5 November 2025

Final report
For the Core Organic third call funded project:

DIVERSILIENCE

Diversifying organic crop production to increase resilience

01.12.2021 – 31.03.2025

Index

1. General information

1.1 Project information

Project information			
Project acronym	Diversilience		
Project title	Diversifying organic crop production to increase resilience		
Project website	[DIVERSILIENCE (au.dk)]()		
Social media accounts	No		
Details of the project coordinator			
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Institution	Norwegian University of Life Sciences	**Country**	Norway
Start date of project	01.12.2021	**End date of project**	31.03.2025
Duration in months	39		

1.2 Consortium

Partner (name)	Institution/ organisation name, address and country	Type of institution/ organisation[1]	Contact details (phone/e-mail)	Functions[2]	Involved in WPs (no.)	Runtime of the national contract
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Pirjo Mäkelä	University of Helsinki	University	+358 40 827 5501 pirjo.makela@helsinki.fi	WPL	3, 4, 5	01.12.2021 - 30.11.2024
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Paolo Annicchiarico	CREA	Public research institute	+39 0371 404751 Paolo.annicchiarico@crea.gov.it	WPL	1, 2, 3, 4, 5	01.12.2021 - 31.03.2025
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[1] University, Public research center, Private research center, Company, Other

[2] PC = Project coordinator, WPL = Work package leader, WPCL = Work package co-leader, P = Participant

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2. Summary

2.1 Final project summary suitable for web publication for a wider audience

In DIVERSILIENCE we have selected novel resilient lines or populations of several crops, such as lucerne with good survival in Nordic climate, wheat with resistance to common bunt, common bean with drought tolerance and resistance to diseases, white lupin with frost tolerance, as well as buckwheat, white lupin and maize for organic agriculture. Molecular tools for selection of common bunt resistance in wheat have been developed and are now in use by breeders. We have evaluated germplasm collections of cowpea and soybean for tolerance to key stresses (especially drought) and to identify contrasting plant types used for intercropping research, producing indications on elite genetic resources and cultivars of special interest for organic farming. Selection for intercropping (with pea) has also been performed in buckwheat. These results were summarized in the Deliverable report D1.1 and D2.3. We have provided direct and indirect evidence for the high agronomic value of heterogeneous material (evolutionary populations, composite populations, or cultivar mixtures) in terms of yielding ability in low-input systems, yield stability, stress tolerance and/or farmers' acceptability (Deliverable report D2.1): (a) in Norway, wheat populations displayed similar grain yield and protein content and higher yield stability relative to pure line varieties; (b) in Romania, a six-component wheat cultivar mixture was the only material combining moderate tolerance to a set of abiotic or biotic stresses and good yielding ability; (c) in Italy, two white lupin populations showed grain yield, protein content and farmers' appreciation comparable with those of a pure line variety and an elite breeding line; (d) in Romania, a four-component cultivar mixture of soybean displayed higher grain yield than any pure line cultivar, along with no grain quality disadvantage. Indirect evidence arose from the following results: (a) in Denmark, wheat mixtures composed of lines with up to six different resistance genes displayed an increase of tolerance to common bunt; (b) in Slovenia, common bean composite populations, and particularly a commercial one, showed high allelic variation for functional markers associated with several agronomically important traits. Deliverable D2.2 discussed challenges and opportunities to make the seed of heterogeneous material available to organic farmers as a function of the type of material (population or cultivar mixture), the extent of morphophysiological heterogeneity, the ownership of the material, and the potential market size of the species and the cultivar. On the whole, our results justify a greater emphasis on the breeding and the cultivation of genetically heterogeneous cultivars of inbred crops. Our results also provide evidence for the high agronomic value of species mixtures in organic cropping systems (Deliverable report D3.1 and D3.2): (a) in Denmark and Finland mixtures generally increased yield stability and weed competition, especially in relation to pea and camelina; (b) in Slovenia and Northern Italy intercropping cowpea and soybean with sorghum was a successful technique to sustain crop yield and field biodiversity; (c) in Romania mixtures of triticale and peas, wheat and peas contributed to improving soil fertility, reducing the use of chemical fertilizers, and increasing biodiversity; (d) in Romania forage mixtures produced a higher volume of quality forage compared to single-species mixtures and possibly providing supply of grazed forage throughout the year and increasing stability. In Norway, however, none of the mixtures outperformed the pure stand of red clover in terms of yield in the establishment year and first harvesting year. Plots including forage legumes had 30-80% higher yields of barley sown as the following crop, but the grain protein content was not significantly affected.

2.2 Short process update of the whole project

The project was carried out according to the plan, with only some minor deviations as detailed below. For some Tasks there is still data analysis and publication activity to be done. This is expected to be completed before the end of 2026. Then, all objectives of the project are fulfilled.

3. Outcomes of the project

3.1. Main results, discussion, conclusions and fulfilment of objectives

<table>
<tr><td>WP1</td><td>Germplasm enhancement for adaptation and resilience</td></tr>
<tr><td colspan="2">WP leader: Anders Borgen, Agrologica
Responsible partners: Agrologica, CREA, RSR, NMBU, Graminor, LUKE, NARDI, KIS, MVCRI</td></tr>
<tr><td colspan="2">Overall summary of main results, discussion and conclusions of WP1
WP1 has focussed on breeding initiatives of crops for organic production. The state of the art of organic plant breeding differs according to crops and regions. In some situations, it is possible to stand on the shoulders of previous breeding initiatives such as modern varieties bred for conventional farming in the climatic zone, whereas in other situations, the breeding starts from scratch based on landraces. Many crops are in urgent need for improvement and adaptation to both biotic and abiotic stressors in organic production. Even with a relatively short project period of only three years and growing seasons, it has been possible to achieve significant improvements in selected crops. Different crops and different regions meet different challenges, and the relevant method for crop improvement differ according to the state of the art and available knowledge, funding and logistics. In some cases, local landraces can be maintained and improved by local farmers and in other cases genomic and proteomic research is needed to solve specific constrains for organic farming. The current research was spread over the entire range of plant breeding from farmer selection of minor crops such as buckwheat in Finland and open pollinated landraces of maize in Romania to genomic studies of the world's most cultivated crops such a wheat and soybean. In all cases, it was possible to gain significant improvement in germplasm and knowledge, facilitating organic farming. On this background, we conclude that plant breeding is a low hanging fruit to enable increased organic production in Europe.</td></tr>
<tr><td colspan="2">Task 1.1. Improvement of lucerne adaptation to a Nordic climate
A- results: Mixtures of grass and clover is often the basis of organic farming systems, and in particular in cold humid areas, the access to nitrogen from such crops is pivotal for the organic system. Hence, organic farming in Norway often suffers from lack of nitrogen, as legume crops often fails due to winter-kill. A broad collection of well-studied European lucerne material were evaluated in Norway. Based on the 3.5 years in the field it was concluded that the local varieties were better adapted to the climatic conditions, but that European material had a high diversity of traits that could be useful in a long-term breeding program. The Norwegian breeding company Graminor has therefore collected survivor plants after 4 winters for further use. B- fulfilment of objectives: Objectives are largely fulfilled, but genetic analyses are still ongoing and will be part of a PhD thesis to be submitted in 2026. C- changes compared to the project proposal: None.

Task 1.2 Farmer-participatory selection of buckwheat for pure and mixed cropping in Northern Europe
A- results: Buckwheat is a traditional crop in several countries including Finland, but breeding of buckwheat has been limited compared to the major crops in agriculture. Moreover, breeding for diversity and mixed cropping is a new field of research, rarely exploited in practical breeding. To diversify crop production and maintain buckwheat production in Finland, we studied the potential to select and adapt buckwheat varieties to Finnish conditions in mixtures with pea. The method of crop improvement was based on mass selection in a participatory approach. It was concluded that the optimal harvest time for buckwheat is rather flexible. Peas has a lower flexibility in optimal harvest time than buckwheat, but in a pea-buckwheat mixture, it is possible to select a window for harvesting ripe seed of both crops. It is shown in much research, including DIVERSILIENCE WP3 that diversity and mixed cropping improve resilience. This means that a high yield can be expected in a monoculture of a well-adapted variety under optimal conditions, but that mixed cropping decrease yield loss in cases of suboptimal conditions. This was also shown in the case of buckwheat-pea mixtures, where the highest yielding varieties were best suited for</td></tr>
</table>

monoculture production whereas lower yielding varieties benefited from mixed cropping with peas. Buckwheat is a cross-pollinating crop with a very broad maturity and harvesting time. It seems that by harvesting early over three consecutive years, it is possible to select for early harvest and thereby gradually shift the crop to adapt local conditions. **B- fulfilment of objectives:** Fulfilled. **C- changes compared to the project proposal:** We used mixtures with pea rather than faba bean, according to farmers' recommendations.

Task 1.3 Generation of wheat germplasm resistant to common bunt for Northern Europe
A- results: Wheat is generally an extremely well-studied crop, but for organic farming, there are relevant traits that are rarely studied in conventional research. Common bunt is a seed borne disease that has been effectively controlled by pesticides for the past century. Therefore, organic wheat production face considerable problem with this disease as organic farming abstain from use of pesticide seed treatments. Danish and Romanian partners studied wheat phenotypically and genotypically to identify genetic resources of resistance to common bunt and to develop genetic markers for selection. We mapped 21 RPR genes responsible for bunt resistance and identified another 30 genes that can be used in breeding to control common bunt. Most of these genes have effect only against avirulent races of bunt, and virulence is present in Europe against most of these resistance genes. Only Bt9, the rye translocations 1RS:1AL and possibly a few more genes seem to be effective against all races of bunt present in Europe. Therefore, it is in most cases necessary to pyramid several genes into wheat breeding lines to be able to control common bunt exclusively by resistance. We also studied the effect of diversity and concluded that a mixture of a high number of resistance genes in a population can reduce bunt infection even if virulence is present against the individual resistance genes in the mixture. **B- fulfilment of objectives:** Fulfilled. **C- changes compared to the project proposal:** None.

Task 1.4 Development of winter-hardy lines and populations of white lupin
A- results: A procedure for the reliable evaluation of frost tolerance under artificial conditions was established and used to identify new breeding lines of white lupin with good frost tolerance. A good correlation between frost susceptibility in controlled conditions and winter mortality based on field data was observed. A GWAS analysis identified two SNPs that were associated with the frost survival ratio. Preliminary genomic prediction models were also developed; these exhibited prediction abilities close to 0.70. From a genetic base including progenies from 16 crosses between four elite sweet-seed breeding lines and four elite landraces of international origin, CREA developed an original evolutionary population by (a) the initial selection for low alkaloid content of F3 progeny plants, (b) pooling nearly 1800 sweet-seed seeds sorted out in equal amounts from plants of the 16 crosses and letting the material evolve under natural selection in autumn-sown, densely-planted plots for two cropping years in Lodi. From this material, RSR and Agrologica planned the selection of region-specific evolutionary populations for Sardinia, Sicily, Tuscany, and Denmark under autumn sowing across two cropping years. In Italy, only the selection in Sardinia could be completed (due to too calcareous soils in Tuscany, excessive frosts in Denmark, and excessive drought in Sicily). Participative stratified selections with farmers, technicians and researchers, where conducted in the organic farm of the Cooperative San Nicolò Gerrei, in San Nicolò Gerrei (Sardinia) in 2022 and 2024. These field days served also as a dissemination opportunity about the project and the new opportunities offered by Organic Heterogenous Material. In the last project year, RSR and CREA carried out a comparative trial and participative evaluation of the naturally adapted and selected lupin populations, in collaboration with AGRIS (the agency for agricultural, agro-industry and forestry research and innovation of the Region of Sardinia) which hosted the experiment at «San Michele» experimental farm in Ussana (Sardinia). The experiment is described in detail in D2.1. **B- fulfilment of objectives:** Partly fulfilled; the field experiments failed in several locations, but this is also a result. **C- changes compared to the project proposal:** None.

