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Biodiversity of Weeds in Fields of Grain in South-Eastern Poland

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Abstract: Analysis of weed infestation of selected fields of grain (winter wheat, spring wheat, spring triticale) was conducted between 2013 and 2016 in five commercial farms in south-eastern Poland (49°52′ N, 21°46′ E) based on a quantitative and qualitative (quadrat) method and an agro-phytosociological method. The quadrat analysis was conducted prior to weeding procedures, and the agro-phytosociological analysis by grain harvest. The biodiversity of weed communities was measured with the Shannon and Simpson indices. The degree of weed infestation of grain species was significantly differentiated by weeding procedures carried out by farmers. The highest share of weeds in grain crops included dicot weeds (80.6–86.4% of all species, depending on location), and the remaining weed groups were a much smaller issue. The greatest weed infestation was found in spring triticale, and the smallest in winter wheat. The highest Shannon biodiversity index was recorded in the field of triticale, and the lowest in the field of winter wheat. The Simpson index points to the greatest biodiversity in fields of triticale and the smallest in fields of spring wheat. The conducted research will help categorize segetal flora characteristics for a given crop, determine its quantity and species composition, and evaluate biodiversity of weeds in fields of grain.

Keywords: segetal flora; weed quantity; weed mass; grain species

1. Introduction

Weeds are part of agroecosystem biodiversity. In fact, weed infestation of crops is shaped by habitat conditions. The properties of weeds that make them more abundant than crops are mainly rapid initial growth rate, high efficiency of CO_2, water and nutrient assimilation; adaptability to changing environment, high multiplication rate, adaptation of fruit and seeds to long-distance dispersal, nonconcomitant seed germination (polymorphism of dormancy), seed longevity [1,2]. The presence of various weed species in a crop field increases the diversity of soil microflora and microfauna, is conducive to the residence of a number of antagonistic insects [3,4]. Country-level biodiversity includes genetic diversity, which determines inherent variability within the population and between populations of organisms; a genetic signature that relates to energy for survival and reproduction in different climates; genetic diversity which determines species diversity of the studied ecosystem or planet. In evaluating biodiversity, the variability of taxons in the ecosystem must be taken into account.

Biodiversity increases in parallel to the number of species and balances their share, but also depends on their uniform distribution, interspecies diversity, group diversity, or ecosystem biodiversity [2,5,6]. The growth stage of individual biocoenoses influences species variety in the given ecosystem. The more mature the phytocenosis, the more plant species it contains [7]. Genetic, species, and ecological diversities interact. The connections between the three measures of natural abundance make it hard to separate them [2,4,5]. The key role in limiting or maintaining biodiversity is played by agricultural activity, which determines the intensity of cultivation and agrotechnical procedures. Other important factors include geography and topography, and the related climate conditions. In fact, weed infestation of crops is shaped by habitat conditions. The number and species structure of segetal weeds depend e.g., on soil quality and properties, i.e., granulometric composition, fertility, pH, and water air relationships in soil [1,3,8]. The factors that have the greatest influence on weed infestation include agrotechnical weed control procedures, such as crop rotation, cultivation, selection of species and cultivars, sowing time, sowing quantity, row spacing, soil mulching [3,8,9]. Weed biodiversity also has a number of biological functions in and around fields. Moreover, it plays a significant role in the nutrient cycle and use, as well as in maintaining the balance of crops attacked by diseases and pests [10]. However, weed infestation in fields of grain is a serious problem in plant production. The quantitative relations between weed species can change at different grain growth stages and over the years. This demonstrates the adaptability of weeds to agrotechnical cycles [7,11]. Weeds compete with other plants for nutrients, water, and light, and in consequence cause high crop losses [1,3,8,12]. They assimilate much more water and nutrients than crops. Therefore, they can be particularly competitive in case of elements deficiency in soil. Another factor affecting crop loss is the collection of weed seeds together with crops. It has a significant influence on lowering the quality of agricultural products. The growing share of grains in the crop structure in Poland—over 75% [13]—facilitates the growth of segetal plants in fields of crops. Weeds, which are undesirable plants in crop fields, affect both the quantity and quality of yield. Regular mechanic weeding procedures do not eliminate weeds; they remain on arable soils more or less long-lastingly by means of appropriate multiplication and adaptability to changing environmental conditions. The conditions vary depending on the type of crops [3,7]. In fields of grain, weeds occur in relatively long-lasting multispecies communities. EU regulations require the monitoring of biodiversity in Member States, including biodiversity in rural areas and the efficiency of various action plans [6,14]. Poland is obliged to protect and monitor the environment and biodiversity in ways specified in legal regulations and based on scientific knowledge. Evaluation and monitoring of biodiversity can take place in various spatial scales, which influences the selection of methods and indicators. Hence, the aim of this paper was to evaluate weed infestation in fields of selected winter and spring grains on farms in south-eastern Poland. The conducted research will enable the categorization of segetal flora characteristic for various species of grain crops, the determination of its quantity and species composition, and the evaluation of biodiversity in this region of Europe.

2. Materials and Methods

Analysis of weed infestation of selected fields of grain (winter wheat, spring wheat, spring triticale) was conducted between 2013 and 2016 in five commercial farms in south-eastern Poland in the Strzyżowski District (49°52′ N, 21°46′ E). In terms of geomorphology, the area of the Strzyżów District is located in the Alpine Zone, the Carpathian Province, the Western Carpathians Sub-Province, the Outer Carpathians Macroregion, the Mesoregion of the Strzyżowski Foothills and Dynowski Foothills. This area is almost entirely located in the Wisłok catchment—the second-order watercourse feeding the Vistula [15]. In the area of the district, there are podzolic soils and marshes located on the plains of the Wisłok valley as well as brown and podzolic soils produced as a result of weathering of the Carpathian flysch rocks, which are predominant in the areas located higher. According to the general classification, these soils belong to the soils of mountainous areas with medium valuation classes. The parent rocks are the subsoil, flysch rocks or crumb rock and loess slope clays, while the soils are mostly of the dust type, most often used as arable soils [15,16].

2.1. Agrotechnical Treatments

The forecrop of grains was diversified, but included mainly grains and rape (Table 1).

Table 1. Forecrop and fertilization used on the farms under study.

Cultivated Plant	Forecrop	Fertilization
		*(A)
Winter wheat	Rape	N—160 kg·ha^{-1}, P_2O_5—66 kg·ha^{-1}, K_2O—66 kg·ha^{-1}, S—40 kg·ha^{-1}, MgO—9 kg·ha^{-1}
Spring wheat	Corn	N—120 kg·ha^{-1}, P_2O_5—56 kg·ha^{-1}, K_2O—50 kg·ha^{-1}, S—45 kg·ha^{-1}, MgO—9 kg·ha^{-1}
Spring triticale	Winter rape	N—50 kg·ha^{-1}, P_2O_5—40 kg·ha^{-1}, K_2O—40 kg·ha^{-1}
		(B)
Winter wheat	Corn	N—120 kg·ha^{-1}, P_2O_5—60 kg·ha^{-1}, K_2O—60 kg·ha^{-1}
Spring wheat	Potato	N—90 kg·ha^{-1}, P_2O_5—40 kg·ha^{-1}, K_2O—40 kg·ha^{-1}, S—40 kg·ha^{-1}, MgO—15 kg·ha^{-1}
Spring triticale	Winter rape	N—50 kg·ha^{-1}, P_2O_5—30 kg·ha^{-1}, K_2O—30 kg·ha^{-1}
		(C)
Winter wheat	Rape	N—60 kg·ha^{-1}, P_2O_5—40 kg·ha^{-1}, K_2O—40 kg·ha^{-1}
Spring wheat	Corn	N—120 kg·ha^{-1}, P_2O_5—45 kg; K_2O—45 kg·ha^{-1}, S—45 kg·ha^{-1}, MgO—20 kg·ha^{-1}
Spring triticale	Rape	N—60 kg·ha^{-1}, P_2O_5—55 kg·ha^{-1}, K_2O—60 kg·ha^{-1}
		(D)
Winter wheat	Potato	N—90 kg·ha^{-1}, P_2O_5—50 kg·ha^{-1}, K_2O—50 kg·ha^{-1}
Spring wheat	Fodder beet	N—70 kg·ha^{-1}, P_2O_5—42 kg·ha^{-1}, K_2O—42 kg·ha^{-1}
Spring triticale	Rape	N—50 kg·ha^{-1}, P_2O_5—34 kg·ha^{-1}, K_2O—34 kg·ha^{-1}
		(E)
Winter wheat	Oat	N—130 kg·ha^{-1}, P_2O_5—50 kg·ha^{-1}, K_2O—50 kg·ha^{-1}
Spring wheat	Winter rape	N—90 kg·ha^{-1}, P_2O_5—40 kg·ha^{-1}, K_2O—40 kg·ha^{-1}
Spring triticale	Winter rape	N—80 kg·ha^{-1}, P_2O_5—45 kg·ha^{-1}, K_2O—50 kg·ha^{-1}

* farm indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa.

