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## ORIGINAL RESEARCH PAPER

# The effect of decomposing biomass of the grasses *Festuca arundinacea*, *F. ovina*, and *F. rubra* on the species composition and quality of lawns

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**Abstract**

The aim of the study was to assess the impact of cut vegetative shoots of chosen lawn grass cultivars of *Festuca* being left on the lawn sward surface on the species composition, sodding and appearance, and over-wintering of the lawn. The influence of decomposing biomass was studied in a field experiment between 2008 and 2014. Each cultivar was sown as a monoculture on microplots with an area of 1 m<sup>2</sup>. The control consisted of sites from which the cut sward had been removed immediately after cutting.

The results obtained may indicate an allelopathic effect of the cut sward of the cultivars left on the lawn surfaces. The following had the most negative effects on the species composition of the lawn sward (from greater to lesser negative impact): *F. ovina* 'Espro', *F. rubra* 'Areta', *F. arundinacea* 'Asterix', and *F. ovina* 'Pintor'. With the exception of 'Espro', these cultivars also limited the presence of dicotyledonous plants in the lawn sward. The cover of dicotyledonous plants and other unsown grasses was also recorded on the sites with *F. rubra* 'Olivia' and 'Nimba'. The greatest negative influence on the sodding of the lawn swards was demonstrated by the latter *F. rubra* cultivar, whereas *F. ovina* 'Espro' had the greatest negative influence on the appearance. However, no differences were found in assessments of over-wintering of the cultivars at the study sites. However, taking into account the scale of these impacts on the characteristics evaluated, the cultivars of *Festuca* species tested can be recommended for extensive use, where a cut sward can be left on the surface of the lawn. Some caution in this respect is recommended when it comes to *F. ovina* 'Espro' and *F. rubra* 'Areta' and 'Nimba'.

**Keywords**

allelopathy; lawns; cut sward; lawn quality

**Introduction**

Grassy surfaces perform a variety of functions in terms of both nature and economy. Lawns provide a place for rest, play, walking, and sports. They are also used in engineering technology, for the sodding of roadside areas (e.g., shoulders, embankments) [1]. Grassy surfaces are used widely for public facilities and private properties. They show a much greater ability than trees or shrubs to impact particulates and heavy metal deposition [2]. As a result of their annual spontaneous renewal, they are the cheapest component of green areas. All this suggests that the laying and maintaining of lawns is a very common practice. On average, they occupy 50% of gardens and sometimes

even 80–90% [3]. They are usually used extensively often with the cut sward left on the surface of the lawn.

The literature in the field of allelopathy shows that cut vegetative organs of plants release chemical substances during decomposition which may stimulate or inhibit the growth and development of other plants [4,5]. It is also known that grass leaves are a rich source of these substances [6,7]. A speculative research hypothesis is put forward that leaving a cut sward on lawns may contribute to changes in the species composition and a deterioration of the functional values and durability of the lawn sward as a result of such allelopathic interactions.

The primary aim of this study was to assess the impact a cut sward of the lawn grass cultivars left on the surface has on the species composition, sodding, appearance, and over-wintering of the lawn.

## Material and methods

The study included six lawn grass cultivars of three species – *Festuca arundinacea* Schreb. ‘Asterix’, *F. ovina* L. ‘Espro’ and ‘Pintor’, and *F. rubra* L. ‘Olivia’, ‘Areta’, and ‘Nimba’. These cultivars are the most commonly used in Poland for turfing anthropogenic soils. *Festuca arundinacea* (Fa) is the species with a broad ecological amplitude, and because of its strong root system, it is useful for its high resistance to extreme environmental conditions [8]. *Festuca arundinacea* ‘Asterix’ is characterized by a particularly strong root system, good winter hardiness, and resistance to drought, dustiness, salinity, and the presence of heavy metals in the substrate. It is usually recommended for seeding on slopes, roadsides and postindustrial waste landfills and sports grounds. *Festuca ovina* (Fo) also has a well-developed root system and resistance to drought [9]. For this reason, it is recommended for laying lawns in dry places or on sandy soils and for strengthening slopes [2]. *Festuca ovina* ‘Espro’ is used in seed mixes intended for the turfing of nutrient-poor soils, and for sowing slopes, roadsides, car parks, and reclamation areas. It is also used on recreational lawns [10]. The ‘Pintor’ cultivar is recommended in seed mixes for lawns that receive extensive use and for flowerbeds [9]. *Festuca rubra* (Fr) is the most durable component of lawn swards. One of its important features is its persistence in difficult conditions and its resistance to stress factors [11]. It is characterized by a long vegetation period, developing very early in spring. It is used to sod slopes, roadsides, and areas located in difficult habitat conditions, as well as intensively used recreation areas. *Festuca rubra* ‘Areta’, ‘Nimba’, and ‘Olivia’ produce long underground stolons. This species has a long life-span, spreads quickly, and covers the ground well. It has slow regrowth after cutting, making it useful for parkland and ornamental lawns, and for turfing slopes [12]. The cultivar ‘Nimba’ belongs to the *F. rubra* ssp. *commutata* group; it develops a strong root system and has a long life-span and so creates a dense sward. It regrows slowly after cutting and is drought-resistant. This cultivar is most often used for recreational, ornamental, and sports lawns, as well as shady areas [12]. Cultivar ‘Olivia’ produces a strong root system which creates good ground turfing throughout the entire vegetation period. It is recommended for lawns that are used with moderate intensity, and for ornamental lawns.

