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YIELD AND WEED INFESTATION OF WINTER WHEAT IN DEPENDENCE ON SOWING DENSITY AND AGRICULTURAL PRACTICE LEVEL

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Abstract. The experiment was carried out in 2005-2007 at the Education and Research Station Krasne near Rzeszów in the brown soil formed from loess, classified as the good wheat complex. The aim of this study was to estimate the effect of four sowing densities on the number, air-dry weight and species composition of weeds and the grain yield of winter wheat under conditions of two levels of agricultural practices. Intensification of level of wheat agricultural practices significantly reduced both the numbers of weeds – on average by 39.2 pcs·m^{-2} (49.4%) and their air-dry weight (by 46.4%). An effect of the number of sown wheat grains on weed density was not proved statistically, but the dry weight of weeds from plots with the highest sowing density was less (by 50.5%) than from the plots where sowing density was 250 grains·m^{-2}. Wheat cultivation at intensive level of agricultural practices resulted in an increase in grain yield in the years of the study from 0.49 to 0.82 t·ha^{-1}. The sowing 450 and 550 grains·m^{-2} provided the highest grain yields, 6.51 and 6.79 t·ha^{-1}; respectively; a difference in the yield level between those densities amounted to 4.1% and was statistically insignificant. The lowest yield of wheat grain 4.84 t·ha^{-1} was found under conditions of the smallest sowing density.

Key words: intensity of agricultural practices, sowing density, species composition of weeds, weeds, yield components

INTRODUCTION

The proper sowing density of seeds and complex protection against exceeding weed infestation is the basic and important factor of cereal plants cultivation, having an effect on the yield level and the yield structure [Podolska and Stankowski 2001, Wesołowski 2003]. One of the ways of weed infestation control in integrated programs of cereal plant protection is an attempt to obtain the proper stand density. Therefore, to reduce the development of weeds, using a larger sowing density of the agricultural crop is recommended [Michalski 1999, Piekarczyk 2010]. Also an increase in intensity of

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cultivation technology contributes to a growth in canopy density, which limits the occurrence of weed infestation. Selection of cereal cultivars which are characterized by an intensive growth rate, high tillering and a long stem also cause that there are definitely less weeds in the field [Podolska and Mazurek 1999]. However, one should bear in mind that excessive sowing density favors the spread of diseases and lodging, which may considerably reduce the yield height and worsen the grain quality. Under conditions of changing profitability of cereal production, especially in technologies with varied level of agricultural practices, it seems to be justified to determine the rational sowing density of new cultivars [Wesołowski 2005, Dubis and Budzyński 2006].

The aim of this study was to estimate the effect of four sowing densities on the number, air-dry weight and species composition of weeds and the grain yield of winter wheat under conditions of two levels of agricultural practices. A research hypothesis was formulated assuming that an increase in wheat sowing density will reduce weed infestation, but the level of agricultural practices will be a decisive factor influencing the yield and a decrease in the number and air-dry weight.

MATERIAL AND METHODS

The study was carried out in 2005-2007 under conditions of the Rzeszów Foothills on the experimental plot owned by the Education and Research Station Krasne (50°03' N; 22°06' E) of the University of Rzeszów. The experiment was located in the brown soil formed from loess, classified as the IIIa quality class, the good wheat complex, with pH in 1 M KCl 6.3-6.8, a moderate abundance of phosphorus, potassium and magnesium. The experiment was established in the randomized complete block design with four replications, and the area of the plot for harvesting was 15 m^2.

Two experimental factors were considered in the experiment:

- sowing density of winter wheat (number of germinating grains per 1 m^2): A – 250, B – 350, C – 450, D – 550,
- agricultural level: a – standard, b – intensive.

Standard level of agricultural practices involved the application of fertilization: N – 80 $kg \cdot ha^{-1}$, P – 26.5 $kg \cdot ha^{-1}$, K – 66.5 $kg \cdot ha^{-1}$ and weed and pest control: Chwastox Turbo 340 SL – 2.0 $dm^3 \cdot ha^{-1}$ and Bi 58 Nowy EC 400 – 0.5 $dm^3 \cdot ha^{-1}$.