Forecrop harvest was followed by post-harvest tillage. Moreover, in autumn each year prior to spring grain cultivation, mineral phosphorus, and potassium fertilization was applied, followed by prewinter ploughing. Nitrogen fertilizers were sown in spring by mixing with soil by means of a cultivation aggregate (cultivator + cage roller). Fertilizer doses used on the farms (Table 1) were determined by the content of those ingredients in the soil. Certified C1 seeds were sown according to normal agricultural practice [17] in the third quarter of September, whereas spring wheat and spring triticale were sown in the third decade of March. The norm for winter and spring wheat sowing was 400 pcs m^{-2}, and for spring triticale 450 pcs m^{-2}. On all farms, the same grain cultivars were used: winter wheat—cv. "Bamberka", spring wheat—cv. "Bogatka", spring triticale—cv. "Borowik". Grain seeds were treated with Baytan Universal 094 FS in the amount of 400 mL of the preparation and 200 mL of water per 100 kg of seeds, and Baytan Trio 180 FS in the amount of 200 mL of the preparation and 400 mL of water per 100 kg of seeds. In the all farms mechanical and chemical weed control was used. Herbicide spraying took place with the use of a tractor-mounted field sprayer. Plant protection against diseases and pests was used according to the recommendations of the Institute of Plant Protection—National Research Institute [18] (Table 2).

Table 2. Mechanical and chemical cultivation was used on the farms under study (A–E).

Mechanical Treatments	Chemical Treatments
Shallow ploughing, presowing, ploughing	Apyros 75 WG (sulfosulfuron) + Starane 333 EC (fluroksypyr) 26.5 g·ha^{-1} + 0.8 dm^3 ha $^{-1}$
Cultivator, prewinter ploughing, spring harrowing	Chwastox MP 600 SL (mekoprop-P) + Agritox Turbo 750 SL(MCPA + dicamba) 1 dm^3 ha^{-1} + 1.25 dm^3 ha^{-1}
Shallow ploughing, harrowing, presowing, ploughing	Chwastox MP 600 SL (mekoprop-P) + Starane 330 EC (fluroksypyr) 1 dm^3 ha^{-1} + 0.8 dm^3 ha^{-1}

2.2. Cultivation

All farms used mechanical and chemical weed control by means of agrotechnical weeding procedures and chemical plant protection agents (Table 2).

The active substances of the herbicides used on the farms under study are shown in Table 3.

Table 3. Active substances of herbicides used in cultivation.

Preparation Trade Names	Active Substances	Content of Active Substances	Dosage	Utility Forms	Grace *
			Herbicides		
Apyros 75 WG	Sulfosulfuron	75%	26.5g·ha^{-1}	Granules for water suspension	Not applicable
Starane 333 EC	Fluroxypyr	31.56%	0.8 dm^3 ha^{-1}	Concentrate for water suspension	Not applicable
Chwastox MP 600 SL	Mecoprop-P	52.9%	1 dm^3 ha^{-1}	Concentrate for water suspension	Not applicable
Agritox Turbo 750 SL	MCPA + Dicamba	55.71% 7.59%	1.25 dm^3 ha^{-1}	Concentrate for water suspension	Not applicable

* Sources: [19].

2.3. Soil Assessment

Before the start of the experiment, soil samples were collected from each farm: 20 samples each from the topsoil (0–20 cm), making up a collective 0.5 kg sample [20]. Samples were tested for the granulometric composition of the soil, the content of assimilable phosphorus, potassium and magnesium, and soil pH [21–23]. The granulometric composition and physico-chemical parameters of the soil were analyzed in the certified laboratory of the Regional Chemical and Agricultural Research Laboratory in Rzeszów, with the following methods:

- the granulometric composition of soil was determined by means of laser diffraction [16];
- pH: in a suspension of 1 mol KCl dm^{-3} and in a suspension of H_2O with a potentiometric method [16];
- organic carbon content Corg.—Tiurin's method [22];
- assimilable magnesium content—Schachtschabel method [24];
- assimilable phosphorus and potassium content—Egner–Riehm method [21,22].

The results of soil analysis were evaluated based on limit values established by the Institute of Soil Science and Plant Cultivation—National Research Institute in Puławy [24].

2.4. Analysis of Weed Infestation in Grains

The evaluation of weed infestation in grain crops on the farms under study was based mainly on the quadrat method and the agro-phytosociological method. The evaluation of crop and weed growth stage was based on the BBCH-scale [25]. The mass of the weed species was measured with the weight method. The quadrat method was applied prior to using weed control methods, whereas agro-phytosociological weed assessment was carried out prior to grain harvest. The quadrat analysis of weed was carried out on a surface of 1 m^2 in four replicates [26].

2.4.1. Quadrat Method

The research involved the assessment of species composition, species quantity, and measurement of fresh and air-dried weed mass [26].

The number of weeds per 1 m^2 was measured using the following formula:

$$L_{ch} = \frac{(L1 + L2 + L3 + L4)}{(lp * pr)},$$

where:

L_{ch} = number of weeds of a given species per 1 m^2;
L_1; L_2; L_3; L_4 = number of plants in a quadrat in subsequent measurements [No.];
l_p = number of measurements;
p_r = quadrat surface [m^2] [26].

The weight analysis of weeds allowed to determine the mass of all weed species in a given field. The weed floristic list was compiled. To that end, a thorough search in the entire field was conducted, and a list of all weed species from the field was established and their names entered in an analysis sheet.

Sampling. In the crop plot, all weeds were removed from a surface covered by a randomly placed quadrat. Then, the plants were placed in plastic containers and labeled for reference. This was carried out four times in each field. The plants collected during sampling were sorted and divided into groups of individual weed species; fresh mass of each species was measured, and the results were recorded in the analysis sheet. Masses of all plants of a given weed species were totaled and the average from four replicates was calculated for each crop plot. All results were recorded in the sheet. The mean weight of weeds was calculated as the arithmetic mean of four replicates.

The measurement of air-dried mass in fresh plant material involved drying the sample until air-dried in a natural or artificial way at a temperature of up to 60 °C with forced air flow [26]. The paper refers to air-dried weed mass.

2.4.2. Agro-Phytosociological Method

This method was used to evaluate weed infestation in crops prior to harvest. The agro-phytosociological analysis was based on determining soil coverage by crops and weeds. The analysis included soil coverage in %—separate for crops and weeds. Crop and weed growth stages were determined based on the BBCH scale. The highest possible crop coverage was 100%. In order to determine soil coverage by weeds, a floristic list was compiled including all weed species from the given field, divided by class (monocot, dicot and fern) [25]. At the top of the list were the species that were the most numerous in each class. The analysis was carried out in each field, including their entire surface, except for the borders to eliminate the border effect on the analysis results. In determining soil coverage, weeds were considered separately from crops. For each weed class, soil coverage was calculated as a percentage [26].

2.4.3. Weed Community Structure

The structure of communities in the grain crops under study was described with two ecological indices: Shannon biodiversity index (H′) and Simpson dominance index (SI). Shannon index was calculated based on the Shannon–Weaver formula (1) [27],

$$H = -\sum_{j=1}^{n} \text{pilnpi} \quad (1)$$

where: Pi = $\frac{ni}{N}$—the ratio of weeds of a given species ni to the total number of weeds *N* on the sample area.