The influence of the cut sward of the above-mentioned cultivars left on the lawn surface was studied in the Didactic-Research Station in Sosnowica, SE Poland, between 2008 and 2014, and in a field experiment in 2003, using the random blocks method (in triplicate) on a light mineral soil. Each cultivar was sown as a monoculture on microplots with an area of 1 m<sup>2</sup> (the plant density on each plot was the same).

During the growing season over the study period 2008–2014, equal amounts of mineral fertilizers were applied to all plots (N – 150, P – 88, K – 144 kg ha<sup>-1</sup>). Phosphate and potassium fertilizers were divided into two equal doses and sown on two dates. The first dose was applied in the third decade of April and the second in the third decade of August. Nitrogen fertilizers were divided into four doses and applied after every 2–3 cuttings. During the growing season, 12–15 cuttings (depending on the year) were carried out at a height of 4 cm. Cutting was performed when the plants reached a height equal to 200% of an agreed sward height (8 cm). The number of cuttings and applications of fertilizers were adapted to the intensity of lawn usage of the “Relax” type [13].

**Tab. 1** Design of the field experiment with lawn grass cultivars of *Festuca arundinacea* (Fa), *F. ovina* (Fo), and *F. rubra* (Fr).

A – sites with the cut sward left on the lawn			B – control sites with the cut sward removed from the lawn immediately after cutting		
Fa 'Asterix'	Fo 'Espro'	Fo 'Espro'	Fo 'Espro'	Fa 'Asterix'	Fo 'Espro'
Fr 'Olivia'	Fr 'Areta'	Fr 'Areta'	Fr 'Olivia'	Fr 'Olivia'	Fr 'Areta'
Fr 'Nimba'	Fo 'Pintor'	Fa 'Asterix'	Fr 'Areta'	Fr 'Nimba'	Fo 'Pintor'
Fo 'Pintor'	Fr 'Nimba'	Fr 'Nimba'	Fo 'Pintor'	Fo 'Pintor'	Fr 'Nimba'
Fr 'Areta'	Fr 'Olivia'	Fr 'Olivia'	Fr 'Nimba'	Fr 'Areta'	Fr 'Olivia'
Fo 'Espro'	Fa 'Asterix'	Fo 'Pintor'	Fa 'Asterix'	Fo 'Espro'	Fa 'Asterix'

**Tab. 2** Scale to assess the functional characteristics of the cultivars tested [15].

Scale	Functional characteristic		
	Appearance	Turfing	Over-wintering survival
1	Inadequate	Inadequate (no leaves)	Very poor
3	Poor	Poor	Poor
5	Acceptable	Acceptable	Medium
7	Good	Good	Good
9	Very good	Very good (perfect carpet)	Very good

The study evaluated the effect of the individual grass cultivars cut and left on the lawn surface on the species composition, turfing and appearance, and the over-wintering of the lawn sward. The control consisted of sites from which the cut sward was removed immediately after cutting (Tab. 1).

The species composition of the lawn sward was assessed using the Weber squares method [14] annually in the spring (a week after the beginning of the vegetative growth) and in the fall (October). This method involves determining the cover of species. The assessment was carried out using a square frame with dimensions of  $0.5 \times 0.5 \text{ m} = 0.25 \text{ m}^2$ , divided into 25 squares with an area of  $0.01 \text{ m}^2$ . The frame was laid randomly on the lawn sward and the area covered by each species within the squares was determined. The measurements were repeated four times to obtain the sum of the areas occupied by each species per  $1 \text{ m}^2$ , and the percentage of the area occupied by each of the species making up the lawn sward was determined. Empty spaces (nonsodded) were also included. At the same time, the turfing and the appearance of the sward were assessed, but the over-wintering ability was assessed only in the spring according to a 9-point scale (1 = worst, 9 = best; Tab. 2). From the perspective of the assessment of the biological, compositional, and aesthetic values of the lawn sward, a difference of 1 point was taken to be significant [15].

