

# THE EFFECT OF CROPPING METHOD ON THE YIELD, SEED CHEMICAL COMPOSITION AND SEGETAL DIVERSITY OF LENTIL (*LENS CULINARIS MEDIC.*) UNDER ORGANIC FARMING CONDITIONS

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(Received 16<sup>th</sup> Feb 2021; accepted 14<sup>th</sup> May 2021)

**Abstract.** This study evaluated how growing lentil (*Lens culinaris Medic*) with barley (*Hordeum vulgare*) or oats (*Avena sativa* L.) as a supporting plant impacts on its yield, seed chemical composition and segetal diversity in an organic system. The field experiment was conducted over the 2017-2018 period, at the Agricultural Experimental Station in Grabów (Masovian Voivodeship, Poland). The one-factor experiment was set up as a randomized blocks design with four replicates. The study showed that a higher seed yield was obtained under the cropping method, where a supporting crop was used than in sole cropping. In turn, the 1000 seed weight was 4.0% higher in sole cropping. The yield share of lentil grown with oat was lower than with barley. Seeds of lentil grown with cereals contain similar amounts of protein, fat, fibre and phosphorus as those grown in sole cropping. Cropping method of lentil have a significant effect on weed infestation. In both years of the study, the highest weed infestation was observed in lentil grown in sole cropping. Sowing lentil with supporting crops significantly reduced weed infestation.

**Keywords:** *sole cropping, evaluation, supporting plant, influence, weed infestation*

## Introduction

The lentil (*Lens culinaris Medic*) is one of the oldest - apart from pea - cultivated high-protein crops (Piróg et al., 2003). Lentil seeds contain the less antinutritive substances among all legume crops. These are mainly composed of the galactosaccharide group: stachyose, raffinose, and verbascose (Urbano et al., 1995). Lentil is valuable species because of its nutritional quality (Hefnawy, 2011). It is rich sources of complex carbohydrates, proteins, dietary fibers, group B vitamins, mineral components, characterized by high share of exogenous amino acids (especially lysine, leucine, arginine, histidine, valine) (Costa et al., 2006; Joshi et al., 2017; Kowalczyk et al., 2007; Kahraman, 2016; Wang et al., 2008, 2009; Karadavut and Genc, 2010; Hamdi et al., 2012). They are characterized by anti-oxidant properties (Szwejkowska, 2012) and high nutritive value both as human food and fodder for animals (Erskine and Sarker, 2004). The content of nutrients in seeds significantly depends on genetic and environmental factors (Erskine and Sarker, 2004). Moreover, lentil can have a potential role in crop rotation, in particular in organic farms (Gan et al., 2003; Sellami et al., 2019). In spite of many beneficial characteristics of lentil, the acreage of cultivation is quite low. The main reason for this is likely due to its high susceptibility to lodging and low competitiveness against weeds (Carr et al., 1995; Chaudhary et al., 2011). One of the

methods for limiting lentil against lodging and reducing of weed infestation can be its intercropping with other crop species such as cereal (Duchene et al., 2017; Zawieja, 2006). In organic farming, in which herbicide is prohibited there is important need to seek new solutions for controlling weeds occurrence (Bond and Grundy, 2001). According to several authors (Duer, 2002; Vlachostergios and Roupakias, 2008; Avola et al., 2008) such role can have row intercropping, proper crop rotation, diverse agrotechnic, selection of varieties adapted to soil and climatic conditions with greater competitiveness in relation to undesirable species.

The aim of this study was to evaluate the effect of cropping method on yield, lentil seeds chemical composition and segetal diversity.

## Materials and methods

### *Field experiment and cultivation management*

A field study was carried out at the Agricultural Experimental Station in Grabów [51°21'18"N 21°40'09"E] (Masovian Voivodeship, Poland) belonging to the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy (Lublin voivodeship) (Fig. 1). The experiment was conducted over the period of 2017 to 2018. The one-factor experiment was set up as a randomized blocks design with four replicates. The area of a single plot was 35 m<sup>2</sup> and for harvest – 30 m<sup>2</sup>. In each year the total number of plots in the experiment was 12. The experiment was established on a Luvisol soil with sandy loam texture classes, belonging to a very good rye complex (www.commonswikipedia.org). The soil was characterized by the following nutrient content: (mg·100 kg<sup>-1</sup> soil): P 11.1–13.0; K 15.1–20.4 and Mg 4.0–6.2. Soil pH, as determined in 1 N KCl, was 5.5–6.3. The scheme of the trial included one factor: cropping method of lentil, cultivar ‘Anita’ [sole cropping (A), intercropping with two cereal species – barley (B) (*Hordeum vulgare* L. - cultivar ‘Ella’), oat (C) (*Avena sativa* L. - cultivar ‘Bingo’)]. The preceding crop was legume/grass mixture. The density (plants·m<sup>-2</sup>) of lentil in pure cropping was 200, in row intercropping – 100; oat as supporting plant – 250 and barley –150. The row spacing was 20 cm. Cereals were sown separately in the interrows of the lentil crop. In 2017 the lentil seeds were sown in the first 10 days of April, and in 2018 in the second 10 days of April. Mineral fertilization and plant protection products were not applied. The plots were harrowed twice to control weeds in the mixtures. Plants were harvested at the full maturity stage of mixture components in the first 10 days of August. The height of the plants, the height to the first and last pod, the number of pods and seeds on the plant, the weight of seeds per plant, the air dry weight of the stem of one plant and the weight of the pods were determined before harvest. The number and weight of grain per cereal plant, weight of 1000 seeds, and number of production shoots were also determined. The total lentil and cereal seed yield, lentil seed yield, component percentage in yield and weight of 1000 seeds at 14% humidity were determined after harvest. The percentage of species in mixtures was determined after splitting the crop harvested from the whole plot.

