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Research Article

THE EFFECT OF WINTER CATCH CROPS ON WEED INFESTATION IN SWEET CORN DEPENDING ON THE WEED CONTROL METHODS

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ABSTRACT
An experiment was carried out in east-central Poland (52°06' N, 22°55' E) over 2008–2011 to study the effect of winter catch crops on the weed infestation, number, and fresh matter of weeds in sweet corn (*Zea mays* L. var. *saccharata*). The following winter catch crops were grown: hairy vetch (*Vicia villosa* Roth.), white clover (*Trifolium repens* L.), winter rye (*Secale cereale* L.), Italian ryegrass (*Lolium multiflorum* L.) and winter turnip rape (*Brassica rapa* var. *typica* Posp.). The catch crops were sown in early September and incorporated in early May. The effect of the catch crops was compared to the effect of FYM (30 t·ha^{-1}) and control without organic manuring (NOM). Three methods of weed control were used: HW – hand weeding, twice during the growing period, GCM – the herbicide Guardian Complete Mix 664 SE, immediately after sowing of corn seeds, Z+T – a mixture of the herbicides Zeagran 340 SE and Titus 25 WG applied at the 3–4-leaf stage of sweet corn growth. Rye and turnip rape catch crops had least weeds in their fresh matter. Sweet corn following winter catch crops was less infested by weeds than corn following farmyard manure and non-manured corn. Least weeds and their lowest weight were found after SC, BRT and VV. LM and BRT reduced weed species numbers compared with FYM and NOM. The greatest weed species diversity, determined at the corn flowering stage, was determined after SC and FYM. The number and weight of weeds were significantly lower when chemically controlled compared with hand weeding. The best results were observed after a post-emergent application of the mixture Z+T. The weed species diversity on Z+T-treated plots was clearly lower compared with GCM and HW.

Keywords: weed infestation, green manure, organic fertilisation, weed control method, *Zea mays* L. var *saccharata.*

INTRODUCTION

In the integrated and ecological agriculture systems, more attention is being paid to the cultivation of catch crops, which should be a regular part of crop rotation. The cultivation of catch crops for ploughing in is a precursor of the long-lasting organic matter, which is an energy source for micro-organisms, and influences physical and chemical properties of the soil [Vos and van der Putten 2001, Marshall et al.2003, Clark et al. 2007]. When catch crop organic matter is regularly supplied to the soil, its biological activity can be preserved. Catch crops incorporated as green manures prior to sweet corn cultivation favourably affect the quantity and quality of ear and kernel yields [Zhang et al. 2010, Zaniewicz-Bajkowska et al. 2011, Rosa 2014].

Sweet corn is a poor competitor with weeds in the initial period of growth. Weed infestation can contribute to decreased yields of ears by up to 85% [Williams 2010]. It is therefore crucial to control weeds from the very beginning of sweet corn cultivation. The most effective method of weed control is to apply herbicides which, however, have an adverse effect on the natural environment and may negatively affect yield quality.

Because of environmental and human health concerns, worldwide efforts are being made to reduce the heavy reliance on synthetic herbicides that are used to control weeds. The modern approach to the issue of weed control in integrated agriculture involves a rational (that is taking into account the economic calculus) combination of effective methods, which are safe for the environment and consumers, applied to reduce the number of unwanted segetal plants to the level known as the economic threshold for weeds occurring in a crop plant [Singh et al. 2003, Armengot et al. 2013].

Many authors stress that well established catch crops efficiently compete with weeds; some plants species cultivated for incorporation are even able to hamper weed seed sprouting and initial growth [Teasdale et al. 1991, Akemo et al. 2000, Caporali et al. 2004, O'Reilly et al. 2011]. What is more, Liebman and Davis [2000] as well as Barberi [2002] believe that catch crops can be an alternative to chemical weed control.

The objective of this work was to assess the effect of winter catch crop ploughed in and an application of different weed control methods on weed infestation of sweet corn.

MATERIAL AND METHODS

The experiment was carried out over 2008–2011 at the Experimental Station of the Siedlce University of Natural Sciences and Humanities, which is located in east-central Poland (52°03'N, 22°33'E). According to the international system of FAO classification, the soil was classified as a Luvisol (LV) [World Reference… 2006]. The experiment was established in a split-block design with three replicates.