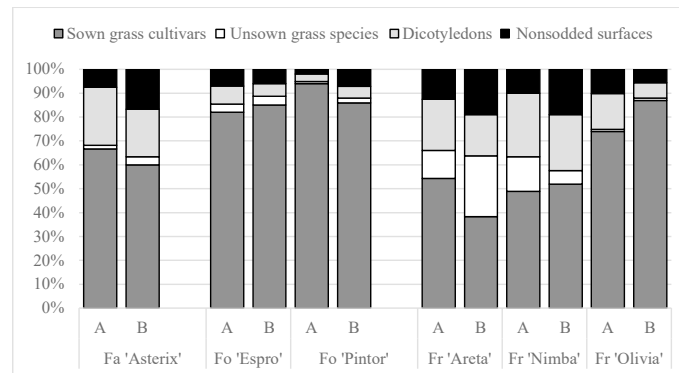
All data were processed statistically by one-way analysis of variance and Tukey's test for  $\alpha \leq 0.05$ , using the SAS v.91 program. Mean tabulated values in the columns between which no statistically significant differences occurred are marked with the same letter.

## Results

### Species composition of lawn sward – initial state

In assessing the influence of the cut sward left on the lawn surface on the species composition of the lawn, the following elements were taken into account: (i) the cover of the sown lawn grass cultivar in its lawn sward, (ii) the nonsown species of grasses and dicotyledonous plants, and (iii) the nonsodded surfaces. The year 2008 was set

as the starting point (6 years after the lawn was laid). The cover of grasses (sown and nonsown species), dicotyledonous plants, and nonsodded surfaces was different at A sites, allocated for the cut sward to be left on the lawn surface, and at B sites, where the sward was removed immediately after cutting (Fig. 1). In the spring of 2008, the greater cover of sown lawn grass cultivars was found in the lawns with *F. ovina* and with *F. rubra* 'Olivia'. The less frequent sown cultivars were maintained in the lawn swards with *F. rubra* 'Areta' and 'Nimba', as well as *F. arundinacea* 'Asterix'. These lawn swards contained a significant cover of nonsown species, both grasses and dicotyledonous plants.



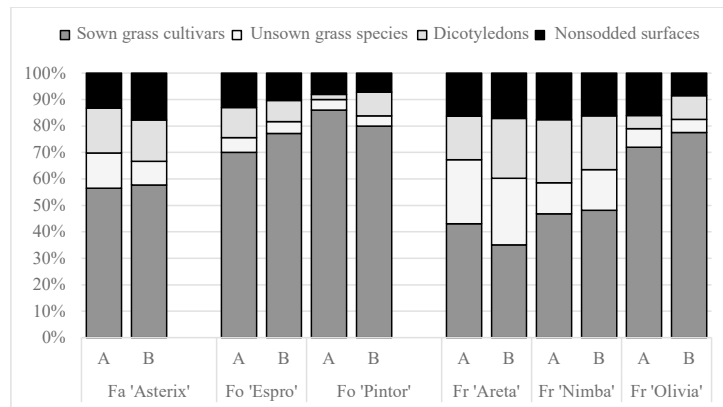
**Fig. 1** The cover of sown grass cultivars, nonsown grass species, dicotyledonous plants, and nonsodded surfaces in the lawn sward at Sites A, allocated for cut sward to be left on the lawn surface, and at Sites B, where the removal of sward was planned immediately after cutting, measured in spring 2008 (initial state).

A detailed analysis of the species composition of the lawns studied showed that after 5 years of use, there was no significant difference between the cover of *F. arundinacea* 'Asterix' and of dicotyledonous plants in the lawn sward at Sites A and B. However, the cover of nonsown grasses and areas not covered with vegetation at Sites A was half that of Sites B. The botanical composition of the two lawn swards with *F. ovina* was satisfactory. The cover of 'Espro' at Sites A and B was similar, and there were no major differences in the cover of nonsown species of grasses, dicotyledonous plants, and nonsodded surfaces. However, these differences were noted in the *F. ovina* 'Pintor' lawn swards. At Sites A, the cover of the sown cultivar was 94%; other grass species constituted around 1%, and the remaining 5% was occupied by dicotyledonous plants and nonsodded surfaces. At Sites B, 86% of the area was occupied by 'Pintor', while only about 2% was nonsown grass species, about 5% dicotyledonous plants, and >7% nonsodded surfaces. The botanical composition of the lawn swards with *F. rubra*, especially 'Areta' and 'Nimba', was definitely unsatisfactory. In the first case, at Sites A, the cover of 'Areta' was low and amounted to 54%, whereas at Sites B it was only 38%. At Sites A, nonsown species occupied half the area of dicotyledonous plants, and nonsodded surfaces constituted about 13%. At Sites B, there was a significant cover of other grass species (25%) and dicotyledonous plants (17.2%), and the remaining 20% of the surface was nonsodded. At both Sites A and B, the cover of *F. rubra* 'Nimba' was also low, amounting to about 50%, and dicotyledonous plants made up a significant cover (A: 26.6%; B: 23.4%). However, nonsown grass species predominated at Sites A, their cover being inversely related to that of nonsodded surfaces, which was almost half as large as at Sites B. The cover of *F. rubra* 'Olivia' in the lawn sward was about 87% at Sites B and 74% at Sites A. Sites A had a higher cover of dicotyledonous plants (15%) and nonsodded surfaces (10.1%) than Sites B. The cover of nonsown grasses was similar at the two sites.