### *Chemical analysis of lentil seeds*

Material for chemical analysis was collected at commercial maturity each year. The following parameters were determined in seed samples: N, P (determination by the flow analysis (CFA) and spectrometric detection), K (determination by atomic emission

spectroscopy (FAES)). Moreover total protein (mineralization in sulfuric acid; determination by the Kjeldahl distillation method), fat content (Soxhlet method) were also determined. The analysis of the chemical composition of the seeds was performed at the Main Chemical Laboratory, accredited by Polish Accreditation Centre (PCA) of the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy.



**Figure 1.** Location of the study site (Public Domain, <https://commons.wikimedia.org/w/index.php?curid=89531>)

### Weed infestation

Evaluation of weed infestation in lentil crop was performed before harvest using the quantitative-gravimetric method. Analysis deals with the determination of the number, species composition, fresh and dry matter of weeds per sample areas delineated by a 1 x 0.50 m quadrat frame.

For comparison of weed infestation of lentil, the biomass index was determined and calculated for two years (2017 and 2018) according to the formula by Patriquin (1988):

$$\text{biomass index} = \frac{\text{crop biomass} * 100}{\text{weed biomass} + \text{crop biomass}}$$

The structure of weed composition in the studied crops was also described using two indices: the Shannon-Wiener index ( $H'$ ) and the Simpson dominance index ( $SI$ ). The Shannon's index is an indicator of species diversity. It depends on the number of species and their relative quantitative proportions and is calculated according to Shannon and Weaver's (Zanin et al., 1992):

$$H' = -\sum p_i \ln p_i$$

where:  $p_i$  – ratio of weed number the species to the overall weed abundance on each site.

The Simpson index ( $SI$ ) is an indicator described the probability of occurring two individuals of the same species. It takes into account the number of species and the relative abundance of each species and is described by the Simpson model (Zanin et al., 1992):

$$SI = \sum pi^2$$

Value ranges from 0 to 1, with values close to 1 indicating a clear dominance of one or more species and a low diversity of the community.

### **Weather conditions**

Throughout the experiment period, weather conditions varied substantially between the years (Table 1). In the first year of the study (2017), at the end of the second 10 days of April there was a strong cool down, and at night there was frost, which prevented the sowing of cereal and lentil. In 2017 the highest amount of precipitation was recorded in April, exceeded the long-term average by 77%. In June and the first 10 days of July a small amount of precipitation (32.6 and 9.7 mm respectively) was recorded and it was lower than the long-term average by 54.1 and 65.0% respectively. It had a negative effect on the plants growth and development. In the first 10 days of August there were very small amounts of precipitation (0.9 mm). The average air temperature exceeded the long-term average by 1.4 °C. In 2018, the amount of precipitation in May (97.4 mm) and July (118.5 mm) exceeded the average from multi-years by 70.9 and 41.1% respectively, which favoured the yields of lentil. During April and June the total precipitation was only 65% and 63% of the long-term average, respectively. The average air temperature in this vegetative season exceeded the long-term average by 2.4 °C.

**Table 1.** Course of weather conditions during the vegetation periods

Specification	Month						Sum/Average III-VIII
	March	April	June	July	August	Sept.	
	2017						
Precipitation (mm)	35.8	69.1	34.4	32.6	86.3	55.3	313.5
Air temperature °C	5.7	7.5	13.9	18.1	18.6	19.6	13.9
	2018						
Precipitation (mm)	14.1	25.3	97.4	44.6	118.5	70.6	370.5
Air temperature °C	-0.1	13.3	17.0	18.4	20.4	20.2	14.9
Average precipitation from multi-year* (mm)	30.0	39.0	57.0	71.0	84.0	75.0	356.0
Average air temperature from multi-year* (°C)	1.6	7.7	13.4	16.7	18.3	17.3	12.5

\*Mean for 1871-2000

### **Statistical analysis**

The data presented are the mean values from the years 2017-2018, as a result of a similar reaction of the examined plants to different cropping method during two years of the study. The results were statistically analyzed with the use of the variance analysis using Statistica v.10.0 program. Tukey's multiple comparison test was used to compare differences between the means for cropping method while confidence intervals for the means of LSD ( $\alpha = 0.05$ ) were used.