The effect of winter catch crops and weed control methods on the weed infestation, number, and fresh matter in 'Sweet Nugget F_1' sweet corn was investigated. The following winter catch crops were grown: VV – hairy vetch (*Vicia villosa* Roth.), TR – white clover (*Trifolium repens* L.), SC – winter rye (*Secale cereale* L.), LM – Italian ryegrass (*Lolium multiflorum* L.) and BRT – winter turnip rape (*Brassica rapa* var. *typica* Posp.). Their seeds were sown in early September in the years 2008–2010, at the following rates: VV – 70 kg, TR – 20 kg, SC – 180 kg, LM – 35 kg, BRT – 12 kg per 1 ha. Different nitrogen rates were applied: 30 kg $N \cdot ha^{-1}$ for VV and TR, and 60 kg $N \cdot ha^{-1}$ for SC, LM and BRT. The rates of phosphorus and potassium applied to all the catch crop plants were 40 kg $P_2O_5 \cdot ha^{-1}$ and 80 kg $K_2O \cdot ha^{-1}$, respectively. The effect of winter catch crops was compared to a control plot without organic manure (NOM) and farmyard manure (FYM) at a rate of 30 $t \cdot ha^{-1}$. Green matter of the catch crops (roots + above ground parts) and FYM were incorporated in early May.

Directly before catch crop incorporation, the samples of plant material (roots + above ground parts) were taken to assess fresh (FM) and dry matter (DM) yields. Samples were taken from an area of 1 m^2 at three randomly selected places in each experimental combination. The dry matter contents in the catch crops were determined using the oven-drying gravimetric method. Moreover, the percentage share of weeds in catch crop biomass and dominating weeds were determined.

The field for cultivation of the catch crop plants and sweet corn was prepared in accordance with the principles of proper agricultural technology.

Seeds of sweet corn were sown in the years 2009–2011 between 11 and 24 May, at a spacing of 60 × 25 cm. Before sowing, mineral fertilisers were applied at the following rates: 60 kg N (urea), 50 kg P_2O_5 (superphosphate), 180 kg K_2O (60% potassium chloride) per 1 ha. When plants of sweet corn were 20 cm high, top dressing with 60 kg $N \cdot ha^{-1}$ (ammonium nitrate) was applied. Three weed control methods were applied: HW – hand weeding (twice during the growing season), GCM – herbicide Guardian CompleteMix 664 SE (acetochlor + terbuthylazine) immediately after sowing of sweet corn seeds, at the rate of 3.5 $l \cdot ha^{-1}$ per 250 dm^3 water, Z+T – a mixture of the herbicides Zeagran 340 SE (bromoxynil + terbuthylazine) (1.6 $l \cdot ha^{-1}$) + Titus 25 WG (rimsulfuron) (40 $g \cdot ha^{-1}$) + adjuvant Trend 90 EC (0.1%) per 250 dm^3 water, applied at the 3–4 leaf stage of sweet corn growth. Herbicide treatments were performed by knapsack sprayer. Other cultivation practices followed the generally established rules of sweet corn agrotechnology.

The effect of the examined factors on weed infestation was assessed twice each year. The primary infestation was studied in the initial period of sweet corn growth, 21 days after seed sowing. After that, manual (HW) and chemical (Z+T) weeding was performed. Another hand weeding followed in HW plots after 42-49 days from sweet corn sowing, depending on the study year. The assessment of secondary infestation was performed 72 days after sweet corn sowing when tassels appeared on corn plants. Weed infestation was determined by the quantitative-weighing method. This method entailed determining the number of individual weeds species and their fresh mass in each plot. Samples were taken from an area of a selected 0.5 m^2 at three randomly selected places in each plot. The number and weight of the weeds were expressed per 1 m^2.

The following indices of weed species diversity were calculated:

- Shannon-Wiener index of species diversity (H'), which takes into account species evenness and richness. The index reflects the probability that two individuals chosen randomly from a sample will represent different species. Its value depends on the species number and proportions between species numbers [Zanin et al. 1992]:

$$H' = -\sum (p_i \ln p_i)$$

- Simpson's index of domination (D), reflects the probability of choosing two individuals representing the same species. It takes into account species number and relative abundance of each species [Zanin et al. 1992]:

$$D = \sum {p_i}^2$$

where p_i is the share of ith species in the sample.

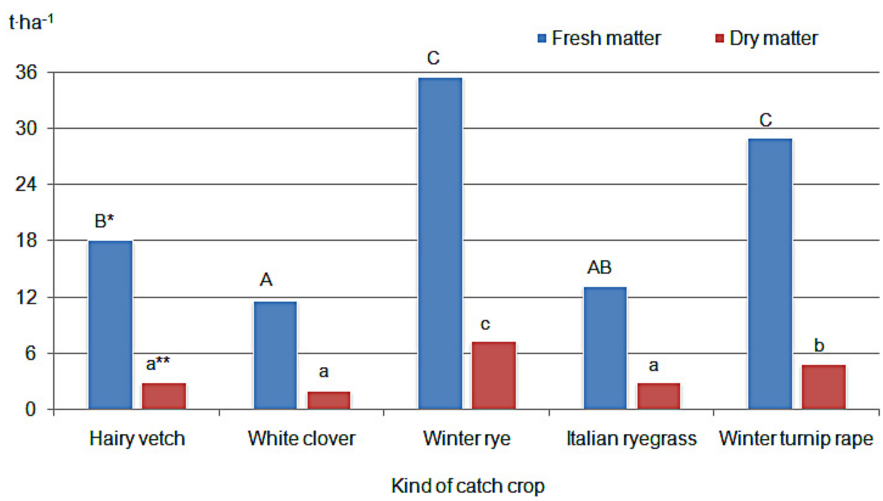
The results were statistically analysed by ANOVA following the model for the split-block design. The significance of differences was determined by the Tukey test at the significance level of $P \leq 0.05$. All the calculations were performed in Statistica 10.0.

