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LEAF DYNAMICS OF *FESTULOLIUM* AND *DACTYLIS GLOMERATA* L. AT THE END OF THE GROWING SEASON

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Abstract

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The paper is focused on the assessment of leaf extension rate (LER), leaf appearance rate (LAR) and leaf senescence rate (LSR) in the *Festulolium* (*Festuca arundinacea* Schreb. × *Lolium multiflorum* Lam.) and in the *Dactylis glomerata* L. at the end of the growing season from the end of September to the beginning of December. In summer, the swards were used for a single cut (beginning of June) or for a double cut (beginning of June and end of July). Measurements were made in three periods from 14 Sept. to 11 Oct., from 11 Oct. to 29 Oct., and from 29 Oct. to 6 Dec. In the first period, LER was higher in *Dactylis glomerata* L. (3.770 mm tiller^{-1} d^{-1}) than in *Festulolium* (2.376 mm tiller^{-1} d^{-1}). In the second and third period, LER was higher in *Festulolium* (0.859 resp. 0.271 mm tiller^{-1} d^{-1}) than in *Dactylis glomerata* L. (0.694, resp. 0.199 mm tiller^{-1} d^{-1}). LAR values measured in *Festulolium* in the studied periods were 0.277 leaf tiller^{-1} d^{-1}, 0.079 leaf tiller^{-1} d^{-1} and 0.038 leaf tiller^{-1} d^{-1} and LAR values of *Dactylis glomerata* L. were 0.225 leaf tiller^{-1} d^{-1}, 0.054 leaf tiller^{-1} d^{-1} and 0.027 leaf tiller^{-1} d^{-1}. In the course of the whole period of study, LSR showed the highest values in *Dactylis glomerata* L. (7.869 mm tiller^{-1} d^{-1}, 5.947 mm tiller^{-1} d^{-1} and 4.757 mm tiller^{-1} d^{-1}) while the LSR values of *Festulolium* were lower (2.904 mm tiller^{-1} d^{-1}, 2.375 mm tiller^{-1} d^{-1} and 1.205 mm tiller^{-1} d^{-1}). The influence of both the species and the period of measurement on the LER, LAR and LSR values was statistically highly significant ($P < 0.01$) to very highly significant ($P < 0.001$). The interaction between the species and the period of measurement was very highly significant ($P < 0.001$) in the LER characteristic. The influence of the intensity of sward use in summer on the LSR values was very highly significant ($P < 0.001$), too.

leaf extension rate, leaf senescence rate, leaf appearance rate, *Festulolium*, cocksfoot

Swards intended for extension of the grazing period require grass species resistant to cold. This is a challenge for hybrids of *Festuca arundinacea* Schreb. and *Lolium multiflorum* Lam. (OPITZ VON BOBERFELD and BANZHAF, 2006). A basic unit of production in the grass community is tiller. Density and volume of tillers determine biomass production. Leaf appearance rate, leaf extension rate and leaf senescence rate are key components determining the tiller volume during vegetation (VIRKAJÄRVI and JÄRVENRANTA, 2001). The growth of grasses culminates at the turn of May and June while the growth rate decreases at the end of the growing season. Nevertheless, the growth of new leaves and the decay of older leaves may continue during winter, too (HENNESSY et al., 2004). These components were studied by various authors in *Festuca arundinacea* Schreb. (ZARROUGH et al., 1984; SKINNER and NELSON, 1995), in *Lolium perenne* L. (GAUTIER et al., 1999; HENNESSY et al., 2004), *Phleum pratense* L. or *Festuca pratensis* Huds. (VIRKAJÄRVI and JÄRVENRANTA, 2001). However, data are missing for the conditions of Central Europe and for other species suitable for a possible extension of the grazing period. In this connexion, some festucoid hybrids come into consideration (*Festuca arundinacea* Schreb. × *Lolium multiflorum* Lam.), which combine the resistance to low temperatures of the *Festuca* sp. and the high herbage quality of the *Lolium* sp. (CASLER et al., 2002). REGAL and ŠINDELÁŘOVÁ (1970) mentioned swards with the dominance of *Dactylis glomerata*, which can be used in the late autumn.

The objective of this paper is to evaluate leaf appearance rate (LAR), leaf extension rate (LER) and leaf senescence rate (LSR) in the *Festulolium* (*Festuca arundinacea* Schreb. × *Lolium multiflorum* Lam.) and in the *Dactylis glomerata* L. at the end of the growing season from the end of September to the beginning of December.

