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EFFECT OF SOIL TILLAGE SYSTEMS AND STRAW MANAGEMENT ON WEEDS IN CEREAL STANDS*

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A b s t r a c t. The experimental crop rotation was as follows: each crop was cultivated using two different variants of tillage, i.e. conventional tillage (CT) and minimum tillage (MT). Straw remaining on plots after the harvest of all crops was chopped and treated with four different fertilisers. In the first variant, the preparation Beta-liq was applied at the dose of 1 t ha^{-1} (A), in the second one, the dose of liquid fertiliser DAM 390 was 100 kg ha^{-1} (B), and in the third one the preparation Unifert was applied at the dose of 230 kg ha^{-1} (C). The fourth variant (D) was control, i.e. without fertilisers. In all experimental variants, the total dose of nitrogen was 30 kg ha^{-1}. The Canonical Correspondence Analysis (CCA) revealed that in stands of spring barley with conventional tillage and application of Unifert (CT, C) numbers of the following weed species were increased: *Fallopia convolvulus* and *Silene noctiflora*. In the variant with Unifert (C) and in control (D) increased number of *Amaranthus sp* and *Galium aparine* plants were found, while *Chenopodium album* was more frequent in the variant with Beta-liq (A). Basing on results of CCA it is obvious that in winter wheat stands *Cirsium arvense*, *Galium aparine* and *Lactuca serriola* occurred above all in the variants with minimum tillage (MT) and with Unifert (C), and also in the control variant (D). Weed species *Consolida orientalis*, *Fallopia convolvulus*, *Silene noctiflora,* and *Veronica agrestis* were more frequent in CT and A variants, while in variant B increased numbers of *Chenopodium album* and *Veronica polita* were found.

K e y w o r d s: weeds, straw management, soil tillage systems

INTRODUCTION

The transformation of Czech agriculture has been associated with a number of changes in methods of arable farming. Numbers of farm animals, above all of cattle,

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have been reduced and at present more and more farms operate either fully without animal production or with it, but without any need of straw (Procházková *et al.* 1999).

At the same time, however, the percentages of cereals and other straw-producing crops have increased. To maintain and/or even to increase soil fertility, the importance of straw management and its incorporation into the soil after the harvest has markedly increased. This means that especially within the minimum tillage system the different methods of straw management and incorporation are very important (Kubát 1998).

Usually more than a half of the required supply of organic substances into the soil originates from post-harvest plant residues. The remainder (i.e. 40-50% of the total requirement) must be supplied in the form of organic fertilisers. However, the amount of organic substances produced in this form is not sufficient and for that reason the importance of straw as their source is continuously increasing (Klír 1997).

These changes in straw management as well as different forms of applied nitrogen can, in combination with various methods of minimum tillage, influence the weed infestation of cereals.

MATERIALS AND METHODS

The effects of application of various fertilisers on straw and of different methods of tillage on the weed infestation in spring barley and winter wheat were studied in a field experiment established in the experimental station of the Mendel University of Agriculture and Forestry Brno (Czech Republic) situated at the altitude of 184 m above sea level. The long-term averages of annual precipitation and of temperatures are 481 mm and 9.2°C, respectively.

This field experiment was established in 2004. The size of individual plots was 410 m^2 (21 x 19.5 m) and each variant had four replications. The experimental crop rotation was as follows: grain maize, spring barley, safflower, winter wheat and winter wheat. Each crop was grown using two different variants of tillage: in the first one the conventional method of tillage was used (CT). After the harvest of forecrop, the first operation was stubble breaking with a plough to the depth of 0.10 m. Thereafter the field was ploughed to the depth of 0.20-0.24 m. Pre-sowing tillage and sowing itself were performed together using a drilling machine. In the second variant the method of minimum tillage (MT) was used. In this case stubble breaking to the depth of 0.10 m was performed immediately after the harvest. In this variant, ploughing was replaced by shallow loosening of soil to the depth of 0.15 m and the pre-sowing tillage and sowing itself were performed also together, using a sowing combination.

