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

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**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-Illecebretum verticillati* found in stubble fields and communities with *Illecebrum verticillatum* observed in cereals and tuber crops in period I were replaced with patches of *Echinochloa-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 Kaluszyn 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 form 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 ($S_W$) was employed to reflect the extent of changes in communities in individual study periods. The index was calculated according to the following formula:

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

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-Illecebratum verticillati* and *Digitarietum 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 | |

I. Ch. Spergulario-Illecebritum verticillati

| Illecebrum verticillaturn | V | 1389 | IV | 250 | II | 31 |
|--------------------------|---|------|----|-----|----|----|
| Spergularia rubra | IV | 152 | III | 119 | II | 81 |

II. Ch. Radiolion linoidis

| Hypericum humifusum | V | 839 | IV | 237 | II | 165 |
|---------------------|---|-----|----|-----|----|-----|
| Radiola linoides | V | 397 | III | 75 | I | 6 |
| Gypsophila muralis | II | 46 | II | 96 | I | 12 |
| Centunculus minima | IV | 219 | III | 93 | I | 12 |

III. Ch. Isoëto-Nanojuncetea

| Juncus bufonius | V | 516 | V | 250 | IV | 162 |
|------------------|---|-----|---|-----|----|-----|
| Juncus capitatus | IV | 213 | IV | 112 | I | 12 |
| Plantago intermedia | IV | 258 | III | 100 | II | 67 |
| Gnaphalium uliginosum | V | 316 | III | 312 | III | 62 |
| Gnaphalium luteo-album | II | 22 | I | 6 | I | 6 |

IV. D. var. hygrophilous species

| Veronica serpyllifolia | V | 442 | IV | 187 | II | 5 |
|------------------------|---|-----|----|-----|----|---|
| Polygonum hydropiper | IV | 406 | III | 100 | III | 334 |
| Sagina procumbens | IV | 179 | III | 69 | II | 18 |
| Mentha arvensis | III | 555 | III | 93 | II | 87 |
| Peplis portula | III | 147 | II | 50 | II | 319 |
| Stachys palustris | II | 202 | II | 56 | III | 197 |
| Bidens tripartita | II | 77 | I | 56 | IV | 372 |
| Potentilla anserina | II | 32 | II | 31 | III | 68 |
| Lysimachia nummularia | II | 64 | II | 31 | I | 19 |

IV. Ch. Aperion spica-venti, Centauretalia cyanii

| Scleranthus annuus | IV | 87 | III | 50 | I | 19 |
|---------------------|---|-----|----|----|---|---|
| Anthemis arvensis | III | 111 | IV | 112 | IV | 197 |
| Centarea cyanus | III | 51 | II | 69 | II | 25 |
| Arnoseris minima | III | 61 | I | 6 | I | 43 |
| Anthoxanthum aristatum | II | 58 | II | 25 | II | 75 |
| Vicia hirsuta | II | 26 | II | 31 | II | 31 |
| Apera spica-venti | II | 26 | II | 25 | I | 6 |
| Vicia angustifolia | II | 25 | I | 19 | I | 12 |
| Teesdalea nudicaulis | II | 32 | | | | |

V. Ch. Digitarietum ischaemum

| Digitaria ischaemum | IV | 425 | V | 628 | III | 281 |

VI. Ch. Echinochlooo-Setarietum

| Echinochloa crus-galli | I | 32 | IV | 1022 | V | 1246 |
|------------------------|---|----|----|------|---|-----|
| Raphanus raphanistrum | III | 67 | II | 31 | II | 56 |
VII. Ch. Panico-Setarion

| Species           | S | P | IV | III | II |
|-------------------|---|---|----|-----|----|
| Spergula arvensis | V | 135| IV  | 87  | II  | 87 |
| Rumex acetosella  | V | 584| III | 106 | III | 81 |
| Setaria pumila    | II | 61 | IV  | 578 | IV  | 584|
| Setaria viridis   | II | 58 | III | 284 | II  | 100|

VIII. Ch. Polygono-Chenopodietalia Polygono-Chenopodion

| Species             | S | P | IV | III | II |
|---------------------|---|---|----|-----|----|
| Chenopodium album   | III| 252| V  | 569 | IV  | 459|
| Polygonum aviculare s. | III| 58 | IV  | 62  | III | 68 |
| Sonchus arvensis    | II | 22 | I   | 44  | I   | 37 |
| Galinsoga parviflora | II | 35 | III | 203 | I   | 6  |
| Veronica persica    | II | 100| II  | 184 | I   | 6  |
| Capsella bursa-pastoris | I | 6  | I   | 12  | I   | 25 |

