



**Uniwersytet
w Siedlcach**

Uniwersytet w Siedlcach

University of Siedlce

<https://bazawiedzy.uws.edu.pl>

Publikacja / Publication	The effect of farming method on the dynamics of communities from the alliance Radiolion linoidis (Rias Goday 1961) Pietach 1965 in Kałuszyn Upland agrocenoses
Autorzy / authors	Skrajna Teresa Małgorzata
Adres publikacji w Repozytorium URL / Publication address in Repository	https://bazawiedzy.uws.edu.pl/info/article/UPH6ad55d87681a4e4f9115597f8a664b9c/
Data opublikowania w Repozytorium / Deposited in Repository on	2021-10-22
Rodzaj licencji / Type of licence	Uznanie Autorstwa CC BY / Attribution CC BY
Cytuj / Cite	Skrajna T.M., The effect of farming method on the dynamics of communities from the alliance Radiolion linoidis (Rias Goday 1961) Pietach 1965 in Kałuszyn Upland agrocenoses, „Acta Agrobotanica”, 2014, t.67, nr 1, s. 85–98.

THE EFFECT OF FARMING METHOD ON THE DYNAMICS OF COMMUNITIES FROM THE ALLIANCE *Radiolion linoidis* (RIAS GODAY 1961) PIETACH 1965 IN KAŁUSZYN UPLAND AGROCENOSSES

Teresa Skrajna

Department of Agricultural Ecology, University of Nature Science and Humanity
B. Prusa 14, 08-110 Siedlce, Poland
e-mail: tskrajna@op.pl

Received: 15.12.2012

Abstract

The work presents the results of studies carried out from 1994 to 2010 on changes in phytocenoses with *Radiolion linoidis* species due to increased intensification of the farming process. The research material consisted of 136 phytosociological relevés taken from the same sites located in cereals, tuber crops/maize and stubble fields. The relevés were grouped based on three periods reflecting changes in farming system: period I (1994–1997) – traditional farming system; period II (2002–2004) – shift from traditional to intensive farming; period III (2008–2010) – intensive farming system. Communities with *Radiolion linoidis* continued to disappear over the whole study period due to farming intensification. The phytocenoses *Spergulario-Illecebrum verticillati* found in stubble fields and communities with *Illecebrum verticillatum* observed in cereals and tuber crops in period I were replaced with patches of *Echinochloo-Setarietum* in maize and stubble fields as well as the association *Vicietum tetraspermae* in cereals in period III. The values of Sørensen's index of community similarity and of the dynamics index emphasize how advanced the process of changes in and impoverishment of communities was.

Key words: field weeds, threatened species, field under cultivation, dynamics index (V), Sørensen's index of similarity

INTRODUCTION

Intensive development of agricultural production technology in Europe began in the first part of the 20th century [1] and in Poland in the second part of the 20th century. Modern agrotechnology and intensive application of chemicals in field production have led to the disappearance of many specialised species and whole communities [2–5]. Other factors that have promoted the impoverishment of flora in agrocenoses

include abandoning marginal land, reduced diversity of cultivated fields, for example smaller percentages of fields under *Secale cereale* L. and *Linum usitatissimum* L., and ploughing under of stubble fields which are the main place where many short-lived ground species develop [6,7]. They also include communities with *Radiolion linoidis* included in the list of endangered segetal communities in Poland [8].

In the study area, traditional cultivation methods in the 1990s supported communities from the alliance *Radiolion linoidis* with a large share of *Illecebrum verticillatum* in agrocenoses [9–13].

The purpose of this work was to analyse transformations of communities from the alliance *Radiolion linoidis* due to changes in habitat conditions resulting from intensification of the farming process.

MATERIALS AND METHODS

Field observations were performed over the period 1994–2010 in the same sites located in cultivated fields of 23 localities of the Kałuszyn Upland [14] (Fig. 1). There was a total of 136 phytosociological relevés taken using the Braun-Blanquet approach [15] in fields under cereals, root crops/maize and in stubble fields. Next, the relevés were grouped according to the following three periods to reflect changes in farming methods:

- period I (1994–1997) – traditional farming system;
- period II (2002–2004) – transformation period – shift from traditional to intensive farming;
- and period III (2008–2010) – intensive farming system.

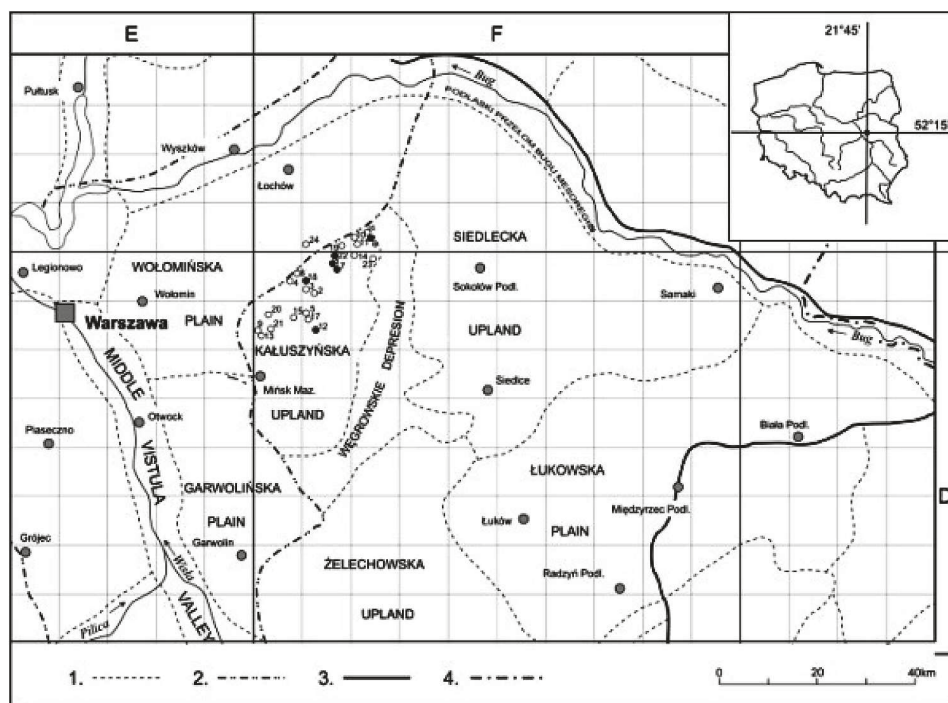


Fig. 1. The location of study area.

1 – current locality *Illecebrum verticillatum* (2008–2010); 2 – locality *Illecebrum verticillatum* do 1994–2002; 3 – limits of the mesoregions; 4 – limits of the macroregions; 5 – limits of the provinces; 6 – borders of country.