Task 1.5 Common bean selection for tolerance to drought and biotic stresses, and plant type characterization for intercropping

A- results: The common bean local diversity in colour, shape, taste and other traits differ cannot be maintained by European-wide commercial varieties leading to loss of local food cultures. In Slovenia and Bulgaria, we tested a collection of 25 common bean genotypes, differing on the basis of origin, and the varieties were described by 16 selected descriptors. Apart from selecting under field conditions, the material was characterised using genotyping, genomic and proteomic methods describing the genetic diversity and relevant traits. The Task identified potential accessions relevant for breeding for drought tolerance, protein concentration and resistance to three dominating plant diseases, including *Colletotrichum lindemuthianum*, *Pseudomonas savastanoi* pv. *phaseolicola*, and *Xanthomonas phaseoli* pv. *phaseoli*. We identified lines with tolerance to one, two or to all three pathogens and thereby improved the basis for further plant breeding of common bean relevant for organic plant breeding. **B- fulfilment of objectives:** Fulfilled. **C- changes compared to the project proposal:** A transcriptome study was replaced by a proteomic analysis.

Task 1.6 Adaptation to Southern Europe and plant type characterization for intercropping of a world collection of cowpea germplasm and a set of soybean varieties

A- results: Cowpea has not been widely used in Europe, as it is a warm season crop. However, with increasing temperatures, cowpea could become an important crop and contribute to protein supply in Europe, given that adapted germplasm become available. A world-wide collection of germplasm was studied in Italy for the potential in Southern Europe. As the climate conditions for successful cowpea production moves to the north, an important trait is the photoperiod of cowpea, and the study therefore had this trait in focus. Growth habit was identified and grouped into idiotypes of erect, climbing and bushy types and maturity time was measured (some accessions did not mature at all under the Italian conditions). Soybean is already established as a widely grown crop in Southern Europe, and adapted varieties are available. For both soybean and cowpea, the crops may have different purposes for either human consumption or feed production of either grain or biomass. Late maturing ideotypes with high biomass production may be suited for silage feed whereas early maturing types with lower biomass production may be better suited for grain production. **B- fulfilment of objectives:** Fulfilled. **C- changes compared to the project proposal:** None.

Task 1.7 Farmer-participatory development of open-pollinated varieties of maize for Southern Europe

A- results: One of the side effects of the globalisation of seed production and plant breeding is the loss of local varieties and genetic diversity. To maintain local varieties, local varieties of maize was studied in Romania and characterised for yield and quality traits, and improvement was made using a participatory approach of on farm selection. **B- fulfilment of objectives:** Fulfilled. **C- changes compared to the project proposal:** None.

WP2	*Exploitation of heterogeneous material*

WP leader: Paolo Annicchiarico, CREA

Responsible partners: CREA, RSR, NMBU, Graminor, Agrologica, NARDI, KIS, Arcoiris, NIBIO

Overall summary of main results, discussion and conclusions of WP2

This WP aimed at providing a scientific assessment of the value of heterogeneous material (evolutionary populations, composite populations, or cultivar mixtures), as well producing scientific information that could contribute to optimize the development of this material. Its results provided direct or indirect evidence for the high agronomic value of heterogeneous material in terms of yielding ability in low-input systems, yield stability, stress tolerance and/or farmers' acceptability, based on the following results: (a) in Norway, wheat populations displayed similar grain yield and protein content and higher yield stability relative to pure line varieties; (b) in Romania, a six-component wheat cultivar mixture was the only material combining moderate tolerance to a set of abiotic or biotic stresses and good yielding ability; (c) in Italy, two white lupin populations showed grain yield, protein content and farmers' appreciation comparable with those of a pure line variety and an elite breeding line; (d) in Romania, a four-component cultivar mixture of soybean displayed higher grain yield than any pure line cultivar, along with no grain quality disadvantage. Indirect evidence arose from the following results: (a) in Denmark, wheat mixtures composed of lines with up to six different resistance genes displayed an increase of tolerance to common bunt; (b) in Slovenia, common bean composite populations, and particularly a commercial one, showed high allelic variation for functional markers associated with several agronomically important traits. These results, and results of methodological interest for the development of heterogeneous material, were summarized in the Deliverable D2.1. Deliverable D2.2 discussed challenges and opportunities to make the seed of heterogeneous material available to organic farmers as a function of the type of material (population or cultivar mixture), the extent of morphophysiological heterogeneity, the ownership of the material, and the potential market size of the species and the cultivar. On the whole, our results justify a greater emphasis on the breeding and the cultivation of genetically heterogeneous cultivars of inbred crops.

Task 2.1 - Crop-pathogen co-evolution and optimization of wheat population diversity for tolerance to common bunt in Denmark

A- Results. Eight mixtures composed of wheat lines with known genes of resistance to common bunt were set up. Each mixture included from one to six different resistance genes. Each mixture was contaminated by a race of common bunt with virulence to one of the resistance genes in the mixture. Each year the infection level in the field was recorded, and grain and spores were harvested and resown in the following year. Over a four year-period, the infection level of common bunt gradually decreased, confirming that selection towards resistance in the mixture dominate over selection for virulence in the fungal spores. However, bunt infection was still detectable in most mixtures after four years, even in mixtures with a high degree of diversity in resistance genes. The selection pressure was high in the experiment caused by artificial inoculation, with infection levels much higher than what would be acceptable in commercial agriculture conditions. Under farming conditions with lower infection levels, it would take more years and/or more genes to achieve a control over common bunt. **B- Fulfilment of objectives.** The activity fulfilled its objectives, showing that some selection and adaptation took place and the mixtures became more resistant to the primary infection from external spores. **C- Changes compared to the project proposal.** No change.

Task 2.2 - Effect of within-crop diversity and farmer selection on common wheat yield, yield stability and grain quality in Norway

A- Results. The activity focused on four Norwegian breeding populations issued from two types of "farmer's selection" (i.e., selection for kernel weight using air separation, and manual selection of good-looking spikes), four organic populations from Denmark, and a set of Scandinavian breeding lines, recent or old varieties, and landraces, evaluated in organic farms at four locations. Populations and pure lines bred in Norway exhibited similar mean yield and protein content, but the former showed higher yield stability. Among the two farmer's selection methods, selecting for kernel weight resulted in more stable yields and higher protein content than spike selection. On average, old cultivars out-yielded recent germplasm, achieving higher average yields and yield stability while possessing similar protein content.

Grain yield (0% water content), protein content, and Modified AMMI stability values (MASV) for these two traits (lower MASV indicates higher stability), for wheat populations selected on the basis of spike appearance or kernel weight and old or modern pure line varieties bred in Norway or Denmark

Test	Grain yield [t/ha[1]]	Stability of grain yield (MASV)	Protein content [%]	Stability of protein content (MASV)
Population (NO), n = 8	1.29	0.54	14.3	0.89
Pure line (NO), n = 11	1.28	0.95	14.2	1.25
Significance	Ns	**	ns	ns

Population (NO), n = 8	1.29	0.54	14.3	0.89
Population (DK), n = 4	1.24	0.83	14.5	1.09
Significance	Ns	**	*	ns
New pure lines, n = 9	1.26	1.05	14.2	1.22
Old pure lines, n = 2	1.34	0.51	14.3	1.38
Significance	*	**	ns	ns
Kernel weight sel., n = 4	1.27	0.38	14.5	0.89
Spike selection, n = 4	1.31	0.70	14.1	0.89
Significance	Ns	*	**	ns

* = P < 0.1, ** = P < 0.01, ns = not significant

B- Fulfilment of objectives. The activity fulfilled its objectives, showing (a) greater yield stability under organic conditions of genetically heterogeneous wheat material relative to pure lines, and (b) better yield and yield stability of old cultivars relative to recent germplasm bred for conventional farming. **C- Changes compared to the project proposal.** No change.

Task 2.3 - Effect of within-crop diversity on common wheat yield, grain quality and stress tolerance in Romania

A- Results. This study included the best six Romanian pure line varieties, three mixtures of these varieties, and five foreign populations, evaluated at NARDI Fundulea in the season 2021-22 and in two farms in 2022-2023. On average, variety mixtures displayed a slight yield advantage over pure line varieties (+4.8%), whereas the populations, possibly because of their exotic origin, were the lowest yielding material. When considering the individual entries, the results highlighted the particularly high agronomic value of the mixture with highest genetic diversity, i.e., that composed of six varieties. This mixture featured moderate tolerance to all abiotic or biotic stresses, good competitive ability (based on the leaf area index), and good yielding ability, a combination of traits expected to provide highest yield stability. Good agronomic value was also showed by the mixture of five varieties and the variety Glosa (which was susceptible to drought).

Characteristics of Romanian pure line cultivars, mixtures of these lines, and foreign populations of wheat

Genotype	Leaf area index	Yield (kg/ha)	Frost susceptibility	Drought susceptibility index	Common bunt resistance
	Average of test environments				
Mean of 6 pure line varieties	*2.2*	*2429*	*5.2*	*0.9*	*2.2*
Mean of 5 foreign populations	*2.3*	*2161*	*3.0*	*1.1*	*2.0*
Mean of 3 varieties mixtures	*2.4*	*2546*	*3.0*	*0.8*	*2.4*
Variety mixture four varieties	2.6	2241	3.0	0.7	2.3
Variety mixture of five varieties	2.1	2814	3.0	0.8	2.4
Variety mixture of six varieties	2.4	2583	3.0	1.0	2.6
LSD ($P < 0.05$)	0.5	233	0.5	0.6	0.1

B- Fulfilment of objectives. The activity fulfilled its objectives, indicating the high interest for organic or low input systems of heterogeneous material, especially cultivar mixtures with fairly large number of components. **C- Changes compared to the project proposal.** No change.

Task 2.4 - Effect of crop diversity and farmer selection on grain yield and grain quality of white lupin in Italy

A- Results. This work focused on two evolutionary populations from Sardinia developed without or with farmers' mass selection, the original population developed in Northern Italy, an elite breeding line bred from the same genetic base, and the recent variety Arsenio, evaluated in a drought-prone site of Sardinia for grain yield, protein content, acceptability by farmers, and seed alkaloid content. Just two years of previous natural selection of the evolutionary population in Sardinia were sufficient to let emerge a significant yield advantage relative to the original population. This population showed no yield disadvantage – rather, a slight trend towards higher yield - compared with the elite inbred line and Arsenio. However, this population showed higher content of alkaloids, especially relative to the breeding line (selected for very low alkaloid content), albeit still below the safe threshold of 400 mg/kg for animal feeding. Farmers' selection failed to lead to an additional yield advantage relative to natural selection of the population.

