Zeszyty Problemowe Postępów Nauk Rolniczych
nr 602, 2020, 3–12
DOI 10.22630/ZPPNR.2020.602.11

SPECIES RICHNESS AND WEED ABUNDANCE IN WINTER DEPENDING ON THE DATE OF SOWING AND NPK FERTILIZATION

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Summary. The aim of the study was to assess the biodiversity of segetal flora in winter wheat depending on the date of sowing (four dates, every two weeks: I – 15–16 September, II – 29–30 September, III – 14–15 October, and IV – 28–29 October) and NPK fertilization level (kg · ha^{-1}): 1 NPK (310 kg · ha^{-1}), including 140 N, 70 P and 100 K, or 1.5 NPK (465 kg · ha^{-1}), including 210 N, 105 P and 150 K. On the earliest sowing date (I date), the weed assemblage was the most numerous, both in the tillering (BBCH 22-25) and milk maturity phases (BBCH 77-79). The dominant weeds were: *Viola arvensis, Veronica arvensis, Geranium pusillum.* The NPK fertilization level significantly differentiated the density of weeds only during the milk maturity stage. Compared to the lower dose, the higher dose of fertilizers contributed to a rise in the number of weeds per 1 m^2, simultaneously causing a decrease in weed biomass. In the phase of milk maturity (BBCH 77-79), the Shannon-Wiener index increased with the delay in sowing, but at the same time the Simpson dominance index decreased.The different levels of fertilization applied did not have any significant effect on the values of both biological indicators.

Key words: winter wheat, date of sowing, NPK, weed species diversity, weed density end biomass

INSTRODUCTION

A large share of cereals in the total structure of crops, in addition to the more intensive cultivation of winter cereals, creates favourable conditions for weed infestation. Winter wheat, because of its long vegetative phase, slow development in autumn and specific

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morphological traits (such as short culms), belongs to plants which are poorly competitive towards weeds. Hence, to obtain a large yield it is necessary to eliminate the factors that restrain the growth and development of wheat, and these include agricultural crop pests like weeds. Agriculture has effected many changes in the floristic composition of weeds in agricultural biocenoses. Frequent sowing of cereals after cereals leads to the formation of simplified phytocenoses, composed mainly of a few weed species [Woźniak 2019]. But researchers underline that one species of a weed that occurs in a mass number often poses a more serious competitive threat to cultivated plants than several ones achieving similar density in a field of crops [Brzozowska and Brzozowski 2011]. Thus, weeding must be carried out during the vegetative growth phase of a cereal crop, from emergence to tillering [Rasmussen et al. 2009, Pilipavicius et al. 2010]. Chemical plant protection, although highly effective, is often responsible for environmental pollution and disturbed biological balance. Nowadays, an important role in reducing weed infestation of agricultural ecosystems is attributed to such agricultural technologies that improve the competitiveness of a crop, thereby limiting the density of weeds in a field [Tang i in. 2014, Gaba i in. 2018, Jiang i in. 2018]. Such treatments include the optimal sowing date of winter cereals, although it is difficult to ensure it in Poland. In many cases, due to unfavourable weather conditions, the sowing must be delayed until rainfall comes [Oleksiak 2014, Singh i in. 2019]. Another yield-promoting solution is adequate crop fertilization, especially with nitrogen, but here it is important to choose the proper fertilization regime, including the dosage and application of a fertilizer. The hypothesis tested in this experiment was that the extent of weed infestation of a crop field is dynamic and depends on the conditions in a given habitat as well as the applied agrotechnical treatments. With a view of reducing the consumption of herbicides and consequently the need for more intensive agrotechnical treatments, this study was launched in order to evaluate the biodiversity of segetal flora in winter wheat, on the basis of species composition, density and biomass of weeds (also with the use of biodiversity indices Shannona-Wienera i Simpsona), depending on the sowing date of wheat and NPK fertilization levels.