MATERIAL AND METHODS

Vegetation and measurements on marked tillers

The experiment was conducted at the Research Station of Fodder Crops in Vatín, belonging to Mendel University of Agriculture and Forestry Brno, Czech Republic (49°31'N, 15°58'E). In 1970–2000, the mean annual precipitation was 617 mm and the mean annual temperature amounted to 6.9 °C. In 2007, the mean annual precipitation was 705.3 mm and the mean annual temperature amounted to 8.3 °C. Maximum, minimum and mean daily temperatures in the monitored period of year 2007 are presented in Fig. 1. Values of daily total precipitation and snow cover thickness in the monitored period of year 2007 are presented in Fig. 2. Soil type is typical Cambisol, sand-loamy, occurring on the diluvium of biolitic orthogneiss. The experiment was established in 2004 from a monoculture of the *Festulolium* (*Festuca arundinacea* Schreb. × *Lolium multiflorum* Lam.) var. Felina and the orchardgrass (*Dactylis glomerata* L.) var. Vega. The sowing amount was 20 kg.ha^{-1}. The area of experimental plots was 1.25 × 5 m. Experimental measurements were made in 2007. Nitrogen (N), phosphorus (P) and potassium (K) were applied as a single dose in spring at 50, 30 and 60 kg.ha^{-1}. In summer, the sward was used either for a single cut (beginning of June) or for a double cut (beginning of June and end of July). The experimental period lasted from 14 September to 6 December. New tillers were marked at the end of each measuring period.

The total number of marked tillers at the beginning of each period was 160, 80 tillers for each of the species (40 for a single-cut grass stand and 40 for a double-cut grass stand). A selection was made of tillers occurring at a regular distance of 0.15 m on a section of 1.5 m. The surveyed tillers were marked with coloured wires at the base. Green leaf blades and visible leaf sheaths were measured to an accuracy of 1 mm. Fully unfolded leaves were considered those with apparent ligules. Activity of meristems in leaves finishes when ligules are differential. Sheaths continue in growth till fully development of ligules. The 1st, 2nd and 3rd period of measurement was from 14 Sept. to 11 Oct., from 11 Oct. to 29 Oct. and from 29 Oct. to 6 Dec., respectively.

The leaf extension rate (LER) was measured as a difference in the total length of green leaf blades of the youngest leaves between two subsequent measurements according to the following formula:

$$\text{LER (mm tiller}^{-1}\text{ d}^{-1}) = (L_{0(t1)} - L_{0(t0)}) + L_{+1(t1)}/d,$$

where t_0 and t_1 designate the beginning and the end of the growth-measuring period, L_0 the length of the youngest leaf, L_{+1} the length of new leaf at the time t_1 not recorded at t_0 and d the numer of growth days.

The leaf senescence rate (LSR) was calculated as a difference in the total length of leaf blades of fully unfolded leaves between the two subsequent measurements. Measured was only the length of the green parts of leaf blades. A formula used for the calculation was as follows:

$$\text{LSR (mm tiller}^{-1}\text{.d}^{-1}) = (L_{-4(t0)} - L_{-4(t1)}) + (L_{-3(t0)} - L_{-3(t1)}) + (L_{-2(t0)} - L_{-2(t1)})/d,$$

where t_0 and t_1 designate the beginning and the end of the growth-measuring period, L_{-2} to L_{-4} the length of the second to fourth (oldest), fully unfolded leaf.

The leaf appearance rate (LAR) was calculated according to the following formula:

$$\text{LAR (leaf tiller}^{-1}\text{ d}^{-1}) = \text{LER}/L_{-1}$$

where L_{-1} is a length of the youngest fully developed leaf in time t_1.

Statistical evaluation

The statistical evaluation was made by programme Statistica 7.0 CZ. The analysis was made by using ANOVA. Independent variables in the model used were the sown species (Species) and the period of measurement (Period) including the „Species × Period" interaction. Data from swards with different intensities of use in summer (Intensity) were evaluated according to the „Species, Intensity, Species × Intensity" model. Dependent variables in the model used were mean daily values (LER, LSR, LAR) or maximum values (length of youngest fully unfolded leaf, number of leaves on the plant).

RESULTS

In the first period of study (Tab. I), LER was higher in the *Dactylis glomerata* L. (3.770) than in the *Festulolium* (2.376 mm tiller^{-1} d^{-1}). In the second and third period of study, LER was higher in the *Festulolium* (0.859 and 0.271 mm tiller^{-1} d^{-1}) while the LER values of *Dactylis glomerata* L. were 0.694 and 0.199 mm tiller^{-1} d^{-1} (Fig. 3). Species exhibited a statistically highly significant ($P < 0.01$) influence and Period displayed a statistically very high influence ($P < 0.001$) on the LER value. Statistically very highly significant ($P < 0.001$) was the „Species × Period" interaction. In the first period (Tab. I), LSR was higher in the *Dactylis glomerata* L. (7.869 mm tiller^{-1} d^{-1}) than in the *Festulolium* (2.904 mm tiller^{-1} d^{-1}). A similar trend was observed in the second and third period, too (Fig. 4), in which the LSR values in the *Festulolium* were 2.375, resp. 1.205 mm tiller^{-1} d^{-1}, while those in the *Dactylis glomerata* L. were 5.947 resp. 4.757 mm tiller^{-1} d^{-1}. In the first period of study (Tab. I), the LAR values in the *Festulolium* and the *Dactylis glomerata* L. were 0.277, resp. 0.225 leaf tiller^{-1} d^{-1}, in the second period they amounted to 0.079, resp.

