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EFFECTIVENESS OF WEED CONTROL AND THE YIELD OF WINTER TRITICALE DEPENDING ON THE TENDING METHOD AND NITROGEN FERTILIZATION

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Abstract. Field experiment with the growth of winter triticale (cultivar Grenado) was conducted in years 2007-2009 at the Didactic-Experimental Center in Tomaszkowo which is part of the University of Warmia and Mazury in Olsztyn. The study was carried out on typical medium brown soil, fertility class IVb. Weed control and yields were studied. Tending method was the first experimental factor and it covered: no tending, harrowing, and protection with Mustang 306 SE herbicide. The level of fertilization with nitrogen at 0, 40, 80, 120, and 160 kg N·ha^{-1} was the second factor. The three-year-long experimental period was characterized by high diversity of weather conditions. During all the research years, triticale chemically protected against weeds with herbicide gave significantly higher yields – on mean 5.73 t·ha^{-1}, compared with mechanical tending (5.11 t·ha^{-1}) and no tending (4.81 t·ha^{-1}). Nitrogen fertilization up to 120 kg N·ha^{-1} increased triticale yield significantly.

Key words: grain yield, harrowing, herbicide, weeds, winter triticale

INTRODUCTION

Weeding procedures carried out during growth from the emergence to the tillering stage are of basic significance to weed control in winter cereals [Jędruszczak et al. 2004]. One of the most important methods of protection against weeds is herbicide treatment carried out during autumn cereal growth and in spring from growth resumption to the end of the tillering stage. In the system of integrated agriculture, interventionist herbicide application is preferred, after field inspection, in contrast with preventive application. At present, taking into account the possible danger of environment and agricultural products poisoning, which results from the application of plant protection means, more and more often the conviction is reborn that the application of mechanical weed control methods is necessary, among which harrowing is thought to have the greatest significance in dense lowland meadows [Wesołowski and Cierpiała 2009].

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According to Dobrzański and Adamczewski [2006], it ought to be applied regardless of the significance of herbicides.

Until the beginning of the 1970s, harrowing was the basic treatment that limited infestation in cereals. The amount of mechanical weeding treatment depends on the changes in weed population dynamics, soil condition and humidity, and the length of the period in which it may be carried out without causing plant damage. It is recommended to harrow well-rooted plants. Too early harrowing causes excessive meadow thinning and yield lowering. It ought to be taken into consideration that it only damages small weed seedlings. Harrowing, as tending treatment, also plays other functions, among others it improves soil aeration [Dobrzański and Adamczewski 2006]. In the studies by Hruszka [2004], in winter triticale grown in naturally correct rotation, single harrowing after growth resumption was the least unreliable in yield protection, and additional harrowing did not give measurable production effects. In keeping cereal lowland meadow weed free, an important role is given also to other agrotechnical procedures, which strengthen the competitiveness of a cultivated plant in relation to segetal plants [Skrzypczak and Pudełko 2003]. These procedures include mineral fertilization, first of all with nitrogen [Deryło and Szymankiewicz 1998, Rudnicki 1998]. Strategy of fertilization with this element in important, including its dose and application method.

Taking into consideration the topicality of the above issues in agriculture, studies were carried out whose aim was to determine the effect of various plant tending methods and nitrogen fertilization levels on weeding effectiveness and winter triticale yield.