Intensive level of agricultural practices involved an increased NPK fertilization in an amount of N – 120 $kg \cdot ha^{-1}$, P – 39.5 $kg \cdot ha^{-1}$ and K – 99.5 $kg \cdot ha^{-1}$. Additionally, foliar fertilization and full plant protection were used, applying herbicides: Puma Uniwersal 069 EW – 1.2 $dm^3 \cdot ha^{-1}$ + Sekator 125 OD – 0.15 $dm^3 \cdot ha^{-1}$, insecticides: Karate Zeon 050 CS – 0.1 $dm^3 \cdot ha^{-1}$, fungicides: Juwell TT 483 SE – 1.2 $dm^3 \cdot ha^{-1}$ (I treatment), Swing Top 183 SE 1.2 $dm^3 \cdot ha^{-1}$ (II treatment), growth regulators: Moddus 250 EC – 0.4 $dm^3 \cdot ha^{-1}$ and foliar fertilizers 2-times: Ekolist Standard – 3.0 $dm^3 \cdot ha^{-1}$.

On all the plots grain was dressed with the seed dressing Sarfun 65 DS in an amount of 250 g per 100 kg of seeds. The previous crop for the winter wheat of the cultivar Smuga was oats. After the harvesting of the previous crop, the post-harvest cultivation set with skimming was conducted. Then the pre-sow plowing was made. The soil was cultivated for sowing with a cultivation unit (cultivator with a string roller). The time of wheat sowing fell between 20th and 30th of September every year. Before the harvest, the number of ears per 1 m^2 was determined. The harvesting of wheat was conducted from 10th to 20th August. After harvesting, the grain yield from each plot was determined, and the number of grains per ear and the 1000 grain weight was determined on the basis of biometric measurements of 10 plants collected from the plot in two replications.

The analysis of weed infestation of the winter wheat canopy after the application of cultivation practices was carried out with the quantitative-gravimetric method, by means of determining the species composition and the number and air-dry weight of weeds. The assessment of weed infestation was carried out in two randomly selected places of each plot, using a frame of 0.5 × 0.5 m. The statistical analysis of the results of the study was carried out with the method of variance, using the program ANALWAR–5FR. Tukey's t-test was used for a detailed comparison of the averages at the significance level $P = 0.05$.

Meteorological conditions at sowing and during the autumn growth of winter wheat were favorable. Quite changeable precipitation and thermal conditions occurred in the years 2005-2007 during the spring-summer growth of winter wheat. In 2005 and 2006 in the period from March to August, the total precipitation was 521.1 and 425.0 mm and was higher than the average precipitation total from the long-term period (126.7 and 110.1% of the long-term standard).

In comparison with the years 2005 and 2006, the rainfall in the growing period of the year 2007 was considerably lower, on average 335.7 mm, which accounted for 87.9% of the long-term standard. The average air temperature in 2005 and 2006 was similar and amounted to 12.7 and 13.4°C, in comparison with 12.5°C for the long-term temperature. The year 2007, in turn, was considerably more warm and dry, with the average air temperature 16.3°C. Changeable meteorological conditions in the period of the study had an impact on the varied weed infestation and yield of winter wheat.

RESULTS AND DISCUSSION

Analyzed factors had not an explicit effect on the number and air-dry weight of weeds in winter wheat (Table 1). The number of weeds in wheat canopy depended mainly on the level of agricultural practices, the weather conditions and the interaction of those factors. In comparison with the standard agricultural practices, a higher level of agricultural practices significantly reduced the numbers of weeds on average by 39.2 pcs$\cdot$m^{-2} (49.4%). the smallest reduction in the number of weeds (45.6%) was observed in 2005, whereas the largest – 58.4% – in 2007. Although the numbers of weeds decreased along with an increased sowing density of wheat, this relationship was not proved statistically. Also the study by Wesołowski [2003] and Piekarczyk [2010] over the weed infestation of spring and winter wheat indicated that the number of weeds depended mainly on a higher level of agricultural practices, whereas to a lesser degree was determined by the sowing density of wheat.

