DIVERSILIENCE - Diversifying Organic Crop Production to Increase Resilience

D3.1 - Farmer-participatory design and assessment of multispecies intercrops of cool-season grain crops

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Content

Abstract

Multispecies mixtures of crops are challenging to design and manage due to the complex relationships between species in the mixtures. Both practical and biological obstacles arise when agriculture moves from monoculture to polyculture crops. However, crop mixtures could provide a tool to stabilize yield fluctuations, increase diversity and resilience, and support ecological intensification in organic farming.

The general objective was to design and evaluate together with organic farmers, grain and forage mixtures for Northern and Southern Europe on the basis of crop use, management factors, phenology, plant type and expected compatibility, using earlier data and knowledge, scientific literature and farmers' experience. All designed mixtures were tested experimentally under organic farming to verify the agronomic value and farmers' acceptability of the crop mixtures. The advantages and challenges related to the crop mixtures in terms of the total crop yield, management practices and a range of other aspects of their agricultural performance were determined.

This report summarizes the most promising multispecies grain legume-based mixed crops developed in the project and their agronomic performance in the field experiments in Northern and Southern Europe. The advantages of crop mixtures over pure stands are discussed along with practical issues related to mixed crops investigated and agroecological measures.

Introduction

Organic farming relies heavily on biological nitrogen fixation by legumes. In addition, legumes have key importance to reduce the acute European and farm insufficiency for feed proteins and to respond to the increasing demand for organically produced high-protein food. Legumes are grown mainly as pure crops but also as intercrops, for example for fodder.

Crop diversity is indispensable for food security, sustainable development, resilience and adaptation to climate change (FAO 2019). Intercropping, especially of legume-based mixtures, has repeatedly been shown to provide greater value than the mean response of pure stand crops in terms of productivity and yield stability (Raseduzzaman & Jensen 2017). Legume-based mixed crops possess many advantages in terms of agronomic performance and ecosystem services by greater spatial and temporal efficiency of resource use, facilitation effects and limitation of weeds, pests and diseases (Picasso et al., 2011). However, its adoption in European agriculture is partly limited by technical challenges in crop sowing or harvesting and crop use, difficulties in obtaining balanced mixtures, but also because most grain legumes have competitive disadvantages when associated with cereals (Annicchiarico et al. 2019). Information on useful plant traits that favor the compatibility of associated species is limited for grain legumes, and similarly multi-species mixtures have been much less explored than binary mixtures.

The farmer-participatory co-design and evaluation of intercrops (taking also account of crop management and crop use issues) will ensure the addressing of all relevant research issues and links between agrobiodiversity and ecosystems services, while favouring the future adoption of best-performing intercrops by farmers within each target region (McPhee et al. 2021).

The aims of the research work reported in this deliverable were to produce information on challenges and opportunities of intercropping particularly for mixture that were substantially neglected by earlier research in Europe, and co-design with farmers and other stakeholders innovative multispecies mixture of grain crops and assess their agronomic value relative to pure crops.

Field experiments in Denmark

In the first year trial 2022, the trial was set up with two replicates of 6 or 10 m^2, but with the same seed rate, so that one repetition had a higher seed rate per m^2 than the other. The seeding rate did not influence the conclusions, and the values in the table 1 are therefore average values between the two repetitions.

The trial was conducted on unfertilised sandy soil JB-2 on autumn ploughed land after clover grass. The trial was sown with 4 rows in each plot with 40 cm row spacing. The trial was row cleaned twice. The number of plants in one row was lower and more fluctuating than in the others, perhaps due to row cleaning damage, and it was therefore removed before the trial was finalised. After harvesting, the harvested product was divided by species and weighed separately to determine the distribution between species.

In pure stands, the recommended seeding rate for the species was sown. In two-component mixes, 50% of the recommended seed rate for the species was sown and in 7-component mixes, 1/7 of the recommended seed rate for the species was sown.

Wheat was chosen as the mixing partner in all 2-component mixes. However, there was not enough wheat for all trials. Therefore, the wheat variety sent was replaced in all trials with a variety mix from Agrologica (Pop-Udbytte).

