties at 3 locations in 2021 and 2022.

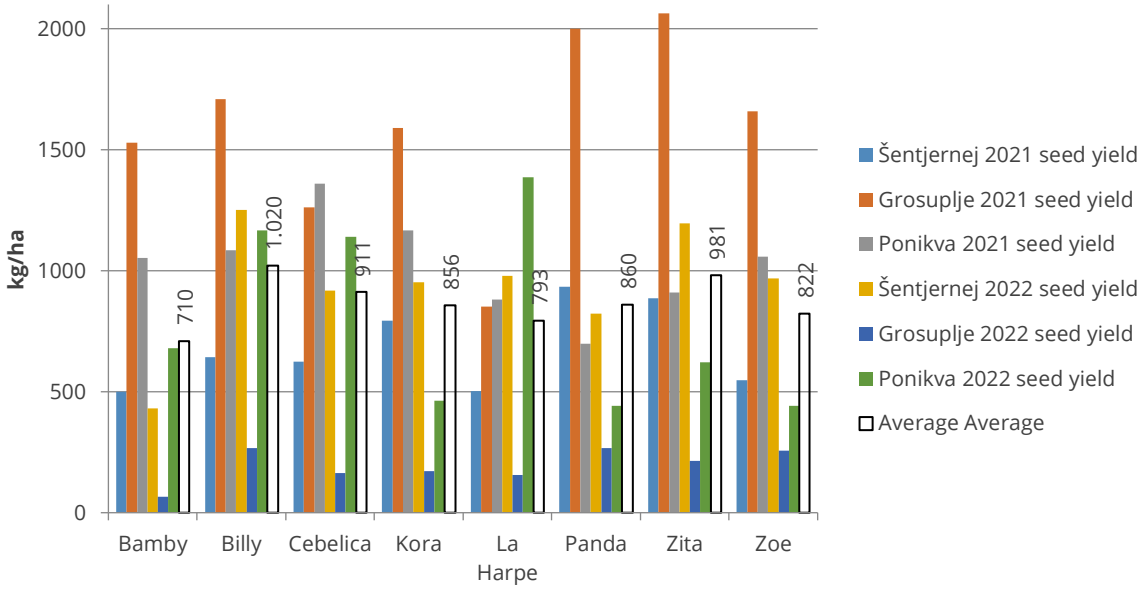

Fig. 45. Seed yield for buckwheat varieties at 3 locations in 2021 and 2022.

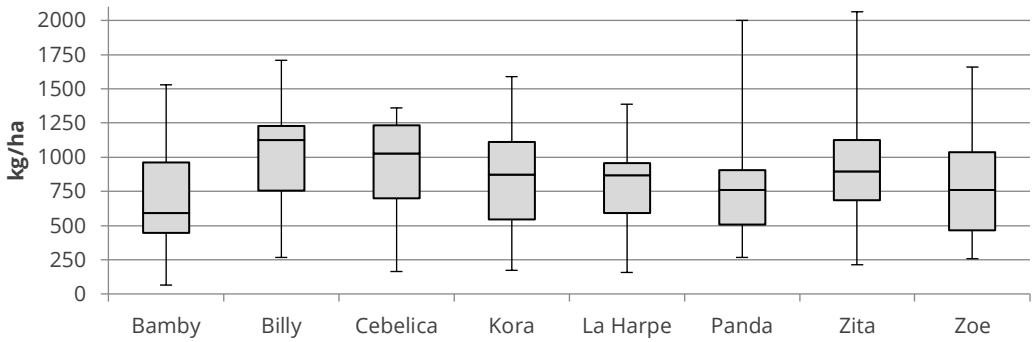

Fig. 46. Buckwheat seed yield: 8 varieties at the locations Grosuplje, Šentjernej and Ponikva in 2021 and 2022.

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The number of days to flowering was determined by KIS and the farmer. It reached the stage of flowering from 28 for the earliest variety to 35 days in 2021 in between 26 days at Grosuplje to 49 days at Ponikva 2022.

Seed yield averages were for the 2 years at 3 locations between 710 kg/ha (Bamby) to 1021 kg/ha (Billy). Ponikva yields in 2021 were higher, with 7/8 of the maximum values for all data. Yields were calculated by manual sampling in the field, as combine harvesting was not possible. The yield at Ponikva in 2021 is questionable, as it was estimated based on manual sampling in the field due to the impossibility of harvesting. The other trials were harvested with combine harvester.

The median yields had different values, ranging from 590 (Bamby) to 1124 kg/ha (Billy). The distribution of seed yield for 13 varieties at 3 locations in 2 seasons is shown in this Figure 12. Billy and Čebelica had the highest medians (1124 and 1029 kg/ha, respectively). Zita and Panda reached the highest maximum seed yield values (2063 and 2000 kg/ha, respectively). Panda and Zita reached the highest minimum values (both 267 kg/ha). Panda and Zita had the largest gap between the minimum and maximum values. Kora and Zoe had the largest interquartile range in seed yield. Čebelica and La Harpe had the smallest gap between their minimum and maximum values. La Harpe, Panda and Zita had the lowest interquartile range of seed yield in the figure. Bamby, Zoe and Panda had the narrowest medians (590, 758 and 760 kg/ha respectively).

Farmer participatory trials in Czech Republic

2020

PROBIO started talks with organic farmers about buckwheat farmers' participatory trials (FPTs) in 2021 and 2022. Phenotyping assessment traits for buckwheat were set together with CRI.