### **Results and discussion**

Species of supporting crop, cropping method and the course of weather conditions had the effect on growth, development and yielding of lentil, oat and barley. Effect of course weather on the lentil yield is confirmed also by Piróg et al. (2003), Biçer and

Sakar (2004), Filek et al. (2000) and Szwejkowska (2012). The analysis was prepared for two years of the study: 2017 and 2018. In the period of the study the more favorable weather conditions in 2018, allowed to obtain higher total yields of lentils as grown with cereals in sole cropping (Table 2).

**Table 2.** Total seeds yield of lentil and supporting plant and thousand seeds weight of lentil depending on cropping method (mean  $\pm$  standard deviation)

Year	2017			2018			2017-2018		
	A*	B	C	A	B	C	A	B	C
Cropping method	Mean $\pm$ SD						Mean		
Seeds yield (t·ha <sup>-1</sup> )	0.57 $\pm 0.07a^{**}$	3.12 $\pm 0.12c$	1.64 $\pm 0.15b$	2.03 $\pm 0.52a$	2.74 $\pm 0.10c$	2.45 $\pm 0.25b$	1.30	2.93	2.04
Weight of 1000 seeds (g)	42.53 $\pm 1.27a$	40.98 $\pm 1.22a$	41.00 $\pm 4.02a$	49.81 $\pm 3.48c$	47.63 $\pm 0.85a$	47.92 $\pm 3.60b$	46.17	44.31	44.46
Number of pods on main steams (per plant)	1.80 $\pm 0.34$	1.38 $\pm 0.19$	1.73 $\pm 0.23$	2.30 $\pm 0.61$	1.23 $\pm 0.29$	1.43 $\pm 0.84$	2.05	1.31	1.58
Number of pods on lateral steams (per plant)	8.60 $\pm 0.50$	5.23 $\pm 0.65$	6.55 $\pm 0.77$	10.23 $\pm 0.32$	7.00 $\pm 0.13$	7.50 $\pm 0.17$	9.41	6.11	7.03
Total number of pods on lateral steams (per plant)	10.40 $\pm 1.70c$	6.61 $\pm 0.75a$	8.28 $\pm 0.96b$	12.43 $\pm 0.09c$	8.23 $\pm 0.03a$	9.93 $\pm 0.04b$	11.42	7.42	9.10
Seeds number per plant	11.30 $\pm 1.77c$	6.88 $\pm 1.62a$	9.05 $\pm 1.80b$	12.87 $\pm 2.15a$	8.43 $\pm 2.85b$	9.43 $\pm 2.93b$	12.08	7.66	9.24
Seed weight per plant (g)	1.55 $\pm 1.11c$	0.38 $\pm 0.04a$	0.48 $\pm 0.11b$	1.75 $\pm 0.32c$	0.58 $\pm 0.13a$	0.56 $\pm 0.17b$	1.65	0.48	0.52
The share of lentil in mixture yield (%)	100.0	2.75	3.25	100.0	11.03	17.80	100.0	6.89	10.53

\*A – lentil-sole cropping; B – lentil + oats; C – lentil + barley

\*\*Mean  $\pm$  standard deviation values followed by different letters are significantly different at  $p \leq 0.05$  according to Tukey's honestly significant difference (LSD) test

Higher yield obtained in 2018 was the result of a greater number of pods, seeds number and seed weight on a lentil plant as well as a higher weight of 1000 seeds and grain weight on oat and barley plants (Table 2). Independent from the cereal species, the higher yields were found under the cropping methods, where lentil was grown with supporting plants than in sole cropping. In both years of the study, higher yield was provided by growing lentils with oats compared to growing with barley or in sole cropping (statistically significant differences).

Oat were more competitive to lentils than barley, resulting in a lower percentage of legume seeds in mixture with oat (Table 2). These results are in agreement with those reported by Nargis et al. (2004), who noted that the highest lentil yields were recorded in sole cropping. Those authors reported also that number and weight of pod per one plant was higher in sole cropping of lentil. Kraska et al. (2020) stated that lentil seed yield grown with oat was lower by 9.4% compared with that of the sole cropped. Gomez et al. (1983) reported that the highest seed yield were obtained in a mixture of lentil with barley or wheat. Similarly, Ahmed et al. (1987) stated that reduction of lentil seed yield grown in mixture with wheat was higher than with cereal crop. But Çiftçi and Ülker (2005) reported that the higher seed yields were lentil was grown with wheat not barley. Those authors noted also that mixed grown of lentil with wheat have a significant effect on plant height, seeds and straw yield, plant population (m<sup>2</sup>).

However, the statistical analysis did not confirm the cropping method to have a significant effect on plant height. Żabiński (2008) reported reaction of lentil on sowing with supporting crop and stated that it depends mainly on properties of the evaluated cultivar. The percentage of seeds yield of lentil grown with supporting crop, regardless cereal species, was significantly lower than in sole sowing.