After the harvest, straw remaining on the plots was chopped and treated with fertilisers. To balance the C:N ratio, three various fertilisers were applied on straw in the total dose of 30 kg N per hectare. In the first variant, the preparation Betaliq was applied at the dose of 1 t ha^{-1} (A); this fertiliser contained 3% N, 5% K_2O and sugar residues. In the second variant, the liquid fertiliser DAM 390 was applied at the dose of 100 kg ha^{-1} (B); this fertiliser contained 30% N. In the third variant the liquid fertiliser Unifert was applied at the dose of 230 kg ha^{-1} (C); this fertiliser contained 13% N and 3% K_2O. The fourth variant was used as control, i.e. without fertilisers (D).

The weed infestation was evaluated in spring, prior to the application of herbicides. In both stands, i.e. in spring barley and in winter wheat grown after winter wheat, this evaluation was performed on 24th April 2005 and on 8th May 2006. The numbers of individual weeds were counted in 16 replications on plots with the area of 1 m^2. The weed infestation was evaluated using the method of multi-dimensional analysis of ecological data. The selection of the optimum analysis was performed on the basis of the length of gradient, which was estimated by means of Detrended Correspondence Analysis (DCA). The obtained results were processed using the method of Canonical Correspondence Analysis (CCA). When testing the significance of results by means of the Monte-Carlo test, in total 499 permutations were calculated. These data were processed using the program Canoco 4.0 (Ter Braak 1998).

RESULTS AND DISCUSSION

In stands of spring barley 19 and 22 weed species were found out in 2005 and 2006, respectively (Tab. 1 and Tab. 2). In winter wheat stands the corresponding numbers were 17 and 24 weed species in 2005 and 2006, respectively (Tab. 3 and Tab. 4).

Basing on results of DCA, the length of gradient was 3.819 in stands of spring barley, while in stands of winter wheat the corresponding value was 6.426. For that reason it was decided to use the method of correspondence analysis (CCA) for further processing of results. Results of CCA were significant on the level of $\alpha = 0.002$ for all canonical axes and for weed infestation of both crops. Basing on frequencies of the occurrence of weeds in individual experimental variants the CCA defined the spatial arrangement of individual weed species and variants of factors in the ordination diagram (Fig. 1, 2). In these diagrams, weed species and factor variants are represented as points. If the point representing a certain species is situated in the same quadrant and/or if it is close to the point representing a certain variant, it is possible to conclude that its occurrence is more correlated with such a variant.

Table 1. Numbers of individuals of weed species in the stand of spring barley in 2005 (sums of 16 replications)

Weed species	Variants of tillage and straw management							
	CT				MT			
	A	B	C	D	A	B	C	D
Amaranthus sp.	3	0	0	0	0	0	0	0
Anagallis arvensis	1	0	0	0	0	0	0	0
Carthamus tinctorius	0	0	1	0	0	0	0	0
Cirsium arvense	1	10	9	9	29	64	45	47
Convolvulus arvensis	1	0	0	0	1	0	3	0
Fallopia convolvulus	8	11	18	37	2	1	13	7
Fumaria officinalis	0	1	0	0	0	0	0	0
Galinsoga parviflora	2	0	16	0	0	0	0	0
Galium aparine	5	3	8	21	13	20	8	10
Helianthus annuus	0	0	0	0	1	0	0	0
Chenopodium album	17	35	18	9	12	13	4	0
Chenopodium hybridum	0	0	3	0	0	0	0	0
Lamium amplexicaule	3	0	0	0	0	0	0	1
Microrrhinum minus	0	1	0	0	0	0	0	0
Persicaria lapathifolia	0	2	0	1	1	0	1	0
Silene noctiflora	4	8	35	9	1	0	12	3
Sinapis arvensis	0	0	1	0	1	0	1	2
Thlaspi arvense	0	0	1	0	0	1	0	0
Veronica polita	7	7	13	2	2	16	8	5

In the variant with Unifert and in control (C, D) *Amaranthus sp.* and *Galium aparine* plants were more frequent. The species *Galium aparine* is a very competitive weed and it could be expected that it would either easily dominate in a stand which was weakened due to the lack of nitrogen (D) or that the nutrients supplied in the liquid fertiliser Unifert could increase its competitiveness. The occurrence of *Amaranthus sp.* and of *Chenopodium album* was markedly influenced by the year, and their numbers were high above all in 2006. However, in spite of this, *Chenopodium album* was more frequent in variant A. The liquid fertiliser Beta-liq contains residual sugar and this can stimulate soil micro-organisms; their increased activities may influence seeds present in soil. Due to this microbial activity the seeds may be released from dormancy and can start to germinate. On the other hand, however, soil micro-organisms may also attack and kill these seeds so that their number may be reduced. This obviously concerned the species *Galium aparine* because its numbers were lower in this variant.