I: *The effect of species and period on leaf extension rate (LER), leaf appearance rate (LAR) and leaf senescence rate (LSR), length of the youngest, fully unfolded leaf and number of leaves on the plant in 2007*

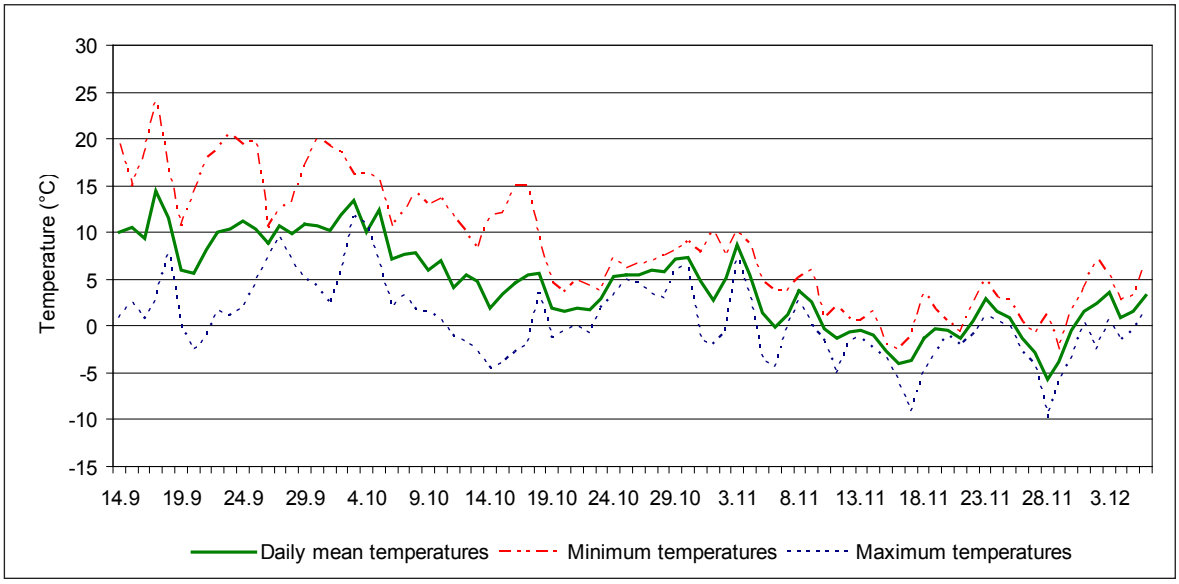
	1st period		2nd period		3rd period			P–values		
	Festulolium	*Dactylis glomerata*	*Festulolium*	*Dactylis glomerata*	*Festulolium*	*Dactylis glomerata*	s.e.m.*	Species	Period	Species × Period
LER (mm tiller^{-1}.d^{-1})	2.376	3.770	0.859	0.694	0.271	0.199	0.316	0.003	<0.001	<0.001
LAR (leaf tiller^{-1}.d^{-1})	0.277	0.225	0.079	0.054	0.038	0.027	0.017	0.008	<0.001	0.319
LSR (mm tiller^{-1}.d^{-1})	2.904	7.869	2.375	5.947	1.205	4.757	0.701	<0.001	<0.001	0.165
Length of youngest fully unfolded leaf (mm)	164	178	140	136	123	123	8.053	0.499	<0.001	0.361
Number of leaves on the plant	3.4	4.6	3.1	4.1	2.6	3.6	0.122	<0.001	<0.001	0.566

*Species × period s.e.m. As the number of tillers varied between the treatment groups, the largest s.e.m. is presented here.