RESULTS AND DISCUSION

Biomass yields of the catch crops are presented in Figure 1. The greatest fresh (FM) and dry matter (DM) yields were produced by winter rye (35.5 t·ha^{-1} FM and 7.3 t·ha^{-1} DM) and winter turnip rape catch crops (29.1 t·ha^{-1} FM and 4.9 t·ha^{-1} DM). Rye produced over twice as much DM as hairy vetch and Italian ryegrass and over three times more DM than white clover. Farmyard manure at a rate of 30 t·ha^{-1} supplied the soil with 7.6 t·ha^{-1} dry matter.

Analysis of the percentage share of weeds in the fresh matter of winter catch crops demonstrated substantial differences in their resistance to infestation by weeds (Figure 2). The infestation ranged from 2.8 to 25.3%, being the lowest in winter rye (2.8%) and winter turnip rape (4.1%) catch crops, and the greatest in Italian ryegrass catch crop (25.3%). In general, the dominant weedy species in the catch crops were *Viola arvensis* L., *Amaranthus retroflexus* L., *Anthemis arvensis* L., *Matricaria perforata* Mérat., *Vicia sativa* L. and *Elymus repens* (L.) Gould. However, not all the aforementioned species occurred in each catch crop (Table 1). The most weedy species were noted in white clover, winter rye and Italian ryegrass (four in each catch crop) and the least in hairy vetch (two). What is more, self-seeded *Secale cereale* plants were found in hairy vetch. Only *Viola arvensis* L. accompanied all the catch crops.

The species composition of weed communities depends largely on soil and climate conditions [Zarzecka and Gąsiorowska 2001] and agrotechnical practices [Pszczółkowski 2003]. In this study, 21 days after sweet corn sowing, 14



* Values followed by the same uppercase letters are not significantly different at $P \leq 0.05$
** Values followed by the same lowercase letters are not significantly different at $P \leq 0.05$

Figure 1. The amount of biomass (t•ha^{-1}) produced by the winter catch crops (mean for 2009–2011)

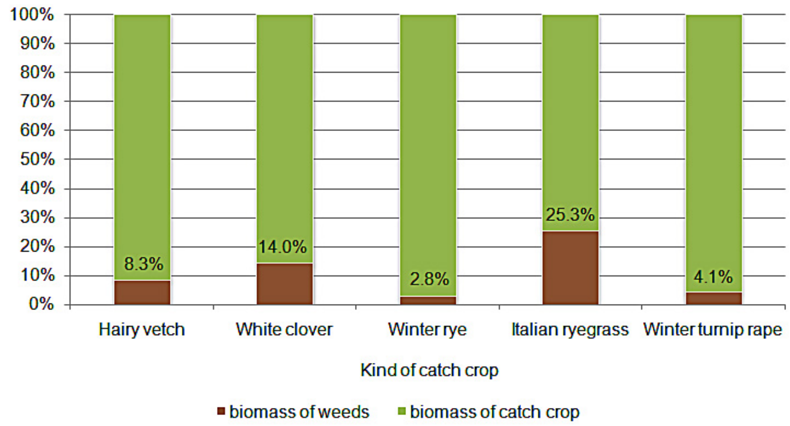


Figure 2. Share of weeds (%) in the catch crops biomass (mean for 2009–2011)

Table 1. The dominant weed species in the catch crops biomass (mean for 2009–2011)

Weed species	Kind of catch crop				
	Hairy vetch (VV)	White clover (TR)	Winter rye (SC)	Italian ryegrass (LM)	Winter turnip rape (BRT)
Viola arvensis L.	+	+	+	+	+
Amaranthus retroflexus L.	+	+	+	+	–
Anthemis arvensis L.	–	–	+	+	+
Matricaria perforata Mérat.	–	+	–	–	–
Vicia sativa L.	–	–	+	–	–
Secale cereale (self-seeded)	+	–	–	–	–
Elymus repens (L.) Gould.	–	+	–	+	+

+ – species presence, – – species absence.