The lentil grown in sole cropping was characterized by the higher 1000 seed weight, number of pods, number of seeds per pod, seed weight and dry weight stem and siliques of one crop than those grown with supported crop (significant differences) (Tables 2 and 3). Lentil grown with supported crops was characterized by the higher settlement of first pod on stem. Cropping method have not any effect on height of last pod settlement and height of plants (Table 3). The beneficial effect of intercropping of lentil with oats as a supporting crop on thousand seed weight is confirmed by Kraska et al. (2020). Compared to sole cropping, a significant decrease in plant density was however found (on average by 13.2%). These authors reported that weight of 1000 seeds, number of pods per plant, and first pod height did not differ significantly in the treatments with the lentil varieties. Moreover, these authors stated that lentil cropping method did not differ number of pods from single lentil plant. Nargis et al. (2004) reported that plant height, number of pods and thousand seeds weight were higher in the treatment where a supporting crop was used. According to Vlachostergios and Roupakias (2008) there are large possibilities to increase seed yield of lentil grown under organic farming conditions through appropriate cultivar selection. Rasheed et al. (2008) reported significant correlation between thousand seed weight and seed yield. Positive correlation between seed yield and number of pod per plant and height of plant are confirmed by Amarah et al. (2005), Ayub et al. (2001), Kar et al. (1995), Naseem et al. (1995) and Veerabandhiran and Jahangir (1995). In a study of Lopez-Bellido et al. (2005) number of pods per plant is negatively correlated with number of plants per unit area. According to many authors the appropriate density of plants per unit area determines their proper growth and development and is a guarantee to obtain a high seed yield (Saleem et al., 2012; Oujj et al., 2016). In the study of Kraska et al. (2018), the number of lentil plants per unit area was significant higher (by 15%) in lentil sole cropping.

**Table 3.** Stem dry matter of one plant, dry matter of siliques, height to the 1st and the last pod, height to top of plant depending on cropping method (g) (mean ± standard deviation)

Year	2017			2018			2017-2018		
	A*	B	C	A	B	C	A	B	C
	Mean ± SD								
Dry matter of stem per one plant	0.12 ±0.004a**	0.05 ±0.007c	0.05 ±0.006b	0.14 ±0.005a	0.06 ±0.006b	0.06 ±0.008c	0.13	0.06	0.06
Dry matter of siliques	0.03 ±0.004a	0.02 ±0.006a	0.03 ±0.004a	0.08 ±0.002a	0.07 ±0.005a	0.07 ±0.008a	0.05	0.04	0.05
Height to the 1 <sup>st</sup> pod	22.3 ±4.12c	27.6 ±2.55b	24.3 ±1.35a	35.6 ±4.27c	37.8 ±3.25b	38.7 ±2.15a	28.9	32.7	31.5
Height of the last pod	30.0 ±4.14c	31.6 ±2.22b	29.3 ±1.48a	38.6 ±4.14c	39.8 ±2.22b	40.8 ±1.48a	34.3	35.7	35.1
Height to top	30.9 ±4.21c	32.6 ±1.67a	29.7 ±2.84b	42.8 ±4.21c	43.5 ±1.67a	43.8 ±2.84b	36.8	38.1	36.7

\*A – lentil-sole cropping; B – lentil + oats; C – lentil + barley

\*\*Mean ± standard deviation values followed by different letters are significantly different at  $p \leq 0.05$  according to Tukey's honestly significant difference (LSD) test

Chemical composition of lentil seeds significantly depended on weather conditions during growing seasons. Course of weather condition in 2017 had the beneficial effect on raising the concentration of protein and fat in lentil seeds, but caused higher fibre content and have a little effect on potassium and phosphorus content (Table 4). Intercropping with cereals has no effect on protein, fat, fibre, and phosphorus content (no significant differences) in seeds. Higher content of potassium was noted (significant differences). Intercropping lentil with oats as a supporting crop significantly reduced the content of protein and nitrogen compared to sole cropped lentil. According to Karadavut and Palta (2010) chemical composition of lentil seeds depends on cultivar, type of soil and weather conditions. According to Stacey et al. (2006) and Palta et al. (2010) the content of nutrients component, especially ash, nitrogen, total, fibre, fat and water-soluble protein is feature that vary during growth and development of plant. In the opinion of Stepniak-Sołyga and Wojtasik (2003), a limited amount of precipitation and higher air temperature during the growing season promotes the accumulation of total protein in legume seeds. This was confirmed by Kraska et al. (2018). In study of those authors in the years, when the total precipitation was lowest and the average air temperatures highest, the total protein content in lentil seeds was significantly higher than in the wet and slightly colder year. In turn, Szwejkowska (2012) stated that limited amount of precipitation significantly reduced protein yield from unit area.

