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INFLUENCE OF CROP ROTATION AND METEOROLOGICAL CONDITONS ON DENSITY AND BIOMASS OF WEEDS IN SPRING BARLEY (*Hordeum vulgare* L.)

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Abstract

The paper presents the analysis of changes in weed infestation in spring barley cultivated in the years 1990–2004 in crop rotation with a 25% proportion of this cereal (potato – spring barley – sowing peas – winter triticale), when it was grown after potato, and in crop rotation with its 75% proportion (potato – spring barley – spring barley – spring barley), when it was grown once or twice after spring barley. In the experiment, no weed control was applied. Every year in the spring (at full emergence of the cereal) and before the harvest, the composition of weed species and weed density of particular weed species were determined, and before the harvest also their biomass. Weed density increased linearly on all plots during the 15-year period. The average values confirm the increase in weed biomass in the case when spring barley was grown once or twice after this crop; however, those differences were influenced by the previous situation only during some seasons. Weed density and biomass showed high year–to–year variability and a positive correlation with the amount of precipitation and a negative correlation with temperature during the period of the study. A negative correlation between the yield of barley and weed biomass was shown.

Key words: spring barley, crop rotation, air temperature, precipitation, weed density, weed biomass, year–to–year changes

INTRODUCTION

Among agricultural technical factors, high doses of nitrogen fertilizers, simplified structure of crop rotations and application of herbicides have had the strongest influence on the weed community structure development (H y v ö n e n , 2004). Simplifications in crop rotations, both in Poland and worldwide, tend towards increasing the share of cereals in them (B u c z y ń s k i and M a r k s , 2003; H y v ö n e n , 2004; S m i t h et al. 2008). Cereals are considered to be crops which increase weed infestation, even more so if they are not protected with herbicides (V e l y k i s and S a t k u s , 2006; A d a m i a k , 2007). Among the cereals, spring barley is considered to be a particularly weak competitor for weeds because of its delicate structure and relatively low height of the plants (B u c z y ń s k i and M a r k s , 2003). The issue of its positioning in the crop rotation remains, as a consequence, one of major importance.

From the perspective of changes taking place in weed communities under the influence of strong agricultural technique factors, their intensity as well as the trend over time are of particular interest (M i l b e r g et al. 2000; L o s o s o v á et al. 2004; L u n d k v i s t et al. 2008). Long–term studies and observations seem to be particularly valuable. They show whether and when an agricultural ecosystem, and with it the weed community, “get used” to the repeated external factor and relative stabilisation occurs at a level different from the baseline (M a h n , 1984). Studies conducted over whole decades allow identification of the species withdrawing from fields and endangered and show those representing increasing expansiveness (L a t o w s k i , 2002; A n d r e a s e n and S t r y h n , 2008; K a a r and F r e y e r , 2008).

The aim of the presented work is to present the analysis of weed infestation changes in unprotected spring barley cultivated for 15 years in extreme positions, in terms of quality, with regard to the density of weeds and their biomass. An attempt was also undertaken to determine the correlation between cereal yield and weed community characteristics.

MATERIALS AND METHODS

The numeric data that form the basis for this paper come from a closed statistical field experiment carried out during the years 1990–2004 at the Production – Experimental Enterprise "Bałcyny" Limited Liability Company (N = 53°35′49″, E = 19°51′20,3″). The experiment was conducted on typical podzolic soil formed of light dusty clay, classified according to agronomic categories as medium soil with humus content in the cultivated layer from 1.28 to 1.42% and average abundance of available macro- and micronutrients (W a n i c , 1997). Weed communities in spring barley (*Hordeum vulgare* L.) cultivated in two crop rotations, with its proportion of 25 and 75%, were the subject of the experiment. The crop rotations were as follows:

A – 25%: potato – spring barley – sowing pea – winter triticale

B – 75%: potato – spring barley – spring barley – spring barley.

Three following fields sown with spring barley were selected for the study: in crop rotation A – after potato (potentially, the most favourable position), and in B – where barley was grown once and twice after spring barley (i.e. the second and third time in the same field).

During the years 1990–1993, the Bielik cultivar of spring barley was grown, whereas in 1994–2000 – cv. Ars, 2000–2004 – cv. Rodion. Spring barley was sown every year at a density of 350 germinating seeds per 1m^2, fertilizing it with balanced doses of mineral components (NPK) depending on the position in the crop rotation. Their total doses (kg ha^{-1}) were as follows: 260 – after potato, 280 – after spring barley, and 300 – where it was sown twice after spring barley. In the experimental fields, no weed control was applied (during the entire period of the experiment) in order to make the role of the previous crop more clearly visible in that respect.