The air-dry weight values were similar to those concerning the number of weeds (Table 1). The largest values of air-dry weight (57.6 g$\cdot$m^{-2}) were observed in 2005, and an increase in intensity of agricultural practice level significantly limited the weed biomass – by 46.4%. The largest air-dry weight of weeds (62.8 g$\cdot$m^{-2}) was observed on plots with the most sparse sowing of wheat. An increase in wheat sowing density to 550 grains per m^2 significantly decreased the dry weight of weeds – by 31.7 g$\cdot$m^{-2} (50.5%). also the results of the study by Halinarz [2010] indicates the explicit effect of sowing density on spring wheat weed infestation. According to the author, in each year of the study the more dense wheat canopy with the number of 800 grains per m^2 was characterized by a larger productivity and at the same time it had a limiting effect on the weed biomass growth in wheat.

Table 1. Number and air dry weight of weeds in winter wheat canopy
Tabela 1. Liczba i powietrznie sucha masa chwastów w łanie pszenicy ozimej

Experimental factors Czynniki doświadczenia	Number of weeds, pcs·m^{-2} Liczba chwastów, szt.·m^{-2}			Mean Średnia	Air dry weight of weeds Powietrznie sucha masa chwastów g·m^{-2}			Mean Średnia
	2005	2006	2007		2005	2006	2007	
Sowing density, pcs·m^{-2} – Gęstość siewu szt.·m^{-2}								
250	111.4	86.4	61.5	86.4	78.3	60.3	49.7	62.8
350	89.4	69.7	49.7	69.6	70.1	49.7	35.6	51.8
450	79.3	54.1	38.1	57.2	59.0	40.1	25.4	41.5
550	76.1	49.9	35.7	53.9	49.7	29.3	14.3	31.1
Mean – Średnia	89.1	65.0	46.3	66.8	64.3	44.8	31.2	46.8
Agricultural practice level – Poziom agrotechniki								
Standard Standardowy	98.1	83.8	56.2	79.4	65.1	51.2	38.1	51.5
Intensive Intensywny	53.4	43.7	23.4	40.2	36.7	27.5	18.5	27.6
Mean – Średnia	75.8	63.8	39.8	59.8	50.9	39.4	28.3	39.5
Mean for years Średnia dla lat	82.4	64.4	43.0	–	57.6	42.1	29.7	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
sowing density – gęstości siewu				ns – ni				8.0
agricultural level – poziomu agrotechniki				24.2				18.8
years – lat				13.5				10.4
interaction – interakcji:								
sowing density × agricultural practice level gęstości siewu × poziom agrotechniki				ns – ni				ns – ni
sowing density × years gęstości siewu × lata				ns – ni				7.6
agricultural practice level × years poziomu agrotechniki × lata				15.8				8.3

ns – ni – non-significant differences – różnice nieistotne

The number and air-dry weight of weeds were significantly modified by the climatic conditions in individual years of the study. The lowest values of both features were observed in the rather dry and warm year 2007, and the highest in 2005, which was characterized by an increased total precipitation in the spring-summer growth period of wheat. The mean number of weeds in the first year of the experiment was significantly lower than in the years 2006 and 2007. Air-dry weight of weeds in 2005 was by 26.9% lower than in 2006 and by 48.4% than in 2007. Also Dąbek-Gad and Bujak [2002] as well as Gawęda [2007] observed diversification of the number and air-dry weight of weeds in winter wheat under the influence of the weather conditions in the years of the study. According to Wesołowski [2003], high rainfall in the period growth of wheat may stimulate germination of still new parts of weed diaspores, which contributes to a growth in their numbers and biomass.

In the phytocenosis of winter wheat 33 weed species occurred, including 30 annual and 5 perennial (Table 2). The studied factors did not modify significantly the species composition of winter wheat canopy. Predominant species, with *Viola arvensis*, *Matricaria maritima* ssp. *inodora* and *Apera spica-venti* distinguishing themselves in the numbers, accounted for, depending on the analyzed experimental factors, from 92.3 to 98.1% of the number of all the weeds. Among perennial species, *Elymus repens* predominated. Introducing intensive agricultural practices reduced the number of weeds by 7 species and decreased the numbers of *Apera spica-venti* and *Chenopodium album.* Predominant species, that is *Viola arvensis* and *Matricaria maritima* ssp. *indora*, turned out to be rather resistant to the applied herbicides, which was confirmed also in the study of Kwiatkowski [2009] and Piekarczyk [2010]. Idziak *et al.* [2007] observed that *Viola arvensis* as a predominant taxon in winter wheat stands has large competitive abilities , both on the control plot and under conditions of stress induced by herbicide application.

