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Weed infestation of soybean depending on the cultivar and row spacing under organic and conventional cultivation conditions

Zachwaszczenie soi w zależności od odmiany i rozstawy rzędów w warunkach uprawy metodą ekologiczną i konwencjonalną

Summary. An experiment in growing soybean was conducted at the Czesławice Experimental Farm, belonging to the University of Life Sciences in Lublin, over the period 2018–2020. Three experimental factors were included in this study: cultivation method (conventional and organic), soybean cultivar (Aldana and Merlin), and row spacing (22.5 cm and 35 cm). The species composition, number, and air-dry weight of weeds were evaluated. The Shannon-Wiener diversity index (H') and the Simpson dominance index (SI) were also calculated for the weed community in the soybean crop. Compared to conventional farming, organic cultivation significantly increased the number and dry weight of weeds as well as the numbers of the dominant species *Echinochloa crus-galli*. A significantly higher number and dry weight of weeds were found in the cv. Aldana crop than in the case of Merlin. In comparison with narrow-row cultivation, sowing soybean at the wider row spacing resulted in a greater number of weeds, in particular of the species *Echinochloa crus-galli*. Interrow width in the soybean crop did not cause differences in weed dry weight. The experimental factors slightly modified the Shannon-Wiener (H') and Simpson (SI) indices.

Key words: soybean, weed infestation in crops, organic and conventional methods, row spacing, cultivar

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INTRODUCTION

Weed infestation in a crop field is determined by habitat factors and agronomic practices as well as by cultivar properties [Gawęda et al. 2015, Sebayang and Rifai 2018, Sebayang and Fatimah 2019, Chojnacka and Haliniarz 2020, Gawęda et al. 2020]. Individual cultivars differ not only in their type of use, earliness group, and sensitivity to diseases, but also in their competitiveness against weeds which results, among others, from different rates of initial growth [Shawon et al. 2018, Marín 2021].

Soybean (*Glycine max* L. Merr.) is one of the leading crops grown in the world and at the same time the most important species of the Fabaceae [Praczyk 2017]. It is a plant of particularly high economic value because its seeds contain about 40% of protein with an excellent amino acid composition, 20% of fat, and other valuable minerals, among others calcium, phosphorus, and potassium [Abbasi Surki et al. 2010, Filoda and Mrówczyński 2016].

Due to the high consumer interest in healthy food, soybean is grown more and more frequently under the organic system, in which it produces yields at a satisfactory level [Cox et al. 2018, Vincent-Caboud et al. 2019]. Its high resistance to diseases and pests, *inter alia*, speaks for growing soybean using organic methods. Under the conditions of our country, agricultural pests currently do not pose a major threat to soybean. Weed infestation, however, is a factor that significantly reduces the productivity of this crop since the number of weeds above 10–20 plants per 10 m^2 of plantation causes serious yield losses [Praczyk 2017]. Apart from careful tillage, optimal row spacing also has great importance in reducing weed infestation [Różyło and Pałys 2014]. Effective reduction of weed infestation, in turn, determines the possibility of growing soybean using organic methods [Strażyński et al. 2020].

The aim of this study was to evaluate the species composition, number, and air-dry weight of weeds in the crop of two soybean cultivars sown at different row spacings under organic and conventional cultivation conditions. The study hypothesized that sowing of both soybean cultivars at a narrower row spacing would effectively reduce weed infestation in the crop grown using both the conventional and organic cultivation methods.

MATERIALS AND METHODS

The experiment was conducted at the Czesławice Experimental Farm, belonging to the University of Life Sciences in Lublin (51°18'23"N, 22°16'2"E) over the years 2018–2020, on loess-derived Luvisol soil (good wheat soil complex, soil class II). The soil on which the experiment was set up had neutral pH (pH in 1 M KCl = 7.1). It was characterized by high availability of phosphorus (129.5 mg P kg^{-1} soil) and potassium (177.6 mg K kg^{-1} soil) as well as by very high magnesium availability (68.6 mg Mg kg^{-1} soil). The humus content was at a level of 11 g kg^{-1}.

