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DIVERSE MULTISPECIES INTERCROPPING OF ANNUAL PLANTS FOR ORGANIC FARMERS IN SOUTH-EAST ROMANIA

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Abstract

Cropping system diversification is a key factor in developing more sustainable crops and increase food security. A two-year field experiment was conducted at South-East part of Romania, to emphasize the right plant types, both legumes and non-legumes which can be used in intercropping system for organic agriculture. Intercropping pattern with two (Peas + Camelina; Peas + Flax; Peas + Oats; Flax + Oats; Spring Wheat + Camelina and Spring Wheat + Flax) and three species (Peas + Camelina + Spring Wheat; Peas + Flax + Spring wheat; Peas + Flax + Oats; Peas + Camelina + Oats) was used. Sole cropping of peas, camelina, flax, oats and spring wheat were also used. Two sowing rates were tested, at 50% and 100% of the recommended amount of seed. Results showed that averaged across years and intercropping patterns, yields were significantly more increased in mixtures crops compared to sole cropping ones. Through the land equalization ratio (LER) with values greater than 1, the mixtures of crops (of two or three species) that use environmental resources more efficiently and productively were identified.

Key words*: participatory research, crop mixtures, legumes, cereals, field pea, oat, flax, camelina.*

INTRODUCTION

Intercropping is a system that results in two or more species being sown and harvested together (Parvin et al., 2023). Although they have been known for a very long time and have been commonly used throughout the world, in Europe, intercropping significantly reduced its area in the 20th century with the increase in mechanization and chemical intensification of agricultural production. Today, intercropping is most commonly found in organic and low-input farming systems (Ergon et al., 2016). In recent years, the concept of ecological intensification has been developed. This concept seeks to increase the contribution of natural cycles and resource flow in agricultural production through the widespread use of ecosystem support and regulation services provided mainly by beneficial organisms. Cultivation of mixed crops, especially with leguminous, appears to be an option worthy of support for this intensification. Potential benefits of these systems include reduced input costs, rotational benefits and soil improvement (Fletcher, 2020; Iannetta et al., 2021). Due to the symbiotic nitrogen fixation and protein content of legumes, intercropping is of particular interest to legume-based mixtures, such as annual legume-cereal mixtures, in terms of production, yield stability and environmental services (Raseduzzaman & Jensen, 2017; Martin et al., 2020). Intercropping requires compatibility when it comes to management (eg. maturity and harvest time of cereal crops) and species interactions (eg. facilitation, competition). Therefore, it is important to identify optimal combinations of species and varieties within species for different regions (Lizarazo et al., 2020). Identifying suitable plant types for intercropping is particularly important for species at a competitive disadvantage, as is often the case with cereal legumes associated with cereals (Annicchiarico et al., 2019). In Romania,

there are current studies of different annual crop mixtures of peas and cereals as cover crops (Petcu et al., 2022a), perennial mixtures with alfalfa or trifolium and grasses, in order to prove their productivity (Naie et al., 2024) or mixtures with medicinal plants used for their efficacy in repealing pests (Petcu et al., 2022b).
To be successful, it is recommended that mixtures to 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 used quite a bit, but different mixtures of species have started to be used to intercropping. Some examples of intercropping (mixes) with two and three species are presented in this paper, in order to identify the best combinations for production and the degree of utilization of the land.

MATERIALS AND METHODS

With organic farmers involvement has been designed and implemented different crop mixtures cultivation trials in organic agriculture conditions in Fundulea, Călărași, Romania (Field GPS coordinates: 44.446430, 26.514995) on chambic chernozem soil in 2022 and 2023.
The crop structure was composed of grain pea (cultivar Lavinia), spring cereals were: naked oat, spring wheat (cultivar T4068-19), camelina (cultivar Camelia), oil flax (cultivar Lirina). Two sowing rates were tested, at 50% and 100% of the recommended amount of seed. 100% seed rate was considered for wheat and oat - 500 germinable seeds/m^2; pea - 125 germinable seeds/m^2; camelina and flax - 450 germinable seeds/m^2. The intercropping variants were:

1. Pea+ spring wheat
2. Pea + oat
3. Pea + flax
4. Pea + camelina
5. Flax + spring wheat
6. Flax + oat
7. Camelina + spring oat
8. Camelina + oat
9. Pea + camelina + spring wheat
10. Pea + camelina + oat
11. Pea + flax + spring wheat
12. Pea + flax + oat

Along with these mixtures, variants of pure cultures were also used.
All experimental variants were analysed for production (kg/ha) and land equivalent ratio (LER).
Land equivalent ratios were calculated to measure the relative productivity of intercropping compared to pure/single cropping (monocrop). The calculation formula was the following 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).
A value for LER of 1.0 means that productivity in intercropping is equivalent to that in pure cropping. The values of LER value of > 1.0 mean that in intercropped culture it is more productive than in pure culture, it is so 'over-yielding' as shown by Willey and Osiru (1972).