Simpson index *SI* accounts for the number of species and the relative quantity of each species, and was calculated with a modified formula: $D = \frac{\sum n(n-1)}{N(N-1)}$, where n—number of specimens of a given species; N—number of all specimens of all species [28]. This index assumes values from 0 to 1, in which values close to 1 point to a significant dominance of one or several species and small diversity of the community [26]. Furthermore, the end result was transformed into the so-called Simpson's Index of Diversity: 1—D, and then into the Simpson's Reciprocal Index: $= \frac{1}{D}$ [26,28].

2.4.4. Soil Conditions

The research was conducted in soil consisting of flysch sediments, referred to as Carpathian loess or carbonate-free loess-like soil. Classification of these soils: autogenic—luvisols—lessive—pseudogley [29]. The granulometric composition of the soils points to sandy loam (Table 4).

Table 4. Granulometric composition of soil (%) (average from 2013–2016).

Farms *	Percentage of Fraction with Diameter (mm Diameter)			Grain Size Subgroup
	Sand	Silt	Clay	
	2.0–0.05 mm	0.05–0.002 mm	<0.002 mm	
A	72.95	18.47	8.58	Sandy loam
B	65.08	25.21	9.71	Sandy loam
C	75.05	18.56	6.39	Sandy loam
D	70.40	19.94	9.66	Sandy loam
E	72.60	16.97	10.43	Sandy loam
Average	71.22	19.83	8.95	Sandy loam

Source: own study based on the results of the Regional Chemical and Agricultural Station in Rzeszów, * farms indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa.

The concentration of assimilable phosphorus ranged from low to high; potassium—from medium to very high; magnesium—from very low to low, with a medium level of copper, manganese, iron, and zinc in soils. The content of humus in the topsoil ranged from 1.1 to 2.78 g kg^{-1}, and the soil pH ranged from acidic to neutral (Table 5). The soils where cereal crops were grown belonged to the agronomic category of medium soils, good rye to defective wheat complex, valuation class IIIa to IVb [16].

Table 5. Physico-chemical properties of soil in the Podkarpackie province (2013–2016) (g kg^{-1}of soil).

Farms *	Macronutrients (mg·100^{-1} of Soil)			$CaCO_3$ (g kg^{-1})	Humus (g kg^{-1})	pH (KCL)	Micronutrients (mg kg^{-1} of Soil)			
	P_2O_5	K_2O	Mg				Cu	Mn	Zn	Fe
A *	5.5–14.1	17.0–28.1	3.8–13.7	0.02	1.79–2.69	5.3–6.7	5.61	177.1	14.4	1581
B	5.1–17.0	11.7–28.3	2.5–15.0	0.03	1.45–1.70	4.9–7.4	5.71	172.9	14.5	1572
C	10.6–16.3	11.4–20.1	2.8–6.4	0.02	1.98–2.75	4.6–5.6	5.61	177.1	14.4	1569
D	5.2–12.4	15.2–25.6	3.1–8.7	0.03	2.13–2.65	4.4–6.1	5.34	169.2	15.1	1610
E	8.5–29.0	13.4–22.0	1.8–7.3	0.02	2.01–2.78	5.1–6.2	5.68	172.3	14.9	1597
Mean	5.1–29.0	11.4–28.3	1.8–15.0	0.02–0.03	1.45–2.78	-	5.59	173.7	14.7	1586

Source: data was compiled on the basis of the results obtained by the District Chemical and Agricultural Station in Rzeszów (2013–2016); * farm indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa.

2.5. Meteorological Conditions

In the vegetation period of winter and spring grains between the years 2013/2014–2015/2016, the weather was changing, which is presented in Table 6. Grain vegetation period 2013/2014 was considered wet, whereas vegetation periods 2014/2015 and 2015/2016 were very wet, which is reflected in the values of the hydrothermal coefficient of Selyaninov (Table 6). However, significant variation of the hydrothermal coefficient was observed between individual months of the vegetation period. In grain vegetation period 2013, September, October, and November were very wet, whereas in 2014, the months from April through November were very dry. In vegetation period 2015/2016, almost all months in 2015 except for June were wet and extremely humid, whereas in 2016, April, May, and June were wet and extremely humid, and July and August were very dry (Table 6).

Table 6. Average monthly air temperature and total rainfalls during grain vegetation between 2013 and 2016 in Dukla.

Year	Month	Rainfall (mm) Decade of the Month			Sum of Rainfall (mm)	Temperature (°C) Decade of the Month			Average Temperature (°C)	Sielianinov Hydrothermal Coefficient
		1	2	3		1	2	3		
2013/2014	September	35.1	41.4	47.9	124.4	14.3	14.2	10.6	13.0	3.2
	October	21.2	24.6	32.2	78	10.1	8.6	12.5	10.4	2.5
	November	18.1	20.8	16.1	55.0	5.1	5.0	4.6	4.9	3.7
	December	6.2	16.9	8.1	31.2	2.9	3.0	3.1	3.0	-
	January	5.9	4.2	7.5	17.6	2.1	2.0	2.4	2.2	-
	February	6.5	1.5	2.0	10.0	-2.5	-2.8	-2.3	-2.5	-
	March	4.4	7.2	5.8	17.4	1.8	2.2	1.9	2.0	-
	April	7.8	7.2	6.4	21.4	15.1	14.1	17.3	15.5	0.5
	May	19.1	20.2	8.9	48.2	17.6	18.9	19.8	18.8	0.9
	June	12	16.5	13.5	42	18.4	18.9	25.4	20.9	0.7
	July	27.2	20.8	14.5	62.6	20.1	21.6	22.2	21.3	1.0
	August	33.2	45.1	15.3	93.6	20.8	21.9	22.1	21.6	1.4
	Total				601.4					
2014/2015	September	11.2	10.1	12.7	34.0	15.6	15.8	16.9	16.1	0.7
	October	11.3	16.8	11.7	39.8	11.6	11.8	12.1	11.8	1.1
	November	2.8	3.0	3.6	9.4	5.9	6.3	6.2	6.1	0.5
	December	13.4	16.1	10.9	40.4	1.2	1.4	1.9	1.5	-
	January	10.1	9.7	11.2	31.0	-1.2	-1.8	-1.7	-1.6	-
	February	3.62	7.45	5.53	16.6	4.3	4.6	4.8	4.6	-
	March	8.0	9.2	8.6	25.8	7.6	7.8	7.1	7.5	-
	April	22.5	23.8	25.1	71.4	10.8	9.8	11.2	10.6	2.2
	May	46.8	75.2	62.1	184.1	13.7	13.8	13.6	13.7	4.5
	June	6.0	7.1	6.5	19.6	20.4	23.1	25.4	23.0	0.3
	July	40.3	45.1	42.7	128.1	19.8	19.3	21.5	20.2	2.1
	August	14.0	21.0	25.0	60.0	20.1	19.6	22.2	20.6	1.0
	Total				660.2					
2015/2016	September	22.5	14.5	29	66.0	15.4	15.1	16.1	15.53	1.4
	October	10.1	13.8	18.7	42.6	12.5	12.6	12.8	12.6	1.1
	November	19.2	21.4	17.2	57.8	8.6	7.6	8.7	8.3	2.3
	December	11.4	15.0	18.7	45.1	4.0	5.1	3.6	4.2	-
	January	6.9	2.5	5.2	14.6	1.2	1.8	1.9	1.6	-
	February	12.9	18.2	23.1	54.2	4.6	4.3	4.8	4.6	-
	March	6.8	5.6	4.2	16.6	5.4	7.2	8.0	6.9	-
	April	26.3	19.6	24.1	70.0	9.8	8.7	11.6	10.0	2.3
	May	21.8	47.1	38.2	107.1	11.6	12.6	12.9	12.4	2.9
	June	55.7	49.8	53.1	158.6	16.9	17.3	17.2	17.1	3.1
	July	15.4	9.4	10.2	35.0	20.2	19.6	21.3	20.4	0.6
	August	19.7	11.1	15.2	46.0	21.6	20.6	21.8	21.3	0.7
	Total				713.6					

Source: own study according to data from the COBORU meteorological station at SDOO in Dukla. The following ranges of values $p_{0.05}$ for the Selyaninov coefficient were assumed: extremely dry $k \leq 0.4$; very dry $0.4 < k \leq 0.7$; dry $0.7 < k \leq 1.0$; quite dry $1.0 < k \leq 1.3$; optimal $1.3 < k \leq 1.6$; quite damp $1.6 < k \leq 2.0$; wet $2.0 < k \leq 2.5$; very wet $2.5 < k \leq 3.0$; extremely humid $k > 3.0$ [30].