Data on the changes in farming intensification and percentages of area under individual crops were derived from surveys carried out among the owners of the fields where permanent study areas were located. Soil conditions were determined using agricultural soil maps at a scale of 1:5000. Relevés from the study periods were arranged into tables according to individual crops and stubble. Then, phytosociological classification was made [16] and used to analyse the structural changes in the communities.

Sørensen's index of similarity (SW_s) was employed to reflect the extent of changes in communities in individual study periods. The index was calculated according to the following formula:

Moreover, the dynamics index V was used to analyse changes in the floristic composition of agrophytocenoses in the sites studied. The index reflects an increase or decrease in constancy of occurrence and is a measure of species dynamics [17]:

$$V = S_3 / S_1 * 100\%$$

where:

S_1 – constancy of occurrence of a given species in period I (1994–1997);

S_3 – constancy of occurrence of a given species in period III (2008–2010).

The species which were characterised by an absolute increase or decrease in constancy of 4 percent points were considered to be species whose constancy

changed significantly. Vascular plant terminology in the study followed Mirek et al. [18].

RESULTS

Comparisons of the present state of the communities with their state 17 years ago revealed dynamic changes taking place in the structure of agrocenoses for all the crop groups and stubble fields. A number of community transformations associated with changes in the land use structure and farming intensification took place.

Changes in stubble communities

Changes in syntaxonomic affiliation of communities were observed in the study area in stubble fields. Two associations including lower units were recognised in period I: *Spergulario-Illecebretrum verticillati* and *Digitalietum ischaemi*. They were floristically rich phytocenoses: there was a total of 113 species in stubble fields (Table 1). Number of species per relevé ranged between 26 and 53, on average 32 species. There was observed a mass occurrence of *Illecebrum verticillatum* in both associations. Moreover, a large cover of the following hygrophilous species was observed: species of the association *Radiolion linoidis* such as *Hypericum humifusum*, *Radiola linoides* and *Centunculus minimus*, of the classes *Isoëto-Nanojuncetea* – *Juncus bufonius*, *Juncus capitatus*, *Gnaphalium uliginosum* and *Plantago intermedia* as well as other moisture-loving species like the

most numerous *Veronica serpyllifolia*, *Polygonum hydropiper* and *Sagina procumbens*. There was observed a mass occurrence of the following acidophilous weeds: *Rumex acetostella* and *Spergula arvensis* and others.

Table 1
Changes in stubble communities in years 1994-2010

Farming system	traditional		transformation period		intensive	
In period	1994-1997		2002-2004		2008-2010	
Numbers of species with in the releve	26-53 32		22-37 27		19-28 24	
Numbers of releves	31		16		16	
No	1		2		3	
	S	D	S	D	S	D
I. Ch. <i>Spergulario-Illecebretrum verticillati</i>						
<i>Illecebrum verticillatum</i>	V	1389	IV	250	II	31
<i>Spergularia rubra</i>	IV	152	III	119	II	81
II. Ch. <i>Radiolion linoidis</i>						
<i>Hypericum humifusum</i>	V	839	IV	237	II	165
<i>Radiola linoides</i>	V	397	III	75	I	6
<i>Gypsophila muralis</i>	II	46	II	96	I	12
<i>Centunculus minima</i>	IV	219	III	93	I	12
III. Ch. <i>Isoëto-Nanojuncetea</i>						
<i>Juncus bufonius</i>	V	516	V	250	IV	162
<i>Juncus capitatus</i>	IV	213	IV	112	I	12
<i>Plantago intermedia</i>	IV	258	III	100	II	67
<i>Gnaphalium uliginosum</i>	V	316	III	312	III	62
<i>Gnaphalium luteo-album</i>	II	22	I	6	I	6
IV. D. var. hygrophilous species						
<i>Veronica serpyllifolia</i>	V	442	IV	187	II	5
<i>Polygonum hydropiper</i>	IV	406	III	100	III	334
<i>Sagina procumbens</i>	IV	179	III	69	II	18
<i>Mentha arvensis</i>	III	555	III	93	II	87
<i>Peplis portula</i>	III	147	II	50	II	319
<i>Stachys palustris</i>	II	202	II	56	III	197
<i>Bidens tripartita</i>	II	77	II	56	IV	372
<i>Potentilla anserina</i>	II	32	II	31	III	68
<i>Lysimachia nummularia</i>	II	64	II	31	I	19
IV. Ch. <i>Aperion spicae-venti</i>, <i>Centauretalia cyani</i>						
<i>Scleranthus annuus</i>	IV	87	III	50	I	19
<i>Anthemis arvensis</i>	III	111	IV	112	IV	197
<i>Centaurea cyanus</i>	III	51	II	69	II	25
<i>Arnoseris minima</i>	III	61	I	6	I	43
<i>Anthoxanthum aristatum</i>	II	58	II	25	II	75
<i>Vicia hirsuta</i>	II	26	II	31	II	31
<i>Apera spica-venti</i>	II	26	II	25	I	6
<i>Vicia angustifolia</i>	II	25	I	19	I	12
<i>Teesdalea nudicaulis</i>	II	32				
V. Ch. <i>Digitarietum ischaemi</i>						
<i>Digitaria ischaemum</i>	IV	425	V	628	III	281
VI. Ch. <i>Echinochloo-Setarietum</i>						
<i>Echinochloa crus-galli</i>	I	32	IV	1022	V	1246
<i>Raphanus raphanistrum</i>	III	67	II	31	II	56