RESULTS AND DISCUSSIONS

From a climatic point of view, both years of experimentation in the Fundulea area were a very dry and hot year. The amount of precipitation that fell between March and July 2022 was 178.8 mm and in 2023 was 203.6 mm below the multi-year average for this period (291 mm), registering a deficit of 112.2 respectively 87.4 mm and the average monthly air temperatures were above the multi-year average of the period. The distribution of precipitation was unfavourable in 2023 because most of it was in April. The average monthly air temperatures were above the multi-year average of the period in 2022 but April and May were below multi-year average (Table 1).

Table 1. Average air temperature (°C) and monthly distribution of precipitation (mm) during the crop vegetation period. Fundulea, 2022-2023

Month	March	April	May	June	July	Sum
Temperature 2022	4.4	12.1	17.9	22.6	25.0	
Temperature 2023	8.2	10.8	16.9	22.3	26.1	
Multi-annual average	4.9	11.3	17	20.8	22.7	
Precipitation 2022	12.3	47.6	30.1	59.6	29.2	178.8
Precipitation 2023	10.0	77.2	32.4	40.2	43.8	203.6
Multi-annual average	37.4	45.1	62.5	74.9	71.1	291

The moisture deficit from March and May cumulated with cold from March to April in 2023 created unfavourable condition during early stage of vegetation, determining relatively low yield in 2023 as compared cu 2022. On the other hand, lower plant emergence in 2023 may have been due to dry conditions during tillage in 2022-2023 season, resulting in a course seedbed due to soil clods on the soil surface. So, yield of pea in pure culture was 700 kg (year 2023) and 854 kg/ha (year 2022), spring wheat produced 2232 and 3083 kg/ha respectively, camelina produced between 203 and 282 kg/ha, oat yield was over 3000 kg/ha and the yield of oil flax was 1800 kg/ha in 2023 and 3112 kg/ha in 2022, respectively (Figure 1). The lower productions in 2023 are due to the very strong drought this year.

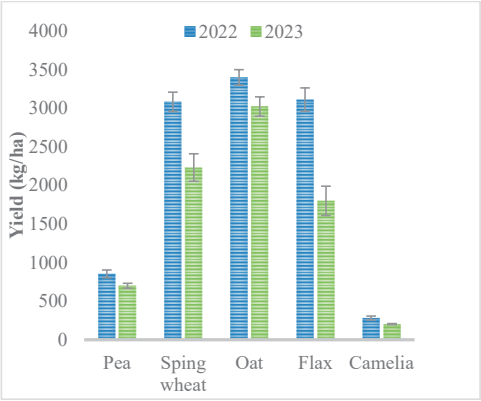

Figure 1. Mean grain yield in pure culture for pea, spring wheat, oat, flax and camelina obtained in 2022 and 2023

The variance analysis showed that in the year 2022 the seed rate per hectare had a very significant effect on the productions obtained in the mixtures of two species compared to the year 2023 (Table 2).

Table 2. Analyses of variance for the yield in intercrops with two species and two seed rate per hectare

Source of variance	FD	Factor F and significance	Factor F and significance
		2022	2023
Factor A (seed rate per hectar)	1	29.60***	5.01
Error A	2		
Factor B (Intercrop)	7	47.68***	10.61***
Interaction AxB	7	7.03	0.37
Error B	28		

In the mixtures of two species, the yields were superior to those obtained in pure culture in both years of experimentation. The studied seed sowing rate (50 and 100% of the recommended sowing rate) of pea intercropped with wheat, oat, flax as well as flax intercropped with wheat or oat exhibit significant positive effect on yield in 2022 and insignificant effects in 2023 (Figure 2). Sowing pea at the recommended or reduced seed rate in intercropping system with camelina resulted the same values of yield during condition of 2022. In the same time, we can see that during condition of 2023 year 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 was a reduced competition among adjacent plants, which led to an increase in the amount of solar radiations intercepted by plants, as well as increment aeration and light distribution among plants, which led to increased photosynthetic activities and dry matter accumulation per individual plants, and therefore increasing seed yields/ha) (Figure 2).

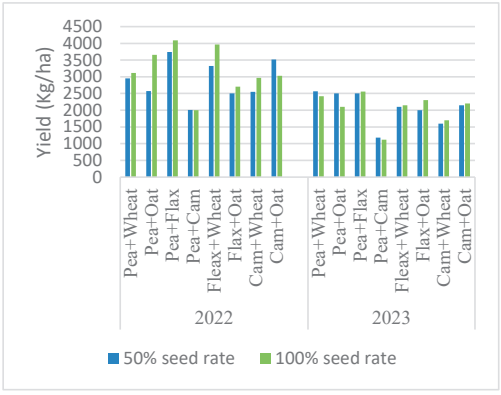

Figure 2. The yields of pea intercropped with spring wheat/oat/flax/camelina, flax intercropped with spring wheat/oat and camelina intercropped with spring wheat/oat obtained during 2022 and 2023 seasons

The analysis of the relative productivity of the intercropped crop compared to the pure crop, based on the land equivalent ratio (LER) is presented in figure three. Thus, in 2022, the superiority of using a reduced sowing rate compared to the recommended seed rate per hectare was highlighted. The pea and oat mixture has LER values of 1 at 100% sowing

rate and over 2 at reduced sowing rate (50%) (Figure 3).

