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EFFECTS OF THE PENETRATION OF *Artemisia vulgaris* L. INTO MAIZE CROPS AS A RESULT OF THE USE OF REDUCED TILLAGE

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Abstract

In recent years, a significant increase in weed infestation of agricultural crops with *Artemisia vulgaris* has been observed in the south-western region of Poland. The ease of migration of this expansive species results from the fact that it does not face competition from segetal weeds and therefore poses a great threat to the ecological balance. During the period 2008–2011, a floristic study was carried out using the Braun-Blanquet method in an abandoned field adjacent to a maize monoculture grown under two tillage systems: plough and ploughless tillage. These observations allowed an evaluation of the actual risk of spread of *Artemisia vulgaris* depending on tillage system. The vicinity of the abandoned field had a significant effect on the penetration of *Artemisia vulgaris* into maize crops. Higher numbers of individuals of this species were found under ploughless tillage compared to plough tillage, regardless of the distance from the field edge, and its increased competitive effects on *Viola arvensis* L. and *Veronica persica* L. could be observed. The lowest grain yield was obtained under ploughless tillage where the strong competitive effects of *Artemisia vulgaris* were observed even in the plot most distant from the abandoned field adjacent to the maize crop.

Key words: weed community, reduced tillage, *Artemisia vulgaris*, migration, penetration, competitive effects, *Zea mays*

INTRODUCTION

In recent years, a significant increase in weed infestation of agricultural crops with *Artemisia vulgaris* L. has been observed in the south-western region of Poland, in particular in land restored to agricultural use where ploughless tillage is used [1]. The ease of migration of this expansive species belonging to persistent plants, which produces underground rhizomes and exhibits high competitive strength in relation to crop plants and segetal weeds as well as high allelopathic effects on soil microorganisms, poses a great threat to the ecological balance of agricultural ecosystems [2]. The spread of this species is facilitated by its reproduction method, which is both generative and vegetative. As a typical herbaceous chamaephyte whose overwintering buds are situated up to 50 cm above ground level, it shows a high ability to survive under adverse winter conditions and to reproduce in the next growing season. Mugwort disperses its seeds by releasing achenes without a pappus and reproduces vegetatively by means of underground rhizomes [3,4]. It is assumed that the cultivation of maize *Zea mays* L. under the ploughless tillage system, in the case of which it is necessary to use wide interrows, creates particularly favorable conditions for *Artemisia vulgaris*, a species hitherto not found in this agrocenosis, to penetrate and spread into maize crops from ruderal areas.

The aim of this study, conducted during the period 2009–2011, was to evaluate the effects of the penetration and spread of *Artemisia vulgaris* from an adjacent abandoned field into maize crops under ploughless tillage conditions, compared to plough tillage, and to show increased competitive effects of *Artemisia vulgaris* in a weed community and its influence on grain yield depending on the distance of colonization from the field edge.

MATERIALS AND METHODS

Observations of weed communities were carried out in the period 2009–2011 in a short-term maize *Zea mays* L. monoculture, where winter wheat was the previous crop before the establishment of the experiment, and in an abandoned field adjacent to it. In this maize monoculture, two tillage systems were used: plough tillage – involving post-harvest tillage (grubber to a depth of 15 cm + cage roller) and primary tillage (ploughing to a depth of 25 cm + harrow), and ploughless tillage – involving cultivating and seedbed preparation for sowing using a tillage unit. Each tillage system was used in a 1.5 ha field on grey-brown podzolic soil derived from heavy loamy sand on light loam; the same selective herbicide for control of *Artemisia vulgaris* L. was applied prior to emergence in both treatments. The habitat characteristics are given in Table 1. An estimation of percent ground cover by a particular species in the weed community was made in a 100–200 m^2 area in the abandoned field adjacent to the maize crop and for both tillage treatments. Each year, a total of 25 vegetation relevés were made for both tillage systems and in the abandoned field, determining biodiversity components such as the average number of species; dominant, annual and perennial species found in all relevés were also distinguished. The following indicators were calculated for the investigated agricultural ecosystems: CC – constancy class and CI – cover index for particular weed species according to the Braun-Blanquet scale [5,6].