Table 2. Numbers of individuals of weed species in the stand of spring barley in 2006 (sums of 16 replications)

Weed species	Variants of tillage and straw management							
	CT				MT			
	A	B	C	D	A	B	C	D
Amaranthus sp.	47	44	65	39	14	19	68	141
Anagallis arvensis	0	0	2	0	0	0	0	0
Carthamus tinctorius	3	1	1	0	4	0	0	0
Cirsium arvense	0	0	0	1	0	5	2	10
Consolida orientalis	0	0	0	1	0	0	0	0
Euphorbia helioscopia	0	4	0	0	0	0	0	0
Fallopia convolvulus	9	4	8	7	12	2	1	3
Galinsoga parviflora	2	1	0	0	0	5	5	0
Galium aparine	1	3	5	37	1	3	15	14
Helianthus annuus	0	0	0	0	0	7	2	7
Hyoscyamus niger	0	0	0	0	0	0	0	2
Chenopodium album	87	80	57	37	43	28	50	28
Chenopodium hybridum	0	1	15	4	0	1	30	12
Lamium purpureum	0	0	0	0	1	0	0	1
Microrrhinum minus	0	0	0	5	0	0	0	0
Persicaria lapathifolia	1	7	3	0	1	5	2	1
Plantago major	0	0	0	0	1	1	0	0
Silene noctiflora	1	0	9	8	0	0	0	0
Sinapis arvensis	0	1	0	3	0	0	1	0
Sonchus oleraceus	2	0	0	0	0	0	0	0
Thlaspi arvense	0	5	1	0	1	4	14	4
Veronica polita	1	1	3	2	4	12	10	2

Table 3. Numbers of individuals of weed species in the stand of winter wheat in 2005 (sums of 16 replications

Weed species	Variants of tillage and straw management							
	CT				MT			
	A	B	C	D	A	B	C	D
Capsella bursa-pastoris	1	1	0	0	0	0	0	0
Cirsium arvense	0	1	0	0	1	0	0	0
Consolida orientalis	13	13	12	21	6	1	3	6
Convolvulus arvensis	1	0	0	0	0	0	0	0
Euphorbia helioscopia	0	0	0	0	0	0	1	1
Fallopia convolvulus	5	4	0	0	0	0	0	0
Fumaria officinalis	0	1	2	0	1	0	1	0
Galium aparine	8	21	26	108	90	29	74	202
Lactuca serriola	0	0	0	0	1	0	0	1
Lamium amplexicaule	1	6	1	4	3	1	2	1
Lamium purpureum	2	2	0	0	1	0	0	0
Silene noctiflora	6	1	4	0	0	0	0	0
Stellaria media	0	1	0	0	0	0	0	0
Thlaspi arvense	1	0	1	0	0	2	1	0
Veronica agrestis	37	22	33	4	34	11	13	6
Veronica polita	0	4	0	0	0	0	0	1
Viola arvensis	1	4	0	0	0	0	0	0

Table 4. Numbers of individuals of weed species in the stand of winter wheat in 2006 (sums of 16 replications)

Weed species	Variants of tillage and straw management							
	CT				MT			
	A	B	C	D	A	B	C	D
Anagallis arvensis	3	3	0	0	0	0	0	0
Artemisia vulgaris	1	0	0	0	0	0	0	0
Capsella bursa-pastoris	0	0	0	0	5	0	0	0
Cirsium arvense	0	0	2	0	0	4	8	28
Consolida orientalis	22	5	21	27	4	7	4	7
Fallopia convolvulus	54	36	22	25	17	18	15	1
Fumaria officinalis	1	3	4	1	1	1	1	0
Galium aparine	7	4	17	58	47	49	139	143
Geranium pusillum	0	0	0	0	0	1	0	0
Hyoscyamus niger	2	0	0	0	0	0	0	0
Chenopodium album	33	49	26	5	31	18	37	8
Chenopodium hybridum	6	7	7	2	1	0	3	0
Lactuca serriola	0	0	1	0	0	0	0	0
Lamium amplexicaule	1	0	0	0	0	0	2	0
Lamium purpureum	0	0	0	0	1	0	0	0
Persicaria lapathifolia	5	0	0	1	0	0	0	0
Silene noctiflora	38	13	7	4	7	0	0	0
Sinapis arvensis	0	0	1	0	0	0	3	0
Sonchus arvensis	0	0	2	0	0	0	0	0
Sonchus oleraceus	2	0	0	0	0	0	0	0
Thlaspi arvense	0	0	1	0	0	6	1	0
Tripleurospermum inodorum	0	1	0	0	3	0	0	0
Veronica polita	5	1	10	1	11	8	4	15
Viola arvensis	0	3	0	0	0	1	0	0