IX. Ch. Stellarietea mediae

| Species         | S | P | IV | III | II |
|-----------------|---|---|----|-----|----|
| Viola arvensis  | IV | 61 | IV  | 451 | IV  | 284|
| Fallopia convolvulus | IV | 81 | IV  | 112 | II  | 56 |
| Stellaria media | III| 80 | V   | 600 | IV  | 265|
| Matricaria maritima subsp. inodora | I | 69 | II  | 106 | IV  | 353|
| Conyza canadensis | II | 106| II  | 37  | II  | 62 |
| Myosotis arvensis | I | 22 | I   | 6   | I   | 37 |

X. Accompanying species

| Species             | S | P | IV | III | II |
|---------------------|---|---|----|-----|----|
| Achillea millefolium | IV | 64 | III | 44  | I   | 19 |
| Elymus repens       | III | 71 | III | 106 | III | 725|
| Equisetum arvense   | III| 61 | III | 69  | I   | 44 |
| Veronica arvensis   | II | 26 | II  | 31  | III | 125|
| Polygonum lapatifolium | II | 45 | II  | 25  | III | 68 |
| Cerastium holostoeides | II | 26 | II  | 31  | I   | 6  |
| Cirsiwm arvense     | II | 39 | I   | 37  | I   | 44 |
| Convolvulus arvensis | I | 26 | I   | 19  | I   | 12 |
| Ranunculus repens   | II | 35 | I   | 9   | I   | 6  |
| Hypochoeris radicata | II | 8  | I   | 6   | I   | 12 |
| Plantago lanceolata | II | 6  | I   | 6   | I   | 6  |
| Erodium cicutarium  | II | 29 | I   | 6   | I   | 6  |
| Leontodon autumnalis | II | 48 | I   | 6   |    |    |
| Polygonum persicaria | I | 13 | II  | 56  | III | 100|
| Rorippa sylvestris  | I | 13 | I   | 13  | III | 184|
| Trifolium repens    | I | 13 | I   | 9   | I   | 25 |
| Agrostis stolonifera | I | 6  | I   | 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; 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; Taraxacum vulgar 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. *Echinocloaceae-Setarietum*, as well as the community *Setaria pumilla-Setaria viridis*. The cover of *Illecebrum verticillatum*, all the species from *Radiola linoidis* and *Isoëto-Nanojuncetalia* 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-Nanojuncetalia*. What is more, phytocenoses of the association *Spergulario-Illecebrutum 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 agroecenoses included the association *Arnoseris minima*, 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 Nanojuncetalia*, in which the species with the highest constancy and cover included the following: *Radiola linoides*, *Centunculus minimus*, *Hypericum humifusum*, *Juncus bufonius* and *Juncus capitatus*. *Arnoseris 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 weed 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. Agroecenoses 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 *Arnoseris 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. Agroecenoses 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 *Gallium 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 ischaemii* was frequently found in the typical variant and the variant with *Illecebrum verticillatum*, whereas the variant with *Echinocloaceae-Setarietum sperguletosum* was infrequent (Table 3). Hygrophilous species from the class *Isoëto-Nanojuncetalia* – *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 *Echinocloaceae-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 (1994-1997) | transformation period (2002-2004) | intensive (2008-2010) |
|----------------|------------------------|---------------------------------|----------------------|
| In period      |                        |                                 |                      |
| Numbers of species with in the relevé | 17-32                  | 15-29                           | 17-27                |
| Numbers of relevés | 24                     | 23                              | 22                   |
| Cultivated plant: |                       |                                 |                      |
| Secale cereale  | S                      | D                               | S                    |
| Secale cereale/Triticale | D                     | S                               | D                    |
| Triticale      | S                      | D                               | S                    |

#### I. Ch. Isoëto-Nanojuncetea
- *Juncus bufonius* | V 502 | V 465 | III 275 |
- *Juncus capitatus* | IV 215 | III 40 |
- *Plantago intermedia* | III 61 | III 100 | II 30 |
- *Gnaphalium uliginosum* | III 123 | III 180 | II 70 |

#### II. Ch. Radiolion Linoidis
- *Hypericum humifusum* | IV 306 | III 90 | II 40 |
- *Radiola linoides* | V 572 | III 50 | I 10 |
- *Gypsophila muralis* | I 17 | II 30 | I 10 |
- *Centunculus minimus* | V 274 | II 80 | I 20 |
- *Myosurus minimus* | II 69 | III 130 | I 70 |