The evaluation of the competitive effects of *Artemisia vulgaris* in the weed community and of its influence on maize grain yield was made based on single-factor field experiments set up as a completely randomized design in four replicates characterized by low soil variation [7]. The experiments were performed using two tillage systems: plough and ploughless tillage, in 25 m^2 plots at a distance of 5 m, 10 m and 15 m from the field edge. The state and level of weed infestation were evaluated by quadrat sampling, carried out at BBCH 56 at full growth by counting weeds in a 1.0 m^2 quadrat in four quadrat throws to determine the number of plants per plot area, and by the agrophytosociological method before maize harvest, estimating the percent ground cover by weeds.

During harvest, grain yield and thousand grain weight (TGW) (on a 15% moisture content basis) were determined for each tillage system. Single-factor analysis of variance was used to statistically analyze the results. The significance of differences was tested using Tukey's 95% confidence interval.

Table 1
Habitat indicators

Soil type	Grey-brown podzolic soil derived from heavy loamy sand on light loam classified as good rye complex
Ph	5.0–5.3
Organic matter content	1.2–1.5
Tillage system	plough, ploughless tillage

RESULTS

The phytosociological observations carried out during the period 2009–2011 showed high species variation in the weed community of the abandoned field on grey-brown podzolic soil. In total, 32 taxa were found at this site (Table 2). Among the monocotyledonous species of the investigated phytocoenosis, the annual taxa *Echinochloa crus-galli* (L.) Beauv and *Setaria viridis* (L.) P. Beaur., with the highest degree of constancy and cover, were constantly present in the community, whereas other perennial species, such as *Elymus repens* (L.) Gould, *Lolium* spp., *Arrhenatherum elatius* (L.) P., *Bromus hordeaceus* L., *Anthoxanthum odoratum* L., and *Holcus mollis* L., had a low cover index, occurred with a medium or low frequency, and showed low constancy.

In the floristic list that included 23 dicotyledonous species, *Chenopodium album* L., *Matricaria inodora* L., *Geranium pusillum* Burm. F. ex L and *Viola arvensis* L. were frequently present annual taxa with high cover indices, whereas the following perennial taxa: *Artemisia vulgaris*, *Cirsium arvense* (L.) Scop, *Achillea millefolium* L., *Tanacetum vulgare* L., *Solidago gigantea* Aiton, and *Convolvulus arvensis* L., persisted in the community for long periods of time.

The other species such as: *Galium mollugo* L., *Carduus nutans* L., *Taraxacum officinale* F. H. Wigg. aggr, *Erigeron canadiensis* L., *Polygonum aviculare* L., *Sonchus arvensis* L., *Crepis biennis* L., *Melandrium album* Garcke, *Centaurea cyanus* L., *Vicia tetrasperma* L. Moench, *Trifolium dubium* Sibth or *Veronica arvensis* L., occurred with lower frequency and were characterized by a low cover index on this type of soil (Tables 2 and 3).

Tillage system had a significant effect on weed infestation of maize grown under the same habitat conditions. In the weed community found in the ploughed field, a total of 20 mono- and dicotyledonous species were recorded, including two dominant species with the highest cover indices (1065 for *Echinochloa crus-galli* and 1219 for *Chenopodium album*; they were present in all relevés and classified in the highest constancy classes. Apart from them, *Viola arvensis* and *Veronica persica* showed high constancy, but they had lower ground cover. The remaining weed species were found in the community with medium frequency, occasionally, rarely or sporadically and were characterized by a low cover index, i.e. below 340 (Tables 2 and 3).

Under ploughless tillage, on the other hand, 16 taxa were distinguished and among them three dominant species present in all relevés: *Echinochloa crus-galli* for which the cover index increased by 758 compared to plough tillage and *Chenopodium album* in the case of which the cover index increased by 547. Under such tillage conditions, *Setaria viridis* also significantly increased its proportion, since its cover index was 1556 and rose by 460 in comparison to plough tillage. *Artemisia vulgaris,* as a perennial dicotyledonous species, initially occurred rarely, though with a rather high cover index, but each year it increased its proportion in the community and in 2011 its presence was found in 72% of relevés (Table 2). Other species frequently appearing in the community were characterized by lower cover indices and particularly low numbers were found for two species, *Viola arvensis* and *Veronica arvensis*, with respect to which strong competitive effects of *Artemisia vulgaris* could be observed (Tables 2 and 3). In the weed infestation structure of the maize crop under ploughless tillage, the number of dicotyledonous species decreased and the study found increased incidence of annual monocotyledonous and perennial dicotyledonous species, frequently or constantly present, in comparison with plough tillage.