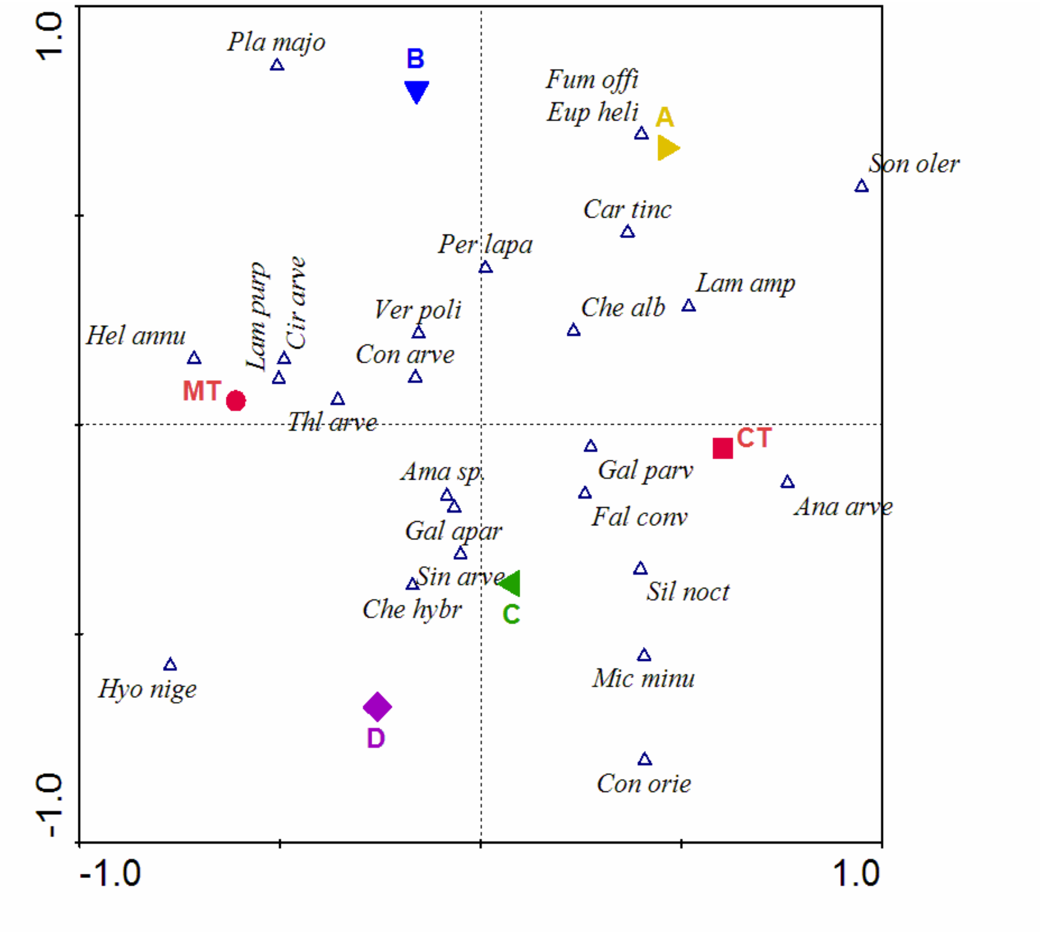

Fig. 1. Ordination diagram expressing effects of various methods of straw management and different tillage on the occurrence of weeds in stands of spring barley

