CORE Organic Cofund

"SCOOP: Developing intercropping systems with camelina to increase the yield and quality parameters of local underutilized crops"

Deliverable report

D 2.3. Report on farm scale trials

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Introduction

Large field trials with camelina intercropping were established in the second year of the project on the intercropping system identified locally as the most promising. Those trials were established at local organic farmers' farms (identified in T1.2) The trials were run at farm scale with locally available equipment and common organic practices, taking into account the opinions and suggestions of local organic growers and other actors in the LL. The assumption was to run demo trials at minimum surface of 0.5 ha, and to use them to showcase the SCOOP results in the rural community in relation with the living labs and demo-days. This report presents the final results of the intercropping trials conducted at farm scale across different environmental conditions in Poland, Italy, Bulgaria and Turkey.

1. Results from large scale trials conducted in Poland.

In Poland, based on the opinions and suggestions of local organic farmers and other Living Lab participants, as well as on the results of small-scale experiments conducted at the University of Warmia and Mazury (UWM), the most promising system was identified as the cultivation of spring camelina intercropped with spring spelt wheat. Therefore, in the following two years (2023 and 2024), large-scale field experiments were established to compare the cultivation of these species in sole cropping and in intercropping systems. These experiments were conducted on an organic farm run by a local farmer near Olsztyn. The production methods applied followed commonly used organic farming practices, making use of locally available machinery, tractors, and other agricultural equipment.

In 2023, the large-scale field experiment, covering an area of 1.42 hectares, was established in Butryny village, near Olsztyn on 11 April 2023 (Fig. 1.1). In 2024, a similar experiment was set up on an area of 1.16 hectares. Rye was used as the preceding crop for both experiments. No mineral fertilisers, chemical plant protection products, or irrigation were applied. In the year preceding the experiments, liming was carried out using lake chalk at a rate of 7 Mg/ha. Cattle manure was applied at a rate of 40 t/ha, once every four years.

In these experiments, both spring camelina (*Camelina sativa* cv. Olivia) and spring spelt (*Triticum spelta* cv. Wirtas) were sown as sole crops and in intercropping systems. In sole cropping, the seeding rates were 8 kg/ha for camelina and 200 kg/ha for spelt. In intercropping, the seeding rates were 6.2 kg/ha for camelina and 140 kg/ha for spelt. In all sowing variants, the row spacing was 12.5 cm.

No additional crop management practices were carried out during the growing season. Despite the extensive production system and unfavourable weather conditions—particularly due to irregular rainfall distribution—the growth and development of the plants were appropriate (Fig. 1.2). Harvesting of camelina, spelt, and the intercrop was carried out in a single operation using a combine harvester on 17 August 2023 (Fig. 1.3) and 30 July 2024, respectively.

Fig. 1.1. Location and establishment of the large-scale field experiment in Butryny village, near Olsztyn in 2023

Fig. 1.2. Plant growth and development in 2023 growing season

Fig. 1.3. Harvesting of plants on 17 August 2023

It should be emphasised that in each year of the study (2023 and 2024), the average air temperature during the plant growing season (April–August) was higher by 1.6°C and 1.9°C, respectively, compared to the long-term average (1991–2021), which was 15.0°C (Fig. 1.4). In terms of precipitation, a similar total amount of rainfall (386 mm) was recorded during the 2024 growing season. However, its distribution was highly unfavourable for plant growth and development, as approximately 72% of the total rainfall occurred at the end of July and in August, when the plants had already completed their development. In contrast, during the first three crucial months (April–June) of 2024, precipitation levels were very low, which negatively affected plant growth and development.

A similarly situation occurred in 2023, when the total precipitation during the growing season was only 258 mm, 27% lower than the long-term average. Rainfall distribution was also unfavourable, with a particularly severe deficit in May 2023 (only 27% of the long-term average). Although precipitation in June 2023 was close to the long-term average, which had a partially positive effect on plant growth and development, around 49% of the total rainfall occurred at the end of July and in August, when the plants were already reaching the end of their development.