METHODS

In 2014–2016, a field trial with the winter wheat cultivar Arkadia grown after winter wheat was carried out at the Experimental Station in Tomaszkowo (53º42′ N; 20º26′ E), affiliated with the University of Warmia and Mazury in Olsztyn. Soil tillage was performed in line with relevant recommendations. The experiment was laid out in the random block design, with three replicates, on eutrophic, proper, heavy brown soil [Marcinek and Komisarek 2011], which is classified as a Haplic Combisol (Eutric) in WRB taxonomy [IUSS Working Group WRB 2015]. The surface area of a single plot was 16 m^2. The first experimental factor consisted of dates of sowing (four dates, at two-week intervals) 15–16 September, II – 29–30 September, III – 14–15 October, IV – 28–29 October. The amount of sown wheat kernels was 400 pieces per square meter. The second factor was composed of NPK fertilization levels (in kg · ha^{-1}): 1 NPK (310 · kg ha^{-1}), including 140 N, 70 P and 100 K, and 1.5 NPK (465 kg · ha^{-1}), including 210 N, 105 P and 150 K. Nitrogen fertilizers were applied on three dates (Table 1). The scope of investigations encompassed an evaluation of the structure of weeds in winter wheat on two dates: in spring, when the vegetative growth was resumed, which corresponded to the tillering phase of wheat (BBCH 22-25), and then during the milk maturity phase of winter wheat (BBCH 77-79). The study included an assessment of the species composition of weed populations and the number of specimens for each species, and the latter analysis also involved the determination of weed air-dry biomass. All analyses were performed on plants collected from 0.5 m^2 of a plot using a frame, in four replications, and the results were converted per 1 m^2.

Table 1. Regimes of winter wheat nitrogen fertilization

Tabela 1. Schemat nawożenia azotem pszenicy ozimej

Dates of nitrogen application Terminy stosowania azotu	Type of fertilizer Rodzaj nawozu	1 NPK	1.5 NPK
After resumed vegetative growth Po wznowieniu wegetacji (BBCH 12-21)	ammonium nitrate saletra amonowa 34%	70	100
Stem elongation Strzelanie w źdźbło (BBCH 32-33)	urea mocznik 46%	40	60
Inflorescence emergence Kłoszenie (BBCH – 52-53)	urea mocznik 46%	30	50

The structure of weed assemblages in the analysed systems was also evaluated with the help of two biological indices [after Heip et al. 1998]: the Shannon-Wiener biodiversity index ($H = -\Sigma$ pi ln pi; where: pi = n/N, i.e. the ratio of a number to biomass of specimens of i-th species to the total number or biomass of all specimens in the sampled area), and the Simpson dominance index, described with the formula: Si = Σ (pi)^2.

Statistical methods. The research results concerning the number and mass of weeds in wheat during the milk maturity phase were processed statistically with a two-factorial variance analysis in a random split-plot sub-block system. The significance of differences was assessed with the Duncan's test at the probability of error set at 0.05. All calculations were performed in a Statistica software package.

The years when the experiment was carried out (2014–2016) had highly variable weather conditions (Table 2). The first two seasons (2013/2014 and 2014/2015) were conducive to the emergence of weeds in autumn, while the low temperatures and water deficits in the third season limited weed emergence.

Table. 2. Air temperatures and rainfall in the vegetation period of winter wheat in 2013–2016 according to Meteorological Station in Tomaszkowo

Tabela 2. Temperatury powietrza i opady w okresie wegetacji pszenicy ozimej w latach 2013–2016 według Stacji Meteorologicznej w Tomaszkowie

Month Miesiąc	Air temperature Temperatura [°C]				Rainfall Opady [mm]			
	1961–2010	2013–2014	2014–2015	2015–2016	1961–2010	2013–2014	2014–2015	2015–2016
IX	12.6	11.3	13.6	13.5	57.1	101.1	25,9	63.8
X	7.7	8.9	8,8	6.1	46.0	16.0	15.1	19.4
XI	2.8	5.0	3.7	4.8	47.9	18.0	34.0	84.5

