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ORIGINAL RESEARCH PAPER

# Diversity of weed communities in soybean [*Glycine max* (L.)] crop growing under direct sowing depending on cover crops and different herbicide doses

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## Abstract

Despite being harmful for agricultural production, weeds are an essential component of biodiversity in agricultural landscapes. A field study was conducted during the period 2007–2009 on grey-brown podzolic soil (sandy), designated as PWsp, with the granulometric composition of silt and classified Class 2 in agricultural land suitability. The study evaluated the structure of weed communities based on selected indicators of diversity of a soybean crop grown under no-tillage with mulch from winter rye, winter oilseed rape, and white mustard as well as using herbicide rates reduced by 25% and 50% in relation to the standard rate (2 L ha$^{-1}$). The studied factors were as follows: (***i***) mulch plant species and mulch management method; (***ii***) rates of the foliar herbicide Basagran 600 SL (a.i. bentazon; 600 g L$^{-1}$). The results of this study confirm that no-tillage with mulch significantly changes the diversity of weed flora in a soybean crop. Among the mulches used, the mowed rye and winter oilseed rape in particular increased the values of the general diversity (*H*′), species richness (*d*), and evenness (*J*′) indices relative to the control treatment. On the other hand, the study found a strong decrease in the value of the dominance index (*c*). Reduced herbicide rates modified only the species richness index, in the case of which the 75% rate resulted in its significantly higher values compared to the full rate.

## Keywords

biodiversity; direct sowing; diversity indices; *Glycine max*; herbicide doses; mulch

## Introduction

The goal of modern agriculture is to produce high-quality agricultural products, but also to protect environmental resources, including biodiversity [1,2]. Biodiversity in crop fields performs a number of functions, which include the following: maintenance of a balance between crop pests and pathogens, ensuring the flow of nutrients, protection against erosion, regulation of water relations, and exerting a beneficial effect on soil structure [3–6]. Many factors, such as habitat, climate, and agrotechnology, influence the species composition of weed communities. One of the most important agronomic factors which regulate the occurrence of weeds is the crop plant, as it requires a number of cultural practices [7]. Depending on the level of farming intensity, agricultural activity may promote the maintenance of biodiversity or even increase it, or else, it may have a limiting effect on the species richness and population numbers of various organisms being part of agricultural ecosystems. The composition of segetal flora in a particular field depends on the growing season, the type of cultivation, agronomic practices, and the crop plant species [8–10]. An adverse effect is also conditioned by the number of weed species and their quantitative relationships, particularly in the case of dominant species. A weed community comprising several species may be, and often is, more harmful than a community consisting of more than 10 species. In this case, the harmfulness of weeds is determined not by the number of species but by the total number and total biomass of weeds [11–13]. According to the principles of sustainable agriculture, weed number should be reduced to a level that does not significantly affect crop yields and, at the same time, does not create a risk of extinction of rare species [14,15]. Organizational and economic changes in crop production involve a number of reduced tillage and crop cultivation practices. Under the conventional crop production system, it is tillage that is to a large extent oriented towards reducing weed infestation, whereas in the case of reduced tillage technologies and the no-tillage system, weed infestation can be a substantial problem. Therefore, it becomes necessary to investigate weed infestation with a special focus on the nature of the changes taking place in weed communities. Under good habitat conditions, the use of agronomic practices that promote the achievement of competitive advantage by the crop plant as early as possible will allow excessive weed infestation to be avoided under reduced tillage conditions [16].

Soybean cultivation is becoming more and more popular in many countries, including Poland, due to the high nutritional value of its seeds as well as its resistance to diseases and pests [17]. Although in the European Union the global soybean growing area is less than 0.5% (almost 80% of this surface is on the American continent), a significant boom in its production can be expected [18]. However, weed infestation is a factor that significantly reduces soybean yield. In the study of Vollmann et al. [19], under strong competition of weeds soybean maturity was delayed, plant height was reduced, the grain yield decreased, and seed quality was highly affected.

The aim of this study was to evaluate the structure of weed communities based on selected measures of biodiversity in a soybean crop grown under no-tillage, depending on mulch plant species and mulching method as well as reduced herbicide rates.