2021

5 organic farmers were involved in FPTs of buckwheat. 3 farmers had long-term experience with growing buckwheat 2 farmers did not grow buckwheat for grain production in the past. Trial layout was set with minimum plot size of 300 m^2 and seed rate of 200 plants per m^2. Sowing width wasn't required, due to available equipment of the farms. The list of varieties: Devyatka (Russian federation); Drushina (Russian federation); Čebelica (Slovenia); Le Harpe (France); Panda (Poland); Zoe (Czech Republic); Zita (Czech Republic); Zamira (Czech Republic); Kora (Poland); Billy (Austria); Bamby (Austria).

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PROBIO did phenotypic assessment for all the farms with at least 2 visits per farm. Assessment ideally took part with farmers attending it. Besides scoring, soil and biomass samples were taken for analysis at CRI.

A field day presenting different buckwheat varieties was held on 24.7.2021 at one of the participating farms EKOFARMA PROBIO s.r.o. Dagmar Janovská (CRI) and Werner Vogt-Kaute (NATUR) were present at this event.

2022

4 organic farmers were involved in FPTs of buckwheat. Co-operation with one farm did not continue. All the 4 farms in 2022 were involved in the trials as in the previous year. Trial layout was set with minimum plot size of 300m^2 and seed rate of 200 plants per m^2. Sowing width was varied, due to available equipment of the farms. The list of varieties: Darja (Slovenia/Denmark); Devyatka (Russian federation); Drushina (Russian federation); Eskalar (Germany); Hajnalka (Hungary); Kora (Poland); Lifago (Germany); Lileja (Slovenia); MHR Korona (Poland); MHR Smuga (Poland); Oberon (Hungary); VB Nojai (Lithuania); Zita (Czech Republic).

- Four varieties were kept from 2021 as a control. New varieties were tested. PROBIO was looking for varieties suitable for grain production and varieties suitable as green manure.
- PROBIO did phenotypic assessment for all the farms involved in buckwheat FPTs with at least 2 visits per farm. Assessment ideally took part with farmers attending it. Besides scoring, soil and biomass samples were taken for analysis at CRI. PROBIO did evaluation of winter wheat varieties, separate harvest for yield estimation. Qualitative laboratory assays were done.
- A demonstrational event on 16 March 2023 was organised in co-operation with the Association of Private Farming of the Czech Republic about buckwheat and practical tips for upcoming season. The event was held in Tetín.
- A demonstrational event on 21 June 2023 was organised in co-operation with BOKU at EKOFARMA PROBIO s.r.o. in Velké Hostěrádky. The topic was introduction to ECOBREED project with goals, results and commented examination of winter wheat varieties. The guest speaker was Heinrich Grausgruber (BOKU).
- Farmer buckwheat bulletin 2021 was presented at BIOFACH 2022.
- Adam Brezáni was a guest speaker at one demonstrational event held by CRI at Sasov on 23 September 2022 and at two training events for farmers held on 29 August 2022 in Okrouhlice and 30 August 2022 in Soběkury.
- The first buckwheat population from RGA was received.
- Dehusking and groat yield estimation of all buckwheat varieties from 2021 and 2022 were done at CRI. Special device for dehusking buckwheat was repaired at CRI and adjusted for buckwheat.

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2023

Additional 3 population from RGA were received. Three organic farmers were involved in FPTs of buckwheat. All 3 farms are located in cadastre of Velké Hostěrádky. The list of buckwheat varieties: Zita (Czech Republic); M Kora (Poland); Lifago (Germany); MHR Smuga (Poland); Syn 21. (Slovenia); Syn P1 22.1 (Slovenia); Syn P1 22.2 (Slovenia); Syn P2 22.3 (Slovenia).

- Zita and Kora remained as a control. MHR Smuga and MHR Korona were selected as the most perspective varieties for future grain production, but only MHR Smuga seed was available in 2023. Lifago was selected as a perspective variety for green manure production. The goal of the trial was to present the best varieties at the final demonstrational event that was held on 16 September 2023 in Velké Hostěrádky. The event was visited by about 700 participants mostly from the general public.
- The presentation with titled "Buckwheat, a special chance for an Eastern Europe?" was held at Demeter conference in Lumpėnai, Lithuania on 2.7.2023 and 26.9.2023 at Day of organic farming in Bojnice, Slovakia.
- Werner Vogt-Kaute (NATUR) was presenting soybean FPTs results of ECOBREED project on 11-12.11.2023 in Benešov.
- Qualitative assays including falling number of 19 different buckwheat varieties from 2021 and 2022 will be done in cooperation with University of Chemistry and Technology in Prague in early 2024.

Farmer participatory trials in the United Kingdom

Buckwheat was grown at 3 sites over the course of the project, Nafferton, Gilchesters and Thornton Farm. Buckwheat grain yields in the FPT were very variable in the UK with lost trials and low grain yields due to severe weed competition being a key problem. The exception was at Gilchester's where relatively high grain yields were observed in 2022 with 2.92 t/ha for the variety Kora followed by 2.86 t/ha for La harpe and 2.78 t/ha for Zoe. For other trials grain yields were generally low at or just below 1t/ha which limits the potential value for this crop in organic production systems.

Successful establishment is key to this crop and even in some cases like Nafferton Farm in 2021 and 2023 where crop establishment was even and competition with weeds was successful grain yields were still low. The small seed size and asynchronous ripening of buckwheat pose key challenges for the future success of buckwheat as a commercial crop in the UK although in many cases it is used in cover crop mixes which are increasing in their adoption especially in regenerative farming systems.

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