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Allelopathic properties of selected lawn cultivars of *Poa pratensis* and their utilization in garden compositions

Allelopatyczne właściwości wybranych gazonowych odmian *Poa pratensis* i ich wykorzystanie w kompozycjach ogrodowych

Summary. The study objective was to assess the impact of the vegetative shoots of the lawn cultivars of *Poa pratensis* (one of the most valuable lawn grasses), cut and left on the lawn surface, on the species composition and overwinter survival of a lawn. The investigation was conducted in a field experiment. Each cultivar was sown in monoculture, on microplots covering 1 m^2 each. In the control objects, the cut biomass was removed immediately after the cutting. The investigation showed that 'Bila' had the strongest negative impact on the share of sown lawn grass cultivars (sensitivity to the biomass of the same cultivar remaining after cutting). The smallest share of other, unsown grass species in objects where the cut biomass remained was observed in lawns with 'Nandu' and, in the case of dicotyledons – with 'Bila'. The biomass left on the lawn surface after cutting did not have a significant influence on the overwinter survival of the plants. The negative impact of *P. pratensis* biomass, both on the sown cultivars and other groups of plants, can indicate its allelopathic properties. Therefore, the grass of this species should not be left on the lawn after cutting. The aboveground biomass cut and left on the lawn surface was shown to have a clearly varied influence on the soil pH: in the case of the 'Ani' and 'Bila' cultivars, the influence was unequivocally negative. In addition, the biomass of these cultivars did not result in significantly increased levels of assimilable forms of phosphorus, potassium and magnesium in the soil.

Key words: allelopathy, lawns, cut sward, *Poa pratensis*, changes in sward species composition, soil pH

INTRODUCTION

Grassy terrains perform a variety of natural and social functions, finding an application in both public and private spaces, and being used in various styles and types of gardens [Zachariasz and Lipińska 2017]. In home gardens, they are a place of rest, games and meetings, they serve to improve the aesthetics of the surroundings, give the impression of a larger space and blend in well with traditional and modern design style [Harkot and Lipińska 2007]. These functions make them occupy an average of 50% and sometimes even 80–90% of the garden area [Harkot and Lipińska 2007]. Unfortunately, they are very often used quite extensively, with the biomass left on the surface of the lawn after mowing. There is a widespread belief that vegetative aboveground shoots will enrich the substrate with essential nutrients. On the other hand, it is known that multispecies and multi-cultivar plant communities (such as well-composed lawns), growing in a specific ecological niche, better or worse tolerate the company of other living organisms. In order to survive, plants have many mechanisms of impact on the living environment, among others, through biochemical interactions of the biological nature called allelopathy [Lipińska et al. 2018, 2019]. A species with allelopathic properties may modify the growth and development of co-components in the mix, releasing allelopathic substances from both living and dead (mown) plant parts [Lipińska et al. 2018]. Grass leaves are particularly abundant source of these substances [Lipińska and Harkot 2005].

One of the basic, very valuable species of grass, commonly used for the construction of garden lawns is *Poa pratensis* [Martyniak 2003a, b, Prończuk and Prończuk 2003]. Its lawn cultivars are often composed in a seed mixture with varieties of other species, not always guaranteeing the durability of the established lawn [Prończuk and Prończuk 2008]. Therefore, this fact prompts to look for the causes of this condition, and one of the least known reasons are the allelopathic interactions of plants [Lipińska et al. 2019]. Recognition of these interactions is not only of cognitive, but also practical great importance, because they can lead to disruptions in many life processes of plants, and consequently affect the species composition and durability of the lawn.

The aim of the study was to assess the allelopathic vegetative interactions of aboveground shoots of selected lawn cultivars of *Poa pratensis* on the species composition of a lawn. It was assumed that the aboveground biomass of these cultivars contains allelopathic substances that can be washed out by water during both plant growth and after mowing, affecting changes in the species composition of grasslands and their durability.

MATERIAL AND METHODS

The above hypothesis was verified in field trials carried out at the Didactic and Research Station in Sosnowica. The research was carried out in 2010–2014. These studies were within the scope of a wider experiment established using the randomized blocks method (in triplicate) in 2003 on light mineral soil.

