ANNALES UMCS
VOL. LXXI (3) SECTIO E AGRICULTURA 2016

[1] Department of Grassland and Landscape Forming, University of Life Sciences in Lublin
ul. Akademicka 15, 20-950 Lublin, e-mail: hllpl@yahoo.com
[2] Department of Landscape Architecture, Cracow University of Technology
ul. Podchorążych 1, 30-084 Kraków
[3] State School of Higher Education in Chełm
ul. Wojsławicka 86, 22-100 Chełm

HALINA LIPIŃSKA[1], MAGDALENA SYKUT[1],
AGNIESZKA KĘPKOWICZ[1], WIESŁAW WAŃKOWICZ[1],
ALICJA BIESKE-MATEJAK[1], AGATA ZACHARIASZ[2],
RAFAŁ KORNAS[3], WOJCIECH LIPIŃSKI[3],

The allelopathic impact of the cut aboveground biomass of *Lolium perenne* on the species composition and the aesthetic value of lawns

Allelopatyczny wpływ skoszonej biomasy nadziemnej *Lolium perenne* na skład gatunkowy i walory estetyczne trawnika

Summary. The study objective was to assess the allelopathic impact of the cut aboveground vegetative shoots of the selected lawn cultivars of *L. perenne* on the decorative value and species composition of the sward, including the share of dicotyledons. The studies were conducted in field conditions. The following indicators of the allelopathic impact of *L. perenne* were chosen: the share of the sown cultivars and dicotyledons in the lawn sward, general aspect, sward density and overwinter survival in object A, where the cut biomass was left, and in control object B, from which the biomass was removed immediately after cutting. The biomass of 'Nira' and 'Stadion' cultivars, cut and left on the lawn surface, exhibited auto-allelopathic properties by reducing their own share in the sward. The share of dicotyledons in the sward was reduced to the largest extent in the treatment where the cut biomass of 'Nira' cultivar was left. Only the 'Stadion' cultivar had a significantly lower sward density and a poorer general aspect of the sward in objects where the cut biomass was left in comparison with the objects where the cut biomass was removed. All the cultivars under study had better overwinter survival results in the objects where the cut biomass was left on the lawn surface.

Key words: allelopathy, cut lawn sward, *Lolium perenne*, botanical composition, general aspect, compactness, wintering plants

INTRODUCTION

Turf grasses are a valuable component of the natural environment. Because of their significant biological and aesthetic role in green areas, it is difficult to replace these

plants with other species. Hence, recent years have seen a rapidly increasing interest in establishing lawns [Harkot and Lipińska 2007]. In conurbations, lawns have a favourable influence on the microclimate, reduction of noise and vibration caused by road traffic. It is difficult to imagine an attractive garden without lawns as they introduce light, space and calm green that have a favourable influence on human well-being and psyche. The green of the lawns highlights the morphological properties of ornamental trees, shrubs and herbaceous plants, particularly blooming plants. In urbanised areas, grass surfaces expand the biologically active areas and are frequently used for recreation purposes. They are also widely used on untypical surfaces such as car parks or roofs of buildings [Kępkowicz 2000]. Laws have become a dominant feature of gardens also in rural areas, occupying from 40 to 70% of the garden area [Harkot and Lipińska 2007].

The durability, attractiveness and composition of multi-species lawn sward is influenced by a number of habitat factors as well as physical and chemical processes resulting from the proximity of other species [Lipińska and Harkot 2007, Lipińska and Lipiński 2009]. The mutual impact between plants via chemical substances is called allelopathy. These substances are released from the living aboveground parts of the plants and secreted by the roots. They also form during the decomposition of dead plant parts [Lipińska and Harkot 2005]. Leaves are the richest source of allelopathic substances in the aboveground vegetative shoots of plants [Lipińska 2005]. Therefore, cutting and leaving them on the lawn surface can have a negative impact on the species composition and functional value of the sward due to the allelopathic impact of the released substances on the growing plants [Lipińska *et al.* 2013]. On the other hand, there is a widespread belief that leaving the cut sward on the lawn surface enables the re-circulation of matter within the lawn, thanks to which mineral fertilization can be reduced and the problem of disposing of the cut grass can be avoided.