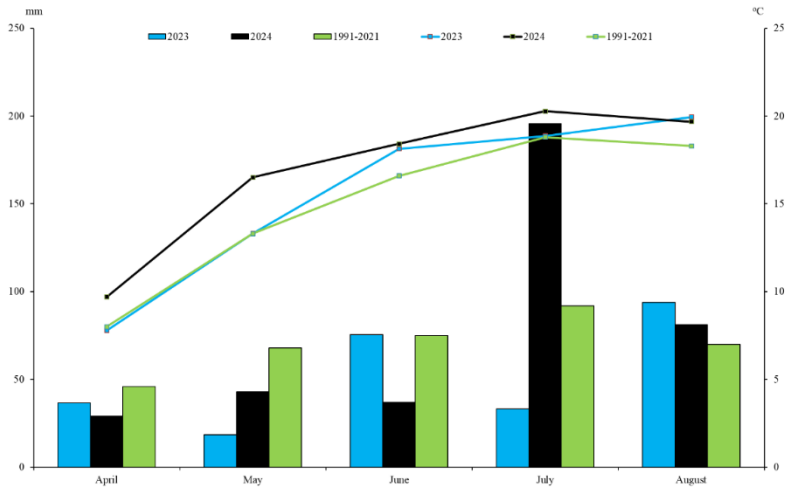


Fig. 1.4. Average air temperatures and total precipitation in 2023 and 2024 compared to the long-term average (1991–2021).

The average moisture content of straw and weeds at harvest ranged from 22.44% for spelt to 39.88% for camelina (Table 1.1). The moisture content of spelt straw was more consistent between years compared to that of camelina straw, which was high in 2023 (45.45%). Meanwhile, the straw moisture content from the intercropping of camelina and spelt was also more stable between years, averaging 25.33%.

Table 1.1. Straw moisture content (%) of the studied species.

Species	**Year**		**Average**
	2023	**2024**	
Camelina	45.45	34.50	39.98
Spelt	21.57	23.30	22.44
Cam+spelt	25.99	24.67	25.33

The dry biomass yield of spelt straw and weeds in sole cropping averaged 1.23 Mg/ha d.m. and was slightly higher compared to the yield obtained from intercropping, which amounted to 1.20 Mg/ha d.m. (Table 1.2). It should be noted, however, that the yield varied considerably between the years of the study. In 2023, the yield of spelt in sole cropping was 1.73 Mg/ha d.m., while in 2024 it was only 0.72 Mg/ha d.m. This was due to less favourable weather conditions, particularly lower precipitation. Similar trends were observed for the intercropping system.

In contrast, the straw and weed biomass yield from camelina grown in sole cropping was significantly lower, at 0.65 Mg/ha d.m. However, it was much more consistent across the two years of the study, which may indicate better tolerance of camelina to the amount and distribution of precipitation, at least in terms of straw biomass yield.

Table 1.2. Biomass yield (straw and weeds) of the studied species (Mg/ha d.m.)

Species	**Year**		**Average**
	2023	**2024**	
Camelina	0.63	0.67	0.65
Spelt	1.73	0.72	1.23
Cam+spelt	1.71	0.70	1.20

The seed yield of spelt in sole cropping (average 1.35 Mg/ha d.m.) was significantly higher compared to the seed yield of camelina (0.50 Mg/ha d.m.) also grown in sole cropping system (Table 1.3). However, for both species, large differences between years were observed, with 2024 yields being lower by 57% and 46% compared to 2023, for spelt and camelina respectively. The lower seed yields in 2024 may have been caused by considerably higher air temperatures throughout almost the entire growing season, combined with low precipitation in April and June.

Intercropping of spelt with camelina resulted in an average 26% reduction in spelt seed yield compared to sole cropping. Similarly, camelina seed yield in intercropping was on average 52% lower than in sole cropping. In this respect, year-to-year differences were minor. The seed yield from intercropping of spelt and camelina in 2023 was 1.69 Mg/ha d.m., while in 2024 it was 54% lower, with the two-year average amounting to 1.24 Mg/ha d.m.

Table 1.3. Seed yield of the studied species (Mg/ha d.m.).