Vetch was the only species that wasn't planted in pure stands, as I felt that this wouldn't make sense from a cultivation perspective.

The trial was generally repeated in 2023, by including also naked barley, naked oat, flax, poppy seeds (*Papaver somniferum*), quinoa, cumin seed and faba beans as components in the mixture. Unfortunately, due to drought on the sandy soil, the total trail was discarded and not harvested. However, some conclusions were achieved.

Table 1. Results of field trials from 2022.

	Biomass in weed	Yield per plot	Rel. yield compared with pure wheat til hvede	Rel. yield compared with wheat mixture	Yield distribution in procent					
					Camelina	Buckwheat	Vetch	Pea	Oat	Lupin	Wheat
	Visuel %	gram	%	%	%	%	%	%	%	%	%
Polyculture -all	10,0	1.054,8	104,9		16,3	3,9	9,2	4,1	48,8	5,5	12,3
buckwheat -pure	45,0	768,7	76,5	84,6		100,0					
Buckwheat+wheat	15,0	908,7	90,4			8,8					91,2
Camelina, pure	15,0	523,7	52,1	79,5	100,0						
Camelina + Wheat	12,5	658,9	65,5		21,3						78,7
Oat, pure	3,5	1.770,7	176,1	138,9							
Oat+wheat	11,0	1.274,7	126,8						53,0		47,0
Wheat, pure	12,5	1.005,4	100,0						1,8	2,0	96,2
Lupin, pure	45,0	482,7	48,0	53,6						100,0	
Lupin+wheat	23,5	899,9	89,5			1,5	3,9		1,6	14,5	81,9
Vetch+wheat	13,5	764,7	76,1			0,9	32,2		1,4	1,4	66,0
Pea, pure	75,0	161,7	16,1	18,2				100,0			
Pea+wheat	18,5	888,4	88,4			3,0	4,6	19,1			77,1

Observations, considerations and conclusion

- There were too much variation in the numbers for statistics to make sense. The conclusion is therefore subjectively assessed.
- Polyculture in 2022 has given a yield on par with wheat in pure stands with a grain content of 61%. This covers the fact that oats have increased the yield mainly due

to the content of chaff, while the other species generally have lower yields but with a higher protein and fat content.

- In both years, total crop failure we observed in one or more pure stands. In 2022 peas had total crop failure due to pea leaf weevil (*Sitona lineatus*). In 2023 quinoa didn't germinate due to poor seed quality. Several crops in 2023 were severely surpressed due to draught, in particular dild, poppy seed, faba beans, and coriander. The loss of a component in mixtures were compensated by giving more space to better performing components. This explains the increased yield stability of mixtures over pure stands in particular in extreme environments such as the draught conditions in 2023.
- The camelina ripened earliest and was generally overripe at harvest. This calls for earlier varieties when used as mixing partner.
- The lupins matured late and were slightly immature at harvest.
- The selected buckwheat variety (Kora) matured uniformly and simultaneously with grain, whereas the variety Emka was too late for at mixture.
- Cereals are in general stronger competitors than the others (maybe except vetch), and oats are a stronger competitor than wheat, partly perhaps due to yellow goutfly (*Chlorops pumilionis*) infestation in wheat.
    - Even if oats are compensated for the 20-30% chaff content, oats are still a better competitor than wheat and the other species.
- Common oats could be replaced with naked oats in the mixture to increase digestibility.
- Lupin and buckwheat have done well in pure stand but are poor competitors in mixtures. Considering the seed price, they contribute too little in a mix because they are outcompeted by the cereals. Vetch and camelina offer more protein and fat for the money.
- Mixtures have generally increased yield stability and weed competition, especially in relation to pea.
- Two-component mixes have performed as well as polyculture in terms of yield, but polyculture has provided better weed competition.