VII. Ch. Panico-Setarion						
<i>Spergula arvensis</i>	V	135	IV	87	II	87
<i>Rumex acetosella</i>	V	585	III	106	III	81
<i>Setaria pumila</i>	II	61	IV	578	IV	584
<i>Setaria viridis</i>	II	58	III	284	II	100
VIII. Ch. Polygono-Chenopodietalia Polygono-Chenopodion						
<i>Chenopodium album</i>	III	252	V	569	IV	459
<i>Polygonum aviculare</i> s.	III	58	IV	62	III	68
<i>Sonchus arvensis</i>	II	22	I	44	I	37
<i>Galinsoga parviflora</i>			II	35	III	203
<i>Veronica persica</i>			II	100	II	184
<i>Capsella bursa-pastoris</i>	I	6	I	12	II	25
IX. Ch. Stellarietea mediae						
<i>Viola arvensis</i>	IV	61	IV	451	IV	284
<i>Fallopia convolvulus</i>	IV	81	IV	112	II	56
<i>Stellaria media</i>	III	80	V	600	IV	265
<i>Matricaria maritima</i> subsp. <i>inodora</i>	I	69	II	106	IV	353
<i>Conyza canadensis</i>	II	106	II	37	II	62
<i>Myosotis arvensis</i>	I	22	I	6	II	37
X. Accompanying species						
<i>Achillea millefolium</i>	IV	64	III	44	I	19
<i>Elymus repens</i>	III	71	III	106	III	725
<i>Equisetum arvense</i>	III	61	III	69		
<i>Veronica arvensis</i>	II	26	II	31	III	125
<i>Polygonum lapatifolium</i>	II	45	II	25	III	68
<i>Cerastium holosteoides</i>	II	26	II	31	I	6
<i>Cirsium arvense</i>	II	39	I	37	I	44
<i>Convolvulus arvensis</i>	II	26	I	19	I	12
<i>Ranunculus repens</i>	II	35	I	9	I	6
<i>Hypochoeris radicata</i>	II	8	I	6	I	12
<i>Plantago lanceolata</i>	II	6	I	6	I	6
<i>Erodium cicutarium</i>	II	29	I	6	I	6
<i>Leontodon autumnalis</i>	II	48			I	6
<i>Polygonum persicaria</i>	I	13	II	56	III	100
<i>Rorippa sylvestris</i>	I	13			III	184
<i>Trifolium repens</i>	I	13			II	25
<i>Agrostis stolonifera</i>	I	6			II	128

Sporadical species: II – *Ranunculus sardous* 1,2; *Riccia sorocarpa* 1; *Anthoceros punctatus* 1; IV – *Arabidopsis thaliana* 1,2,3; *Odontites verna* 1,2; *Myosotis stricta* 1,2; *Polygonum tomentosum* 1,3; *Vicia tetrasperma* 1; *Vicia sativa* 1; *Spergula morisonii* 1; *Chamomilla recutita* 1; *Melandrium noctiflorum* 2,3; VIII-*Atriplex patula* 1,2,3; *Geranium pusillum* 1,2,3; *Oxalis fontana* 1,2,3; *Rumex crispus* 1; *Euphorbia helioscopia* 2,3; *Lamium purpureum* 2,3; *Chenopodium polyspermum* 2,3; *Sonchus oleraceus* 2; *Sonchus asper* 2; *Veronica agrestis* 2; IX-*Galeopsis tetrahit* 1,2,3; *Thlaspi arvense* 2,3; *Lapsana communis* 3; *Sinapis arvensis* 3; X-*Stellaria graminea* 1,2,3; *Poa annua* 1,2,3; *Plantago major* 1,2,3; *Equisetum sylvaticum* 1,2,3; *Trifolium arvense* 1,2; *Medicago lupulina* 1,2; *Galeopsis ladanum* 1,2; *Holcus lanatus* 1,2; *Cerastium semidecandrum* 1,2; *Arenaria serpyllifolia* 1,3; *Amaranthus retroflexus* 1,3; *Taraxacum officinale* 1,3; *Symphytum officinale* 1,3; *Potentilla norvegica* 1,3; *Lactuca serriola* 1; *Medicago sativa* s. *falcata* 1; *Lysimachia vulgaris* 1; *Artemisia vulgaris* 1; *Tanacetum vulgare* 1; *Chamomilla suaveolens* 1; *Cerastium arvense* 1; *Lathyrus pratensis* 1; *Polygonum amphibium* 1; *Artemisia campestris* 1; *Allium vineale* 1; *Dactylis glomerata* 1; *Knautia arvensis* 1; *Hieracium pilosella* 1; *Hypericum perforatum* 1; *Trifolium pratense* 1; *Galium aparine* 2,3; *Crepis capillaris* 2; *Daucus carota* 3; *Epilobium montanum* 3; *Gnaphalium sylvaticum* 3; *Tussilago farfara* 3;

Explanatory notes: numbers after species inform about numbers of columns in the table:

S – phytosociological constancy, D – cover factor;

In period II, one more association was distinguished, i.e. *Echinochloo-Setarietum*, as well as the community *Setaria pumilla-Setaria viridis*. The cover of *Illecebrum verticillatum*, all the species from *Radiolion linoidis* and *Isoëto-Nanojuncetea* and acidophilous species was markedly reduced. On the contrary, a higher share of the following nitrophilous species was observed: *Chenopodium album*, *Stellaria media* and *Matricaria maritima* subsp. *inodora*. Additionally, new species established, e.g. *Veronica persica* and *Galinsoga parviflora*. The overall number of stubble species was lower: 85. The average number of species per relevé was lower, too, and amounted to 27.

Period III saw an even faster rate of disappearance of species and whole syntaxa representing the class *Isoëto-Nanojuncetea*. What is more, phytocenoses of the association *Spergulario-Illecebretrum verticillati* were not found, whereas rare patches of *Digitarietum ischaemii* *Illecebrum verticillatum* were replaced by numerous plants of *Polygonum hydropiper*, *Peplis portula* and *Bidens tripartita*.

Changes in weed communities of cereal crops

At the beginning of the study, rye was the only winter cereal, with its cover ranging from 45 to 60%. These agrocenoses included the association *Arnosserido-Scleranthetum*, either typical or the variant with *Illecebrum verticillatum*, as well as the community with *Aperion spicae-venti*, the variant with *Illecebrum verticillatum*. The vertical structure of the stand was not distinct and often consisted of just one stratum. Thinner rye stands at the stage of grain maturation favoured the development of ground weeds. *Illecebrum verticillatum* plants were common and were accompanied by numerous species of the association *Radiolion linoidis* and of the class *Isoëto-Nanojuncetea*, in which the species with the highest constancy and cover included the following: *Radiola linoides*, *Centunculus minimus*, *Hypericum humifusum*, *Juncus bufonius* and *Juncus capitatus*. *Arnosseris minima* was also a numerous characteristic species in the lowest layer, whereas *Apera spica-venti* was the dominant species in the upper one (Table 2). Cereal communities were infested by 82 weedy species, on average 24 species per relevé.

In 2002–2004 the total area of land under winter cereals decreased and half of it was under *Triticale*. The average cover of this cereal was higher and reached 64%. Higher stand density substantially reduced the development of ground weeds. Agrocenoses in this period included the community *Aperion spicae-venti*, the typical variant and the hygrophilous variant with *Juncus bufonius* and the dominating species *Apera spica-venti*. The withdrawing species included *Arnosseris minima* and other acidophilous species. What is

more, there was a drastic drop in the constancy and cover of the following species from the order *Radiolion linoidis*: *Illecebrum verticillatum*, *Radiola linoides*, *Centunculus minimus*, and *Hypericum humifusum*. The greater cover of *Matricaria maritima* subsp. *inodora*, *Vicia tetrasperma* and *Polygonum lapathifolium* subsp. *pallidum* indicates the improved nutrient status of the habitats. Agrocenoses included 66 species. The number of species per relevé was slightly lower and ranged from 15 to 29, averaging 23 species. There was also a decrease in total weed cover.