Table 2. Species composition and number of weeds per m^2 in the canopy of winter wheat depending on sowing density and agricultural practice level (means for 2005-2007)
Tabela 2. Skład gatunkowy i liczba chwastów na m^2 w łanie pszenicy ozimej w zależności od gęstości siewu i poziomu agrotechniki (średnie z lat 2005-2007)

Dominant weed species Dominujące gatunki chwastów	Sowing density, pcs·m^{-2} Gęstość siewu, szt.·m^{-2}				Agricultural practice level Poziom agrotechniki	
	250	350	450	550	standard standardowy	intensive intensywny
Viola arvensis Murray	37.8	26.9	23.5	20.4	44.3	19.0
Matricaria maritima ssp.indora (L.) Dostál	16.6	14.1	12.4	12.9	14.1	10.9
Apera spica-venti (L.) Beauv.	7.2	6.2	6.1	5.4	8.9	1.2
Chenopodium album L.	6.9	6.0	4.4	3.4	5.1	1.5
Echinochloa crus-gali (L.) P.B.	5.7	4.9	4.0	3.8	3.2	3.0
Elymus repens (L.) P. Beauv.	3.3	2.8	1.2	1.4	1.2	1.9
Stellaria media (L.) Vill.	1.2	1.8	0.5	1.1	0.3	0.4
Galium aparine L.	1.0	0.9	0.4	0.8	0.3	0.2
Fallopia convolvulus (L.) Á. Löve	0.9	0.5	0.4	0.0	0.2	0.0
Galeopsis terahit L.	0.5	x	0.2	0.4	0.1	0.2
Convolvulus arvensis L.	0.5	0.5	0.2	x	0.1	0.3
Cirisum arvense (L.) Scop.	0.3	0.3	0.1	0.4	0.1	0.2
Other species Pozostałe gatunki	4.5	4.7	3.8	3.9	1.5	1.4
Total number of weeds Ogółem liczba chwastów	86.4	69.6	57.2	53.9	79.4	40.2
Total number of species Ogółem liczba gatunków	25	22	18	19	26	19

0,0 – species occurring in less than 0.1 per m^2 – gatunek występował w liczbie mniejszej niż 0,1 szt.·m^{-2}
x – species not occurring – gatunek nie występował

An increase in the wheat sowing density resulted in a decrease in the number of the most predominant short-living species: *Viola arvensis*, *Matricaria maritima* ssp. *indora*, *Apera spica-venti* and *Chenopodium album.* The number of specimens of *Elymus repens* was also reduced. Those results are partly similar to those obtained by

Wesołowski *et al.* [2003], but an increase in density of spring wheat canopy caused compensation of *Cirsium arvense* and *Apera spica-venti.*

The grain yield of winter wheat was dependent on the level of agricultural practices, sowing density and the years of the study, whereas no significant interactions were found between the experimental factors (Table 3). An increase in agricultural practice intensity resulted in a significant growth in grain yield, on average by 10.1%. The largest increase in yield under conditions of intensive level of agricultural practices was indicated in 2005, and it was 0.82 t·ha^{-1}; and the smallest – 0.49 t·ha^{-1} – occurred in 2006. Favorable effect of intensive agricultural practices on winter wheat productivity was also observed in the studies by Kwiatkowski *et al.* [2006] and Czarnocki *et al.* [2009].

