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

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Abstract


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 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 0.225 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 0.277 leaf tiller⁻¹ d⁻¹, 0.097 leaf tiller⁻¹ d⁻¹ and 0.038 leaf tiller⁻¹ d⁻¹ and LAR values of Dactylis glomerata L. were 0.122 leaf tiller⁻¹ d⁻¹, 0.025 leaf tiller⁻¹ d⁻¹ and 0.038 leaf tiller⁻¹ d⁻¹. In the course of the whole period of study, LSR showed the highest values in Dactylis glomerata L. (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 ŠINDLÁŘOVÁ (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 Vatin, 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 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:

\[ \text{LER (mm tiller}^{-1}\text{d}^{-1}) = \frac{(L_{t+1} - L_{t-1}) + (L_{t+2} - L_{t})}{d}, \]

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 number 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:

\[ \text{LSR (mm tiller}^{-1}\text{d}^{-1}) = \frac{(L_{t-1} - L_{t+1}) + (L_{t} - L_{t+2})}{d}, \]

where \( t_0 \) and \( t_1 \) designate the beginning and the end of the growth-measuring period, \( L_0 \) to \( L_1 \) the length of the second to fourth (oldest), fully unfolded leaf.

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

\[ \text{LAR (leaf tiller}^{-1}\text{d}^{-1}) = \frac{\text{LER}}{L_1}, \]

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

<table>
<thead>
<tr>
<th></th>
<th>1st period</th>
<th>2nd period</th>
<th>3rd period</th>
<th>P-values</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Festulolium</td>
<td>Dactylis</td>
<td>Festulolium</td>
<td>Dactylis</td>
</tr>
<tr>
<td>LER (mm tiller$^{-1}$.d$^{-1}$)</td>
<td>2.376</td>
<td>3.770</td>
<td>0.859</td>
<td>0.694</td>
</tr>
<tr>
<td>LAR (leaf tiller$^{-1}$.d$^{-1}$)</td>
<td>0.277</td>
<td>0.225</td>
<td>0.079</td>
<td>0.054</td>
</tr>
<tr>
<td>LSR (mm tiller$^{-1}$.d$^{-1}$)</td>
<td>2.904</td>
<td>7.869</td>
<td>2.375</td>
<td>5.947</td>
</tr>
<tr>
<td>Length of youngest fully unfolded leaf (mm)</td>
<td>164</td>
<td>178</td>
<td>140</td>
<td>136</td>
</tr>
<tr>
<td>Number of leaves on the plant</td>
<td>3.4</td>
<td>4.6</td>
<td>3.1</td>
<td>4.1</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th></th>
<th>Single cut</th>
<th>Double cut</th>
<th>P-values</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Festulolium</td>
<td>Dactylis</td>
<td>s.e.m.*</td>
</tr>
<tr>
<td>LER (mm tiller$^{-1}$.d$^{-1}$)</td>
<td>1.389</td>
<td>1.721</td>
<td>0.954</td>
</tr>
<tr>
<td>LAR (leaf tiller$^{-1}$.d$^{-1}$)</td>
<td>0.140</td>
<td>0.105</td>
<td>0.123</td>
</tr>
<tr>
<td>LSR (mm tiller$^{-1}$.d$^{-1}$)</td>
<td>2.741</td>
<td>8.486</td>
<td>1.608</td>
</tr>
<tr>
<td>Length of youngest fully unfolded leaf (mm)</td>
<td>166</td>
<td>171</td>
<td>119</td>
</tr>
<tr>
<td>Number of leaves on the plant</td>
<td>3.0</td>
<td>4.3</td>
<td>3.1</td>
</tr>
</tbody>
</table>

*Species × intensity s.e.m. As the number of tillers varied between the treatment groups, the largest s.e.m. is presented here.
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\(^{-1}\)
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.

Leaf senescence rate (LSR) 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 (BE-LÄNGER, 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.
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 L.) 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). Závažnosti vlivů (P < 0,001) byla interakce mezi druhem a periodou u charakteristiky LER. Velmi vysoce průkazný vliv (P < 0,001) na hodnoty LER, LAR a LSR. Velmi vysoce průkazná (P < 0,01) byla interakce mezi druhem a periodou u charakteristiky LER. Velmi vysoce průkazný vliv (P < 0,01) na hodnoty LSR měla také intenzita využití v letním období.

REFERENCES


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