Kraska et al. (2018) reported that lentil grown with oat as supporting crop significantly reduced nitrogen, phosphorus, potassium and micro-components (Cu, ZN, Mn, Fe, B) compared to sole cropping. The highest air temperature during growing season and insufficient amount of rainfall significantly decreased the content of micro-components. Özer and Kaya (2010) reported that the seed K content in different lentil varieties ranged from 2.85 to 4.63 g kg<sup>-1</sup> and P 0.57-1.35 g kg<sup>-1</sup>. Alghamdi et al. (2014) found that K and P content to be was significantly correlated to the lentil genotype, and this content was from 6.74 to 10.61 g kg<sup>-1</sup> and from 2.87 to 5.47 g kg<sup>-1</sup>, respectively.

**Table 4.** Concentrations of protein, fibre, fat, phosphorus and potassium in lentil seeds depending on cropping method (g·kg<sup>-1</sup>s.m.)

Year	2017			2018			2017-2018		
	A*	B	C	A	B	C	A	B	C
<b>Cropping method</b>									
<b>Content</b>									
Protein	261.3a**	272.5 <sup>a</sup>	277.1 <sup>a</sup>	254.9 <sup>a</sup>	263.1 <sup>a</sup>	264.2 <sup>a</sup>	258.1	267.8	270.6
Fat	7.1 <sup>a</sup>	7.2 <sup>a</sup>	6.9 <sup>a</sup>	6.7 <sup>a</sup>	6.9 <sup>a</sup>	6.9 <sup>a</sup>	6.9	7.1	6.9
Crude fibre	37.2 <sup>a</sup>	36.3 <sup>a</sup>	37.1 <sup>a</sup>	34.8 <sup>a</sup>	35.5 <sup>a</sup>	35.3 <sup>a</sup>	36.0	35.9	36.2
Phosphorus	5.6 <sup>a</sup>	5.6 <sup>a</sup>	5.7 <sup>a</sup>	5.4 <sup>a</sup>	5.3 <sup>a</sup>	5.4 <sup>a</sup>	5.5	5.4	5.5
Potassium	11.2 <sup>a</sup>	11.3 <sup>a</sup>	11.6 <sup>a</sup>	11.0 <sup>a</sup>	11.1 <sup>a</sup>	11.6 <sup>a</sup>	11.1	11.2	11.6

\*A – lentil-sole cropping; B – lentil + oats; C – lentil + barley

\*\*Values followed by a different letter are significantly different (p < 0.05)

Lentil is a species that poorly competitor with weeds (Singh et al., 2018). Pawłowski et al. (1990) states the need for the reduction of weeds, which significantly affected the development of legumes and the level of their yield. Cropping method of lentil have a

significant effect on weed infestation in crop, expressed by fresh and dry of weeds weight, their number and weed species composition. In both years of the study, the highest weed infestation was observed in lentil grown in sole cropping (Tables 5-7). While the lowest weed infestation was noted in lentil grown with barley as supporting crop. Sowing of lentil with barley resulted in increasing competitiveness of lentil against to weeds and reduced weight of weeds by an average of 80%. Intercropping of lentil with oat reduced weed infestation by 38% in 2017 and by 82% in 2018 compared with growing lentil in sole cropping. Fresh and dry matter were significantly less in lentil cropped with barley than with oat. Number of weeds in lentil varied by the cropping method and year of the study. The higher weed infestation was noted in 2017, in which number of weeds was significantly higher than in 2018 (Tables 6 and 7). Intercropping of lentil with cereals as supporting crops have effect on weed infestation expressed as number of weeds. In both years of the study the higher weeds number was noted in lentil grown in sole cropping. While sowing lentil with barley was more competitive. Number of weeds in such as cropping method of lentil was less than in sole cropping. Sowing lentil with barley reduced number of weeds species by 16% in 2017 and by 24% in 2018 than in sole cropping. In the study of Kraska et al. (2020) the weed species composition in lentil crop grown in pure sowing and in mixed variety stand was similar. In the study of those authors, sowing lentil with oats reduced number of dicotyledonous weeds from 43 to 39. While it caused the increase in number of monocotyledonous from 6 to 9. Bojarszczuk et al. (2013) and Staniak et al. (2013, 2014) found that mostly dicotyledonous weeds, such as *Chenopodium album*, *Stellaria media*, *Capsella bursa-pastoris*, and *Galinsoga parviflora*, were dominant in cereal-legume mixtures. According to Bojarszczuk et al. (2013) and Staniak et al. (2013) weather conditions have the influence on limited of effect mixture. The beneficial effect of mixture was observed in wet years.

Regardless of the lentil cropping method, segetal diversity was similar. The dicotyledonous weeds has the highest percentage in weeds structure. In 2017 depending on cropping method, the percentage of dicotyledonous weeds was from 62% (in sole cropping of lentil) to 83% (in lentil grown with oat) of all weeds. While in 2018 in lentil grown with cereals, monocotyledonous weeds have dominant share (mean 70%). Bojarszczuk et al. (2013), Staniak et al. (2013, 2014) and Bojarszczuk et al. (2017) reported that dicotyledonous weeds were dominant in cereal-legume mixtures.