Field experiments in Romania

Background

Intercropping is an agricultural system in which two or more species are sown and harvested together (Raseduzzaman &Jensen 2017). Today, intercropping is most commonly found in organic and low-input farming systems. In recent years, the concept of ecological intensification has been developed. To be successful, mixtures must be composed of crops that have complementary rather than competing traits, as they use resources more efficiently than single crops. In Romania, multispecies crops are not

used quite as often, but different mixtures of species have started to be used to create cover crops. Such as the mixture between cereals (Triticale) and legumes (field pea) (Petcu et al. 2022).

Objectives

The objectives of the study were to evaluate multispecies intercrops for the pedoclimatic conditions in the south-east of Romania and in the ecological agriculture system, in order to identify the best combinations for production and the degree of utilization of the land.

Methods

In NARDI, Fundulea, Romania, we studied the multispecies mixtures consisted by two and three crops in comparison with pure crops: pea + camelina; pea +flax; pea +oats; spring wheat + camelina, spring wheat + flax; pea + camelina + spring wheat; pea + flax + spring wheat; pea + flax + oats and pea + camelina + oats. Two sowing rates were tested, at 50% and 100% of the recommended amount of seed. All experimental variants were analyzed for production (t/ha), weight of 1000 grains (MMB) and land equivalent ratio (LER). Land equivalent ratio was calculated using the formula: LER= (Production of crop A from the intercrop system / production of crop A from the pure crop system) + (Production of crop B from the intercrop system / production of crop B from the pure crop system).

Results

In the mixtures of two species, the yields were superior to those obtained in pure culture in all years of experimentation. The studied seed sowing rate (50 and 100% of the recommended sowing rate) of pea intercropped with wheat, oats, flax as well as flax intercropped with wheat or oats exhibit significant positive effect on yield in 2022 and insignificant effects in 2023.

Sowing pea at the recommended or reduced seed rate in intercropping system with camelina resulted the same levels of yield during the environmental conditions of 2022. However, during environmental conditions of year 2023, the highest yields were obtained at reduced seed rate. These results may be due the fact that in the dry year 2023 at the reduced sowing rate the competition among adjacent plants was reduced, which led to an increase in the amount of solar radiation intercepted by plants, as well as increment aeration and light distribution for plants.

In the mixture of pea, camelina and oats, the level of production was between 2000 and 3500 kg/ha, the differences being due to the climatic conditions. The year 2023 generated a higher degree of weeding, which led to lower production. Similar results were obtained with the mixture of pea, flax and oats. The lower level of production in the

mixture of pea, flax and oats could be due to the presence of the cuscuta (*Cuscuta campestris* Yunck) more in 2023 compared to 2022.

Conclusions

Good results in terms of the yield were obtained with the mixtures between peas and cereals. In the mixture of three species, oats came with a production increase. Through LER with values greater than 1, the mixtures of crops that use environmental resources more efficiently and productively were identified. It could be concluded that to obtain the best land usage the best option was to use intercropping with two species as compared to intercropping with three species.

Figure 1. On the left two species mixture of pea + flax. In the middle two species mixture of spring wheat + pea, and on the right flax stand with cuscuta attack (*Cuscuta campestris* Yunck) in 2023.

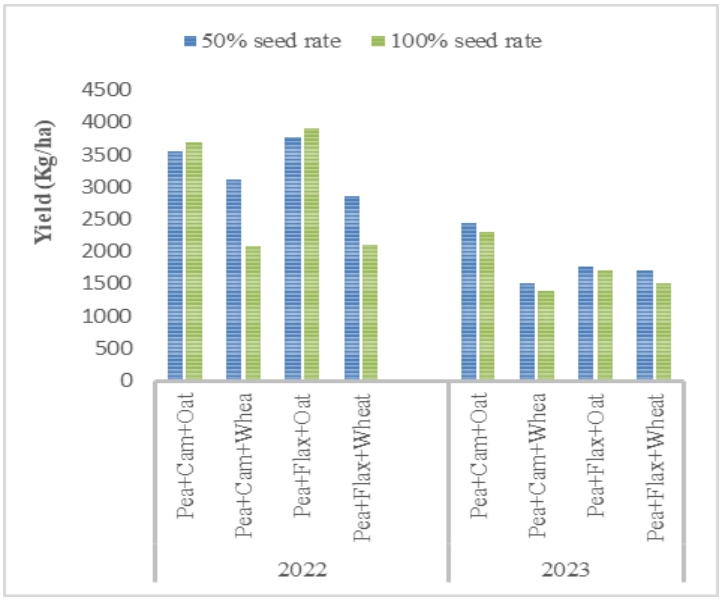

Figure 2. The yields of pea intercropped with camelina and oats/spring wheat, pea intercropped with flax and spring wheat/oat obtained during 2022 and 2023 seasons.