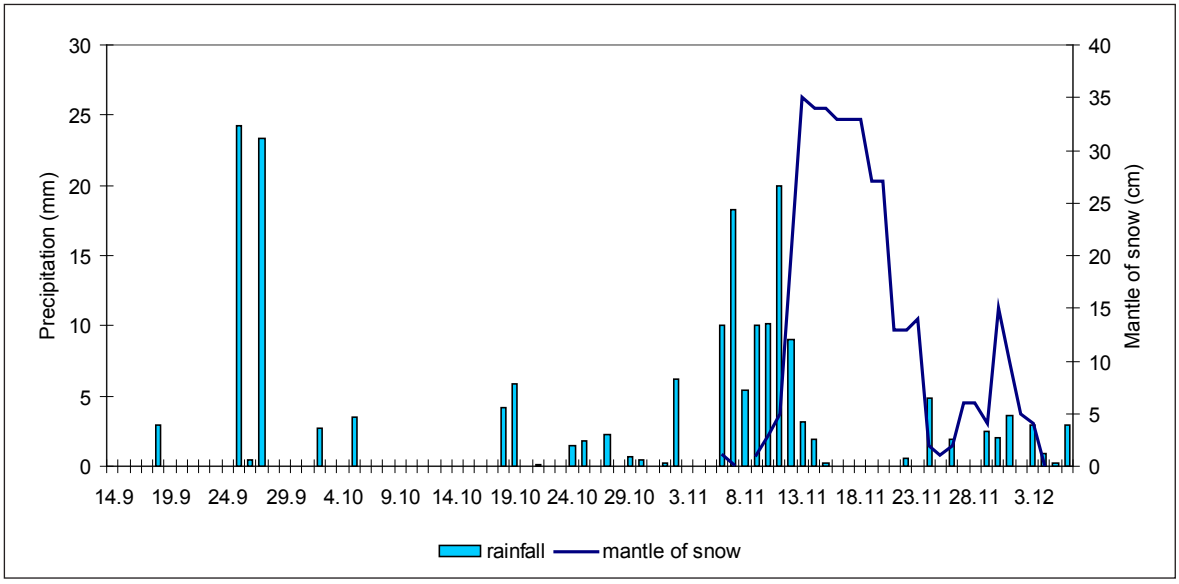
II: *The effect of species and intensity of use in summer on leaf extension rate (LER), leaf appearance rate (LAR), leaf senescence rate (LSR), length of the youngest, fully unfolded leaf and number of leaves on the plant in 2007*

	Single cut		Double cut			P–values		
	Festulolium	*Dactylis glomerata*	*Festulolium*	*Dactylis glomerata*	s.e.m.*	Species	Intensity	Species × Intensity
LER (mm tiller^{-1}.d^{-1})	1.389	1.721	0.954	1.492	0.230	0.013	0.058	0.557
LAR (leaf tiller^{-1}.d^{-1})	0.140	0.105	0.123	0.105	0.016	0.062	0.540	0.548
LSR (mm tiller^{-1}.d^{-1})	2.741	8.486	1.608	4.103	0.531	<0.001	<0.001	<0.001
Length of youngest fully unfolded leaf (mm)	166	171	119	123	6.730	0.388	<0.001	0.861
Number of leaves on the plant	3.0	4.3	3.1	4.0	0.105	<0.001	0.233	0.059

*Species × intensity s.e.m. As the number of tillers varied between the treatment groups, the largest s.e.m. is presented here.



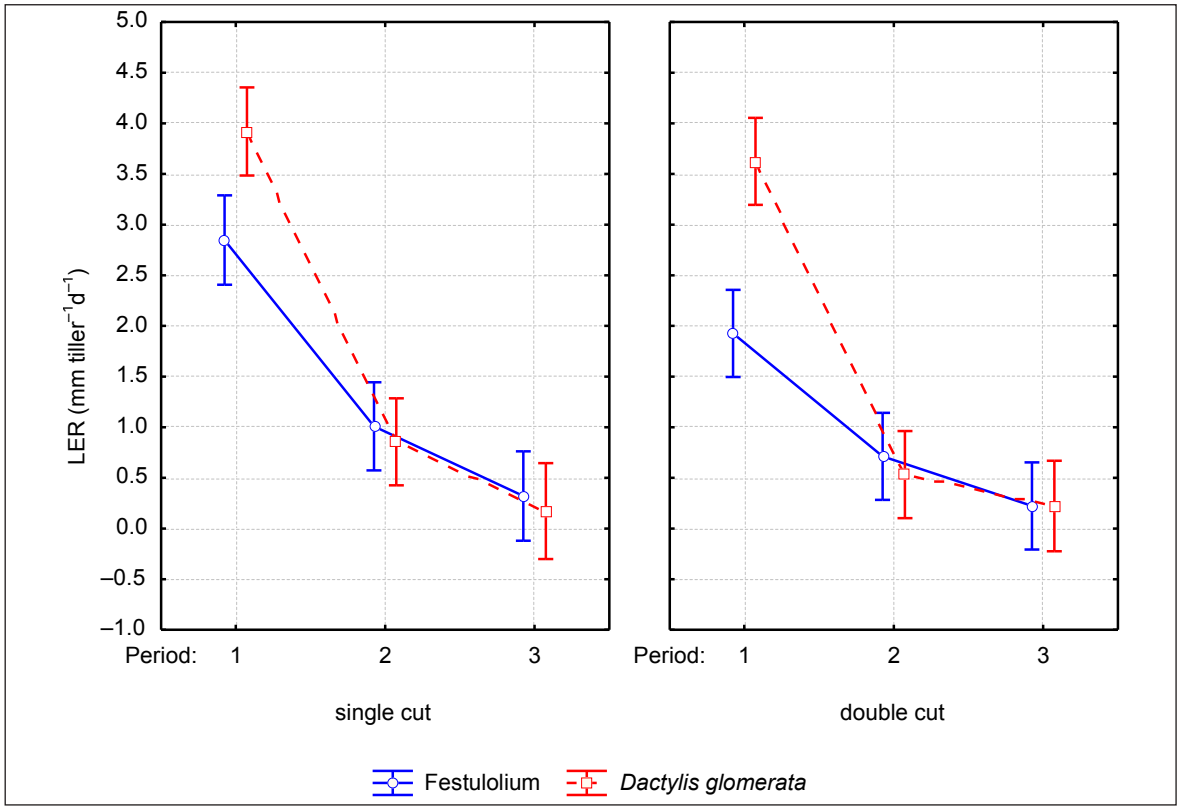
1: *Average daily temperature, maximum daily temperature and minimum daily temperature in °C from 14 September to 6 December 2007*