The research covered three lawn cultivars of *P. pratensis*: ‘Ani’ (not very subtle leaf blades, average compositional value, good coverage of the ground, creates a strong root system, it is useful for lawns intensively and extensively used); ‘Bila’ (medium early with green, broad leaf blades, good compositional value, strong and dense root system,

on lawns used quite intensively) and 'Nandu' (with dark-green leaf blades, very good compositional value, the root system is compact and strong, slowly grows back after mowing, useful for medium and very intensive lawns). Each cultivar was sown in monoculture on 1 m^2 microplots. In the years 2003–2010 preceding the actual experiment and in the years 2010–2014 during the growing season, the same quantities of mineral fertilizers were applied to all plots, and during the growing season, 12–15 cuts were carried out [Lipińska et al. 2018] leaving the biomass on selected plots since 2008 (initial state for analysis). The control consisted of objects, from which the cut biomass was removed immediately after mowing (Tab. 1).

Studies evaluated the effect of biomass of tested cultivars cut and left on the lawn surface on the species composition – by means of the Weber squares method and the overwintering of the lawn according to the 9-point scale (Tab. 2) in accordance with the methodology given in previous study [Lipińska et al. 2018]. From the point of view of the assessment of biological, compositional and aesthetic values of lawn, the difference of 1° is considered significant [Domański 1992].

Table 1. Design of the field experiment with lawn grass cultivars of *Poa pratensis* (*Pp*)

A – sites with the cut sward left on the lawn			B – control sites with the cut sward removed from the lawn immediately after cutting		
'Ani'	'Bila'	'Nandu'	'Ani'	'Bila'	'Nandu'
'Bila'	'Ani'	'Nandu'	'Nandu'	'Ani'	'Bila'
'Ani'	'Nandu'	'Bila'	'Ani'	'Nandu'	'Bila'

Table 2. Scale to assess the over-wintering survival of the cultivars tested [Domański 1992]

Scale	Over-wintering survival
1	Very poor
3	Poor
5	Medium
7	Good
9	Very good

Studies evaluated the effect of biomass of tested cultivars cut and left on the lawn surface on the species composition – by means of the Weber squares method and the overwintering of the lawn according to the 9-point scale (Tab. 2) in accordance with the methodology given in previous study [Lipińska et al. 2018]. From the point of view of the assessment of biological, compositional and aesthetic values of lawn, the difference of 1° is considered significant [Domański 1992].

Chemical and physicochemical analyses of the soil were carried out in an accredited laboratory of the Chemical-Agricultural Station in Lublin. In the soil material, the pH and content of available forms of phosphorus, potassium and magnesium were determined [Lipińska et al. 2019].

Results of the research were statistically analyzed in the SAS ver. 91 software using a one-factor analysis of variance. To verify the significance of differences between means, T-Tukey confidence intervals ($p \leq 0.05$) were applied.

RESULTS

Changes in the species composition of the lawn

In spring 2008 (after five years of use) on object A with mown biomass left on the lawn, the species composition of lawn with cultivar 'Ani' of *P. pratensis* was unsatisfactory. The proportion of sown cultivar was only 40%, while the remaining area was occupied primarily by dicots (about 40%) and other non-sown grass species (about 20%) (Fig. 1). In the study years (2010–2014), on object with mown and left grass (A), the share of sown cultivar remained at a level similar to the initial state, and the share of dicotyledonous plants decreased significantly (especially in the initial observation period), while others non-sown grass species increased their share. On the other hand, on the control object (B), from which the cut biomass was removed, the proportion of sown cultivars increased in relation to the initial state and initially exceeded even 50%. In the last year of research, however, this share has drastically decreased. Number of weeds was significantly less, but other non-sown grass species increased their share. Comparing the species composition of 'Ani' lawn on objects A and B, attention is paid to the smaller share of sown cultivar, and the larger group of plants on the object where the mowed biomass (A) was left than on object, from which the biomass was removed (B).