#### Species composition of lawn swards during the study period

During the research period (2008–2014), the species composition of the lawn swards changed in relation to their initial states, and the magnitude of these changes depended

on the site and the cultivar/donor tested (Fig. 2). A decrease in the cover of the sown cultivars was observed at all sites, but the highest cover in the lawn sward (>70%) was maintained by *F. ovina*; that of *F. rubra* 'Olivia' was similar. However, the lowest cover of sown cultivars was found in lawn swards with *F. rubra* 'Areta' (especially at B sites) and 'Nimba'. In these swards, a fairly high cover of other nonsown grasses and nonsodded surfaces was also maintained. However, compared to 2008, the increase in the cover of other grasses and nonsodded surfaces did not exceed 10%. With the exception of the sites with *F. arundinacea* 'Asterix' and *F. rubra* 'Nimba', the cover of dicotyledonous species also increased.



**Fig. 2** The cover of sown grass cultivars, nonsown grass species, dicotyledonous plants, and nonsodded surfaces in the lawn sward at Sites A, where cut sward was left on the lawn surface, and at Sites B, where the sward was removed immediately after cutting (mean values from 2008 to 2014).

Taking into account the averages for the research period, data on the species composition of the lawn swards at Sites A and B showed that the cover of sown grass cultivars in the lawn swards was significantly different between these sites only in the case of *F. ovina* 'Espro' and *F. rubra* 'Areta'. The exception was at the sites with 'Areta', where the cover of sown cultivars was greater when the cut sward was left on the lawn. Similar relationships were found for the lawn swards with *F. ovina* 'Pintor', but these differences were not statistically significant. A lack of significant differences was also noted at sites with *F. arundinacea* 'Asterix' and *F. rubra* 'Nimba' and 'Olivia'. Nevertheless, a smaller cover of the sown species was found at the sites where the cut sward was left on the surface of the lawn sward (Tab. 3).

The nonsown grass species found in the lawn sward most frequently were annual bluegrass (*Poa annua* L.) and Kentucky bluegrass (*Poa pratensis* L.). The largest cover of this group of plants was found in swards with *F. rubra* 'Areta', while the smallest was

**Tab. 3** The percentage of sown lawn grass cultivars 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	56.5 <sup>a</sup>	57.7 <sup>a</sup>
<i>F. ovina</i>	'Espro'	70.0 <sup>a</sup>	77.2 <sup>b</sup>
	'Pintor'	86.0 <sup>a</sup>	80.0 <sup>a</sup>
<i>F. rubra</i>	'Areta'	43.1 <sup>b</sup>	35.1 <sup>a</sup>
	'Nimba'	46.8 <sup>a</sup>	48.2 <sup>a</sup>
	'Olivia'	72.0 <sup>a</sup>	77.5 <sup>a</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

found in those with *F. ovina* 'Pintor' and 'Espro', and *F. rubra* 'Olivia'. At all of these sites, however, no effect was noted due to the cut sward being left on the lawn surface (Tab. 4). This effect was visible only at sites with *F. arundinacea* 'Asterix', with significantly fewer nonsown grass species recorded at the sites where the cut material was removed immediately after cutting (B).

**Tab. 4** The cover of nonsown grass species 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	13.3 <sup>b</sup>	9.0 <sup>a</sup>
<i>F. ovina</i>	'Espro'	5.6 <sup>a</sup>	4.5 <sup>a</sup>
	'Pintor'	4.0 <sup>a</sup>	3.8 <sup>a</sup>
<i>F. rubra</i>	'Areta'	24.2 <sup>a</sup>	25.2 <sup>a</sup>
	'Nimba'	11.8 <sup>a</sup>	15.3 <sup>a</sup>
	'Olivia'	7.0 <sup>a</sup>	5.0 <sup>a</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

The most common species of dicotyledonous plants in the swards were: *Taraxacum officinale* F. H. Wigg., *Hieracium pilosella* L., *Plantago lanceolata* L., *P. major* L., and *Achillea millefolium* L. Their cover was smallest in the swards with *F. ovina* 'Pintor' and 'Espro', and *F. rubra* 'Olivia'. Most notably, on the plots with 'Pintor' and 'Olivia', the cover of dicotyledonous plants was significantly lower at A sites compared to the sites where the cut sward was removed immediately after cutting (Tab. 5). Similar relationships were found for the swards with *F. rubra* 'Areta'. However, a significantly higher cover of this group of plants was found at sites where the sward was left (A) in the case of the *F. rubra* 'Nimba', but the cover of dicotyledonous plants at both sites with *F. arundinacea* 'Asterix' and *F. ovina* 'Espro' did not differ significantly.