Table. 2. cont. / cd. tab.2

Month Miesiąc	Air temperature Temperatura [°C]				Rainfall Opady [mm]			
	1961–2010	2013–2014	2014–2015	2015–2016	1961–2010	2013–2014	2014–2015	2015–2016
XII	–1.2	2.2	–0.3	3.5	36.6	27.7	61.8	56.6
I	–2.9	–3.7	0.4	–4.1	31.2	48.4	46.8	24.7
II	–2.3	1.2	0.7	2.3	21.9	8.1	6.8	57.1
III	1.2	5.1	4.2	2.9	28.5	57.7	45.1	21.6
IV	7.0	8.8	6.7	7.4	34.2	26.0	38.2	28.8
V	12.7	12.9	11.8	13.6	54.6	32.7	29.7	56.9
VI	15.9	14.4	15.5	17.1	79.0	50.8	29.5	69.3
VII	18.0	20.4	17.6	18.1	75.4	37.3	81.9	130.4
VIII	17.3	17.3	19.9	17.0	68.7	86.1	14.3	70.4
Mean or sum (IV–VII)	13.4	14.1	12.9	14.1	243.2	146.8	179.3	285.4

RESULTS AND DISCUSION

The field experiment was carried out in the presence of medium density of weeds in the second and third years of the research (158.3 and 86.3 pcs · m^{-2}, respectively) and low one in the third year (on average 24.1 pcs · m^{-2}) – Table 3.

In the three consecutive years, there were 17, 11 and 12 weed species, respectively. The following ones prevailed: *Viola arvensis, Veronica arvensis*, *Geranium pusillum*, *Capsella bursa-pastoris*, *Thlaspi arvense* and *Stellaria media.* The specimens represent-

Table. 3. Densities and dominant species composition of weed infestations in winter wheat tillering phase (BBCH 22-25)

Tab. 3. Zagęszczenie i dominujące gatunki chwastów występujące w łanie pszenicy ozimej po wznowieniu wegetacji, w fazie krzewienia (BBCH 22-25)

Year of research Rok badań	Weed density per 1 m^2 [total number of species] Zagęszczenie chwastów na 1 m^2 [liczba gatunków ogółem]	Dominant species of weeds [plants · m^{-2}] Dominujące gatunki chwastów [szt · m^{-2}]
2014	86.3 (17)	*Viola arvensis* MURRAY (31.7)*, Veronica arvensis* L. (21.5), *Geranium pusillum* BURM. F. ex L. (7,2), *Capsella bursa-pastoris* (L.) MEDIK. (6.7), *Thlaspi arvense* L. (4.2)*, Stellaria media* (L.) VILL. (2.2)
2015	158.3 (11)	*Viola arvensis* MURRAY (103.5*), Geranium pusillum* BURM. F. ex L. (28.4)*, Veronica persica* Poir. (8.6), *Capsella bursa-pastoris* (L.) MEDIK. (1.6), *Thlaspi arvense* L. (1.5)
2016	24.1 (12)	*Viola arvensis* MURRAY (9.7), *Stellaria media (L.) VILL.* (4.9), *Veronica arvensis L*. (2.0*), Capsella bursa-pastoris* (L.) MEDIK. (2.0*), Thlaspi arvense L*. (1.9)

ing these species made up 87.6, 86.5 and 85.1% of all weeds, respectively, and their respective shares during the milk maturity phase equalled 86.8, 99.0 and 49.4%.

The competitiveness of a species should be viewed through the prism of its competition with other weeds present in a crop field. In this experiment, after the vegetative growth was resumed, in the wheat tillering phase (BBCH 22-25), the weed assemblage was on average most numerous in the fields of wheat sown on the earliest date (I date) (156.5 pcs · m^{-2}), being the least numerous in the wheat field sown the latest (22.1 pcs · m^{-2}) – Table 4.