Lolium perenne ranks first among the six most important lawn species in Europe. Thanks to its peculiar morphological and biological properties, this species is particularly suitable for establishing decorative lawns. However, it is also used for the turfing of intensively used areas (e.g. sports fields) and extensively used areas [Domański and Golińska 2003, Grabowski *et al.* 2003, Radkowski et. al 2006, Wolski *et al.* 2006]. It is used in the rehabilitation of areas degraded by industry and in the development of areas adjoining motorways and expressways where it protects the soil against water and wind erosion and has a favourable influence on the aesthetic value of landscape [Pawluśkiewicz 2009].

The studies were undertaken with the assumption that the sward cut and left on the surface of a *L. perenne* lawn has allelopathic properties that can have both a positive and negative influence on the durability and quality of the lawn. In order to verify the hypothesis above, investigations were conducted to assess the allelopathic impact of the cut aboveground vegetative shoots of the selected lawn varieties of *L. perenne* on the decorative value and species composition of the sward, including the share of dicotyledons.

MATERIAL AND METHODS

The allelopathic properties of the lawn cultivars of *L. perenne*, namely ‘Niga’, Nira’ and ‘Stadion’, were studied in field conditions. The experiment assessed the impact on

the species composition, sward density, general aspect and overwinter survival of the sward exerted by the biomass of the 'Niga', Nira' and 'Stadion' cultivars of *L. perenne*, cut and left on the lawn surface. In the control objects, the cut sward was removed from the lawn surface immediately after the defoliation (cutting). The studies were conducted at the Didactic-Research Station in Sosnowica in the years 2007–2010 on a randomised block design experiment (with three replications) established on a light mineral soil in 2003. Each cultivar was sown in monoculture, on microplots covering 1 m^2 each (Tab. 1).

Table 1. Diagram of the field experiment with cultivars of *L. perenne*
Tabela 1. Schemat doświadczenia polowego z odmianami *L. perenne*

A – objects where the cut sward was left on the lawn/ obiekty z pozostawianą na powierzchni trawnika skoszoną biomasą			B – control objects where the cut sward was removed from the lawn immediately after cutting/ obiekty kontrolne, z powierzchni których skoszoną biomasę usuwano		
'Stadion'	'Niga'	'Stadion'	'Niga'	'Stadion'	'Stadion'
'Nira'	'Nira'	'Nira'	'Stadion'	'Nira'	'Niga'
'Niga'	'Stadion'	'Niga'	'Nira'	'Niga'	'Nira'

Table 2. Assessment scale of the functional characteristics studied [Domański 1992]
Tabela 2. Skala ocen badanych cech użytkowych [Domański 1992]

Scale Skala	Functional characteristic/ Cecha użytkowa		
	general aspect aspekt ogólny	sward density zadarnienie	overwinter survival przezimowanie
1	inadequate/ zły	inadequate (no leaves)/ złe (brak liści)	very poor/ bardzo słabe
3	poor/ słaby	poor/ słabe	poor/ słabe
5	acceptable/ dostateczny	acceptable/dostateczne	medium/ przeciętne
7	good/ dobry	good/ dobre	good/ dobre
9	very good/ bardzo dobry	very good (perfect carpet)/ bardzo dobre (idealny dywan)	very good/ bardzo dobre

In the growing season in the years of 2007–2010, equal amounts of mineral fertiliser were applied in all microplots: N – 150, P – 88, K – 144 kg ha^{-1} according to the guidelines [Harkot *et al.* 2003]. The lawn was cut 12 to 15 times per growing season (depending on the year) to the height of 4 cm at the time when the height of the plants reached 200% of the cutting height adopted. The frequency of cutting was adapted to the intensity of use of "Relaks" – type lawns, according to the recommendations issued by COBORU (Polish Research Centre for Cultivar Testing) [Domański 2002].

Each spring (one week into the growing season) and each autumn (October), the species composition of the sward (Weber's squares method), sward density and general aspect were assessed. The overwinter survival was assessed in the spring only. The sward density, general aspect and overwinter survival assessment, were carried out according to COBORU recommendations [Domański 1992], using a 9-step scale (Tab. 2).

RESULTS

In the field experiment in the spring of 2008 (fifth year from the establishment of the experiment), the share of 'Niga', 'Nira' and 'Stadion' cultivars in the sward of the objects was varied. The percentage share of the 'Niga' cultivar in objects where the cut biomass was left (A) and in objects where the cut biomass was removed (B) amounted to about 70%, the share of dicotyledons was about 28% while of the unsown grass species 1–2% (Fig. 1).