Grain yield, acceptability by farmers and technicians, and grain quality traits in Sardinia of white lupin evolutionary population (EP) material selected in Sardinia without or with farmers' mass selection, the original EP, the variety Arsenio and the breeding line 5.23

Material	Dry grain yield (t/ha)	Farmer acceptability score (1-9)[a]	Technician acceptability score (1-9)[a]	Grain protein content (%)	Protein yield (t/ha)	Quilonizidine alkaloid content (mg/kg)
EP, natural selection	1.352 a	6.97 ab	6.50 ab	39.2 bc	0.530 a	351 a
EP, farmer selection	1.260 ab	7.37 a	6.71 ab	38.7 c	0.487 ab	202 bc
Original EP	1.135 b	6.86 ab	6.32 b	40.3 ab	0.457 b	171 c
Arsenio	1.281 ab	6.51 b	6.88 a	40.4 ab	0.517 ab	270 b
Line 5.23	1.270 ab	6.82 ab	6.25 b	41.1 a	0.512 ab	95 d
LSD ($P < 0.05$)	0.140	0.60	0.48	1.4	0.060	70

B- Fulfilment of objectives. The activity fulfilled its objectives, showing the occurrence of a yield increase of the evolutionary population after just two years of region-specific natural selection and the remarkable agronomic value of this population compared with elite inbred line material. **C- Changes compared to the project proposal.** The selection of evolutionary populations also in Tuscany, Sicily and Denmark could not be completed due to various reasons (unsuitable soil, excessive frost, etc.).

Task 2.5 - Comparison of soybean variety mixtures vs. pure lines for agronomic value in Romania

A- Results. This study compared pure line cultivars with mixtures of two, three or four cultivars for grain yield and protein content, for both semi-early maturity (00) and semi-late (group I) variety groups. There was a clear trend towards increasing crop yield as a function of increasing genetic diversity of the mixtures, with an advantage of the mixtures over the individual cultivars averaging 11% for the two-cultivar mixtures, 26% for the three-cultivar mixtures, and 60% for the four-cultivar mixtures. A similar trend emerged even when comparing the top-yielding mixture with the top-yielding cultivar, with an advantage of 11% for the top-yielding two-cultivar mixtures, 21% for the top-yielding three-cultivar mixtures, and 38% for the top-yielding four-cultivar mixture. The best four-line mixture displayed seed protein and seed oil contents comparable with those of the top-yielding individual cultivars.

Mean and range values of grain yield (kg/ha) for soybean mixtures of different complexity and their component pure line cultivars, and yield advantage of mixtures expressed by the yield ratio of mixture to individual cultivars for mean yield and for values of top-yielding materials

			Yield ratio	
Material	Mean	Range	Mean yield	Top-yielding
Individual cultivars (average)	1060	600 – 1300	–	–

Two-line mixtures	1183	900 – 1450	1.11	1.11
Three-line mixtures	1340	1100 – 1580	1.26	1.21
Four-line mixtures	1753	1680 – 1800	1.60	1.38

B- Fulfilment of objectives. This study fulfilled its objectives, highlighting a clear yield advantage of the greatest intra-variety genetic diversity (represented by a four-cultivar mixture) in the absence of any disadvantage for grain quality traits. **C- Changes compared to the project proposal.** No change.

Task 2.6 - Comparison of composite populations vs. pure lines for common bean and runner bean in Slovenia

A- Results. This study focused on 3 composite populations of common bean (*Phaseolus vulgaris* L.) and 3 of its related species runner bean (*Phaseolus coccineus* L.), each originated from 2 to 4 component lines. These materials and their component lines were evaluated for a large number of vegetative and reproductive traits and for functional DNA markers associated with agronomically important traits (resistance to viruses, bacteria, rust, fungus, drought, and high temperatures; earliness; yield), to identify shifts in the frequency of plant types and allelic diversity that could be related to different levels of resistance to biotic/abiotic stresses. In common bean, the allelic diversity analysis showed a significant deviation from Hardy-Weinberg equilibrium only for the commercial composite variety KIS Amand (where, however, one component got often predominant after the 4-6 cycles of variety multiplication). A high level of within-population allele diversity for functional markers emerged in common bean, especially for KIS Amand, with individual components of the same population that were genetically distinct from each other and from the pure lines/standards. Runner bean material was much more uniform genetically (with its composites that were grouped together closely to the pure line/standard). It should be noted that while most composites captured a high degree of genetic variation for agronomic traits, pure lines/standards might concentrate positive values of agronomically favourable traits. However, the results of a field trial performed in 2022 (not part of this project) suggested a positive impact of higher genetic heterogeneity.
B- Fulfilment of objectives. The activity fulfilled its objectives highlighting, in particular, the high allelic richness in markers associated with agronomically important traits of a common bean composite population bred in Slovenia. **C- Changes compared to the project proposal.** No change.

WP3	*Exploitation of intercropping*

WP leader: Pirjo Mäkelä, UoH

Responsible partners: UoH, LUKE, CREA, RSR, NMBU, Agrilogica, NARDI

Overall summary of main results, discussion and conclusions of WP3

The general objective of WP3 was to co-design and evaluate grain and forage mixtures for Northern and Southern Europe and to identify the most suitable grain and forage mixtures that can be further tested and developed by farmers. The results provided evidence for the high agronomic value of species mixtures in organic cropping systems based on the following results: (a) in Denmark and Finland mixtures generally increased yield stability and weed competition, especially in relation to pea and camelina; (b) in Slovenia and Northern Italy intercropping cowpea and soybean with sorghum was a successful technique to sustain crop yield and field biodiversity; (c) in Romania mixtures of triticale and peas, wheat and peas contributed to improving soil fertility, reducing the use of chemical fertilizers, and increasing biodiversity; (d) in Romania forage mixtures produced a higher volume of quality forage compared to single-species mixtures and possibly providing supply of grazed forage throughout the year and increasing stability. In Norway, none of the mixtures could outperform the pure stand of red clover in the establishment year and first harvesting year. In the first harvesting year, however, all mixtures including red clover (at low N fertilization level) had significantly higher yields than a pure stand of timothy given a high level of N fertilization. Plots including forage legumes had 30-80% higher yields of barley sown as the following crop, but the grain protein content was not significantly affected.

Task 3.1 Farmer-participatory design and assessment of multispecies grain intercrops for Northern Europe

A- results: In Denmark, polyculture in 2022 yielded on par to wheat in pure stands with a grain content of 61%. Oats yield increased due to the content of chaff, while the other species had lower yields with a higher protein and fat content. Total crop failure was observed in one or more pure stands. In 2023 loss of a component in mixtures due to drought was compensated by allowing more space to better performing components explaining the yield stability of mixtures over pure stands. Cereals were in general stronger competitors than the other crops. Pea was infested by weevils and wheat by yellow goutfly. In Finland, grain yield was in general highest in pure oats, followed by the mixtures. Grain yield LER values were always over 1. Weed biomass was reduced in three-crop mixtures more effectively than in pure pea and camelina but not as substantially as in pure oats. No marked differences were observed in the grain quality. In general, the yield stability was the best in mixtures. The highest activity density of carabid beetles, staphylinids and spiders was detected in three crop mixtures and camelina. **B- fulfilment of objectives:** The activity fulfilled its objectives, highlighting the stability and high fat and protein content of mixtures over the pure stands. **C- changes compared to the project proposal:** In Finland, only pea-camelina-oat mixtures were tested following the discussions with organic farmers. In Denmark, growing season 2023 was very dry and experiment was not harvested. Machinery cost was not evaluated.

Task 3.2 Farmer-participatory design and assessment of multispecies forage intercrops as cereal pre-crops for Northern Europe

A- results: In the establishment year and first harvesting year none of the mixtures could outperform the pure stand of red clover. In the first harvesting year all mixtures including red clover (at low N fertilization level) had significantly higher yields than a pure stand of timothy given a high level of N fertilization. Bird’s foot trefoil (cv. Leo) did not perform as well in as red clover in forage mixtures in terms of DM yield and protein concentration but increased the concentration of NDF and metabolizable energy. Addition of bird’s foot trefoil, chicory or ribwort plantain to grass-red clover mixtures did not have a significant effect on DM yield or forage quality. Plots including forage legumes had 30-80% higher yields of barley sown as the following crop, but the grain protein content was not significantly affected. **B- fulfilment of objectives:** Fulfilled, although some data analysis remains. **C- changes compared to the project proposal:** None.

Task 3.3 Farmer-participatory design and assessment of binary associations with warm season cereals of cowpea, soybean and common bean in Southern Europe

A- results: In Northern Italy, intercropping cowpea and soybean with sorghum was a successful technique to sustain crop yield and at the same time increase biodiversity at the field level. The higher yield of the erect-type cowpea encourages a focus on non-climbing types, at least for association with conventional, grain-type sorghum (fairly short <1.5 m). This type of crop arrangement did not impact the performance of intercropping; therefore, a seeder available on farm could be successfully adopted. In Slovenia, the binary association between the two species/selected varieties (durum wheat and common bean) proved to be a successful combination on the farm. However, winter wheat and bean intercrop, and maize and bean intercrop were not that successful. Winter wheat yield was not affected by intercropping, but it reduced the yield of the bean. Intercropping also reduced maize yields. In Slovenia a set of 30 cowpea genetic resources with dwarf growing habit were characterized and evaluated. **B- fulfilment of objectives:** The activity fulfilled its objectives, showing that the factors to further improve the agronomic value and farmers’ acceptability of the proposed mixtures are optimization of sorghum sowing rates and a better synchronization of the maturity period of sorghum and legumes as well as timely early season weed management. **C- changes compared to the project proposal:** There were no changes/deviations compared to the project proposal.

Task 3.4 Farmer-participatory design and assessment of multispecies grain intercrops for Southern Europe

A- results: The results showed the importance of multispecies crops for grain production, emphasizing that there are a number of variables that farmers must take into account. Thus, for the conditions in Romania, good results were obtained with mixtures of two species consisting of triticale and peas, wheat and peas. These mixtures contribute to improving soil fertility, reducing the use of chemical fertilizers, and increasing biodiversity. Farmers should choose the most productive varieties because those that are low-yielding in pure culture behave similarly in mixtures. In the mixture of three species, oats came with an increase in production if the pea genotype was a productive one. **B- fulfilment of objectives:** The activity fulfilled its objectives as the most promising crop combinations were selected, and it was shown that the mixtures were productive and increased the biodiversity. **C- changes compared to the project proposal:** There were no changes.

Task 3.5 Farmer-participatory design and assessment of multispecies forage mixtures for Southern Europe

A- results: Multi-species mixtures produce a higher volume of quality forage compared to single-species mixtures and their inclusion in pastures can lead to a more constant supply of grazed forage throughout the year. Sometimes mixtures are used as a buffer against drought. A series of multi-species mixtures were developed to find solutions adapted to the requirements of farmers who want to implement and best manage this type of crops. Thus, these mixtures were formed of alfalfa (different varieties), perennial grasses (a variety of *Dactylis glomerata*, *Festuca arundinacea* and *Phleum pratense*) and medicinal plants (*Hyssopus officinalis, Melissa officinalis, Anethum graveolens*). The results obtained are relevant for small and medium-sized farmers who want to improve the sustainability and diversity of their products. Also, for farmers in areas affected by drought or climate instability. **B- fulfilment of objectives:** The research work carried out contributed to the achievement of the project objectives which aimed to improve the productivity and resilience of organic crops by better utilizing crop diversity. Based on the evaluation, the most promising crop combinations that provide functional biodiversity for control strategies were selected. **C- changes compared to the project proposal:** There were no changes.