The experiment was set up as a split-plot design in three replicates, in plots with an area of 21.6 m^2 (2.7 × 8 m). Three experimental factors were included in the experiment: cultivation method (conventional and organic), soybean cultivar (Aldana and Merlin), and row spacing (22.5 cm and 35 cm).

Each year, both soybean cultivars were sown in the first 10 days of May, at a depth of 3 cm and at a design density of 80 plants per 1 m^2. After harvest of the previous crop, which was spring wheat throughout the entire experiment, skimming (at a depth of 8 cm), double harrowing, and autumn ploughing (at a depth of 25 cm) were done. In the spring, harrowing, cultivating, harrowing, sowing, and post-sowing harrowing were performed. Under conventional farming, mineral fertilizers were applied before sowing at the following rates: N – 30 kg ha^{-1} (34.5% ammonium nitrate), P – 40 kg ha^{-1} (40% superphosphate), K – 80 kg ha^{-1} (60% potassium salt), while at the beginning of flowering (BBCH 51) the second dose of nitrogen fertilizer was applied at a rate of 20 kg ha^{-1}. Under the organic system, mineral fertilization involved double application of the organic fertilizer Bio-algeen S90 (a single dose of 200 ml per 100 dm^3 of water): at the stage of soybean emergence (BBCH 09) and at the stage of side shoot growth (BBCH 21). In the conventional method, before sowing seeds were dressed with the seed dressings Nitragina (bacteria *Bradyrhizobium japonicum*) and Vitavax 200 FS (carboxin, thiuram), at a rate of 400 mL 100 kg^{-1} seed with an addition of water at a proportion of 1 : 1. Subsequently, immediately after sowing, Afalon Dyspersyjny 450 SC (linuron) + Dual Gold 960 EC (S-metolachlor) were applied at a rate of 1 dm^3 + 1.25 dm^3 ha^{-1}. In the organic treatment, soybean seeds were dressed only with Nitragina, whereas weeds were controlled by using triple harrowing: 3 days after sowing and at the plant growth stages BBCH 12 (trifoliolate leaf on the 2nd node unfolded) and BBCH 13 (trifoliolate leaf on the 3rd node unfolded).

Each year, the soybean cultivar Aldana was harvested in the first decade of September, while cv. Merlin in the second decade of September.

Compared to the long-term period, lower total rainfall was recorded in the 2019 growing season, whereas in 2018 the total rainfall was similar to the long-term mean (Fig. 1).

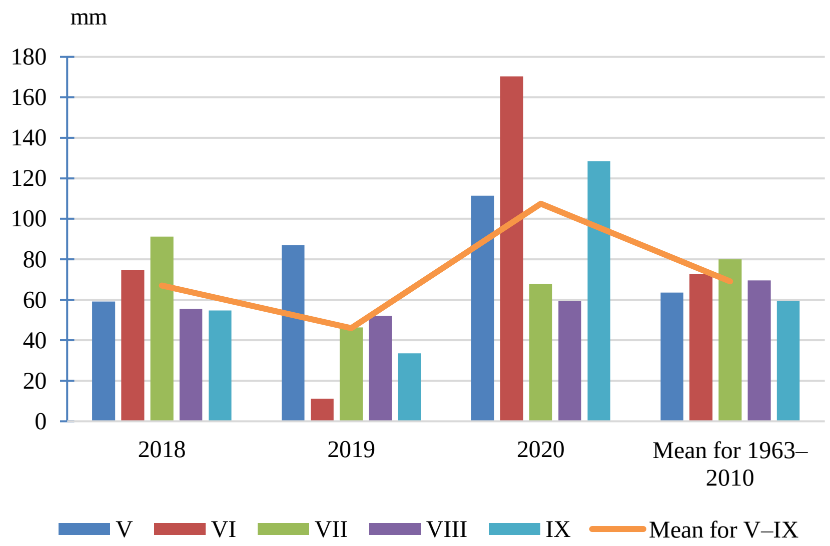

Fig. 1. Total precipitations (mm) in the growing season of soybean, recorded by the Meteorological Station in Czesławice