MATERIAL AND METHODS

Field experiment with the growth of winter triticale cultivar Grenado was carried out in years 2007-2009 at the Didactic-Experimental Center in Tomaszkowo (53°42' N; 20°26' E), which is part of the University of Warmia and Mazury in Olsztyn, on good rye complex typical medium brown soil, fertility class IVb. Triticale was sown every year in the second decade of September in the number of 500 caryopses per 1 m^2. The experiment was carried out as a random sub-block design, in four repetitions, with two factors. The first factor was plant tending method: 1) no tending, 2) harrowing (full tillering – BBCH 25), 3) protection with the herbicide Mustang 306 SE (full triticale tillering – BBCH 25) at the dose of 0.5 $dm^3 \cdot ha^{-1}$. The second factor was nitrogen fertilization level (0-160 kg $N \cdot ha^{-1}$): a) no nitrogen, b) 40 kg $N \cdot ha^{-1}$ after growth resumption (BBCH 23-24) – ammonium nitrate, c) 80 kg $N \cdot ha^{-1}$ (40 kg $N \cdot ha^{-1}$ after growth resumption (BBCH 23-24) – ammonium nitrate and 40 kg $N \cdot ha^{-1}$ at full straw shooting stage (BBCH 37) – granulated urea), d) 120 kg $N \cdot ha^{-1}$ (60 kg $N \cdot ha^{-1}$ after growth resumption (BBCH 23-24) – ammonium nitrate and 60 kg $N \cdot ha^{-1}$ at full straw shooting stage (BBCH 37) – granulated urea), e) 160 kg $N \cdot ha^{-1}$ (70 kg $N \cdot ha^{-1}$ after growth resumption BBCH 23-24) – ammonium nitrate, 50 kg $N \cdot ha^{-1}$ at the end of tillering (BBCH 29) – granulated urea, and 40 kg $N \cdot ha^{-1}$ at the end of straw shooting stage (BBCH 49) – granulated urea).

The obtained results were statistically processed, using the analysis of variance for two- and three-factor experiments in split-plot sub-block design. Significance of the differences were checked using the Tukey's test, with the error probability of $P = 0.05$.

Relations between weeding effectiveness and triticale yield were expressed as linear correlation coefficients (r).

In the three-year-long study period, diverse weather conditions occurred (Table 1). The third research year was the most favourable for plant growth. Precipitation during the spring-summer triticale growth (April-July), which amounted to 242.9 mm, was similar to the many-years mean (241.1 mm). In the second year, its shortage occurred (by 37.7% in comparison with the many-years mean) but it was distributed rather evenly. On the other hand, in the first year, there was a clear excess of precipitation, by 57.6% in comparison with the many-years mean. Diversified weather conditions in the consecutive research seasons had a significant effect on weed development and winter triticale yield.

Table 1. Air temperature and precipitation during the growth period of spring triticale in 2007--2009 according to the Meteorological Station in Tomaszkowo

Tabela 1. Temperatura powietrza i opady w okresie wegetacji pszenżyta ozimego w latach 2007--2009 według Stacji Meteorologicznej w Tomaszkowie

Month Miesiąc	Temperature – Temperatura, °C				Precipitation – Opady, mm			
	long term mean średnia z wielolecia	month mean średnia z miesiąca			long term sum suma z wielolecia	month sum suma miesięczna		
	1961-2000	2007	2008	2009	1961-2000	2007	2008	2009
January – Styczeń	-2.9	2.6	0.3	-3.3	22.8	115.4	66.2	24.7
February – Luty	-2.4	-2.5	2.6	-2.0	20.4	23.5	24.7	31.7
March – Marzec	1.2	5.5	2.9	1.3	26.8	27.8	52.4	57.9
April – Kwiecień	6.9	7.5	7.7	9.4	36.1	24.7	31.4	4.8
May – Maj	12.7	13.8	12.3	12.4	51.9	93.5	27.0	52.9
June – Czerwiec	15.9	17.7	16.9	14.9	79.3	88.1	32.7	136.9
July – Lipiec	17.7	17.7	18.4	20.4	73.8	173.7	57.7	48.3
August – Sierpień	17.2	18.3	18.4	17.6	67.1	68.0	102.1	19.3
Mean or sum (April – July) Średnia lub suma (kwiecień – lipiec)	14.1	15.0	14.7	14.9	308.2	448.0	250.9	262.2

RESULTS

Field experiment with winter triticale was carried out with medium infestation in the first (99.5 plants·m^{-2}) and second (117.1 plants·m^{-2}) research year and high infestation in the third year (170.9 plants·m^{-2}) – Table 2. In the three-year-period, one that occurred the most frequently was *Geranium pusillum*, whose density in the third year of the experiment was 65.6 plants·m^{-2}. The weed developed fast, was expansive, and formed a "dense carpet", which made it difficult for the cultivated plant to grow and develop. In the analyzed experiment, the following weeds were also the most frequently occurring ones: *Veronica arvensis*, *Viola arvensis*, and *Stellaria media*. Limiting competition on the part of the more "dangerous" weed species often led to the development of others, until now classified as ground zone, which did not pose a major threat to cereals. Examples of this in the experiment were *Geranium pusillum* and *Viola arvensis*.