Table 4. Species composition and number of weeds per 1 m^2 in winter triticale stand on tillering stage (BBCH 22-25), average 3-year

Tabela 4. Skład gatunkowy i liczba chwastów na 1 m^2 w łanie pszenicy ozimej po wznowieniu wegetacji, w fazie krzewienia (BBCH 22-25), średnio z 3 lat

Species composition Gatunki chwastów	Sowing date Termin siewu*				NPK fertilization level Poziom NPK*	
	I	II	II	IV	1	1.5
Viola arvensis MURRAY	87.6	74.0	22.9	8.8	48.6	47.9
Veronica arvensis L.	13.6	8.9	8.7	3.4	7.8	9.5
Geranium pusillum BURM. F. ex L.	21.4	15.1	6.9	4.3	11.0	12.8
Capsella bursa-pastoris (L.) MEDIK.	6.7	2.2	2.9	1.9	2.3	4.6
Matricaria maritima L. subsp. Inodora (L.) DOSTAL	5.1	5.3	1.2	0.2	2.7	3.3
Stellaria media (L.) VILL.	8.1	1.9	0.7	0.7	2.8	2.8
Galium aparine L.	2.2	0.4	1.0	0.7	0.7	1.5
*Matricaria maritim*a L. subsp. Inodora (L.) DOSTAL	1.6	0.3	0.2	–	0.7	0.3
Other species Pozostałe gatunki	10.2	10.4	6.1	2.1	7.5	7.1
Total [plants · m^{-2}] Razem [szt. · m^{-2}]	156.5	118.5	50.6	22.1	84.1	89.8
$LSD_{0.05}$ – $NIR_{0.05}$**	8.1				r.n.	
Number of species Liczba gatunków	17	13	13	10	13	17

*as in the methodology; ** LSD0.05 – least significant difference at the significance level of

α = 0.05* jak w metodyce; ** NIR 0,05 – najmniejsza istotna różnica przy poziomie istotności α = 0.05

Slightly more weeds grew in the plots with the more intensive NPK fertilization (89.8 pcs · m^{-2}), but at no significant difference relative to the plots which received the lower fertilization dose (84.1 pcs · m^{-2}). During the milk maturity phase (BBCH 77-79), the segetal weed community was most numerous in winter wheat fields sown on the first date (65.5 pcs · m^{-2}), same as in spring, and decreased significantly for each subsequent sowing date until the lowest level of 13.8 pcs · m^{-2} in wheat sown on the latest date (Table 5). In turn, the highest fertilization level applied to wheat fields contributed to a significant increase in the density of weeds per 1 m^2 (from 34.2 to 37.3 pcs · m^{-2}). All weed communities in the experiment continued to be dominated by the species which appeared in the highest number in spring. In a Hungarian study completed by Bónis et al. [2010], the highest density of weeds per 1 m^2 after the resumed vegetative growth, during the period from tillering to stem elongation, was observed in a field of wheat sown on the optimal date. However, the most severe weed infestation during the milk maturity phase was recorded in the delayed sowing variant, where wheat did not form a compact field. According to Fodor and Pálmai [2008], delayed sowing results in inferior growth of wheat and higher production of weed biomass. The literature, however, provides contrary opinions. In Indian studies, delayed wheat sowing reduced the weed biomass in wheat and increased its yield [Singh 2019]. For example, Ruža and Kreita [2008] maintain that excessively early sowing, conducive to a more rapid growth of crops in autumn, can be a cause of greater weed infestation, which may lead to a lower yield of wheat.

Table 5. Species composition and number of weeds per 1 m^2 in winter wheat stand on tillering stage,average 3-year

Tabela 5. Skład gatunkowy i liczba chwastów na 1 m^2 w łanie pszenicy ozimej w fazie dojrzałości mlecznej, średnio z 3 lat