Triticale was the only winter species cultivated in period III and its average cover reached 70%. The agrophytocenoses underwent further transformations; the association *Vicietum tetraspermae*, the typical variant with *Juncus bufonius* and *Rhinanthus serotinus*, became the leading dominant. Great numbers of new species, *Bromus secalinus* and *Vicia villosa*, were found in some patches. In addition, the following nitrophilous newcomers increased their cover: *Matricaria maritima* subsp. *inodora*, *Sonchus arvensis* and *Galium aparine*. Hygrophilous species of the alliance *Radiolion linoidis* became very rare, whereas moisture-loving species characterised by higher nutrient requirements, like *Bidens tripartita*, increased their cover. The community was made up of 65 species, 22 species per relevé on average.

Changes in weed communities of tuber crops/maize

In period I, potatoes were grown for livestock under the traditional farming system. They were characterised by substantial secondary weed infestation. These phytocenoses included two associations; *Digitarietum ischaemi* was frequently found in the typical variant and the variant with *Illecebrum verticillatum*, whereas the variant with *Echinochloo-Setarietum sperguletosum* was infrequent (Table 3). Hygrophilous species from the class *Isoëto-Nanojuncetea* – *Juncus bufonius* and *Illecebrum verticillatum*, present in all patches at high cover, made them easily recognisable. These phytocenoses consisted, respectively, of a total of 61 and 19 species per patch, on average.

During the period of farming process transition, 60% of cropped land was under maize. Patches of *Digitarietum ischaemii* were seldom, whereas patches of *Echinochloo-Setarietum* became the dominant association which was much more diversified internally compared to period I. Hygrophilous species representing the syntaxa analysed clearly withdrew from the phytocenoses. Similarly, there was a clear decrease in the number of acidophilous species, particularly *Spergula arvensis*, *Anthemis arvensis* and *Rumex acetosella*. Moreover, there was observed a marked increase in the share of panicoid weeds but the overall weed cover

in maize decreased. Also, the number of species making up the phytocenoses and the average number of species per relevé diminished (58 and 15, respectively). The above-mentioned changes progressed during the period of intensive farming, when only maize was cultivated. The dominance of *Echinochloa crus-galli*

increased by further 30% compared with the previous period. The number and cover of nitrophilous species increased, the greatest changes being observed for *Thlaspi arvense*. The overall number of species slightly decreased to a level of 50, but the average number of species per patch remained the same.

Tabela 2
Changes in weed communities of cereal crops in years 1994-2010

Farming system	traditional		transformation period		intensive	
In period	1994-1997		2002-2004		2008-2010	
Numbers of species with in the releve	17-32 24		15-29 23		17-27 22	
Numbers of releves	23		10		10	
Cultivated plant:	<i>Secale cereale</i>		<i>Secale cereale/Triticale</i>		<i>Triticale</i>	
no	1		2		3	
	S	D	S	D	S	D
I. Ch. Isoëto-Nanojuncetea						
<i>Juncus bufonius</i>	V	502	V	465	III	275
<i>Juncus capitatus</i>	IV	215	III	40		
<i>Plantago intermedia</i>	III	61	III	100	II	30
<i>Gnaphalium uliginosum</i>	III	123	III	180	II	70
II. Ch. Radiolion Linoidis						
<i>Hypericum humifusum</i>	IV	306	III	90	II	40
<i>Radiola linoides</i>	V	572	III	50	I	10
<i>Gypsophila muralis</i>	I	17	II	30	I	10
<i>Centunculus minimus</i>	V	274	II	80	I	20
<i>Myosurus minimus</i>	II	69	III	130	II	70
III. Ch. Spergulario-Illecebreum verticillati						
<i>Illecebreum verticillatum</i>	V	865	IV	150	II	20
<i>Spergularia rubra</i>	IV	83	II	30	II	30
IV. D. var. hygrophilous species						
<i>Polygonum hydropiper</i>	IV	174	III	140	IV	140
<i>Sagina procumbens</i>	IV	189	II	40	II	30
<i>Peplis portula</i>	III	113	III	50	II	40
<i>Veronica serpyllifolia</i>	III	61	III	50	I	10
<i>Bidens tripartita</i>	III	56	III	50	IV	60
<i>Mentha arvensis</i>	II	74	II	80	II	30
<i>Stachys palustris</i>	II	35	II	40	II	80
<i>Potentilla anserina</i>	II	22	I	20	I	20
<i>Lysimachia nummularia</i>	I	13	III	20		
V. Ch. Arnoserido-Scleranthetum						
<i>Arnosseris minimus</i>	III	350	I	10		
<i>Anthoxanthum aristatum</i>	II	133	II	30	III	130
<i>Scleranthus annuus</i>	II	22	I	90	I	10

VI. Ch. Vicietum tetraspermae

<i>Vicia tetrasperma</i>	I	6	II	235	IV	520
<i>Bromus secalinus</i>					III	345
<i>Polygonum tomentosum</i>	I	13	II	30	II	40

VII. Ch.D. Aperion spicae-venti**Centauretalia cyani**

<i>Apera spica-venti</i>	V	750	V	785	V	505
<i>Anthemis arvensis</i>	IV	233	IV	355	IV	200
<i>Spergula arvensis</i>	IV	91	IV	110	II	80
<i>Centaurea cyanus</i>	III	74	III	90	III	60
<i>Vicia hirsuta</i>	I	128	II	370	III	360
<i>Arabidopsis thaliana</i>	I	4	I	10	II	70
<i>Vicia angustifolia</i>	I	9	I	10	II	30
<i>Vicia villosa</i>					III	500

VII. Ch. Stellarietea mediae

<i>Viola arvensis</i>	IV	96	V	170	V	210
<i>Fallopia convolvulus</i>	III	52	IV	70	IV	110
<i>Stellaria media</i>	II	22	I	20	II	30
<i>Polygonum aviculare</i> s.	II	22	II	30	I	20
<i>Chenopodium album</i>	II	22	I	10	I	10
<i>Myosotis arvensis</i>	II	26	I	20	II	30
<i>Matricaria maritima</i> subsp. <i>inodora</i>	I	9	III	130	III	220
<i>Sonchus arvensis</i>	I	17			III	130
<i>Oxalis fontana</i>	I	4	I	10	II	30
<i>Echinochloa crus-galli</i>			I	20	II	30