Table 2. Density and major weed species that occur in large numbers in winter triticale during the tillering phase
Tabela 2. Zagęszczenie i główne gatunki chwastów występujące w pszenżycie ozimym licznie w fazie krzewienia

Research year Rok badań	Infestation plants·m^{-2} Zachwaszczenie na 1 m^2	Dominant weed species, plants·m^{-2} Dominujące gatunki chwastów, szt.·m^{-2}
2007	99.5	*Stellaria media* (25.2), *Veronica arvensis* (11.4), *Veronica persica* (7.9), *Viola arvensis* (14.1), *Galium aparine* (8.7), *Capsella bursa-pastoris* (8.1), *Sonchus arvensis* (5.7)
2008	117.1	*Veronica arvensis* (45.5), *Viola arvensis* (38.7), *Capsella bursa-pastoris* (13.4), *Matricaria maritima* L. subsp. *inodora* (8.2)
2009	170.9	*Geranium pusillum* (65.6), *Veronica arvensis* (36.3), *Viola arvensis* (31.2), *Thlaspi arvense* (11.2), *Stellaria media* (9.4), *Matricaria maritima* L. subsp. *inodora* (4.7)

From the two tending methods, definitely higher weeding effectiveness was reached through the application of the herbicide Mustang 306 SE (mean from the three years 74.4%) in comparison with mechanical tending (mean from the three years 24.4%) – Table 3. The herbicide limited most effectively the developed weed mass in the firs year of the experiment (on mean by 82.8%). In the second and third year, herbicide application ensured the reduction of the air dry mass of weeds in the lowland meadow at a lower level, on mean by 71.2% and 69.3%, respectively. Like in the case of herbicide application, the best results of harrowing were obtained in the first year of the experiment, with the highest precipitation (on mean 27.9% weeding effectiveness). Harrowing was the least effective in the third year (on mean 21.0%), in the conditions of high precipitation shortage in April (by 86.7% of the norm).

Table 3. Effectiveness of tending treatment, expressed as the loss of the air dry matter of weeds, at the milk stage of winter triticale grain, %
Tabela 3. Skuteczność zabiegów pielęgnacyjnych, wyrażona ubytkiem powietrznie suchej masy chwastów, w fazie dojrzałości mlecznej ziarna pszenżyta ozimego, %

Specification Wyszczególnienie	Research year – Rok badań			Mean Średnia
	2007	2008	2009	
Plant tending method – Sposób pielęgnacji roślin				
Harrowing – Bronowanie	27.9	24.2	21.0	24.4
Herbicide – Herbicyd	82.8	71.2	69.3	74.4
$LSD_{0.05}$ – $NIR_{0,05}$	9.9	4.6	5.2	6.0
Nitrogen fertilization method – Sposób nawożenia azotem, kg N·ha^{-1}				
No nitrogen – Bez azotu	48.8	42.2	38.4	43.1
40	58.2	46.5	44.3	49.6
40 + 40	56.1	48.8	48.1	51.0
60 + 60	58.3	49.2	47.2	51.6
70 + 50 + 40	55.4	52.1	48.1	51.9
$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	ns – ni	ns – ni
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat 2.4				

ns – non-significant differences – ni – różnice nieistotne

Nitrogen fertilization was conducive to better weeding effectiveness (regardless of the dose). Also, a tendency for effectiveness improvement with the increase of nitrogen dose was found.

The highest grain yield was obtained in the second year of the experiment, with the lowest and evenly distributed precipitation (on mean 6.77 t·ha^{-1}). On mean, from the three years, tending treatment applied to winter triticale had a significant yield-protection effect. This is confirmed by the values of linear correlation coefficients between the treatment effectiveness and yield size (Tables 4 and 5).