**Tab. 5** The percentage of dicotyledonous plants 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	16.9 <sup>a</sup>	15.6 <sup>a</sup>
<i>F. ovina</i>	'Espro'	11.4 <sup>a</sup>	8.0 <sup>a</sup>
	'Pintor'	2.0 <sup>a</sup>	9.0 <sup>b</sup>
<i>F. rubra</i>	'Areta'	16.4 <sup>a</sup>	22.6 <sup>b</sup>
	'Nimba'	23.8 <sup>b</sup>	20.3 <sup>a</sup>
	'Olivia'	5.0 <sup>a</sup>	9.0 <sup>b</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

The lowest vegetation cover was recorded on microplots with *F. rubra* 'Nimba' and *F. arundinacea* 'Areta' and 'Asterix' at both sites, whereas the greatest was for plots with *F. ovina* 'Pintor', where the smallest cover of nonsodded surfaces was recorded (Tab. 6). Comparing the percentage of nonsodded surfaces at the sites where the cut sward was left (A) with the control sites from which the cut sward was removed (B), significant differences were found only in the case of *F. arundinacea* 'Asterix' and *F. rubra* 'Olivia'. In the first case, the percentage of the surface not covered by vegetation was smaller at A sites, whereas in the second case, it was the opposite; more nonsodded areas were



**Tab. 6** The percentage of non-sodded lawn surfaces at 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	13.3 <sup>a</sup>	17.7 <sup>b</sup>
<i>F. ovina</i>	'Espro'	13.0 <sup>a</sup>	10.3 <sup>a</sup>
	'Pintor'	8.0 <sup>a</sup>	7.2 <sup>a</sup>
<i>F. rubra</i>	'Areta'	16.3 <sup>a</sup>	17.2 <sup>a</sup>
	'Nimba'	17.6 <sup>a</sup>	16.2 <sup>a</sup>
	'Olivia'	16.0 <sup>b</sup>	8.5 <sup>a</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

recorded at A sites with 'Olivia'. Leaving *F. ovina* 'Espro' and 'Pintor' and *F. rubra* 'Areta' and 'Nimba' on the lawn surface after cutting did not result in any significant differences between the plant cover of the surfaces at Sites A and B.

In assessing, the species composition of lawn swards compared to their initial state in 2008, it should be noted that the decrease in the cover of sown seed grass cultivars was usually greater at A sites than B sites under the conditions of the impact of cut sward left on their surfaces (A), and control conditions where the sward was removed immediately after cutting (B). The exception was the swards with the *F. rubra* 'Nimba' and 'Olivia' (Tab. 7). The largest differences between Sites A and B were observed in the swards with *F. arundinacea* 'Asterix' and *F. rubra* 'Areta'. At the sites where the cut sward was left on the lawn sward, the cover of sown cultivars decreased greatly (>10%) in relation to the initial state, whereas at the sites where the sward was removed, there was no more than a 3.5% decrease. Leaving the cut sward of these cultivars on the surface of the lawn resulted in the largest increase in the cover of nonsown grass species in the lawn sward; this phenomenon was less striking at B sites. On sites where the cut sward of *F. arundinacea* 'Asterix' and *F. rubra* 'Areta' and 'Olivia' were left on the surface of the lawn, there was a significant decrease from 2008 in the cover of dicotyledonous species. Compared to B sites, 63% fewer weeds were also recorded at A sites in the

**Tab. 7** The percentage of decrease or increase in the cover of sown and nonsown grass species, dicotyledonous plants, and nonsodded surfaces compared 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 2008 to 2014).

Assessed elements of species composition of lawn sward					
Cultivar/donor	Sites	Sown grass cultivars	Nonsown grass species	Dicotyledonous species	Nonsodded surfaces
Fa 'Asterix'	A	-10.2	11.8	-7.4	5.8
	B	-2.3	5.7	-4.4	1.0
Fo 'Espro'	A	-12.0	2.1	3.9	6.0
	B	-7.8	0.8	2.7	4.3
Fo 'Pintor'	A	-8.0	3.1	-1.1	6.0
	B	-6.0	1.8	4.2	0.0
Fr 'Areta'	A	-11.2	12.4	-5.0	3.8
	B	-3.2	-0.2	5.3	-1.8
Fr 'Nimba'	A	-2.1	-2.6	-2.9	7.6
	B	-3.7	9.6	-3.2	-2.8
Fr 'Olivia'	A	-2.0	6.1	-10.0	5.9
	B	-9.5	4.1	2.5	2.9

lawn swards with *F. ovina* 'Pintor'. In terms of the percentage of non-sodded surfaces, the greatest differences between sites A and B were found for the lawn swards with *F. rubra* 'Nimba' and *F. ovina* 'Pintor'.