Table 3. Grain yield depending on sowing density and agricultural practice level, t·ha^{-1}
Tabela 3. Plon ziarna w zależności od gęstości siewu i poziomu agrotechniki, t·ha^{-1}

Sowing density, pcs·m^{-2} Gęstość siewu, szt.·m^{-2}	Year Rok	Agricultural practice level – Poziom agrotechniki		Mean Średnia
		standard – standardowy	intensive – intensywny	
250	2005	4.65	5.25	4.95
	2006	5.05	5.41	5.23
	2007	4.05	4.60	4.33
Mean – Średnia		4.58	5.09	4.84
350	2005	5.80	6.61	6.21
	2006	6.45	6.82	6.64
	2007	5.05	5.68	5.37
Mean – Średnia		5.77	6.37	6.07
450	2005	6.20	7.11	6.66
	2006	6.59	7.22	6.91
	2007	5.60	6.32	5.96
Mean – Średnia		6.13	6.88	6.51
550	2005	6.35	7.32	6.84
	2006	6.92	7.52	7.22
	2007	6.01	6.63	6.32
Mean – Średnia		6.43	7.16	6.79
Mean – Średnia	2005	5.75	6.57	6.16
	2006	6.25	6.74	6.50
	2007	5.18	5.81	5.50
Mean – Średnia		5.73	6.37	6.05
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:				
sowing density – gęstości siewu				0.35
agricultural practice level – poziomu agrotechniki				0.37
years – lat				0.40
interaction – interakcji:				
sowing density × agricultural practice level – gęstości siewu × poziom agrotechniki				ns – ni
sowing density × years – gęstości siewu × lata				0.65
agricultural practice level × years – poziomu agrotechniki × lata				0.55

ns – ni – non-significant differences – różnice nieistotne

Increasing sowing density also had a positive effect on winter wheat productivity. In the present study, the highest grain yields, 6.51 and 6.79 t·ha^{-1}, respectively, were obtained at sowings of 450 and 550 grains·m^{-2}. A sowing of 450 grains·m^{-2} – in comparison with the maximal density – decreased the grain yield by 4.1%, and the difference was statistically insignificant. The smallest grain yield (4.84 t·ha^{-1}) was obtained on plots with the most sparse sowing. A similar response of spring wheat on the applied sowing densities was reported by Michalski [1999] and Wesołowski [2005]. The study by Podolska and Stankowski [2001] indicated that winter wheat gave a significantly lower yield at very sparse sowings – 150 grains·m^{-2} in comparison with the other densities (300, 450 and 600 grains·m^{-2}), between which no significant differences were observed. Dubis and Budzyński [2006] report the occurrence of a significant interaction of the sowing density of winter wheat with the weather conditions, which was also proved in the present study. In each year of the study the most favorable wheat yield was ensured by dense sowing – 550 grains·m^{-2}, and at the most sparse sowing, the yield was significantly smaller. Favorable meteorological conditions in 2005-2006 determined higher yields of wheat. A higher mean grain yield – 6.50 t·ha^{-1} – was obtained in 2006 (as compared with 2007).

An increase in the number of sown grains per m2 had a significant effect on the number of ears, which increased from 499 to 660 pcs.·m^{-2} (Table 4). Also the intensification of agricultural level favored an increase in the final number of ears – it was on average 541 pcs·m^{-2}. With an increase in sowing density, the number of grains in ears decreased. The ears from plots with the smallest sowing density of wheat were characterized by the highest mean number of grains. No significant differences in the number of grains in ears between the densities 450 and 600 grains·m^{-2} were found. As in the study by Wesołowski [2005] and Czarnocki *et al.* [2009], an effect of levels of agricultural practices on the value of this feature was not proved.

Table 4. Some elements of winter wheat yield structure depending on sowing density and agricultural practice level (means for 2005-2007)
Tabela 4. Elementy struktury plonu pszenicy ozimej w zależności od gęstości siewu i poziomu agrotechniki (średnie z lat 2005-2007)