WP4	*Dissemination and communication*

WP leader: Anniken Fure Stensrud, NORSØK
Responsible partners: NORSØK, CREA, NMBU, NIBIO, UoH, LUKE, Agrologica, NARDI, KIS, RSR, Arcoiris, MVCRI

Overall summary of main results, discussion and conclusions of WP4

A website for the project has been operated through the CORE Organic Cofound webpage. A dynamic dissemination and communication plan has been managed through Teams. Publications from the project has been published at the open electronic archive Organic Eprints. Newsletters has been published on the website: Innovative strategies for combating common bunt; Intercropping and agroecosystem enhancement through DIVERSILIENCE; Success of three-crop mixtures in Finnish organic cropping system; The importance of frost tolerance in white lupin- phenotypic and genotypic tools for its improvement; DIVERSILIENCE project update. Articles have been published on Agropub: Frøblandinger for økt utnyttelse av arealer og ressurser; Genetisk mangfold styrker avlingene i økologisk kornproduksjon; Agrologica & Landsorten: Når tradisjon møter innovasjon i økologisk såkornproduksjon. "Tools" from the project will be published on Organic Farm Knowledge.

A- results: Information about the project in English is available at https://projects.au.dk/coreorganiccofund/2021-call-projects/diversilience. The dissemination and communication plan was operated through our Teams room for internal use in the project. **B- fulfilment of objectives:** The website gives basic information about the project to the project partners, other researchers and different stakeholder groups. The dissemination plan fulfill the general objective of WP4; coordination of the dissemination, communication and outreach activities. **C- changes compared to the project proposal:** The project use a website provided under the CORE Organic website instead of an own website. This makes the information more available for different target groups.

WP5	*Project management*
WP leader: Åshild Ergon, NMBU **Responsible partners:** NMBU, UoH, CREA, Agrilogica	
Overall summary of main results, discussion and conclusions of WP5 The objectives of the WP was largely achieved.	
A- results: We had an online kickoff meeting in early 2022, and a physical meeting in Mariager, Denmark, in June 2023. One WP-leader meeting was also held, and we communicated by email as well. The coordinator was not able to take part in the CORE Organic meeting in 2022 but was represented by a member of the NMBU group. The coordinator participated in the CORE Organic/AGROECOLOGY meeting in Brussels in May 2025. **B- fulfilment of objectives:** Objectives were almost fulfilled. **C- changes compared to the project proposal:** The last annual meeting was not held.	

3.2 Deliverables and milestones status

Deliverable No.	Deliverable name	Link to the document[3]	Planned delivery month[4]	Actual delivery month[4]	Reasons for changes/delay and explanation of consequences in case of delay, if any
D1.1.	Characterization of genetic variation for the development of diverse and resilient crops for the organic sector	https://orgprints.org/id/eprint/56378/	35	43	The project was extended. No consequences.
D1.2	Farmer-participatory breeding for the organic sector	*Combined with D1.1*	35	43	This Deliverable report was combined with Deliverable 1.1. No consequences.
D2.1	Value of genetically heterogeneous crops for organic farming according to DIVERSILIENCE results, and implications for organic breeders and farmers	https://orgprints.org/id/eprint/55121/	35	40	The project was extended. No consequences.
D2.2	Well-performing heterogeneous varieties developed by DIVERSILIENCE: results and opportunities for introduction into cultivation	https://orgprints.org/id/eprint/56391/	35	40	The project was extended. No consequences.
D3.1	Farmer-participatory design and assessment of multispecies intercrops of cool-season grain crops	https://orgprints.org/id/eprint/55120/	35	35	
D3.2	Farmer-participatory design and assessment of multispecies forage intercrops	https://orgprints.org/id/eprint/56379/	35	43	The project was extended. No consequences.
D3.3	Farmer-participatory design and assessment of warm-season legume-cereal binary associations for southern Europe	https://orgprints.org/id/eprint/55180/	35	40	The project was extended. No consequences.
D4.1	Project website	DIVERSILIENCE	1	3	We decided to use the website provided under the CORE Organic website.

[3] e.g. documents as orgprints.org/33121 or other types of deliverable (e.g. Apps or devices)
[4] Measured in months from the project start date (month 1)

D4.2	Dissemination	[Organic Eprints - Any field (including documents) matches any of "DIVERSILIENCE"]	2	4	Dissemination plan was established in the beginning of the project, but the dissemination is an ongoing process during the whole project period Publications from the project are published at the open electronic archive Organic Eprints
D5.1	Mid-term and final report to the CO board		18, 36	18, 43	We were given an extended deadline for the final report

Milestone No.	**Milestone name**	**Planned achievement month[5]**	**Actual achievement month[5]**	**Reasons for changes/delay and explanation of consequences, if any.**
M1.1.	Final list of material and protocols for phenotyping and genotyping agreed upon	4	7	Simple communication error
M1.2	Definition of target traits and farmer-participatory selection procedures	4	7	Simple communication error
M2.1	Definition of target traits and farmer-participatory evaluation procedures for assessing the value of heterogeneous material relative to pure stand crops	4	4	
M3.1	Co-designing of field experiments with organic farmers and researchers Completed	4	4	
M4.1	The project website established	1	3	Coordination and communication with the Core Organic team took some more time than expected
M4.2	A detailed dissemination plan established and routines for continuous input and updating of both the website and the dissemination plan established	2	4	Detailed planning of the dissemination necessary for all participants after start of the project. No consequences of the delay

[5] Measured in months from the project start date (month 1)

M5.1	Annual project meetings held	2, 17, 35	2, 20, -	No consequences of the delay of the second annual meeting. The third annual meeting not held as there were little interest among partners, possibly because the initiative was taken too late by the coordinator and some partners had already completed their work by then. Unknown consequences
M5.2	Additional online WP leader meetings held	7, 26	7, -	The last WP leader meeting was not held. No consequences

4. Publications and dissemination activities

4.1 Communication and Dissemination (C&D) Plan

In Norway, farmers and the agricultural advisory service was invited to a meeting to plan the field experiments. The experiments were later presented at altogether four open field days. Results have been presented on a scientific conference in Brno (Czech Republic) in 2023 and in Coimbra (Portugal) in May 2025 (both Eucarpia conferences). A video (in English) presenting DIVERSILIENCE was made at the CORE Organic kick-off meeting and a video about the role of species diversity in agriculture (in Norwegian) is also made and is accessible on YouTube. Several scientific publications are planned; two of these will be presented as part of a PhD thesis at NMBU due in early 2026 (Task 1.1). Two Master's theses have been produced based on the experiments (Task 3.2).

In Finland, a project blog (in Finnish) was established and updated during the growing seasons 2022 and 2023, field days were organised in both experimental sites. Results were introduced to stakeholders in Organic Days (Finland) and Agricultural Science Days (Finland), and first season results were presented in an invited meeting with Ministry of Agriculture and Forestry officials. One article was published in Finnish organic magazine Luomulehti. Two practice abstracts were published. One scientific manuscript is submitted and two manuscripts are under preparation. There were no deviations.

In Italy, farmers, seed producers and agricultural advisors were invited to visit cowpea field in September/October 2022. Farmers were also involved in Sprin 2023 (4 April 2023; in person meeting at CREA-ZA, Lodi) to discuss results of soybean and cowpea trials and set up the intercropping experiment. In Summer 2024 famers had a field visit (2 September 2024) to assess acceptability of intercropping treatments. Results of lupin frost tolerance, cowpea and intercropping experiments were presented in national scientific conferences (see details in 4.2). Three graduating students were involved and trained in project activities: 1) Pozzi, L. (2022–2023). Characterization of *Vigna unguiculata* for cultivation in intecropping with summer cereals (original title in Italian: Caratterizzazione varietale di *Vigna unguiculata* per la consociazione con cereali estivi). Università degli Studi di Milano. Supervisor: Prof. Pietro Marino Gallina; co-supervisor: Dr. Daniele Cavalli; 2) Pessina, R. (2022–2023). Effect of plant type and spatial arrangement on the biomass yield of summer cereal-legume mixtures. Università degli Studi di Milano. Supervisor: Prof. Salvatore Roberto Pilu; co-supervisor: Dr. Daniele Cavalli; 3) Sisto, P. (MS thesis to be presented in 2025). Evaluating two contrasting genotypes of cowpea (*Vigna unguiculata* (L.) Walp.) and a variety of soybean for intercropping with sorghum for forage production (original title in Italian: Valutazione di due genotipi contrastanti di fagiolo dall'occhio (*Vigna unguiculata* (L.) Walp.) e di una varietà di soia per la consociazione con sorgo finalizzata alla produzione di foraggio). Università degli Studi di Milano. Supervisor: Pietro Marino Gallina; co-supervisor: Dr. Daniele Cavalli.

In Denmark, the project results have been presented on 5 open field days demonstrating the bunt research and plant breeding. The research has been presented orally at 3 international webinars, 6 international conference presentations and at 9 national meetings. Eight newsletters and 8 conference papers have been published during the project period.

In Romania, an open field day was organized. Several scientific papers have been published and results have been presented at several scientific conferences, in Farmer's magazines and in social media.

In Slovenia, an open field day has been organized. A national extension service conference and a national biannual scientific conference were used to communicate the results of the project to professionals, farmers and others. Social media was used to communicate project aims and results. Results were also disseminated through several scientific papers, presentations at scientific meetings, workshops, meetings with policy makers and university teaching.

In Bulgaria, several meetings with farmers, agronomists, and researchers were held in early 2023 to plan and design field experiments. Demonstration plots were established in three regions: Plovdiv, Sadovo, and General Toshevo. These were visited during open field days held in 2023 and 2024, organized by the Maritsa Vegetable Crops Research Institute, the Institute of Plant Genetic Resources in Sadovo, and the Dobrudzha Agricultural Institute - institutes operating under the umbrella of the Bulgarian Agricultural Academy. Feedback from participating farmers was collected and integrated into the design of subsequent experimental trials. In 2025, a dedicated dissemination event took place at the AgroHub Intelligent Greenhouse of the Maritsa Vegetable Crops Research Institute (MVCRI) in Plovdiv. A short video (with Bulgarian subtitles) presenting the DIVERSILIENCE project and showcasing both field and greenhouse activities was shown and distributed to participants, including members of the Bulgarian Organic Farmers' Association. Preliminary research results were shared at several national and international scientific events, including: Second International Conference on Plant Systems Biology and Biotechnology, 25–27 September 2023, Plovdiv, Bulgaria (three presentations); International Congress on Oil and Protein Crops, EUCARPIA Oil and Protein Crops Section, 2–4 November 2023, Antalya, Türkiye (two presentations); 10th International Conference of Young Scientists, 20–23 June 2024, Plovdiv, Bulgaria; IV International Green Biotechnology Congress, 7–8 November 2024, Sofia, Bulgaria (two presentations). In addition, dissemination materials included a pamphlet acknowledging the DIVERSILIENCE project, prepared for the International Agricultural Exhibition AGRA2025 (18–22 February 2025, International Fair, Plovdiv). To date, two scientific papers in Q1 journals with high impact factors, two book chapters in Springer Nature / Scopus-indexed volumes, and a PhD abstract have been published under the project. Three additional peer-reviewed manuscripts are currently under development (Task 3.1). There were no significant deviations from the planned activities. One PhD thesis was successfully defended in 2023. A second PhD project, initiated in 2024, focuses on the performance of selected common bean accessions under organic management conditions at MVCRI and is expected to be completed in 2026.