Table 2. The species composition of weeds (plant·m^{-2}) 21 days after sweet corn sowing (mean for 2009–2011)

Weed species	Kind of organic manure							Weed control method		Mean
	NOM[1)]	FYM	Catch crops					no weeding[2)]	GCM	
			VV	TR	SC	LM	BRT			
Annual species										
Echinochloa crus-galli (L.) P. Beauv.	38.5	52.1	32.6	40.9	33.8	41.5	51.0	76.6	6.3	41.5
Chenopodium album L.	33.2	26.7	27.9	11.3	48.0	39.7	37.3	35.3	28.7	32.0
Veronica arvensis L.	22.5	31.4	24.9	30.8	32.0	23.7	13.6	45.1	6.8	26.0
Fallopia convolvulus (L.) Á. Löve	53.9	8.9	3.0	17.2	14.2	11.3	12.4	24.6	9.9	17.3
Amaranthus retroflexus L.	5.9	17.8	7.1	13.0	5.9	9.5	11.3	20.2	-	10.1
Geranium pusillum L.	1.2	3.6	9.5	14.2	3.6	10.7	24.9	19.4	-	9.7
Matricaria perforata Mérat.	-	2.4	-	3.0	3.6	7.1	4.7	4.8	1.3	3.0
Viola arvensis L.	2.4	1.2	1.2	4.7	1.2	2.4	-	2.7	1.0	1.9
Galium aparine L.	-	-	1.2	-	-	-	-	0.4	-	0.2
Persicaria maculosa Gray	-	-	-	1.2	-	-	-	0.4	-	0.2
Stellaria media (L.) Vill.	-	-	-	1.2	-	-	-	0.4	-	0.2
Number of annual species	7	8	8	10	8	8	7	11	6	11
Perennial species										
Elymus repens (L.) Gould.	7.1	1.2	8.3	8.3	3.6	4.1	-	5.6	3.8	4.7
Sonchus arvensis L.	4.7	2.4	3.6	2.4	-	-	-	3.2	0.5	1.9
Cirsium arvense (L.) Scop.	1.2	-	-	-	-	-	-	0.4	-	0.2
Number of perennial species	3	2	2	2	1	1	0	3	2	3
Total number of species	10	10	10	12	9	9	7	14	8	14

[1)] NOM – control without organic manure, FYM – farmyard manure, VV – hairy vetch, TR – white clover, SC – winter rye, LM – Italian ryegrass, BRT – winter turnip rape.
[2)] no weeding – no weeding to 21 days from sweet corn sowing, GCM – Guardian CompleteMix 664 SE.

weed species including 11 annuals and 3 perennials, were noted (Table 2). They belonged to the species typically establishing in sweet corn crop. Irrespective of the examined factors, the dominant species among the annuals were *Echinochloa crus-galli* (L.) P. Beauv., *Chenopodium album* L., *Veronica arvensis* L., *Fallopia convolvulus* (L.) Á. Löve, *Amaranthus retroflexus* L. and *Geranium pusillum* L. Of the perennials, the most common weed was *Elymus repens* (L.) Gould. The composition of the weed species was similar to that found in the study carried out in east-central Poland (Zarzecka and Gugała 2005, Kosterna 2014). On day 21 after sowing, most weedy species (12) were recorded in TR plots and the least (7) in BRT plots.

Pre-emergent GCM resulted in by 7 times less weedy species compared with the treatment where weeds were not controlled for 20 days of sweet corn cultivation. The most noxious weeds establishing in sweet corn include: *Ch. album*, *F. convolvulus*, *A. retroflexus, E. crus-galli* oraz *Polygonum aviculare* [Waligóra et al. 2008]. No *A. retroflexus*, *G. pusillum*, *G. aparine*, *P. maculosa*, *S. media* or *C. arvense* species were found in GCM-treated plots. Additionally, GCM reduced the number of *E. crus-galli*, *V. arvensis*, *F. convolvulus* and *Ch. album* by 92, 85, 60 and 24%, respectively.

Number of weeds recorded 72 days after sweet corn planting was the same as during the first assessment. However, the species composition was different (Table 3). During the second assessment, annual *G. aparine*, was not found but *S. arvensis* and *M. arvensis* were present. *C. arvense* was not found either. *E. crus-galli*, *F. convulvulus*, *V. arvensis* were the most abundant species. Of the dominating species, least *E. crus-galli* plants were noted for NOM control, and *F. convulvulus* and *V. arvensis* after LM catch crop. Least weedy species were recorded after LM and BRT catch crops (8), and most (11) after FYM. For all the organic manuring treatments, the average number of weeds representing each species declined compared with the first assessment. It was due to the weed control treatments applied to HW and Z+T plots.

An application of Z+T on day 21 of sweet corn growing killed most weedy species observed at the beginning of sweet corn growing season. Also, hand weeding performed twice contributed to a reduced number of weedy species as well as

Table 3. The species composition of weeds (plant·m^{-2}) 72 days after sweet corn sowing (mean for 2009–2011)