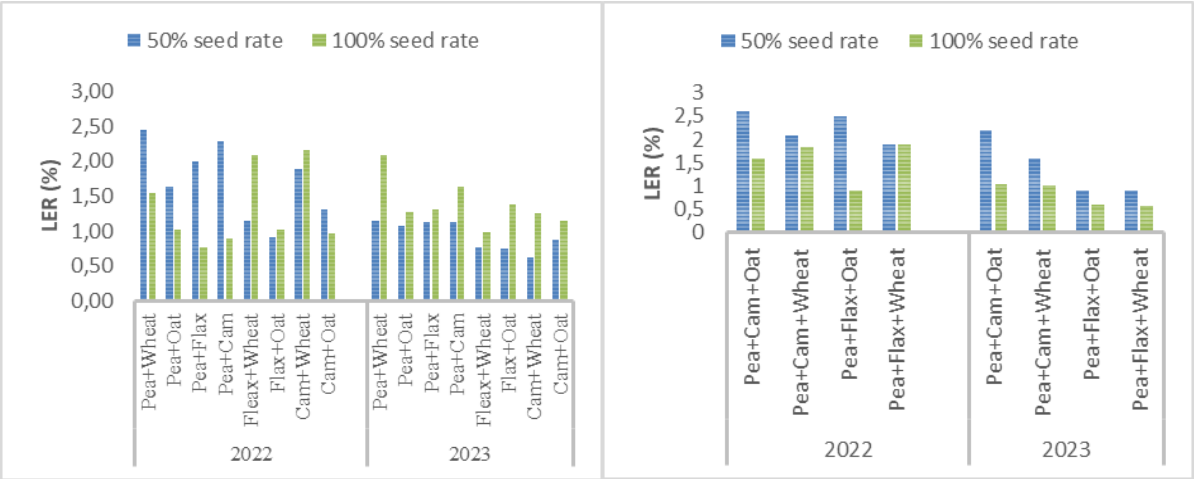

Figure 3. On the left, the land equivalent ratio (LER) for intercropping with two species and on the right the land equivalent ratio (LER) for mixtures of three species.

Field experiments in Finland

Background

Species mixtures are expected to increase the yield stability, 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. In legume-based mixtures, the legume component is expected to increase the availability of nutrients (Lizarazo et al. 2020).

Objectives

The objective was to co-design and evaluate together with organic farmers, oats-pea-camelina mixtures for Northern Europe with special emphasis on phenology, competition, yield, and nitrogen availability.

Methods

Two field experiments were conducted at an organic farm in Hyvinkää, Finland. The experiments consisted of pure stands of pea (*Lathyrus oleraceus* Lam.), oats (*Avena sativa* L.), and camelina (*Camelina sativa* L. Crantz.) and their three-crop mixtures. In 2022, the relative seeding densities (%) of oats, pea, and camelina in oats:pea:camelina mixtures were 20:50:30 and 33:33:33 of their respective pure stand density; in 2023, the seeding densities were 50:50:50 and 33:33:33 of the pure stand density. Plant samples were collected five times during the growing season. Plant species were separated and identified, dried, weighed and ground, and N content was analysed. Plots were harvested at maturity. Seed yield was dried, separated and weighed, 1000 seed weight and protein content was analysed. Crude fat content was analysed from camelina and test weight from oats.