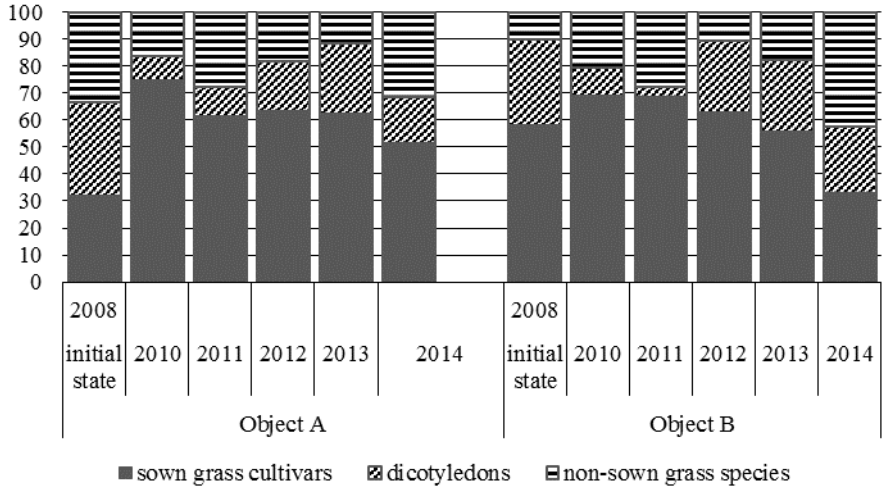

Fig. 1. Changes in the species composition of the sward with the 'Ani' cultivar of *P. pratensis* in object A where the cut biomass was left on the lawn surface, and in object B where the cut biomass was removed

Assessing the species composition of lawn from the 'Bila' *P. pratensis* cultivar, it was shown that in spring 2008 the proportion of sown species was also unsatisfactory and amounted to only about 40% on the assessed objects (Fig. 2). In the years of research, regardless of the object, this condition worsened. During this time, opposite tendencies were observed in other, non-sown species of grasses and dicotyledonous plants, especially on object B, from which the mown biomass was removed. On the object, where the cut biomass was remained, the proportion of dicotyledonous plants was significantly reduced in relation to the initial state and was smaller than on the control object. However, the biomass left on the lawn also had a negative effect on *P. pratensis* plants, causing them to subside. Free space was occupied by other, non-sown grasses, the share of which increased many times and was larger than on the control object (B).

In spring 2008, the species composition of the lawn with participation of 'Nandu' *P. pratensis* was rated unsatisfactory on object, where it was planned to leave the mown biomass (A) and satisfactory on object selected as control (B) (Fig. 3). The initial proportion of 'Nandu' plants was 32% and 58%, respectively (Fig. 3). The other components had similar, about 30%, share of both dicotyledonous plants and other grasses on object A, while quite large share of weeds (32%) and a small share of other grasses (10%) on object B. In the years of assessment in relation to the initial state, the increase in the share of plants of the sown cultivar was observed, the larger one on the object with the residue (A) than the biomass removed (B). Also on object A, possibly under the influence of biomass remaining, a greater reduction of weeds was noted than on object B, from which the biomass was removed. The cut biomass that was left on the lawn showed similar effect on the participation of other, non-sown grass species. The share of this group of plants has been significantly reduced compared to the state of 2008. In turn, on object, from which the mown biomass was removed, other grasses significantly increased their share in 2014.

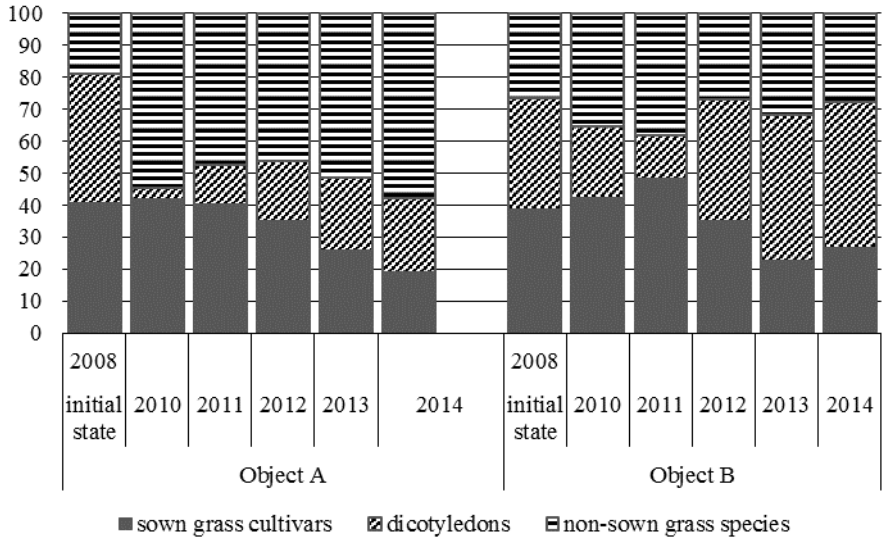

Fig. 2. Changes in the species composition of the sward with the 'Bila' cultivar of *P. pratensis* in object A where the cut biomass was left on the lawn surface, and in object B where the cut biomass was removed