Table 4. Winter triticale yield depending on the plant tending method and nitrogen fertilization, t·ha^{-1}

Tabela 4. Plonowanie pszenżyta ozimego w zależności od sposobu pielęgnacji roślin oraz nawożenia azotem, t·ha^{-1}

Specification Wyszczególnienie	Research year – Rok badań			Mean Średnia
	2007	2008	2009	
Plant tending method – Sposób pielęgnacji roślin				
No tending – Bez pielęgnacji	4.51	6.27	3.64	4.81
Harrowing – Bronowanie	4.63	6.77	3.93	5.11
Herbicide – Herbicyd	5.08	7.26	4.85	5.73
$LSD_{0.05}$ – $NIR_{0,05}$	0.43	0.51	0.31	0.21
Nitrogen fertilization method – Sposób nawożenia azotem, kg N·ha^{-1}				
No nitrogen – Bez azotu	3.28	4.99	3.24	3.84
40	4.62	6.34	3.90	4.95
40 + 40	4.93	7.01	4.41	5.45
60 + 60	5.36	7.54	4.69	5.86
70 + 50 + 40	5.49	7.95	4.46	5.97
$LSD_{0.05}$ – $NIR_{0,05}$	0.36	0.40	0.29	0.20
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat 0.53				

Table 5. Linear correlation coefficients (r) between the effectiveness of weeding tending procedures and winter triticale grain yield

Tabela 5. Współczynniki korelacji liniowej (r) pomiędzy skutecznością pielęgnacyjnych zabiegów odchwaszczania a wielkością plonu ziarna pszenżyta ozimego

Specification Wyszczególnienie	Grain yield – Plon ziarna, t·ha^{-1}		
	Year – Rok		
	2007	2008	2009
Harrowing – Bronowanie	-0.2463	0.9124*	0.8376*
Herbicide – Herbicyd	0.9299*	0.9303*	0.9704*
In general – Ogółem	0.3546*	0.3368	0.7464*

* correlation coefficient significant for P = 0.05 – współczynnik korelacji istotny dla P = 0,05

In all the years, triticale protected with herbicide gave a significantly higher yield (on mean 5.73 t·ha^{-1}) in comparison with mechanical tending (on mean 5.11 t·ha^{-1}) and with no tending (on mean 4.81 t·ha^{-1}). Coefficient of correlation between weeding effectiveness and triticale yield for the first year of the experiment indicates that in the conditions of water excess, mechanical tending did not have a significant effect on the increase in triticale yield. Nitrogen fertilization significantly increased grain yield from

the level of 120 kg N·ha^{-1} (on mean 5.86 t·ha^{-1}). It should be mentioned that with the application of nitrogen at the dose of 160 kg N·ha^{-1} (in three parts), the highest grain yield was obtained (on mean 5.97 t·ha^{-1}) but the differences were insignificant in comparison with fertilization at the dose of 120 kg N·ha^{-1} (on mean 5.86 t·ha^{-1}).

DISCUSSION

In the presented experiment, the species composition of weeds and their competitiveness in relation to the cultivated plant to a large extent depended on the weather conditions. Many authors pay attention to such relations [Deryło and Szymankiewicz 1998, Brzozowska 2003, Hruszka 2004, Wesołowski and Cierpiała 2009]. According to others, competitive effect of one weed species, which occurs in large amounts, on cereals is greater than the one of several species in similar numbers [Ellmann and Urbanowski 1991, Jędruszczak 1993]. According to Pawłowski and Woźniak [1998], in recent decades, the process of depletion of the floristic composition of weeds in agricultural fields has been taking place.