Species	**Year**		**Average**
	2023	**2024**	
Camelina	0.65	0.35	0.50
Camelina int	0.31	0.17	0.24
Spelt	1.90	0.81	1.35
Spelt int	1.38	0.61	1.00
Cam+spelt	1.69	0.78	1.24

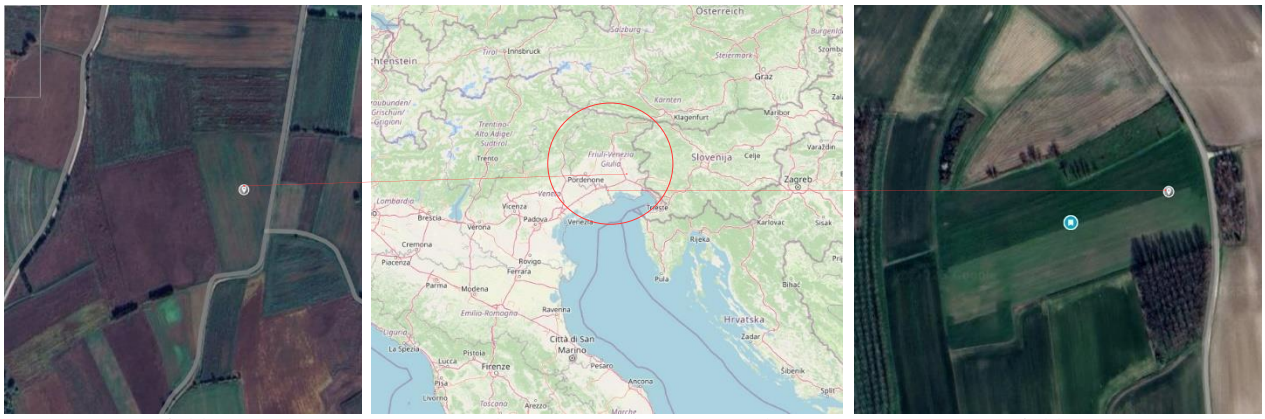
In 2024, based on the opinions and suggestions of local organic farmers and other Living Lab participants, additional one-off large-scale field experiments were established to test the intercropping of spring camelina with oat (*Avena sativa*) and narrow-leaved lupin (*Lupinus angustifolius*). Oat was sown at a rate of 120 kg/ha together with camelina at 6 kg/ha on an area of 0.27 ha. An identical area was used for the sowing of lupin at 117 kg/ha intercropped with camelina. In both cases, the preceding crop was winter rye, and following the rye, a phacelia (*Phacelia tanacetifolia*) was introduced as cover crop.

In the oat–camelina intercropping system, the seed yields of oat and camelina were 963 kg/ha d.m. and 26 kg/ha d.m., respectively. Camelina was completely suppressed by oat and failed to withstand the competition from this species. Similarly, in the lupin–camelina intercropping system, the seed yields were 185 kg/ha d.m. for lupin and 67 kg/ha d.m. for camelina. In this combination, camelina was again suppressed by the companion crop. Additionally, the lupin yield was well below expectations due to damage caused by wild animals, yet camelina still yielded at a very low level. The low yields in these systems were also influenced by insufficient rainfall, particularly during the early stages of plant development.

2. Results from large scale trials conducted in Italy.

To be consistent with the outcomes of the Italian Living Lab and based on the results of the small-scale experiments run by the University of Bologna, the most promising intercropping system was identified in the cultivation of camelina together with chickpea and lentils, considering two sowing periods, spring and autumn, in order to assess which could lead to a better performance of the two crops.

In 2023 two sowing dates has been tested, one in the spring time and one in autumn. The first trial has been carried out in Buttrio (sowing date 25/02/2023), and the second one in Rivignano (sowing date 18/10/2023).