Species composition Gatunki chwastów	Sowing date Termin siewu *				NPK fertilization level Poziom NPK*	
	I	II	II	IV	1	1,5
Viola arvensis MURRAY	41.0	25.5	11.5	4.7	19.9	21.4
Veronica arvensis L.	12.7	4.8	5.3	3.2	5.7	7.0
Geranium pusillum BURM. F. ex L.	3.7	2.3	0.5	0.3	1.6	1.8
Capsella bursa-pastoris (L.) MEDIK.	2.0	–	–	0.1	0.2	0.8
Matricaria maritima L. subsp. Inodora (L.) DOSTAL	0.7	0.3	–	0.2	0.5	0.1
Thlaspi arvense L.	0.5	0.6	0.2	0.1	0.1	0.5
Stellaria media (L.) VILL.	–	0.2	0.1	0.2	0.3	–
Galium aparine L.	0.5	0.7	1.3	0.3	0.4	1.0
Veronica persica Poir.	–	0.7	0.6	0.7	0.2	0.7
Other species Pozostałe gatunki	4.4	5.3	3.9	4.0	5.3	4.0
Total [plants · m^{-2}] Razem [szt. · m^{-2}]	65.5	40.4	23.4	13.8	34.2	37.3
$NIR_{0.05}$	2.4				2.0	
Number of species Liczba gatunków	14	17	15	18	22	15

*as in the methodology; ** LSD0.05 – least significant difference at the significance level of $\alpha = 0.05$* jak w metodyce; ** NIR 0,05 – najmniejsza istotna różnica przy poziomie istotności $\alpha = 0.05$

The harmful effect of weeds growing in a field of crops. beside the density of segetal plants, arises from the amount of biomass they generate, which together influences the competition for ecological factors (Table 6). In this experiment, the highest amount of biomass was produced by the segetal flora in a field cropped on the earliest date when the wheat reached the milk maturity phase, i.e. BBCH 77-79 (36.28 g · m^{-2}), whereas the lowest amount of weed biomass was recorded in a field of wheat sown on the last date (6.67 g · m^{-2}). Regarding the weed biomass produced, the relationship was different than the one concerning the density of weeds. Wheat fertilized with the higher NPK doses was more competitive towards weeds, which then produced much lower biomass (15.05 g · m^{-2}) than weeds from the plots receiving the lower fertilization doses (18.13 g · m^{-2}). Similar relationships were observed in an experiment with spring barley conducted in Iran [Rahnavard et al. 2009].

Table 6. Species composition and number of weeds per 1 m^2 in winter triticale stand on tillering stage,average 3-year

Tabela 6. Powietrznie sucha masa chwastów na 1 m^2 w łanie pszenicy ozimej w fazie dojrzałości mlecznej, średnio z 3 lat badań

Species composition Gatunki chwastów	Sowing date Termin siewu*				NPK fertilization level Poziom NPK*	
	I	II	II	IV	1	1,5
Viola arvensis MURRAY	13.12	6.46	3.83	1.52	5.92	6.53
Veronica arvensis L.	3.64	0.63	0.23	0.40	1.34	1.11
Geranium pusillum BURM. f. ex L.	1.96	1.82	0.37	0.13	0.48	1.67
Matricaria maritima L. subsp. inodora (L.) DOSTAL	10.67	1.23	0.00	0.18	5.93	0.11
Capsella bursa-pastoris (L.) MEDIK.	3.87	–	–	0.03	0.65	1.30
Thlaspi arvense L.	0.88	0.24	0.22	0.12	0.11	0.61
Stellaria media (L.) VILL.	0.63	0.34	0.58	0.05	0.59	0.21
Galium aparine L.	0.57	0.50	1.87	0.67	0.56	1.24
Other species Pozostałe gatunki*	0.94	3.23	1.80	3.53	2.55	2.21
Total [g · m^{-2}] Razem [g. · m^{-2}]	36.28	14.49	8.94	6.66	18.13	15.05
NIR $_{0.05}$	3.29				0.80	

*as in the methodology; ** LSD0.05 – least significant difference at the significance level of

α = 0.05* jak w metodyce; ** NIR 0,05 – najmniejsza istotna różnica przy poziomie istotności α = 0.05

In our experiment, after the vegetative growth was resumed, the biodiversity of segetal flora expressed with the Shannon-Wiener index calculated during the tillering phase of winter wheat tended to decrease with the subsequently delayed sowing dates (from 1.65 to 0.75), which was probably connected with the different vegetative growth period of the cereal in autumn, as this usually corresponded to the decreasing number of species of weeds in the weed community (Fig. 1). In turn, during the milk maturity phase of wheat, the Shannon-Wiener index value increased demonstrably for each subsequent date of sowing, rising from 1.27 to 2.02, and meanwhile the Simpson dominance index declined (from 0.44 to 0.20). This is associated with the fact that the values obtained from calculations of the Shannon-Wiener and Simpson indices depend on both the number of species found in a sample and the number of specimens (or amount of the biomass) in a given assemblage of plants. In the wheat sown on later dates, the lesser density of the crop created suitable conditions for the sprouting and growth of single specimens of different weed species, which resulted in the modification of the values of these biological indices.