Results

Grain yield was in general highest in pure oats, followed by the mixtures (Figure 4). Of the mixtures, 50:50:50 was highest yielding. Grain yield LER values in 2022 were 0.94 for 50:20:30 mixture and 1.12 for 33:33:33 mixture. In 2023 the LER for grain yield was 1.06 for 50:50:50 mixture and 1.01 for 33:33:33 mixture. The biomass LER values were 1.11 for 50:20:30 mixture and 1.17 for 33:33:33 mixture in 2022, whereas in 2023 the biomass LER values were 1.21 for 50:50:50 mixture and 1.26 for 33:33:33 mixture. 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 basic quality of seeds. While pure oats provided the strongest weed suppression, the inclusion of oats in pea and camelina contributed to enhanced weed control (Figure 5). There was no marked occurrence of diseases, though in 2022 some white blister rust (*Albugo candida* (Pers.) Kuntze) was observed in camelina. No marked difference was observed in pest damage between pure and mixed stands. Highest activity density of carabid beetles, staphylinids and spiders was detected in three crop mixture plots and camelina plots over the two growing seasons.

Conclusions

In general, three-crop mixtures had LER above 1 indicating they are more productive than pure crops. The main obstacle in Finland for the tested three-crop mixtures is related to marketing of the yield as the industry has no interest towards crop mixtures. Seeding three-crop mixtures can be challenging as without specific machinery, three rounds of seeding is required.

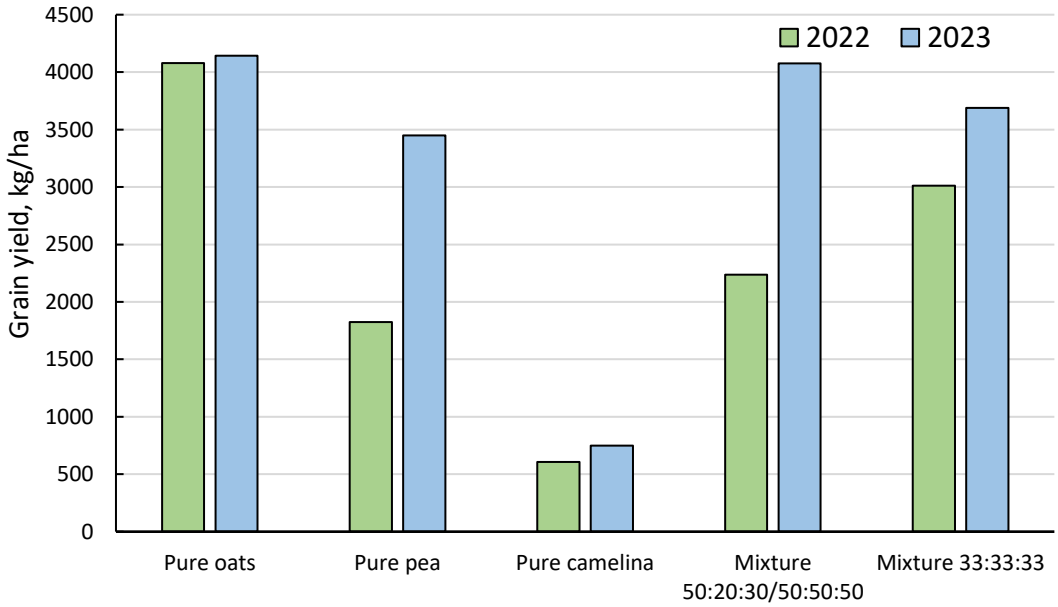

Figure 4. Grain yield of pure oats, pea and camelina and their three-crop mixtures in 2022 and 2023 in field experiment in Hyvinkää, Finland.

Figure 5. Weeds in (a) 33:33:33% mixture of pea, oats, and camelina (b) pure oats, (c) pure pea, and (d) pure camelina in field experiment in 2022 in Hyvinkää, Finland.

Conclusions

Mixed crops were in general most productive especially in terms of area. There are indications that two-crop mixtures could be the most potential combinations. The advantage of polycultures is in better competitive ability against weeds. Further research efforts should concentrate on design of mixtures and development of market for crop mixtures.

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