## Material and methods

### Plant material and growth conditions

A field study was carried out in the period 2007–2009 at the Czesławice Experimental Farm (51°30′ N, 22°26′ E), belonging to the University of Life Sciences in Lublin, Poland. It was located on grey-brown podzolic soil (sandy) – PWsp (34% of fine particles). The soil contained 15.0 g $kg^{-1}$ of humus, 14.6 mg P 100 $g^{-1}$ soil, 28.1 mg K 100 $g^{-1}$ soil, and 5.3 mg Mg 100 $g^{-1}$ soil, whereas the pH (in 1 mole $dm^{-3}$ KCl) was 5–6. The experiment was set up as a split-plot design in three replicates in plots with the sown area of 33.6 $m^{-2}$ and the harvested area of 15.0 $m^2$. Its design included two experimental factors:

- Cover crop species: A – treatment without mulch (control) using the full recommended rate of the following soil herbicides: Afalon Dyspersyjny 450 SC [1 $dm^3$ $ha^{-1}$ (a.i. linuron; 450 g per liter of herbicide)] + Sencor 70 WG [250 g $dm^3$ $ha^{-1}$ (a.i. metribuzin; 70% per liter of herbicide)] (the soil herbicides were applied right after soybean sowing); B – mowed winter rye; C – desiccated winter rye; D – mowed winter oilseed rape; E – desiccated winter oilseed rape; F – desiccated white mustard.
- Treatments of a foliar-applied herbicide – Basagran 600 SL (a.i. bentazon; 600 g $L^{-1}$), applied at the recommended 100% rate (2.0 L $ha^{-1}$) and at rates reduced by 25% (1.5 L $ha^{-1}$) and 50% (1.0 L $ha^{-1}$). The herbicide was used at the 3–4 leaf stage of soybean in all treatments.

Soybean 'Aldana' was grown after a previous crop of winter wheat. During fall tillage, the following was done: pre-sowing ploughing to a depth of 22 cm and harrowing.

At the time of ploughing, 26.2 kg P and 99.6 kg K per hectare were applied (the same P and K fertilization was used in the control treatment), whereas 25 kg N (1/2 of the planned rate) was applied right before sowing. Winter oilseed rape 'California' at an amount of 180 seeds per 1 $m^2$ (8 kg $ha^{-1}$), winter rye 'Dańkowskie Złote' – 400 seeds per 1 $m^2$ (150 kg $ha^{-1}$), and white mustard 'Polka' at an amount of 200 seeds per 1 $m^2$ (40 kg $ha^{-1}$) were sown at the recommended seeding times.

In the spring, further doses of nitrogen fertilization were applied: the second half of the N dose (25 kg $ha^{-1}$) in the rye and oilseed rape crops, in the control treatment the full rate of N (50 kg $ha^{-1}$). In the plot after white mustard, 1/2 of the rate was applied on the day of soybean sowing not to stimulate the growth of weeds in fall and early spring. In spring, no-tillage operations were carried out. Weed management was based on the incorporated mulches and the application of the foliar herbicide. To desiccate the winter rye and winter oilseed rape crops, the herbicide Roundup Energy 450 SL was used at a rate of 2.0 $dm^3$ $ha^{-1}$ – a.i. glyphosate [*N*-(phosphonomethyl) glycine; 450 g $dm^3$ of herbicide]. The treatment was carried out about 14 days before soybean sowing. The cover crops were mowed with a mower-shredder 10 days later, and next, the plant material was evenly distributed over the entire surface of the plot. The herbicide Basagran 600 SL was used at the 2–3 true leaf stage (V2/V3 – two/three sets of unfolded trifoliate leaves) [20].

Before sowing, seeds were treated with Funaben T 480 SL (a.i. 332 g of thiuram and 148 g of carbendazim in kg of seed dressing) – 200 g per 100 kg of seeds. Additionally, the seeds of soybean were inoculated with two bacterial strains: *Bradyrhizobium japonicum* and *Rhizobium leguminosarum*. The following mixture of herbicides: Afalon Dyspersyjny 450 EC (a.i. linuron; 450 g $L^{-1}$) – 1 L $ha^{-1}$ + Sencor 70 WG (a.i. metribuzin; 70%) – 0.3 kg $ha^{-1}$, was soil-applied in the control plot after soybean sowing. The soybean sowing parameters were as follows: density – 100 seeds per 1 $m^2$; row spacing – 21 cm; depth – 4 cm; time of sowing – at the turn of April and May. The soybean was sown using Väderstad's Carrier Drill CRD 300. In the second and third year of the study, interventional application of the herbicide Fusilade Forte 150 EC was necessary due to the strong occurrence of *Echinochloa crus-galli*.