The different fertilization levels applied did not have any evident influence on how values of the two indices were shaped or on the density and biomass of weeds during the analysed wheat development phases. When calculating values of the biological indices, small and large specimens are treated the same although their importance in a field of crops is different. Hence, this research also included the calculations of the indices for the generated weed bio-

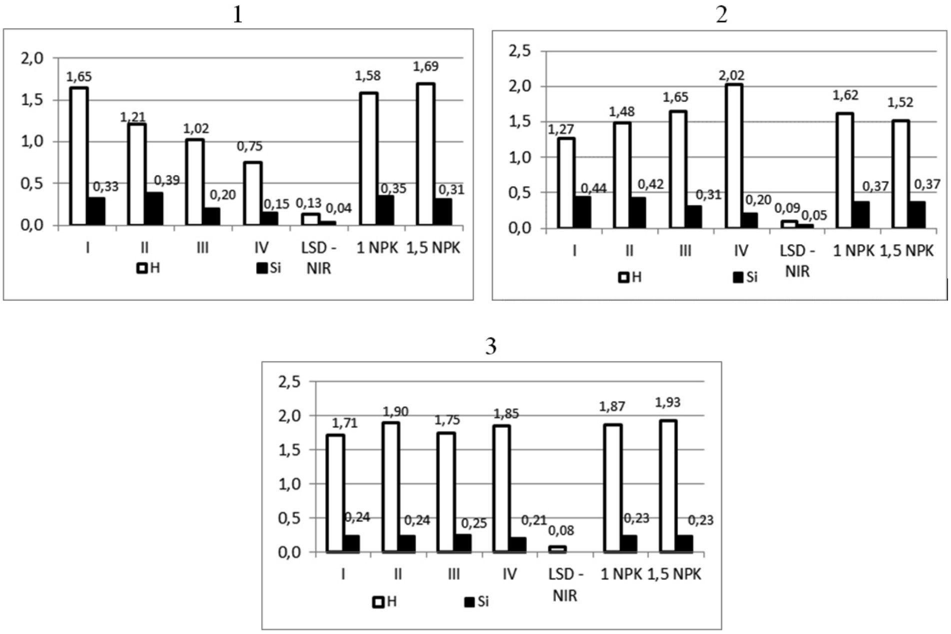

Fig. 1. Ecological index: diversity of Shannon-Wiener (*H*) and Simpson dominance (*Si*) for: 1 – number of weeds in the tillering stage, 2 – the number of weeds in the milky maturity stage, 3 –mass of weeds in the milk maturity stage, depending on the date of sowing and the level of NPK, average 3-year

Rys. 1. Wskaźniki ekologiczne: różnorodności Shannona-Wienera (*H*) i dominacji Simpsona (*Si*) dla: 1 – liczby chwastów w fazie krzewienia, 2 – liczby chwastów w fazie dojrzałości mlecznej, 3 – masy chwastów w fazie dojrzałości mlecznej; w zależności od terminu siewu i poziomu NPK, średnio z 3 lat

mass produced before the harvest of wheat in the milk maturity phase. The analysed indices achieved similar three-year average values, for both the different sowing dates (from 1.75 to 1.85) and for the two levels of fertilization (1.87–1.93), which suggests high stability of the weed assemblages in wheat fields. Opinions of researchers concerning the effect of fertilization of competitiveness of cereals and weeds are divided [Tang i in. 2014, Gaba i in. 2018, Jiang i in. 2018]. In the study of Tang et al. [2014], balanced fertilization of wheat increased its competitiveness in relation to weeds. However, in a study by Santín-Montanyá et al. [2013], nitrogen fertilization was found to have little impact on the number and species diversity of weeds in wheat fields. According to Jiang [2018], balanced fertilization maintained the species richness of weeds and resulting in high wheat yields.