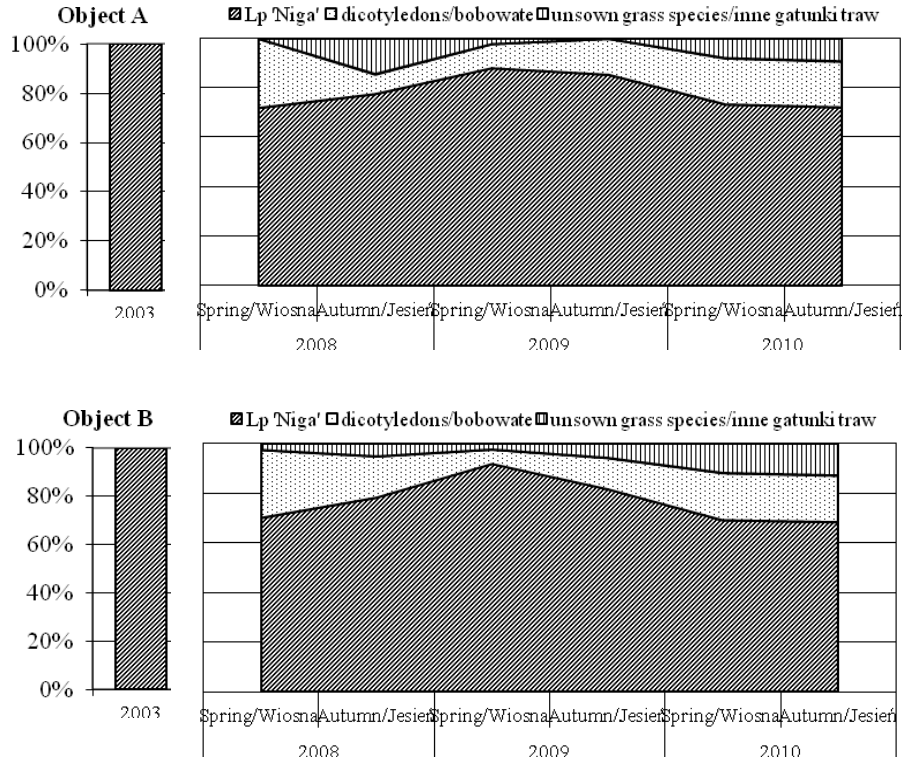

Fig. 1. Percentage share of the 'Niga' cultivar of *L. perenne*, dicotyledons and unsown grass species in objects where the cut biomass was left on the lawn surface (A) and in objects where the cut biomass was removed (B) in the years 2008–2010 (Spring, Autumn – measurement date)
Rys. 1. Procentowy udział odm. 'Niga' *L. perenne*, bobowatych oraz innych gatunków traw na obiektach A (z pozostawianą na powierzchni trawnika skoszoną biomasą) i B (z powierzchni których skoszoną biomasę usuwano) w latach 2008–2010 (wiosna, jesień – termin pomiaru)

In the subsequent years, the floristic composition of objects A and B was similar in the spring and autumn. Particularly the assessments in the autumn showed an increased share of the sown cultivar and unsown grass species and a decreased share of dicotyledons.