Table 2
Selected biodiversity components of weed communities
under the investigated tillage systems

Biodiversity components of weed communities	Tillage systems					
	Abandoned field		Plough tillage			
Total number of species, including:	32		20		16	
annual monocotyledonous: *Echinochloa crus-galli, Setaria* spp	3		2		2	
perennial monocotyledonous: *Elymus repens*	6		–		1	
annual dicotyledonous	11		18		10	
perennial dicotyledonous: *Artemisia vulgaris, Cirsium arvense, Convolvulus arvense*	11		–		2	
other perennial: *Equisetum arvense*	1		–		1	
Dominant species	*CC	*CI	*CC	*CI	*CC	*CI
Echinochloa crus-galli (L.) Beauv	V	1041	V	1065	V	1823
Setaria viridis (L.) P. Beaur.	IV	1062	III	596	V	1056
Elymus repens (L.) Gould	III	975	–	–	III	282
Artemisia vulgaris (L.)	IV	1966	–	–	V	1324
Chenopodium album (L.)	IV	1783	V	1219	IV	1766
Viola arvensis (L.)	–	–	V	969	–	–
Veronica persica (L.)	–	–	IV	345	–	–
Papaver rhoaes (L.)	–	–	IV	209	–	–
Matricaria inodora (L.)	III	963	IV	255	–	–
Geranium pusillum Burm. F. ex L	–	–	–	–	III	487
Sum of cover indices	7790		4658		6738	