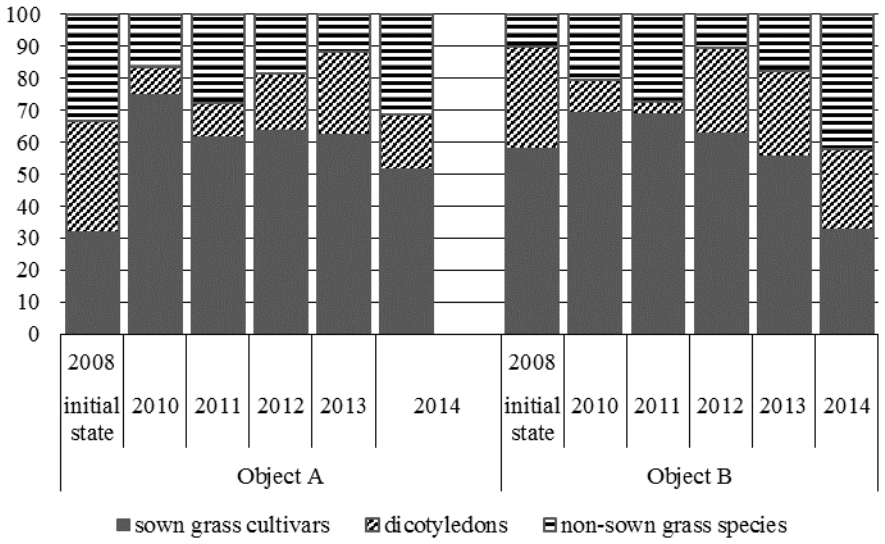

Fig. 3. Changes in the species composition of the sward with the 'Nandu' cultivar of *P. pratensis* in object A where the cut biomass was left on the lawn surface, and in object B where the cut biomass was removed

Taking into account the averages for the research period (2010–2014), data on the species composition of lawns on objects A and B showed that the proportion of sown grass cultivars in the lawn between these objects differed significantly only in the case of 'Ani', the share of the sown cultivar in the lawn was greater when mown biomass was removed from the lawn surface immediately after mowing. Similar relations were found in the 'Bila' lawns, but these differences were not statistically significant. Lack of significant differences was also noted on objects with 'Nandu', however, a larger proportion of the sown cultivar was on objects, where the mown biomass was left on the surface of lawn (Tab. 3).

Among the sodding plants, non-sown grass species were found in the lawn; it was the most often annual bluegrass. Among the assessed lawns, significantly higher share of this group of plants was found in the lawn with 'Ani' and 'Bila' ($p = 0.01$) on objects with biomass mown and left on the lawn surface (Tab. 3). Only in the case of objects with 'Nandu', a larger share of non-sown grasses was recorded on objects, where the mown biomass was removed immediately after the treatment (B). The research shows that especially the most effective inhibitor for dicotyledonous plants was the mown and left biomass of 'Bila' cultivar (Tab. 3). In comparison with objects, from which the cut biomass was removed immediately after mowing, the share of this group of plants was many times lower. Lower share of dicotyledonous plants on objects with the biomass remainder than with the removed one directly after mowing, was also found in the 'Ani' and 'Nandu' lawn, however, from a statistical point of view, these differences were irrelevant.

Table 3. Share of sown grass cultivars, unsown grass species and dicotyledons in the sward of lawn cultivars of *Poa pratensis* in object A where the cut biomass was left on the lawn surface, and in object B where the cut biomass was removed

Cultivar	Parameter	Objects	
		A	B
'Ani'	sown grass cultivars	35.9[a]	49.1[b]
	non-sown grass species	40.2[b]	29.6[a]
	dicotyledons	23.3[a]	26.5[a]
'Bila'	sown grass cultivars	32.4[a]	34.9[a]
	non-sown grass species	50.7[b]	31.2[a]
	dicotyledons	20.3[a]	33.5[b]
'Nandu'	sown grass cultivars	62.8[a]	57.9[a]
	non-sown grass species	20.3[a]	22.9[a]