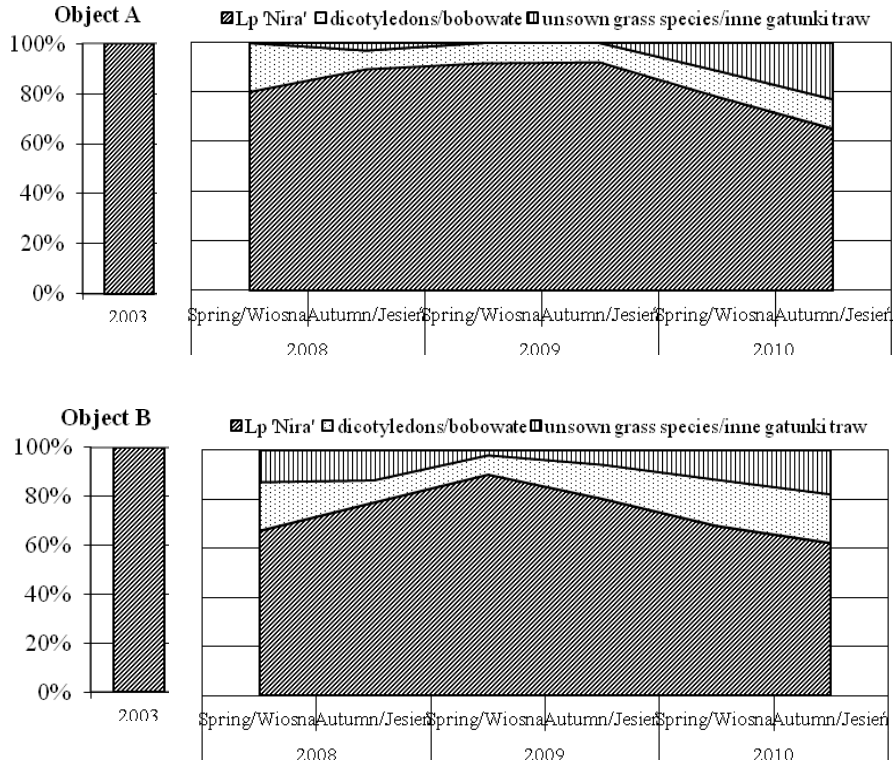

Fig. 2. Percentage share of the 'Nira' cultivar of *L. perenne*, dicotyledons and unsown grass species in objects where the cut biomass was left on the lawn surface (A) and in objects where the cut biomass was removed (B) in the years 2008–2010 (Spring, Autumn – measurement date)
Rys. 2. Procentowy udział odm. 'Nira' *L. perenne*, bobowatych oraz innych gatunków traw na obiektach A (z pozostawianą na powierzchni trawnika skoszoną biomasą) i B (z powierzchni których skoszoną biomasę usuwano) w latach 2008–2010 (wiosna, jesień – termin pomiaru)

In the spring of 2008, the share of 'Nira' *L. perenne* in objects A (where the cut biomass was left) was 80% and the share of dicotyledons was 20%. In objects B, the share of the 'Nira' cultivar was smaller (67%) while the share of dicotyledons was 20% and of unsown grass species – 13% (Fig. 2). In the subsequent assessments (autumn 2008 and spring 2009), the share of the 'Nira' cultivar increased both in objects A and B, while the share of dicotyledons decreased. This trend lasted in object A until the autumn of 2009, but in the autumn of 2010 the share of unsown grass species increased to as much as 23% at the expense of the 'Nira' cultivar (by 15% smaller than in the spring of 2008). In object B, where the cut biomass was removed, the share of the 'Nira' cultivar in the sward was successively decreasing from the spring of 2009 (90%) to the autumn of 2010 (62%). In the same period, the share of dicotyledons rose by 12% and unsown grass species by 16%. It was worth noting that, at the end of the three-year study period, there was a similar share of the 'Nira' cultivar in objects A (65%), where the cut biomass was left, and in objects B (62%), where the cut biomass was removed.