Organic field in Buttrio
46°01'53.1"N 13°20'34.1"E

Friuli Venezia Giulia region, Italy

Organic field in Rivignano
45°51'46.8"N 13°02'19.7"E

Fig. 2.1. Locations of trials in Italy

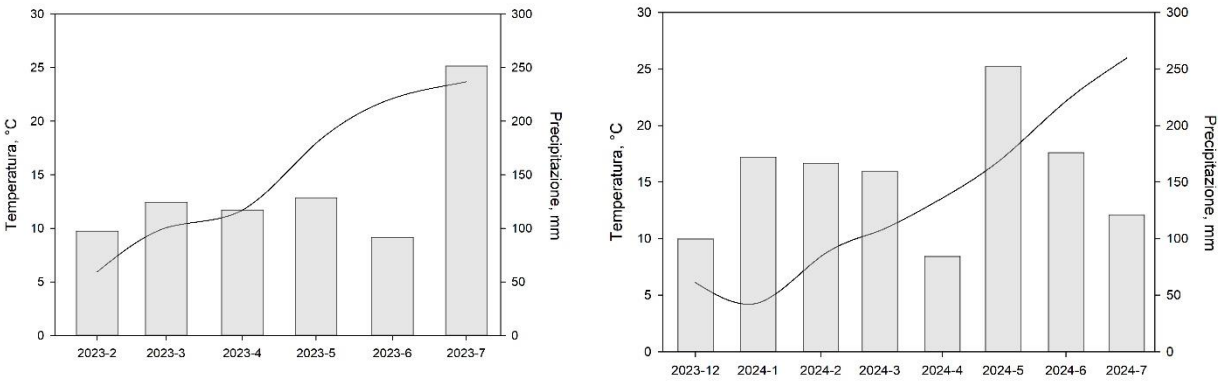


Fig. 2.2. Mean temperature and monthly rainfall for 2023 and 2024 growing seasons; Udine S.O. weather station 46°02'06.8"N 13°13'36.1"E

Table 2.1. Fields and crops details

	Buttrio	Rivignano
Location	46°01'53.1"N 13°20'34.1"E	45°51'46.8"N 13°02'19.7"E
Farm type	Organic arable farm	Organic arable farm
Mechanization	Farm owned implements	Farm owned implements
Field size	2 ha	1 ha
Soil	Silty loam, no gravel	Sandy loam, gravel (5%)
Intercropping mixture or sole crop	Camelina + lentils or chickpea	Camelina + chickpea, sole camelina, sole chickpea
Camelina variety	Calena	Calena
Lentil variety	Itaca	/
Chickpea variety	Cicerone	Sultano
Sowing rate camelina, sole	6 kg/ha	12 kg/ha
Sowing rate camelina, intercropping	6 kg/ha	6 kg/ha; 12 kg/ha
Sowing rate lentil, intercropping	100 kg/ha	/
Sowing rate chickpea, sole	/	170 kg/ha
Sowing rate chickpea, intercropping	150 kg/ha	170 kg/ha
Sowing date	25/02/2023	18/10/2023
Sowing equipment and mode	Pneumatic seed drill with two hoppers and two metering units; intercropped camelina and lentils sown in one pass	in-line mechanical seed drill with one hopper; Intercropped chickpea and camelina seeds has not been mixed in the tank; two drill passes, the second with camelina
Previous crop	Buckwheat	Soybean
Soil tillage	Moldboard plow + power harrow	Minimum tillage
Fertilization	No	No
Mechanical weed control	No	No
Irrigation	No	No

Fig. 2.3. Rivignano location. Photos' sequence from minimun tillage sowing (October 2023) to harvest time (July 2024) also on the next pages