2.6. Statistical Analyses

The research results were analyzed statistically using analysis of variance, by means of statistical software SAS v.9.2 [31]. Statistical analyses were based on a two-way analysis of variance (farm × crop) and Tukey's multiple tests, with the assumed level of relevance $p_{0.05}$. The significance of sources of variance was subject to the F-Snedecor test [32,33].

3. Results

3.1. Number and Air-Dried Mass of Weeds in Fields of Grains

The greatest number of weeds in a field of grain was recorded in spring wheat and spring triticale, and the smallest in winter wheat. Weed infestation in spring wheat and spring triticale was almost twice as high as in winter wheat. The greatest weed infestation in spring wheat was found on farm A, and the smallest on farm D. Winter wheat suffered from the greatest weed infestation on farm C, with rape as forecrop, and the smallest on farm B, with potato as forecrop. In the case of spring triticale, the greatest weed infestation occurred on farm B, and the smallest on farm E, whereas farms A and D turned out homogeneous in terms of this characteristic (Table 7).

Table 7. Number and air-dried mass of weeds in fields of grains (pcs m^{-2}).

Farms *	Number of Weeds (No m^{-2})			Air-Dried Mass of Weeds (g m^{-2})		
	Winter Wheat	Spring Wheat	Spring Triticale	Winter Wheat	Spring Wheat	Spring Triticale
A	8.0c	76.8a	28.8b	9.1a	17.7a	42.8a
B	2.0d	23.2c	72.0a	0.3e	1.9d	13.6b
C	30.4a	42.0b	21.6bc	3.8c	8.2b	2.4 cd
D	15.6b	6.4d	34.8b	7.5b	2.8d	6.2c
E	13.6b	20.8c	16.8cd	2.3d	5.9c	4.0c
$LSD_{0.05}$	3.55	8.6	8.5	1.2	1.9	3.5

* Farm indicators: A—$Lubla_1$, B—Dobrzechów, C—$Lubla_2$, D—Wiśniowa, E—Markuszowa. Letter indicators at averages determine the so-called homogeneous groups (statistically homogeneous). The occurrence of the same letter pointer at averages (at least one) means that there is no (no) statistically significant difference between them.

The greatest air-dried area of weed in a field of grain was observed in spring triticale crop, and the smallest in winter wheat. In the case of the latter, the greatest weed mass was recorded on farm A, and the smallest on farm B, with corn as forecrop. Weed mass in the field of spring wheat was almost by half lower than weed mass in spring triticale. The greatest air-dried weed mass in spring wheat was found on farm A, and the smallest on farm B. Weed mass on farms B and D did not differ significantly from each other. The greatest air-dried weed mass in spring triticale was noted on farm A, and the smallest on farm E, whereas the weed mass on farms D and E turned out homogeneous (Table 7).

3.2. Floristic Composition of Weeds

Weed infestation of winter wheat grown on all farms included a total of 11 weed species (Table 8). The presence of taxons per a single crop field ranged from two (farm B) to four weed species (farms A, D) and five taxons on farm E. The most frequent were ANTAR, CIRAR, VIOAR [34] from the dicot class, and EQUAR from the *Equisetaceae* family, the fern (*Polypodiop*) class, which were found in three out of five examined fields of winter wheat; CONAR and POLCO were found in a relatively high quantity but lower recurrence per farm. Significant differences in weed infestation in winter wheat between the examined farms were found in such species as ANTAR, APHAR, CIRAR, CONAR, EQUAR, RUMAA, and VIOAR (Table 8). The occurrence of the remaining species was less frequent, and they were not found on all farms. Significant differences in air-dried weed mass were recorded in the case of such species as CIRAR, CONAR, EQUAR. The greatest air-dried weed mass was observed in the case of CONAR, whereas the remaining species produced a significantly lower weed mass, which did not depend on location (Table 8). The greatest soil coverage by segetal plants was recorded on farm C and amounted to 12.3%, with the soil coverage by winter wheat of 87.7%. Dominating weed species in those crops were ANTAR and CIRAR belonging to dicots, and EQUAR belonging to the *Equisetales* order, the *Equisetidae* subclass, the *Polypodiopsida* class [35] (Table 8).

Table 8. The species composition, number and air-dried weed mass and soil coverage in a field of winter wheat per 1 m^2.

No	Species *	Number of Weeds ($No\ m^{-2}$)					$LSD_{0.05}$	Air-Dried Mass of Weeds ($g\ m^{-2}$)					$LSD_{0.05}$
		A	B	C	D	E		A	B	C	D	E	
1	ANTAR	0.0	1.2	8.8	5.2	0.0	0.8	0.0	0.2	1.9	0.4	0.0	0.1
2	APHAR	0.0	0.0	0.0	2.4	0.0	ns	0.0	0.0	0.0	0.5	0.0	ns
3	CIRAR	0.0	0.0	4.0	3.2	3.2	0.5	0.0	0.0	0.5	0.7	0.4	0.1
4	CONAR	1.6	0.0	0.0	4.8	0.0	0.3	4.2	0.0	0.0	5.9	0.0	0.5
5	EQUAR	2.4	0.0	8.0	0.0	3.2	2.7	0.6	0.0	1.3	0.0	0.8	0.1
6	POLLA	0.0	0.0	1.6	0.0	0.0	ns	0.0	0.0	0.0	0.0	0.0	ns
7	POLCO	0.0	0.0	0.0	0.0	3.2	ns	0.0	0.0	0.1	0.0	0.1	ns
8	RUMAA	3.2	0.0	0.0	0.0	0.0	0.6	3.8	0.0	0.0	0.0	0.0	ns
9	VICCR	0.0	0.0	0.0	0.0	0.1	ns	0.0	0.0	0.0	0.0	0.1	ns
10	VICTE	0.0	0.0	8.0	0.0	0.0	ns	0.0	0.0	0.0	0.0	0.0	ns
11	VIOAR	0.8	0.8	0.0	0.0	4.0	0.2	0.5	0.1	0.1	0.0	1.0	ns
Sum of species		4	2	5	4	5	-	4	2	5	4	5	-
	*	97.8	96.5	87.7	92.4	95.1	-	-	-	-	-	-	-
	**	0.0	0.0	0.0	0.9	0.0	-	-	-	-	-	-	-
	***	2.0	3.5	11.2	6.7	4.2	-	-	-	-	-	-	-
	****	0.2	0.0	1.1	0.0	0.7	-	-	-	-	-	-	-

farm indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa; ANTAR—*Anthemis arvensis*; APHAR—*Aphanes arvensis*; CIRAR—*Cirsium arvense*; CONAR—*Convolvulus arvensis*; EQUAR—*Equisetum arvense*; POLCO—*Polygonum convolvulus*; POLLA—*Polygonum lapathifolium*; RUMAA—*Rumex acetosella*; VICCR—*Vicia cracca*; VICTE—*Vicia tetrasperma*; VIOAR—*Viola arvensis*; * soil coverage with crop (%); ** soil coverage with monocot weeds (%); *** soil coverage with dicot weeds (%); **** soil coverage with *Equisetaceae* weeds (%).