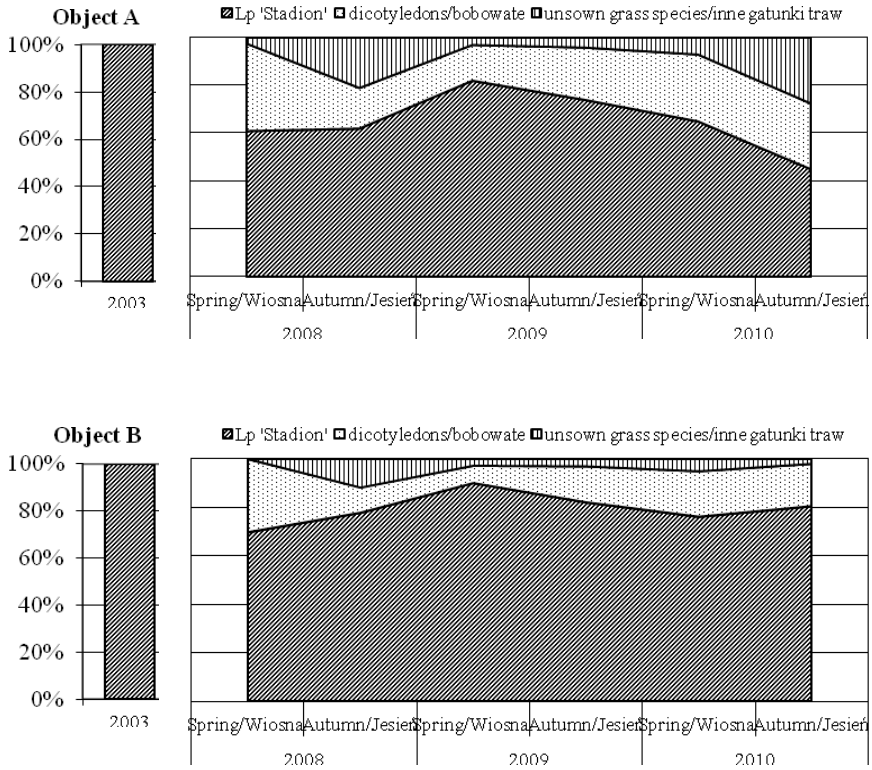

Fig. 3. Percentage share of the 'Stadion' cultivar of *L. perenne*, dicotyledons and unsown grass species in objects where the cut biomass was left on the lawn surface (A) and in objects where the cut biomass was removed (B) in the years 2008–2010 (Spring, Autumn – measurement date)
Rys. 3. Procentowy udział odm. 'Stadion' *L. perenne*, bobowatych oraz innych gatunków traw na obiektach A (z pozostawianą na powierzchni trawnika skoszoną biomasą) i B (z powierzchni których skoszoną biomasę usuwano) w latach 2008–2010 (wiosna, jesień – termin pomiaru)

In the spring of 2008, the share of the 'Stadion' cultivar was 61% in objects where the cut biomass was left (A) and 70% in objects where the cut biomass was removed (B). In object A, dicotyledons accounted for 36.5% and unsown grass species for 2.5%, while in object B the share of dicotyledons was 30% (Fig. 3). In the subsequent assessments, greater changes in the species composition were recorded in objects A where the cut biomass was left on the lawn surface. From the autumn of 2009, the share of the 'Stadion' cultivar in object A was decreasing successively and in the autumn of 2010 was by 16% lower than in the spring of 2008 (initial state), while the share of unsown grass species increased by as much as 10 times. In object B, where the cut biomass was removed, the share of the 'Stadion' cultivar was similar or higher than the initial state throughout the study period. The share of dicotyledons and unsown grass species was similar or lower than in the spring of 2008.

In objects with the 'Nira' donor, the share of dicotyledons was significantly higher in objects B, where the cut biomass was removed, while in objects with the 'Stadion' donor, the share of dicotyledons was significantly higher in objects A, where the cut biomass was left on the lawn surface (Tab. 3). In objects with the 'Niga' donor, the share of dicotyledons in objects A and B was similar (the differences were insignificant).

Table 3. Percentage share of dicotyledons in the lawn sward: A – objects where the cut sward was left on the lawn and B – control objects where the cut sward was removed from the lawn immediately after cutting (mean values from 2008–2010)*
Tabela 3. Udział roślin dwuliściennych (%) w murawie trawnikowej: na obiektach A – z pozostawianą na powierzchni trawnika skoszoną biomasą i B – z powierzchni których skoszoną biomasę usuwano (średnie z lat 2008–2010)*

Cultivars of/ Odmiany *L. perenne* (donors/donory)	Objects/ Obiekty	
	A	B
'Niga'	16.3a	16.8a
'Nira'	11.1a	15.0b
'Stadion'	24.3b	16.9a

* The same letters indicate the lack of significant differences between mean values in the particular lines
* Jednakowe wskaźniki literowe przy średnich w wierszach oznaczają brak istotnych statystycznie różnic pomiędzy nimi