The status of spring barley weed infestation was determined yearly in the spring (at full germination of the cereal) and before harvest, in two replications, in each field determining the number and composition of weed species on the designated surface areas (1m^2). In the analysis conducted before harvest, the number of shoots was counted in case of monocotyledonous weed species. During the second time, the unit weight of weeds by species was also determined.

The correlation between the studied characteristics of weed communities and the amount of precipitation and average temperatures during the study period was determined by applying the linear correlation coefficients. The linear year–to–year trends were determined for the studied characteristics of weed communities. The linear correlation between density and biomass of weeds in the communities and yield of barley was also analyzed. Those linear trends were determined according to the following formula:

$$y = a + b \cdot x$$

where:

x – value of the independent variable (here: consecutive years of the study, yield)

y – value of the dependent variable corresponding to the value of x (here: weed density, weed biomass)

a – regression constant (free expression) – determines the intersection point of the determined regression straight line with the dependent variable axis y

b – tangent of the slope of the regression axis relative to the independent variable x axis; it indicates by how much the dependent variable y will change if the independent variable x changes by one unit.

RESULTS

The weather conditions under which the vegetation of spring cereals and accompanying weeds took place during the 11-year period in question quite varied (Table 1). On the basis of total precipitation during the period from April through August, according to the criteria developed by K a c z o r o w s k a (1962) and P r z e d p e ł s k a (1973), the years 1997 and 1999 were classified as very wet, 1998 and 2004 as wet, 1990, 1993, 1996, 2000, 2001, 2002 and 2003 as average seasons, 1991, 1994 and 1995 were classified as dry, and 1992 as very dry. The seasons of 1992, 1994, 1995 and 2002 were warm as for this region of north–eastern Poland, those in the years 1990, 1993, 1999–2001, 2003, 2004 were mild, while in 1991 and 1996–1998 were cold.

Weed density of communities formed in the spring, expressed as the 15-year average, did not differ significantly depending on the position; the corresponding variability coefficients were also similar (Table 2). It is worth noticing, nevertheless, that both the average value and two extremes (minimum and maximum) were the lowest in the position after potatoes and the highest where spring barley was cultivated twice after spring barley. Minor differences between the positions are the resultant of varying effects during individual years (Fig. 1) when potato, as a weed-controlling previous crop (compared to both positions after barley), fulfilled its role in the spring only on 4 occasions, while on 3 occasions the density of weeds after potato was higher during that period compared to both fields in which barley was cultivated once or twice after spring barley. The slightly higher density of weeds in the positions after spring barley resulted from generally high values, particularly in those treatments, during the years 1999 and 2004. The linear year–to–year trends determined for weed density in individual positions were increasing and significant. The trend determined for the treatments with spring barley cultivated in crop rotation A after potato was statistically confirmed, although it was the weakest among all three. Independently of the strong correlation with passing time, weed density in spring barley in the spring also showed a significant positive correlation (although weaker the than year–to–year trend) with the intensity of precipitation in April; higher humidity of the soil after rains favoured more abundant germination of segetal vegetation (Table 3).

Table 1

Precipitation and temperature during the growing season (from April through August) during the period of study

Month	Total precipitation (mm)														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
April	23.6	13.0	38.4	19.3	46.1	40.7	10.8	22.6	44.5	101.6	20.2	43.5	10.0	23.6	35.4
May	62.0	60.6	34.1	30.9	90.7	32.8	93.5	99.0	58.3	69.1	32.5	31.3	90.1	78.6	57.6
June	83.0	72.4	13.3	87.6	43.0	48.5	64.5	71.7	141.9	155.6	33.1	48.8	72.5	60.7	69.5
July	75.6	61.4	69.5	103.4	22.9	71.7	72.4	187.6	57.5	75.5	104.2	135.1	43.2	118.2	81.6
August	88.0	46.7	17.2	108.2	69.2	85.4	59.1	59.1	58.3	53.0	140.9	81.8	87.3	34.9	75.2
Total	332.2	254.1	172.5	349.4	271.9	279.1	300.3	440.0	360.5	454.8	330.9	340.5	303.1	316.0	319.3
Month	Air temperature (°C)														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
April	8.9	8.3	7.1	9.4	9.1	7.8	7.1	3.9	9.0	8.3	10.9	7.3	7.3	6.1	7.0
May	14.2	10.2	14.0	17.5	12.5	12.8	13.2	11.4	13.2	11.1	13.5	12.2	16.1	14.1	12.5
June	16.9	15.1	18.6	14.9	15.8	17.1	15.4	15.7	16.2	16.7	15.9	13.8	19.3	16.5	15.8
July	17.2	19.5	20.1	16.8	21.8	20.6	15.3	16.9	16.2	19.1	15.3	19.5	19.8	18.8	17.2
August	18.2	18.6	20.9	16.5	18.3	19.2	17.9	18.3	15.2	16.9	16.9	18.4	15.7	17.4	16.8
Average	15.1	14.3	16.1	15.0	15.5	15.5	13.8	13.2	14.0	14.4	14.5	14.2	15.6	14.6	13.4