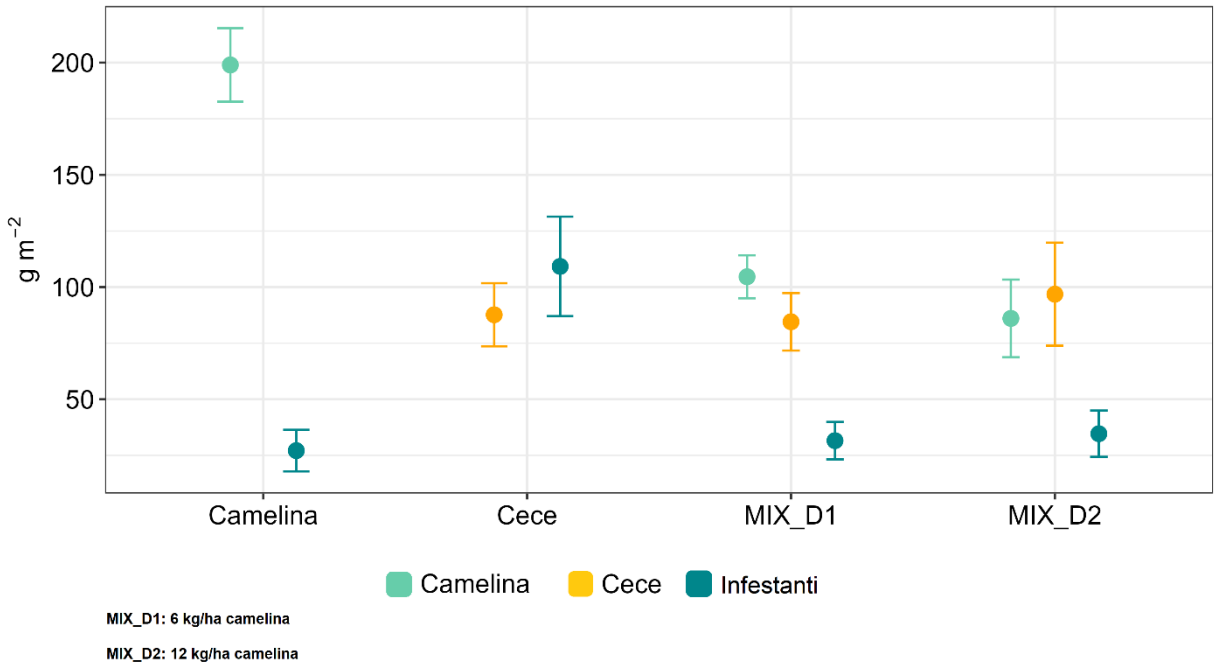



Fig 2.4. Yields for camelina and chickpea (cece), weeds (infestanti) biomass for the 2024 camelina sole and camelina+chickpea in Rivignano

Results

The outcomes of the two years of farm tests had been "seen" by LL members during several field visits and discussed in a final meeting. The major points to be highlighted are:

- camelina and the legumes suffer greatly from an excess of soil moisture, especially if occurring at sowing time or immediately after;
- crop emergence at Buttrio location during spring 2023 suffered for the wet soils at planting time and frequent rain in the following weeks. Consequently there was a low number of plants per m^2 and a limited development of plants, leading to a strong weeds competition;
- the autumn sowing has more chances to take place with the proper conditions regarding soil moisture;

- the chickpea - and camelina - could withstand low temperatures during January 2024 in Rivignano (21 days with minimum temperatures in between 0 and minus 3°C; Ariis weather station);
- harvesting both crops in the intercropping parcels was easier on combine settings for the camelina/lentil mix than the camelina/chickpea mix due to seed size differences;
- camelina yields were significantly decreased by intercropping compared to sole crop;
- chickpea yields had not been decreased when intercropped with camelina;
- weeds biomass were significantly lower in intercropping compared to sole chickpea crop, highlighting a clear effect of weeds suppression by the intercropping system.

Table 2.2. Yields. Qualitative synthesis (*)

	Harvesting year	Buttrio 46°01'53.1"N 13°20'34.1"E	Rivignano 45°51'46.8"N 13°02'19.7"E
Intercropping camelina+lentil – spring sown	2023		
Intercropping camelina+chickpea – spring sown	2023		
Sole crop camelina – autumn sown	2024		
Sole crop chickpea – autumn sown	2024		
Intercropping camelina+chickpea; camelina yeld – autumn sown	2024		
Intercropping camelina+chickpea; chickpea yeld – autumn sown	2024		

Colours legend tab. 2

Yield: low. Sole or combined yield < 0,5 Mg·ha^{-1}
Yield medium. Sole or combined yield ~ 1 Mg·ha^{-1}
Yield: good. Sole or combined yield > 1,5 Mg·ha^{-1}

Low, medium and good yield values had been defined by LL members comparing revenue and production cost of other crop alternatives (e.g. small grains, oil crops).
** Yields values have not been directly measured, but have been estimated by means of volume and specific weight of harvested grain.*

Conclusions

Intercropping camelina and chickpea or lentil at Buttrio location had been hindered by frequent rains after sowing time. Soil was not in the conditions to timely drain the excess of water because of its texture and massive structure. Consequently crops germination and stands were poor and weeds biomass was high. The end of winter sowing period, in Friuli Region, for crops as camelina and grain legumes has probably to be restricted to soils with a good/excellent infiltration rate of rain water.