#### III. Ch. Spergulario-Illecebretum verticillati
- *Illecebrum verticillatum* | V 865 | IV 150 | II 20 |
- *Spergularia rubra* | IV 83 | II 30 | II 30 |

#### IV. D. var. hygrophilous species
- *Polygonum hydropiper* | IV 174 | III 140 | IV 140 |
- *Sagina procumbens* | IV 189 | II 40 | II 30 |
- *Peplis portula* | III 113 | III 50 | II 40 |
- *Veronica serpyllifolia* | III 61 | III 50 | I 10 |
- *Bidens tripartita* | III 56 | III 50 | IV 60 |
- *Mentha arvensis* | II 74 | II 80 | II 30 |
- *Stachys palustris* | II 35 | II 40 | II 80 |
- *Potentilla anserina* | II 22 | I 20 | I 20 |
- *Lysimachia nummularia* | I 13 | III 20 |

#### V. Ch. Arnoserido-Scleranthetum
- *Arnoseris minimus* | III 350 | I 10 |
- *Anthoxanthum aristatum* | II 133 | II 30 | III 130 |
- *Scleranthus annuus* | II 22 | I 90 | I 10 |
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| VI. Ch. *Vicietum tetraspermae* |  |
|-------------------------------|---|
| *Vicia tetrasperma*           | I 6 II 235 IV 520 |
| *Bromus secalinus*            | III 345 |
| *Polygonum tomentosum*        | I 13 II 30 II 40 |

| VII. Ch. D. *Aperion spicae-venti* |
|-----------------------------------|
| *Centaurelia cyani*               |
| *Apera spica-venti*               | V 750 V 785 V 505 |
| *Anthemis arvensis*               | IV 233 IV 355 IV 200 |
| *Spergula arvensis*               | IV 91 IV 110 II 80 |
| *Centaurea cyanus*                | III 74 III 90 III 60 |
| *Vicia hirsuta*                   | I 128 II 370 III 360 |
| *Arabidopsis thaliana*            | I 4 I 10 II 70 |
| *Vicia angustifolia*              | I 9 I 10 II 30 |
| *Vicia villosa*                   | III 500 |

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

| VIII. *Accompanying species*      |
|-----------------------------------|
| *Rumex acetosella*                | IV 243 IV 110 II 40 |
| *Equisetum sylvaticum*            | IV 78 III 100 II 30 |
| *Veronica arvensis*               | II 26 II 40 III 50 |
| *Cirsium arvense*                 | II 22 II 40 II 120 |
| *Elymus repens*                   | II 30 |
| *Equisetum arvense*               | II 26 I 10 I 10 |
| **Rhinanthus serotinus**          | I 52 II 120 II 235 |
| *Daucus carota*                   | I 13 II 20 II 30 |
| *Poa annua*                       | I 17 II 30 II 30 |
| *Arenaria serpyllifolia*          | I 60 II 30 |
| *Galium aparine*                  | 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; *Coryza canadensis* 3; VIII – *Polygonum lapathifolium* 1,2,3; *Ranunculus repens* 1,2,3; *Achillea millefolium* 1,2,3; *Melandrium album* 1,2,3; *Cerasitum 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; *Cerasitum 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; *Cerasitum 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 |
| Numbers of releves | 10 | 10 | 10 |
| No. | 1 | 2 | 3 |

| I. Ch. Isoëto-Nanojuncetea |
|---------------------------|
| *Juncus bufonius* | V | 990 | III | 140 | II | 40 |
| *Gnaphalium uliginosum* | III | 140 | II | 70 |  |
| *Juncus capitatus* | II | 40 |  |
| *Plantago intermedia* | I | 20 | I | 10 |  |

| II. Ch. Radiolion linoidis |
|---------------------------|
| *Hypericum humifusum* | I | 10 | I | 20 |  |
| *Radiola linoides* | II | 30 |  |
| *Ranunculus sardous* | I | 10 |  |

| III. Ch. Spergulario-Illecebretum verticillati |
|-----------------------------------------------|
| *Illecebrum verticillatum* | V | 630 | II | 0 |  |
| *Spergularia rubra* | II | 40 | II | 30 | II | 30 |  |

| IV. D. var. hygrophilous species |
|---------------------------------|
| *Bidens tripartita* | III | 425 | II | 110 |  |
| *Polygonum hydropiper* | III | 220 | I | 20 | II | 80 |  |
| *Mentha arvensis* | II | 245 | II | 30 | II | 30 |  |
| *Peplis portula* | II | 245 |  |
| *Veronica serpyllifolia* | II | 30 | I | 30 |  |
| *Potentilla anserina* | I | 20 | II | 30 | I | 10 |  |
| *Equisetum sylvaticum* | I | 20 | II | 40 | II | 30 |  |
| *Sagina procumbens* | I | 20 | II | 30 |  |