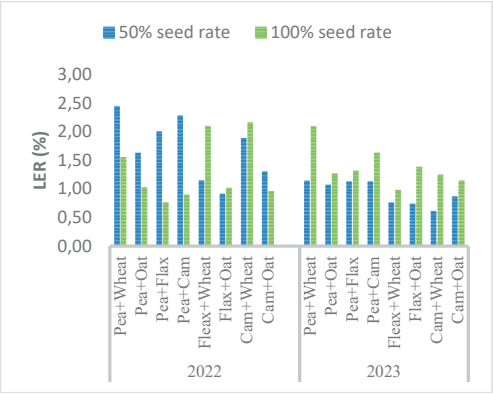

Figure 3. Land equivalent ratio (LER) for intercropping with two species

In the intercropping peas and flax, the land equalization ratio (LER) had a value below 1 at the recommended sowing rate compared to 50% of the recommended sowing rate, where the LER had a value of 2 (Figure 3) during 2022 season. Safina (2017) reported that land equivalent ratio (LER) ranged from 1.63 to 1.86 for intercropping flax with faba bean Giza-2 or Giza-843 varieties. Klimek-Kopyra et al. (2018) stated that intercropping pea with flax caused a significant increase in the number of seeds per pod and number of pods per plant.

Abd-Rabboh et al. (2021) found that when sugar beet and flax were intercropped, the maximum sugar beet root production and economic return of both crops were achieved by sowing flax at 12.5% of the recommended seed rate after 21 or 35 days of sowing sugar beet at 100% of the recommended seed rate (second or third sowing date).

Mixtures consisting of three species were also studied.

The variance analysis showed that in the year 2022 the seed rate per hectare had a very significant effect on the productions obtained in the mixtures of three species compared to the year 2023 (Table 3) when only component of mixture had a very significant effect.

Thus, in the mixture of peas, 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 productions. Similar results were obtained with the mixture of peas, flax and oats (Figure 4). The lower level of production in the mixture of peas, flax and oats could be due to the presence of the cuscuta (*Cuscuta campestris*) more in 2023 compared to 2022 (Figure 5).

Table 3. Analyses of variance for the yield in intercrops with three species and two seed rate per hectare

Source of variance	FD	Factor F and significance	Factor F and significance
		2022	2023
Factor A (seed rate per hectar)	1	14.70***	2.98
Error A	2		
Factor B (Intercrop)	7	119.27***	15.06***
Interaction AxB	7	26.98***	0.26
Error B	28		

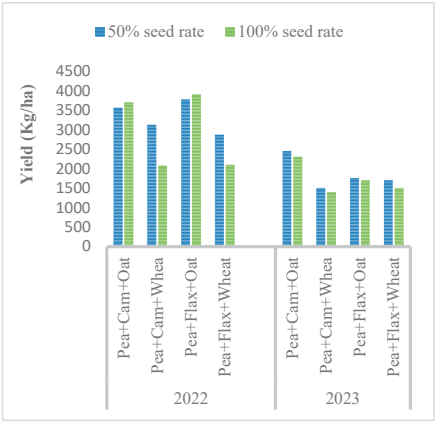

Figure 4. The yields of pea intercropped with camelina and oat/spring wheat, pea intercropping with flax and spring wheat/oat obtained during 2022 and 2023 seasons

Figure 5. Aspect of the flax crop with cuscuta attack (*Cuscuta campestris*), 2023

The mixture of three species consisting of peas + spring wheat/oats are not always profitable in the mixed culture at the rate of seed recommended for sowing (Figure 6).

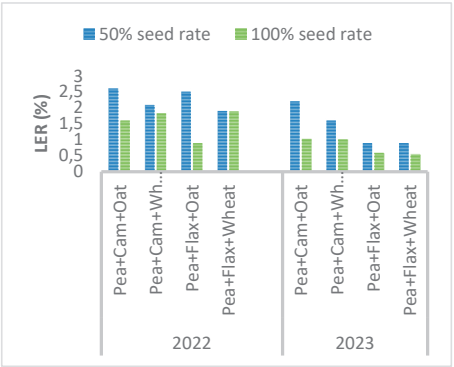

Figure 6. The land equivalent ratio (LER) for mixtures of three species

The mixture of three species in 2023 had LER values ranging from 0.5 to 1.04 at reduced seed rate, indicated that grain yield was reduced when three species were grown together, compared to their pure crops. The only pea intercrop with camelina and oat/spring wheat at recommended seed rate had LER values over 1 (Figure 6).

The reason for lower LER values at Fundulea in 2023 compared to 2022 could be beside the soils and climate of a region, factors including row intercrop planting configurations and the compatibility of the cultivars grown can affect yield outcomes.

Other studies examined the potential for reductions in nitrogen fertiliser use or fungicide use in intercropping systems, and any soil legacy effects that may improve subsequent cereal crop yields (Roberts & Dowling, 2020).

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 the land equalization ratio (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.

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