In order to check how the experimental factors affect the structure of weed communities, on the basis of the botanical composition and the number of individuals of particular species, the following diversity indices were calculated at two times: before herbicide treatment and before soybean harvest:

- General diversity index [21]: $H' = -\Sigma(p_i \log p_i^2)$, which is dependent on the number of species and their quantitative proportions ($p_i$ – the importance probability for each species in the sample). The higher the value of the $H'$ index, the greater the diversity of the community.
- Species richness index [22]: $d = 1 - \Sigma p_i^2$ ($p_i$ – the importance probability for each species in the sample.
- The evenness index ($J'$) is treated as a measure of evenness of species distribution within the community. It is defined as the ratio of observed diversity, as measured by the Shannon index ($H'$), to maximum diversity, with a given number of species $S$ and described by the following formula [20]: $J' = H'/\log S$. The range of the value of the evenness index ($J'$) is from 0 to 1. It is equal to 1 when the observed diversity is equal to the maximum diversity, that is, when all species have an equal proportion in the community. On the other hand, the more these two values differ from each other, the closer the value of this index is to 0.
- Dominance index [23]: $c = (n_i/N)$ 100%, where $n_i$ – the importance value for each species, $N$ – the total importance value. The range of the value of this index is from 0 to 1; values close to 1 indicate a clear dominance of one or several species, which means lower diversity.

## Statistical analysis

The study results were statistically analyzed by analysis of variance (ANOVA), while the differences between means were estimated by Tukey's HSD test at a significance level $p = 0.05$.

 

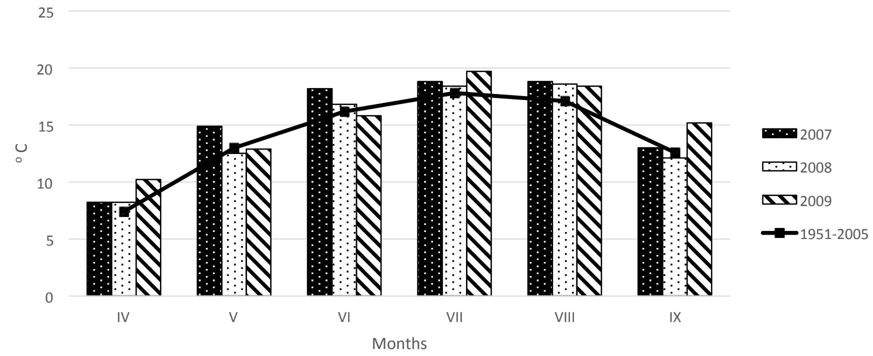


**Fig. 1** Mean monthly air temperature (°C) at the Czesławice Meteorological Station, Poland, in 2007–2009.

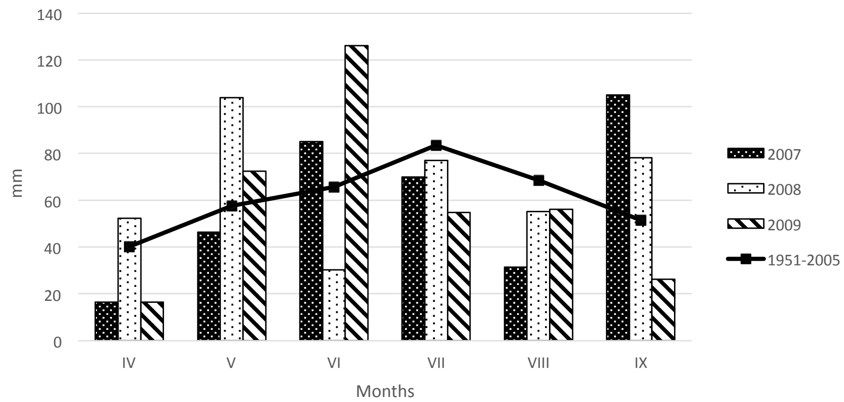


**Fig. 2** Total rainfall and rainfall distribution (mm) at the Czesławice Meteorological Station in 2007–2009.

### Weather conditions in the study area

The weather conditions varied. The mean air temperature for the growing period was as follows in the successive years: 17.1°C, 16.8°C, 16.6°C; it was higher than the long-term mean (15.3°C). Only in the first year was the total rainfall (338.0 mm) close to the long-term mean (327.1 mm), but it was lower in the following years of the study by 16% and 11%, respectively, compared to the long-term mean. In the last 10-day period of August and in the first 10 days of September in each year, the rainfall was relatively low and did not pose a threat to soybean seed harvest (Fig. 1 and Fig. 2).