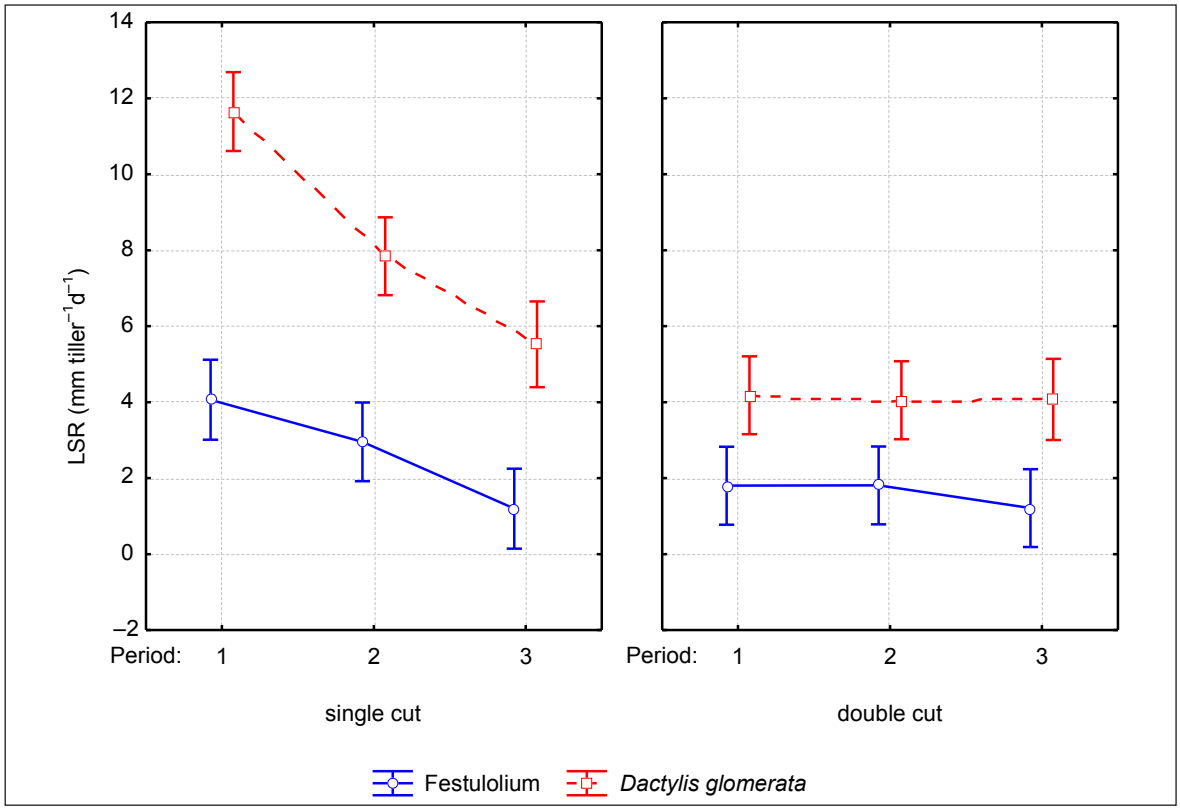
2: *Daily precipitation (mm) and snow cover thickness (cm) from 14 September to 6 December 2007*