VIII. Accompanying species

<i>Rumex acetosella</i>	IV	243	IV	110	II	40
<i>Equisetum sylvaticum</i>	IV	78	III	100	II	30
<i>Veronica arvensis</i>	II	26	II	40	III	50
<i>Cirsium arvense</i>	II	22	II	40	II	120
<i>Elymus repens</i>	II	30			I	20
<i>Equisetum arvense</i>	II	26	I	10	I	10
<i>Rhinanthus serotinus</i>	I	52	II	120	II	235
<i>Daucus carota</i>	I	13	II	20	II	30
<i>Poa annua</i>	I	17	II	30	II	30
<i>Arenaria serpyllifolia</i>			I	60	II	30
<i>Galium aparine</i>					III	130

Sporadic species: *II* – *Riccia sorocarpa* 1; *Anthoceros punctatus* 1; *V* – *Teesdalea nudicaulis* 1; *VII* – *Capsella bursa-pastoris* 1,2,3; *Galeopsis tetrahit* 1,2,3; *Geranium pusillum* 1,2; *Digitaria ischaemum* 1,2; *Raphanus raphanistrum* 1; *Setaria pumila* 1; *Sonchus oleraceus* 2,3; *Conyza canadensis* 3; *VIII* – *Polygonum lapathifolium* 1,2,3; *Ranunculus repens* 1,2,3; *Achillea millefolium* 1,2,3; *Melandrium album* 1,2,3; *Cerastium arvense* 1,2; *Rumex obtusifolius* 1,2; *Trifolium repens* 1,2; *Rorippa sylvestris* 1,2; *Erodium cicutarium* 1,2; *Agrostis stolonifera* 1,3; *Convolvulus arvensis* 1,3; *Knautia arvensis* 1,3; *Lactuca serriola* 1,3; *Allium vineale* 1; *Cerastium holosteoides* 1; *Epilobium montanum* 1; *Galeopsis ladanum* 1; *Leontodon autumnalis* 1; *Lysimachia vulgaris* 1; *Medicago sativa falcata* 1; *Plantago lanceolata* 1; *Polygonum amphibium* 1; *Stellaria graminea* 1; *Cerastium semidecandrum* 2; *Symphytum officinale* 3;

Explanatory notes: numbers after species inform about numbers of columns in the table:

S – phytosociological constancy, D – cover factor;

Table 3
Changes in weed communities of tuber crops/maize in years 1994-2010

Farming system	traditional		transformation period		intensive	
In period	1994-1997		2002-2004		2008-2010	
Numbers of species with in the releve	17-24		13-18		14-18	
	19		15		15	
Numbers of releves	10		10		10	
No.	1		2		3	
	S	D	S	D	S	D
I. Ch. <i>Isoëto-Nanojuncetea</i>						
<i>Juncus bufonius</i>	V	990	III	140	II	40
<i>Gnaphalium uliginosum</i>	III	140	II	70		
<i>Juncus capitatus</i>	II	40				
<i>Plantago intermedia</i>			I	20	I	10
II. Ch. <i>Radiolion linoidis</i>						
<i>Hypericum humifusum</i>	I	10	I	20		
<i>Radiola linoides</i>	II	30				
<i>Ranunculus sardous</i>			I	10		
III. Ch. <i>Spergulario-Illecebretum verticillati</i>						
<i>Illecebrum verticillatum</i>	V	630	II	0		
<i>Spergularia rubra</i>	II	40	II	30	II	30
IV. D. var. hygrophilous species						
<i>Bidens tripartita</i>	III	425			II	110
<i>Polygonum hydropiper</i>	III	220	I	20	II	80
<i>Mentha arvensis</i>	II	245	II	30	II	30
<i>Peplis portula</i>	II	245			II	160
<i>Veronica serpyllifolia</i>	II	30	I	30		
<i>Potentilla anserina</i>	I	20	II	30	I	10
<i>Equisetum sylvaticum</i>	I	20	II	40	II	30
<i>Sagina procumbens</i>	I	20			II	30
V. Ch. <i>Digitarietum ischaemi</i>						
<i>Digitaria ischaemum</i>	IV	422	V	510	V	250
VI. Ch. <i>Echinochloo-Setarietum</i>						
<i>Echinochloa crus-galli</i>	III	850	V	1570	V	2175
<i>Raphanus raphanistrum</i>	III	50	I	20	I	20
VII. Ch. <i>Panico-Setarion</i>						
<i>Setaria pumila</i>	III	30	V	405	V	530
<i>Setaria viridis</i>	II	70	II	110	III	170
<i>Spergula arvensis</i>	IV	385	I	10	I	10
<i>Rumex acetosella</i>	IV	110	III	60	II	40
VIII. Ch.D <i>Polygono-Chenopodion</i>						
<i>Polygono-Chenopodietalia</i>						
<i>Chenopodium album</i>	IV	315	III	80	III	130
<i>Galinsoga parviflora</i>	I	10	I	60	II	80
<i>Capsella bursa-pastoris</i>	I	10	II	40	II	80

IX. Ch. *Stellarietea mediae*

<i>Viola arvensis</i>	V	120	II	30	II	30
<i>Anthemis arvensis</i>	IV	200	II	70	II	30
<i>Fallopia convolvulus</i>	III	80	II	30	II	30
<i>Centaurea cyanus</i>	III	50	I	20	I	20
<i>Conyza canadensis</i>	II	30				
<i>Thlaspi arvense</i>	I	10	II	40	III	295
<i>Stellaria media</i>	I	60	II	30	II	40
<i>Matricaria maritima</i> subsp. <i>inodora</i>					II	40

X. Accompanying species

<i>Elymus repens</i>	V	335	IV	150	III	140
<i>Achillea millefolium</i>	II	30	I	20	I	10
<i>Veronica arvensis</i>	II	70	I	20	II	30
<i>Cirsium arvense</i>	II	30	I	10	I	60
<i>Erodium cicutarium</i>	II	40	I	10	I	10
<i>Galeopsis ladanum</i>	II	40	I	10		
<i>Polygonum persicaria</i>	II	30				
<i>Amaranthus retroflexus</i>	I	50	I	60	II	30
<i>Polygonum lapathifolium</i>	I	20	I	20	II	120
<i>Galium aparine</i>	I	10	II	20	II	40
<i>Agrostis stolonifera</i>			I	20	II	30