## Results

### Before herbicide treatment

In evaluating the ecological indicators for the soybean crop before herbicide treatment, they were shown to significantly vary under the influence of the mulch treatments throughout the study period (Tab. 1). The values of the *H′*, *d*, and *J′* indices were significantly higher in the second (2008) and third (2009) years than in the first season: the general diversity index (*H′*) by 33.3%, the species richness index (*d*) by 34.8%, and the evenness index (*J′*) by 54.6%. The dominance index (*c*) was significantly (more than twice) higher in the first year than in the second and third years of the study.

In all mulch treatments, the values of the *H′* index were significantly higher than in the treatment without mulch (A), on average by 58.3%. The values of the *J′* index

**Tab. 1** Indicators of diversity of weed communities: general diversity index (*H′*), the species richness index (*d*), the evenness index (*J′*) and dominance index (*c*), depending on the crop species cover before herbicide treatment.

| Mulching treatment | Index *H′* 2007 | *H′* 2008 | *H′* 2009 | *H′* mean | *d* 2007 | *d* 2008 | *d* 2009 | *d* mean | *J′* 2007 | *J′* 2008 | *J′* 2009 | *J′* mean | *c* 2007 | *c* 2008 | *c* 2009 | *c* mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.14 | 0.91 | 0.95 | 0.70 | 2.60 | 4.38 | 6.05 | 4.34 | 0.19 | 0.19 | 0.29 | 0.22 | 0.92 | 0.48 | 0.51 | 0.64 |
| B | 1.56 | 1.69 | 1.65 | 1.63 | 9.30 | 11.28 | 12.57 | 11.05 | 0.35 | 0.72 | 0.53 | 0.53 | 0.28 | 0.14 | 0.22 | 0.21 |
| C | 1.29 | 1.94 | 1.63 | 1.62 | 5.91 | 11.37 | 11.50 | 9.59 | 0.42 | 0.53 | 0.47 | 0.47 | 0.67 | 0.19 | 0.21 | 0.36 |
| D | 1.50 | 2.25 | 1.81 | 1.85 | 9.62 | 10.69 | 10.84 | 10.38 | 0.60 | 0.15 | 0.69 | 0.48 | 0.32 | 0.10 | 0.17 | 0.20 |
| E | 1.22 | 2.11 | 1.66 | 1.66 | 6.45 | 10.23 | 12.81 | 9.83 | 0.36 | 0.70 | 0.63 | 0.56 | 0.37 | 0.12 | 0.22 | 0.24 |
| F | 1.12 | 2.05 | 1.76 | 1.64 | 5.94 | 10.19 | 10.37 | 8.83 | 0.61 | 0.32 | 0.55 | 0.49 | 0.43 | 0.14 | 0.17 | 0.25 |
| Mean | 1.14 | 1.83 | 1.58 | | 6.64 | 9.69 | 10.69 | | 0.42 | 0.44 | 0.53 | | 0.50 | 0.20 | 0.25 | |
| $LSD_{(0.05)}$ | Years of research – 0.281 | | | | Years of research – 1.744 | | | | Years of research – 0.090 | | | | Years of research – 0.134 | | | |
| | Mulching treatments – 0.510 | | | | Mulching treatments – 3.132 | | | | Mulching treatments – 0.210 | | | | Mulching treatments – 0.240 | | | |

A – control; B – mowed winter rye; C – desiccated winter rye; D – mowed winter oilseed rape; E – desiccated winter oilseed rape; F – desiccated white mustard; n.s. – not significant.

also exhibited significant variations; in the control treatment it reached a value of 0.22, that is, lower on average by 56.5% than in the mulched plots.

The *d* index showed the lowest species richness in the treatment without mulch (A), i.e., 4.34. Each type of mulch used substantially enriched the species richness of the plots studied; it was most enriched by the mowed winter rye (B) (11.05) and the mowed winter oilseed rape (D) (10.38).

The *c* index reached the highest value, 0.64, in the treatments without mulch (A). The incorporation of mulch in the form of desiccated rye (C) reduced the value of this index by 43.8%, while in the case of the other mulches by 60.9–68.8%, compared to treatment A. The analysis of the mulch forms showed a higher increasing trend for the *H′*, *d*, and *J′* indices in the mowed treatments than in the treatments with desiccated mulch, whereas an opposite trend was found in the case of the *c* index.