The autumn sowing of intercropped camelina and chickpea was more successful in Rivignano location. Both climatic conditions at sowing time and soil drainage characteristics have favoured a good crop germination. Mid October sowing also experiences a lower weed pressure, with less weed species germinating compared to spring time. Camelina had a smothering effect on weeds, both in sole crop and when intercropped with chickpea.

Camelina and Chickpea growing habitus complemented each other quite well, resulting in a good solution for organic farming. The most demanding operation was the simultaneous harvest of the two grains, due of the difference in seed size.

LL members highlight that camelina as sole crop probably can benefit of an increased sowing rate, to better respond to non optimal pedoclimatic conditions at sowing time.

Camelina as not been a problem as volunteer on the following crop (quinoa, spring 2025 in Rivignano), confirming its flexibility to be used as main crop, in intercropping or as companion crop to smooth weeds.

3. Results from large scale trials conducted in Turkey.

Based on the results of small-scale trials, large scale trials were conducted during the 2021/2022 autumn and 2022 spring sowing periods, the intercropping combination of camelina and fenugreek has shown promising potential. The trials were established in two organic farms of CRIFIC close to Ikizce Research and Production Farm (45 km and 30 km far from CRIFIC). Ikizce has a semi-arid continental climate with hot, dry summers and cold, snowy winters. The average annual precipitation for the successive two years (2023 and 2024) was 280,87 mm, the average temperature was 13,90 ^{o}C, and the humidity was 71,37% (fig 1.2.).

The experimental soil was classified as loam-clay loam. The lime ratio was high, the organic matter was low, the available phosphorus was medium and the pH level was neutral.

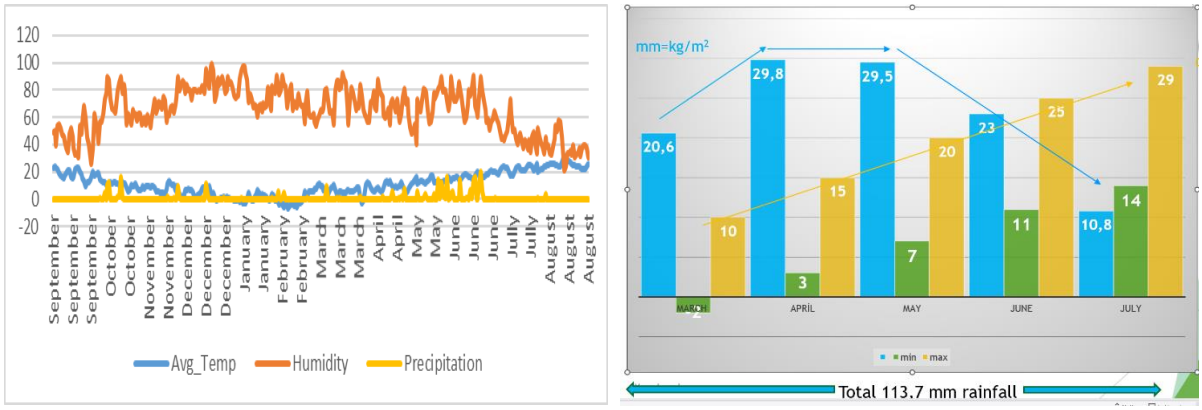


Fig 3.2. The average temperature, Humidity and precipitation during the vegetation period of large trials of SCOOP (Haymana/Ikizce) in 2023 and 2024

Camelina (*Camelina sativa*) was the main crop, and the companions was fenugreek (*Trigonella foenum graecum*). Local varieties were used in the experimental such as; CV Çiftçi (fenugreek), CV Arslanbey (Camelina). The quantity of seed rates was 50:50 in intercropping parcels. The quantity of the seeds were; 20 kg/ha in fenugreek, and 10 kg/ha in Camelina in sole cropping. No irrigation or fertilization was applied throughout the two successive growing period. Fenugreek was initially sown using a grain drill with a row spacing of 17 cm. Following this, camelina was planted at a 90-degree angle, maintaining the same 17 cm spacing, in 0,5 ha area. Despite the autumn sowings of 2023, 2024 sowings were carried out in the spring. The 2023 spring had a satisfied rainfall compared to 2024, which experienced notably lower rainfall, totaling just 113.7 mm (images a-i).