CONCLUSIONS

1. The weed community was the most numerous in the wheat fields sown on the earliest date, both in the tillering phase (BBCH 22-25) and during milk maturity (BBCH 77--79), whereas the smallest number of weeds appeared in the wheat plots sown the

latest. Similar relationships were determined for the biomass of weeds in wheat during the milk maturity phase. The dominant weeds were: *Viola arvensis, Veronica arvensis, Geranium pusillum.*

2. The biodiversity of segetal plants, expressed with the Shannon-Wiener index, after the resumed vegetative growth, was distinctly lower in the tillering phase (BBCH 22-25) for each consecutive date on which wheat had been sown (for 1.65 to 0.75), which was associated with the duration of the wheat vegetative growth in autumn. In turn, during the milk maturity phase of wheat, the Shannon-Wiener index (for 1.27 to 2.02), increased while the Simpson dominance index (for 0.44 to 0.20). decreased when the sowing date was delayed.
3. The NPK fertilization levels significantly differentiated the density of weeds during the milk maturity phase. Compared to the lower NPK fertilization level, the higher NPK dose was conducive to an increase in the number of weeds per 1 m^2 (z 34.2 do 37.3 plants · m^{-2}), but at the same time led to a decrease in the biomass produced by weeds (z 18.13 do 15.05 g · m^{-2}).
4. The two different fertilization levels did not have an distinctly observable effect on the values of the biological indices, in terms of both the weed density and biomass, during the two wheat development phases analysed in this study.

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BOGACTWO GATUNKOWE I OBFITOŚC CHWASTÓW W PSZENICY OZIMEJ W ZALEŻNOŚCI OD TERMINU SIEWU I POZIOMU NAWOŻENIA NPK

Streszczenie. Celem pracy była ocena bioróżnorodności flory segetalnej w pszenicy ozimej, w zależności od zróżnicowanych terminów siewu (cztery terminy, co dwa tygodnie: I – 15–16 września, II – 29–30 września, III – 14–15 października, IV – 28–29 października) i poziomu nawożenia NPK (kg · ha^{-1}): 1 NPK (310 kg · ha^{-1}), w tym 140 N, 70 P i 100 K oraz 1,5 NPK (465 kg · ha^{-1}), odpowiednio 210 N, 105 P i 150 K. W najwcześniejszych zasiewach pszenicy (I termin) zbiorowisko chwastów było najliczniejsze, zarówno w fazie krzewienia (BBCH 22-25) – (156,5 szt · m^{-2}), jak i w fazie dojrzałości mlecznej (BBCH 77-79), (65,5 szt · m^{-2}), a najmniej chwastów występowało w pszenicy wysiewanej najpóźniej (odpowiednio 22,1 i 13,8 szt · m^{-2}). Dominującymi chwastami były: *Viola arvensis, Veronica arvensis*, *Geranium pusillum.* Poziom nawożenia NPK jedynie w fazie dojrzałości mlecznej istotnie różnicował zagęszczenie chwastów. Większe nawożenia NPK przyczyniało się do wzrostu ich liczby na 1 m^2 (37,3, w porównaniu do 34,2 szt · m^{-2}), ale jednocześnie do obniżenia wytworzonej ich biomasy (15,05 g · m^{-2}), w porównaniu z mniejszym nawożeniem NPK (18,13 g · m^{-2}). W fazie dojrzałości mlecznej pszenicy (BBCH 77-79), wraz z opóźnieniem terminu siewu wzrastał wskaźnik Shannona-Wienera, ale jednocześnie zmniejszał się wskaźnik dominacji Simpsona.

Słowa kluczowe: pszenica ozima, termin siewu, NPK, bioróżnorodność gatunkowa chwastów, zagęszczenie i biomasa chwastów