The same letters indicate the lack of significant differences between mean values in the particular lines

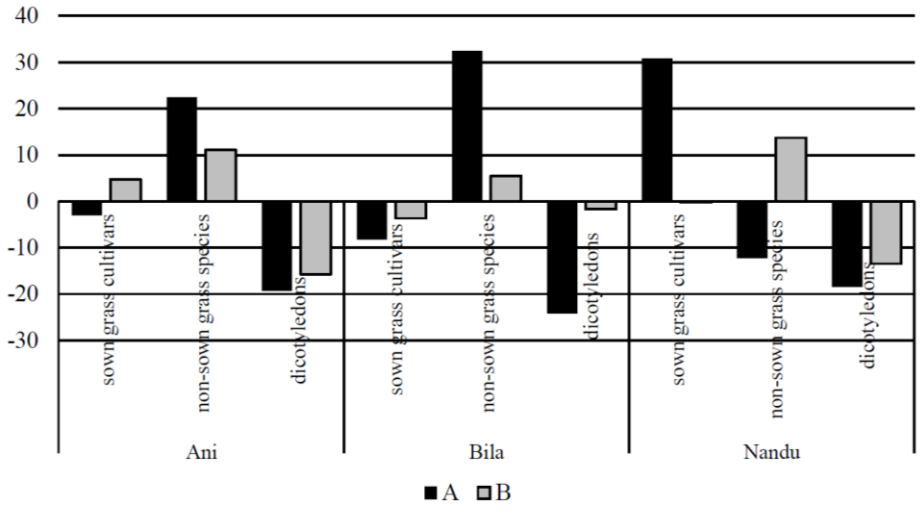

Fig. 4. Percentage of inhibition or increase in the proportion of sown and non-sown grass species, dicotyledonous plants to the initial state (from 2008) in the lawn sward: A – sites where the cut sward was left on the lawn and B – control sites where the cut sward was removed from the lawn immediately after cutting (mean values from 2010–2014)

Studies evaluated changes in the species composition of lawns under the influence of cut and left biomass (A) and control biomass (B – of which the biomass was removed immediately after the treatment) also in relation to the initial state (2008). On this basis, it should be stated that the decrease in the proportion of sown grass cultivars was usually higher on objects A than B, with the exception of the lawn with 'Nandu' cultivar (Fig. 4). However, this

decrease did not exceed 10%. On objects, from which the biomass was removed, it was even smaller, and even an increase in the share of sown 'Ani' was observed.

Leaving the mown biomass of the tested cultivars on the surface of the lawn resulted in the largest increase in the proportion of other, non-sown grass species in the lawn. This phenomenon was less dynamic on object B. The exception was the lawn with 'Nandu', where smaller share of other grass species was recorded on objects A than B.

Comparing, in turn, the decrease or increase of dicotyledonous species on objects A and B, it can be concluded that the mown biomass of all cultivars left on the surface caused a decrease in the share of this group of plants in relation to the state of 2008. The biggest differences between objects A and B were found on lawns with 'Bila' (respectively –24.2% and –1.73%), while on other objects, these differences were smaller (around 5%).

Overwintering

The obtained results indicate different overwintering of studied *P. pratensis* cultivars (Tab. 4). The overwintering of 'Ani' and 'Bila' plants was rated as medium to good, 'Nandu' cultivar – good to very good. Also in the studies of Stawiska and Prończuk [2006], the 'Bila' plants were characterized by poor overwintering. In the conducted tests, significantly higher assessment of 'Bila' overwintering was noted under conditions of interaction of the mown biomass (A) left on the surface of the lawn than in the control conditions (B). Reverse dependencies were recorded on plots with 'Nandu' cultivar. This cultivar was characterized by a 1.3° weaker overwintering on the object (A) than on the object (B).