Sporadic species: IV – *Stachys palustris* 1,2,3; *Lysimachia nummularia* 2; VIII – *Euphorbia helioscopia* 1,3; *Polygonum aviculare* s. 1; *Chenopodium polyspermum* 1; *Sonchus oleraceus* 2,3; *Sonchus arvensis* 2; IX – *Anthoxanthum aristatum* 1,2; *Arnoseris minima* 1; *Scleranthus annuus* 1; *Vicia hirsuta* 1; *Vicia angustifolia* 1; *Vicia villosa* 1; *Vicia tetrasperma* 3; *Galeopsis tetrahit* 1; *Myosotis arvensis* 2,3; *Lapsana communis* 2,3; X – *Taraxacum officinale* 1,2,3; *Convolvulus arvensis* 1,2,3; *Equisetum arvense* 1,2,3; *Lactuca serriola* 1,2,3; *Erysimum cheiranthoides* 1; *Arenaria serpyllifolia* 1; *Equisetum sylvaticum* 1; *Stellaria graminea* 1; *Stellaria graminea* 2; *Ranunculus repens* 2; *Rhinanthus serotinus* 2; *Leontodon autumnalis* 2; *Knautia arvensis* 2; *Cerastium holosteoides* 2; *Medicago falcata* 2; *Plantago lanceolata* 2,3; *Rorippa sylvestris* 3; *Poa annua* 3;

Explanatory notes: numbers after species inform about numbers of columns in the table:

S – phytosociological constancy, D – cover factor;

Index of community dynamics and similarity

The comparison of the conditions in period I and II in the agrophytocenoses studied revealed changes leading to the impoverishment and simplification of communities. In the crop groups analysed, the number of disappearing and withdrawing species was not compensated by new taxa (Table 4).

92 species in stubble fields, 71 in cereals and 50 in tuber crops/maize displayed dynamic tendencies. The withdrawing species included stenotopic taxa, that is, hygrophilous and acidophilous species which were withdrawing due to changes in habitat conditions (Table 5). The group of spreading species was less numerous. These weeds have a wide ecological amplitude;

moreover, they are usually common species/ taxa with a high nutrient requirement (Table 6).

The comparison of the communities for the period analysed by means of Sørensen's index (SW_s) confirmed marked similarities between period I and II communities for all the crop groups analysed (Table 7). The changes in agrocenoses over these periods were slow. Much greater differences were found when periods II and III were compared. The value of the index diminished clearly, which was accompanied by an increase in field production intensification and changes in agrophytocenoses. The lowest value of the index was obtained when period I was compared with period III. The similarity was as low as $SW_s = 0.29$ for tuber crops/maize.

Table 4
Number of species responding to changes in farming methods

Site	Stubble	Cereals	Tuber crops / <i>Zea mays</i>
Number of species found in period I only	35	19	22
Number of species found in period II only	10	5	10
Number of withdrawing species	55	38	35
Number of species with increasing cover	27	33	15

Table 5
Dynamic index of the weed species decreasing the coverage in years 1994–1997 – 2008–2010

Cultivated plant:	stubble field	cereals	root crops/ <i>Zea mays</i>
Dynamic index	V	V	V
<i>Radiola linoides</i>	16	11	0
<i>Juncus capitatus</i>	26	0	0
<i>Centunculus minimus</i>	28	22	
<i>Illecebrum verticillatum</i>	31	30	0
<i>Gnaphalium luteoalbum</i>	32		
<i>Potentilla norvegica</i>	28		
<i>Gypsophila muralis</i>	35	58	
<i>Hypericum humifusum</i>	45	51	0
<i>Plantago intermedia</i>	61	63	
<i>Sagina procumbens</i>	41	46	0
<i>Gnaphalium uliginosum</i>	57	58	50
<i>Veronica serpyllifolia</i>	39	23	0
<i>Scleranthus annuus</i>	31	46	0
<i>Digitaria ischaemum</i>	65	0	
<i>Arnoseris minima</i>	39	0	0
<i>Spergularia rubra</i>	51	46	75
<i>Juncus bufonius</i>	65	73	44
<i>Equisetum arvense</i>	39	38	50
<i>Polygonum hydropiper</i>	87	86	67
<i>Peplis portula</i>	83	92	100
<i>Mentha arvensis</i>	68	77	100
<i>Rumex acetosella</i>	65	66	57
<i>Polygonum aviculare</i>	75	92	0
<i>Raphanus raphanistrum</i>	75	0	40
<i>Convolvulus arvensis</i>	48	77	50
<i>Spergula arvensis</i>	47	54	17
<i>Erodium cicutarium</i>	22	0	25
<i>Fallopia convolvulus</i>	46		75
<i>Cirsium arvense</i>	73		67
<i>Oxalis fontana</i>	39		
<i>Galeopsis tetrahit</i>	32		0
<i>Myosotis arvensis</i>	55		
<i>Sonchus arvensis</i>	55		
<i>Centaurea cyanus</i>	48		40
<i>Plantago major</i>	48		
<i>Stellaria graminea</i>	48	0	
<i>Vicia angustifolia</i>	48		0
<i>Lysimachia nummularia</i>	48	0	
<i>Apera spica-venti</i>	24		
<i>Plantago lanceolata</i>	24	0	
<i>Cerastium holosteoides</i>	22	0	

<i>Poa annua</i>	65		
<i>Leontodon autumnalis</i>	22	0	
<i>Ranunculus repens</i>	18		
<i>Achillea millefolium</i>	29		33
<i>Chenopodium album</i>		46	71
<i>Elymus repens</i>		66	67
<i>Potentilla anserina</i>		92	50
<i>Anthemis arvensis</i>			38
<i>Viola arvensis</i>			38
<i>Equisetum sylvaticum</i>		49	
<i>Myosurus minimus</i>		86	

Table 6
Dynamic index of the weed species increasing the coverage in years 1994–1997 – 2008–2010

Cultivated plant:	stubble field	cereals	root crops/ Zea mays
Dynamic index	V	V	V
<i>Amaranthus retroflexus</i>	581		300
<i>Echinochloa crus-galli</i>	517		250
<i>Capsella bursa-pastoris</i>	388	153	400
<i>Veronica arvensis</i>	218	192	100
<i>Polygonum lapathifolium subsp. lapathifolium</i>	151	58	200
<i>Stellaria media</i>	149	138	200
<i>Stachys palustris</i>	113	115	200
<i>Matricaria maritima subsp. inodora</i>	504	690	
<i>Arabidopsis thaliana</i>	129	690	
<i>Arenaria serpyllifolia</i>	129	345	
<i>Agrostis stolonifera</i>	388	115	
<i>Polygonum lapathifolium subsp. pallidum</i>	291	307	
<i>Bidens tripartita</i>	178	106	
<i>Rorippa sylvestris</i>	161	115	
<i>Vicia hirsuta</i>	121	230	
<i>Galinsoga parviflora</i>	221		300
<i>Trifolium repens</i>	194		200
<i>Setaria pumila</i>	194		300
<i>Polygonum persicaria</i>	388		
<i>Symphytum officinale</i>	388		
<i>Geranium pusillum</i>	194		
<i>Chenopodium album</i>	145		
<i>Elymus repens</i>	138		
<i>Potentilla anserina</i>	136		
<i>Vicia tetrasperma</i>		805	
<i>Lactuca serriola</i>		460	
<i>Oxalis fontana</i>		690	
<i>Vicia angustifolia</i>		345	
<i>Sonchus arvensis</i>		288	
<i>Myosotis stricta</i>		230	
<i>Daucus carota</i>		230	
<i>Rhinanthus serotinus</i>		173	
<i>Cirsium arvense</i>		153	
<i>Fallopia convolvulus</i>		134	
<i>Veronica persica</i>			500
<i>Galium aparine</i>			400
<i>Euphorbia helioscopia</i>			200
<i>Setaria viridis</i>			167
<i>Equisetum sylvaticum</i>			150