*CI – *Cover index,* *CC– *Constancy class*

Table 3
Biodiversity of weed communities in maize depending on tillage system

No.	Abandoned field: Weed species	No. of occurrences	*CC	*CI	Plough tillage: Weed species	No. of occurrences	*CC	*CI	Ploughless tillage: Weed species	No. of occurrences	*(S)	*Wsp.
1	*Echinochloa crus-galli* (L.) Beauv	40	V	2041	*Echinochloa crus-galli* (L.) Beauv	40	V	1065	*Echinochloa crus-galli* (L.) Beauv	40	V	1823
2	*Setaria viridis* (L.) P. Beaur.	40	IV	2621	Setaria viridis (L.) P. Beaur.	29	III	596	Setaria viridis (L.) P. Beaur.	37	V	1056
3	*Elymus repens* (L.) Gould	37	III	975	*Chenopodium album* (L.)	39	V	1219	*Elymus repens* (L.) Gould	24	III	282
4	*Lolium* spp.	33	II	282	*Viola arvensis* (L.)	37	V	969	*Chenopodium album (L.)*	40	V	1324
5	*Arrhenatherum elatius* (L.) P. Beauv.	30	II	161	*Veronica persica* (L.)	31	IV	345	*Artemisia vulgaris* (L.)	32	IV	1766
6	*Bromus hordeaceus* (L.)	31	II	114	*Papaver rhoaes* (L.)	26	IV	209	*Geranium pusillum* Burm. F. ex L	29	IV	506
7	*Apera spica-venti* (L.)	28	I	78	Matricaria inodora (L.)	29	IV	255	*Centaurea cyanus* (L.)	19	III	487
8	*Anthoxanthum odoratum* (L.)	27	I	56	*Capsella bursa-pastoris* (L.) Medik	22	III	233	*Fallopia convolvulus* (L.) Á. Löve	18	III	125
9	*Holcus mollis* (L.)	30	I	55	Solanum nigrum L. emend. Mill.	21	III	212	*Papaver rhoaes* (L.)	19	III	155
10	*Artemisia vulgaris* (L.)	29	IV	1966	*Centaurea cyanus* (L.)	18	III	579	*Veronica persica* (L.)	19	III	145
11	*Chenopodium album* (L.)	18	IV	1783	*Stellaria media* (L.) Vill.	13	II	61	Solanum nigrum L. emend. Mill.	22	III	133
12	*Matricaria inodora* (L.)	19	III	963	*Aethusa cynapium* (L.)	16	II	95	*Aethusa cynapium* (L.)	21	III	135
13	*Geranium pusillum* Burm. F. ex L	20	II	321	*Geranium pusillum* Burm. F. ex L	14	II	55	*Polygonum aviculare* (L.)	18	III	127
14	*Viola arvensis* (L.)	12	II	299	Fallopia *convolvulus* (L.) Á. Löve	14	II	58	*Equisetum arvense* (L.)	12	II	88
15	*Cirsium arvense* (L.) Scop	17	II	234	*Polygonum persicaria* (L.)	11	II	41	*Viola arvensis* (L.)	7	I	69
16	*Achillea millefolium* (L.)	14	II	159	*Fumaria officinalis* (L.)	11	II	21	*Cirsium arvense* (L.) Scop.	3	I	+
17	*Tanacetum vulgare* (L.)	11	II	142	*Thlaspi arvense* (L.)	10	II	22				
18	*Solidago gigantea* Aiton	9	II	166	*Galium aparine* (L.)	10	II	10				
19	*Convolvulus arvensis* (L.)	8	II	76	*Euphorbia helioscopia* (L.)	3	I	+				
20	*Galium mollugo* (L.)	6	I	72	*Matricaria inodora* (L.)	3	I	+				
21	*Carduus nutans* (L.)	7	I	72								
22	*Taraxacum officinale* F. H. Wigg. aggr.	4	I	66								
23	*Erigeron canadiensis* (L.)	3	I	63								
24	*Polygonum aviculare* (L.)	2	I	56								
25	*Sonchus arvensis* (L.)	4	I	54								
26	*Crepis biennis* (L.)	3	I	52								
27	*Melandrium album* Garcke	3	I	36								
28	*Centaurea cyanus* (L.)	-3	I	34								
29	*Vicia tetrasperma* (L.) Moench	2	I	35								
30	*Trifolium dubium* Sibth	2	I	30								
31	*Veronica arvensis* L,.	2	I	30								
32	*Equisetum arvense* (L.)	2	I	30								

*CI – Cover index, *CC– Constancy class

The vicinity of the abandoned field had a significant effect on the penetration of *Artemisia vulgaris* into maize crops, especially under ploughless tillage. In close vicinity to the abandoned field, the number of individuals of this species per plot area was much higher compared to plough tillage and did not decline significantly with its penetration further into the field (Tables 4 and 5). It was characteristic, however, that each year the number of plants of this species per unit area increased regardless of the distance from the field edge (Tables 4 and 5).

The strong competitive effects of *Artemisia vulgaris* were observed in relation to the following constant species found in great numbers in the weed community at the beginning of the growing season: *Viola arvensis* and *Veronica persica*, which are typical for habitats on podzolic soil (Table 5).

Under plough tillage, single *Artemisia vulgaris* individuals were only found on the field edges; they were lower, in worse condition and did not compete with other species in the community, such as *Viola arvensis* or *Veronica persica*; maize was better able to cope with their presence in the crops. Based on an estimate of percent ground cover by particular weed species made before harvest, it can also be concluded that the competition of *Artemisia vulgaris* towards *Viola arvensis* and *Veronica persica* was weaker than in ploughless tillage, where it eliminated these species completely from the community. Despite that these species occurred in great numbers at the beginning of the growing season, they were not found to be present before harvest, whereas under plough tillage they continued to be present until harvest (Tables 4 and 5).

The obtained results for maize plant height and the level of yield are also evidence of significant competitive effects of the species in question on maize growth, in particular under ploughless tillage conditions. The study showed significant differences in grain yields obtained from the plots distant from the field edge compared to the grain yield harvested on the field edge, which was only 65.6 dt·ha^{-1} (Table 5). Under plough tillage, on the other hand, both on the field edge with the low incidence of *Artemisia vulgaris* and in the treatments without its presence, the study did not find such significant differences in plant height as well as the highest yield (123.5 dt·ha^{-1}) and grains of large size and weight were obtained.