Experimental factor Czynniki doświadczenia	Number of ears, pcs·m^{-2} Liczba kłosów, szt.·m^{-2}	Number of grains per ear Liczba ziaren w kłosie, szt.	Weight of 1000 grains Masa 1000 ziaren g
250	499	41.1	45.3
350	565	38.4	44.0
450	620	36.0	44.9
550	660	36.5	43.1
Mean – Średnia	586	38.0	44.3
Standard – Standardowy	515	37.2	43.1
Intensive – Intensywny	567	40.5	45.2
Mean – Średnia	541	38.8	44.2
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:			
sowing density gęstości siewu	35.0	2.0	0.80
agricultural practice level poziomu agrotechniki	43.0	ns – ni	1.25
interaction – interakcji	21.0	ns – ni	0.95

ns – ni – non-significant differences – różnice nieistotne

Relationship between TGW and the sowing density and level of agricultural practices was observed. Significantly the highest values of thousand grain weight of winter wheat were obtained on plots with the intensive agricultural practice level. The thousand grain weight was the largest from the most sparse sowings, whereas the smallest at a density of 550 grains·m^{-2}. Thus TGW decreased along with a larger sowing density and extensification of the level of agricultural practices. This tendency was shown by the study of Kwiatkowski *et al.* [2006] and by Dubis and Budzyński [2006]. Wesołowski [2005], in turn, obtained the largest values of the thousand grain weight of spring wheat on plots with extensive level of agricultural practices, and sowing density did not affect this feature.

CONCLUSIONS

1. Applied sowing densities and agricultural practice levels did not modify significantly the species composition of weeds of winter wheat canopy. The predominating among short-living weeds were: *Viola arvensis*, *Matricaria maritima* ssp. *inodora* and *Apera spica-venti*, and of perennial weeds, *Elymus repens* occurred the most frequently.
2. Increasing intensity of agricultural practice level had an effect on limiting the number of weeds and their air-dry weight. An explicit effect of the number of sown wheat grains on the weed density was not indicated. At a sowing density of 500 grains·m^{-2} dry weight of weeds was by 50% smaller in comparison with a density of 250 grains·m^{-2}.
3. Intensive agricultural practices, in comparison with the standard agricultural practices had an effect on an increase in the value of yield structure components, which resulted in an increase in grain yield on average by 10%.
4. Increasing sowing density had a positive effect on winter wheat productivity, and the highest grain yields, 6.51 and 6.79 t·ha^{-1}, respectively, were obtained for sowings of 450 and 550 grains·m^{-2}. Those sowing densities affected a higher number of ears per plant, although grain plumpness worsened then and the number of grains per ear was decreased.

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PLONOWANIE I ZACHWASZCZENIE PSZENICY OZIMEJ W ZALEŻNOŚCI OD GĘSTOŚCI SIEWU I POZIOMU AGROTECHNIKI

Streszczenie. Doświadczenie przeprowadzono w latach 2005-2007 w Stacji Dydaktyczno-Badawczej Krasne koło Rzeszowa na glebie brunatnej wytworzonej z lessu, kompleksu pszennego dobrego. Celem badań było określenie wpływu czterech gęstości siewu na liczbę, powietrznie suchą masę i skład gatunkowy chwastów oraz plon ziarna pszenicy ozimej w warunkach dwóch poziomów agrotechniki. Intensyfikacja poziomu agrotechniki pszenicy ograniczała istotnie zarówno liczebność chwastów –średnio o 39,2 szt.$\cdot$m^{-2} (49,4%) oraz ich powietrznie suchą masę (o 46,4%). Nie potwierdzono statystycznie wpływu liczby wysianych ziaren pszenicy na liczbę chwastów, jednak sucha masa chwastów z poletek o największej gęstości siewu była mniejsza (o 50,5%) niż z poletek, na których gęstość siewu wyniosła 250 ziaren$\cdot$m^{-2}. Uprawa pszenicy przy intensywnej agrotechnice powodowała zwiększenie plonu ziarna w latach badań w zakresie od 0,49 do 0,82 t$\cdot$ha^{-1}. Wysiew 450 i 550 ziaren$\cdot$m^{-2} zapewniał największe plony ziarna, odpowiednio 6,51 i 6,79 t$\cdot$ha^{-1}; różnica w poziomie plonowania między tymi gęstościami wynosiła 4,1% i była statystycznie nieistotna. Najmniejszy plon ziarna pszenicy 4,84 t$\cdot$ha^{-1} uzyskano w warunkach najniższej gęstości siewu.

Key words: chwasty, gęstość siewu, intensywność uprawy, komponenty plonu, skład gatunkowy chwastów

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