During the experiment, the highest amount of rainfall occurred in 2020 (especially in May, June, and August). At that time, the total rainfall was higher by 192.1 mm than the long-term mean rainfall for this period and by 307.3 mm than the amount of rainfall recorded in the driest growing season in 2019. In all years of soybean cultivation, at the time of sowing (May) the amount of rainfall was sufficient for soybean germination and emergence and it was similar to the long-term mean rainfall. All soybean growing seasons were characterized by a higher average air temperature than the long-term mean (Fig. 2). The second year of the experiment (2019) was the warmest, particularly the months of May, June, and July when the average temperature much exceeded the long-term mean temperature for this period. Unfavorable temperature for soybean germination and emergence was observed in May 2020 when its value was lower by 2.4°C in comparison with the long-term mean for this month.

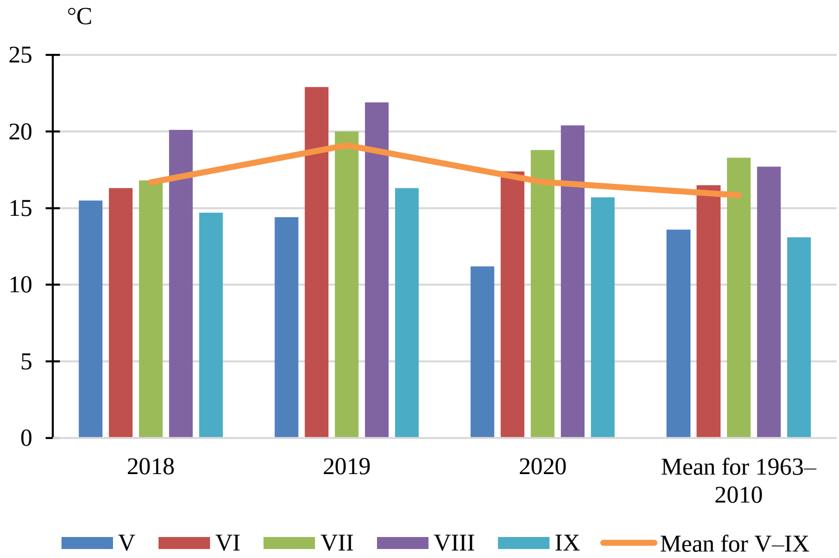

Fig. 2. Air temperature (°C) in the growing season of soybean, recorded by the Meteorological Station in Czesławice

Evaluation of the species composition of the weed community and of the number and air-dry weight of weeds was performed each year during seed growth and ripening (BBCH 85) using the dry-weight-rank method. The sampling area was delineated with a 1 m × 0.5 m quadrat frame in two randomly selected places in each plot. The Shannon-Wiener diversity index (H') and the Simpson dominance index (SI) [Shannon 1948, Simpson 1949] were calculated according to the following formulas: $H' = -\Sigma\, Pi \ln Pi$, $SI = \Sigma\, Pi^2$, where: Pi – probability of species occurrence in a sample, $Pi = n/N$, n – number of individuals in species, N – total number of individuals in the sampling area, ln – natural logarithm.

The higher the value of the Shannon-Wiener index, the greater the diversity of a community. The range of Simpson index values is from 0 to 1, with values close to 1 indicating a clear dominance of one or several species.

The study results were analyzed by analysis of variance (ANOVA), while the significance of differences was estimated by Tukey's test at a significance level of $p < 0.05$. Statistica 13.1 software was used to perform the calculations.

RESULTS

The statistical analysis showed that the number and dry weight of weeds in the soybean crop differed significantly depending on the cultivation method and cultivar (Tab. 1). Under organic cultivation, the number of weeds was higher by 61.0%, while the weed weight by 43.3% than in the conventional method. A substantially higher value of both weed infestation indicators was found in the cv. Aldana crop in comparison with Merlin, respectively by 33.6% in the case of the number of weeds and by 66.8% for the weed dry weight. The interrow width in the soybean crop affected the number of weeds, but did not modify their dry weight. As regards the row spacing of 35 cm, the number of weeds was found to be higher by 17.2% than under narrow-row cultivation (22.5 cm).