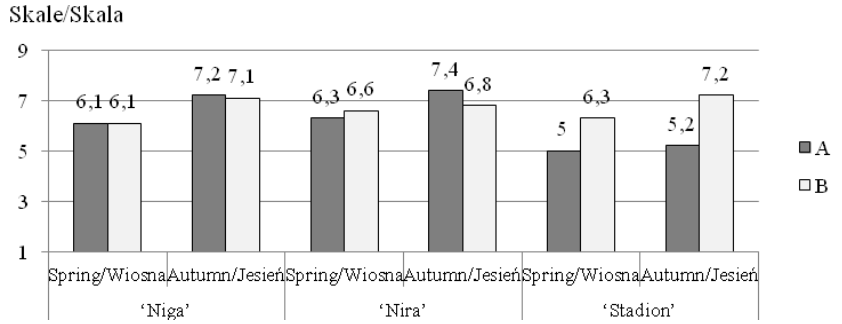

Fig. 4. Sward density of objects with 'Niga', 'Nira' and 'Stadion' cultivars of *L. perenne* (9-step scale where 1 denotes poor and 9 very good sward density): A – objects where the cut sward was left on the lawn, B – control objects where the cut sward was removed from the lawn immediately after cutting (Spring, Autumn – measurement date; mean values from 2008–2010)
Rys. 4. Zadarnienie obiektów z odmianami 'Niga', 'Nira' i 'Stadion' *L. perenne* (w 9-stopniowej skali, gdzie 1 oznacza zadarnienie złe, 9 – bardzo dobre): A – obiekty z pozostawianą na powierzchni trawnika skoszoną biomasą, B – obiekty kontrolne, z powierzchni których skoszoną biomasę usuwano (wiosna, jesień – termin pomiaru; średnie z lat 2008–2010)

The allelopathic impact of the biomass of the 'Nira', 'Niga' and 'Stadion' cultivars of *L. perenne* (donors), cut and left on the lawn, was also indicated by the assessments of sward density which is a measure of the durability of the cultivars comprising a particular sward and determines its aesthetic value [Czarnecki and Harkot 2002, Jankowski *et al.* 2003, Starczewski and Affek-Starczewska 2011b].

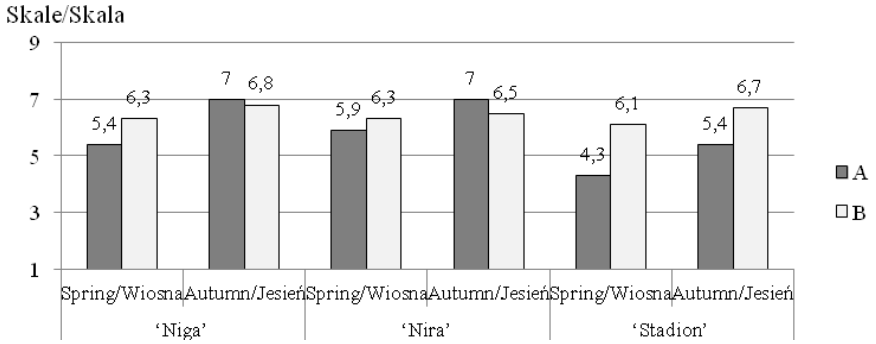

Fig. 5. General aspect of the sward in objects with 'Niga', 'Nira' and 'Stadion' cultivars of *L. perenne* (9-step scale where 1 denotes poor and 9 very good general aspect): A – objects where the cut sward was left on the lawn, B – control objects where the cut sward was removed from the lawn immediately after cutting (Spring, Autumn – measurement date; mean values from 2008–2010)

Rys. 5. Aspekt ogólny muraw na obiektach z odmianami 'Niga', 'Nira' i 'Stadion *L. perenne* (w 9-stopniowej skali, gdzie 1 oznacza zadarnienie złe, 9 – bardzo dobre): A – obiekty z pozostawianą na powierzchni trawnika skoszoną biomasą, B – obiekty kontrolne z powierzchni których skoszoną biomasę usuwano (wiosna, jesień – termin pomiaru; średnie z lat 2008–2010)

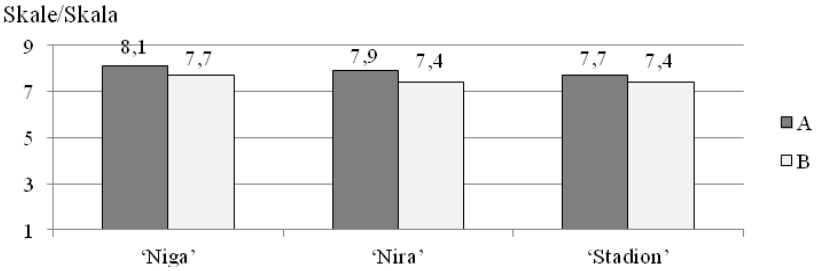

Fig. 6. Overwinter survival of swards in objects with 'Niga', 'Nira' and 'Stadion' cultivars of *L. perenne* (9-step scale where 1 denotes poor and 9 very good overwinter survival): A – objects where the cut sward was left on the lawn, B – control objects where the cut sward was removed from the lawn immediately after cutting (mean values from 2008–2010)