During the assessment of weed infestation in fields of spring wheat, 14 weed species were identified, of which the most frequent were dicot weeds: BRANA (52.8%), SINAR (17.0%), and CIRAR (8.8%). The share of these three species in the weed structure amounted to 78.6%. The only monocot weed was APESV, which was only found on farms B, C, and E (Table 9). Significant differences in weed infestation in winter wheat between the examined farms were found in such species as ANTAR, APESV, CIRAR, EQUAR, GAELA, POLAV, POLCO, SINAR, VIOAR. In four out of five farms, CIRAR and EQUAR was recorded, with small numbers of other taxons. The most frequent weed species in fields of spring wheat on farm A was BRANA (Table 9). A very large share of rape in fields of spring wheat was a direct result of the forecrop, which was winter rape, leaving behind numerous fallen seeds of that species. On farms B and E, the dominating species was SINAR, with a 65.5% and 30.8% share in all weeds, respectively. Crops were least affected by weeds on farm D, where only four species were recorded with the smallest quantity of all farms under study. It was observed that the differentiated floristic composition in the examined farms resulted from the forecrop (Table 9). It turned out that the air-dried weed mass depended significantly on the species. A significant influence of that factor was recorded in the case of four species: ANTAR, BRANA, CIRAR, and EQUAR. On average, the highest weed mass was generated by CIRAR. On farm A, the most frequent was BRANA, which was related with the forecrop (Table 9). The greatest soil coverage by segetal plants was recorded on farm C and amounted to 11.7%, with the soil coverage by spring wheat of 88.3%. Dominating weed species in those crops were ANTAR and SINAR belonging to dicots, and EQUAR belonging to the *Equisetaceae* family, the *Equisetales* order [35] (Table 9).

Table 9. Species composition, number, and air-dried weed mass and soil coverage in a field of spring wheat (pcs m^2).

No	Species *	The Number of Weeds ($No\ m^{-2}$)					$LSD_{0.05}$	Air-Dried Mass of Weeds ($g\ m^{-2}$)					$LSD_{0.05}$
		A	B	C	D	E		A	B	C	D	E	
1	ANTAR	0.0	0.0	4.0	0.0	4.8	0.4	0.0	0.0	0.8	1.1	1.0	0.1
2	APESV	0.0	0.8	0.7	0.0	1.6	0.2	0.0	0.1	0.1	0.0	0.1	ns
3	APHAR	0.0	0.0	2.5	0.0	0.0	ns	0.0	0.0	0.5	0.0	0.0	ns
4	BRANA	67.2	0.0	0.0	0.0	0.0	ns	10.8	0.0	0.0	0.0	0.0	0.5
5	CIRAR	6.4	0.0	11.5	0.8	4.0	0.5	6.2	0.0	2.3	0.2	4.3	0.7
6	EQUAR	0.8	0.0	3.5	1.6	2.4	0.4	0.2	0.0	0.7	1.0	0.9	0.2
7	GAELA	0.0	2.4	1.5	0.0	1.6	0.3	0.0	0.3	0.3	0.0	0.2	ns
8	GALAP	0.0	0.8	0.6	0.0	0.0	ns	0.0	0.1	0.1	0.0	0.0	ns
9	POLAV	0.8	0.0	1.1	3.2	0.0	0.3	0.2	0.0	0.2	0.5	0.0	ns
10	POLCO	0.0	4.0	1.0	0.0	0.0	0.3	0.0	0.1	0.2	0.0	0.0	ns
11	POLLA	0.0	0.0	5.0	0.0	0.0	ns	0.0	0.0	1.0	0.0	0.0	ns
12	RUMAA	0.0	0.0	5.6	0.0	0.0	ns	0.0	0.0	1.1	0.0	0.0	ns
13	SINAR	0.0	15.2	3.3	0.0	6.4	1.3	0.0	0.8	0.6	0.0	0.4	ns
14	VIOAR	1.6	0.0	1.7	0.8	0.0	0.2	0.3	0.0	0.0	0.0	0.0	ns
Sum of species		5	5	13	4	6	-	5	5	13	4	6	-
	*	93.8	95.6	88.3	96.9	94.5	-	-	-	-	-	-	-
	**	0.0	0.1	0.2	0.0	0.2	-	-	-	-	-	-	-
	***	6.0	4.3	10.8	2.9	4.0	-	-	-	-	-	-	-
	****	0.2	0.0	0.7	0.2	1.3	-	-	-	-	-	-	-

farm indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa; * farm indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa; ANTAR—*Anthemis arvensis*; APESV—*Apera spica-venti;* APHAR—*Aphanes arvensis*; BRANA—*Brassica napus;* CIRAR—*Cirsium arvense*; EQUAR—*Equisetum arvense;* GAELA—*Galeopsis ladanum;* GALAP—*Galium aparine;* POLAV—*Polygonum avicular;* POLCO—*Polygonum convolvulus;* POLLA—*Polygonum lapathifolium;* RUMAA—*Rumex acetosella;* SINAR—*Sinapis arvensis;* VIOAR—*Viola arvensis*; * soil coverage with crop (%); ** soil coverage with monocot weeds (%); *** soil coverage with dicot weeds (%); **** soil coverage with *Equisetaceae* weeds (%).

Fields of spring triticale grown in five farms contained in total 20 weed species, including 13 on farm A, and six in each of the remaining farms (Table 10). Weed species that were found in at least two fields of spring triticale, belonging to the dicot class, included ANTAR, LAMAM, POLLA, and VICCR, the monocot class—APESV, and the *Polypodiopsida* class—EQUAR. The direct forecrop of spring triticale on farm A was rape and winter wheat, which was most probably the reason for higher weed infestation in crops. Significant differences in weed infestation in winter wheat were found in such species as ANTAR, APESV, CENCY, CHEAL, CIRAR, EQUAR, LAMAM, POLLA, POLCO, POLAV, STEME, TAROF, VICCR, VICSA, VIOAR, and VERPE (Table 10). On farm B, the greatest weed infestation was recorded in the case of rape as the forecrop, and the most frequent weeds were VIOAR, VERPE, and TAROF. The lowest quantity of weeds was observed on farm E, and the most frequent weed was VICCR. The great difference in weed infestation between farms did not result from the direct forecrop, which was rape in both cases. After an inquiry, it turned out that it was due to the short usage period of the plot of land on farm B purchased only 2 years earlier. Additionally, high weed infestation was caused by years of set-aside of the purchased land and its location around uncultivated fields, which were a rich source of weed seeds transferred in soil (Table 10).

It turned out that air-dried weed mass significantly depended on the location in the case of such species as BRANA, CIRAR, EQUAR, POLAV, STEME, TAROF, VIOAR, VERPE, and VICCR (Table 10). Among 20 weed species, the largest air-dried weed mass was recorded for BRANA and TAROF found on farm A. Such a large air-dried mass of common dandelion resulted from its late growth stage defined as one of the ripening and fruit coloring stages. Among other species, a significant share in the measured weed mass was noted for VICCR, VIOAR, and VERPE. The share of other species did not influence their frequency in that period. It was expected that a reverse relationship would occur in the case of increasing share of weed species. The greatest air-dried weed mass in a field of spring triticale was observed on farm A, and the smallest on farm C. The air-dried weed mass on farm B was almost three times lower that on farm A (Table 10). The highest soil coverage by segetal plants was recorded on farm A and amounted to 19%, which resulted in an 81% density of the field of spring triticale. The smallest soil coverage by segetal plants was recorded on farm E and amounted to 5.4%, with the soil coverage by spring wheat of 95.4%. The lowest soil coverage in spring triticale crops involved monocot weeds, with their only representative being APESV from the monocot class (Table 10).

Table 10. Species composition, number, and weed mass and soil coverage in a field of spring triticale per 1 m^2.