Weed species	Kind of organic manure							Weed control methods			Mean
	NOM[1)]	FYM	Catch crops					HW[2)]	GCM	Z+T	
			VV	TR	SC	LM	BRT				
Annual species											
Echinochloa crus-galli (L.) P. Beauv.	10.7	27.3	20.1	16.6	23.7	20.1	20.1	25.1	21.8	12.4	19.8
Fallopia convolvulus (L.) Á. Löve	35.0	11.3	13.6	7.1	8.9	5.9	10.7	12.7	25.4	1.5	13.2
Viola arvensis L.	18.4	15.4	11.3	16.0	7.7	5.9	7.7	9.7	23.9	1.8	11.8
Chenopodium album L.	-	8.3	2.4	1.2	9.5	11.3	2.4	10.9	4.1	-	5.0
Sinapis arvensis L.	3.6	4.7	2.4	3.6	1.2	2.4	3.6	9.1	-	-	3.0
Matricaria perforata Mérat.	4.7	4.7	1.2	-	1.2	-	7.7	6.1	2.3	-	2.8
Amaranthus retroflexus L.	-	2.4	2.4	2.4	1.2	5.9	-	3.0	3.0	-	2.0
Geranium pusillum L.	1.2	-	-	2.4	2.4	-	3.6	2.5	1.5	-	1.4
Stellaria media (L.) Vill.	1.2	2.4	-	-	-	-	-	1.5	-	-	0.5
Myosotis arvensis (L.) Hill.	-	1.2	1.2	-	-	-	-	-	1.0	-	0.3
Persicaria maculosa Gray	-	-	-	1.2	-	-	-	-	-	0.5	0.2
Veronica arvensis L.	-	-	-	1.2	-	-	-	-	0.5	-	0.2
Number of annual species	7	9	8	9	8	6	7	9	9	4	12
Perennial species											
Elymus repens (L.) Gould.	4.7	17.2	5.9	19.0	8.9	9.5	3.6	13.0	2.0	14.5	9.8
Sonchus arvensis L.	1.2	1.2	1.2	-	-	1.2	-	2.0	-	-	0.7
Number of perennial species	2	2	2	1	1	2	1	2	1	1	2
Total number of species	9	11	10	10	9	8	8	11	10	5	14

[1)] NOM – control without organic manure, FYM – farmyard manure, VV – hairy vetch, TR – white clover, SC – winter rye, LM – Italian ryegrass, BRT – winter turnip rape

[2)] HW – hand weeding, GCM – Guardian CompleteMix 664 SE, Z+T – Zeagran 340 SE + Titus 25 WG + Trend 90 EC number of plants of a given species. In GCM-treated plots, the number of weedy species increased during the second compared with the first counting. What is more, some species increased in abundance (in particular *E. crus-galli*, *Viola arvensis*, *F. convolvulus*) whereas the abundance of *Ch. album*, *Veronica arvensis*, *E. repens* declined, *S. media* and *S. arvensis* being totally eliminated.

Number of weeds and amount of their dry matter per unit of area, reflecting weed infestation in sweet corn cultivated in the experimental plots, was significantly affected by organic manuring and weed control methods (Tables 4–5).

Regardless of weed control method, on day 21 after sweet corn sowing the least weeds (119.2 no.$\cdot$m^{-2}) were found following an incorporation of VV catch crop (Table 4). In contrast, most weeds (170.7 no.$\cdot$m^{-2}) were noted for NOM and a similar number after LM and BRT catch crops (149.9 and 155.0 no.$\cdot$m^{-2}, respectively). No significant changes in the number of weeds and amount of their fresh matter were observed in GCM-treated plots due to an application of different organic manuring. In plots which were not treated for 20 days after corn sowing, least weeds were recorded after VV and most after BRT and in NOM. All the catch crops which were followed by sweet corn reduced the weight of fresh matter compared with FYM and NOM, the greatest decrease being observed after BRT and SC. It amounted to, respectively, 61% and 55% compared with FYM, and 67% and 62% compared with NOM.

Pre-emergent application of GCM reduced the number of weeds and amount of their fresh matter compared with non-treated plots by 78 and 89%, respectively.

The average number of weeds, determined 72 days after corn planting, was by 77.4 no.$\cdot$m^{-2} lower and the average fresh matter weight by 355.6 g$\cdot$m^{-2} greater compared with the first assessment (Table 5). The decrease in weed abundance was due to weed control practices applied in HW and Z+T plots. Also, developing corn plants and weeds that remained between rows competed with newly established weeds. A lower number of weeds per unit area resulted in them freely increasing in size and weight. According to Jodaugienė et al. [2006], weed sprouting is poorer in the period starting in mid-summer compared with spring and early summer so the effect of weed control methods is the most pronounced during the first part of the growing season. In turn Armengot et al. [2013] stress that total eradication of weeds in cultivated fields is not necessary but weeds should be controlled to the level when they do not affect negatively the crop plant.

Regardless of the weed control method, significantly most weeds were counted after farmyard manure (on average 93.6 no.$\cdot$m^{-2}). FYM is widely believed to be a source of weed infestation in arable fields [Wichrowska and Jaskólski 2014]. The number of diaspores spread with FYM may in extreme cases exceed 420 th no.$\cdot$mg^{-1}. Bedding and faeces are the major sources of weeds in farmyard manure [Pleasant and Schlather 1994].