Rys. 6. Przezimowanie muraw na obiektach z odmianami 'Niga', 'Nira' i 'Stadion *L. perenne* (w 9-stopniowej skali, gdzie 1 oznacza zadarnienie złe, 9 – bardzo dobre): A – obiekty z pozostawianą na powierzchni trawnika skoszoną biomasą, B – obiekty kontrolne z powierzchni których skoszoną biomasę usuwano (średnie z lat 2008–2010)

In the objects with the 'Niga' and 'Nira' cultivars (donors), no significant differences were found in the sward density of objects where the cut biomass was left on the lawn (A) and objects where the cut biomass was removed from the lawn (B) (Fig. 4). In objects with the 'Stadion' donor, on the other hand, the sward density in objects where the cut biomass was left was significantly poorer (lower by 1.6º) than in objects where the cut biomass was removed. The date did not influence the assessments of the sward densi-

ty of objects A and B with 'Niga' and 'Nira' cultivars while the sward density of objects with the 'Stadion' cultivar in objects B was better in the autumn than spring.

The general (aesthetic) aspect, strongly correlated with characteristics such as sward density or regrowth rate, is a very important factor in the assessment of a lawn [Prończuk 2002, Starczewski and Affek-Starczewska 2011a]. The general aspect of the objects with 'Niga' and 'Nira' cultivars was rated as acceptable to good while those with the 'Stadion' cultivar – from poor to good (Fig. 5). Leaving the cut biomass on the lawn did not have a significant impact on the aspect of the lawns with the 'Nira' and 'Niga' cultivars (regardless of the assessment date), but it had a negative impact on the assessments of this parameter for the 'Stadion' cultivar, particularly in the spring. In objects where the cut biomass was left (A), the assessed general aspect ranged from poor to acceptable, while in objects where the cut biomass was removed immediately after cutting (B), the assessment ranged from acceptable to good.

The overwinter survival of the 'Niga', Nira' and 'Stadion' cultivars of *L. perenne* was good in all objects. Objects where the cut biomass was left on the lawn received better assessments (Fig. 6).

DISCUSSION

The biomass of the 'Niga', 'Nira' and 'Stadion' cultivars, cut and left on the lawn, influenced the floristic composition of the sward but the intensity of the allelopathic effects depended on the cultivar studied. The similar share of the 'Niga' cultivar in the spring of 2008 and autumn of 2010 in the sward of objects A and B, where the cut biomass was left or removed, indicates the lack of self-inhibition. The smaller share of other unsown plant species in the sward of objects A in 2010 in comparison with 2008 indicates the negative allelopathic effect of substances released from the biomass left on the lawn. Laboratory tests showed that the vegetative aboveground shoots of the 'Niga' cultivar contain more allelopathic substances (flavonoids and phenolic acids) than the 'Nira' and 'Stadion' cultivars (unpublished). In objects B where the cut biomass was removed, the similar share of the 'Niga' cultivar in the spring of 2008 and autumn of 2010 could have resulted from the allelopathic effect of the root exudates of this cultivar on other plant species [Lipińska and Oleszek 2002]. The decreased share of the 'Nira' cultivar, from 80% in 2008 to 60% in 2010 in objects where the cut biomass was left (A) indicates the allelopathic effects of the substances released from this biomass both on the 'Nira' cultivar and dicotyledons whose share in the sward fell from 20% in the spring of 2008 to 12% in the autumn of 2010. Studies by other authors also indicate that *L. perenne* is an effective inhibitor for many plant species. According to Lambert *et al.* [2010], the allelopathic properties of this species can effectively inhibit *Cynodon dactylon*. Also according to Zuk and Fry [2006], allelopathic substances present in the leaves and roots of *L. perenne* are capable of inhibiting the growth and development of *Zoysia japonica*, a species that frequently occurs in lawn swards. On the other hand, Kovar *et al.* [2013] demonstrated an inhibitory impact of water extracts of *L. perenne* on the root length of *P. annua* (a species regarded as a weed in lawn swards) and a stimulating impact on the leave length of the test species.