4.2 Scientific articles

We have published 18 peer-reviewed papers in scientific papers, 8 peer-reviewed scientific conference papers and 4 papers in agricultural newspapers (Appendix 3).

4.3 Stakeholders oriented articles in the CORE Organic Cofund newsletter

Xiao, C., Mäkelä, P., & Alakukku, L. (2024). Success of three-crop mixtures in Finnish organic cropping system. *CORE Organic Newsletter*.

Borgen, A., & Stensrud, A. (2024). Innovative strategies for combating common bunt. *CORE Organic Newsletter*.

Pipan, B., Meglič, V., Petcu, V., Petcu, E., & Stensrud, A. (2024). Intercropping and agroecosystem enhancement through DIVERSILIENCE. *CORE Organic Newsletter*.

Lindemann, M. (2023). DIVERSILIENCE project update. *CORE Organic Newsletter*.

Stensrud, A. (2024). The importance for frost tolerance in white lupin: Phenotypic and genotypic tools for its improvement. *CORE Organic Newsletter*.

4.4 Practice abstracts

Himanen S, Mäkelä P. Öljykasvien sekaviljely luomutuotannossa. 2024. Öljykasvien sekaviljely luomutuotannossa

We have not published any practice abstracts on Organic Farm Knowledge yet. This will be conducted soon.

4.5 Other dissemination activities and material

Other dissemination activities are listed in Annex 3.

4.6 Publications and other dissemination material in Organic Eprints

Annicchiarico, Paolo; Borgen, Anders; Ergon, Åshild; Bråtelund, Signe; Frøseth, Randi Berland; Dieseth, Jon Arne; Petitti, Matteo; Petcu, Victor and Pipan, Barbara (2025) **Value of genetically heterogeneous crops for organic farming according to DIVERSILIENCE results, and implications for organic breeders and farmers.** CREA.

Annicchiarico, Paolo; Borgen, Anders; Ergon, Åshild; Frøseth, Randi Berland; Dieseth, Jon Arne; Petitti, Matteo; Petcu, Victor; Pipan, Barbara and Lo Fiego, A. (2025) **Well-performing heterogeneous varieties developed by DIVERSILIENCE: results and opportunities for introduction into cultivation.** CREA.

Berlin, Anna; Potgieter, Lizel; Edin, Eva; Borgen, Anders; Andersson, Björn; Novakazi, Fluturë and Bengtsson, Therese (2025) **Genetic diversity of common bunt in Europe.** In: *Absstracts of the XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Borgen, Anders (2025) **Co-evolution of virulence and resistance in heterogeneous wheat populations.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Borgen, Anders (2025) **Marker assisted breeding of organic heterogeneous wheat in Denmark.** In: *Book of Abstracts of the VI EUCARPIA Section Meeting Organic and Low Input Agriculture*. [Submitted]

Borgen, Anders (2024) **The Landrace no. 13.** Working paper.

Borgen, Anders (2023) **Unlocking the resistance to common bunt.** Wheat Initiative.

Borgen, Anders (2023) **Co-evolution of virulence and resistance in heterogeneous wheat populations.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.*. [Submitted]

Borgen, Anders (2023) **The Landrace no. 11.** *The Landrace*, 24 May 2023, 11, pp. 1-11.

Borgen, Anders (2023) **Sigtekornet nr 11.** *Sigtekornet*, 24 May 2023, 11, pp. 1-11.

Borgen, Anders (2023) **Udfordringer for øget plantebaseret kost.** Agrologica, KU-FOOD day.

Borgen, Anders (2023) **Økologisk planteforædling.** , Kalø Økologiske Landbrugsskole.

Borgen, Anders (2023) **Organic plant breeding.** , Kalø Økologiske Landbrugsskole.

Borgen, Anders (2023) **Dyrkning, sorter og diversitet i korn.** Sogn Jord- og Hagebruksskule , Aurland.

Borgen, Anders (2023) **Korn.** , Sogn Jord- og Hagebruksskule, Aurland.

Borgen, Anders (2023) **The Landrace no. 10.** *The Landrace*, 10, pp. 1-13.

Borgen, Anders (2023) **Sigtekornet nr. 10.** *Sigtekornet*, 10, pp. 1-13.

Borgen, Anders (2022) **Implementing EU seed legislation co-herent with UNDROP in Denmark -the Landsorten example.** .

Borgen, Anders (2022) **Organic Heterogeneous Material.** , Heterogenous seed materials webinar.

Borgen, Anders (2022) **Dyrkning, sorter og diversitet i korn.** [Cereal varieties, cropping and diversity.] , Presentation at Kornets Hus 2.11.2022.

Borgen, Anders (2022) **The Landrace no.9.** *The Landrace*, 9, pp. 1-8.

Borgen, Anders (2022) **Sigtekornet nr. 9.** *Sigtekornet*, 9, pp. 1-8.

Borgen, Anders (2022) **Phenotyping for bunt resistance.** Workshop on genetic markers for bunt resistance Mariager, DK, 18th July 2022.

Borgen, Anders (2022) **Organic plant breeding and seed production.** European Consortium for Organic Plant Breeding, ECO-PB Young Breeders Network Florence, Italy, 2nd – 3rd June 2022.

Borgen, Anders (2022) **Landsorten - a seed system for improved crop diversity.** , GrainLab, Nottingham, 30th April-1st May -2022.

Borgen, Anders (2022) **The Landrace no. 8.** Landsorten, Mariager, DK.

Borgen, Anders (2022) **Sigtekornet nr 8.** Landsorten, Mariager, DK.

Borgen, Anders (2022) **Germination inhibiters and zonulin - keys to understanding the impact of wheat on human health.** , GrainLab, Nottingham, 30th April-1st May -2022.

Borgen, Anders (2022) **Landsorten and the BOOST project.** , Webinar "Ongoing Nordic projects - heritage cereals" 5th April, 2022.

Borgen, Anders (2022) **Landsorten.** Foreningen Kornets Hus , Generalforsamling i Kornets Hus, 17.02.2022.

Borgen, Anders (2022) **Spiringsprocesser som nøglen til forståelse hvede og helse.** , Kalø Højskole, 30.01.2022.

CORE organic

Borgen, Anders (2022) **Spirehæmmernes betydning for sundhedsaspekter i hvede.** , Danske Ernæringsterapeuters årsmøde, Helsingør Ferieby, 29.01.2022.

Borgen, Anders and Christensen, Dennis Kjær (2025) **Genetic markers for bunt resistance.** .

Borgen, Anders and Christensen, Dennis Kjær (2025) **Co-evolution of virulence and resistance in heterogeneous wheat populations.** .

Borgen, Anders and Christensen, Dennis Kjær (2023) **Gene postulation based on phenotyping wheat varieties with a differential set of virulence races of common bunt (Tilletia caries).** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.*. [In Press]

Borgen, Anders and Christensen, Dennis Kjær (2023) **Annotation of differential lines used for resistance trials for common bunt.** In: *Book of Abstracts*, pp. 22-25.

Borgen, Anders; Ciuca, Matilda; Petcu, Victor; Ergon, Åshild; Harkingto, Harkingto; Zanotto, Stefano; Pecetti, Luciano; Nazzicari, Nelson; Annicchiarico, Paolo; Keskitalo, Marjo; Tomlekova, Nasya; Pipan, Barbara; Meglic, Vladimir and Petitti, Matteo (2025) **Characterization of genetic variation for the development of diverse and resilient crops for the organic sector.** .

Borgen, Anders; Forster, Monika; Sedaghatjoo, Somayyeh; Christensen, Dennis Kjær and Maier, Wolfgang (2023) **Determination of virulence of European races of common bunt using a differential set of wheat cultivars.** In: Buerstmayr, Hermann and Lunzer, Magdalena (Eds.) *Book of Abstracts XXII International Workshop of Bunt and Smut Diseases*, University of Natural Resources and Life Sciences, Vienna, Vienna, pp. 16-18.

Borgen, Anders and Lunzer, Magdalena (2023) **Annotation of differential lines used for resistance trials for common bunt.** In: Bürstmayr, Hermann (Ed.) *Book of Abstracts - XXII International Workshop on Bunt and Smut Diseases*, pp. 22-25.

Borgen, Anders; Mäkelä, Pirjo; Alakukka, Laura; Himanen, Sari; Petcu, Victor; Petitti, Matteo; Petcu, Victor and Pipan, Barbara (2025) **Farmer-participatory design and assessment of multispecies intercrops of cool-season grain crops.** NMBU.

Borgen, Anders; Müller, Karl-Josef; Vollenweider, Carl; Löschenberger, F.; Henriksson, Tine; Christensen, Dennis Kjær and Dumalasova, Veronika (2023) **Registered varieties and Organic Heterogeneous Material (OHM) with resistance to common bunt in Europe.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.*. [Submitted]

Borgen, Anders; Sedaghatjoo, Somayyeh; Dennis Kjær, Christensen and Maier, Wolfgang (2023) **Determination of virulence of European races of common bunt using a differential set of wheat cultivars.** In: Bürstmayr, Hermann (Ed.) *Book of Abstracts - XXII International Workshop on Bunt and Smut Diseases*, pp. 16-18.

Brumă, Ioan Sebastian; Toader, Maria; Popescu, Gabriel; Petcu, Victor and Georgescu, Emil (2023) **The Evolution of Alfalfa, as Important Crop in Organic Farming System in Romania.** *Romanian Agricultural Research*, 40, pp. 297-306.

Cavalli, Daniele; Annicchiarico, Paolo; Pipan, Barbara; Meglic, Vladimir and Petitti, Matteo (2025) **Farmer-participatory design and assessment of warm-season legume cereal binary associations for southern Europe.** CREA.

Christensen, Dennis (2025) **Genetic Mapping of Common Bunt Resistance Gene Bt13.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Disease*. [Submitted]

Christensen, Dennis (2025) **Genetic Mapping of Resistance Genes to Common Bunt (Tilletia caries) in PI 119333.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Christensen, Dennis (2025) **Mapping Bt-resistance genes controlling common bunt in wheat.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Christensen, Dennis Kjær (2025) **Preliminary Genetic Mapping of Common Bunt Resistance Gene Bt2.** In: *Abstract of the XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Christensen, Dennis Kjær (2025) **Genetic Mapping of Common Bunt Resistance Gene Bt5.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Disease*. [Submitted]

Christensen, Dennis Kjær (2025) **Genetic Mapping of Common Bunt Resistance Gene Bt6.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Christensen, Dennis Kjær (2025) **Preliminary Genetic Mapping of Common Bunt Resistance Gene Bt4.** In: *Abstracts of The XXIII International Workshop on Bunt and Smut Diseases*. [Submitted]

Christensen, Dennis Kjær and Borgen, Anders (2023) **Genetic Mapping of Common Bunt Resistance Gene Bt1.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.* [Submitted]

Christensen, Dennis Kjær and Borgen, Anders (2023) **Genetic Mapping of Common Bunt Resistance Gene Bt10.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.* [Submitted]

Christensen, Dennis Kjær and Borgen, Anders (2023) **Genetic mapping of Common Bunt Resistance Gene Bt13.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.* [Submitted]

Christensen, Dennis Kjær and Borgen, Anders (2023) **Genetic mapping of Common Bunt Resistance Gene Bt9.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.* [Submitted]

Christensen, Dennis Kjær and Borgen, Anders (2023) **Genetic Mapping of Common Bunt Resistance Gene BtZ.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.* [Submitted]

Christensen, Dennis Kjær; Borgen, Anders and Dallinger, Hermann Gregor (2023) **Genetic Mapping of Common Bunt Resistance Gene Bt7.** In: Bürstmayr, Hermann (Ed.) *Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.*. [Submitted]

Ergon, Åshild (2022) **DIVERSILIENCE.** ICROFS, https://projects.au.dk/. Online at **https://projects.au.dk/coreorganiccofund/2021-call-projects/diversilience**, accessed on: 8 August 2022.