Table 7
Values of Sørensen's index for communities in individual study periods

Periods compared Site	I - II	II - III	I - III
Stubble field	0.456	0.405	0.355
<i>Secale cereale</i>	0.484	0.416	0.373
Tuber crops / <i>Zea mays</i>	0.336	0.318	0.291

DISCUSSION

The changes due to farming intensification taking place over 17 years in the communities with *Radiolion linoidis* indicated an improved nutrient status of these habitats. The community composition and structure changed; all the syntaxa with species representing the aforementioned association disappeared in stubble fields, cereals and tuber crops. They were replaced by associations widespread in Poland and characterised by wide amplitude of habitats where they grow. The association *Echinochloa-Setarietum* was observed in stubble fields and maize, whereas *Vicietum tetraspermae* and species-impovertised communities representing the association *Aperion spicae-venti* were found in cereals. The scale of these transformations is also reflected in the low value of Sørensen's coefficient. The analysis of the changes in species composition of the communities in period I and III demonstrated that the species disappeared much faster than new ones appeared (Table 4, 5). Many works, both Polish and foreign, have examined the issue of impoverishment and disappearance of specialised communities [2,5,19–24].

Species that spread and reached the highest values of the dynamics index included eurytopic and nitrophilous species, such as: *Echinochloa crus-galli*, *Chenopodium album*, *Galinsoga parviflora*, *Stellaria media*, *Matricaria maritima* subsp. *inodora* and *Elymus repens*, which are believed to be common expansive weeds in Poland [25,26]. The establishment of these species is possible, because maize has become a dominant crop plant and now the area under maize is around 60% of cropped land. Communities establishing in maize consist of the smallest number of species (an average of 16 species per patch), compared with cereals or tuber crops. According to Gołębiewska and Kaus [27], the number of weedy species in maize depends on weed control methods and ranges from 11 to 16 species per relevé [28], whereas monoculture is associated with the following dominant species: *Chenopodium album*, *Echinochloa crus-galli*, *Elymus repens* and others [29]. The application of herbicides, e.g. triazine products, substantially reduces the development of weeds [28] whereas monoculture is associated with the development of weed dominance, for example *Chenopodium album*, *Echinochloa crus-galli*, *Elymus repens*, and others. Compensation of

weeds which quickly develop resistance to herbicides has already been noticed in the agrocenoses studied, as exemplified by a mass occurrence of *Echinochloa crus-galli*

CONCLUSIONS

1. Communities from the *Radiolion linoidis* alliance were greatly reduced due to changes in farming methods.
2. Acidophilous phytocenoses *Spergulario-Illecebre-tum verticillati* disappeared in stubble fields, while phytocenoses with *Illecebrum verticillatum* in cereals and tuber crops.
3. Various forms of the common association *Echinochloa-Setarietum* established in maize and stubble fields, whereas patches of *Vicietum tetraspermae* in cereals.
4. The greatest differences were found for the communities between study period I and III, as reflected by a low value of Sørensen's index ($SW_s=0.29$).
5. The impoverishment of communities took place; the number of disappearing and withdrawing species was higher than the number of new taxa.

Acknowledgements

Research supported by the Ministry of Science and Higher Education of Poland as part of the statutory of the Department of Agricultural Ecology, Siedlce University of Natural Sciences and Humanities.

REFERENCES

1. Ellis RH, Nelson IL, Hopkins GW, Hamlett BJ, Memmott J. Pollinator webs, plant communities and the conservation of rare plants: arable weeds as a case study: pollinator webs and rare plant conservation. *J Appl Ecol.* 2006; 43(2): 246–257. <http://dx.doi.org/10.1111/j.1365-2664.2006.01130.x>
2. Kornaś J. The extinction of the association *Sperguleto-Lolietum remoti* in flax cultures in the Gorce (Polish Western Carpathian Mountains). *Bull Acad Pol Sci.* 1961; 2(9): 37–40.
3. Kulp HG, Cordes H. Veränderung der soziologischen Bindung in Ackerwildkraut-Gesellschaften auf Sandböden. *Tuexenia.* 1986; (6): 25–36.