Table 1. Number and air-dry weight of weeds in soybean crop depending on cultivation method, cultivar and row spacing (mean for 2018–2020)

Specification	Number of weeds (pcs·m^{-2})	Air-dry weight of weeds (g·m^{-2})
cultivation method		
Conventional	13.6	21.5
Organic	21.9	30.8
$LSD_{0.05}$	1.14	5.34
cultivar soybean		
Aldana	20.3	32.7
Merlin	15.2	19.6
$LSD_{0.05}$	1.14	5.34
row spacing		
35 cm	19.1	26.9
22.5 cm	16.3	25.4
$LSD_{0.05}$	1.14	ns

ns – not significant at $p \leq 0.05$

During the experiment, *Echinochloa crus-galli* was the dominant weed species in the soybean crop (Tab. 2). *Galinsoga parviflora* was also found in quite large numbers, whereas among perennial weeds – *Equisetum arvense*. The plant community in the conventionally grown soybean crop was composed of 17 weed species, out of which 12 belonged to annual taxa – 70.6%. In the organically cultivated plots, 6 perennial weed species and 14 annual ones – accounting for 70.0% of the total number of taxa – were observed. Under organic farming conditions, the species *Echinochloa crus-galli* was dominant in the soybean crop and its numbers were higher by 37.2% than under conventional cultivation. *Gnaphalium uliginosum*, *Matricaria maritima* ssp. *inodora*, *Veronica arvensis*, *Convolvulus arvensis*, and *Elymus repens* were observed to be present only in the organically cultivated plots, whereas the species *Fallopia convolvulus*, *Veronica persica* and *Plantago major* only in the conventionally grown soybean crop.

Twenty weed species were observed in the crops of both soybean cultivars (Tab. 2). Perennial taxa accounted for 35.0% of the total weeds infesting the Aldana crop and for 25.0% in the Merlin crop. The weed species *Convolvulus arvensis*, *Plantago major*, and *Fallopia convolvulus* infested only the Aldana crop, whereas *Gnaphalium uliginosum*, *Setaria viridis*, and *Veronica arvensis* were only found in the Merlin crop. The numbers of the dominant species *Echinochloa crus-galli* were higher by 42.9% than for cv. Aldana.

Twenty two weed species were found in the plot with the wider row spacing (35 cm), whereas under narrow-row cultivation (22.5 cm row spacing) there were two taxa less (Tab. 2). In the soybean crop grown at a row spacing of 35 cm, the number of individuals of the dominant species *Echinochloa crus-galli* was found to be higher by 31.8%. *Gnaphalium uliginosum*, occurring at a row spacing of 22.5 cm, was not found to be present in this treatment. However, specimens of *Setaria viridis*, *Veronica arvensis*, and *Convolvulus arvensis*, not infesting soybean sown at the narrower row spacing, occurred in the plots with the wider row spacing.

Table 2. Species composition of weeds per 1 m^2 in soybean crop depending on cultivation method, cultivar and row spacing (mean for 2018–2020)