Explanation notes to the ordination diagram: Variants of straw management ▶A – application of Beta-liq fertiliser; ▼B – application of DAM 390 fertiliser; ◀C – application of Unifert fertiliser; ◆D – control, without fertiliser application. Variants of tillage ■CT – conventional tillage, ●MT – minimum tillage; Abbreviations of weed species: *Ama sp. – Amaranthus sp., Ana arve – Anagallis arvensis, Car tinc – Carthamus tinctorius, Cir arve – Cirsium arvense, Con orie – Consolida orientalis, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Gal parv – Galinsoga parviflora, Gal apar – Galium aparine, Hel annu – Helianthus annuus, Hyo nige – Hyoscyamus niger, Che albu – Chenopodium album, Che hybr – Chenopodium hybridum, Lam ample – Laminum amplexicaule, Lam purp – Lamium purpureum, Mic minu – Microrhinum minus, Per lapa – Persicaria lapathifolia, Pla majo – Plantago major, Sil noct – Silene noctiflora, Sin arve – Sinapis arvensis, Son oler – Sonchus oleraceus, Thl arvee – Thlaspi arvense, Ver poli – Veronica polita*

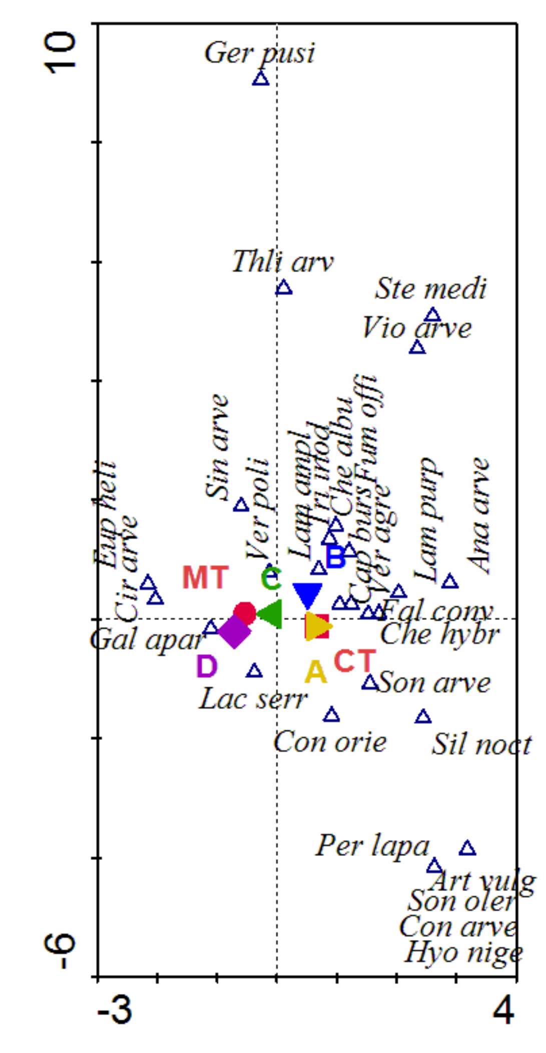

Fig. 2. Ordination diagram expressing effects of various methods of straw management and different tillage on the occurrence of weeds in stands of winter wheat

Explanation notes to the ordination diagram: Variants of straw management ▶A – application of Beta-liq fertiliser; ▼B – application of DAM 390 fertiliser; ◀C – application of Unifert fertiliser; ◆D – control, without fertiliser application. Variants of tillage ■CT – conventional tillage, ●MT – minimum tillage; Abbreviations of weed species: *Ana arve – Anagallis arvensis, Art vulg – Artemisia vulgaris, Cap burs– Capsella bursa-pastoris, Cir arve – Cirsium arvense, Con orie – Consolida orientalis, Con arve – Convolvulus arvensis, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Gal apar – Galium aparine, Ger pusi – Geranium pusillum, Hyo nige – Hyoscyamus niger, Che albu – Chenopodium album, Che hybr – Chenopodium hybridum, Lac serr – Lactuca serriola, Lam ampl – Lamium amplexicaule, Lam purp – Lamium purpureum, Per lapa – Persicaria lapathifolia, Sil noct – Silene noctiflora, Sin arve – Sinapis arvensis, Son arve – Sonchus arvensis, Son oler – Sonchus oleraceus, Ste medi– Stellaria media, Thl arve – Thlaspi arvense, Tri inod – Tripleurospermum inodorum, Ver agre – Veronica agrestis, Ver poli – Veronica polita, Vio arve – Viola arvensis.*

In the variant with minimum tillage (MT), weed species *Cirsium arvense* and *Veronica polita* were more frequent. Shallow tillage reduced the root system of *Cirsium arvense* only partly, while in the case of *Veronica polita* its seeds obviously accumulated in this shallow loosened layer and due to these facts the numbers of plants of both species were increased in this experimental variant. The occurrence of other species was either influenced by other factors or it was so low that this could be quite random.