4. Popiela A. The distribution of character species of the *Isoëto-Nanojuncetea*-class in Poland: *Centunculus minimus*, *Radiola linoides* and *Ilecebrum verticillatum*. *Fragm Flor Geobot.* 1998; 43(2): 223–230.
5. Lososová Z. Estimating past distribution of vanishing weed vegetation in South Moravia. *Preslia.* 2003; 75(1): 71–79.
6. Hoste I, van Landuyt W, Verloove F. Landschap en flora in beweging, 19de en 20ste eeuw. In: van Landuyt W, Hoste I, Vanhecke L, van den Brecht P, Verduyck W, de Beer D, editors. *Atlas van de Flora van Vlaanderen en het Brussels Gewest.* 2006. p. 45–67.
7. Storkey J, Meyer S, Still KS, Leuschner C. The impact of agricultural intensification and land-use change on the European arable flora. *Proc Biol Sci.* 2011; 279(1732): 1421–1429. <http://dx.doi.org/10.1098/rspb.2011.1686>
8. Ratyńska H, Boratyński A. Czynna ochrona roślin i zbiorowisk segetalnych i ruderalnych [Active protection of segetal and ruderal plants and vegetation]. *Przegl Przyr.* 2000; 11(2–3): 43–56.
9. Skrzyczyńska J, Skrajna T. Flora segetalna Wysoczyzny Kałuszyńskiej [The segetal flora of the Kałuszyn Upland]. *Acta Agrobot.* 1999; 52(1–2): 183–202. <http://dx.doi.org/10.5586/aa.1999.019>
10. Skrzyczyńska J, Skrajna T. Zbiorowiska polne Wysoczyzny Kałuszyńskiej. Cz I. Zespoły zbożowe [Field communities of the Kałuszyn Upland. Part I. Cereal communities]. *Fragm Agron.* 2004; 4(84): 32–44.
11. Skrajna T, Skrzyczyńska J. Chwasty ściernisk Wysoczyzny Kałuszyńskiej [Weeds of stubble fields of the Kałuszyn Upland]. *Zesz Nauk Akad Ped Siedlce Ser Rol.* 2003; 63: 59–69.
12. Skrajna T, Skrzyczyńska J. Stanowiska wilgociolubnych chwastów polnych na Wysoczyźnie Kałuszyńskiej [Stations of the selected hygrophilous field weeds in the Kałuszyńska Upland]. *Fragm Flor Geobot Pol.* 2006; 13(2): 293–299.
13. Skrajna T, Skrzyczyńska J. Plant communities and associations of root crops of the Kałuszyńska Upland. *Acta Agrobot.* 2008; 61(2): 121. <http://dx.doi.org/10.5586/aa.2008.052>
14. Woś A. Climatic regions of Poland. Polish Scientific Publishers PWN; 1999. p 183–224.
15. Pawłowski B. Skład i budowa zbiorowisk roślinnych oraz metody ich badania. [In:] Szafer W., Zarzycki K, editor. *Szata roślinna Polski I.* Warsaw: Polish Scientific Publishers PWN; 1972. p. 237–268.
16. Matuszkiewicz W. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Warsaw: Polish Scientific Publishers PWN; 2001.
17. Korniak T. Flora segetalna północno-wschodniej Polski, jej przestrzenne zróżnicowanie i współczesne przemiany [Segetal flora of north-eastern Poland, its spatial variation and modern changes]. *Acta Acad Agric Tech Olst Agric.* 1992; 53(supp A): 3–76.
18. Mirek Z, Piękoś-Mirkowa H, Zajac A, Zajac M. Flowering plants and pteridophytes of Poland – a checklist. In: Mirek Z, editor. *Biodiversity of Poland.* Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2002; 1: 442.
19. Kornaś J. Zespoły synantropijne. [In:] Szafer W, Zarzycki K, editors. *Szata roślinna Polski I.* Polish Scientific Publishers PWN; 1972; 1: 442–465.
20. Pinke G. Letzte Vorkommen von *Caucalidion* – Arten im Nordwesten Ungarns. *J Plant Prot.* 2004; 19: 73–82.
21. Smart SM, Bunce RGH, Marrs R, LeDuc M, Firbank LG, Maskell LC, et al. Large-scale changes in the abundance of common higher plant species across Britain between 1978, 1990 and 1998 as a consequence of human activity: tests of hypothesised changes in trait representation. *Biol Conserv.* 2005; 124(3): 355–371. <http://dx.doi.org/10.1016/j.biocon.2004.12.013>
22. Kropáč Z. Segetal vegetation in the Czech Republic: synthesis and syntaxonomical revision. *Preslia.* 2006; 78: 123–209.
23. Clark CM, Tilman D. Loss of plant species after chronic low-level nitrogen deposition to prairie grasslands. *Nature.* 2008; 451(7179): 712–715. <http://dx.doi.org/10.1038/nature06503>
24. Lososova Z, Simonova D. Changes during the 20th century in species composition of synanthropic vegetation in Moravia (Czech Republic). *Preslia.* 2008; 80: 291–305.
25. Towpasz K, Barabasz-Krasny B. Differentiation of segetal vegetation in the Czarnożęcko-Strzyżowski Landscape Park (Southeastern Poland). *Pam Puł.* 2006; 143: 183–193.
26. Węgrzynek B. Alien plant species as the source of noxious weeds in Poland. In: Pyšek P, Pergl J, editors. *Biological Invasion: towards a synthesis.* Neobiota. 8; 2009. p. 111–121.
27. Gołębiewska H, Kaus A. Wpływ zróżnicowanych systemów uprawy na stan zachwaszczenia kukurydzy [Influence of diversified tillage systems on weed infestation in crop maize]. *Prog Plant Prot Post W Ochr Roślin.* 2009; 49(2): 792–796.
28. Pyšek P, Jarošík V, Kropáč Z, Chytrý M, Wild J, Tichý L. Effects of abiotic factors on species richness and cover in Central European weed communities. *Agric Ecosyst Env.* 2005; 109(1–2): 1–8. <http://dx.doi.org/10.1016/j.agee.2005.02.018>
29. Głowacka A. Dominant weeds in maize (*Zea mays* L.) cultivation and their competitiveness under conditions of various methods of weed control. *Acta Agrobot.* 2011; 64(2): 119. <http://dx.doi.org/10.5586/aa.2011.023>

**Wpływ sposobu gospodarowania na dynamikę
zbiorowisk ze związku *Radiolion linoidis*
(Rias Goday 1961) Pietach 1965
w agrocenozach Wysoczyzny Kałuszyńskiej**

Streszczenie

W pracy przedstawiono rezultaty badań przeprowadzonych w latach 1994–2010 dotyczących przemian fitocenoz z gatunkami *Radiolion linoidis* wywołanych wzrostem intensyfikacji procesu produkcji. Materiał badawczy stanowiło 136 zdjęć fitosocjologicznych wykonanych na stałych powierzchniach w uprawach zbóż, okopowych/kukurydzy i na ścierniskach. Zdjęcia pogrupowano na trzy okresy przedstawiające zmiany sposobu

produkcji. I-okres (lata 1994–1997) tradycyjny sposób gospodarowania; II – okres (lata 2002–2004) – okres przestawiania produkcji na intensywną i III – okres (lata 2008–2010) – intensywny sposób gospodarowania. W okresie badań, na skutek intensyfikacji uprawy zanikają zbiorowiska z *Radiolion linoidis*. Notowane w I okresie fitocenozy *Spergulario-Illecebreum verticillati* na ścierniskach i zbiorowiska z udziałem *Illecebrum verticillatum* w uprawach zbóż i okopowych zastępowane są w III okresie przez płaty *Echinochloo-Setarietum* w zasiewach kukurydzy i na ścierniskach oraz asocjacje *Vicietum tetraspermae* w zbożach. Wyliczone wartości wskaźników podobieństwa zbiorowisk Sørensen i dynamiki podkreślają głęboki zakres przemian i ubożenia zbiorowisk.

Handling Editor: Elżbieta Weryszko-Chmielewska

This is an Open Access digital version of the article distributed under the terms of the Creative Commons Attribution 3.0 License (creativecommons.org/licenses/by/3.0/), which permits redistribution, commercial and non-commercial, provided that the article is properly cited.

©The Author(s) 2013 Published by Polish Botanical Society