## After herbicide treatment

The analysis of the diversity of the flora accompanying the soybean crop grown in monoculture, after herbicide treatment, showed it to vary between years and individual mulch treatments.

The *H′* index reached the highest values in 2008, while they were lower by 15.5% in 2009 and the lowest (28.7%) in 2007 (Tab. 2). The relationships with the mulch plants demonstrated significantly higher values, i.e., greater species diversity, in the mowed treatments (B and D) compared to the control treatment (A). In the treatments with desiccated mulch (C, E, F), the diversity was also significantly greater than in the treatment without mulch. Regardless of the rate used, the herbicide did not have a significant effect on the changes in diversity between treatments.

The trends for the *d* index were similar to those determined in the case of the *H′* index (Tab. 3). During the study period, the highest values of this index were found in 2008 (9.79), lower ones (by 17.8%) in 2009, while the lowest ones (by 28.1%) in the first year of the experiment. The investigated mulch treatments (B–F) resulted in a significant increase in this index (on average by 31.4%) relative to the control treatment (A). The herbicide applied at the 75% rate contributed to significantly higher species richness (by 13.5%) compared to its full rate.

**Tab. 2** General diversity index (*H'*) depending on mulching treatment and herbicide rate before soybean harvest.

| Mulching treatment | Herbicide rate (%) | | | Mean for years | | | Mean |
|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 2007 | 2008 | 2009 | |
| A | 0.82 | 1.09 | 1.06 | 0.95 | 0.63 | 1.40 | 0.99 |
| B | 1.84 | 1.85 | 1.72 | 1.72 | 2.16 | 1.53 | 1.80 |
| C | 1.54 | 1.59 | 1.53 | 1.23 | 1.79 | 1.64 | 1.55 |
| D | 1.81 | 1.87 | 1.84 | 1.54 | 2.22 | 1.75 | 1.84 |
| E | 1.94 | 1.50 | 1.61 | 1.55 | 2.01 | 1.49 | 1.68 |
| F | 1.44 | 1.43 | 1.35 | 0.77 | 2.07 | 1.38 | 1.41 |
| Mean | 1.56 | 1.56 | 1.52 | 1.29 | 1.81 | 1.53 | |
| $LSD_{(0.05)}$ | Years of research – 0.201 | | | | | | |
| | Mulching treatments – 0.362 | | | | | | |
| | Herbicide rate – n.s. | | | | | | |

Explanation as in Tab. 1.

**Tab. 3** Species richness index (*d*) depending on mulching treatment and herbicide rate before soybean harvest.

| Mulching treatment | Herbicide rate (%) | | | Mean for years | | | Mean |
|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 2007 | 2008 | 2009 | |
| A | 4.63 | 7.95 | 5.43 | 5.47 | 3.44 | 9.09 | 6.00 |
| B | 9.24 | 9.51 | 8.43 | 8.71 | 11.32 | 7.19 | 9.07 |
| C | 8.33 | 9.40 | 8.22 | 6.99 | 10.55 | 8.41 | 8.65 |
| D | 10.32 | 11.41 | 8.41 | 8.02 | 11.29 | 10.82 | 10.04 |
| E | 9.12 | 9.12 | 7.61 | 8.90 | 10.32 | 6.62 | 8.61 |
| F | 7.46 | 7.72 | 6.96 | 4.14 | 11.83 | 6.17 | 7.38 |
| Mean | 8.17 | 9.19 | 7.51 | 7.04 | 9.79 | 8.05 | |
| $LSD_{(0.05)}$ | Years of research – 1.520 | | | | | | |
| | Mulching treatments – 2.671 | | | | | | |
| | Herbicide rate – 1.523 | | | | | | |

Explanation as in Tab. 1.

The evenness index of species distribution in the soybean crop did not show significant changes under the influence of the experimental factors used (Tab. 4). There was only a decreasing trend in the value of the index in the control treatment (A) relative to the mulch treatments (B–F). A higher evenness was observed in the plots after mowed rye (B) and desiccated oilseed rape (E).