The allelopathic potential of the ‘Nira’ cultivar is also shown by the results of laboratory tests where the presence of the decomposing leaves of this cultivar in the substrate had a negative impact on the seedling growth of the ‘Stadion’ cultivar. The ‘Stadion’ cultivar of *L. perenne* turned out to be more sensitive than ‘Niga’ and ‘Nira’ to the substances released from the aboveground biomass cut and left on the lawn. The poorer growth of *L. perenne* in the presence of its own exudates is also mentioned by other authors who explain it with the self-allelopathic properties of this species [Kraus *et al.* 2002, Lipińska 2002]. According to Cheplick and Salvadori [1991], the mutual impact between plants is stronger if the plants are closely related to each other. The successively decreasing share of the ‘Stadion’ cultivar in the lawn sward in object A had a negative impact on the assessments of sward density and general aspect: they were significantly worse than in object B. On the other hand, the values of these parameters for the ‘Niga’ and ‘Nira’ cultivars were similar in both objects A, where the biomass was left, and objects B, where the biomass was removed after cutting.

Knowledge of the correlations presented above is important because the species composition of the sward determines the aesthetic value of the lawn [Grabowski *et al.* 2010], understanding the mechanisms of allelopathy enables the selective and biological control of weeds as well as protection of plants against vermin anid disease, also in grass ecosystems [Lehoczky et al. 2011, Farooq *et al.* 2011, 2013, Arif *et al.* 2015].

CONCLUSIONS

1. The biomass of the ‘Niga’, ‘Nira’ and ‘Stadion’ cultivars, cut and left on the lawn, had a varied impact on the floristic composition of the sward. The share of the ‘Niga’ cultivar in the sward of objects where the biomass was left (A) or removed (B) was similar, while the ‘Nira’ and ‘Stadion’ cultivars showed self-allelopathic properties. The share of these cultivars was smaller in objects where the cut biomass was left than in those where the biomass was removed (smaller by 20% in the case of ‘Nira’ and by 44% in the case of ‘Stadion’). The share of dicotyledons in the sward was reduced to the largest extent in objects where the cut biomass of the ‘Nira’ cultivar was left.

2. The assessments of the sward density and general aspect of the sward in objects where the cut biomass of the ‘Stadion’ cultivar of *L. perenne* was left (A) were significantly worse results than in objects where the cut biomass was removed (B). The values of these parameters for the ‘Nira’ and ‘Niga’ cultivars were similar both in objects A, where the biomass was left, and objects B, where the biomass was removed after cutting.

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Streszczenie. Celem badań polowych była ocena allelopatycznych oddziaływań skoszonych wegetatywnych pędów nadziemnych wybranych gazonowych odmian *L. perenne* na walory ozdobne oraz skład gatunkowy murawy, w tym na udział w niej roślin dwuliściennych. Jako wskaźniki allelopatycznych oddziaływań *L. perenne* przyjęto udział wysianych odmian oraz roślin dwuliściennych w murawie trawnika, aspekt ogólny, zadarnienie i przezimowanie na obiekcie A – na powierzchni którego pozostawiano skoszoną biomasę traw – i na obiekcie B kontrolnym – z powierzchni którego biomasę usuwano bezpośrednio po skoszeniu. Pozostawiana na powierzchni trawnika skoszona biomasa odmian 'Nira' i 'Stadion' wykazywały właściwości autoallelopatyczne, ograniczając swój udział w murawie. Udział roślin dwuliściennych w murawie był najsilniej ograniczany na obiektach z pozostawianą skoszoną biomasą odmiany 'Nira'. Istotnie gorsze oceny zadarnienia powierzchni i aspektu ogólnego muraw na obiektach z pozostawianą na powierzchni skoszoną biomasą niż na obiektach, z których skoszoną biomasę usuwano, uzyskała tylko odmiana 'Stadion'. Wszystkie odmiany otrzymały wyższe oceny przezimowania na obiektach, na których skoszoną biomasę pozostawiano na powierzchni trawnika.

Słowa kluczowe: allelopatia, ścięta murawa trawnika, życica trwała, skład gatunkowy, aspekt ogólny, zadarnienie, przezimowanie