0.054 leaf tiller^{-1} d^{-1}, and in the third period they were 0.038, resp. 0.027 leaf tiller^{-1} d^{-1} (Fig. 5). Species and Period had a statistically significant influence ($P < 0.01$) on LAR. The length of the youngest fully unfolded leaf (Tab. I) was in the *Festulolium* and the *Dactylis glomerata* L. 164 mm, resp. 178 mm in the first period, 140 mm, resp. 136 mm in the second period, and 123 mm in the third period. Period had a statistically very highly significant influence on the length of leaves ($P < 0.001$). The number of leaves in the first period (Tab. I) was 3.4 in the *Festulolium* and 4.6 in the *Dactylis glomerata* L. In the second and third period, it was 3.1, resp. 4.1 and 2.6, resp. 3.6. Species and Period had a statistically very highly significant influence ($P < 0.001$) on the number of leaves.

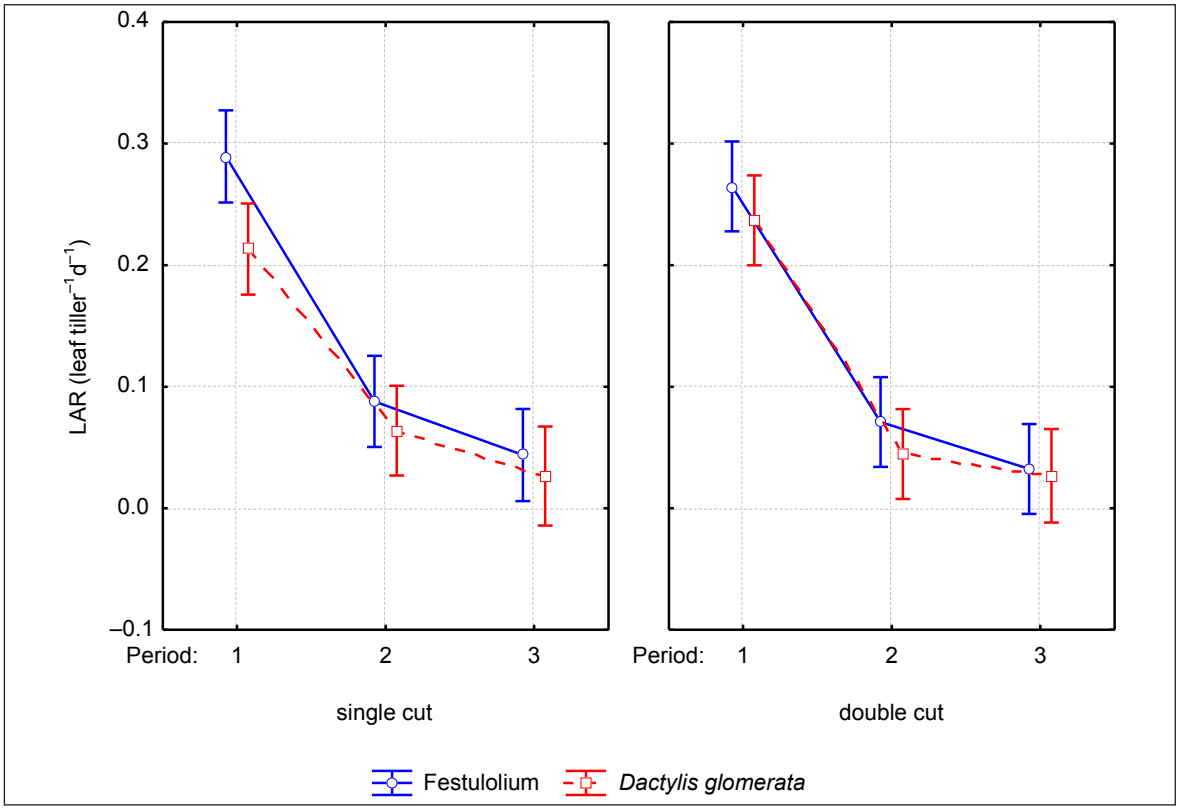
LER, LSR and the length of youngest fully unfolded leaf at the end of the growing season were affected by the intensity of use in summer, too (Tab. II). The LER value was 1.389 mm tiller^{-1} d^{-1} and 1.721 mm tiller^{-1} d^{-1} in the single- and double-cut *Festulolium* sward, respectively, and 1.721 mm tiller^{-1} d^{-1} and 1.492 mm tiller^{-1} d^{-1} in the single- and double-cut sward of *Dactylis glomerata* L., resp. The difference between the species was statistically significant ($P < 0.05$) while the influence of the intensity of use was on the boundary of significance. The LSR value was 2.741 mm tiller^{-1} d^{-1} and 1.608 mm tiller^{-1} d^{-1} in the single- and double-cut sward of *Festulolium*, respectively. The LSR value in the single- and double-cut sward of *Dactylis glomerata* L. was 8.486 mm tiller^{-1} d^{-1}