Table 4. Influence of the cut biomass left on the lawn surface on the overwinter survival of the sward with *P. pratensis* (according to the 9-point COBORU scale), mean values for the years 2010–2014

Cultivar	Objects	
	A	B
'Ani'	6.8[a]	7.2[a]
'Bila'	6.1[a]	5.7[a]
'Nandu'	6.8[a]	8.1[a]

The same letters indicate the lack of significant differences between mean values in the particular lines

Physicochemical and chemical properties of the soil

There is a fairly common belief that leaving the mown biomass enables secondary circulation of matter within the mowing area, due to which mineral fertilization can be reduced, and there is no problem with its management. To verify this common opinion, analyses were performed on the content of macroelements in soil and its pH. The analysis results showed that the pH of the soil from beneath the sward of the lawn grass cultivars under study was acidic or slightly acidic, and it clearly varied both between the studied cultivars and the individual objects: A – where the cut biomass left on the lawn surface, and B – where the biomass was removed immediately after the cutting (Tab. 5). A particularly large difference in soil acidity was observed where the biomass of the 'Ani' and 'Bila" cultivars was left on the surface, while no acidifying effect was observed in the case of the 'Nandu' cultivar. On the other hand, there was a greater vari-

ation in the P, K and Mg contents between cultivars, but smaller between objects A and B. The content of phosphorus in the soil ranged from 9.3 to 14.6 mg, assessed mainly as an average. Only on the objects with mown and left biomass (A) of 'Ani' cultivar, the content of this component was lower than on objects with this cultivar, but from which the biomass was removed (B). Potassium content in the samples tested was also medium and low. On the 'Ani' and 'Bila' objects, on which mown biomass was left on the lawn surface, lower values were found. In turn, magnesium content in the soil on all objects

Table 5. Soil pH and contents of bioavailable phosphorus, potassium and magnesium (mg · 100 $g^{-1)}$ under lawns of turf grass cultivars *P. pratensis*

Cultivar	Object	pH	Reaction	Content of bioavailable elements content (mg · 100g^{-1} soil)		
				Phosphorus (P_2O_5)	Potassium (K_2O)	Magnesium (Mg)
'Ani'	A	5,05	acidic	9.3 (L)	6.1 (L)	3.8 (M)
	B	5,89	slightly acidic	14.4 (M)	8.6 (M)	4.3 (H)
'Bila'	A	5,45	acidic	11.7 (M)	7.2 (L)	4.3 (H)
	B	5,73	slightly acidic	11.1 (M)	11.5 (M)	4.8 (H)
'Nandu'	A	5,9	slightly acidic	14.6 (M)	9.1 (M)	3.8 (M)
	B	5,81	slightly acidic	11.1 (M)	10.4 (M)	4.3 (H)

A – sites with the cut sward left on the law; B – control sites with the cut sward removed from the lawn immediately after cutting; nutrients status: L – low, M – medium, H – high

was high; the only exception was the lawn with 'Ani' and 'Nandu', on the surface of which the mown biomass was left. On these objects, the abundance in this element was rated as an average. Therefore, leaving the plant biomass on the surface of the lawn did not increase the content of available forms of phosphorus, potassium and magnesium in the soil.

DISCUSSION

One of the important stages in the study upon allelochemical interactions of plants is the observation of this phenomenon in the ecosystem [Lipińska 2001]. Changes in the species composition of lawns and overwintering were adopted as indicators of allelopathic interactions of studied *Poa pratensis* species. These are very important usable features of lawns, which determine not only positive aesthetic impressions, but also can prove the durability of species included in the lawn and their adaptation to habitat conditions [Czarnecki and Harkot 2002, Grabowski et al. 2010].

Differences in the values of evaluated parameters found in the field studies indicate the effect of the mown biomass left on the lawn surface on its floristic composition and durability. However, this impact varied and depended on the donor – cultivar and the

parameter assessed. Differences in the strength of allelopathic interactions between different plant cultivars have also been demonstrated in other studies [Kovar et al. 2013, Lipińska et al. 2014]. According to these authors, differences may be due to the diverse plant's ability to synthesize allelopathins.