Species	Cultivation method		Cultivar soybean		Row spacing	
	C	E	A	M	35 cm	22.5 cm
I. Annual species						
Amaranthus retroflexus L.	0.6	1.4	1.3	0.7	1.1	0.8
Capsella bursa-pastoris (L.) Medik.	0.4	0.4	0.4	0.4	0.3	0.5
Chenopodium album L.	1.2	1.2	1.4	0.9	1.4	0.9
Echinochloa crus-galli (L.) P. Beauv.	4.3	5.9	6.0	4.2	5.8	4.4
Fallopia convolvulus (L.) Á. Löve	0.2	–	0.2	–	0.1	0.1
Galinsoga parviflora Cav.	2.1	3.4	3.2	2.3	2.6	2.9
Galinsoga quadriradiata Ruiz & Pav.	0.5	1.0	0.9	0.7	0.8	0.7
Gnaphalium uliginosum L.	–	0.1	–	0.1	–	0.1
Matricaria maritima ssp. *inodora* (L.) Dostál	–	0.2	0.1	0.1	0.1	0.1
Polygonum lapathifolium L.	0.3	0.2	0.3	0.2	0.2	0.3
Setaria viridis (L.) P. Beauv.	–	0.1	–	0.1	0.1	–
Stellaria media (L.) Vill.	0.1	0.3	0.3	0.1	0.4	0.1
Veronica arvensis L.	–	0.1	–	0.1	0.1	–
Veronica persica Poir.	0.3	–	0.2	0.1	0.2	0.1
Vicia hirsuta (L.) Gray	0.1	0.3	0.1	0.2	0.1	0.2
Viola arvensis Murr.	0.3	0.2	0.4	0.1	0.3	0.2
II. Perennial						
Cirsium arvense (L.) Scop.	0.2	0.5	0.3	0.5	0.5	0.3
Convolvulus arvensis L.	–	0.3	0.3	–	0.3	–
Elymus repens (L.) Gould	–	1.8	1.1	0.7	1.0	0.8
Equisetum arvense L.	1.9	2.4	2.0	2.3	1.9	2.3
Plantago major L.	0.1	–	0.1	–	0.1	0.1
Sonchus arvensis L.	0.8	0.7	0.9	0.6	1.0	0.5
Stachys palustris L.	0.2	1.4	0.8	0.8	0.7	0.9
Number of weed species	17	20	20	20	22	20

C – conventional, E – organic, A – Aldana, M – Merlin

The statistical analysis revealed that among the experimental factors, only the interaction of the cultivar and row spacing caused differences in the number of weeds in the soybean crop. The interaction of the experimental factors was not proven to have an effect on the dry weight of weeds. The significantly highest number of weeds was found in the cv. Aldana crop sown at the wider row spacing (35 cm), while the lowest one for cv. Merlin grown at both row spacings used (Tab. 3). In the Aldana crop, the highest number of weed species was also observed in the plots with a row spacing of 35 cm (Tab. 4). Among others, the perennial taxon *Convolvulus arvensis*, not infesting the other plots, was found to be present in this plot as well as the highest number of specimens of *Echinochloa crus-galli*, the dominant weed species in the soybean crop, was recorded.

Table 3. Interactive dependencies of cultivar and row spacing in determining the number and weight of weeds in soybean crop (mean for 2018–2020)

Cultivar soybean	Row sparing (cm)	Number of weeds (pcs·m^{-2})
Aldana	35	23.0
	22.5	17.5
Merlin	35	15.2
	22.5	15.1
$LSD_{0.05}$	2.14	

Table 4. Interactive dependencies of cultivar and row spacing in determining weeds composition per 1 m^2 in soybean crop (mean for 2018–2020)

Species	Cultivar Aldana		Cultivar Merlin	
	35 cm*	22.5 cm	35 cm	22.5 cm
I. Annual species				
Amaranthus retroflexus L.	1.6	1.1	0.8	0.5
Capsella bursa-pastoris (L.) Medik.	0.1	0.6	0.5	0.3
Chenopodium album L.	1.7	1.1	1.2	0.7
Echinochloa crus-galli (L.) P. Beauv.	7.2	4.8	4.4	3.9
Fallopia convolvulus (L.) Á. Löve	0.1	0.3	–	–
Galinsoga parviflora Cav.	3.6	2.7	1.6	3.0
Galinsoga quadriradiata Ruiz & Pav.	0.6	1.1	0.9	0.4
Gnaphalium uliginosum L.	–	–	–	0.2
Matricaria maritima ssp. *inodora* (L.) Dostál	–	0.3	0.1	–
Polygonum lapathifolium L.	0.1	0.4	0.2	0.2
Setaria viridis (L.) P. Beauv.	–	–	0.3	–
Stellaria media (L.) Vill.	0.4	0.2	0.3	–
Veronica arvensis L.	–	–	0.3	–
Veronica persica Poir.	0.2	0.1	0.2	–
Vicia hirsuta (L.) Gray	0.2	–	0.1	0.4
Viola arvensis Murr.	0.6	0.2	–	0.2
II. Perennial				
Cirsium arvense (L.) Scop.	0.5	0.2	0.4	0.5
Convolvulus arvensis L.	0.6	–	–	–
Elymus repens (L.) Gould	1.3	1.0	0.7	0.6
Equisetum arvense L.	2.1	1.8	1.8	2.8
Plantago major L.	0.1	0.2	–	–
Sonchus arvensis L.	1.3	0.5	0.7	0.5
Stachys palustris L.	0.7	0.9	0.7	0.9
Number of weed species	19	18	18	15