Table 2

Density and biomass of weeds in spring barley and their variability expressed using simple statistics

Weed community characteristic	Position (rotation system – previous crop)	Average for 15 years	Min. – max.	V, %	Equation of the linear year–to–year trend	r
		plants m^{-2} or g m^{-2}				
spring						
Density	A–p	273.0	72.0–496.0	42.3	y = 16.286x + 142.71	0.63*
	B–b	280.4	94.0–502.0	49.7	y = 26.407x + 69.143	0.85*
	B–bb	286.7	126.0–584.0116,00	46.5	y = 23.646x + 97.562	0.79*
before harvest						
Density	A–p	150.3	65.9–406.0	57.7	y = 11.104x + 61.438	0.57*
	B–b	148.2	58.0–450.0	67.2	y = 16.014x + 20.086	0.72*
	B–bb	156.8	68.0–324.0	52.5	y = 13.293x + 50.457	0.72*
Biomass	A–p	89.1	35.8–192.4	55.6	y = 2.9623x + 65.358	0.27
	B–b	106.4	24.7–270.6	68.7	y = 5.4905x + 62.487	0.34
	B–bb	123.4	42.6–317.2	66.3	y = 1.8563x + 108.58	0.10

V– year–to–year variability coefficient, r – linear correlation coefficient determining the significance of the year–to–year linear trend; * – r significant at p =0.05; position of the spring barley (position): A–p – in crop rotation system A after potato, B–b – in crop rotation system B the first time after spring barley, B–bb – in crop rotation system B the second time after spring barley

Table 3

Linear correlation coefficients between weed density and biomass and precipitation and temperature during the study period

Item		Weed density	Weed biomass
spring (tillering stage)			
April	– precipitations	0.32*	
	– air temperature	–0.11	
before harvest (end of vegetation)			
May	– precipitations	–0.08	0.21
	– air temperature	–0.04	–0.56*
June	– precipitations	0.18	0.47*
	– air temperature	–0.08	–0.09
July	– precipitations	0.08	0.11
	– air temperature	0.02	0.09
August	– precipitations	0.04	–0.32*
	– air temperature	–0.41*	–0.18
April-August	– precipitations	0.16	0.35*
	– air temperature	–0.31*	–0.4*

* – correlation significant at p = 0.05

The density of weeds before spring barley harvest as compared to the situation in the spring was usually reduced and only in a few cases was it larger (in the position after potato in 1998 and 2001, in the position after barley in 1991 and 1998 as well as in the position with the cultivation of spring barley twice after spring barley in 2001 – Fig. 1). On average, for the 15 years of the study, that reduction in all three positions was 45–47%, and the average values for the treatments were convergent (Table 2). The position after cultivation of barley twice was marked by being evidently lower compared to the maximum density in the other treatments during the period of the study and relatively the lowest (although not drastically differing from the others) coefficient of year–to–year variance. For all the positions, the increasing linear year–to–year trend was confirmed statistically but the linear correlation coefficients were slightly lower than in the spring.

The most frequently observed decrease in weed density during the period preceding the harvest of spring barley resulted from early completion of growth by numerous segetal plants under the influence of warmer weather and their dropout from the community. The above thesis is confirmed by the negative correlation between weed density before harvest and temperature during the period from April till August, in particular in August (Table 3). Precipitation, most of which stimulated more abundant germination, was not important for weed density before harvest (no correlation).