| V. Ch. Digitarietum ischaemi |
|------------------------------|
| *Digitaria ischaemum* | IV | 422 | V | 510 | V | 250 |  |

| VI. Ch. Echinochloa-Setarietum |
|--------------------------------|
| *Echinochloa crus-galli* | III | 850 | V | 1570 | V | 2175 |  |
| *Raphanus raphanistrum* | III | 50 | I | 20 | I | 20 |  |

| VII. Ch. Panico-Setarion |
|--------------------------|
| *Setaria pumila* | III | 30 | V | 405 | V | 530 |  |
| *Setaria viridis* | II | 70 | II | 110 | III | 170 |  |
| *Spergula arvensis* | IV | 385 | I | 10 | I | 10 |  |
| *Rumex acetosella* | IV | 110 | III | 60 | II | 40 |  |

| VIII. Ch.D Polygono-Chenopodion |
|---------------------------------|
| *Polygono-Chenopodietalia* |
| *Chenopodium album* | IV | 315 | III | 80 | III | 130 |  |
| *Galinsoga parviflora* | I | 10 | I | 60 | II | 80 |  |
| *Capsella bursa-pastoris* | I | 10 | II | 40 | II | 80 |  |
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**IX. Ch. Stellarietea media**

| Species                        | S  | D  | D  | D  |
|--------------------------------|----|----|----|----|
| *Viola arvensis*               | V  | 120| II | 30 |
| *Anthemis arvensis*            | IV | 200| II | 70 |
| *Fallopia convolvulus*         | III| 80 | II | 30 |
| *Centaurea cyanus*             | III| 50 | I  | 20 |
| *Conyza canadensis*            | II | 30 |
| *Thlaspi arvense*              | I  | 10 | II | 40 |
| *Stellaria media*              | I  | 60 | II | 30 |
| *Matricaria maritima subsp. inodora* | II | 40 |

**X. Accompanying species**

| Species                        | S  | D  | D  | D  |
|--------------------------------|----|----|----|----|
| *Elymus repens*                | V  | 335| IV | 150| III | 140|
| *Achillea millefolium*         | II | 30 | I  | 20 | I  | 10 |
| *Veronica arvensis*            | II | 70 | I  | 20 | II | 30 |
| *Cirsium arvense*              | II | 30 | I  | 10 | I  | 60 |
| *Erodium cicutarium*           | II | 40 | I  | 10 | I  | 10 |
| *Galeopsis ladanum*            | II | 40 | I  | 10 |
| *Polygonum persicaria*         | II | 30 |
| *Amaranthus retroflexus*       | I  | 50 | I  | 60 | II | 30 |
| *Polygonum lapathfolium*       | I  | 20 | I  | 20 | II | 120|
| *Galium aparine*               | I  | 10 | II | 20 | II | 40 |
| *Agrostis stolonifera*         | I  | 20 | II | 30 |