In 2017, in both experimental treatments, independently of cropping method, *Plantago major*, *Viola arvensis*, *Cirsium arvense*, *Chenopodium album*, and *Erigeron canadensis* were weeds that occurred in greatest number, whereas among monocotyledonous weeds these were *Echinochloa crus-galli* and *Elymus repens*. Moreover, in the lentil sole cropping, 18 weed species was noted, in lentil grown with barley – 17 weed species and in lentil with oat – 14.

In 2018, weed infestation and weed species composition were significantly less than in 2017, as in sole cropping of lentil as grown with cereal as the supporting crops, *Chenopodium album* and *Echinochloa crus-galli* were weeds that occurred in the greatest number. In all treatments 9 weeds species were found. While in the lentil sole cropping, the 18 weed species were noted, in lentil grown with barley – 5 weed species and in lentil with oat – 3.

Jędruszczak et al. (2006) noted 32 weed species in triticale-lupine mixture and 28 weed species in rye with serradella. Staniak and Księżak (2010) noted from 25 to 28 weed species in barley/oat and pea/vetch grown under organic conditions. In the study



of Kraska et al. (2020), *Echinochloa crus-galli*, *Galinsoga parviflora*, *Sonchus arvensis* and *Cheopodium album* were species that occurred in the greatest numbers in lentil crop grown under organic farming conditions. The statistical analysis did not confirm that the lentil cropping method have a significant effect on dicotyledonous weeds number. In turn, it was found that there were significantly less (by 22.4%) monocotyledonous weeds and their dry matter was lower (by 30.5%) in lentil grown with supporting crop.

**Table 5.** Fresh and dry matter of weeds ( $\text{g}\cdot\text{m}^{-2}$ ) depending on lentils cropping method in 2017-2018

Cropping method	Fresh matter			Dry matter		
	2017	2018	Mean	2017	2018	Mean
A*	817.5**	260.7 <sup>c</sup>	539.1	703.4 <sup>c</sup>	248.6 <sup>b</sup>	476.0
B	546.9 <sup>b</sup>	161.9 <sup>b</sup>	354.4	151.1 <sup>b</sup>	44.1 <sup>a</sup>	97.6
C	175.0 <sup>a</sup>	55.0 <sup>a</sup>	115.0	141.6 <sup>a</sup>	43.6 <sup>a</sup>	92.6
Mean	513.1	159.2	-	332.0	112.1	-

\*A – lentil-sole cropping; B – lentil + oats; C – lentil + barley

\*\*Values followed by a different letter are significantly different ( $p < 0.05$ )

**Table 6.** Weed species composition and number of weeds depending on lentils cropping method the in the first year of the study ( $\text{plants}\cdot\text{m}^{-2}$ )

Weed species	Cropping method		
	A*	B	C
Monocotyledonous weeds:			
<i>Echinochloa crus-galli</i>	74.7	37.3	6.0
<i>Elymus repens</i>	42.7	16.0	3.3
<i>Poa annua</i>	2.0	2.0	-
<i>Setaria pumila</i>	-	-	2.7
Sum of monocotyledonous weeds	119.3	55.3	12.0
Dicotyledonous weeds:			
<i>Anthemis arvensis</i>	1.3	0.7	
<i>Capsella bursa-pastoris</i>	2.0	5.3	6.7
<i>Chenopodium album</i>	58.7	54.0	34.7
<i>Cirsium arvense</i>	39.3	8.7	13.3
<i>Erigeron canadensis</i>	15.3	32.0	8.0
<i>Fallopia convolvulus</i>	2.7	1.3	5.3
<i>Geranium molle</i>	1.3	1.3	0.7
<i>Matricaria maritima</i> L. ssp. <i>inodora</i>	0.7	0.7	-
<i>Plantago major</i>	59.3	72.7	9.3
<i>Polygonum aviculare</i>	2.0	2.7	
<i>Polygonum lapathifolium</i>	1.3	-	-
<i>Sonchus arvensis</i>	-	-	2.7
<i>Sonchus asper</i>	0.7	0.7	
<i>Stellaria media</i>	5.3	8.0	7.3
<i>Viola arvensis</i>	7.3	15.3	14.7
Sum of dicotyledonous weeds	197.3	203.3	104.0
<i>Equisetum arvense</i>	1.3	8.0	10.0
Total	317.9	266.6	126.0
Number of species	18	17	14