Results of CCA indicate that species *Cirsium arvense*, *Galium aparine* a *Lactuca serriola* occurred above all in stands of winter wheat with minimum tillage, application of Unifert and without fertilisers (variants MT, C, D). The main reasons of their increased numbers were obviously the shallow tillage and their high competitiveness.

In stands with traditional tillage and application of Beta-liq (CT, A) weed species *Consolida orientalis*, *Fallopia convolvulus*, *Silene noctiflora* and *Veronica agrestis* were more frequent. It seems that these weeds germinated from an old reserve of their seeds in soil. Due to the deeper tillage, these seeds were taken to upper soil layers where they could germinate. It is also possible that the residual sugar contained in Beta-liq could also promote the stimulation of these seeds.

In variant B (with liquid fertiliser DAM 390), species *Chenopodium album* and *Veronica polita* were more frequent. It seems that their germination could be influenced either by a different form of N or by its gradual release.

CONCLUSION

Application of different N-fertilisers on straw and different methods of tillage obviously either change the soil environment or directly influence seeds of weed species. A very competitive species such as *Galium aparine* can be dominant even under conditions of nitrogen deficiency. The fertiliser Beta-liq, which contained also residual sugar, either influences the activity of soil microorganisms or affects directly weed seeds. In some weed species (e.g. *Chenopodium album*, *Fallopia convolvulus* or *Silene noctiflora*) this can contribute to their increased occurrence while in others (e.g. *Galium aparine*) their numbers can be reduced. Both of these phenomena may change the pattern of weed infestation of stands of spring barley and winter wheat.

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WPŁYW SYSTEMÓW UPRAWY GLEBY ORAZ ZAGOSPODAROWANIA SŁOMY NA ZACHWASZCZENIE W ŁANIE ZBÓŻ

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Streszczenie. W doświadczeniu zastosowano następujący płodozmian: każda z roślin uprawnych była uprawiana przy użyciu dwóch różnych systemów uprawy gleby, tj. uprawy tradycyjnej (CT) oraz uprawy minimalnej (MT). Słoma pozostająca na polu po zbiorze wszystkich upraw była siekana oraz stosowano na nią cztery różne rodzaje nawozów. W pierwszym wariancie stosowano preparat Beta-liq w dawce 1 t ha^{-1} (A), w drugim wariancie stosowano płynny nawóz DAM 390 w dawce 100 kg ha^{-1} (B), a w trzecim – preparat Unifert w dawce 230 kg ha^{-1} (C). Czwarty wariant (D) stanowił obiekt kontrolny, tzn. nie stosowano w nim żadnego nawożenia. We wszystkich wariantach doświadczenia całkowita dawka azotu wynosiła 30 kg ha^{-1}. Analiza Canonical Correspondence Analysis (CCA) wykazała, że w łanach jęczmienia jarego przy uprawie tradycyjnej oraz zastosowaniu preparatu Unifert (CT, C) następował wzrost liczby następujących gatunków chwastów: *Fallopia convolvulus* oraz *Silene noctiflora*. W wariancie z preparatem Unifert (C) oraz w wariancie kontrolnym (D) stwierdzono podwyższoną liczbę roślin *Amaranthus sp* i *Galium aparine*, podczas gdy gaturek *Chenopodium album* występował liczniej w wariancie z Beta-liq (A). Na podstawie wyników analizy CCA można stwierdzić w sposób oczywisty, że w łanach pszenicy ozimej *Cirsium arvense*, *Galium aparine* i *Lactuca serriola* występowały przede wszystkim w wariantach z uprawą minimalną (MT) i z preparatem Unifert (C), ale także w wariancie kontrolnym (D). Gatunki chwastów *Consolida orientalis*, *Fallopia convolvulus*, *Silene noctiflora*, oraz *Veronica agrestis* występowały częściej w wariantach CT oraz A, podczas gdy w wariancie B stwierdzono podwyższone liczby roślin *Chenopodium album* i *Veronica polita*.

Słowa kluczowe: chwasty, zagospodarowanie słomy, systemy uprawy gleby