Sporadical 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; *Scleranthis annuaus* 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; *Convvolulus 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 / *Zea mays* |
|-----------------------------------|---------|---------|--------------------------|
| 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 / *Zea mays* |
|-------------------|---------------|---------|-------------------------|
| *Radiola linoides* | V             | V       | V                       |
| *Juncus capitatus* | 16            | 11      | 0                       |
| *Centunculus minus* | 28          | 22      | 0                       |
| *Illtecebrum verticillatum* | 31     | 30      | 0                       |
| *Gnaphalium luteoalbum* | 32      |         |                          |
| *Potentilla norvegica* | 28      |         |                          |
| *Gypsophila muralis* | 35      | 58      |                          |
| *Hypericum humifusum* | 45      | 51      | 0                       |
| *Plantago intermedia* | 61     | 63      |                          |
| *Sagina procumbens* | 41      | 46      | 0                       |
| *Gnaphalium uliginosum* | 57    | 58      | 50                      |
| *Veronica serpyllifolia* | 39    | 23      | 0                       |
| *Scleranthus annuus* | 31     | 46      | 0                       |
| *Digitaria ischaemum* | 65     | 0       |                          |
| *Arnoseris minima* | 39     | 0       | 0                       |
| *Spergularia rubra* | 51     | 46      | 75                      |
| *Juncus bufonius* | 65     | 73      | 44                      |
| *Equisetum arvense* | 39     | 38      | 50                      |
| *Polygonum hydropiper* | 87     | 86      | 67                      |
| *Peplis portula* | 83     | 92      | 100                     |
| *Mentha arvensis* | 68     | 77      | 100                     |
| *Rumex acetosella* | 65     | 66      | 57                      |
| *Polygonum aviculare* | 75    | 92      | 0                       |
| *Raphanus raphanistrum* | 75    | 0       | 40                      |
| *Convolvulus arvensis* | 48     | 77      | 50                      |
| *Spergula arvensis* | 47     | 54      | 17                      |
| *Erodium cicatarium* | 22     | 0       | 25                      |
| *Fallopia convolvulus* | 46     |         | 75                      |
| *Cirsium arvense* | 73     |         | 67                      |
| *Oxalis fontana* | 39     |         |                          |
| *Galeopsis tetrahit* | 32     |         | 0                       |
| *Myosotis arvensis* | 55     |         |                          |
| *Sonchus arvensis* | 55     |         |                          |
| *Centaurea cyanus* | 48     |         | 40                      |
| *Plantago major* | 48     |         |                          |
| *Stellaria graminea* | 48     | 0       |                          |
| *Vicia angustifolia* | 48     |         | 0                       |
| *Lysimachia nummularia* | 48    | 0       |                          |
| *Apera spica-venti* | 24     |         |                          |
| *Plantago lanceolata* | 24     | 0       |                          |
| *Cerastium holosteoides* | 22     | 0       |                          |
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| Poa annua       | 65 |
|-----------------|----|
| Leontodon autumnalis | 22 0 |
| Ranunculus repens | 18 |
| Achillea millefolium | 29 33 |
| Chenopodium album | 46 71 |
| Elymus repens    | 66 67 |
| Potentilla anserina | 92 50 |
| Anthemis arvensis | 38 |
| Viola arvensis   | 38 |
| Equisetum sylvaticum | 49 |
| Myosurus minimus | 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                    |
| Amaranthus retroflexus | 581 300 |
| Echinochloa crus-galli   | 517 250 |
| Capsella bursa-pastoris | 388 153 400 |
| Veronica arvensis      | 218 192 100 |
| Polygonum lapathifolium subsp. lapathifolium | 151 58 200 |
| Stellaria media        | 149 138 200 |
| Stachys palustris      | 113 115 200 |
| Matricaria maritima subsp. inodora | 504 690 |
| Arabidopsis thaliana   | 129 690 |
| Arenaria serpyllifolia | 129 345 |
| Agrostis stolonifera   | 388 115 |
| Polygonum lapathifolium subsp. pallidum | 291 307 |
| Bidens tripartita      | 178 106 |
| Rorippa sylvestris     | 161 115 |
| Vicia hirsuta         | 121 230 |
| Galinsoga parviflora  | 221 300 |
| Trifolium repens       | 194 200 |
| Setaria pumila        | 194 300 |
| Polygonum persicaria  | 388 |
| Symphytum officinale  | 388 |
| Geranium pusillum      | 194 |
| Chenopodium album      | 145 |
| Elymus repens         | 138 |
| Potentilla anserina    | 136 |
| Vicia tetrasperma     | 805 |
| Lactuca serioli       | 460 |
| Oxalis fontana        | 690 |
| Vicia angustifolia    | 345 |
| Sonchus arvensis      | 288 |
| Myosotis stricta      | 230 |
| Daucus carota         | 230 |
| Rhinanthus serotinus  | 173 |
| Cirsium arvense       | 153 |
| Fallopia convolvulus  | 134 |
| Veronica persica      | 500 |
| Galium aparine        | 400 |
| Euphorbia helioscopia | 200 |
| Setaria viridis       | 167 |
| Equisetum sylvaticum  | 150 |

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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-impoverished 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*, *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 Gólskis 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 agroecoses 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-Illecebrum 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 = 0.29).
5. The impoverishment of communities took place; the number of disappearing and withdrawing species was higher than the number of new taxa.

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

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 Spargulario-Illecebretum verticillati na ścierniskach i zbiorowiska z udziałem Illecebrum verticillatum w uprawach zbóż i okopowych zastępowane są w III okresie przez płaty Echinochlooo-Setarietum w zasiewach kukurydzy i na ścierniskach oraz asociacje Vicietum tetraspermae w zbóżach. Wyliczane wartości wskaźników podobieństwa zbiorowisk Sørensena i dynamiki podkreślają głęboki zakres przemian i ubożenia zbiorowisk.

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