No	Species	The Number of Weeds (No m^{-2})					$LSD_{0.05}$	Air-Dried Mass of Weeds (g m^{-2})					$LSD_{0.05}$
		A	B	C	D	E		A	B	C	D	E	
1	ANTAR	0.8	0.6	6.4	0.0	3.2	0.4	0.2	0.1	1.2	0.0	0.5	0.1
2	APESV	2.4	1.1	0.0	2.2	1.6	0.3	0.2	0.2	0.0	0.4	0.2	ns
3	BRANA	4.0	0.0	0.0	0.0	0.0	ns	15.0	0.0	0.0	0.0	0.0	0.8
4	CENCY	0.0	0.0	4.8	2.3	0.0	0.4	0.0	0.0	0.4	0.5	0.0	ns
5	CHEAL	0.0	0.7	2.4	2.1	0.0	0.3	0.0	0.1	0.4	0.4	0.1	ns
6	CIRAR	3.2	5.2	0.0	1.3	0.0	0.5	1.3	1.0	0.0	0.2	0.0	0.1
7	GAELA	0.0	1.1	0.0	0.6	0.0	ns	0.0	0.2	0.0	0.1	0.0	ns
8	GALAP	0.0	0.0	1.6	0.0	0.0	ns	0.0	0.0	0.0	0.0	0.0	ns
9	EQUAR	2.4	9.1	0.0	4.1	2.4	0.8	1.1	1.7	0.4	0.7	1.1	0.3
10	LAMAM	0.8	1.0	0.0	1.3	0.8	0.2	0.3	0.2	0.0	0.2	0.2	ns
11	POLLA	0.8	0.0	4.8	0.0	4.8	0.3	0.0	0.0	0.0	0.0	0.0	ns
12	POLCO	1.6	1.2	0.0	0.7	0.0	0.2	0.3	0.2	0.0	0.1	0.0	ns
13	POLAV	0.0	5.5	0.0	3.1	0.0	0.4	1.6	1.1	0.0	0.6	0.0	0.2
14	STEME	3.2	5.5	0.0	1.2	0.0	0.5	2.0	1.0	0.0	0.1	0.0	0.2
15	TAROF	0.8	10.6	0.0	5.8	0.0	0.9	10.4	2.0	0.0	1.0	0.0	0.7
16	VICCR	4.0	5.8	0.0	2.2	4.0	0.6	1.9	1.1	0.0	0.4	1.9	0.3
17	VICSA	0.0	1.0	1.6	0.7	0.0	0.2	0.3	0.2	0.0	0.1	0.0	ns
18	VIOAR	4.0	12.0	0.0	3.6	0.0	1.0	3.6	2.3	0.0	0.6	0.0	0.3
19	VICTE	0.0	0.8	0.0	0.0	0.0	ns	0.2	0.1	0.0	0.0	0.0	ns
20	VERPE	0.8	10.8	0.0	3.6	0.0	0.8	4.4	2.1	0.0	0.5	0.0	0.4
Sum of species		13	16	6	15	6	-	13	16	6	15	6	-
*		81.0	94.1	89.2	93.3	95.4	-	-	-	-	-	-	-
**		0.9	0.0	0.0	0.0	0.1	-	-	-	-	-	-	-
***		16.1	4.9	11.2	6.2	4.3	-	-	-	-	-	-	-
****		2.0	1.0	0.0	1.1	1.0	-	-	-	-	-	-	-

farm indicators: A—Lubla1, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa; ANTAR—*Anthemis arvensis;* APESV—*Apera spica-venti;* BRANA—*Brassica napus;* CENCY—*Centaurea cyanus;* CHEAL—*Chenopodium album;* CIRAR—*Cirsium arvense;* GAELA—*Galeopsis ladanum;* GALAP—*Galium aparine;* EQUAR–*Equisetum arvense;* LAMAM—*Lamium* amplexicaule; POLLA—*Polygonum lapathifolium;* POLCO—*Polygonum convolvulus;* POLAV—*Polygonum avicular;* STEME—*Stellaria media;* TAROF—*Taraxacum officinale;* VICCR—*Vicia cracca;* VICSA—*Vicia sativa;* VIOAR—*Viola arvensis;* VICTE—*Vicia tetrasperma;* VERPE—*Veronica persica;* * soil coverage with crop (%); ** soil coverage with monocot weeds (%); *** soil coverage with dicot weeds (%); **** soil coverage with *Equisetaceae* weeds (%).

3.3. Biodiversity Indices

The highest Shannon biodiversity index was recorded in the field of triticale, and the lowest in the field of winter wheat. This means that all species in the field of triticale had the same priority, and the plant community manifested the greatest biodiversity (Table 11). Biodiversity indices reflect the composition of communities in much more detail than just species richness (i.e., number of species present). In fact, they also account for the relative number of various species. A biodiversity index is a mathematical measure of species diversity in a community. Biodiversity indices reflect the composition of communities in much more detail than just species richness (i.e., number of species present). Simpson index (D) determines habitat biodiversity. It also established the probability of randomly picking two specimens of the same species. Index "D" ranges from 0 to 1, where 0 stands for unlimited biodiversity, and 1 no biodiversity. In general, the closer to 1, the poorer the biodiversity. For the sake of intuitiveness and clarity, the end result D was transformed into the so-called Simpson's Index of Diversity: 1—D, and then to the Simpson's Reciprocal Index: 1/D. In the case of such results, the greater the number, the greater the biodiversity. The latter index points to the greatest biodiversity in fields of triticale and the smallest in fields of spring wheat (Table 11).

Table 11. Biodiversity indices in fields of grain.

Species	Farms *					Average
	A	B	C	D	E	
Shannon index (H′)						
Winter wheat	0.56	0.29	0.64	0.64	0.14	0.45
Spring wheat	0.22	0.45	0.97	0.53	0.72	0.58
Spring triticale	0.92	0.90	0.68	1.00	0.72	0.84
Simpson index (D)						
Winter wheat	0.20	0.04	0.24	0.24	0.18	0.18
Spring wheat	0.76	0.46	0.09	0.20	0.15	0.33
Spring triticale	0.05	0.10	0.18	0.07	0.16	0.11
Simpson's Reciprocal Index						
Winter wheat	5.00	25.00	4.17	4.17	5.56	8.78
Spring wheat	1.31	2.17	10.11	5.00	6.66	5.05
Spring triticale	20.00	10.00	5.55	14.28	6.25	11.21

* farm indicators: A—Lubla$_1$, B—Dobrzechów, C—Lubla$_2$, D—Wiśniowa, E—Markuszowa.