Fig 3.3. Images a,b,c,d,e,f from 2023 large scale trials and g, h, i from 2024 large scale trials

The morphologic and yield differences were shown in İmage j. Based on the average measurements of 30 plants selected annually from a large area, camelina has reached a height of 66.1 cm in 2023, compared to just 53.4 cm in 2024. Fenugreek grew to 71.9 cm in the first year but show a significant decline in the second year, reaching only 32.5 cm. The decrease in yield over time was also reflected in the reduction of both the number of pods and the number of seeds per pod (Image j and table 1). A yield of 0.762 Mg/ha fenugreek and 0.084 Mg/ha camelina were recorded in 2023 and a 0,30 Mg/ha fenugreek and 0,010 Mg/ha camelina was recorded in 2024. The aging hedge during harvest, along with seed loss in the straw, contributed to a decline in yield, as well.

Image j. The comparision of Plant high and , number of pods and number of seed per pods in the successive two years of 2023 and 2024.

		Plant high (cm)	Number of Pod	Number of seed per pod
camelina	2023	66,1	10,03	10,41
	2024	53,4	7,95	8,03
fenugreek	2023	71,9	7,25	9,75
	2024	32,5	4,3	4,7

Table.1. The main Plant high(cm), number of pods (number), and number of seed (number) per pods of 2023 and 2024.

The main weed populations were*; Avena fatua, Chenopodium albüm, Convolvulus arvensis* and *Sinapis arvensis*. In entomological studies various insect species have identified across different orders. Within the Coleoptera order, notable species include *Phyllotreta nigripes* (Fabricius), *Phyllotreta corrugata* and Saulcy (Chrysomelidae), Lapsa sp. (Tenebrionidae), *Meligethes flavipes* (Nitidulidae), and *Smaragdina biornata angorensis* (Chrysomelidae). Meanwhile, species from the Hemiptera order include *Aphis fabae* (Scopoli), *Brevicoryne brassicae* (L.), and *Myzus* (Nectarasiphon) *persicae* (Sulzer).

4. Results from large scale trials conducted in Bulgaria.

The data from Bulgarian partner has been not delivered.

5. Conclusion

The farm-scale intercropping trials conducted within the SCOOP project across Poland, Italy, and Turkey demonstrated that the integration of camelina with various companion crops offers both opportunities and challenges, strongly influenced by local climatic conditions, soil properties, and species compatibility.

In Poland, intercropping spring camelina with spelt wheat showed moderate success under organic management. Although seed yields of both species were reduced under intercropping compared to sole cropping the system proved more resilient than expected. Trials with additional species (oat and narrow-leaved lupin) revealed that camelina is highly susceptible to suppression by more competitive crops, particularly under dry conditions.

In Italy, results varied significantly between the spring and autumn sowings. Intercropping camelina with chickpea or lentil under spring sowing was hindered by excessive soil moisture, poor germination, and heavy weed pressure. In contrast, autumn sowing at the Rivignano site provided better growing conditions, with camelina and chickpea complementing each other well. The intercropping system effectively suppressed weeds without significantly compromising chickpea yield, although camelina performance was reduced. The ease of harvesting intercropped mixtures varied depending on species, with lentil–camelina mixes proving more manageable than chickpea–camelina due to seed size differences.

In Turkey, camelina intercropped with fenugreek produced promising results in the first year but experienced severe yield declines in the second year due to low precipitation, reduced plant growth, and increased pest and weed pressure. The results underline the importance of adequate early-season soil moisture for crop establishment in semi-arid regions. Camelina's performance was particularly vulnerable to drought, with a dramatic reduction in both plant height and seed yield in the second year.

Across all locations, camelina showed some potential as a companion crop in organic systems, offering weed suppression benefits and reasonable resilience in straw yield under stress. However, its seed yield was consistently reduced in intercropping systems, and its success was highly dependent on both the choice of companion species and the sowing date. The results emphasise the need for careful adaptation of intercropping systems to local environmental and agronomic conditions to maximise the benefits of diversification while minimising competition between crops.