Weed biomass assessed before spring barley harvest and presented as an average for all years was the lowest in the position after potato in crop rotation A (Table 2). The worse position, i.e. cultivation in the rotation system with a 75% proportion of cereal (B), first immediately after the cereal and next for the third time consecutively in the same field, contributed to increasingly abundant development of competing vegetation. Particularly clear differences unfavorable for autogenic positions were observed during the years 1991, 1997 and 1999 when there existed conditions particularly favourable for development of weeds (Fig. 1). Only in 1993 the weeds found the best conditions for development in the potentially unfavorable position (after potato) and the biomass generated by them was higher than in both positions after barley. During that year, the mass of weeds in general was not big: it did not exceed 100 g per 1 m^2. The biomass of weeds in the treatment after potato was characterized by relatively lower variability over time and the lowest value of the upper extreme. The linear year–to–year trend was not confirmed in any position. The figure indicates that this characteristic showed a rather irregular fluctuation. During the 15 years (assessment from the establishment of the experiment), three periods could be identified covering different numbers of years during which a gradual increase of biomass took place, followed by its rapid decrease. Those were the following periods: 1990–1991, 1992–1999, and 2000–2004. A significant (drastic) decrease of biomass during the years 1992 and 2000, after periods of its lush development, could be caused by drought in May and June of those years. The negative correlation with temperature in May and a positive one with the quantity of precipitation in June as well as mathematical confirmation of those correlations for the period from April until August correspond with the above observations (Table 3).

The yield of spring barley showed a negative linear correlation with total biomass generated by the weeds; its correlation with weed density was not confirmed (Fig. 2).

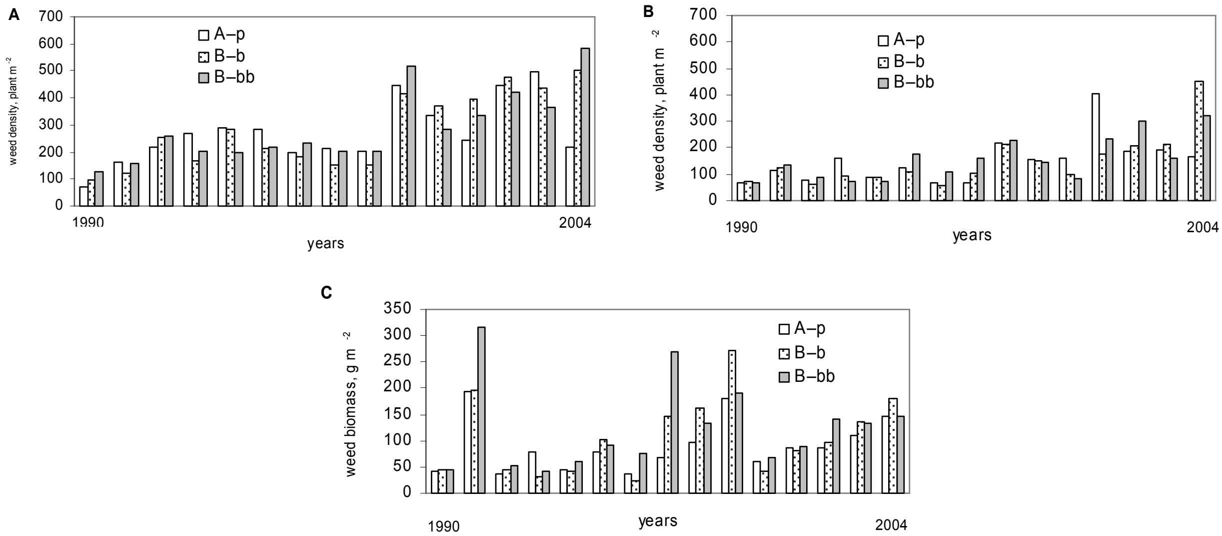

Fig. 1. Density and biomass of weeds in spring barley during the years 1990–2004; (A) in the spring, (B, C) before barley harvest; position of spring barley (position): A–p – in crop rotation A after potato, B–b – in crop rotation B the first time after spring barley, B–bb – in crop rotation B the second time after spring barley