Just like during the first assessment, the number of weeds after all the catch crops was significantly lower compared with FYM and NOM.

Table 4. Number and fresh mass of weeds (g$\cdot$m^{-2}) 21 days after sweet corn sowing (mean for 2009–2011)

Kind of organic manures	Number of weeds per m^2			Fresh matter of weeds (g$\cdot$m^{-2})		
	Weed control methods		Mean	Weed control methods		Mean
	no weeding [2)]	GCM		no weeding	GCM	
NOM [1)]	272.0 b*	69.3 a	170.7 c	670.2 b	47.1 a	358.7 d
FYM	250.1 ab	45.3 a	147.7 b	560.0 b	41.8 a	300.9 c
VV	197.5 a	40.9 a	119.2 a	289.8 a	13.3 a	151.6 ab
TR	232.6 ab	64.0 a	148.3 b	275.6 a	69.3 a	172.4 b
SC	243.3 ab	48.0 a	145.7 b	247.1 a	23.1 a	135.1 a
LM	235.8 ab	64.0 a	149.9 bc	263.1 a	42.7 a	152.9 ab
BRT	270.0 b	40.0 a	155.0 bc	208.0 a	28.4 a	118.2 a
Mean	243.0 B**	53.1 A	148.1	359.1 B	38.0 A	198.5

[1)] NOM – control without organic manure, FYM – farmyard manure, VV – hairy vetch catch crop, TR – white clover catch crop, SC – winter rye catch crop, LM – Italian ryegrass catch crop, BRT – winter turnip rape catch crop

[2)] no weeding – no weeding to 21 days from sweet corn sowing, GCM – Guardian CompleteMix 664 SE,

* Values within columns followed by the same lowercase letters are not significantly different at $P \leq 0.05$

** Values within rows followed by the same uppercase letters are not significantly different at $P \leq 0.05$

Table 5. Number and fresh mass of weeds (g·m^{-2}) 72 days after sweet corn sowing (mean for 2009–2011)

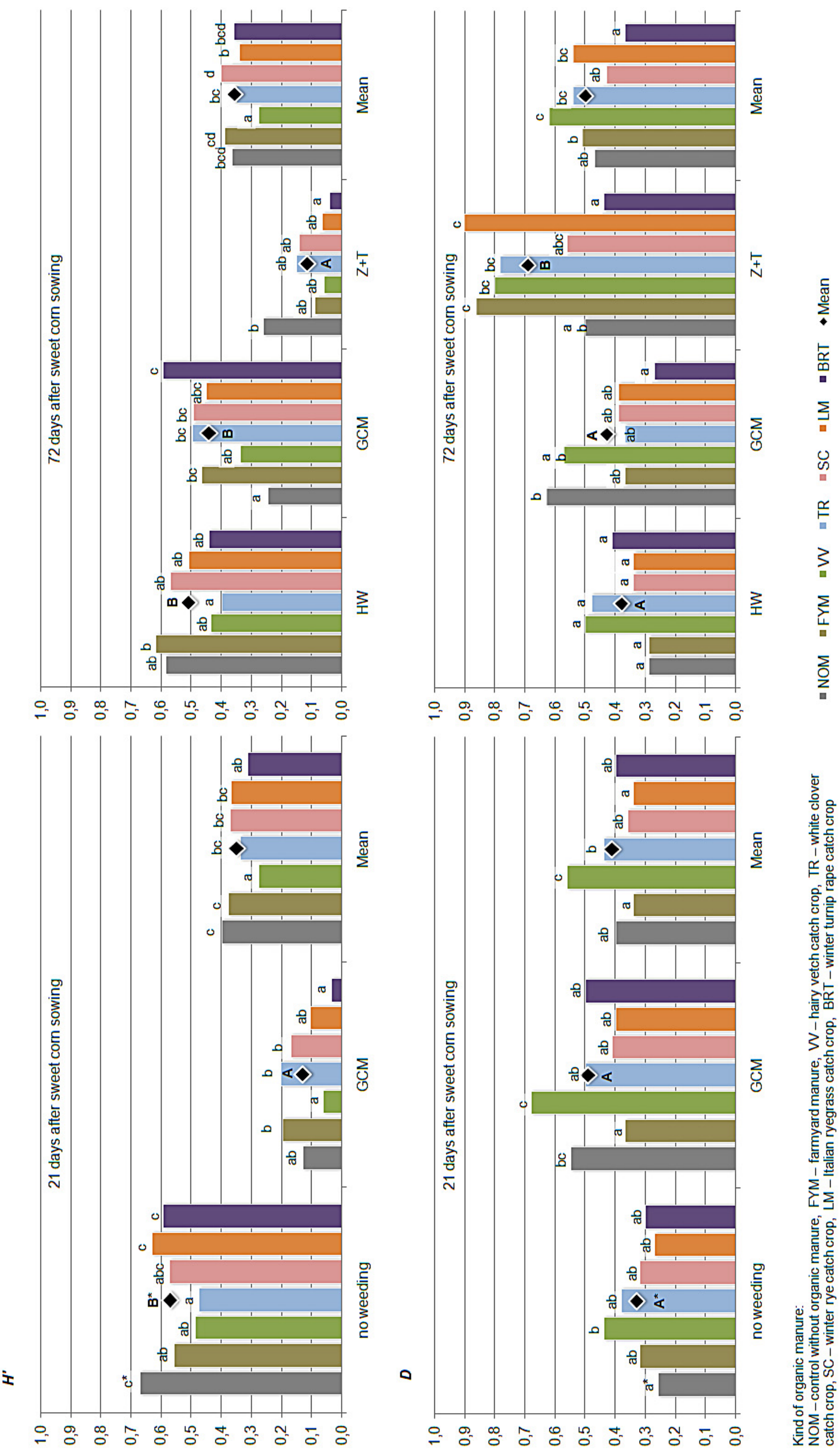
Kind of organic manures	Number of weeds per m^2				Fresh matter of weeds (g·m^{-2})			
	Weed control methods			Mean	Weed control methods			Mean
	HW [2)]	GCM	Z+T		Hw	GCM	Z+T	
NOM [1)]	108.4 b**	99.6 b	30.2 ab	79.4 c	1060.9 ab	695.7 c	52.6 a	603.1 cd
FYM	152.9 c	94.2 ab	33.8 ab	93.6 d	2023.8 d	451.3 b	182.9 a	886.0 e
VV	69.3 a	80.0 ab	39.1 ab	62.8 ab	849.2 a	361.8 ab	82.5 a	431.2 ab
TR	71.1 a	83.6 ab	53.3 b	69.3 b	1151.3 b	358.5 ab	86.4 a	532.1 bc
SC	87.1 ab	85.3 ab	32.0 ab	68.1 b	865.5 a	196.0 a	53.0 a	371.5 a
LM	92.4 ab	64.0 a	30.2 ab	62.2 a	1670.1 c	295.8 ab	77.0 a	681.0 d
BRT	71.1 a	92.4 ab	14.2 a	59.3 a	878.8 a	211.1 a	30.6 a	373.5 a
Mean	93.2 B**	85.6 B	33.3 A	70.7	1214.2 C	367.2 B	80.7 A	554.1