Ergon, Åshild (2022) **Presentation of the project DIVERSILIENCE.** Poster at: CORE Organic kick-off meeting, Brussel, 17.-18.5.2022.

Ergon, Åshild and Petcu, Victor (2025) **Farmer-participatory design and assessment of multispecies forage intercrops.** NMBU.

Franguelli, Nicolò; Cavalli, Daniele; Pecetti, Luciano; Notario, Tommaso and Annicchiarico, Paolo (2024) **Frost tolerance improvement in pea and white lupin by a high-throughput phenotyping platform.** *Frontiers in Plant Science*, 15, p. 1490577.

Mäkelä, Pirjo; Xiao, Chao; Alakukku, Laura; Simojoki, Asko and Himanen, Sari (2024) **Viljelykokeen tuloksia herne—kitupellava—kaura-seoskasvustoista.** [Results of Field Trials on Pea—Flax—Oat Mixed Crops.] *Luomulehti*, 2024, 6, pp. 32-33.

Petcu, Victor (2022) **Raportul științific al proiectului DIVERSILIENCE pentru anii 2021 și 2022 în România.** [Scientifically Report of DIVERSILIENCE Project for 2021 and 2022 in Romania.] National Agriculture Research and Development Institute , Organic Agriculture.

Petcu, Victor; Barbieru, Ancuta; Popa, Mihaela; Lazăr, Cătălin; Ciornei, Laurentiu; Strateanu, Amalia G. and Todirică, Ioana Claudia (2023) **Early Sowing on Some Soybean Genotypes under Organic Farming Conditions.** *Plants*, 12 (12), p. 2295.

Petcu, Victor; Popa, Mihaela; Ciornei, Laurentiu; Todirică, Ioana Claudia; Popescu, Gabriel; Simion, Petruța-Simona and Schitea, Maria (2022) **FORAGE MIXTURES WITH ALFALFA CULTIVARS, PERENNIAL GRASSES AND ANETHUM GRAVEOLENS.** *Revista Lucrări Șriințifice. Seria Agronomie*, 65 (1), pp. 99-104.

Petcu, Victor; Popescu, Gabriel and Todirică, Ioana Claudia (2022) **ADDING VALUE TO WINTER WHEAT CROP BY ORGANIC SEED PRODUCTION – SOCIO-ECONOMIC CASE STUDY.** In: Subić, Jonel; Vuković, Predrag and Jean Vasile, Andrei (Eds.) *Sustainable Agriculture and Rural Development*, Institute of Agricultural Economics, Belgrade, no. III, pp. 87-97. [Submitted]

Stensrud, Anniken Fure (2025) **Frøblandinger for økt utnyttelse av arealer og ressurser.** agropub.no, Tingvoll. Online at **https://www.agropub.no/fagartikler/froblandinger-for-okt-utnyttelse-av-arealer-og-ressurser**, accessed on: 2025.

Stensrud, Anniken Fure (2023) **Agrologica og Landsorten: Når tradisjon møter innovasjon i økologisk såkornproduksjon.** agropub.no, Tingvoll.

Zanotto, Stefano (2023) **Diversifying organic crop production to increase resilience (DIVERSILIENCE CORE Organic).** NMBU.

4.7 Future dissemination actions

The dissemination actions planned for the future are shown in Appendix 4.

5. Expected project impact for the organic sector throughout the project

DIVERSILIENCE has enhanced the economic viability of grain and forage legumes (white lupin, common bean, cowpea, soybean, lucerne) and other major or minor crops (wheat, buckwheat, maize) in organic systems of Northern and Southern Europe by stimulating organic breeding activities aimed to improve the production, tolerance to key biotic and abiotic stresses and acceptability by farmers of these crops, to breed new varieties that can meet the need for feed proteins supply and the availability of crops of key interest for the production of novel high-protein and/or healthy food. Genomic data on bunt resistance developed in the project is now used by plant breeders in Denmark, Sweden, Germany, Austria and Switzerland (Task 1.3). Populations of white lupin adapted for organic conditions in Sardinia have been developed through farmer participative breeding (Task 1.4). Variation in drought tolerance, disease resistance, as well as a range of agronomic traits, useful for breeders has been characterized in a collection of 25 genotypes of common bean (Task 1.5). Accessions of cowpea and soybean were identified as candidates for possible introduction into cultivation or use as genetic resources in Northern Italy and Slovenia (Task 1.6). Organic breeding of populations of maize has been conducted (Task 1.7). DIVERSILIENCE has also developed and tested experimentally new breeding schemes that value and exploit the within-species genetic diversity, such as evolutionary populations with region-specific adaptation or mixtures of lines rather than pure lines of inbred crops (Task 2.2, 2.3). The project has envisaged intercropping as a target of grain legume breeding, by identifying most suitable associated species and legume traits that favour the legume variety adaptation to intercropping (Task 2.4, 2.5), and investigated intercropping with respect to other legume, cereal, grass and herb species, to identify diversified and well-performing legume-based intercrops (WP3). In some cases, farmer-participatory co-design and evaluation of intercrops has been employed, favouring the future adoption of best-performing intercrops by farmers (Task 1.2, 1.4, 1.7, 3.1, 3.3, 3.4, 3.5). Species mixtures are expected to increase the resilience, and functional biodiversity (above and below ground) in organic farming systems. In crop mixtures, the disease and pest pressures are expected to decrease while suppression of weeds will increase. The legume component is expected to increase the availability of nutrients which all increase the sustainability and resilience of crop production in organic systems. Crop diversification may also impact pollinators through increased availability of flower resources compared to pure stand crops. In the majority of cases, mixed cropping tends to increase yield as well as yield stability. Functional biodiversity was tested in various important contexts, such as wheat populations in relation to control of a key disease for organic farming such as common bunt or weed spread and disease intensity in relation to intercrops compared with pure stand crops. The identification of the specific resistance genes and the assessment of virulence in European bunt populations will help breeders prioritise among resistance genes in breeding. The identification of genetic markers will assist breeders to identify breeding lines with resistance, and to stack several genes into single breeding lines. The project focus on legumes will contribute to reduction of greenhouse gas emissions by increased availability of crops reduce the need for nitrogen fertilization and plant-based protein food, whereas the emphasis on minor or orphan crops will contribute to diversify farming systems and landscapes, increase their resilience against extreme events, mitigate risk of crop loss and reverse the loss of biodiversity.

6. Added value of the transnational cooperation in relation to the subject of the project

For each of the three axes of research (exploitation of genetic diversity; value of heterogeneous variety types; design and test of intercrops), DIVERSILIENCE consisted of research initiatives in a set of northern countries (Norway, Denmark, Finland) and a set of southern countries (Italy, Romania, Slovenia, Bulgaria). Crop improvement research was mostly performed within each country, with the perspective for its outcome to be useful also for other countries belonging to the same latitudinal region (e.g., wheat varieties tolerant to common bunt bred in Denmark may well be useful for other northern countries; stress-tolerant common bean material identified in Bulgaria may be useful in other southern countries). Likewise, research on the value of heterogeneous material was mostly country-specific, but in this case the similarity of research questions and approaches adopted in each country addressed the general scientific question about the usefulness of such material relative to homogeneous one (e.g. the work on common wheat populations and variety mixtures in T2.1 and T2.3). In contrast, cross-country cooperative research was conducted for intercrops (e.g. for cool-season legumes in northern countries and warm-season legumes in southern countries) – albeit with different co-design of mixtures as determined by country-specific stakeholders. The performance of similar research initiatives in different countries, albeit on possibly different crops (as dictated by possible specific adaptation to northern or southern countries) is extremely important to verify in different situations the opportunities and challenges of the proposed diversity-based approaches for organic system improvement. Through DIVERSILIENCE, transnational research collaboration and sharing of genetic material, data and methods has been established and or developed further, e.g., between NMBU and CREA on lucerne (including co-supervision of a PhD student, and collaboration in a Horizon 2020 project), between NMBU, Agrologica and NARDI on wheat, between KIS and MVCRI on common bean, and between CREA and KIS on cowpea and soybean. Breeding for bunt resistance in Task 1.3 has led to cooperation among breeders and led to the formation of a European breeding consortium aiming at mapping the resistance genes. The consortium was formed at the physical seminar in 2022 in Mariager, DK and has had several follow up online meeting. The consortium includes researchers, gene banks and 11 commercial wheat breeding companies in Europe.

7. Any discordance with the organic rules during the implementation (explicitly state the reasons)

Two experiments in Norway (Task 1.1 and 3.2) were conducted under semi-organic conditions. The reasons why have been explained carefully in a written document submitted to the secretariate, and the change was approved by CORE Organic.

8. Suggestions for future research

All the topics that we have researched in DIVERSILIENCE are still highly relevant for further research and exploitation to facilitate the development of sustainable food production in Europe.

Annex 1: Project budget and balance overview for the full implementation period of 36 months (in EUR).

Partner no.	Total person months budgeted	Budgeted person months spent at final reporting	Total person months' In-kind contribution	Person months' in-kind contribution spent at final reporting	Total project budget	Total project budget costs – actual spending at final reporting	Total in-kind contribution	In-kind contribution - actual spending at final reporting
P1 – NMBU[1]	13.5	11.4	0	0	251994	214852	11994	3308
P2 – UoH	18	17.9	0	0	96795	96871	41483	41516
P3 – LUKE	6.85	8.62	2.94	3.69	63130	59117	27055	25336
P4 – NIBIO	1.2	1.2	0	0	10000	10000	0	0
P5 – CREA	32.2	32.4	0	0	203506	165546	0	0
P6 – Agrologica	15	15	3	3	152483	151700	30497	30496
P7 – NARDI Fundulea	26	30	4	4	135000	13500	0	0
P8 – RSR			0	0	63000	63000	0	0
P9 - NORSØK [1]	2.4	2.3	0	0	43752	39233	0	0
P10 – Arcoiris					2550	2500	2550	2550
P11 - KIS	9.1	7.84	0	0	48000	48000	0	0
P12 - Graminor [1]	7.25				21000			
P13 - MVCRI [2]	22.6	18.6 +	0	0	50000	50000	0	0
TOTAL					**1142417**			

[1] National budget extended until 31 Dec 2025
[2] National budget extended until 1 Sept 2025

Annex 2: Recommendations to the CORE Organic consortium in relation to launching and monitoring of future transnationally funded research projects

Annex 3: Completed communication and dissemination activities

Peer-reviewed papers in scientific journals

Andonova, M., Aziz, S., Masheva, V., Kiryakov, I., Pipan, B., Meglič, V., & Tomlekova, N. (2024). Response of Slovenian common bean accessions to biotic and abiotic stress. *Phytopathology Research*.