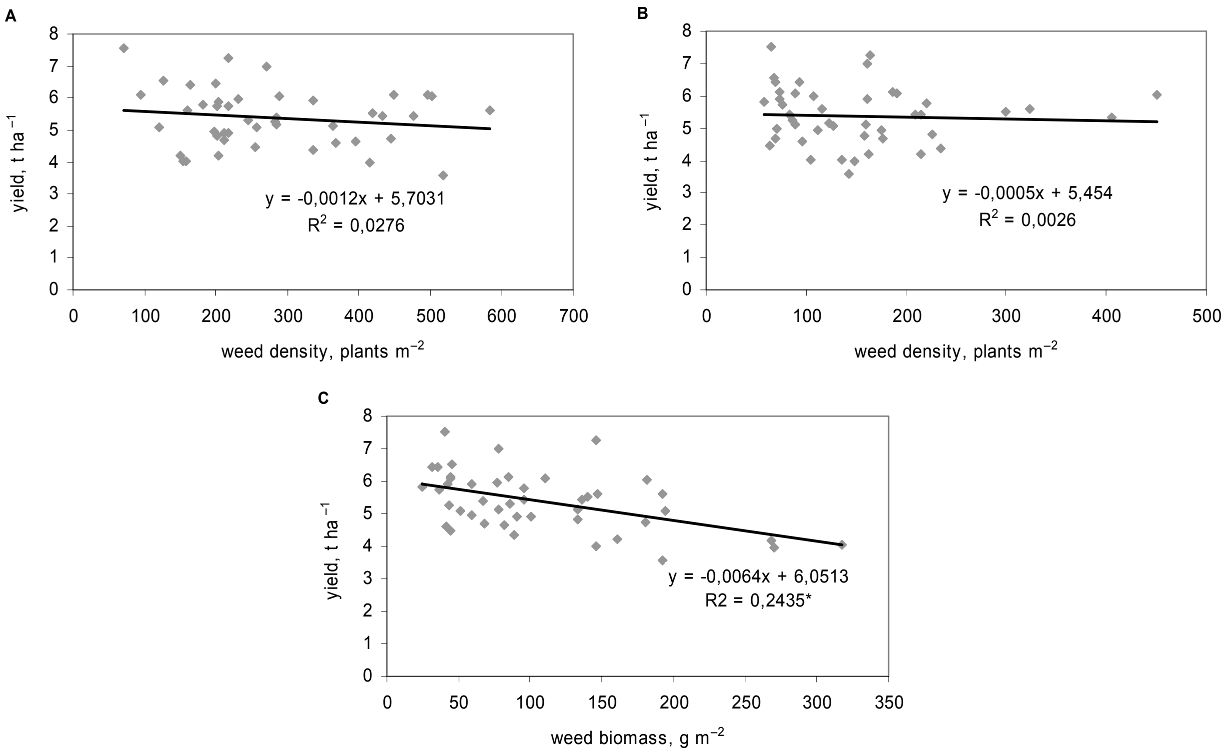

Fig. 2. Correlation of spring barley grain yield with weed density and biomass in the spring (A) and before barley harvest (B, C); R^2 (*) – determination coefficient (significant at p = 0,05)

DISCUSSION

Studies on the influence of crop succession on development of weeds in spring barley have been frequently undertaken in numerous Polish scientific centres. They indicate that the positioning of this cereal in the crop rotation after carefully cultivated root crops allows the application of herbicides to be abandoned (Zawiślak, 1997), while the worsening of previous crop quality, on the other hand, and in particular consecutive cultivation after cereals and after spring barley up to monoculture, results in increased development of weeds (Zawiślak, 1997; Blecharczyk et al. 2000; Buczyński and Marks, 2003; Kostrzewska and Wanic, 2005; Adamiak, 2007). This means mainly the biomass of weeds, but in most cases also weed density, although as concerns the latter situation opinions are not infrequent that there is no correlation between it and the sequence (Kostrzewska and Wanic, 2005). These determinations were made on the basis of experiments repeated over time. The results of our own studies averaged for 15 years indicate no major influence of the position on the density of weeds in the spring and before harvest and confirm the increase in weed biomass in the case that spring barley is cultivated after spring barley and then its cultivation is continued in the same field. The analysis of the data from particular 15 years reveals that the differences in the biomass were influenced by a situation that developed only during some seasons. Longer experiments allow highlighting entirely different issues than short–term experiments (Mahn, 1984). The correlation with weather conditions becomes visible as well as the possible trends over time surface. The correlation between weed density and biomass in cereals, on the one hand, and temperature and precipitation was recognized also in other earlier studies. Under the conditions of Poland, Wanic et al. (2005) as well as Jastrzębska et al. (2006) highlight the positive correlation between the amount of precipitation in April and the spring density of segetal vegetation. Jastrzębska et al. (2006) also point to the negative correlation between temperature during the period from April until August and weed biomass. Milberg et al. (2000), in studies conducted in Sweden, found a significant positive correlation between weed biomass and precipitation in May and during the period of May–June; they did not confirm the correlation with temperature, but the correlation coefficients were negative. In the presented studies, the confirmed correlations of weed density and biomass and temperature were negative, while the correlations with the intensity of precipitation were usually positive, with the exception of the negative correlation of biomass with precipitation in August. Jędruszczak and Antoszek (2004) highlight that the development of phytocoenoses under the influence of an experimental factor is modified by meteorological conditions and other factors, less recognizable, as well as synergies of those factors. In our own studies, the year-to year-variability of weed density in unprotected barley (independent of the position) showed an increasing trend; this applies to both spring and summer communities. Wanic et al. (2005) and Jastrzębska et al. (2006) confirm that correlation for spring weed communities in oats, but it has not been recorded in other studies on barley (Jastrzębska et al. 2006). During 12 years of winter wheat cultivation in an ecological system (weed control using a weeding harrow) Feledyn-Szewczyk (2008) recorded seasonal variability in weed density but no year–to–year increasing trend. Lundkvist et al. (2008) analyzed the dynamics of weed density in spring and their biomass was determined before harvest during the implementation of two different crop rotations under a reduced tillage system. The characteristics of communities showed high year–to–year variability. For each of the cultivated crops, no significant straight trends or differences between those two crop rotations were however found during the 15 years of the study. In our own studies, the biomass of weeds in barley in each studied position increased at certain irregular periods of time and next decreased rapidly, which did not allow determining any significant linear trend. The fluctuating character of the seasonal changes in weed infestation of barley cultivated under an unprotected rotation system and monoculture was also indicated by studies conducted by Adamiak (2007). The variability coefficients that were computed in our own experiment indicate slightly higher year–to–year stability of weed biomass in the position after potato (V = 55.6%) than in the case when the cereal was cultivated once and twice after spring barley (68.7 and 66.3%, respectively). Irrespective of the position, this variability during the period of 15 years was slightly higher than that determined by Milberg et al. (2000) in their studies conducted on spring cereals during a period of 21 years in Sweden (49.4%).