Tillage system, in particular the abandonment of ploughing, proved to be an important factor affecting the penetration and increased competitive effects of mugwort in maize crops grown in monoculture (Tables 4 and 5).

Table 4
Effect of the distance from the field edge on the numbers of *Artemisia vulgaris* (L.) in the weed community and on maize growth and yield under plough tillage in 2009–2011

Distance from the field edge	Average number of weeds per plot area BBCH 36*					Average percent ground cover by weeds [%] BBCH 85*					Plant height [cm]	Grain yield [dt·ha^{-1}]	TGW [g]
	ECHCG	CHEAL	VIOAR	VERPE	ARTVU	ECHCG	CHEAL	VIOAR	VERPE	ARTVU			
5 m	61.1	32.7	32.3	21.5	18.8	3.1	3.3	3.2	2.1	14.5	280.7	105.6	293.8
10 m	42.3	28.3	28.7	20.4	1.9	2.1	2.1	2.2	1.9	1.4	285.3	120.5	296.9
15 m	41.1	27.2	26.4	19.1	0.0	2.0	2.1	2.0	1.8	0.0	285.6	123.5	299.8
$NIR_{(0,05)}$; *LSD* $_{(0.05)}$ for distance	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	12,7	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	0,92	22,3	11,2	14,2

*) growth stage of maize
n.s. – not significant
TGW – thousand grain weight
ECHCG – *Echinochloa crus-galli* (L.) Beauv, CHEAL – *Chenopodium album* (L.), VIOAR – *Viola arvensis (L.),* VERPE – *Veronica persica* (L.), ARTVU – *Artemisia vulgaris* (L.)

Table 5
Effect of the distance from the field edge on the numbers of *Artemisia vulgaris* (L.) in a weed community and on maize growth and yield under ploughless tillage in 2009–2011

Distance from the field edge	Average number of weeds per plot area BBCH 36*					Average percent ground cover by weeds [%] BBCH 85*					Plant height [cm]	Grain yield [$dt \cdot ha^{-1}$]	TGW [g]
	ECHCG	CHEAL	VIOAR	VERPE	ARTVU	ECHCG	CHEAL	VIOAR	VERPE	ARTVU			
5 m	113.2	52.5	31.2	30.2	70.2	7.1	4.3	0.3	1.2	45.6	255	65.6	269.8
10 m	49.1	34.2	26.2	25.1	67.6	5.2	3.4	0.0	0.3	34.3	277	72.5	272.9
15 m	46.6	32.8	25.4	23.9	43.8	5.1	3.3	0.0	0.0	33.4	279	74.1	278.6
$NIR_{(0,05)}$; $LSD_{(0,05)}$ for distance	17,45	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	14,33	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	r.n.; *n.s.*	20,12	11,0	12,35

*) growth stage of maize
n.s. – not significant
TGW – thousand grain weight
ECHCG – *Echinochloa crus-galli* (L.) Beauv, CHEAL – *Chenopodium album* (L.), VIOAR – *Viola arvensis (L.),* VERPE – *Veronica persica* (L.), ARTVU – *Artemisia vulgaris* (L.)

DISCUSSION

The renewed agricultural use of abandoned farmland, the abandonment of plough tillage, and the introduction of surface tillage or direct drilling enable ruderal species to penetrate into some agricultural ecosystems [8]. *Artemisia vulgaris* belongs to species that show characteristics of expansive plants that easily migrate into crop fields. This is facilitated by the lack of competition from segetal weeds and therefore this species poses a great threat to the ecological balance in cereal and maize agroecosystems.

In recent years, a significant increase in weed infestation of agricultural crops with mugwort has been observed in the south-western region of Poland, particularly in maize monocultures, but also in cereals and winter oilseed rape in plantations where reduced tillage practices are used, especially on light soils [9].