* row spacing

The evaluation of the biological diversity of the segetal flora showed a similar value of the Shannon-Wiener diversity index (H') and of the Simpson dominance index (SI) in all experimental treatments (Tab. 5). A trend was only observed that the weed community

exhibited greater diversity under the organic system than in the conventional method and in the Aldana crop relative to Merlin. This is indicated by a slightly lower value of the Simpson dominance index and a slightly higher value of the Shannon-Wiener diversity index.

Table 5. Shannon-Wiener's diversity index (H') and Simpson's dominance index (SI) of the weed community in soybean crop depending on the cultivation method, cultivar and row spacing (mean for 2018–2020)

Specification	H'	SI
cultivation method		
Conventional	0.82	0.21
Organic	0.88	0.18
$LSD_{0.05}$	ns	ns
cultivar soybean		
Aldana	0.87	0.18
Merlin	0.82	0.20
$LSD_{0.05}$	ns	ns
row spacing		
35 cm	0.84	0.20
22.5 cm	0.84	0.19
$LSD_{0.05}$	ns	ns

ns – not significant at $p \leq 0.05$

DISCUSSION

In the presented study, the dominant weed species was *Echinochloa crus-galli*. Hutianskyi et al. [2021] also demonstrated a similar species composition of weeds in a soybean crop. In the experiment of these authors, the following species were found in largest numbers: *Echinochloa crus-galli*, *Chenopodium album*, *Cirsium arvense*, and *Panicum miliaceum*, as well as the presence of the following species was noted: *Amaranthus retroflexus*, *Polygonum lapathifolium*, *Sonchus arvensis*, and *Convolvulus arvensis*, similarly to our study.

Under organic cultivation of soybean, where only harrowing was used to control weeds, weed infestation of soybean was found to be much greater than in the conventionally grown crop. According to Staniak et al. [2011], however, under optimal moisture conditions mechanical weed control allows about 77% of weeds to be destroyed, which should be considered to be an effective weed management method under organic farming. Lacko-Bartošova and Krošlák [2001] found greater weed infestation in the crop and a larger weed seed bank under the organic system compared to the conventional one. Likewise, in a study by Faligowska et al. [2020], the lowest density and weight of weeds were observed under conventional cultivation (a high level of fertilization and chemical protection), whereas the highest values were found for low-input farming (without fertilization and chemical protection). Mechanical weed control used under the low-input system was insufficient to improve the competitiveness of lupin against weeds. In a study by Poudel et al. [2002], the organic system was also characterized by a greater aboveground weed biomass compared to the high-input and conventional system, in which synthetic fertilizers and pesticides were used at the recommended rates.

Similarly to our research, Różyło and Pałys [2011] also proved that row spacing does not cause differences in air-dry weight of weeds, but only contributes to their higher density. These authors' study found a significantly higher number of weeds in an oilseed rape crop, including that of the dominant species, at a wider row spacing (33 cm) than under narrow-row cultivation (25 cm). In a study by Adigun et al. [2020], on the other hand, both the number and weight of weeds in a legume (*Vigna unguiculata* L., Walp) crop were substantially reduced with decreasing row spacing. In the opinion of these authors, this was probably attributable to the greater competitiveness of the crop plant, whose fast growth and covering of the inter rows caused weeds to have reduced access to light compared to the taxa growing in wide inter rows. Daramola et al. [2020, 2022] also proved a decrease in the number and weight of weeds at a narrower row spacing. Moreover, they showed that a narrower spacing between rows and integrated weed control using herbicide and manual weed removal are the most effective in reducing weed infestation, which results in the best productivity of soybean. Kraska et al. [2020] obtained different results demonstrating that sowing lentil at varying row spacings did not have a significant impact on weed infestation in the crop. Nonetheless, the smaller row spacing promoted greater diversity of weed species. Similarly to the research presented in this paper, in these authors' study the legume species compared differed significantly in their competitiveness against weeds. The study by Faligowska et al. [2020] also indicates varying competitiveness of legume species against weeds.