3: *Leaf extension rate (LER) in Festulolium and Dactylis glomerata L. at the end of the growing season in dependence on the intensity of use in summer*



4: *Leaf senescense rate (LSR) in Festulolium and Dactylis glomerata L. at the end of the growing season in dependence on the intensity of use in summer*



5: *Leaf appearance rate (LAR) in Festulolium and Dactylis glomerata L. at the end of the growing season in dependence on the intensity of use in summer*

and 4.103 mm tiller^{-1} d^{-1}, respectively. Species and Intensity of use had a statistically very highly significant influence ($P < 0.001$) on the LSR value. The length of the youngest fully unfolded leaf was 166 mm, resp. 171 mm in the single-cut use and 119 mm, resp. 123 mm in the double-cut use of the sward. Intensity of use had a statistically very highly significant influence ($P < 0.001$) on the length of the youngest fully unfolded leaf.

DISCUSSION

The experiment was made in field conditions and therefore it was a subject to weather oscillations and availability of nutrients. Its duration was one year and the fact should be taken into account as to herein general conclusions. However, results from this field experiment offer valuable estimates that are valid for natural conditions, the fact being demonstrated by VIRKAJÄRVI and JÄRVENRANTA (2001).

Sward growth depends on external factors such as temperature, moisture, nutrition and daytime (HOLÚBEK and HOLÚBEKOVÁ, 2002; VOZÁR et al., 2003; MRKVIČKA and VESELÁ, 2002). The LER values decrease from October to December. At the end of the growing season, they depend namely on temperature and on the shortening daytime (BELANGER, 1996). LER was higher at higher temperatures (Fig. 1) at the turn of September and October than at the end of October, but the growth of leaves continues in the studied species in November, too. Moreover, the sward was under continuous snow cover from 10 November to 3 December (Fig. 2). In spite of the fact, an extension of leaves was recorded also in the third period of measurement (from 29 October to 6 December). The extension of leaves in this period occurred most likely between 29 October and 10 November when mean daily temperatures reached to 5 °C (Fig. 1). The growth of leaves not only at the beginning of December but also in January was reported by HENNESSY et al. (2005). At the turn of September and October, *Dactylis glomerata* L. displayed under the influence of higher temperatures LER values higher (3.770 mm tiller^{-1} d^{-1}) than *Festulolium* (2.376 mm tiller^{-1} d^{-1}). In November and December, the LER values equalled with the *Festulolium* showing LER higher than the *Dactylis glomerata* L. OPITZ VON BOBERFELD and BANZHAF (2006) mention the high share of green foliage in festucoid hybrids at the beginning of December too. For a comparison, the max LER in the *Phleum pratense* L. can be 41 mm tiller^{-1} d^{-1}, in the *Festuca pratensis* Huds. 29 mm tiller^{-1} d^{-1} (VIRKAJÄRVI and JÄRVENRANTA, 2001), and in the grazed *Lolium perenne* L. 3–7 mm tiller^{-1} d^{-1} (TALLOWIN et al., 1995; MARRIOT et al., 1999). A more intensively used sward exhibited a lower LER at the end of the growing season. By contrast, its LSR was higher, though. An older sward has a higher LSR value at the end of the growing

season than a younger, more intensively used sward. The use of the sward until the end of July resulted in a balanced LSR at the end of the growing season. Senescence prevailed over the growth of new leaves particularly in *Dactylis glomerata* L. The highest LSR values were measured in the first period (2.904 resp. 7.869 mm tiller^{-1} d^{-1}). HENNESSY et al. (2004) reported LSR in *Lolium perenne* L. at the turn of October and November from 2.829 to 11.896 mm tiller^{-1} d^{-1}. Although the values in the second and third period were lower, the senescence was not compensated by the development of new leaves. Changes of LAR at the end of the growing season were similar to LER changes, with the LAR values gradually decreasing. The total number of live leaves on the plant was decreasing during the autumn. However, the fact that the growth of leaves was recorded in the course of the entire period of study is decisive with respect to a possible extension of the grazing season. Grazing animals browse on the green leaves at 60–95% while abhorring the senescent leaves (MÍKA et al., 1997).