\*A – lentil-sole cropping; B – lentil + oats; C – lentil + barley

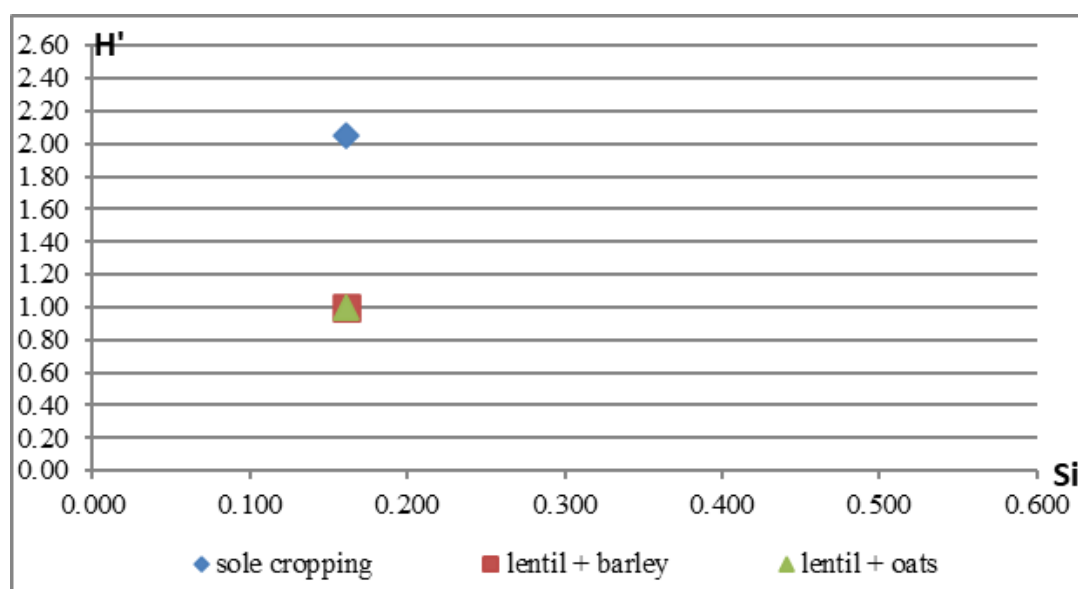
**Table 7.** Weed species composition and number of weeds depending on lentils cropping method the in the second year of the study (plants·m<sup>-2</sup>)

Weeds species	Cropping method		
	A*	B	C
Monocotyledonous weeds:			
<i>Echinochloa crus-galli</i>	10.5	16.5	15.5
Sum of Monocotyledonous weeds	10.5	16.5	15.5
Dicotyledonous weeds:			
<i>Anthemis arvensis</i>	0.5	-	-
<i>Chenopodium album</i>	12.5	3.5	6.0
<i>Cirsium arvense</i>	-	0.5	-
<i>Melandrium album</i> (Mill.) Garcke	1.0	-	-
<i>Polygonum persicaria</i>	0.5	-	-
<i>Solanum nigrum</i>	3.5	-	-
<i>Stellaria media</i>	1.0	0.5	2.0
<i>Viola arvensis</i>	1.5	2.5	-
Sum of Dicotyledonous weeds	20.5	7.0	8.0
Total	31.0	23.5	23.5
Number of species	9	5	3

\*A – lentil-sole cropping; B – lentil + oats; C – lentil + barley

Segetal diversity expressed by Shannon-Wiener index ( $H'$ ) and Simpson's dominance ( $Si$ ) index was dependent on cropping method of lentil (Fig. 2). In both years of the study, the highest segetal diversity was observed in lentil grown in sole cropping ( $H' = 2.048$  and  $1.414$  respectively). No dominance of weed species was noted ( $Si = 0.161$  and  $0.295$ ). Lentil sole cropping was characterized by the highest number of weed species (18 and 9 units). Significantly less biodiversity index for lentil grown with cereal was found (mean  $H = 1.000$  and  $0.884$ ).

In both years of the study the highest index of relation between lentil seeds yield and weeds dry matter was in sole cropping, whereas the lowest yields in such as cropping method was noted (Fig. 3a ,b). While, the lowest index in lentil grown with oats was noted.