#### Turfing, appearance, and over-wintering

Another indicator of the assessment of the influence of cut swards of lawn grass cultivars being left on the lawn surface was the turfing of the surface as assessed in accordance with the scale used. This feature, depending on the site, had values from 6.0 points to 8.5 points (sufficient to very good turfing). The best turfing was found in lawn swards with *F. ovina* ('Espro' and 'Pintor'), while the weakest was observed in those with *F. arundinacea* 'Asterix'. Taking into account the differences in the turfing of lawn swards between Sites A – with the cut sward left on the lawn surface – and Sites B (the control), no overall significant negative impact was found of the cut sward of the cultivars studied being left on the lawn surface. Swards with *F. arundinacea* 'Asterix' and *F. rubra* 'Nimba' had a slightly negative effect. The above-ground parts of the *F. ovina* 'Pintor' and *F. rubra* 'Areta' plants left on the surface of the lawn sward had a beneficial effect on the degree of turfing. Similar relationships were found for *F. ovina* 'Espro' and *F. rubra* 'Olivia', but these differences were not statistically significant (Tab. 8).

**Tab. 8** Turfing (9-point scale) 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	6.0 <sup>a</sup>	6.2 <sup>a</sup>
<i>F. ovina</i>	'Espro'	8.5 <sup>a</sup>	7.9 <sup>a</sup>
	'Pintor'	8.5 <sup>b</sup>	7.8 <sup>a</sup>
<i>F. rubra</i>	'Areta'	7.3 <sup>b</sup>	6.1 <sup>a</sup>
	'Nimba'	6.0 <sup>a</sup>	6.6 <sup>a</sup>
	'Olivia'	8.0 <sup>a</sup>	7.7 <sup>a</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

An important functional feature of the lawn, which is crucial for the quality of the grass surface in terms of both composition and aesthetics, is the appearance of the lawn sward referred to as appearance. Using the Domański scale [15], values were allocated from 5.9 points (sufficient) to 8.5 points (very good). In the assessment of this lawn sward feature, no significant differences were found in the appearance of the majority of lawn swards between Sites A, with cut sward left on the lawn surface, and Sites B, from which the cut sward was removed immediately after cutting. The values of the index were similar at Sites A and B. Only the lawn sward with *F. ovina* 'Pintor' had a more attractive appearance at A sites than B sites. The opposite was found for lawn swards with *F. ovina* 'Espro' where the cut sward was left on the surface, and the appearance was evaluated as significantly weaker (Tab. 9).

The assessment of over-wintering of lawn swards with the cultivars 'Asterix' *F. arundinacea* was good to very good and did not differ between Sites A and B. Neither was there a significant effect of the cut sward being left on the lawn surface on over-wintering in relation to the cultivars of *F. ovina* and *F. rubra*, which scored quite highly on the 9-point scale (Tab. 10). Differences in the over-wintering of the lawn swards between Sites A and B were insignificant, both in accordance with the adopted criterion by Domański [15] and from the statistical perspective.



**Tab. 9** Appearance (9-point scale) of 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	6.0 <sup>a</sup>	6.2 <sup>a</sup>
<i>F. ovina</i>	'Espro'	7.7 <sup>a</sup>	8.7 <sup>b</sup>
	'Pintor'	8.5 <sup>b</sup>	7.5 <sup>a</sup>
<i>F. rubra</i>	'Areta'	7.2 <sup>a</sup>	6.4 <sup>a</sup>
	'Nimba'	5.9 <sup>a</sup>	6.1 <sup>a</sup>
	'Olivia'	7.4 <sup>a</sup>	7.7 <sup>a</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

**Tab. 10** Over-wintering (9-point scale) of 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 2008 to 2014).

Species (donors)	Cultivar	Sites A*	Sites B*
<i>F. arundinacea</i>	'Asterix'	7.9 <sup>a</sup>	7.7 <sup>a</sup>
<i>F. ovina</i>	'Espro'	8.5 <sup>a</sup>	8.5 <sup>a</sup>
	'Pintor'	8.3 <sup>a</sup>	8.3 <sup>a</sup>
<i>F. rubra</i>	'Areta'	7.9 <sup>a</sup>	8.1 <sup>a</sup>
	'Nimba'	8.3 <sup>a</sup>	7.9 <sup>a</sup>
	'Olivia'	8.5 <sup>a</sup>	8.1 <sup>a</sup>

\* The same letters indicate a lack of significant differences between the mean values in each line.

## Discussion

Lawns are multispecies grassland communities in which plant growth and development are modified by a wide range of factors [1], one of them being the phenomenon of allelopathy, which results from the release of chemicals into the environment by plants [16]. These chemicals can be released from living above-ground parts of plants and secreted by roots, but they also arise during the decomposition of the remains of dead plants [17]. Destruction of tissues results in releasing plant components into the soil, many of which may exhibit biological activity [3], which has also been demonstrated by the present study, evidenced by differences in the values of the characteristics evaluated at A sites (cut sward left on the lawn) and B sites (cut sward removed from the lawn immediately after cutting). Allelopathic substances released when plant material is decomposing adversely affect not only plant growth [18] but also the species composition of grasslands [19–21]. There is a common belief that leaving cut sward on the surface of the lawn enables secondary circulation of plant matter within the cutting area, as a result of which mineral fertilization can be reduced, and one problem with cut sward management disappears. Users often do not consider other options, as there are no data in the literature on how cut sward left on the surface of the lawn affects its properties and durability.