CONCLUSIONS

1. In organically grown soybean, the number and air-dry weight of weeds were higher than under the conventional system, respectively by 61.0% and 43.3%.

2. In the cv. Aldana crop, the number of weeds was proven to be higher by 33.6%, while the weed dry weight was found to be higher by 66.8% in comparison with those found for cv. Merlin.

3. Soybean cultivation at the wider row spacing caused a significant increase in the number of weeds in the soybean crop (by 17.2%) compared to narrow-row cultivation.

4. The interaction of the cultivar and row spacing caused differences in the number of weeds in the soybean crop. However, the statistical analysis did not confirm that the interaction of the experimental factors had a significant effect on the dry weight of weeds.

5. The significantly highest number of weeds was found in the cv. Aldana crop grown at a row spacing of 35 cm.

6. The weed species *Echinochloa crus-galli* was found to occur in greatest numbers in the soybean crop. Its numbers were higher under organic cultivation compared to the conventional system, in cv. Aldana relative to Merlin, and at a row spacing of 35 cm in comparison to narrow-row cultivation (22.5 cm).

7. The experimental factors did not cause significant differences in the Shannon--Wiener diversity index (H') and the Simpson dominance index (SI).

REFERENCES

Abbasi Surki A., Sharifzade F., Tavakkol Afshari R., Majnoun Hosseini N., Gazor, H.R., 2010. Optimization of processing parameters of soybean seeds dried in a constant-bed dryer using response surface methodology. J. Agric. Sci. Technol. 12(4), 409–423.

Adigun J.A., Adeyemi O.R., Daramola O.S., Olorunmaiye P.M., 2020. Response of cowpea to inter-row spacing and weed competition. Agric. Trop. Subtrop. 53(2), 73–79. https://doi.org/10.2478/ats-2020-0008

Chojnacka S., Haliniarz M., 2020. Wpływ preparatów biologicznych na plonowanie, zachwaszczenie i jakość ziarna pszenicy orkisz. Agron. Sci. 75(4), 63–74. http://doi.org/10.24326/as.2020.4.5

Cox W.J., Hanchar J.J., Cherney J., 2018. Agronomic and economic performance of maize, soybean, and wheat in different rotations during the transition to an organic cropping system. Agronomy 8(9), 192. https://doi.org/10.3390/agronomy8090192

Daramola O.S., Adeyemi O.R., Adigun J.A., Adejuyigbe C.O., 2020. Weed interference and control in soybean as affected by row spacing in the transition of south west Nigeria. J. Crop. Improv. 34(1), 103–121. https://doi.org/10.1080/15427528.2019.1674759

Daramola O.S., Adeyemi O.R., Adigun J.A., Adejuyigbe C.O., 2022. Influence of row spacing and weed control methods on weed population dynamics in soybean (*Glycine max* L.). Int. J. Pest Manag. 68(1), 43–58. https://doi.org/10.1080/09670874.2020.1795300

Faligowska A., Panasiewicz K., Szymańska G., Ratajczak K., Sulewska H., Agnieszka Pszczółkowska A., Kocira A., 2020. Influence of farming system on weed infestation and on productivity of narrow-leaved lupin (*Lupinus angustifolius* L.). Agriculture 10(10), 459. https://doi.org/10.3390/agriculture10100459

Filoda G., Mrówczyński M. (red.), 2016. Metodyka integrowanej ochrony i produkcji soi dla doradców. Wyd. IOR-PIB w Poznaniu, 7–9.