Aziz, S., Spasova-Apostolova, V., Kiryakov, I., Masheva, V., & Tomlekova, N. (2023). Genotyping of a common bean collection by ISSR, iPBS and combination. *Comptes rendus de l'Académie des Sciences Bulgares*.

Aziz, S., Spasova-Apostolova, V., Kiryakov, I., Masheva, V., & Tomlekova, N. (2024). Genotyping of a common bean collection by SSR. *Comptes rendus de l'Académie des Sciences Bulgares*.

Brumă, I. S., Toader, M., Popescu, G., Petcu, V., & Georgescu, E. (2023). The evolution of Alfalfa as important crop in organic farming system in Romania. *Romanian Agricultural Research, 40*.

Franguelli, N., Cavalli, D., Notario, T., Pecetti, L., & Annicchiarico, P. (2024). Frost tolerance improvement in pea and white lupin by a high-throughput phenotyping platform. *Frontiers in Plant Science, 15*, 1490577. https://doi.org/10.3389/fpls.2024.1490577

Guler, D., Aziz, S., Onat, B., Masheva, V., Kiryakov, I., Salih, B., & Tomlekova, N. (2024). Abiotic stress responding proteins in Bulgarian common bean accessions using LC-MS/MS. *International Journal of Molecular Sciences*.

Guler, D., Aziz, S., Onat, B., Masheva, V., Kiryakov, I., Salih, B., & Tomlekova, N. (2024). Quantitative proteomic analysis of Bulgarian common bean accessions. *Journal of Proteomics Research*.

Kiryakov, I., & Koleva, M. (2023). An overview of anthracnose on beans (*Colletotrichum lindemuthianum*) in Bulgaria. *Bulgarian Journal of Crop Science* [in press].

Kiryakov, I., Andonova, M., Aziz, S., Masheva, V., & Tomlekova, N. (2024). Phytopathology and molecular investigation of resistances to *Pseudomonas savastanoi* pv. *phaseolicola*, *Colletotrichum lindemuthianum*, *Xanthomonas axonopodis* pv. *phaseoli* of common bean Bulgarian collection. *Agronomy*.

Mladenov, P., Aziz, S., Topalova, E., Renaut, J., Planchon, S., Raina, A., & Tomlekova, N. (2023). Physiological responses of common bean genotypes to drought stress. *Agronomy, 13*(4), 1022. https://doi.org/10.3390/agronomy13041022

Petcu, V., Barbieru, A., Popa, M., Lazăr, C., Ciornei, L., Strateanu, A. G., & Todirică, I. C. (2023). Early sowing on some soybean genotypes under organic farming conditions. *Plants, 12*(12), 2295. https://doi.org/10.3390/plants12122295

Petcu, V., Popa, M., Ciornei, L., Todirică, I. C., Popescu, G., Simion, P.-S., & Schitea, M. (2022). Forage mixtures with Alfalfa cultivars, Perennial Grasses and Anethum Graveolens. *Revista Lucrări Științifice. Seria Agronomie, 65*(1), 99–104.

Petcu, V., Popa, M., Ciornei, L., Simion, P. S., Safta, A. S., Todirică, I. C., & Zaharia, A. T. (2024). Diverse Multispecies Intercropping of Annual Plants for Organic Farmers in South-East Romania. Scientific Papers. Series A. Agronomy, 67(2).

Plestenjak, E., Meglič, V., Sinkovič, L., & Pipan, B. (2025). Factors influencing the emergence of heterogeneous populations of common bean (*Phaseolus vulgaris* L.) and their potential for intercropping. *Plants, 13*(8), 1112.

Plestenjak, E., Neji, M., Sinkovič, L., Meglič, V., & Pipan, B. (2025). Genomic insights into genetic diversity and seed coat color change in common bean composite populations. *Frontiers in Plant Science, 13*(8), 1112.

Raina, A., Wani, M. R., Laskar, R. A., Tomlekova, N., & Khan, S. (2023). *Advanced crop improvement, volume 1 – Theory and practice*. Cham, Switzerland: Springer Nature, Springer International Publishing AG. (In press, will be published June–July 2023). Retrieved from https://www.summerfieldbooks.com/product/advanced-crop-improvement-volume-1-theory-and-practice/

Raina, A., Wani, M. R., Laskar, R. A., Tomlekova, N., & Khan, S. (2023). *Advanced crop improvement, volume 2 – Case studies of economically important crops*. Cham, Switzerland: Springer Nature, Springer International Publishing AG. (In press, will be published May–June 2023). Retrieved from https://www.brownsbfs.co.uk/Product/Raina-Aamir/Advanced-crop-improvementVolume-2-Case-studies-of-economi/9783031266683

Todiricǎ, I. C., Petcu, V., Ciornei, L., Grǎdilǎ, M., & Zaharia, T. A. (2024). Regenerative agriculture key traits: Bibliometric analysis and quantitative review. *Romanian Agricultural Research, 41*, 353–361. https://doi.org/10.59665/rar4133

Scientific conference papers and abstracts

Cavalli, D., Pecetti, L., Franguelli, N., Notario, T., Close, T., & Annicchiarico, P. (2023). Evaluating a world mini-collection of domesticated cowpea (*Vigna unguiculata* [L.] Walp.) for intercropping with cereals. In *Proceedings of the 52nd National Conference of the Italian Society for Agronomy*, Napoli, 25–27 September 2023.

Cavalli, D., Pecetti, P., Notario, T., Pessina, R., Pilu, R. S., Marino Gallina, P., & Annicchiarico, P. (2024). Sorghum-legume mixtures for forage production in Northern Italy. In *Proceedings of the 53rd National Conference of the Italian Society for Agronomy*, Matera, 11–14 September 2024.

Ergon, Å., Bråtelund, S., Frøseth, R. B., Dieseth, J. A., Borgen, A., & Annicchiarico, P. (2025). Effect of within-crop diversity and farmer selection on common wheat yield, yield stability and grain protein content in Norway. In *VI EUCARPIA Section Meeting Organic and Low Input Agriculture*, Coimbra, Portugal, 26–28 May 2025.

Franguelli, N., Cavalli, D., Notario, T., Pecetti, L., & Annicchiarico, P. (2024). Assessing frost tolerance in white lupin and pea: A methodological study using the LTER platform. In *Proceedings of the LXVII Italian Society of Agricultural Genetics Annual Congress*, Bologna, 10–13 September 2024.

Harkingto, H., Shafiee, S., Zanotto, S., Amdahl, N., Nazzicari, N., Annicchiarico, P., & Ergon, Å. (2023). Conventional and UAV-based phenotyping to characterize a broad collection of European lucerne germplasm in a Nordic environment. In *EUCARPIA Fodder Crops and Amenity Grasses Section Meeting*, Brno, September 2023.

Petcu, V., Popescu, G., & Todirică, I. C. (2023). Adding value to winter wheat crop by organic seed production – Socio-economic case study. *Sustainable Agriculture and Rural Development, 30*(3), 87–97.

Plestenjak E., M. Neji, L. Sinkovič, V. Meglič, B. Pipan. 2025. *Genomic insights into genetic diversity and seed coat color change in common bean composite populations.* Frontiers in Plant Science.

Plestenjak E., Meglič V, Sinkovič L, Pipan B. 2024. *Factors Influencing the Emergence of Heterogeneous Populations of Common Bean (Phaseolus vulgaris L.) and Their Potential for Intercropping.* Plants. 2024; 13(8):1112.

Pleštanjek, E., Meglič, V., & Pipan, B. (2023). Povezanost barve semenske ovojnice z barvo cvetov pri kompozitnih genskih virih navadnega fižola (*Phaseolus vulgaris* L.) [Association of seed coat color with flower color in common bean (*Phaseolus vulgaris* L.) composite genetic resources]. In B. Čeh (Ed.), *Novi izzivi v agronomiji 2023 = New Challenges in Agronomy 2023: Symposium program and summaries* (pp. 44–45). Laško, Slovenia: Slovenian Society of Agronomy. ISBN 978-961-94613-2-7.

Pleštanjek, E., Meglič, V., & Pipan, B. (2022). Morphological seed characterization of composite genetic resources of *Phaseolus* sp. In Š. Baebler (Ed.), *Plants in Changing Environment: International Conference of the Slovenian Society of Plant Biology: Biotechnical Faculty, University of Ljubljana, September 15–16, 2022, Ljubljana, Slovenia: Book of abstracts* (p. 14). Ljubljana, Slovenia: Slovenian Society of Plant Biology. ISBN 978-961-91014-5-2.

Papers in agricultural newspapers

Petitti, M. (2022). Una popolazione di lupino per l’agricoltura biologica. *Notiziario di Rete Semi Rurali*, 31. Retrieved from https://rsr.bio/notiziario-31/

Pipan, B. (2022, July 27). Žlahtnjenje fižola in genski viri. *Kmečki glas, 79*(30).

Løe, K., Stensrud, A. F., Ergon, Å., & Frøseth, R. B. (2025, March 13). Genetisk mangfold kan gi bedre avlinger i økologisk kornproduksjon. *Agropub*.

Stensrud, A. (2025). Frøblandinger for økt utnyttelse av arealer og ressurser. *Agropub*.

Stensrud, Anniken Fure (2023) Agrologica og Landsorten: Når tradisjon møter innovasjon i økologisk såkornproduksjon. Agropub.

Master Theses

Furuhovde E.-M. 2023. Bird's foot trefoil (Lotus corniculatus) in grass mixtures. MSc thesis, Norwegian University of Life Sciences.

Ødegaard J. 2023 Use of the herbs chicory and ribwort plantain in grassland mixtures. MSc thesis, Norwegian University of Life Sciences.