4. Discussion

The results of our own research explicitly show that the potential state and biodiversity of weeds in winter and spring wheat and spring triticale was significantly differentiated. Increasing weed infestation in crops is caused by more and more popular grain monoculture and applying the same type of herbicide weeding agents for several years in the same field [7]. Looking for new and efficient solutions to reasonably control weeds in a way that takes into account the eco-demands of protecting floristic biodiversity is the primary goal of modern herbological studies [36]. One of the possibilities, so far rarely used in weed management, is the selection of cultivars based on their natural competitiveness with segetal flora. The degree and condition of weed infestation in fields of grain depends on a number of factors, e.g., the abundance of weed seeds in topsoil, the number of weeding procedures, the type of weed control agent used, the dose of herbicide active substance per surface unit, the time of herbicide application, the growth stage of weeds during chemical weeding procedures, and the weather conditions during and directly after spraying. In the conducted research, weed infestation in grains was related to forecrop and location. Weed infestation in fields can also be significantly influenced by the type and number of mechanical tillage procedures, manure fertilization, crop rotation, crop species, plant density in the field, and plant height [4]. In the experiment, mechanical tillage, chemical weed control, and grain species were the same. Weed infestation was differentiated by soil conditions, quantity of weeds in soil and plot location. According to Kieloch [37], a weed community in a given field is subject to dynamic changes due to various agricultural practices. The size of the weed population and its species composition is shaped by two major factors: crop competition and soil seed bank, which more or less depend on various elements of the agrotechnology, such as crop rotation, soil cultivation, sowing time and density, choice of cultivar. According to Haliniarz et al. [38], the aim of the optimal agrotechnology is to increase crop competitiveness against weeds and reduce the weed seed bank in soil. The conducted studies focused on species diversity, species variety, and species richness. The greatest number of weeds in a field of grain was recorded in spring wheat and spring triticale, and in terms of air-dried weed mass—the greatest mass was found in spring triticale. Based on the analysis of species biodiversity of crops in south-eastern Poland, the richest species composition and the greatest biodiversity according to Shannon index was also noted in spring triticale. In fact, they also account for the relative number of various species. The factors that can modify weed infestation in grains are numerous, with fertilization being the most prominent. In the conducted research, fertilization was adjusted to the fertility of soil and the nutritional needs of grain species. According to a number of authors [3,11,39], it is mainly nitrogen fertilization that strongly affects weed infestation. It is believed that increased nitrogen fertilization results in changes to the species composition of weed communities. It is manifested in the disappearance of oligotrophic species and their replacement with nitrophile species [40,41]. Nitrogen facilitates weed emergence, and during full vegetation—depending on the fertilization type—it can reduce or stimulate their occurrence. In the conducted research, the influence of fertilization on the floristic composition of weed communities in fields of grain was not investigated, but such influence was reported by other authors [39,42,43]. According to Czuba [12], Stępień [41], Kwiatkowski et al. [11], this factor differentiates the population size of weed species. The basic biodiversity means of measurement are based on the evaluation of the species composition in a given area (testing for the occurrence of all species and monitoring selected species) and comparison of the present state of the ecosystem to the past (comparison of the area to protected areas). The most frequently used biodiversity measures include Margalef index (D, R1), simplified Margalef index used by the Ministry of Environment, Shannon diversity index (H), Shannon equitability (species share) index (EH, J), dominance index (of Shannon and Weaver), modified Simpson index (D) [26]. In the conducted research, Shannon diversity index ranged from 0.46 to 0.84, depending on the type of crop field. The highest index value was recorded for fields of spring triticale, and the lowest for winter wheat. According to Zanin et al. [26], Shannon index is the highest when the share of species is even, i.e., all species have the same priority. When the number of species is equal, the community with even species distribution is characterized by higher biodiversity. When the share of species is even (p_i), the area with more species is characterized by greater biodiversity [26]. Based on the results, Shannon–Wiener (H) and Simpson (D) indices of biodiversity were calculated. Using the described methodology, it was established that the differences between indices H and D for the analyzed area and time were minor. According to Kotlarz et al. [44], who estimated the diversity of stands of trees, the investigated area of imaging differentiated after the first and second iteration by means of PCA, and the changes were also minor. The aim of conducting other studies and more thorough analyses, e.g., PCA, and thus complete identification of species in the context of biodiversity, requires further research. Agriculture is one of the key factors causing biodiversity decrease. Beside the loss of biodiversity due to habitat damage resulting from the transformation of natural areas into arable land, increasing agricultural activity has led to a significant decrease in biodiversity of agricultural areas. This threatens not only biodiversity but also the entire ecosystem and ecosystem service that agriculture relies upon. According to Erisman et al. [2], the pressure of feeding the increasing human population around the globe, combined with changing diet including more and more animal protein, has an additional negative effect on available arable land and agricultural areas. An agricultural system based on the full potential (functional agricultural biodiversity) opens up possibilities of establishing a resilient system where both food production and nature can develop [1,43,45,46]. Therefore, we recommend a complex approach in order to boost the development and implementation of agricultural practices which use and support biodiversity and ecosystem service in agricultural areas, seminatural enclaves and ecological grounds. An agricultural system based on the potential of functional agricultural biodiversity opens up possibilities of establishing a resilient system where both food production and nature can develop.

5. Conclusions

The greatest number of weeds in a field of grain was recorded in spring wheat and triticale, and the smallest in winter wheat. Weed infestation in winter wheat grown on all farms included a total of 11 weed species. The most frequent were ANTAR, CIRAR, VIOAR belonging to the dicot class, and EQUAR belonging to the *Polypodiopsida* class. Fields of spring triticale contained in total 20 weed species, including 13 on a single farm (A), and six in each of the remaining farms. During the assessment of weed infestation in fields of spring wheat, 14 weed species were identified, of which the most frequent were dicot weeds: BRANA, SINAR, and CIRAR. The only monocot weed found in that crop was APESV, with specimens reported in three out of five locations. The highest Shannon biodiversity index was recorded in the field of triticale, and the lowest in the field of winter wheat. This means that all species in the field of triticale had the same priority, and the plant community manifested the greatest biodiversity. The biodiversity evaluation of selected fields of grain conducted in several towns in the region enables the assessment of biodiversity on the regional, national, and global level. Some of the approved methods of biodiversity assessment are considered time-consuming and/or subjective, others focus on some parameters only and ignore the rest. However, testing a single index (parameter) does not provide a large picture of the situation, so in examining biodiversity, it is best to use several different methods. The data obtained on the diversity of weeds in the south-eastern part of Poland in the fields of cereal plants will be used in some weed control strategies. Additionally, that will be the added value of this project.

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Abbreviations

ALOMY	*Alopecurus myosuroides* L.
ANTAR	*Anthemis arvensis* L.
APESV	*Apera spica-venti* L.
APHAR	*Aphanes arvensis* L.
AVRDC	The World Vegetable Center
BBCH	Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie
BNI	Biological Nitrification Inhibition
BRANA	*Brassica napus* L.
CENCY	*Centaurea cyanus* L.
CGIAR	Consultative Group on International Agricultural Research
CHEAL	*Chenopodium album* L.
CIRAR	*Cirsium arvense* L.
CONAR	*Convolvulus arvensis* L.
EQUAR	*Equisetum arvense* L.
GAELA	*Galeopsis ladanum* L.
GALAP	*Galium aparine* L.
LAMAM	*Lamium amplexicaule* L.
POLAV	*Polygonum aviculare* L.
POLCO	*Polygonum convolvulus* L.
POLLA	*Polygonum lapathifolium* L.

RUMAA	*Rumex acetosella* L.
SINAR	*Sinapis arvensis* L.
STEME	*Stellaria media* (L.) Vill./Cyr.
TAROF	Taraxacum officinale Web.
VERPE	Veronica persica Poir.
VICCR	Vicia cracca L.
VICSA	*Vicia sativa* L.
VICTE	*Vicia tetrasperma* L.
VIOAR	Viola arvensis Murr.
WSSA	Weed Science Society of America

References

1. Duer, I.; Feledyn-Szewczyk, B. Species composition and biomass of weeds in winter wheat cultivated under different crop production systems and their contribution to the uptake of mineral components from the soil. *Pamiętnik Puławski* **2003**, *134*, 65–77. (In Polish)
2. Erisman, J.W.; van Eekeren, N.; de Wit, J.; Koopmans, C.H.; Cuijpers, W.; Oerlemans, N.; Koks, B.J. Agriculture and biodiversity: A better balance benefits both. *Agric. Food* **2016**, *1*, 157–174. [CrossRef]
3. Haliniarz, M. The response of selected agrophytocenosis to different doses of biologically active substances of herbicides. In *Monography*; University of Life Science in Lublin: Lublin, Poland, 2019; p. 207.
4. Feledyn-Szewczyk, B.; Smagacz, J.; Kwiatkowski, C.A.; Harasim, E.; Woźniak, A. Weed Flora and Soil Seed Bank Composition as Affected by Tillage System in Three-Year Crop Rotation. *Agriculture* **2020**, *10*, 186. [CrossRef]
5. Moreta, D.E.; Mathur, P.N.; van Zonneveld, M.; Amaya, K.; Arango, J.; Selvaraj, M.G.; Dedicova, B. Current Issues in Cereal Crop Biodiversity. *Adv. Biochem. Eng. Biotechnol.* **2015**, *147*, 1–35. [CrossRef]
6. Feledyn-Szewczyk, B. Biodiversity as an indicator of environmental monitoring. *Stud. Rep. IUNG-PIB* **2016**, *47*, 105–124.
7. Salonen, J.; Ketoja, E. Undersown cover crops have limited weed suppression potential when reducing tillage intensity in organically grown cereals. *Org. Agric.* **2020**, *10*, 107–121. [CrossRef]
8. Gawęda, D.; Cierpiała, R.; Harasim, E.; Haliniarz, M. Effect of tillage systems on yield, weed infestation and seed quality elements of soybean. *Acta Agrophys.* **2016**, *23*, 175–187.
9. Płaza, A.; Ceglarek, F.; Królikowska, A.; Próchnicka, M. The follow-up action of undersown crops and spring barley straw on yielding and structure elements of yield of winter triticale. *Folia Pomer. Univ. Technol. Stetin.* **2010**, *276*, 31–38.
10. Kowalczyk, E.; Patyra, E.; Kwiatek, K. Pyrrolizidine alkaloids as a threat to human and animal health. *Vet. Med.* **2015**, *71*, 602–607.
11. Kwiatkowski, C.A.; Wesołowski, M.; Drabowicz, M.; Misztal-Majewska, B. The effect of adjuvants and reduced rates of crop protection agents on the occurrence of agricultural pests and on winter wheat productivity. *Ann. UMCS* **2012**, *E-67*, 12–21.
12. Czuba, R.; Wróbel, S. Weed competitiveness in nutrient uptake by crops. *Ann. Soil Sci.* **1983**, *34*, 175–184.
13. GUS. Statistical Yearbook of the Republic of Poland. 2019. Available online: https://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystycznyrzeczypospolitej-polskiej-2019,2,19.html (accessed on 26 October 2020).
14. The EU's Biodiversity Strategy to 2030. Available online: https//ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm (accessed on 26 October 2020).
15. Mendelowski, S. *The Town and Commune of Strzyżów*; Roksana: Krosno, Poland, 2008.
16. Mocek, A. *Soil Science*; State Scientific Publisher: Warsaw, Poland, 2015.
17. Duer, I.; Fotyma, M.; Madej, A. *Code of Good Agricultural Practice*, 3rd ed.; Foundation for Assistance Programs for Agriculture: Warsaw, Poland, 2004; pp. 64–65. ISBN 83-88010-58-1. (In Polish)
18. Strażyński, P. *Recommendations for the Protection of Agricultural Plants. Vol. I*; Spring Cereals and Corn. Publisher: Poznań, Poland, 2020; ISBN 978-83-64655-53-1. (In Polish)