Gawęda D., Cierpiała R., Harasim E., Wesołowski M., Bujak K., 2015. Weed infestation of soybean (*Glycine max* L. Merr.) under different tillage systems. Acta Agrobot. 68(1), 53–58. https://doi.org/10.5586/aa.2015.005

Gawęda D., Haliniarz M., Bronowicka-Mielniczuk U., Łukasz J., 2020. Weed infestation and health of the soybean crop depending on cropping system and tillage system. Agriculture 10(6), 208. https://doi.org/10.3390/agriculture10060208

Hutianskyi R., Popov S., Zuza V., Kuzmenko N., 2021. Dependence of soybean weed infestation on growing conditions in the Eastern Forest-Steppe of Ukraine. Quarant. Plant Protect. 2, 36–41. https://doi.org/10.36495/2312-0614.2021.2.36-41

Kraska P., Andruszczak S., Kwiecińska-Poppe E., Staniak M., Różyło K., Rusecki H., 2020. Supporting crop and different row spacing as factors influencing weed infestation in lentil crop and seed yield under organic farming conditions. Agronomy 10(1), 9. https://doi.org/10.3390/agronomy10010009

Lacko-Bartošova M., Krošlák M.I., 2001. Weed infestation in different farming systems. J. Cent. Eur. Agric. 2(3–4), 173–182.

Marín C., 2021. Spatial and density-dependent multilevel selection on weed-infested maize. Genet. Resour. Crop Evol. 68, 885–897. https://doi.org/10.1007/s10722-020-01031-1

Poudel D.D., Horwath W.R., Lanini W.T., Temple S.R., van Bruggen A.H.C., 2002. Comparison of soil N availability and leaching potential, crop yields and weeds in organic, low-input and conventional farming systems in northern California. Agric. Ecosyst. Environ. 90(2), 125–137. https://doi.org/10.1016/S0167-8809(01)00196-7

Praczyk T. (red.), 2017. Instrukcja uprawy soi. Wyd. IOR-PIB w Poznaniu, 4–6.

Różyło K., Pałys E., 2011. Influence of crop rotation and row spacing on weed infestation of winter rape grown on rendzina soil. Acta Sci. Pol., Agricultura 10(1), 57–64.

Różyło K., Pałys E., 2014. Impact of plant density on the canopy area index and weed infestation depending on different cultivars of winter oilseed rape (*Brassica napus* L., ssp. *oleifera* Metzg.). Ann. UMCS. Sect. E 69(2), 44–55.

Sebayang H.T., Rifai A.P., 2018. The effect of soil tillage system and weeding time on the growth of weed and yield of soybean (*Glycine max* (L.) Merril). J. Degrad. Min. Land Manag. 5(3), 1237–1243. https://doi.org/10.15243/jdmlm.2018.053.1237

Sebayang H.T., Fatimah S., 2019. The effect of tillage systems and dosages of cow manure on weed and soybeans yield (*Glycine max*, Merrill). J. Degrade. Min. Land Manage. 7(1), 1959–1963. https://doi.org/10.15243/jdmlm.2019.071.1959

Shannon C.E., 1948. A mathematical theory of communications. Bell Syst. Tech. J. 27, 379–423, 623–656.

Shawon S.D., Islam M.N., Biswas M., Sarker S., 2018. Competitiveness of Aus rice varieties against weed infestation. J. Sylhet Agril. Univ. 5(1), 7–14.

Simpson E.H., 1949. Measurement of diversity. Nature, 163, 668.

Staniak M., Księżak J., Bojarszczuk J., 2011. Zachwaszczenie kukurydzy w ekologicznym systemie uprawy. J. Res. Appl. Agric. Engineer., 56(4), 123–128.

Strażyński P., Kardasz P., Mrówczyński M. (red.), 2020. Metodyka integrowanej ochrony soi dla doradców. Wyd. IOR-PIB w Poznaniu, 41–50.

Vincent-Caboud L., Vereecke L., Silva E., Peigné J., 2019. Cover crop effectiveness varies in cover crop-based rotational tillage organic soybean systems depending on species and environment. Agronomy 9(6), 319. https://doi.org/10.3390/agronomy9060319

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