Our attempt to solve the above-mentioned issue was carried out under field conditions alone, but it is extremely important to demonstrate how the phenomenon of allelopathy functions within the ecosystem [22]. Species composition of lawn swards, surface turfing, appearance, and over-wintering are some of the characteristics of lawns which are decisive not only for the overall positive aesthetic assessment of lawns, but also their durability [23]. These characteristics were therefore taken as indicators of allelopathic interactions of the decomposing cut sward. Our study demonstrated that the cut sward's impact on the surface of the lawn varied and depended on the feature

studied and the donor – cultivar, even within one species. Differences in the strength of allelopathic interactions between different species and plant cultivars have also been demonstrated in other studies [24]. According to Kovar et al. [24], these differences may be due to the diverse abilities of plants to synthesize allelopathic substances. The largest negative impact on the share of sown grass cultivars was recorded at the following sites (from greater to lesser negative impact): *F. ovina* 'Espro', *F. rubra* 'Areta', *F. arundinacea* 'Asterix', and *F. ovina* 'Pintor'. There are no reports in the literature of the auto-allelopathic properties of the *Festuca* cultivars studied, but this does not rule out their potential allelopathic properties. These were demonstrated under laboratory conditions; *F. ovina* 'Pintor' and *F. rubra* 'Olivia' showed the greatest negative impact of the rotting cut grass leaves on other species. A significant potential was observed in the case of *F. arundinacea* 'Asterix' [25]. A similar significant allelopathic potential of *F. ovina* and *F. rubra* (lawn species commonly used in the USA and Europe) has been demonstrated in study by Bertina et al. [26], where these species were found to significantly limit constituents of the lawn sward. The negative effect of the allelopathic chemicals present in the above-ground parts of *F. rubra* on *Lolium perenne* and *P. pratensis* (also recommended for lawn compounds) has been shown by Bostan et al. [27]. Furthermore, in our study the smallest cover of nonsown grass species was found in lawn swards with *F. ovina* 'Pintor' and 'Espro' and *F. rubra* 'Olivia'. However, compared to the control sites, the influence of the sward being left on the lawn surface was not significant, as confirmed in previous laboratory tests [28]. In relation to the initial state, only the cut sward of *F. rubra* 'Nimba' left on the lawn surface reduced the cover of nonsown grasses in the lawn sward.

The allelopathic properties of the grass cultivars studied here can be indicated by the low soil surface plant coverage. The greatest areas not covered by vegetation were recorded at the sites with cut sward of *F. rubra* 'Nimba' and both cultivars of *F. ovina* left on the lawn surface. According to Bostan et al. [29], the occurrence of bare areas in the vicinity of *F. rubra* may be caused by the presence of allelopathic compounds in their organs. Even small amounts of these compounds can slow down the activity of many biological processes or impair plant absorption of mineral components [30,31], thus causing weaker growth and development of the plants or their suppression [32,33]. Other research [25] shows that there is no fertilization effect of the surface biomass of *F. arundinacea*, *F. rubra*, and *F. ovina* cultivars under examination. Here, leaving the plant biomass on the lawn surface did not significantly increase the content of available forms of phosphorus, potassium and magnesium in the soil.

Based on the floristic composition of the lawn swards, it can be assumed that cut sward left on the lawn surface also affects the frequency of dicotyledonous plants. According to many authors [34–36], the allelopathic properties of some plants can be used to control weed infestations in grasslands [37]. In our study, this impact varied and depended on the species and cultivar, which confirms the considerable variation in the ability to inhibit weeds among lawn grass cultivars. The smallest cover of this group of plants was recorded on plots with *F. ovina* 'Pintor' and *F. rubra* 'Olivia', especially on the sites where the cut sward was left after cutting. However, in relation to the initial state, the cover of dicotyledonous plants was limited to the greatest extent by *F. rubra* 'Olivia' and *F. arundinacea* 'Asterix'. According to Bertin et al. [38,39], the allelopathic properties of *Festuca* species can be used in controlling weeds in various grassy surfaces, such as sport pitches, golf courses, and lawns. Furthermore, in their earlier research, Bertin et al. [40] indicated that *F. ovina* was a particularly effective inhibitor for dicotyledonous plants. In both field and laboratory studies, Bertoldi et al. [41] showed the effectiveness of *F. arundinacea* in fighting weeds. The allelopathic effects of *F. arundinacea* on dicotyledonous species are also indicated by the research of Zhu and Shen [42].