In own studies, a negative correlation between the yield of barley and weed biomass was shown. In literature mathematical evidence for a negative correlation between the yields of cereals and weed infestation intensity can be found (Singh et al. 2005; Wanic et al. 2005; Jastrzębska et al. 2006; Adamiak, 2007); weed biomass usually shows a stronger correlation with the yield than weed density (Wanic et al. 2005). Some studies indicate that the better habitat conditions are found by plants the weaker the power of that correlation (Knezevic et al. 1999). In the present study, similarly to earlier studies on phytocenoses of cereals (Wanic et al. 2005; Jastrzębska et al. 2006), the significance of the correlation between barley yield and weed density was not confirmed.

CONCLUSIONS

1. Weed density increased linearly at all plots during the 15-year period.
2. The average values confirm the increase in weed biomass in case of single and double crop sequence after spring barley; however, those differences were influenced by a situation that developed only during some seasons.
3. Weed density and biomass showed high year–to–year variability and a positive correlation with the amount of precipitation and a negative correlation with temperature during the period of the study.
4. A negative correlation between the yield of barley and weed biomass was shown.

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Wpływ płodozmianu i warunków meteorologicznych na zagęszczenie i biomasę chwastów w jęczmieniu jarym

S t r e s z c z e n i e

W pracy przedstawiono analizę zmian w zachwaszczeniu jęczmienia jarego uprawianego w latach 1990-2004 w płodozmianie z 25% udziałem tego zboża (ziemniak – jęczmień jary – groch siewny – pszenżyto ozime) w następstwie po ziemniaku i w płodozmianie z 75% jego udziałem (ziemniak – jęczmień jary – jęczmień jary – jęczmień jary) w jedno- i dwukrotnym następstwie po sobie. W eksperymencie nie stosowano ochrony przed chwastami. Corocznie, wiosną (w pełni wschodów zboża) i przed zbiorem oznaczano skład gatunkowy i zagęszczenie poszczególnych gatunków chwastów, a przed zbiorem także ich biomasę. Zagęszczenie chwastów wzrastało liniowo w ciągu 15 lat we wszystkich stanowiskach. Wartości średnie potwierdzają zwiększenie masy chwastów przy jedno i dwukrotnym następstwie jęczmienia po sobie, jednak na różnice te rzutował stan zaistniały tylko w niektórych sezonach. Zagęszczenie i biomasa chwastów wykazywały dużą zmienność w latach badań oraz dodatnią korelację z ilością opadów i ujemną z temperaturą w okresie badań. Wykazano ujemną korelację między plonem jęczmienia a biomasą chwastów.