The high values of the *c* index in the first year of the study (0.34) was found. The significantly lower values of this measure (by 32.4%) in the next 2 years of the study resulted from a more even proportion of the weed species in the community and also from the greater species richness (Tab. 5). High values of the *c* index (0.44), were found in the control treatment (A). A significantly higher and more even species composition was found in the treatments with various mulch forms where the values of

**Tab. 4** The evenness index (*J'*) depending on mulching treatment and herbicide rate before soybean harvest.

| Mulching treatment | Herbicide rate (%) | | | Mean for years | | | Mean |
|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 2007 | 2008 | 2009 | |
| A | 0.34 | 0.36 | 0.37 | 0.18 | 0.41 | 0.47 | 0.35 |
| B | 0.67 | 0.49 | 0.60 | 0.59 | 0.66 | 0.51 | 0.59 |
| C | 0.49 | 0.41 | 0.39 | 0.49 | 0.55 | 0.24 | 0.43 |
| D | 0.42 | 0.48 | 0.54 | 0.41 | 0.65 | 0.39 | 0.48 |
| E | 0.63 | 0.57 | 0.41 | 0.66 | 0.55 | 0.38 | 0.54 |
| F | 0.63 | 0.30 | 0.44 | 0.45 | 0.55 | 0.38 | 0.46 |
| Mean | 0.53 | 0.44 | 0.46 | 0.47 | 0.56 | 0.40 | 0.47 |
| $LSD_{(0.05)}$ | Years of research – n.s. | | | | | | |
| | Mulching treatments – n.s. | | | | | | |
| | Herbicide rate – n.s. | | | | | | |

Explanation as in Tab. 1.

**Tab. 5** Dominance index (*c*) depending on mulching treatment and herbicide rate before soybean harvest.

| Mulching treatment | Herbicide rate (%) | | | Mean for years | | | Mean |
|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 2007 | 2008 | 2009 | |
| A | 0.57 | 0.41 | 0.35 | 0.46 | 0.65 | 0.22 | 0.44 |
| B | 0.17 | 0.18 | 0.20 | 0.19 | 0.11 | 0.25 | 0.18 |
| C | 0.27 | 0.24 | 0.27 | 0.35 | 0.23 | 0.21 | 0.26 |
| D | 0.20 | 0.19 | 0.18 | 0.26 | 0.11 | 0.21 | 0.19 |
| E | 0.14 | 0.20 | 0.22 | 0.18 | 0.14 | 0.24 | 0.19 |
| F | 0.33 | 0.32 | 0.34 | 0.59 | 0.14 | 0.27 | 0.33 |
| Mean | 0.28 | 0.26 | 0.26 | 0.34 | 0.23 | 0.23 | |
| $LSD_{(0.05)}$ | Years of research – 0.081 | | | | | | |
| | Mulching treatments – 0.152 | | | | | | |
| | Herbicide rate – n.s. | | | | | | |

Explanation as in Tab. 1.

the index decreased to 0.33, i.e., by 25% (Treatment F), whereas the greatest decline was observed in Treatment B – to 0.18 (by 59 %).