19. List of Registered Plant Protection Products by the Ministry of Agriculture and Rural Development for 2018/2019. Available online: https://www.gov.pl/web/rolnictwo/rejestr-rodkow-ochrony-roslin (accessed on 12 October 2020).
20. Ryzak, M.; Bartmiński, P.; Bieganowski, A. Methods of determination of granulometric distribution of mineral soils. *Acta Agroph.* **2009**, *175*, 97.
21. PN-R-04020, 1994+AZ1. *Chemical and Agricultural Analysis of Soil*; Polish Committee for Standardization: Warszawa, Poland, 2004.
22. PN-R-04023. *Chemical and Agricultural Analysis of Soil. Determination of Available Phosphorus Content in Mineral Soils*; Polish Committee for Standardization: Warsaw, Poland, 1996.
23. PN-ISO 10390:1997. *Soil Quality—Determination of pH*; Polish Committee for Standardization: Warsaw, Poland, 1997.
24. Nawrocki, S. (Ed.) *Fertilizer Recommendations. Part. I. Limit Numbers for Valuation of Soils in Macro- and Microelements. Part I*; Institute of Soil Science and Plant Cultivation: Puławy, Poland, 1985; p. 44. (In Polish)
25. Hack, V.H.; Bleiholder, H.; Buhr, L.; Meier, U.; Schnock-Fricke, U.; Weber, E.; Witzenberger, A. Einheitliche Codierung der phanologischen Entwicklungsstadien mono- und dikotyler Pflanzen—Erweiterte BBCH-Skala, Allgemein. *Nachrichtenbl. Deut. Pflanzenschutzd* **1992**, *44*, 265–270.
26. Domaradzki, K.; Badowski, M.; Filipiak, K.; Franek, M.; Gołębiowska, H.; Kieloch, R.; Kucharski, M.; Rola, H.; Rola, J.; Sadowski, J. Field experiments. In *Methodology Experiments of Biological Evaluation of Herbicides, Bioregulators and Adjuvants*; Domaradzki, K., Ed.; Institute of Soil Science and Plant Cultivation Publishing House: Puławy, Poland, 2001; Chapter 1; p. 167. (In Polish)
27. Zanin, G.; Mosca, G.; Catizone, P. A profile of the potential flora in maize fields of the Po Valley. *Weed Res.* **1992**, *32*, 407–418. [CrossRef]
28. Simpson, R.L.; Leck, M.A.; Parker, V.T. (Eds.) Seed Banks: General Concepts and Methodological Issues. In *Ecology of Soil Seed Banks Red*; Academic Press Inc.: Cambridge, MA, USA, 1989; pp. 3–8.
29. WRB. World Reference Database for Soil Resources. 2014. Available online: http://www.fao.org/3/a-i3794e.pdf (accessed on 8 June 2020).
30. Skowera, B.; Kopcińska, J.; Kopeć, B. Changes in thermal and precipitation conditions in Poland in 1971–2010. *Ann. Warsaw Univ. Life Sci. SGGW Land Reclam.* **2014**, *46*, 153–162. [CrossRef]
31. SAS. *Users Guide*; SAS Institute Inc.: Cary, NC, USA, 2008.
32. Koronacki, J. *Statistics, for Students of Technical and Natural Sciences*; Scientific and Technical Publishers: Warsaw, Poland, 2009; p. 491.
33. John, H.M. *Handbook of Biological Statistics*, 3rd ed.; Sparky House Publishing: Baltimore, MD, USA, 2014; pp. 148–151.
34. WSSA. *Weed Science*; 1985; pp. 12–15. Available online: https://www.cambridge.org/core/journals/weed-science/article/terms-definitions-and-abbreviations/BA04ABB16C2B5D7D1CDF3A50E3CA8FE7# (accessed on 26 October 2020).
35. PPG. The Pteridophyte Phylogeny Group. A community-derived classification for extant lycophytes and ferns. *J. Syst. Evol.* **2016**, *54*, 563–603. [CrossRef]
36. Twardowski, J.P.; Pastuszko, K. Field margins in winter wheat agrocenosis as reservoirs of beneficial ground beetles (Col., Carabidae). *J. Res. Appl. Agric. Eng.* **2008**, *53*, 123–127.
37. Kieloch, R. Influence of cultivar and agrotechnics on the formation of weed infestation in agricultural crops. *Stud. Rep. JUNG-PIB* **2020**, *61*, 51–63.
38. Haliniarz, M.; Gawęda, D.; Nowakowicz-Dębek, B.; Najda, A.; Chojnacka, S.; Łukasz, J.; Wlazło, Ł.; Różańska-Boczula, M. Evaluation of the Weed Infestation, Grain Health, and Productivity Parameters of Two Spelt Wheat Cultivars Depending on Crop Protection Intensification and Seeding Densities. *Agriculture* **2020**, *10*, 229. [CrossRef]
39. Grundy, A.C.; Mead, A.; Bond, W.; Clark, G.; Burston, S. The impact of herbicide management on long-term changes in the diversity and species composition of weed populations. *Weed Res.* **2010**, *51*, 187–200. [CrossRef]
40. Pawlonka, Z.; Skrzyczyńska, J.; Ługowska, M. Influence of tillage methods and nitrogen fertilisation on weed emergence and development in winter triticale. *Acta Sci. Pol. Agric.* **2007**, *6*, 49–57.
41. Stępień, A. Effect of different fertilisation methods on weed infestation and yielding of spring wheat. *Acta Sci. Pol. Agric.* **2004**, *36*, 45–54.

42. Sawicka, B.; Barbaś, P.; Dąbek-Gad, M. The problem of weed infestation in the conditions of using growth bioregulators and foliar fertilization in potato cultivation. *Sci. Nat. Technol.* **2011**, *5*, 1–12.
43. Bojarszczuk, J.; Podleśny, J.; Nowak, J. The assessment of the diversity of weed flora communities in crops cultivated in selected farms in Lubelskie voivodeship. *Prog. Plant Prot. Postępy Ochr. Roślin* **2018**, *58*, 216–223. [CrossRef]
44. Kotlarz, J.; Kubiak, K.; Kacprzak, M.; Czapski, P. Estimation of tree species diversity of forest stands based on their spectral reflectance. *Sylwan* **2016**, *160*, 1036–1045.
45. Stešević, D.; Jovović, Z. Contribution to the knowledge on the weed flora in potato crop in the vicinity of ikšić (Montenegro). *Herbologia* **2011**, *12*, 1–6.
46. Staniak, M.; Bojarszczuk, J.; Księżak, J. Weed infestation of spring cereals cultivated in pure sowing and undersown with serradella (*Ornithopus sativus* L.) in organic farm. *Water. Environ. Rural. Areas* **2013**, *2*, 121–131.