Festulolium and *Dactylis glomerata* L. have a capacity to grow at low temperatures. At the turn of September and October, LER was higher in the *Dactylis glomerata* L. During the autumn, the LER values became equal in the *Dactylis glomerata* L. and in the *Festulolium*, or were higher in the *Festulolium* than in the *Dactylis glomerata* L. On the other hand, the *Festulolium* leaves were dying slower and their LSR was lower during the entire autumn period than those of *Dactylis glomerata* L. Although the single-cut sward used at the beginning of June exhibits a higher LER value at the end of the growing season, it has at the same time a higher share of the senescent material. By contrast, the double-cut sward used also at the end of July displays a lower amount of the senescent material. *Dactylis glomerata* L. and *Festulolium* may be suitable species for the extension of the grazing season. With respect to the share of senescent material towards the end of the growing season, a more intensive use in summer appears more advantageous.

SOUHRN

Dynamika růstu listů *Festulolium* a *Dactylis glomerata* na konci vegetačního období

Cílem příspěvku je vyhodnotit míru prodloužení listů (LER), míru nově vznikajících listů (LAR) a míru odumírání listů (LSR) u *Festulolium* (*Festuca arundinacea* Schreb. × *Lolium multiflorum* Lam.) a *Dactylis glomerata* L. na konci vegetačního období od konce září do počátku prosince. Porost byl v létě využíván jako jednosečný (počátek června) nebo jako dvousečný (počátek června a konec července). Měření proběhlo ve třech periodách od 14. 9. do 11. 10., od 11. 10. do 29. 10. a od 29. 10. do 6. 12. V první periodě byla LER vyšší u *Dactylis glomerata* L. (3,770 mm.odnož$^{-1}$.den^{-1}) než u *Festulolium* (2,376 mm.odnož$^{-1}$.den^{-1}). Ve druhé a třetí periodě byla LER vyšší u *Festulolium* (0,859, resp. 0,271 mm.odnož$^{-1}$.den^{-1}) než u *Dactylis glomerata* L. (0,694, resp. 0,199 mm.odnož$^{-1}$.den^{-1}). LAR byla u *Festulolium* ve sledovaném období 0,277 list.odnož$^{-1}$.den^{-1}, 0,079 list.odnož$^{-1}$.den^{-1} a 0,038 list.odnož$^{-1}$.den^{-1}. *Dactylis glomerata* L. měla LAR 0,225 list.odnož$^{-1}$.den^{-1}, 0,054 list.odnož$^{-1}$.den^{-1} a 0,027 list^{-1} odnož$^{-1}$.den^{-1}. LSR byla v průběhu celého sledovaného období nejvyšší u *Dactylis glomerata* L. (7,869 mm.odnož$^{-1}$.den^{-1}, 5,947 mm.odnož$^{-1}$.den^{-1}, 4,757 mm.odnož$^{-1}$.den^{-1}). *Festulolium* mělo LSR 2,904 mm.odnož$^{-1}$.den^{-1}, 2,375 mm.odnož$^{-1}$.den^{-1} a 1,205 mm.odnož$^{-1}$.den^{-1}. Druh a perioda měření měli statisticky vysoce průkazný vliv ($P < 0,01$) až velmi vysoce průkazný vliv ($P < 0,001$) na hodnoty LER, LAR a LSR. Velmi vysoce průkazná ($P < 0,001$) byla interakce mezi druhem a periodou u charakteristiky LER. Velmi vysoce průkazný vliv ($P < 0,001$) na hodnoty LSR měla také intenzita využití v letním období.
Hodnoty LER klesají od října do prosince. Koncem vegetačního období jsou ovlivněny zejména teplotou, vláhovým stresem a krátící se dobou slunečního svitu. Efekt intenzity světla je vcelku indiferentní. Hodnoty LER se od září postupně snižují. *Festulolium* a *Dactylis glomerata* L. patří k druhům schopným růst při nízkých teplotách. Na přelomu září a října je vyšší LER u *Dactylis glomerata* L. V průběhu podzimu se LER *Dactylis glomerata* L. a *Festulolium* vyrovnává, resp. je vyšší u *Festulolium* než u *Dactylis glomerata* L. Naopak listy *Festulolium* odumírají pomaleji a v průběhu celého podzimu mají nižší LSR než *Dactylis glomerata* L. Jednosečný porost využívaný počátkem června má sice koncem vegetačního období vyšší LER, ale zároveň je zde přítomný vyšší podíl senescentního materiálu. Naopak dvousečný porost využívaný také koncem července vykazuje menší množství senescentního materiálu. *Dactylis glomerata* L. a *Festulolium* mohou být vhodnými druhy pro prodloužení pastevního období. S ohledem na podíl senescentního materiálu koncem vegetačního období je v létě výhodnější intenzivnější využívání.

míra prodloužení listů, míra odumírání listů, míra vzniku nových listů, *Festulolium*, srha laločnatá

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