[1)] NOM – control without organic manure, FYM – farmyard manure, VV – hairy vetch catch crop, TR – white clover catch crop, SC – winter rye catch crop, LM – Italian ryegrass catch crop, BRT – winter turnip rape catch crop
[2)] HW – hand weeding, GCM – Guardian CompleteMix 664 SE, Z+T – Zeagran 340 SE + Titus 25 WG + Trend 90 EC
* Values within columns followed by the same lowercase letters are not significantly different at $P \leq 0.05$
** Values within rows followed by the same uppercase letters are not significantly different at $P \leq 0.05$

Weed abundance was most effectively reduced by BRT and LM catch crops. In GCM-treated plots the most weeds were observed in NOM and in Z+T-treated plots after TR. The greatest differences in the number of weeds and their fresh matter weight between the experimental organic manures were observed in hand weeded (HW) plots. Weed weight was significantly lower after catch crops than FYM. Compared with FYM, the greatest reduction in weed weight was observed after SC and BRT which had produced most biomass. Singh et al. [2003] have reported that catch crops reduce weed infestation because they overgrow weeds, and due to allelopathy. The more green matter is produced by catch crops, the greater the reduction. Bogužas et al. [2010] found that, of the catch crops they examined, winter rape and white mustard were the best, and red clover was the worst (it produced least biomass) at reducing the number of weeds and weight of their fresh matter. Malik et al. [2008], Jędrszczyk and Poniedziałek [2009] and O'Reilly et al. [2011] pointed to rye as a good catch crop which was very efficient at reducing weed load in sweet corn. In the present study, the weight of weeds after VV, SC and BRT was significantly lower compared with NOM. Abdin et al. [2000] reported lower numbers of weeds and their weight after fall rye, hairy vetch, white clover + ryegrass catch crops compared with corn cultivated without catch crop. Also Caporali et al. [2004] claimed that the number and weight of weeds establishing between rows were lower after ryegrass, subclover and hairy vetch catch crops compared with control where no catch crops were incorporated, ryegrass being the best weed competitor.