Because soil loosening operations are not used in ploughless tillage, this tillage system is recommended on light and medium cohesive soils where intensive cereal and maize cultivation can be successfully carried out, since this group of plants tolerates increased soil density in the root zone. Nevertheless, the continued use of reduced tillage systems for several years, apart from causing changes in most physical parameters of soil properties and increased weed infestation of maize, can also affect the weed species structure and results in higher incidence of perennial weeds and increased infestation with annual weeds [10]. This also stems from the fact that the entire mass of weed seeds is accumulated on the soil surface without the possibility to plough them under [11–14].

The literature data show that in the ploughless tillage system a segetal weed community is characterized by lower species diversity, is poorer in dicotyledonous species and there are more monocotyledonous species, such as cockspur grass and green foxtail, but over the years the numbers of perennial weeds, especially mugwort, couch grass or creeping thistle, increase more and more [15,16]. The results obtained in the present study confirm the thesis that under plough tillage there is greater species richness of weed communities and that they are also characterized by greater stability [17].

Numerous scientific reports show that by abandoning part of tillage operations and making mistakes in crop protection, we create better conditions for the growth of weeds than crop plants [18]. The introduction of reduced tillage can also limit the weed control efficacy of herbicides, contribute to increased competitiveness of perennial species and impede their eradication [10,16].

Under ploughless tillage, in maize crops there are particularly favorable conditions for the penetration and spread of mugwort from ruderal areas. The weed community found in the maize monoculture, grown on grey-brown podzolic soil, was characterized by a high proportion of the following species: cockspur grass, white goosefoot, field pansy, and Persian speedwell. The knowledge of the competitive strength of mugwort in maize crops under two tillage systems, plough and ploughless tillage, allowed us to assess at what level of its incidence per unit area this species can indeed create the risk of not achieving expected grain yield and to conclude that the abandonment of plough tillage operations can increase its competitive effects in a weed community and facilitate its penetration from an adjacent abandoned field.

CONCLUSIONS

1. The vicinity of the abandoned field had a significant effect on the penetration of *Artemisia vulgaris* into maize crops, especially under ploughless tillage, and its strong competitive effects were observed in relation to the following constant species: *Viola arvensis* and *Veronica persica*, which were found in the weed community in great numbers.
2. Under ploughless tillage, higher numbers of individuals of *Artemisia vulgaris* were found compared to plough tillage and its presence in maize crops did not decrease significantly irrespective of the distance from the field edge.
3. The lowest grain yield was obtained under ploughless tillage where the strong competitive effects of mugwort were observed even at the plot most distant from the abandoned field adjacent to the maize crop.
4. Tillage system, in particular the abandonment of ploughing, proved to be an important factor affecting the penetration and increased competitive effects of *Artemisia vulgaris* in maize crops grown in monoculture.

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Skutki przenikania *Artemisia vulgaris* (L.) do uprawy kukurydzy w wyniku stosowania uproszczeń uprawowych

Streszczenie

W rejonie południowo-zachodniej Polski w ostatnich latach obserwuje się znaczny wzrost zachwaszczenia upraw rolniczych *Artemisia vulgaris*. Łatwość migracji tego ekspansywnego gatunku wynika z faktu, że nie napotyka konkurencji ze strony chwastów segetalnych i przez to stwarza duże zagrożenie dla równowagi ekologicznej. W latach 2008–2011 prowadzono badania florystyczne metodą Braun-Blanquet`a na odłogu przylegającym do monokultury kukurydzy uprawianej w dwóch systemach uprawowych płużnym i bezpłużnym. Przeprowadzone obserwacje pozwoliły dokonać oceny faktycznego zagrożenia rozprzestrzeniania się *Artemisia vulgaris* w zależności od systemu uprawowego. Sąsiedztwo odłogu miało istotny wpływ na przenikanie *Artemisia vulgaris* w głąb zasiewów kukurydzy. W uprawie bezpłużnej notowano wyższe liczebności okazów tego gatunku w porównaniu z uprawą płużną, niezależnie od odległości od skraju pola i obserwowano wzrost konkurencyjnego oddziaływania na *Viola arvensis* i *Veronica persica*. Najniższe plony ziarna uzyskano w uprawie bezpłużnej, gdzie obserwowano silne konkurencyjne oddziaływanie *Artemisia vulgaris*, nawet na obiekcie najbardziej oddalonym od sąsiadującego z kukurydzą odłogu.

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