a

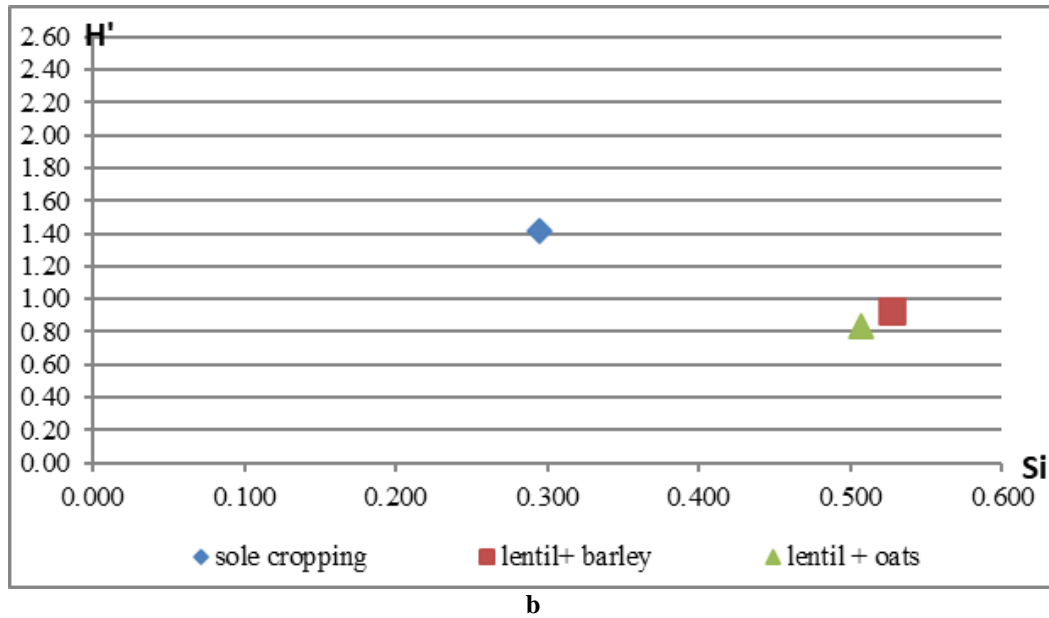
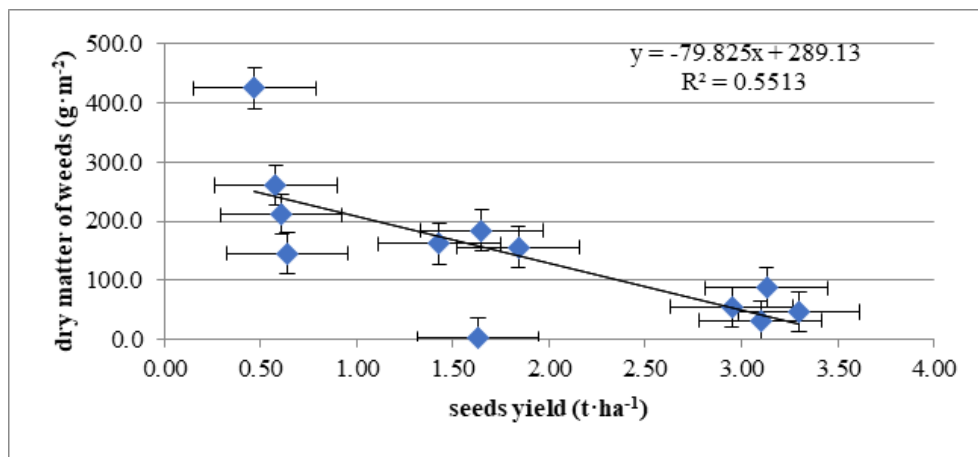
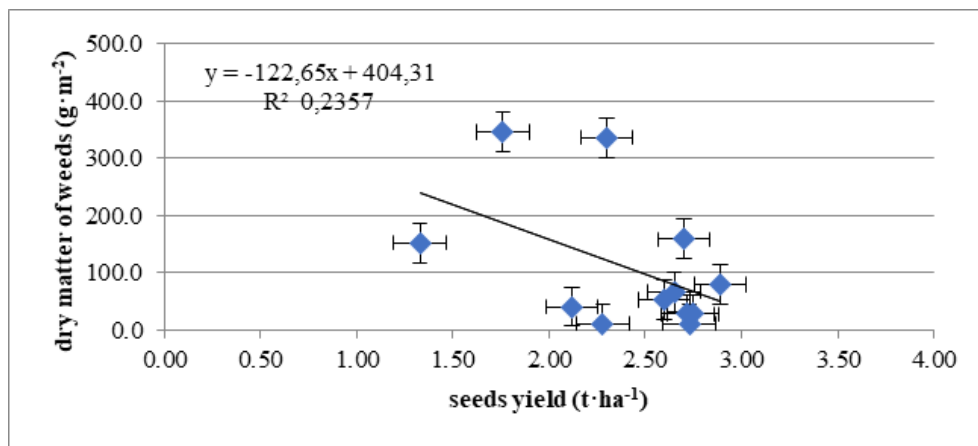


Figure 2. Index of Shannon's diversity ( $H'$ ) and Simpson's dominance ( $SI$ ) in 2017 (a) and 2018 (b)



a



b

Figure 3. Relationship between lentil seeds yield and weeds dry matter in 2017 (a) and 2018 (b)

## Conclusions

The results of this study reveal that independently of cereal species, the higher yields were obtained, where lentil was grown with supporting plants than in sole cropping. The higher thousand seeds weight, pods number, seeds number and seeds weight on plant was noted in lentil grown in sole cropping than with supporting crops. Lentil seeds grown with cereals was characterized by the similar amounts of protein, fat, fibre and phosphorus as grown in sole cropping. Cropping method of lentil have the significant effect on weed infestation. In both years of the study, the highest weed infestation was observed in lentil grown in sole cropping. Sowing lentil with supporting crops significantly reduced weed infestation. Independently of cropping method, *P. major*, *V. arvensis*, *C. arvense*, *Ch. album*, *E. crus-galli* were weeds that occurred in the greatest number.

In summary, one condition for using this cropping method is to select a supporting crop and its proportion in the mixture that will help reduce crop lodging, while in the case of low lentil yield, the supporting component largely decreases the risk of total yield loss.

**Acknowledgements.** This manuscript has not been published or presented elsewhere in part or in entirety, and is not under consideration by another journal. The study design was approved by the appropriate ethics review boards. All the authors have approved the manuscript and agree with submission to your esteemed journal. There are no conflicts of interest to declare.

**Conflict of interests.** The authors declare no conflict of interests. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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