Olorunmaiye [2010] has suggested that leguminous plants can potentially be effective at controlling weeds but the amount of their biomass is crucial here. Under the growing conditions of Poland, Jędrszyk and Poniedziałek [2009] found that weed infestation of sweet corn was lower after white clover compared with the control without catch crop but much higher than after a rye catch crop. Special weed control properties of winter turnip rape and other *Brassica* plants have been highlighted by e.g.: Al-Khatib et al. [1997], Petersen et al. [2001] and O'Reilly et al. [2011]. They are connected with the fact that these plants secrete isothiocyanates which are toxic to some weedy species. It has been proven that winter turnip rape secretes substances which hinder seed sprouting of *Sonchus asper* (L.) Hill, *Matricaria inodora* L., *Amaranthus hybridus* L., *Echinochloa crus-galli* (L.) Beauv. and *Alopecurus myosuroides* Huds. [Petersen et al. 2001]. Also Caamal-Maldonado et al. [2001] and Weih et al. [2008] have pointed to a possibility of using allelopathic properties of plants representing other botanical families to reduce an occurrence of weeds.

In the present study, the herbicides Z+T were the best suppressors of weed number and weight. The superiority of chemical weed control over hand weeding repeated several times has been demonstrated by Abdin et al. [2000] and Malik et al. [2008]. Brandsæter et al. [2012] have suggested that post-emergent herbicides are more effective at reducing weed biomass compared with pre-emergent chemicals.



Kind of organic manure:
NOM – control without organic manure, FYM – farmyard manure, VV – hairy vetch catch crop, TR – white clover catch crop, SC – winter rye catch crop, LM – Italian ryegrass catch crop, BRT – winter turnip rape catch crop

Weed control method:
HW – hand weeding, GCM –Guardian CompleteMix 664 SE, Z+T – Zeagran 340 SE + Titus 25 WG + Trend 90 EC

*Values followed by the same letters are not significantly different at $P \leq 0.05$

Figure 3. Shannon-Wiener index of species diversity (H') and Simpson's index of domination (D) in sweet corn depending on the factors examined (mean for 2009–2011)

Figure 3 demonstrates segetal flora diversity reflected by the Shannon-Wiener index of diversity (*H'*) and Simpson's index of domination (*D*). Values of index *D* range from 0 to 1; values approximating 1 indicate that one or several species are clearly dominant and diversity of the community is low. By contrast, the higher index of diversity (*H'*), the greater diversity of phytocenose [Zanin et al. 1992]. In the experiment discussed here, the average value of index *H'* at the beginning of the growing season and sweet corn flowering did not change and amounted to 0.35. By contrast, the value *D* index increased from 0.41 to 0.50. According to Stupnicka-Rodzyniewicz et al. [2004] and Kostrzewska et al. [2011], the species biodiversity of weeds changes during the growing season and is affected by agrotechnological factors. The authors observed increased biodiversity during the mid-growing season of cereals. Regardless of the weed control method, on day 21 after sweet corn sowing the greatest diversity of weeds was found after FYM (*H'*=0.38) and for NOM (*H'*=0.40), and the lowest after VV (*H'*=0.27). During the second assessment, SC plots had the most diverse species composition of weeds (*H'*=0.40) whereas the least diversity was found for VV plots (*H'*=0.27) (as was the case during the first assessment). Majchrzak and Skrzypczak [2007] found no significant differences between index *H'* values for corn cultivated after spring vetch and control without catch crop. Wanic et al. [2004] pointed out that floristic composition of weed communities got impoverished due to the effect of Italian ryegrass whereas Kuraszkiewicz and Pałys [2003] reported a similar influence of red clover and annual ryegrass. In the study discussed here, weed diversity increased in GCM-treated plots on day 72 from corn planting, compared with the first assessment, the greatest diversity being observed after BRT catch crop.

The highest values of the index of domination (*D*) on day 21 and 72 from sweet corn planting were obtained after VV. Of all the GCM-treated plots, the greatest index *D* was calculated for NOM. In the case of Z+T plots, it was the greatest after FYM and LM. O'Reilly et al. [2011] cultivated sweet corn after rye and oat catch crops and found a significantly lower value of index *D* compared with cultivation without catch crop.

A post-emergent application of the herbicides Z+T definitely reduced species diversity of weeds compared with GCM and hand weeding repeated twice, as revealed by a decline in the value of index of biodiversity (*H'*) and an increase in the index of domination (*D*). Also Yao et al. [2010] observed declining values of index *H'* and increasing values of index *D* after chemical weed control compared with hand weeding.

CONCLUSIONS

1. Winter catch crops incorporated prior to sweet corn planting reduced weed infestation of the crop compared with cultivation including an application of farmyard manure and without catch crop. The most effective weed suppressors were rye, turnip rape and hairy vetch catch crops.
2. Italian ryegrass and turnip rape catch crops reduced weed richness compared with cultivation including an application of farmyard manure and without catch crop.
3. The greatest species diversity of weeds, determined at the flowering stage of sweet corn, was observed after rye catch crop and farmyard manure.
4. Chemical weed control more effectively reduced the number and weight of weeds than hand weeding. The best effects were obtained after post-emergent application of the mixture of herbicides Zeagran 340 SE + Titus 25 WG.
5. Species diversity of weeds following an application of Zeagran 340 SE + Titus 25 WG was definitely lower compared with a pre-emergent application of Guardian CompleteMix 664 SE and hand weeding performed twice.

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