Taking into account the average values for the research period (2010–2014), it should be stated that the biomass of 'Bila' remained exerted the most negative influence on the proportion of sown lawn cultivars (sensitivity to the biomass of the own cultivar left after mowing). The smallest share of other non-sown grass species on biomass-left objects was recorded on the lawn with 'Nandu', while dicotyledonous species – with 'Bila'. The cut biomass left on the lawn had no significant effect on plants' overwintering. Negative impact of the biomass of *Poa pratensis* cultivars left on the lawn surface, both on the sown cultivars and other groups of plants, may indicate its allelopathic properties. Studies of many authors confirm the allelopathic activity of *Poa pratensis*, but most of all, its fodder cultivars [Lipińska and Harkot 2000, 2005, Lipińska and Oleszek 2002, Bostan et al. 2010]. Allelopathic properties of this species may be indicated by present (especially in older tissues) secondary metabolites such as: endogenous gibberellin (A19) with positive action and abscisic acid (ABA) with negative effect [Kączkowski 2009]. In the literature, however, there are few papers dealing with the problem of allelopathic properties of the lawn *Poa pratensis* cultivars [Lipińska et al. 2014]. Therefore, any research that approximates the relationship between lawn cultivars or grass species opens up enormous possibilities of controlling communities using only their natural resources [Macias et al. 2007]. Based on the observation of the floristic composition of lawns, it can be assumed that the mown biomass left on the lawn also affects the participation of dicotyledonous plants, including weeds. According to many authors [Bhowmik and Inderjit 2003, Macias et al. 2007], allelopathic properties of some plants can be used to control weeds, including in grasslands. These observations are also confirmed by the conducted research, in which the influence of the cut and left biomass of the studied cultivars on the share of dicotyledons in the lawn was noticed. This effect varied depending on the cultivar, as in the studies of Bertina et al. [2007], which indicate large variation in weed displacement, among the lawn grass cultivars.

CONCLUSIONS

1. Research has shown that leaving cut leaves on the lawn surface affects its species composition and durability.

2. Biomass mowed and left on the lawn surface had stronger impact on the participation of dicotyledonous plants in the lawn than the sown grass cultivars. This influence also depended on the tested cultivar. The persistence of sown cultivars in the sward was positively influenced by the 'Nandu' biomass left after mowing, causing also the smallest share of other non-sown grasses, while negatively – 'Bila' and 'Ani'. 'Bila' cultivar also proved to be an effective inhibitor for dicotyledonous plants.

3. The cut biomass left on the lawn had no significant effect on plants' overwintering. Slightly weaker overwintering of plants than on control objects was caused by the 'Nandu' biomass, which received the highest scores among the cultivars studied.

4. The aboveground biomass cut and left on the lawn surface was shown to have a clearly varied influence on the soil pH: in the case of the 'Ani' and 'Bila' cultivars, the influence was unequivocally negative.

5. Mowed grass should not be left on the surface of lawns in home gardens, because it shows unfavorable, allelopathic effects on the floristic composition of lawns, without causing significant enrichment of the substrate with minerals.

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Streszczenie. Celem badań była ocena oddziaływania pozostawianych na powierzchni murawy skoszonych wegetatywnych pędów gazonowych odmian *Poa pratensis* (jednego z najbardziej wartościowych gatunków traw gazonowych) na skład gatunkowy oraz przezimowanie trawnika. Wpływ ten badano w doświadczeniu polowym. Każda odmiana była wysiana w monokulturze na mikropoletkach o powierzchni 1 m^2. Kontrolę stanowiły obiekty, z których skoszoną biomasę usuwano bezpośrednio po zabiegu. W badaniach wykazano, że największy ujemny wpływ na udział wysianych gazonowych odmian traw (wrażliwość na pozostawianą po skoszeniu biomasę własnej odmiany) wykazywała 'Bila'. Najmniejszy udział innych niewysianych gatunków traw na obiektach z pozostawianą biomasą notowano na murawach z 'Nandu', natomiast najmniejszy udział gatunków dwuliściennych − na murawach z 'Bila'. Pozostawiana na powierzchni trawnika ścięta biomasa nie miała istotnego wpływu na przezimowanie roślin. Ujemny wpływ biomasy *P. pratensis*, zarówno na wysiane odmiany, jak i inne grupy roślin może świadczyć o jej właściwościach allelopatycznych, zatem skoszona trawa tego gatunku nie powinna być pozostawiania na powierzchni trawnika. Wykazano wyraźny zróżnicowany wpływ pozostawianej skoszonej biomasy nadziemnej na powierzchni murawy trawnika na odczyn gleby – w przypadku odmian 'Ani' i 'Bila' jednoznacznie negatywny. Biomasa tych odmian nie powodowała istotnego wzrostu zawartości przyswajalnych form fosforu, potasu i magnezu w glebie.

Słowa kluczowe: allelopatia, trawniki, skoszona murawa, *Poa pratensis*, zmiany w składzie gatunkowym muraw, pH gleby

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