Weeding effect of harrowing in the analyzed three-year period was on mean about three times lower than the effect of herbicide application and amounted to 24.4%. Dobrzański and Adamczewski [2006] after Dzieżyc [1962] state that cereal harrowing may decrease infestation by 40%-82% depending on the year and treatment date. In the studies by Wesołowski and Cierpiała [2009], harrowing of spring wheat sowings made it possible to limit meadow infestation to a comparable degree as herbicides. Also in literature, diversified effects of weed reduction with the use of chemical methods in winter triticale are mentioned many times. Infestation may vary from the level of below 50% to over 80%, and even up to 100% [Pawłowska et al. 1995, Woźniak 1995, Brzozowski et al. 1997, Romek and Dzienia 2000]. Biological effect of the applied herbicides depends first of all on the weather conditions that occur before and right after the treatment. Sulfonylurea herbicides display, for example, high effectiveness with correct soil humidity. In the conditions of high soil humidity, the wax cover on the surface of leaf blades is less well developed, which makes it easier for the in-leaf herbicides to penetrate plant tissues, and therefore it increases the herbicide effect [Aldrich 1997].

In the analyzed experiment, nitrogen fertilization had a tendency to control weed in triticale meadow more effectively. Research by other authors confirms that the nitrogen fertilization of winter cereals causes lowering of weed number and mass, which is related to the increase in cereal competitiveness in relation to weeds [Borówczak et al. 1996, Rolbiecki and Żarski 1996, Parylak 1997, Blackshaw 2004]. In literature, diversified yield-protection results are given of the conducted tending treatment (both chemical and mechanical) of winter cereals depending on the habitat and study conditions [Deryło and Szymankiewicz 1998, Pawłowski and Woźniak 1998, Romek and Dzienia 2000, Jędruszczak et al. 2004].

CONCLUSIONS

1. Winter triticale weeding effectiveness was significantly higher after the application of the herbicide Mustang 306 SE (on mean 74.4%) in comparison with harrowing (on mean 24.4%).

2. There is a tendency for better weeding effectiveness of triticale fertilised with nitrogen in comparison with growth with no nitrogen fertilization.

3. The highest triticale grain yield was obtained thanks to the application of the herbicide Mustang 306 SE (on mean 5.73 $t \cdot ha^{-1}$), and the lowest in the conditions of no tending (4.81 $t \cdot ha^{-1}$).

4. Nitrogen fertilization up to the level of 120 kg $N \cdot ha^{-1}$ significantly increased triticale grain yield, regardless of the tending method.

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SKUTECZNOŚĆ ODCHWASZCZANIA I PLONOWANIE PSZENŻYTA OZIMEGO W ZALEŻNOŚCI OD SPOSOBU PIELĘGNACJI I NAWOŻENIA AZOTEM

Streszczenie. Eksperyment polowy z uprawą pszenżyta ozimego odmiany Grenado realizowano w latach 2007-2009 w Ośrodku Dydaktyczno-Doświadczalnym w Tomaszkowie, należącym do Uniwersytetu Warmińsko-Mazurskiego w Olsztynie, na glebie brunatnej właściwej, średniej, klasy IVb. Celem badań było określenie wpływu różnych sposobów pielęgnacji roślin i poziomu nawożenia azotem na skuteczność odchwaszczania pszenżyta ozimego i plonowanie roślin. Doświadczenie realizowano metodą podbloków losowanych, w 4 powtórzeniach, z dwoma czynnikami. Pierwszym czynnikiem był sposób pielęgnacji roślin: bez pielęgnacji, bronowanie 1×, ochrona herbicydem Mustang 306 SE. Drugim czynnikiem był poziom nawożenia azotem: 0, 40, 80, 120, 160 kg $N \cdot ha^{-1}$.

We wszystkich latach pszenżyto chronione herbicydem plonowało istotnie wyżej – średnio 5,73 t·ha^{-1} – w porównaniu z pielęgnacją mechaniczną (średnio 5,11 t·ha^{-1}) oraz bez pielęgnacji (średnio 4,81 t·ha^{-1}). Nawożenie azotem istotnie zwiększało plony pszenżyta do poziomu 120 kg N·ha^{-1} (średnio 5,86 t·ha^{-1}).

Słowa kluczowe: bronowanie, chwasty, herbicyd, plon ziarna, pszenżyto ozime

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