The assessment of the turfing and the appearance of the lawn sward involved the subjective assessment of the researcher. Nevertheless, it provides a certain view of the value of these features, which also determine the aesthetic value of lawns. Few studies have focused on this aspect [43,44]. In our study, the lowest values of these features were noted at the sites with cut sward of *F. rubra* 'Nimba' and *F. ovina* 'Espro' left on their surface, whereas *F. ovina* 'Pintor' mainly had a positive impact on these indicators. This cultivar, as demonstrated earlier, significantly limited the occurrence of dicotyledonous species in the lawn sward. However, a cut sward left on the lawn

surface had no significant effect on the over-wintering of the plants. Given the particular complexity of the impact of plants in the grassland habitats, it should be noted that the knowledge thereof creates a real possibility of making use of this phenomenon during lawn exploitation, which will positively affect the durability of components and aesthetic values of a grass field.

## Conclusions

The influence of cut sward left on the lawn surface on species composition, including the cover of sown and nonsown species of grasses and dicotyledonous plants, varied from the initial state in 2008, and depended on the cultivar tested. The largest negative impact on the cover of sown grass cultivars was shown by the following cultivars of cut sward left after cutting (from greater to lesser negative impact): *F. ovina* 'Espro', *F. rubra* 'Areta', *F. arundinacea* 'Asterix', and *F. ovina* 'Pintor'. With the exception of 'Espro', these cultivars also limited the presence of dicotyledonous plants in the lawn sward. An ability to limit the cover of this group of plants was also demonstrated by *F. rubra* 'Olivia', which had a small influence on the cover of sown grasses. In addition, leaving the cut sward of the *F. rubra* 'Nimba' on the surface did not result in any self-limiting effects, but limited the cover of other nonsown grass and dicotyledonous plants.

The greatest negative impact (in relation to the initial state) on the covering of the soil surface with vegetation was demonstrated by the cut sward of *F. rubra* 'Nimba', *F. ovina* 'Pintor', and *F. rubra* 'Areta' left on the lawn sward surface.

The greatest negative influence on the turfing of the lawn sward was demonstrated by cut sward of *F. rubra* 'Nimba' left on its surface, whereas *F. ovina* 'Espro' had the greatest negative influence on appearance. The sward of *F. ovina* 'Pintor' and *F. rubra* 'Areta' left after cutting had a positive influence on all these functional features.

The cut sward of all tested cultivars left on the lawn surface had no significant impact on the assessment of over-wintering of the plants.

The differences in the assessment of functional features of the lawn between the sites where the cut sward was left and where it was removed immediately after cutting may indicate its allelopathic impact. However, taking into account the scale of these impacts, the cultivars of *Festuca* species tested can be recommended for mixtures for extensive use, where a cut sward can be left on the surface of the lawn. Some caution in this respect is recommended in the case of *F. ovina* 'Espro' and *F. rubra* 'Areta' and 'Nimba'.

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### Wpływ rozkładającej się biomasy *Festuca arundinacea*, *F. ovina* i *F. rubra* na skład gatunkowy i walory użytkowe trawnika

#### Streszczenie

Celem badań była ocena oddziaływania skoszonych wegetatywnych pędów wybranych gazonowych odmian traw, pozostawianych na powierzchni murawy, na skład gatunkowy, zadarnienie oraz przezimowanie trawnika. Wpływ rozkładającej się biomasy badano w doświadczeniu polowym w latach 2008–2014 w stacji doświadczalnej zlokalizowanej w południowo-wschodniej Polsce. Każda odmiana była wysiana w monokulturze na mikropletkach o powierzchni 1 m<sup>2</sup>. Kontrolę stanowiły obiekty, z których skoszoną biomasę usuwano bezpośrednio po zabiegu. Otrzymane wyniki badań mogą wskazywać na allelopatyczny wpływ pozostawianej na powierzchni trawnika skoszonej biomasy badanych odmian. Na stabilność składu gatunkowego muraw największy ujemny wpływ miała (kolejno): *F. ovina* 'Espro', *F. rubra* 'Areta', *F. arundinacea* 'Asterix' oraz *F. ovina* 'Pintor'. Z wyjątkiem *F. ovina* 'Espro' odmiany te równocześnie ograniczały występowanie w murawie roślin dwuliściennych. Niski udział w murawie roślin dwuliściennych oraz innych niewysianych traw notowano także na obiektach z *F. rubra* 'Olivia' i 'Nimba'. Największy ujemny

wpływ na zadarnienie muraw wykazywała *F. rubra* 'Nimba', natomiast na aspekt ogólny – *F. ovina* 'Espro'. Nie stwierdzono natomiast różnic w ocenach przetrzymywania roślin pomiędzy badanymi obiektami. Biorąc jednak pod uwagę skalę tych oddziaływań na oceniane parametry, badane odmiany *Festuca* sp., można polecać do mieszanek na ekstensywne użytkowanie, podczas którego skoszona biomasa może być pozostawiana na powierzchni murawy. Pewną ostrożność w tym zakresie należy zalecać w przypadku *F. ovina* 'Espro' oraz *F. rubra* 'Areta' i 'Nimba'.