Other dissemination activities and material

Organization of events

Type of event	Related task(s)	Participating partners	Location	Date
Meeting	T.1.5, T.3.3	KIS	Ljubljana, Slovenia and Zoom	2 Dec 2021
Meeting with farmers and agricultural advisers	T3.2, T2.3, T1.1	NLR, NMBU, NIBIO, Agrilogica, NORSØK	Zoom	23 March 2022
Open Field day	T2.2	Rete Semi Rurale	San Nicolò Gerrei (Sardinia)	14 June 2022
Open field day	T1.3	Agrologica	Agrologica, Denmark	22th June 2022
Open field day	T.1.5, T.3.3	KIS	Jablje, Slovenia	7-Jul-22
Workshop and field day	T1.3	Agrologica	Agrologica	18th July 2022
Maize field Day	T 1.7, T2.4, T3.4, T3.5	NARDI	NARDI fundulea	8/4/2022
Open field day	T3.2, T1.1	NMBU	Ås, Norway	16 August 2022
Open field day	T1.2	Luke	Jokioinen, Finland	18th of AUG 2022
Open field day	T3.2, T1.1	NMBU	Ås, Norway	29 Sept 2022
Open field day	T3.1	UoH	Hyvinkää, Finland	10 August 2023
Open field day	T2.3	NMBU, NIBIO	Vestfold, Norway	16-Aug-23
Open field day	T2.3	NLR, NIBIO, …	Vestfold, Norway	7 Aug 2024
Open field day	T1.2	Luke	Jokioinen, Finland	22nd of AUG 2023
Open field day	T3.3	CREA	Italy	2-Sep-24
Open day	T2.1, T2.2, T3.3	CREA	Italy	5. June 2024
Workshop	T1.4, T3.3	CREA	Bologna Italy	5. June 2024
Open field day		Rete Semi Rurale	Ussana Donorii (Sardinia)	30. Mai 2024
Field day		Rete Semi Rurale	San Nicolò Gerrei (Sardinia)	5. July 2024

Oral presentations at events

Type of event	Related task(s)	Presenting partner(s)	Name of event/Location	Date
Meeting with farmers	T3.2, T2.3, T1.1	NMBU	Online	23 March 2022
CORE Organic meeting	All	NMBU	Brussels, Belgium	17 May 2022
UK GrainLab, Nottingham, UK	T1.3	Agrologica	UK GrainLab, Nottingham, UK	1 May 2022
Round Table	T.1.5, T.3.3	KIS	1st Slovenian Agriculture Development Conference	26-May-22
National organic field day	T1.3 and T2.2	Agrologica	Presentation of demonstration plots	15 June 2022
Meeting with agricultural administration	T3.1	UoH	Organic farming updates, Hyvinkää, Finland	6 Sept 2022

Conference	T.1.5, T.3.3	KIS	PLANTS IN CHANGING ENVIRONMENT - International Conference of the Slovenian Society of Plant Biology, Ljubljana (Slovenia)	15-Sep-22
Researchers night	T.1.5, T.3.3	KIS	Researchers night, Ljubljana (Slovenia)	30 Sept 2022
International Scientific Conference	T1.3, T2.3	NARDI	Online	15 Dec 2022
World pulses day, online event	T.1.5, T.3.3	KIS	World pulses day »Pulses for sustainable future«, online	10 Feb 2022
National, organic extension meeting	T1.2	Luke	Online	4th of April 2023
Lecture	T1.3	Agrologica	Kornets Hus, DK	17. februar 2022
Lecture for students	T1.3	Agrologica	Kalø Højskole, DK	31. januar 2022
Conference presentation	T1.3	Agrologica	GrainLab, UK	31-april 2022
Conference presentation	T1.3	Agrologica	GrainLab, UK	1st May 2022
Lecture for young breeders	T1.3	Agrologica	ECO-PB young breeders course	1-2. June 2022
Field lecture	T1.3	Agrologica	Field lecture	8. June 2022
Field lecture	T1.1, T3.2	NMBU	Ås, Norway	19. June 2023
Open field day	T1.3	Agrologica	Open field day	22th June 2022
Field lecture	T1.3	Agrologica	Field lecture	28th June 2022
Conference	T1.3	Agrologica	International grain seminar	18-19th July 2022
Webinar	T1.3	Agrologica	online conference: Heterogenous seed materials webinar	8th Novemner 2022
Webinar	T1.3	Agrologica	Webinar UNDROP in EU Seed Marketing Reform, the Danish perspective	29th November.
Conference		CREA	LXVII SIGA Annual Congress "Expanding frontiers in crop genetics", Bologna	10.-13. September 2024
Conference		CREA	19th Pan-Hellenic Congress of the Hellenic Scientific Society of Genetics and Plant Breeding “Innovation - Resilience - Sustainable Development - Plant Breeding”, Larissa	16.-18. October 2024
National workshop		CREA	Cropping diversification in organic agriculture, Bologna	5. June 2024
International Scientific Conference	T1.3, T2.3	NARDI	Tulln, Austria	13-15 June 2023
National Organic Days	T3.1	UoH	Mikkeli, Finland	1-2 November 2023
Meeting with decision makers		KIS	KIS 4th Project Day	15th March 2024
Agricultural fair	T3.3	CREA	233 Fiera agricola di Codogno", Codogno, Lodi	14.-15. November 2023
Agricultural fair	T3.3	CREA	233 Fiera agricola di Codogno", Codogno, Lodi	19.-20. November 2024
Congress	T1.4	CREA	19th Pan-Hellenic Congress of the Hellenic Scientific Society of Genetics and Plant Breeding	16.-17. October 2024
CORE Organic and AGROECOLOGY meeting		NMBU	DIVERSILIENCE	19-20 May 2025, Brussels

Other media

Type	Related task(s)	Participating partners	Details
Video	All	NMBU	https://www.youtube.com/watch?v=uELIj5UGSRk
Blog	T3.1	UoH	https://diversilience.blogspot.com/
Radio	T.1.5, T.3.3	KIS	https://val202.rtvslo.si/podkast/frekvenca-x/31057643/174948580
Podcast	T.1.5, T.3.3	KIS	https://www.24ur.com/popkast/dvoboj-prihodnosti-od-pisarne-med-rastlinami-do-pisarne-za-racunalnikom.html
TV	T.1.5, T.3.3	KIS	https://365.rtvslo.si/arhiv/kaj-dogaja/174955599%20od%2017
Social media	T.1.5, T.3.3	KIS	https://www.facebook.com/KISinstitut/posts/pfbid0ipNzewS63Gd3JPQNgXo7hcmwcktHYbzQCiEoaK5VAK34MVfWoGQB1ivCBd6yA3qNl, https://www.facebook.com/KISinstitut/posts/pfbid02urZxczRtYpFgUQkcSjvDPp3JBJa9HxdXJCQ7HxywcAmyR2a9w6Ri9tAZAp3SgEDQl https://www.facebook.com/KISinstitut/posts/pfbid0WmYZXJXMFAFw33XaF6FTVVmi6C79TGiSG3g18JBLo9g733Xxv4efBFCLFEGh871ol, https://www.facebook.com/KISinstitut/posts/pfbid02YZwz1q9jLGyeyTixQrqjp99uQ4A8T8HpFRKLbcwLz2sVdKLi3AH1FkZSQPqZe24el,
Video	T3.2	NMBU	https://www.youtube.com/watch?v=2H10LZaC7EY&t=9s
Video		Rete Semi Rurali & CREA	White Lupin presentation by Paolo Annicchiarico at 2024 Field Day, https://www.youtube.com/@ReteSemiRurali
Video		Rete Semi Rurali & CREA	White Lupin participatory selection during 2024 field days, https://www.youtube.com/@ReteSemiRurali

Other written publications

Type of publication	Related task(s)	Participating partners	Full reference	Year
Conference paper	T1.3	Agrologica	Borgen, A., M.K. Forster, S.Sedaghatjoo, D.K. Christensenn, W. Maier 2023. Determination of virulence of European races of common bunt using a differential set of wheat cultivars. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Christensen, D and A. Borgen 2023A. Genetic mapping of Common Bunt Resistance Gene Bt1. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Christensen, D and A. Borgen 2023B. Genetic mapping of Common Bunt Resistance Gene Bt7. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023

Conference paper	T1.3	Agrologica	Christensen, D and A. Borgen 2023C. Genetic mapping of Common Bunt Resistance Gene Bt9. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Christensen, D and A. Borgen 2023D. Genetic mapping of Common Bunt Resistance Gene Bt10. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Christensen, D and A. Borgen 2023E. Genetic mapping of Common Bunt Resistance Gene Bt13. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Christensen, D and A. Borgen 2023F. Genetic mapping of Common Bunt Resistance Gene BtZ. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Anders Borgen, Karl-Josef Müller, Carl Vollenweider, Franziska Löschenberger, Tina Henrikssen,,Dennis Kjær Christensenn, Veronika Dumalasova2023: Registered varieties and Organic Heterogeneous Material OHM) with resistance to common bunt in Europe. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Anders Borgen, Magdalena Lunzer and Dennis Kjær Christensen 2023: Annotation of differential lines used for resistance trials for common bunt. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T1.3	Agrologica	Anders Borgen and Dennis Kjær Christensen 2023: Gene postulation based on phenotyping wheat varieties with a differential set of virulence races of common bunt (Tilletia caries). Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Conference paper	T2.1	Agrologica	Anders Borgen 2023: Co-evolution of virulence and resistance in heterogeneous wheat populations. Proceedings of the XXII International Workshop on Bunt and Smut Diseases. BOKU, Austria.	2023
Newsletter	T1.3	Agrologica	Anders Borgen 2023: Sigtekornet nr. 11.	2023
Newsletter	T1.3	Agrologica	Anders Borgen 2023: The Landrace no. 11.	2023
Newsletter	T1.3	Agrologica	Anders Borgen 2023: Sigtekornet nr. 10.	2023
Newsletter	T1.3	Agrologica	Anders Borgen 2023: The Landrace no. 10	2023
Newsletter	T1.3	Agrologica	Anders Borgen 2022: Sigtekornet nr. 9	2022
Newsletter	T1.3	Agrologica	Anders Borgen 2022: The Landrace no. 9	2022
Newsletter	T1.3	Agrologica	Anders Borgen 2022: Sigtekornet nr. 8	2022
Newsletter	T1.3	Agrologica	Anders Borgen 2022: The Landrace no. 8	2022
Newsletter	T4	NORSØK, UiO	Chao Xiao, Pirjo Mäkelä & Laura Alakukku. 2024. Success of three-crop mixtures in Finnish organic cropping system. CORE Organic Newsletter	2024
Newsletter	T4	NORSØK, Agrologica	Anders Borgen & Anniken Stensrud. 2024. Innovative strategies for combating common bunt. CORE Organic Newsletter	2024
Newsletter	T4	NORSØK, KIS, NARDI	Barbara Pipan, Vladimir Meglič, Victor Petcu, Elena Petcu & Anniken Stensrud. 2024. Intercropping and agroecosystem enhancement through DIVERSILIENCE. CORE Organic Newsletter.	2024
Newsletter	T4	NORSØK	Mine Lindemann. 2023. DIVERSILIENCE project update. CORE Organic Newsletter.	2023
Newsletter	T4	NORSØK	Stensrud. 2024. The importance for frost tolerance in white lupin: phenotypic and genotypic tools for its improvement. CORE Organic Newsletter.	2024

CORE organic

Annex 4: Future dissemination actions

Activity	Task(s)	Partners	Year	Target audience
Publish "tools" on Organic Farm Knowledge	T4	NORSØK	2025	Farmers
PhD thesis, Harkingto H.	T1.1	NMBU	2026	Scientific community
Peer-reviewed scientific paper on evolutionary and farmer-assisted selection in wheat	T2.3	NMBU, Graminor, NLR, NIBIO, Agrilogica	2026	Scientific community
Peer-reviewed scientific paper on genomic prediction of lucerne traits in Nordic climate	T1.1	NMBU, CREA	2026	Scientific community
Several peer-reviewed scientific papers on forage mixtures and on effects on the next crop in the rotation	T3.2	NMBU	2026	Scientific community
National congress for organic agriculture	T3.2, T2.3, T1.1			
One publication assessing the agronomic value of white lupin evolutionary populations selected for Sardinia	T2.1, T2.2	CREA		
One publication on cowpea-based and soybean-based intercropping experiments	T3.3	CREA		
One publication on the genetic variation and the genome-enabled prediction of white lupin frost tolerance	T2.1, T2.2	CREA		
One publication on the genetic variation of the soybean European collection	T3.3	CREA		
One publication on the morphophysiological variation of the cowpea world collection accessions and GWAS and genome-enabled prediction of its traits	T3.3	CREA		
Five scientific papers on common bean and studies of abiotic and biotic stresses, genomic and proteomic analyses	T1.5	MVCRI		