## Discussion

Species diversity is now an important element taken into account in the protection of agroecosystems against agricultural pests. The changes taking place in weed communities in various agricultural ecosystems may result from crop rotation and related agronomic practices or the use of other direct weed control methods, or all these factors in combination [24–26]. It is therefore extremely important to determine the effect of individual agronomic practices on this characteristic of weed communities. The present experiment found a positive effect of mulch treatments on the indices (*H'*, *d*, *J'*) calculated for this purpose. The mulches used increased the values of these indices, which can be particularly seen in the mowed treatments (B and D) compared to Treatment A (without mulch). The reduced herbicide rates modified only the species richness index (*d*), in the case of which the 75% rate resulted in its significantly higher values compared to those calculated for the treatments with the recommended rates. There is an opposite relationship in the case of the dominance index (*c*); its higher values in the treatment without mulch (A) suggest a lower number of species, but their higher proportions in the sample, and a high percentage of one taxon (*Echinochloa crus-galli*). In the study by Stupnicka-Rodzynkiewicz et al. [11], herbicide rates also caused variations in the values of the diversity and dominance indices for weed communities in a cereal crop. The results of Scursoni et al. [27] suggested that limited use of glyphosate would not have profound effects on weed diversity in soybean. According to Anyszka and Kohut [13], the indices of biodiversity did not depend significantly on the application of herbicide and monoculture but largely confirmed the trends following from the analysis of the status and severity of weed infestation. The results of the study of Gulden et al. [28] demonstrated that midseason weed ground cover was lower when weeds were controlled with glyphosate; however, in most objects this did not result in improved soybean yields. Within locations, species richness, which strongly influenced other diversity indicators, was most affected by the herbicide treatments. These results were confirmed by Feledyn-Szewczyk and Duer [29] who compared the structure of communities in wheat grown under different production systems. The species diversity of the segetal flora was the highest under the organic farming system, whereas the Simpson dominance index was the highest under the conventional system and in monoculture. The same direction of changes was demonstrated by Wrzesińska [30] and Skrzyczyńska et al. [31]. These authors found that tillage reductions, including no-tillage, reduced the values of the species diversity indices for individual diaspores and resulted in an increasing trend for the dominance index. In the research by Cirujeda et al. [10], on the other hand, the values of the evenness index were not significantly different for segetal communities under farming systems of different intensity. The results of the study by Chirila et al. [32] show a very significant effect of climatic conditions and crop rotation system on weed spectrum, number, and biomass of weeds. Under prolonged drought conditions, the higher degree of weed infestation from pod formation to soybean maturity had a negative impact on production. According to Krawczyk [33], the biodiversity of segetal flora is affected by many factors and therefore it is difficult to determine unambiguously change trends. Bàrberi et al. [34] note that there is no clear trend in the evolution of the species composition of weed communities which results from the use of a specific production system. This suggests the existence of poorly-known mechanisms, probably related to the soil seed bank, seed longevity, and dormancy polymorphism as well as numerous adaptation strategies.

## Conclusions

No-tillage with mulch significantly changes the diversity of weed flora. Relative to the control treatment, the values of the general diversity, species richness, and evenness indices increase, while at the same time the value of the dominance index decreases.

The reduced herbicide rates modified only the species richness index (*d*), in the case of which the 75% rate resulted in its significantly higher values compared to the full rate. On the other hand, conventional soybean cultivation technology leads to a lower diversity of weed flora and results in an increased undesired dominance of weeds within the community, e.g., the dominance of *Echinochloa crus-galli*. An excessive increase in the value of the desired indicators may, however, lead to the spread of weeds in agroecosystems or their high dominance. A consequence of this is lower crop yields or increased weed diaspores density in the soil.

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## Różnorodność zbiorowiska chwastów w łanie soi [*Glycine max* (L.) Merr.] uprawianej w siewie bezpośrednim w zależności od gatunków roślin mulczujących i obniżonych dawek herbicydu.

### Streszczenie

Celem badań była ocena struktury zbiorowisk chwastów na podstawie wybranych wskaźników różnorodności w łanie soi uprawianej w siewie bezpośrednim, w zależności od gatunków roślin mulczujących i sposobu zagospodarowania mulczu oraz obniżonych dawek herbicydu. Badania polowe przeprowadzono w latach 2007–2009 na glebie płowej typowej (spiaszczonej) – PWsp, o składzie granulometrycznym pyłu, należącej do drugiego kompleksu przydatności rolniczej. W pracy oceniano strukturę zbiorowisk chwastów na podstawie wybranych wskaźników różnorodności w łanie soi uprawianej w siewie bezpośrednim z wykorzystaniem mulczu z żyta ozimego, rzepaku ozimego i gorczycy białej oraz zastosowaniem obniżonych dawek herbicydu o 25% i 50% wobec dawki standardowej (2 L ha$^{-1}$). Czynnikami badawczymi były: (***i***) gatunki roślin mulczujących i sposób zagospodarowania mulczu; (***ii***) dawki nalistnego herbicydu Basagran 600 SL. Wyniki badań potwierdzają, iż siew bezpośredni w mulcz zmienia istotnie różnorodność flory chwastów w łanie soi. Spośród zastosowanych mulczy, szczególnie koszone żyto i rzepak ozimy zwiększyły wartości wskaźnika ogólnej różnorodności (*H'*), bogactwa gatunkowego (*d*) i równomierności (*J'*), wobec obiektu kontrolnego. Stwierdzono silny spadek wartości wskaźnika dominacji (*c*). Zmniejszone dawki herbicydu modyfikowały tylko wskaźnik bogactwa gatunkowego, gdzie dawka herbicydu obniżona o 25% w stosunku do standardowej wpłynęła istotnie na wzrost bogactwa gatunkowego chwastów w porównaniu do bogactwa gatunkowego w warunkach pełnej dawki herbicydu.